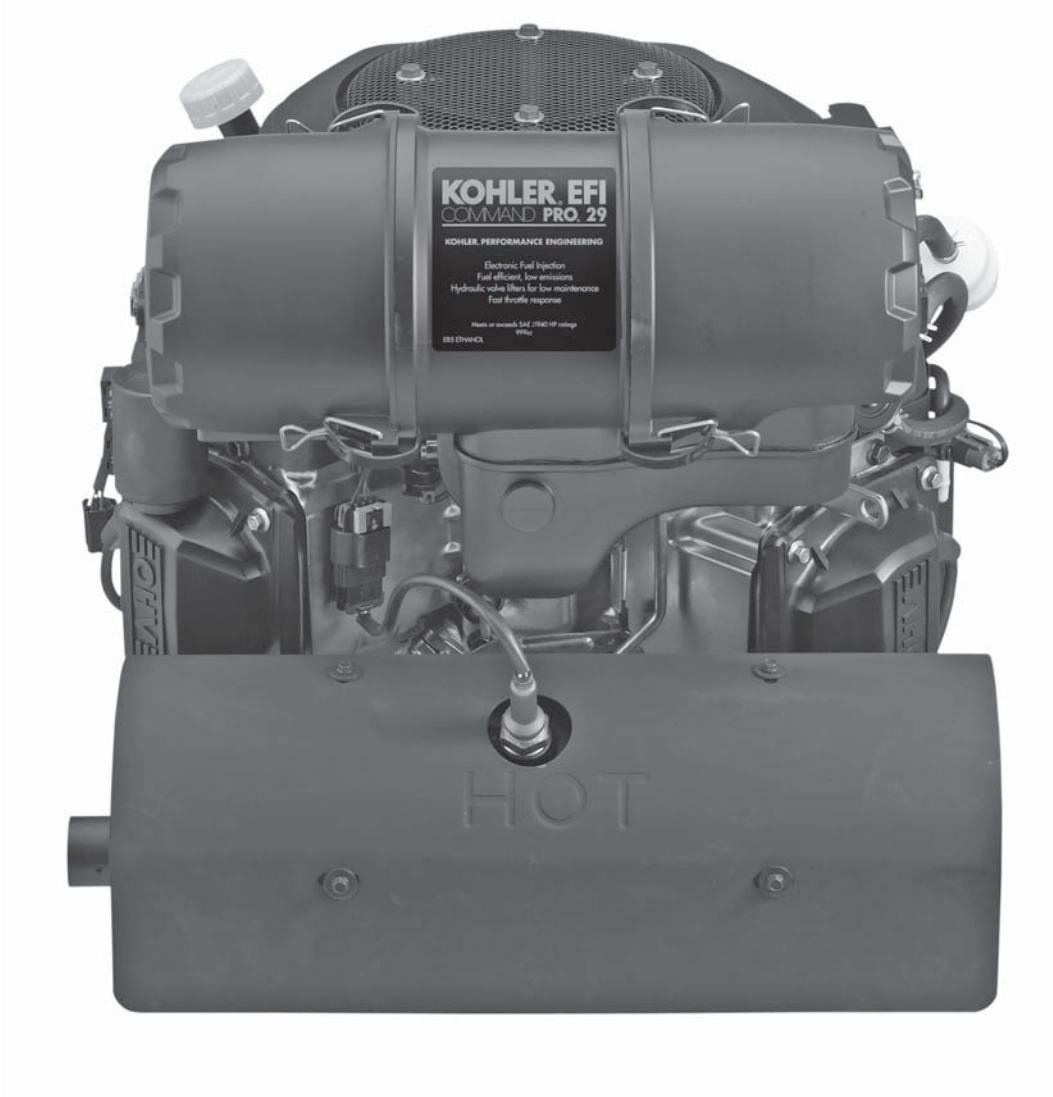
SERVICE MANUAL

KOHLER® Command PRO®

ECV630-ECV749

VERTICAL CRANKSHAFT



KOHLER® ENGINES

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Section 1
Safety and General Information

Safety Precautions

To ensure safe operation, please read the following statements and understand their meaning. Also refer to your equipment manufacturer's manual for other important safety information. This manual contains safety precautions which are explained below. Please read carefully.

WARNING

Warning is used to indicate the presence of a hazard that *can* cause *severe* personal injury, death, or substantial property damage if the warning is ignored.

CAUTION

Caution is used to indicate the presence of a hazard that *will* or *can* cause *minor* personal injury or property damage if the caution is ignored.

NOTE

Note is used to notify people of installation, operation, or maintenance information that is important but not hazard-related.

For Your Safety!

These precautions should be followed at all times. Failure to follow these precautions could result in injury to yourself and others.

WARNING

Accidental Starts can cause severe injury or death.
Disconnect and ground spark plug lead before servicing.

Accidental Starts!

Disabling engine. Accidental starting can cause severe injury or death. Before working on the engine or equipment, disable the engine as follows: 1) Disconnect the spark plug lead(s). 2) Disconnect negative (–) battery cable from battery.

WARNING

Rotating Parts can cause severe injury.
Stay away while engine is in operation.

Rotating Parts!

Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate the engine with covers, shrouds, or guards removed.

WARNING

Hot Parts can cause severe burns.
Do not touch engine while operating or just after stopping.

Hot Parts!

Engine components can get extremely hot from operation. To prevent severe burns, do not touch these areas while the engine is running, or immediately after it is turned off. Never operate the engine with heat shields or guards removed.

WARNING

Explosive Fuel can cause fires and severe burns.
Do not fill the fuel tank while the engine is hot or running.

Explosive Fuel!

Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Do not fill the fuel tank while the engine is hot or running, since spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Do not start the engine near spilled fuel. Never use gasoline as a cleaning agent.

⚠ WARNING

Carbon Monoxide can cause severe nausea, fainting or death.
Avoid inhaling exhaust fumes, and never run the engine in a closed building or confined area.

Lethal Exhaust Gases!

Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled. Avoid inhaling exhaust fumes, and never run the engine in a closed building or confined area.

⚠ CAUTION

Electrical Shock can cause injury.
Do not touch wires while engine is running.

Electrical Shock!

Never touch electrical wires or components while the engine is running. They can be sources of electrical shock.

⚠ WARNING

Cleaning Solvents can cause severe injury or death.
Use only in well ventilated areas away from ignition sources.

Flammable Solvents!

Carburetor cleaners and solvents are extremely flammable. Keep sparks, flames, and other sources of ignition away from the area. Follow the cleaner manufacturer's warnings and instructions on its proper and safe use. Never use gasoline as a cleaning agent.

⚠ WARNING

High Pressure Fluids can puncture skin and cause severe injury or death.
Do not work on fuel system without proper training or safety equipment.

High Pressure Fluid Puncture!

Fuel system is to be serviced only by properly trained personnel wearing protective safety equipment. Fluid puncture injuries are highly toxic and hazardous. If an injury occurs, seek immediate medical attention.

⚠ WARNING

Explosive Fuel can cause fires and severe burns.
Fuel systems ALWAYS remains under HIGH PRESSURE.

Fuel Fire and Burns!

Wrap a shop towel completely around the fuel pump module connector. Press the release button(s) and slowly pull the connector away from the fuel pump module allowing the shop towel to absorb any residual fuel in the high pressure fuel line. Any spilled fuel must be completely wiped up immediately.

Engine Identification Numbers

When ordering parts, or in any communication involving an engine, always give the **Model, Specification and Serial Numbers of the engine.**

The engine identification numbers appear on a decal, or decals, affixed to the engine shrouding. See Figure 1-1. An explanation of these numbers is shown in Figure 1-2.

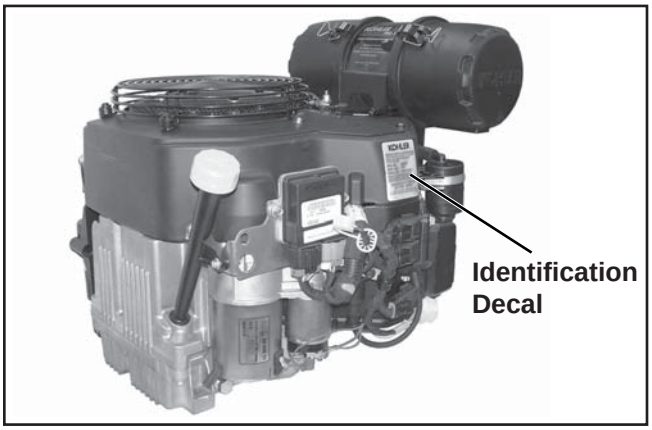


Figure 1-1. Engine Identification Decal Location.

A. Model No.

E C V 749

- Electronic Fuel Injection (EFI)
- Command Engine
- Vertical Crankshaft
- Numerical Designation
  - 630
  - 650
  - 680
  - 730
  - 740
  - 749

B. Spec. No.

- ECV630-XXXX
- ECV650-XXXX
- ECV680-XXXX
- ECV730-XXXX
- ECV740-XXXX
- ECV749-XXXX

C. Serial No.

39 05810334

- Year Manufactured Code
- Factory Code

Code	Year
39	2009
40	2010
41	2011

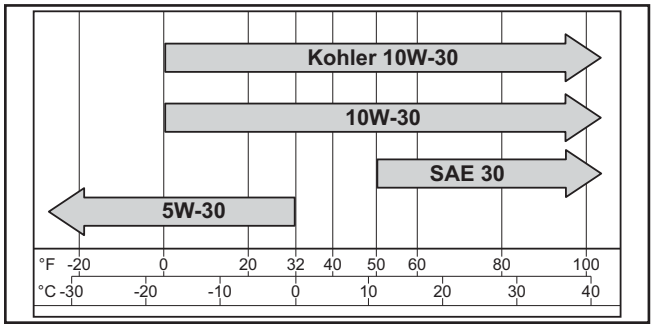
Figure 1-2. Explanation of Engine Identification Numbers.

Oil Recommendations

Using the proper type and weight of oil in the crankcase is extremely important. So is checking oil daily and changing oil regularly. Failure to use the correct oil, or using dirty oil, causes premature engine wear and failure.

Oil Type

Use high-quality detergent oil of **API (American Petroleum Institute) Service Class SJ or higher.** Select the viscosity based on the air temperature at the time of operation as shown in the following table.



NOTE: Using other than service class SJ or higher oil or extending oil change intervals longer than recommended can cause engine damage.

NOTE: Synthetic oils meeting the listed classifications may be used with oil changes performed at the recommended intervals. However, to allow piston rings to properly seat, a new or rebuilt engine should be operated for at least 50 hours using standard petroleum based oil before switching to synthetic oil.

A logo or symbol on oil containers identifies the API service class and SAE viscosity grade. See Figure 1-3.

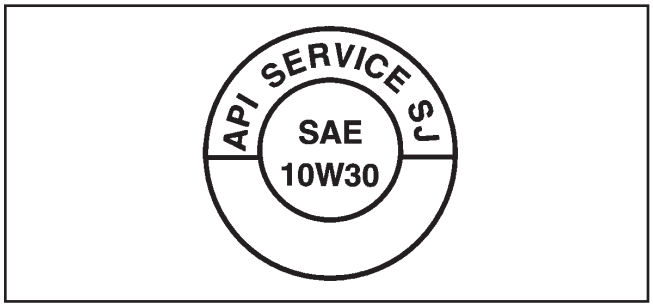
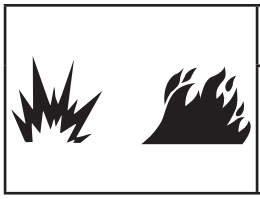


Figure 1-3. Oil Container Logo.



⚠ WARNING

Explosive Fuel can cause fires and severe burns.
Do not fill the fuel tank while the engine is hot or running.

Explosive Fuel!

Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Do not fill the fuel tank while the engine is hot or running, since spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Do not start the engine near spilled fuel. Never use gasoline as a cleaning agent.

Refer to **Section 6 - Lubrication System** for detailed procedures on checking the oil, changing the oil and changing the oil filter.

Fuel Recommendations

General Recommendations

Purchase gasoline in small quantities and store in clean, approved containers. A container with a capacity of 2 gallons or less with a pouring spout is recommended. Such a container is easier to handle and helps eliminate spillage during refueling.

Do not use gasoline left over from the previous season, to minimize gum deposits in your fuel system and to ensure easy starting.

Do not add oil to the gasoline.

Do not overfill the fuel tank. Leave room for the fuel to expand.

Fuel Type

For best results use only clean, fresh, **unleaded** gasoline with a pump sticker octane rating of 87 (R+M)/2 or higher. In countries using the Research Octane Number (RON), it should be 90 octane minimum. Leaded gasoline is not recommended and must not be used on EFI engines or on other models where exhaust emissions are regulated.

Gasoline/Alcohol Blends

Gasohol (up to 10% ethyl alcohol, 90% unleaded gasoline by volume) is approved as a fuel for Kohler engines. Other gasoline/alcohol blends including E20 and E85 are not to be used and not approved. Any failures resulting from use of these fuels will not be warranted.

Gasoline/Ether Blends

Methyl Tertiary Butyl Ether (MTBE) and unleaded gasoline blends (up to a maximum of 15% MTBE by volume) are approved as a fuel for Kohler engines. Other gasoline/ether blends are not approved.

Periodic Maintenance Instructions

⚠ WARNING

Accidental Starts can cause severe injury or death.
Disconnect and ground spark plug lead before servicing.

Accidental Starts!

Disabling engine. Accidental starting can cause severe injury or death. Before working on the engine or equipment, disable the engine as follows: 1) Disconnect the spark plug lead(s). 2) Disconnect negative (–) battery cable from battery.

Maintenance Schedule

Normal maintenance, replacement or repair of emission control devices and systems may be performed by any repair establishment or individual; however, **warranty repairs must be performed by a Kohler authorized service center.**

Frequency	Maintenance Required	Refer to:
Daily or Before Starting Engine	• Check oil level. • Fill fuel tank. • Check air cleaner for dirty[1], loose, or damaged parts. • Check air intake and cooling areas, clean as necessary.[1]	Section 6 Section 5 Section 4 Section 4
Every 25 Hours	• Clean or replace precleaner (if equipped) clean as necessary.[1,3]	Section 4
Every 100 Hours	• Replace element[1] (low-profile air cleaner models). • Remove and clean shrouds and cooling areas.[1] • Change oil. (More frequently under severe conditions). • Check oil cooler fins, clean as necessary (if equipped).	Section 4 Section 4 Section 6 Section 6
Weekly or Every 150 Hours	• Check filter minder.[4] • Inspect air filter paper element and inlet screen area.[4]	Section 4 Section 4
Every 200 Hours	• Replace fuel filter.[1] • Clean, set gap or replace spark plug, and set gap. • Change oil filter.	Section 5 Section 7 Section 6
Every 300 Hours	• Replace heavy-duty air cleaner element and check inner element.[1]	Section 4
Annually or Every 500 Hours	• Have starter serviced.[2]	Section 7

[1]Perform these maintenance procedures more frequently under extremely dusty, dirty conditions.
[2]Have a Kohler Engine Service Dealer perform this service.
[3]Low-profile air cleaner.
[4]Heavy-duty air cleaner.

Storage

If the engine will be out of service for two months or more, use the following storage procedure:

1. Clean the exterior surfaces of the engine. On EFI engines, avoid spraying water at the wiring harness or any of the electrical components.

2. Change the oil and oil filter while the engine is still warm from operation. See **Change Oil and Oil Filter** in Section 6.

3. The fuel system must be completely emptied, or the gasoline must be treated with a stabilizer to prevent deterioration. If you choose to use a stabilizer, follow the manufacturer's recommendations, and add the correct amount for the capacity of the fuel system. Fill the fuel tank with clean, fresh gasoline.

   Run the engine for 2 to 3 minutes to get stabilized fuel into the rest of the system. Close the fuel shut-off valve when the unit is being stored or transported.

   To empty the system, run the engine until the tank and the system is empty.

4. Remove the spark plugs. Add one tablespoon of engine oil into each spark plug hole. Install plugs, but do not connect the plug leads. Crank the engine two or three revolutions.

5. Disconnect the negative (-) battery cable or use a battery minder trickle charger while the unit is in storage.

6. Store the engine in a clean, dry place.

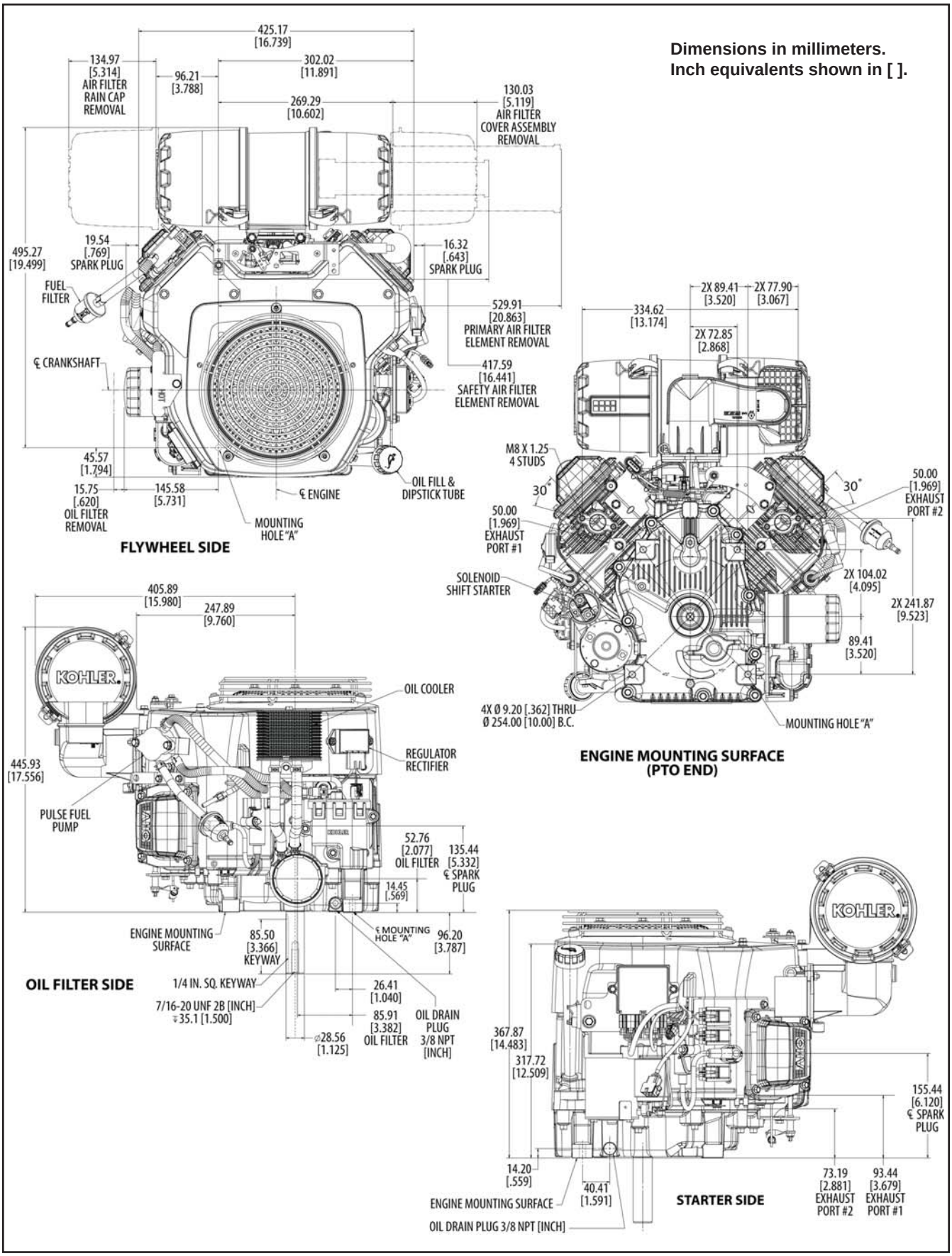


Figure 1-4. Typical Engine Dimensions - ECV749 with Heavy-Duty Air Cleaner.

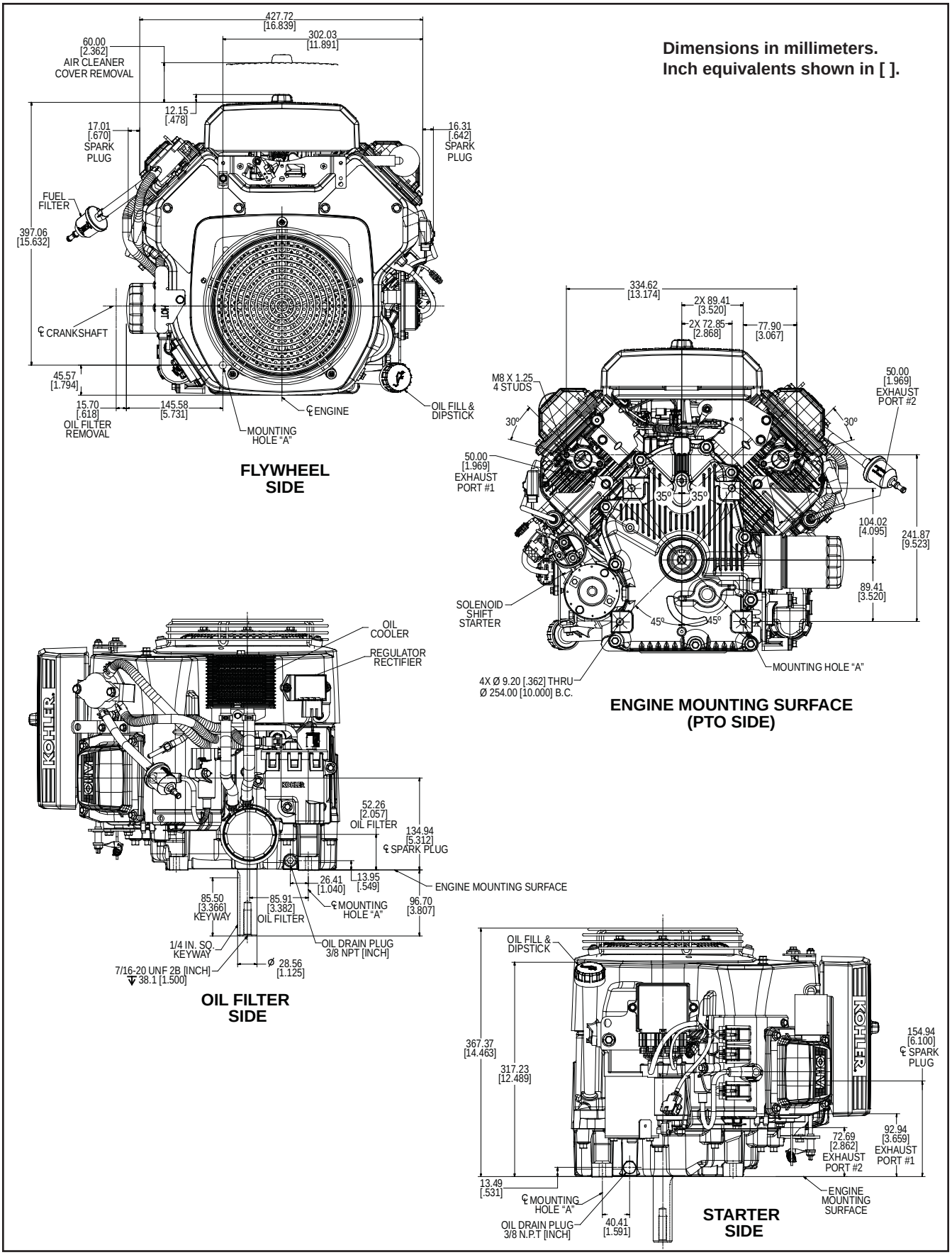


Figure 1-5. Typical Engine Dimensions - ECV749 with Low-Profile Air Cleaner.

General Specifications[1]

Power (@3600 RPM, exceeds Society of Automotive Engineers-Small Engine Test Code J1940.)

ECV630	14.1 kW (19 HP)
ECV650	15.7 kW (21 HP)
ECV680	17.2 kW (23 HP)
ECV730	18.6 kW (25 HP)
ECV740	20.1 kW (27 HP)
ECV749	21.6 kW (29 HP)

Bore

ECV630,ECV650,ECV680	80 mm (3.15 in.)
ECV730,ECV740,ECV749	83 mm (3.27 in.)

Stroke

ECV630,ECV650,ECV680,ECV730,ECV740,ECV749	69 mm (2.72 in.)

Displacement

ECV630,ECV650,ECV680	694 cc (42.4 cu. in.)
ECV730,ECV740,ECV749	747 cc (45.6 cu. in.)

Compression Ratio

ECV630,ECV650,ECV680	8.8:1
ECV730,ECV740,ECV749	9.1:1

Weight	46 kg (102 lb.)
Oil Capacity (w/filter) - approximate, determined by oil filter and oil cooler used:	1.9 L (2 U.S. qt.)
Angle of Operation - Maximum (At Full Oil Level) All Directions	25°

Blower Housing Screws (into cored aluminum hole or weld nut)

M5 Fasteners Torque	6.2 N·m (55 in. lb.) into new holes 4.0 N·m (35 in. lb.) into used holes
M6 Fasteners Torque	10.7 N·m (95 in. lb.) into new holes 7.3 N·m (65 in. lb.) into used holes

Blower Housing Screws (into extruded hole in sheet metal)

M5 Fasteners Torque	2.8 N·m (25 in. lb.) into new holes 2.3 N·m (20 in. lb.) into used holes
M6 Fasteners Torque	2.8 N·m (25 in. lb.) into new holes 2.3 N·m (20 in. lb.) into used holes

Blower Housing Screws

Rectifier-Regulator Fastener Torque	1.4 N·m (12.6 in. lb.)

Camshaft

End Play (With Shim)	0.051/0.381 mm (0.002/0.015 in.)

[1]Values are in Metric units. Values in parentheses are English equivalents. Lubricate threads with engine oil prior to assembly.

Running Clearance.....0.025/0.105 mm (0.001/0.004 in.)

Bore I.D.
- New.....20.000/20.025 mm (0.7874/0.7884 in.)
- Max. Wear Limit.....20.038 mm (0.7889 in.)

Camshaft Bearing Surface O.D.
- New.....19.920/19.975 mm (0.7843/0.7864 in.)
- Max. Wear Limit.....19.914 mm (0.7840 in.)

Connecting Rod

Cap Fastener Torque (torque in increments) .....11.6 N·m (103 in. lb.)

Connecting Rod-to-Crankpin Running Clearance @ 21°C (70°F)
- New.....0.043/0.073 mm (0.0017/0.0029 in.)
- Max. Wear Limit.....0.088 mm (0.0035 in.)

Connecting Rod-to-Crankpin Side Clearance.....0.26/0.63 mm (0.0102/0.0248 in.)

Connecting Rod-to-Piston Pin Running Clearance @ 21°C (70°F) .....0.015/0.028 mm (0.0006/0.0011 in.)

Connecting Rod Piston Pin End I.D. @ 21°C (70°F)
- New.....17.015/17.023 mm (0.6699/0.6702 in.)
- Max. Wear Limit.....17.036 mm (0.6707 in.)

Crankcase

Governor Cross Shaft Bore I.D.
- New.....8.025/8.075 mm (0.3159/0.3179 in.)
- Max. Wear Limit.....8.088 mm (0.3184 in.)

Breather Cover Fastener Torque .....11.3 N·m (100 in. lb.) into new holes
7.3 N·m (65 in. lb.) into used holes

Oil Temperature Sensor Torque.....7.3 N·m (65 in. lb.)

Oil Drain Plug Torque .....13.6 N·m (10 ft. lb.)

Oil Pan

Oil Pan Fastener Torque.....25.6 N·m (227 in. lb.)

Crankshaft

End Play (Free) .....0.025/0.635 mm (0.001/0.025 in.)

Crankshaft Bore (In Crankcase)
- New.....40.972/40.997 mm (1.6131/1.6141 in.)
- Max. Wear Limit.....41.011 mm (1.6146 in.)

Crankshaft to Sleeve Bearing (Oil Pan)
- Running Clearance - New .....0.03/0.12 mm (0.001/0.005 in.)

Crankshaft Bore (Oil Pan) - New .....40.974/41.000 mm (1.6131/1.6141 in.)

Crankshaft Bore (Oil Pan)-to-Crankshaft
- Running Clearance - New .....0.039/0.087 mm (0.0015/0.0034 in.)

Crankshaft - Flywheel End Main Bearing Journal
- O.D. - New ..... 40.913/40.935 mm (1.6107/1.6116 in.)
- O.D. - Max. Wear Limit ..... 40.843 mm (1.608 in.)
- Max. Taper Limit ..... 0.022 mm (0.0009 in.)
- Max. Out-of-Round Limit ..... 0.025 mm (0.0010 in.)

Crankshaft - Oil Pan End Main Bearing Journal
- O.D. - New ..... 40.913/40.935 mm (1.6107/1.6116 in.)
- O.D. - Max. Wear Limit ..... 40.843 mm (1.608 in.)
- Max. Taper ..... 0.022 mm (0.0009 in.)
- Max. Out-of-Round ..... 0.025 mm (0.0010 in.)

Crankshaft - Connecting Rod Journal
- O.D. - New ..... 35.950/35.973 mm (1.4153/1.4163 in.)
- O.D. - Max. Wear Limit ..... 35.941 mm (1.4150 in.)
- Max. Taper Limit ..... 0.018 mm (0.0007 in.)
- Max. Out-of-Round Limit ..... 0.025 mm (0.0010 in.)

Crankshaft T.I.R.
- PTO End, Crank in Engine ..... 0.279 mm (0.0110 in.)
- Entire Crank, in V-Blocks ..... 0.10 mm (0.0039 in.)

Cylinder Bore

Cylinder Bore I.D.
- New - ECV630,ECV650,ECV680 ..... 80.000/80.025 mm (3.1496/3.1506 in.)
- New - ECV730,ECV740,ECV749 ..... 83.006/83.031 mm (3.2680/3.2689 in.)
- Max. Wear Limit - ECV630,ECV650,ECV680 ..... 80.075 mm (3.1526 in.)
- Max. Wear Limit - ECV730,ECV740,ECV749 ..... 83.081 mm (3.2709 in.)
- Max. Out-of-Round ..... 0.120 mm (0.0047 in.)
- Max. Taper ..... 0.05 mm (0.0020 in.)

Cylinder Head

Cylinder Head Fastener Torque
- Hex Flange Nut - Torque in Two Stages ..... first to 16.9 N·m (150 in. lb.)
finally to 33.9 N·m (300 in. lb.)
- Head Bolt - Torque in Two Stages ..... first to 22.6 N·m (200 in. lb.)
finally to 41.8 N·m (370 in. lb.)

Cylinder Head Max. Out-of-Flatness ..... 0.076 mm (0.003 in.)

Rocker Arm Screw Torque ..... 11.9 N·m (105 in. lb.)

Fan/Flywheel

Fan Fastener Torque ..... 9.9 N·m (88 in. lb.)

Flywheel Retaining Screw Torque ..... 71.6 N·m (52.8 ft. lb.)

Fuel Pump

Fuel Pump Module Baffle Fastener Torque ..... 11.9 N·m (105 in. lb.)

Fuel Pump Module Fastener Torque ..... 9.2 N·m (81 in. lb.)

Pulse Pump Bracket Fastener Torque ..... 2.1 N·m (25 in. lb.)

Pulse Pump Fastener to Bracket Torque ..... 7.3 N·m (68 in. lb.) into new holes
6.2 N·m (55 in. lb.) into used holes

Governor

Governor Cross Shaft-to-Crankcase Running Clearance ..... 0.025/0.126 mm (0.0009/0.0049 in.)

Governor Cross Shaft O.D.
- New ..... 7.949/8.000 mm (0.3129/0.3149 in.)
- Max. Wear Limit ..... 7.936 mm (0.3124 in.)

Governor Gear Shaft-to-Governor Gear Running Clearance ..... 0.090/0.160 mm (0.0035/0.0063 in.)

Governor Gear Shaft O.D.
- New ..... 5.990/6.000 mm (0.2358/0.2362 in.)
- Max. Wear Limit ..... 5.977 mm (0.2353 in.)

Governor Lever Nut Torque ..... 7.1 N·m (63 in. lb.)

Ignition

Spark Plug Type (Champion® or Equivalent) ..... RC12YC, XC12YC, or Platinum 3071

Spark Plug Gap ..... 0.76 mm (0.030 in.)

Spark Plug Torque ..... 24.4-29.8 N·m (18-22 ft. lb.)

Ignition Coil Fastener Torque ..... 10.2 N·m (90 in. lb.)

Crankshaft Position Sensor Screw Torque ..... 6.2 N·m (55 in. lb.)

Crankshaft Position Sensor Bracket Screw Torque ..... 7.3 N·m (65 in. lb.)

Crankshaft Position Sensor Air Gap ..... 0.2-0.7 mm (0.008-0.027 in.)

Electronic Control Unit Screw Torque ..... 6.2 N·m (55 in. lb.)

Intake Manifold

Intake Manifold Mounting Fastener Torque
- Torque in Two Stages ..... first to 7.8 N·m (69 in. lb.)
finally to 10.5 N·m (93 in. lb.)

Fuel Injector Cap Fastener Torque ..... 7.3 N·m (65 in. lb.)

Manifold Absolute Pressure (MAP) Sensor Fastener Torque ..... 7.3 N·m (65 in. lb.)

Bracket for Heavy-Duty Air Cleaner to Intake Manifold ..... 9.9 N·m (88 in. lb.)

Air Cleaner to Throttle Body Fastener Nut Torque ..... 8.2 N·m (73 in. lb.)

Muffler

Muffler Retaining Nuts Torque ..... 27.8 N·m (246 in. lb.)

Oxygen Sensor Torque ..... 50.1 N·m (37 ft. lb.)

Oil Filter

Oil Filter Torque ..... refer to filter for instructions

Oil Cooler

Oil Cooler/Adapter Nipple Torque ..... 28.5 N·m (21 ft. lb.)

Oil Cooler Fastener Torque
- Top Fastener ..... 2.8 N·m (25 in. lb.)
- Bottom Fastener ..... 2.3 N·m (20 in. lb.)

Piston, Piston Rings, and Piston Pin

Piston-to-Piston Pin Running Clearance ..... 0.006/0.017 mm (0.0002/0.0007 in.)

Piston Pin Bore I.D.
- New ..... 17.006/17.012 mm (0.6695/0.6698 in.)
- Max. Wear Limit ..... 17.025 mm (0.6703 in.)

Piston Pin O.D.
- New ..... 16.995/17.000 mm (0.6691/0.6693 in.)
- Max. Wear Limit ..... 16.994 mm (0.6691 in.)

Top Compression Ring-to-Groove Side Clearance ..... 0.050/0.095 mm (0.0019/0.0037 in.)

Middle Compression Ring-to-Groove Side Clearance ..... 0.030/0.075 mm (0.0012/0.0030 in.)

Oil Control Ring-to-Groove Side Clearance ..... 0.010/0.011 mm (0.0004/0.0043 in.)

Top and Middle Compression Ring End Gap
- New Bore ..... 0.025/0.56 mm (0.010/0.022 in.)
- Used Bore (Max.) - ECV630,ECV650,ECV680 ..... 0.080 mm (0.0315 in.)
- Used Bore (Max.) - ECV730,ECV740,ECV749 ..... 0.094 mm (0.0370 in.)

Piston Thrust Face O.D.[2]
- ECV630,ECV650,ECV680 ..... 79.962/79.980 mm (3.1481/3.1488 in.)
- ECV730,ECV740,ECV749 ..... 82.949/82.967 mm (3.2657/3.2664 in.)
- Max. Wear Limit - ECV630,ECV650,ECV680 ..... 79.831 mm (3.1430 in.)
- Max. Wear Limit - ECV730,ECV740,ECV749 ..... 82.818 mm (3.2606 in.)

Piston Thrust Face-to-Cylinder Bore[2] Running Clearance
- New - ECV630,ECV650,ECV680 ..... 0.020/0.063 mm (0.0008/0.0024 in.)
- New - ECV730,ECV740,ECV749 ..... 0.0039/0.082 mm (0.0015/0.0032 in.)

Speed Control Bracket (Assembled to Cylinder Heads)

Fastener Torque ..... 10.7 N·m (95 in. lb.) into new holes
7.3 N·m (65 in. lb.) into used holes

Speed Control Bracket (Assembled to Blower Housing)

Fastener Torque ..... 2.8 N·m (25 in. lb.) into new holes
2.3 N·m (20 in. lb.) into used holes

Starter Assembly

Thru Bolt Torque ..... 5.6-9.0 N·m (49-79 in. lb.)

Mounting Screw Torque (All) ..... 16.0 N·m (142 in. lb.)

Brush Holder Mounting Screw Torque ..... 2.5-3.3 N·m (22-29 in. lb.)

[2]Measure 6 mm (0.236 in.) above the bottom of the piston skirt at right angles to the piston pin.

Solenoid (Starter)

Mounting Hardware Torque ..... 4.0-6.0 N·m (35-53 in. lb.)

Nut, Positive (+) Brush Lead Torque ..... 8.0-11.0 N·m (71-97 in. lb.)

Stator

Mounting Screw Torque ..... 6.2 N·m (55 in. lb.) into new holes
4.0 N·m (35 in. lb.) into used holes

Valve Cover

Valve Cover Fastener Torque ..... 6.2 N·m (55 in. lb.)

Valves and Valve Lifters

Hydraulic Valve Lifter to Crankcase Running Clearance ..... 0.011/0.048 mm (0.0004/0.0019 in.)

Intake Valve Stem-to-Valve Guide Running Clearance ..... 0.040/0.078 mm (0.0016/0.0031 in.)

Exhaust Valve Stem-to-Valve Guide Running Clearance ..... 0.052/0.090 mm (0.0020/0.0035 in.)

Intake Valve Guide I.D.
- New ..... 7.040/7.060 mm (0.2772/0.2780 in.)
- Max. Wear Limit ..... 7.134 mm (0.2809 in.)

Exhaust Valve Guide I.D.
- New ..... 7.040/7.060 mm (0.2772/0.2780 in.)
- Max. Wear Limit ..... 7.159 mm (0.2819 in.)

Valve Guide Reamer Size
- Standard ..... 7.050 mm (0.2776 in.)
- 0.25 mm O.S. ..... 7.300 mm (0.2874 in.)

Intake Valve Minimum Lift ..... 8.07 mm (0.3177 in.)

Exhaust Valve Minimum Lift ..... 8.07 mm (0.3177 in.)

Nominal Valve Seat Angle ..... 45°

General Torque Values

Metric Fastener Torque Recommendations for Standard Applications

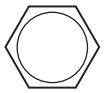
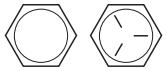
Tightening Torque: N·m (in. lb.) + or - 10%

Size	Property Class 4.8	5.8	8.8	10.9	12.9	Noncritical Fasteners Into Aluminum
M4	1.2 (11)	1.7 (15)	2.9 (26)	4.1 (36)	5.0 (44)	2.0 (18)
M5	2.5 (22)	3.2 (28)	5.8 (51)	8.1 (72)	9.7 (86)	4.0 (35)
M6	4.3 (38)	5.7 (50)	9.9 (88)	14.0 (124)	16.5 (146)	6.8 (60)
M8	10.5 (93)	13.6 (120)	24.4 (216)	33.9 (300)	40.7 (360)	17.0 (150)

Tightening Torque: N·m (ft. lb.) + or - 10%

	Property Class 4.8	5.8	8.8	10.9	12.9	Noncritical Fasteners Into Aluminum
M10	21.7 (16)	27.1 (20)	47.5 (35)	66.4 (49)	81.4 (60)	33.9 (25)
M12	36.6 (27)	47.5 (35)	82.7 (61)	116.6 (86)	139.7 (103)	61.0 (45)
M14	58.3 (43)	76.4 (55)	131.5 (97)	184.4 (136)	219.7 (162)	94.9 (70)

English Fastener Torque Recommendations for Standard Applications

Tightening Torque: N·m (in. lb.) + or - 20%				
Bolts, Screws, Nuts and Fasteners Assembled Into Cast Iron or Steel				**Grade 2 or 5 Fasteners Into Aluminum**
	 **Grade 2**	 **Grade 5**	 **Grade 8**	
Size				
8-32	2.3 (20)	2.8 (25)	---------	2.3 (20)
10-24	3.6 (32)	4.5 (40)	---------	3.6 (32)
10-32	3.6 (32)	4.5 (40)	---------	---------
1/4-20	7.9 (70)	13.0 (115)	18.7 (165)	7.9 (70)
1/4-28	9.6 (85)	15.8 (140)	22.6 (200)	---------
5/16-18	17.0 (150)	28.3 (250)	39.6 (350)	17.0 (150)
5/16-24	18.7 (165)	30.5 (270)	---------	---------
3/8-16	29.4 (260)	---------	---------	---------
3/8-24	33.9 (300)	---------	---------	---------
Tightening Torque: N·m (ft. lb.) + or - 20%				
Size				
5/16-24	---------	----------	40.7 (30)	---------
3/8-16	---------	47.5 (35)	67.8 (50)	---------
3/8-24	---------	54.2 (40)	81.4 (60)	---------
7/16-14	47.5 (35)	74.6 (55)	108.5 (80)	---------
7/16-20	61.0 (45)	101.7 (75)	142.4 (105)	---------
1/2-13	67.8 (50)	108.5 (80)	155.9 (115)	---------
1/2-20	94.9 (70)	142.4 (105)	223.7 (165)	---------
9/16-12	101.7 (75)	169.5 (125)	237.3 (175)	---------
9/16-18	135.6 (100)	223.7 (165)	311.9 (230)	---------
5/8-11	149.2 (110)	244.1 (180)	352.6 (260)	---------
5/8-18	189.8 (140)	311.9 (230)	447.5 (330)	---------
3/4-10	199.3 (150)	332.2 (245)	474.6 (350)	---------
3/4-16	271.2 (200)	440.7 (325)	637.3 (470)	---------

Torque Conversions

N·m = in. lb. x 0.113
N·m = ft. lb. x 1.356
in. lb. = N·m x 8.85
ft. lb. = N·m x 0.737

Section 2
Tools & Aids

Certain quality tools are designed to help you perform specific disassembly, repair, and reassembly procedures. By using tools designed for the job, you can properly service engines easier, faster, and safer! In addition, you'll increase your service capabilities and customer satisfaction by decreasing engine downtime.

Here is the list of tools and their source.

Separate Tool Suppliers:

Kohler Tools
Contact your source of supply.

SE Tools
415 Howard St.
Lapeer, MI 48446
Phone 810-664-2981
Toll Free 800-664-2981
Fax 810-664-8181

Design Technology Inc.
768 Burr Oak Drive
Westmont, IL 60559
Phone 630-920-1300
Fax 630-920-0011

Tools	
Description	**Source/Part No.**
Camshaft Endplay Plate For checking camshaft endplay.	SE Tools KLR-82405
Camshaft Seal Protector (Aegis) To protect seal during camshaft installation.	SE Tools KLR-82417
Cylinder Leakdown Tester For checking combustion retention and if cylinder, piston, rings, or valves are worn.	Kohler 25 761 05-S
Electronic Fuel Injection (EFI) Diagnostic Software Use with Laptop or Desktop PC.	Kohler 25 761 23-S
EFI Service Kit For troubleshooting and setting up an EFI engine.	Kohler 24 761 01-S
Individual Components Available	Design Technology Inc.
Fuel Pressure Tester	DTI-019
Noid Light	DTI-021
90° Adapter	DTI-023
In-line "T" Fitting	DTI-035
Code Plug, Red Wire	DTI-027
Code Plug, Blue Wire	DTI-029
Shrader Valve Adapter Hose	DTI-037
Flywheel Holding Tool (CS Series)	SE Tools KLR-82407
Flywheel Puller To remove flywheel from engine.	SE Tools KLR-82408
Flywheel Strap Wrench To hold flywheel during removal.	SE Tools KLR-82409

Tools (Continued)	
Description	**Source/Part No.**
Hydraulic Valve Lifter Tool To remove and install hydraulic lifters.	Kohler 25 761 38-S
Ignition System Tester For testing output on all systems, including CD.	Kohler 25 455 01-S
Offset Wrench (K & M Series) To remove and reinstall cylinder barrel retaining nuts.	Kohler 52 455 04-S
Oil Pressure Test Kit To test and verify oil pressure.	Kohler 25 761 06-S
Rectifier-Regulator Tester (120 volt current) **Rectifier-Regulator Tester (240 volt current)** Used to test rectifier-regulators.	Kohler 25 761 20-S Kohler 25 761 41-S
Individual Components Available CS-PRO Regulator Test Harness Special Regulator Test Harness with Diode	Design Technology Inc. DTI-031 DTI-033
Spark Advance Module (SAM) Tester To test the SAM (ASAM and DSAM) on engines with SMART-SPARK™.	Kohler 25 761 40-S
Starter Servicing Kit (All Starters) To remove and reinstall drive retaining rings and brushes.	SE Tools KLR-82411
Individual Component Available Starter Brush Holding Tool (Solenoid Shift)	SE Tools KLR-82416
Tachometer (Digital Inductive) For checking operating speed (RPM) of an engine.	Design Technology Inc. DTI-110
Vacuum/Pressure Tester Alternative to a water manometer.	Kohler 25 761 22-S

Aids	
Description	**Source/Part No.**
Camshaft Lubricant (Valspar ZZ613)	Kohler 25 357 14-S
Dielectric Grease (GE/Novaguard G661)	Kohler 25 357 11-S
Dielectric Grease (Fel-Pro)	Lubri-Sel
Electric Starter Drive Lubricant (Inertia Drive)	Kohler 52 357 01-S
Electric Starter Drive Lubricant (Solenoid Shift)	Kohler 52 357 02-S
RTV Silicone Sealant Loctite® 5900 Heavy Body in 4 oz aerosol dispenser. Only oxime-based, oil resistant RTV sealants, such as those listed, are approved for use. Loctite® Nos. 5900® or 5910® are recommended for best sealing characteristics. Loctite® 5910® Loctite® Ultra Black 598™ Loctite® Ultra Blue 587™ Loctite® Ultra Copper 5920™	Kohler 25 597 07-S
Spline Drive Lubricant	Kohler 25 357 12-S

Special Tools You Can Make

Flywheel Holding Tool

A flywheel holding tool can be made out of an old flywheel ring gear as shown in Figure 2-1, and used in place of a strap wrench.

1. Using an abrasive cut-off wheel, cut out a six tooth segment of the ring gear as shown.
2. Grind off any burrs or sharp edges.
3. Invert the segment and place it between the ignition bosses on the crankcase so that the tool bosses will lock the tool and flywheel in position for loosening, tightening or removing with a puller.

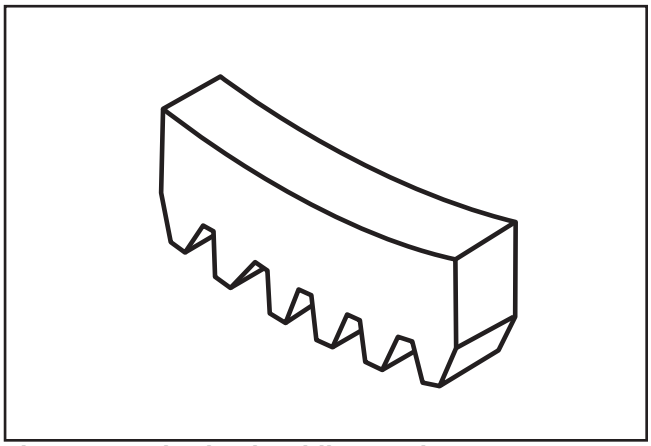


Figure 2-1. Flywheel Holding Tool.

Rocker Arm/Crankshaft Tool

A spanner wrench to lift the rocker arms or turn the crankshaft may be made out of an old junk connecting rod.

1. Find a used connecting rod from a 10 HP or larger engine. Remove and discard the rod cap.
2. Remove the studs of a Posi-Lock rod or grind off the aligning steps of a Command rod, so the joint surface is flat.
3. Find a 1 in. long capscrew with the correct thread size to match the threads in the connecting rod.
4. Use a flat washer with the correct I.D. to slip on the capscrew and approximately 1 in. O.D. (Kohler Part No. **12 468 05-S**). Assemble the capscrew and washer to the joint surface of the rod, as shown in Figure 2-2.

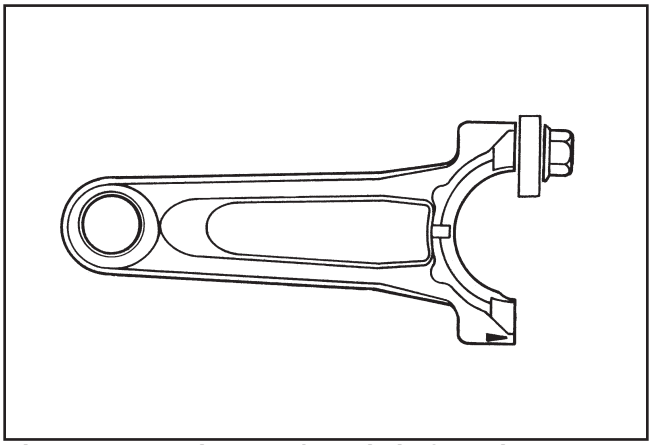


Figure 2-2. Rocker Arm/Crankshaft Tool.

Section 3
Troubleshooting

Troubleshooting Guide

When troubles occur, be sure to check the simple causes which, at first, may seem too obvious to be considered. For example, a starting problem could be caused by an empty fuel tank.

Some general common causes of engine troubles are listed below. Use these to locate the causing factors. Refer to the specific section(s) within this service manual for more detailed information.

Engine Cranks But Will Not Start

1. Empty fuel tank.
2. Fuel shut-off valve closed.
3. Poor fuel, dirt or water in the fuel system.
4. Clogged fuel line.
5. Spark plug lead(s) disconnected.
6. Key switch or kill switch in OFF position.
7. Faulty spark plugs.
8. Faulty ignition coil(s).
9. Battery connected backwards.
10. Safety interlock system engaged.
11. Vacuum fuel pump malfunction, or oil in vacuum hose.
12. Vacuum hose to fuel pump leaking or cracked.
13. Blown fuse.
14. Faulty electronic control unit.
15. Insufficient voltage to electronic control unit.

Engine Starts But Does Not Keep Running

1. Restricted fuel tank cap vent.
2. Poor fuel, dirt or water in the fuel system.
3. Loose wires or connections.
4. Faulty cylinder head gasket.
5. Intake system leak.
6. Faulty ignition coil or coils.
7. Faulty or improperly adjusted throttle controls.
8. Vacuum fuel pump malfunction, or oil in vacuum hose.
9. Vacuum hose to fuel pump leaking or cracked.
10. Blown fuse.
11. Insufficient voltage to electronic control unit.

Engine Starts Hard

1. PTO drive is engaged.
2. Dirt or water in the fuel system.
3. Clogged fuel line or fuel filter.
4. Loose or faulty wires or connections.
5. Faulty spark plugs.
6. Low compression.
7. Weak spark.
8. Fuel pump malfunction causing lack of fuel.
9. Engine overheated - cooling/air circulation restricted.
10. Quality of fuel.
11. Flywheel key sheared.
12. Intake system leak.
13. Faulty or improperly adjusted throttle controls.

Engine Will Not Crank

1. PTO drive is engaged.
2. Battery is discharged.
3. Safety interlock switch is engaged.
4. Loose or faulty wires or connections.
5. Faulty key switch or ignition switch.
6. Faulty electric starter or solenoid.
7. Seized internal engine components.
8. Blown fuse.
9. Insufficient voltage to electronic control unit.
10. Faulty electronic control unit.

Engine Runs But Misses

1. Dirt or water in the fuel system.
2. Spark plug lead disconnected.
3. Poor quality of fuel.
4. Faulty spark plug(s).
5. Loose wires or connections.
6. Engine overheated.
7. Faulty ignition coil or coils.
8. Incorrect crankshaft position sensor air gap.
9. Insufficient voltage to electronic control unit.

Engine Will Not Idle

1. Dirt or water in the fuel system.
2. Stale fuel or dirty fuel injectors.
3. Faulty spark plugs.
4. Fuel supply inadequate.
5. Low compression.
6. Restricted fuel tank cap vent.
7. Engine overheated - cooling system/air circulation problem.

Engine Overheats

1. Air intake/grass screen, cooling fins, oil cooler or cooling shrouds clogged.
2. Excessive engine load.
3. Low crankcase oil level.
4. High crankcase oil level.
5. Lean air-fuel mixture.

Engine Knocks

1. Excessive engine load.
2. Low crankcase oil level.
3. Old or improper fuel.
4. Internal wear or damage.
5. Hydraulic lifter malfunction.
6. Quality of fuel.
7. Incorrect grade of oil.

Engine Loses Power

1. Low crankcase oil level.
2. High crankcase oil level.
3. Dirty air cleaner element.
4. Dirt or water in the fuel system.
5. Excessive engine load.
6. Engine overheated.
7. Faulty spark plugs.
8. Low compression.
9. Exhaust restriction.
10. Low battery.
11. Incorrect governor setting.

Engine Uses Excessive Amount of Oil

1. Incorrect oil viscosity/type.
2. Clogged or improperly assembled breather.
3. Breather reed broken.
4. Worn or broken piston rings.
5. Worn cylinder bore.
6. Worn valve stems/valve guides.
7. Crankcase overfilled.
8. Blown head gasket/overheated.

Oil Leaks from Oil Seals, Gaskets

1. Crankcase breather is clogged or inoperative.
2. Breather reed broken.
3. Loose or improperly torqued fasteners.
4. Piston blowby, or leaky valves.
5. Restricted exhaust.

External Engine Inspection

Before cleaning or disassembling the engine, make a thorough inspection of its external appearance and condition. This inspection can give clues to what might be found inside the engine (and the cause) when it is disassembled.

- Check for buildup of dirt and debris on the crankcase, cooling fins, grass screen, and other external surfaces. Dirt or debris on these areas are causes of higher operating temperatures and overheating.

- Check for obvious fuel and oil leaks, and damaged components. Excessive oil leakage can indicate a clogged or improperly-assembled breather, worn/damaged seals and gaskets, or loose or improperly-torqued fasteners.

- Check the air cleaner cover and base for damage or indications of improper fit and seal.

- Check the air cleaner element. Look for holes, tears, cracked or damaged sealing surfaces, or other damage that could allow unfiltered air into the engine. Also note if the element is dirty or clogged. These could indicate that the engine has been under serviced.

- Check the oil level. Note if the oil level is within the operating range on the dipstick, or if it is low or overfilled.

- Check the condition of the oil. Drain the oil into a container - the oil should flow freely. Check for metal chips and other foreign particles.

  Sludge is a natural by-product of combustion; a small accumulation is normal. Excessive sludge formation could indicate weak ignition, overextended oil change intervals or wrong weight or type of oil was used, to name a few.

  NOTE: It is good practice to drain oil at a location away from the workbench. Be sure to allow ample time for complete drainage.

Cleaning the Engine

After inspecting the external condition of the engine, clean the engine thoroughly before disassembling it. Also clean individual components as the engine is disassembled. Only clean parts can be accurately inspected and gauged for wear or damage. There are many commercially available cleaners that will quickly remove grease, oil, and grime from engine parts. When such a cleaner is used, *follow the manufacturer's instructions and safety precautions carefully*.

Make sure all traces of the cleaner are removed before the engine is reassembled and placed into operation. Even small amounts of these cleaners can quickly break down the lubricating properties of engine oil.

Basic Engine Tests

Crankcase Vacuum Test

A partial vacuum should be present in the crankcase when the engine is operating. Pressure in the crankcase (normally caused by a clogged or improperly assembled breather) can cause oil to be forced out at oil seals, gaskets, or other available spots.

Crankcase vacuum is best measured with either a water manometer, or a vacuum gauge (see Section 2). Complete instructions are provided in the kits.

To test the crankcase vacuum with the manometer:

1. Insert the stopper/hose into the oil fill hole. Leave the other tube of manometer open to atmosphere. Make sure the shut-off clamp is closed.

2. Start the engine and run at no-load high speed (3200-3750 RPM).

3. Open the clamp and note the water level in the tube.

   The level in the engine side should be a minimum of **10.2 cm (4 in.)** above the level in the open side.

   If the level in the engine side is less than specified (low/no vacuum), or the level in the engine side is lower than the level in the open side (pressure), check for the conditions in the table below.

4. Close the shut-off clamp **before** stopping the engine.

To test the crankcase vacuum with the Vacuum/ Pressure Gauge Kit:

1. Remove the dipstick or oil fill plug/cap.

2. Install the adapter into the oil fill/dipstick tube opening.

3. Push the barbed fitting on the gauge solidly into the hole in the adapter.

4. Start the engine and bring it up to operating speed (3200-3600 RPM).

5. Check the reading on the gauge. If the reading is to the **left** of "0" on the gauge, vacuum or negative pressure is indicated. If the reading is to the **right** of "0" on the gauge, positive pressure is present.

   Crankcase vacuum should be 4-10 (inches of water). If the reading is below specification, or if pressure is present, check the following table for possible causes and remedies.

No Crankcase Vacuum/Pressure in Crankcase

Possible Cause	Solution
1. Crankcase breather clogged or inoperative.	1. Disassemble breather, clean parts thoroughly, reassemble, and recheck pressure.
2. Seals and/or gaskets leaking. Loose or improperly torqued fasteners.	2. Replace all worn or damaged seals and gaskets. Make sure all fasteners are tightened securely. Use appropriate torque values and sequences when necessary.
3. Piston blowby or leaky valves (confirm by inspecting components).	3. Recondition piston, rings, cylinder bore, valves, and valve guides.
4. Restricted exhaust.	4. Repair/replace restricted muffler/exhaust system.

Compression Test

A compression test can be performed using a compression tester. Follow the manufacturers instructions for performing the test.

Cylinder Leakdown Test

A cylinder leakdown test can be a valuable alternative to a compression test. By pressurizing the combustion chamber from an external air source you can determine if the valves or rings are leaking, and how badly.

Cylinder Leakdown Tester (see Section 2) is a relatively simple, inexpensive leakdown tester for small engines. The tester includes a quick disconnect for attaching the adapter hose, and a holding tool.

Leakdown Test Instructions

1. Run the engine for 3-5 minutes to warm it up.

2. Remove the spark plug(s) and the air filter from engine.

3. Rotate the crankshaft until the piston (of cylinder being tested) is at top dead center of the compression stroke. Hold the engine in this position while testing. The holding tool supplied with the tester can be used if the PTO end of the crankshaft is accessible. Lock the holding tool onto the crankshaft. Install a 3/8 in. breaker bar into the hole/slot of the holding tool, so it is perpendicular to both the holding tool and crankshaft PTO.

   If the flywheel end is more accessible, use a breaker bar and socket on the flywheel nut/screw to hold it in position. An assistant may be needed to hold the breaker bar during testing. If the engine is mounted in a piece of equipment, it may be possible to hold it by clamping or wedging a driven component. Just be certain that the engine cannot rotate off of TDC in either direction.

4. Install the adapter into the spark plug hole, but do not attach it to the tester at this time.

5. Connect an air source of at least 50 psi to the tester.

6. Turn the regulator knob in the increase (clockwise) direction until the gauge needle is in the yellow **set** area at the low end of the scale.

7. Connect the tester quick-disconnect to the adapter hose while firmly holding the engine at TDC. Note the gauge reading and listen for escaping air at the throttle body, exhaust outlet, and crankcase breather.

8. Check the test results against the following table:

Leakdown Test Results

Air escaping from crankcase breather	Rings or cylinder worn.
Air escaping from exhaust system	Defective exhaust valve/improper seating.
Air escaping from throttle body	Defective intake valve/improper seating.
Gauge reading in “low” (green) zone	Piston rings and cylinder in good condition.
Gauge reading in “moderate” (yellow) zone	Engine is still usable, but there is some wear present. Customer should start planning for overhaul or replacement.
Gauge reading in “high” (red) zone	Rings and/or cylinder have considerable wear. Engine should be reconditioned or replaced.

Section 4
Air Cleaner and Air Intake System

This engine is equipped with a heavy-duty air cleaner, low-profile air cleaner, or special air cleaner supplied by the equipment manufacturer.

Heavy-Duty Air Cleaner

General

These engines use a heavy-duty style air cleaner shown in Figure 4-1, consisting of a cylindrical housing mounted to a bracket, on the throttle body/intake manifold. The air cleaner housing contains a paper element and inner element, designed for longer service intervals. The system is CARB/EPA certified and the components should not be altered or modified in any way.

Service

Weekly and every 150 hours: Check filter minder (if equipped), perform inspection of the paper element and inlet screen area.

Yearly or every 300 hours of operation (more often under extremely dusty or dirty conditions), replace the paper element and check the inner element. Follow these steps.

1. Unhook the two retaining clips on each end and remove the end caps from the air cleaner housing. See Figure 4-1.

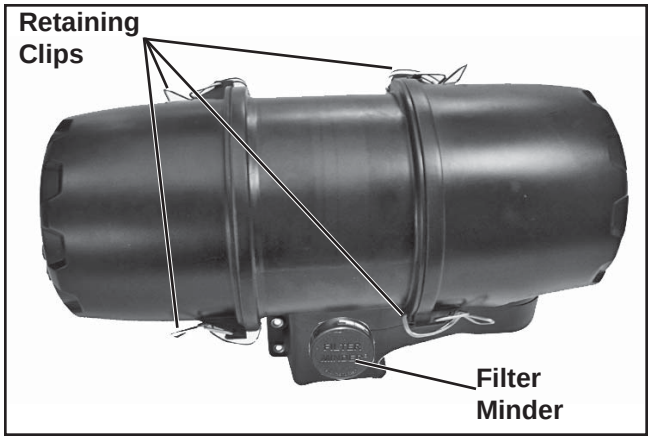


Figure 4-1. Heavy-Duty Air Cleaner.

2. Check and clean the inlet screen. Pull the paper element out of the housing on the opposite side. See Figures 4-2 and 4-3.

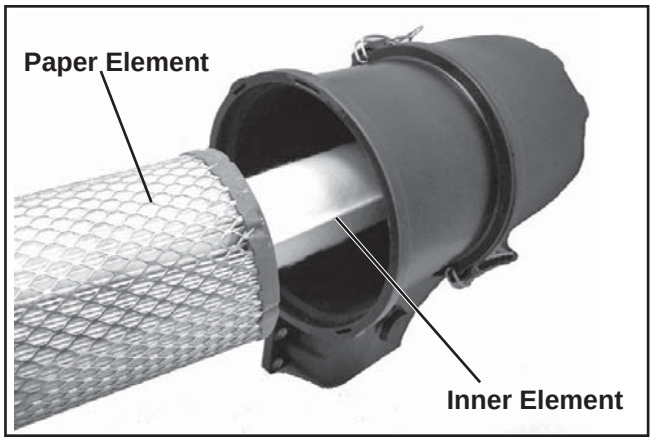


Figure 4-2. Removing Elements.

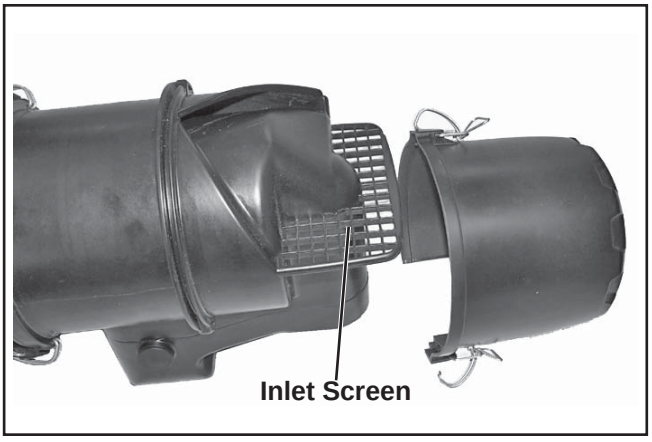


Figure 4-3. Accessing Inlet Screen.

3. After the paper element is removed, check the condition of the inner element. It should be replaced whenever it appears dirty, typically every other time the main element is replaced or every **600 hours**. Clean the area around the base of the inner element before removing it, so dirt does not get into the engine.

4. **Do not wash the paper element and inner element or use compressed air, this will damage the elements**. Replace dirty, bent or damaged elements with new genuine Kohler elements as required. Handle the new elements carefully; do not use if the sealing surfaces are bent or damaged.

5. Check all parts for wear, cracks, or damage, and make sure ejector area is clean. See Figure 4-4. Replace any damaged components.

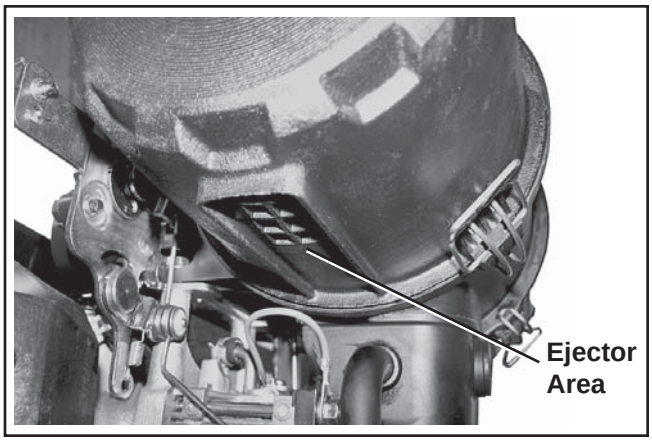


Figure 4-4. Ejector Area.

6. Install the new inner element, followed by the paper element. Slide each fully into place in the air cleaner housing.

7. Reinstall the end caps and secure with the retaining clips. See Figure 4-1.

Removal

1. Remove the three hex flange nuts securing the assembly to the throttle body. See Figure 4-5.

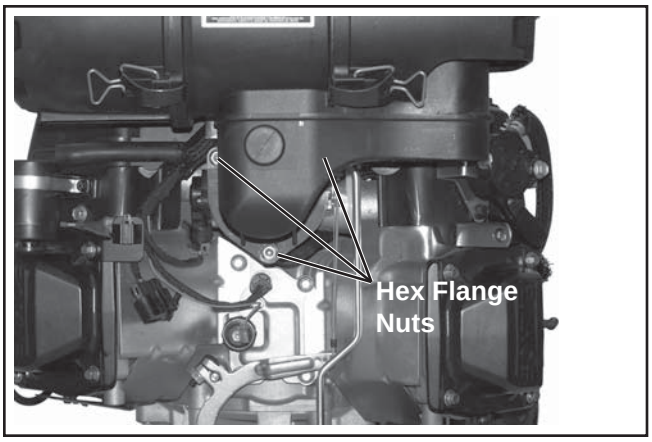


Figure 4-5. Air Cleaner Hex Flange Nuts.

2. Remove two hex flange screws securing the air cleaner assembly to air cleaner bracket.

3. Lift the entire air cleaner assembly off the engine. Disassemble or service as required.

4. Reinstall the components in reverse order of removal.

5. Reset the governor (see Section 5).

Low-Profile Air Cleaner (Optional)

General

An optional air cleaner is the low-profile air cleaner with an oiled-foam precleaner which surrounds a paper element.

The low-profile air cleaner is shown in Figure 4-6.

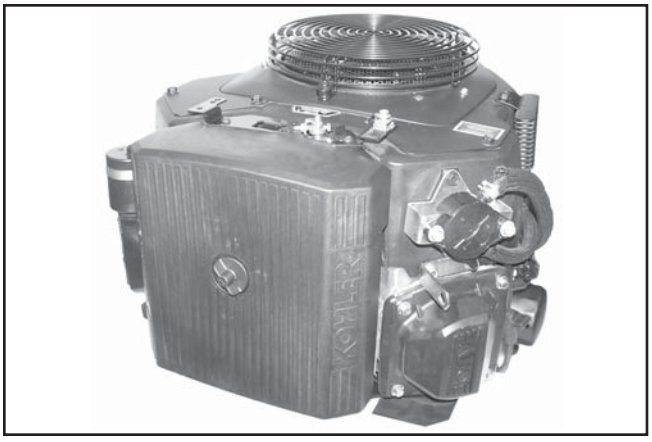


Figure 4-6. Low-Profile Air Cleaner.

Service

Check the air cleaner **daily or before starting the engine**. Check for and correct any buildup of dirt and debris, along with loose or damaged components.

NOTE: Operating the engine with loose or damaged air cleaner components could allow unfiltered air into the engine causing premature wear and failure.

Precleaner Service

If so equipped, wash and reoil the precleaner every **25 hours** of operation (more often under extremely dusty or dirty conditions).

To service the precleaner, see Figures 4-7, 4-8 and 4-9 and perform the following steps:

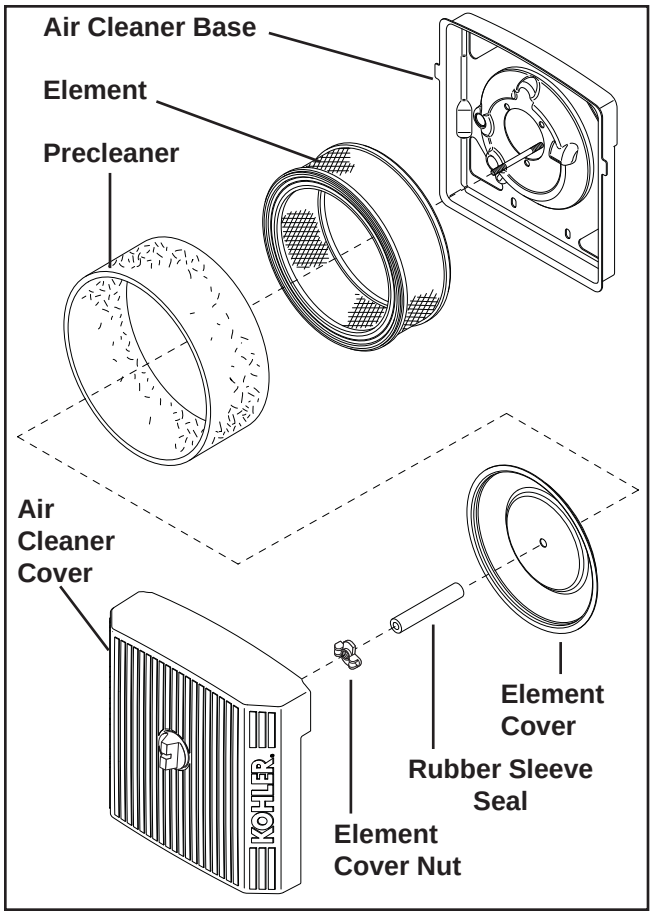


Figure 4-7. Low-Profile Air Cleaner Exploded View.

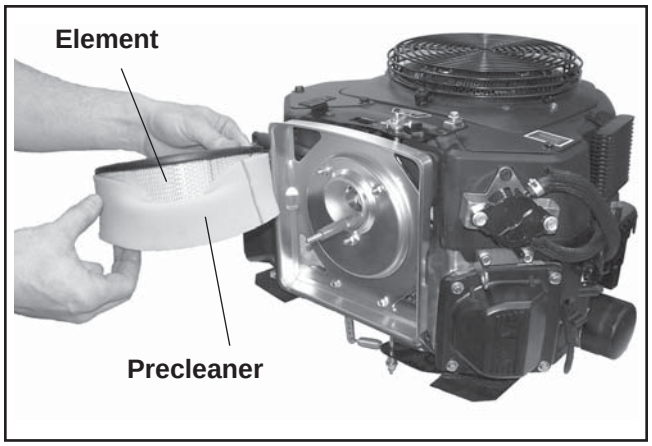


Figure 4-8. Precleaner on Low-Profile Air Cleaner.

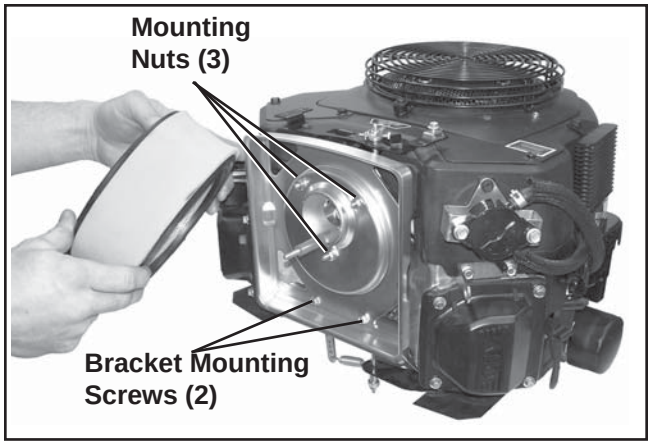


Figure 4-9. Base Plate Removal on Low-Profile Air Cleaner.

1. Loosen the cover retaining knob and remove the cover.

2. Remove the foam precleaner from the paper air cleaner element.

3. Wash the precleaner in warm water with detergent. Rinse the precleaner thoroughly until all traces of detergent are eliminated. Squeeze out excess water (do not wring). Allow the precleaner to air dry.

4. Saturate the precleaner with new engine oil. Squeeze out all excess oil.

5. Reinstall the precleaner over the paper air cleaner element.

6. Reinstall the air cleaner cover. Secure the cover with the retaining knob.

Paper Element Service

Every **100 hours** of operation (more often under extremely dusty or dirty conditions), replace the paper element. See Figure 4-8, and follow these steps:

1. Loosen the cover retaining knob and remove the cover.
2. Remove the wing nut, element cover, and air cleaner element.
3. Remove the precleaner from the paper element. Service the precleaner as described in **Precleaner Service**.
4. **Do not wash the paper element or use pressurized air,** as this will damage the element. Replace a dirty, bent, or damaged element with a genuine Kohler element. Handle new elements carefully; do not use if the sealing surfaces are bent or damaged.
5. Check the rubber sleeve seal for any damage or deterioration. Replace as necessary.
6. Reinstall the paper element, precleaner, element cover, and wing nut.
7. Reinstall the air cleaner cover and secure retaining knob.

Air Cleaner Components

Whenever the air cleaner cover is removed, or the paper element or precleaner are serviced, check the following:

Air Cleaner Element Cover and Seal - Make sure element cover is not bent or damaged. Make sure the rubber sleeve seal is in place on the stud to prevent dust or dirt entry through the stud hole.

Air Cleaner Base - Make sure the base is secured tightly to the throttle body and not cracked or damaged.

NOTE: Damaged, worn or loose air cleaner components can allow unfiltered air into the engine causing premature wear and failure. Tighten or replace all loose or damaged components.

Disassembly/Reassembly - Low-Profile

If the base plate on the low-profile air cleaner has to be removed, proceed as follows:

1. Remove the air cleaner components from the base (see Figures 4-8 and 4-9).
2. Remove the two hex flange screws securing base to the bracket and the three hex flange nuts from the studs from the intake manifold. See Figure 4-9.
3. Remove the base and gasket.
4. Reverse the procedure to reassemble the components. Torque the three hex flange nuts to **7.4-9.0 N·m (65.5-80 in. lb.)** and the two lower mounting screws to **2.8 N·m (25 in. lb.)** into new holes or **2.3 N·m (20 in. lb.)** into used holes.
5. Reset the governor (see Section 5).

Air Intake/Cooling System

To ensure proper cooling, make sure the fixed screen, cooling fins, and other external surfaces of the engine are kept clean **at all times**.

Every **100 hours** of operation (more often under extremely dusty or dirty conditions), remove the blower housing and other cooling shrouds. Clean the cooling fins and external surfaces as necessary. Make sure the cooling shrouds are reinstalled.

Kohler Cleanout kits are recommended to aid inspection and cleanout of the cooling fins. See Figure 4-10.

NOTE: Operating the engine with a blocked fixed screen, dirty or plugged cooling fins, and/or cooling shrouds removed, will cause engine damage due to overheating.

Figure 4-10. Cleanout Kit Installed on Blower Housing.

Section 5
Electronic Fuel Injection (EFI) System

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Description

⚠ WARNING

Explosive Fuel can cause fires and severe burns.
Do not fill the fuel tank while the engine is hot or running.

Explosive Fuel!

Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Do not fill the fuel tank while the engine is hot or running, since spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Do not start the engine near spilled fuel. Never use gasoline as a cleaning agent.

⚠ WARNING

Explosive Fuel can cause fires and severe burns.
Fuel systems ALWAYS remains under HIGH PRESSURE.

Fuel Fire and Burns!

Wrap a shop towel completely around the fuel pump module connector. Press the release button(s) and slowly pull the connector away from the fuel pump module allowing the shop towel to absorb any residual fuel in the high pressure fuel line. Any spilled fuel must be completely wiped up immediately.

The EFI fuel system remains under high pressure even when the engine is stopped. Before attempting to service any part of the fuel system, the pressure must be relieved by following Fuel Pump Module Fuel Connector Removal instructions below.

Fuel Pump Module Fuel Connector Removal

Wrap a shop towel completely around the fuel pump module connector. Press the release button(s) and slowly pull the connector away from the fuel pump module allowing the shop towel to absorb any residual fuel in the high pressure fuel line. Any spilled fuel must be completely wiped up immediately.

Initial Starting/Priming Procedure

Important: The EFI fuel system must be purged of air (primed) prior to the initial start up, and/or any time the system has been disassembled or the fuel tank run dry.

1. Turn the key switch to the ON/RUN position. You will hear the fuel pump cycle on and off. When the fuel pump stops cycling (approximately 20 seconds), the system is primed; start the engine.
2. A completely dry system may require repeating step 1 several times. Wait a minimum of 10 seconds between key OFF and key ON.

Fuel Recommendations

General Recommendations

Purchase gasoline in small quantities and store in clean, approved containers. An approved container with a capacity of 2 gallons or less with a pouring spout is recommended. Such a container is easier to handle and helps prevent spillage during refueling.

- Do not use gasoline left over from the previous season, to minimize gum deposits in your fuel system, and to ensure easy starting.
- Do not add oil to the gasoline.
- Do not overfill the fuel tank. Leave room for the fuel to expand.

Fuel Type

For best results use only clean, fresh, **unleaded** gasoline with a pump sticker octane rating of 87 (R+M)/2 or higher. In countries using the Research Octane Number (RON), it should be 90 octane minimum. Leaded gasoline is not recommended and must not be used on EFI engines or on other models where exhaust emissions are regulated.

Gasoline/Alcohol Blends

Gasohol (up to 10% ethyl alcohol, 90% unleaded gasoline by volume) is approved as a fuel for Kohler engines. Other gasoline/alcohol blends including E20 and E85 are not to be used and not approved. Any failures resulting from use of these fuels will not be warranted.

Gasoline/Ether Blends

Methyl Tertiary Butyl Ether (MTBE) and unleaded gasoline blends (up to a maximum of 15% MTBE by volume) are approved as a fuel for Kohler engines. Other gasoline/ether blends are not approved.

EFI Fuel System Components

General

The Electronic Fuel Injection (EFI) system is a complete engine fuel and ignition management design. The system includes the following principal components:

- Fuel Pump Module and Lift Pump
- Fuel Filter
- High Pressure Fuel Line

- Fuel Line(s)
- Fuel Injectors
- Throttle Body/Intake Manifold
- Electronic Control Unit (ECU)
- Ignition Coils
- Engine (Oil) Temperature Sensor
- Throttle Position Sensor (TPS)
- Crankshaft Position Sensor
- Oxygen Sensor
- Manifold Absolute Pressure Sensor (MAP)
- Wire Harness Assembly & Affiliated Wiring,
- Malfunction Indicator Light (MIL) - optional
- Intake Air Temperature Sensor

Operation

The EFI system is designed to provide peak engine performance with optimum fuel efficiency and lowest possible emissions. The ignition and injection functions are electronically controlled, monitored and continually corrected during operation to maintain the ideal air/fuel ratio.

The central component of the system is the Engine Control Unit (ECU) which manages system operation, determining the best combination of fuel mixture and ignition timing for the current operating conditions.

A lift fuel pump is used to move fuel from the tank through an in-line fuel filter and fuel line. The fuel is then pumped to the fuel pump module. The fuel pump module regulates fuel pressure to a system operating pressure of 39 psi. Fuel is delivered from the fuel pump module through the high pressure fuel line into the injectors, which inject the fuel into the intake ports. The ECU controls the amount of fuel by varying the length of time that the injectors are on. This can range from 2 to over 12 milliseconds depending on fuel requirements. The controlled injection of the fuel occurs every other crankshaft revolution, or once for each 4-stroke cycle. When the intake valve opens, the air/fuel mixture is drawn into the combustion chamber, ignited, and burned.

The ECU controls the amount of fuel being injected and the ignition timing by monitoring the primary sensor signals for engine temperature, speed (RPM), and throttle position (load). These primary signals are compared to preprogrammed maps in the ECU computer chip, and the ECU adjusts the fuel delivery to match the mapped values. After the engine reaches operating temperature, an exhaust gas oxygen sensor provides feedback to the ECU based upon the amount of unused oxygen in the exhaust, indicating whether the fuel mixture being delivered is rich or lean. Based upon this feedback, the ECU further adjusts fuel input to re-establish the ideal air/fuel ratio. This operating mode is referred to as closed loop operation. The EFI system operates closed loop when all three of the following conditions are met:

a. The oil temperature is greater than 60°C (140°F).

b. The oxygen sensor has warmed sufficiently to provide a signal (minimum 400°C, 752°F).

c. Engine operation is at a steady state (not starting, warming up, accelerating, etc.).

During closed loop operation the ECU has the ability to readjust temporary and learned adaptive controls, providing compensation for changes in overall engine condition and operating environment, so it will be able to maintain the ideal air/fuel ratio. The system requires a minimum engine oil temperature greater than 80°C (176°F) to properly adapt. These adaptive values are maintained as long as the ECU is not reset.

During certain operating periods such as cold starts, warm up, acceleration, high load, etc., a richer air/fuel ratio is required and the system operates in an open loop mode. In open loop operation the oxygen sensor output is used to ensure engine is running rich, and the controlling adjustments are based on the primary sensor signals and programmed maps only. The system operates open loop whenever the three conditions for closed loop operation (above) are not being met.

Important Service Notes!

- Cleanliness is essential and must be maintained at all times when servicing or working on the EFI system. Dirt, even in small quantities, can cause significant problems.

- Clean any joint or fitting with parts cleaning solvent before opening to prevent dirt from entering the system.

- Always depressurize the fuel system through the fuel connector on fuel pump module before disconnecting or servicing any fuel system components. See fuel warning on page 5.2.

- Never attempt to service any fuel system component while the engine is running or the ignition switch is ON.

- Do not use compressed air if the system is open. Cover any parts removed and wrap any open joints with plastic if they will remain open for any length of time. New parts should be removed from their protective packaging just prior to installation.

- Avoid direct water or spray contact with system components.
- Do not disconnect or reconnect the ECU wiring harness connector or any individual components with the ignition on. This can send a damaging voltage spike through the ECU.
- Do not allow the battery cables to touch opposing terminals. When connecting battery cables attach the positive (+) cable to the positive (+) battery terminal first, followed by the negative (-) cable to the negative (-) battery terminal.
- Never start the engine when the cables are loose or poorly connected to the battery terminals.
- Never disconnect the battery while the engine is running.
- Never use a quick battery charger to start the engine.
- Do not charge the battery with the key switch ON.
- Always disconnect the negative (-) battery cable before charging the battery, and also unplug the harness from the ECU before performing any welding on the equipment.

Electrical Components

Electronic Control Unit (ECU)

Figure 5-1. Electronic Control Unit (ECU).

General

The ECU is the brain or central processing computer of the entire EFI system. During operation, sensors continuously gather data which is relayed through the wiring harness to input circuits within the ECU. Signals to the ECU include: ignition (on/off), crankshaft position and speed (RPM), throttle position, oil temperature, intake air temperature, exhaust oxygen levels, manifold absolute pressure, and battery voltage.

The ECU compares the input signals to the programmed maps in its memory to determine the appropriate fuel and spark requirements for the immediate operating conditions. The ECU then sends output signals to set the injector duration and ignition timing.

The ECU continually performs a diagnostic check of itself, each of the sensors, and the system performance. If a fault is detected, the ECU can turn on a Malfunction Indicator Light (MIL) (if equipped) on the equipment control panel, store the fault code in its fault memory, and go into a default operating mode. Depending on the significance or severity of the fault, normal operation may continue. A technician can access the stored fault code using a blink code diagnosis flashed out through the MIL. An optional computer software diagnostic program is also available, see Section 2.

The ECU requires a minimum of 6.0 volts to operate.

To prevent engine over-speed and possible failure, a rev-limiting feature is programmed into the ECU. If the maximum RPM limit (4500) is exceeded, the ECU suppresses the injection signals, cutting off the fuel flow. This process repeats itself in rapid succession, limiting operation to the preset maximum.

Service

Never attempt to disassemble the ECU. It is sealed to prevent damage to internal components. Warranty is void if the case is opened or tampered with in any way.

All operating and control functions within the ECU are preset. No internal servicing or readjustment may be performed. If a problem is encountered, and you determine the ECU to be faulty, contact your source of supply. Do not replace the ECU without factory authorization.

The ECU pins are coated at the factory with a thin layer of electrical grease to prevent fretting and corrosion. Do not attempt to remove the grease from the ECU pins.

The relationship between the ECU and the throttle position sensor (TPS) is very critical to proper system operation. If the TPS or ECU is changed, or the mounting position of the TPS is altered, the appropriate TPS Learn Procedure (see page 5.10) must be performed to restore the synchronization.

Wiring Harness

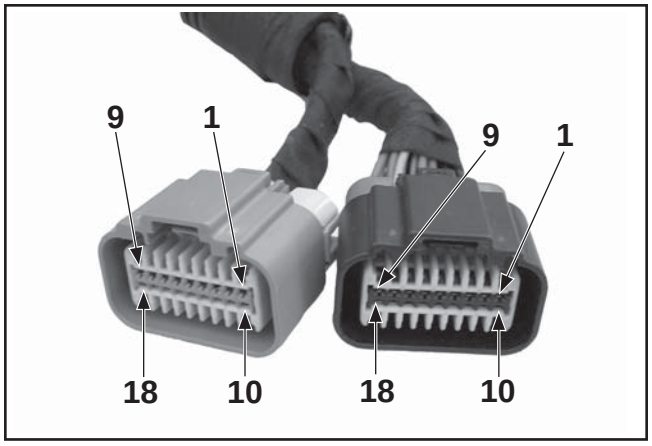


Figure 5-2. ECU Connectors.

General

The wiring harness used in the EFI system connects the electrical components, providing current and ground paths for the system to operate. All input and output signaling occurs through two special all weather connectors that attach and lock to the ECU. The connectors are Black and Grey and keyed differently to prevent being attached to the ECU incorrectly. See Figure 5-2.

The condition of the wiring, connectors, and terminal connections is essential to system function and performance. Corrosion, moisture, and poor connections are as likely the cause of operating problems and system errors as an actual component. Refer to the Electrical System section for additional information.

Electrical System

The EFI system is a 12 VDC negative ground system, designed to operate down to a minimum of 6.0 volts. If system voltage drops below this level, the operation of voltage sensitive components such as the ECU, fuel pump, ignition coils, and injectors will be intermittent or disrupted, causing erratic operation or hard starting. A fully charged, 12 volt battery with a minimum of 350 cold cranking amps is important in maintaining steady and reliable system operation. Battery condition and state of charge should always be checked first when troubleshooting an operational problem.

Keep in mind that EFI-related problems are often caused by the wiring harness or connections. Even small amounts of corrosion or oxidation on the terminals can interfere with the milliamp currents used in system operation.

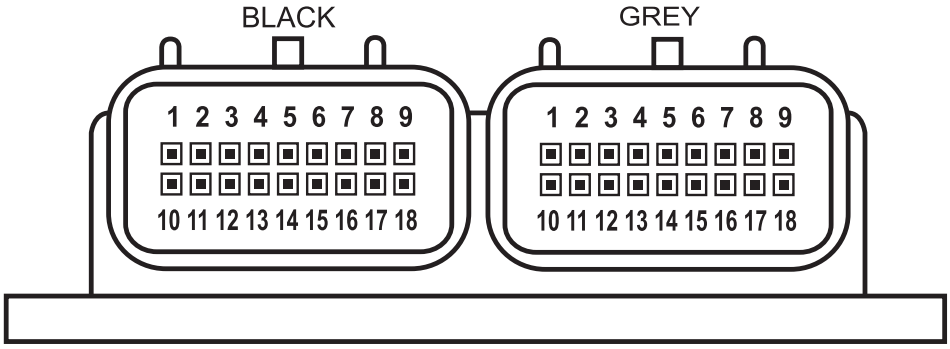
Cleaning the connectors and grounds will solve problems in many cases. In an emergency situation, simply disconnecting and reconnecting the connectors may clean up the contacts enough to restore operation, at least temporarily.

If a fault code indicates a problem with an electrical component, disconnect the ECU connector and test for continuity between the component connector terminals and the corresponding terminals in the ECU connector using an ohmmeter. Little or no resistance should be measured, indicating that the wiring of that particular circuit is OK.

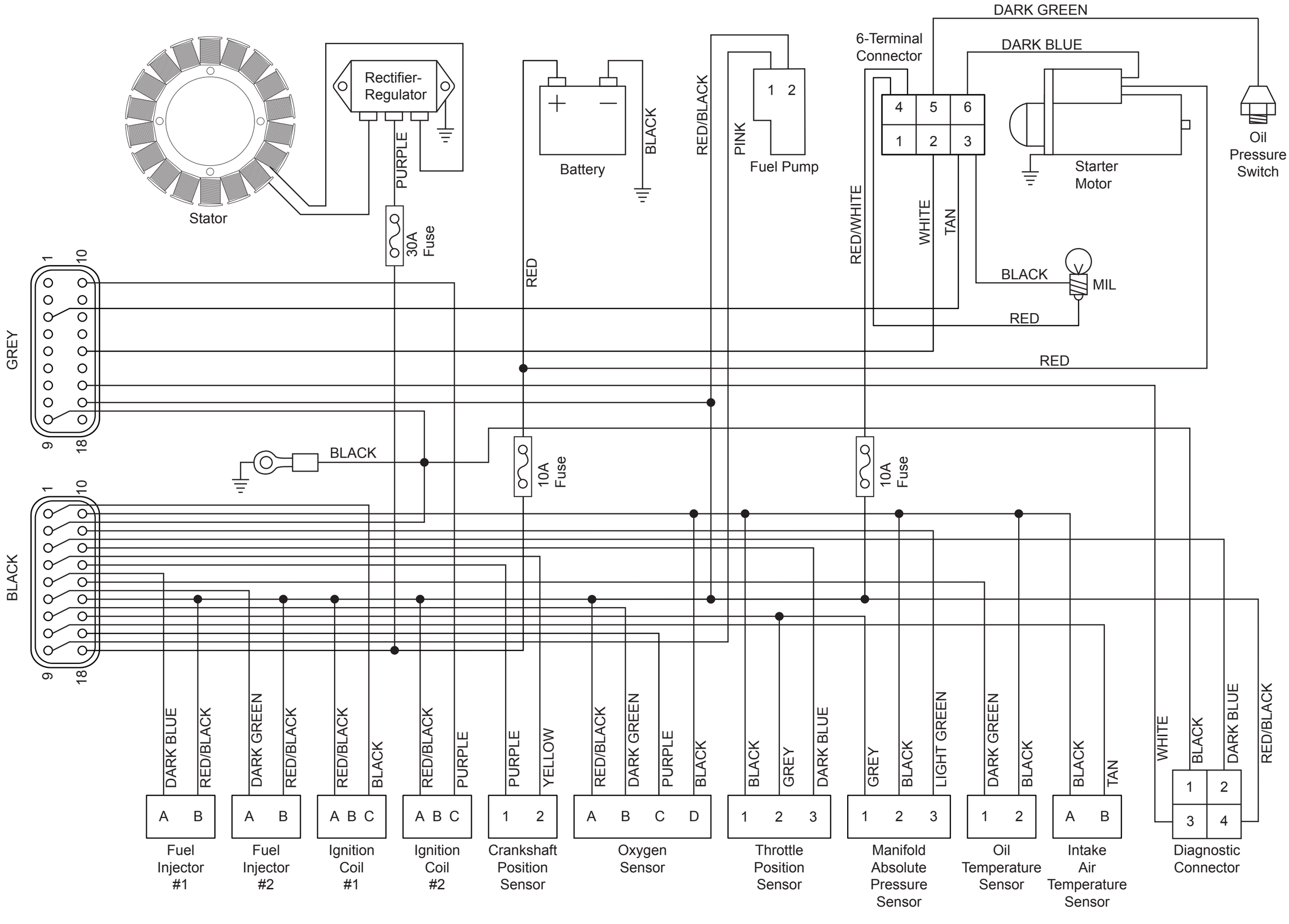
NOTE: When performing voltage or continuity tests, avoid putting excessive pressure on or against the connector pins. Flat pin probes are recommended for testing to avoid spreading or bending the terminals.

Black Connector	
Pin #	Function
1	Ignition Coil #1 Ground
2	Battery Ground
3	Diagnostic Communication Line
4	Speed Sensor input
5	Fuel Injector Output #1 Ground
6	Fuel Injector Output #2 Ground
7	Oxygen Sensor Heater
8	Intake Air Temperature (IAT) sensor input
9	Fuel Pump Ground
10	Ground for IAT, TPS, MAP, O2 and Oil Sensors
11	Manifold Absolute Pressure (MAP) sensor input
12	Throttle Position Sensor (TPS) input
13	Speed Sensor Ground
14	Oil Temperature Sensor input
15	Ignition Switch (Switched +12V)
16	Power for TPS and MAP Sensors (+5V)
17	Oxygen Sensor (O2) input
18	Battery Power (Permanent +12V)

Grey Connector	
Pin #	Description
1	Not Used
2	Not Used
3	Malfunction Indicator Light (MIL) Ground
4	Not Used
5	Not Used
6	Not Used
7	Not Used
8	Not Used
9	Battery Ground
10	Ignition Coil #2 Ground
11	Not Used
12	Not Used
13	Not Used
14	Safety Switch Ground
15	Not Used
16	ECU
17	Fuel Pump Control (+12V)
18	Not Used



Pinout of the ECU


Stator
Rectifier-
Regulator
PURPLE
30A
Fuse
Battery
BLACK
RED
RED/BLACK
PINK
1 2
Fuel Pump
6-Terminal
Connector
DARK GREEN
DARK BLUE
4 5 6
1 2 3
Starter
Motor
Oil
Pressure
Switch
RED/WHITE
WHITE
TAN
BLACK
MIL
RED
RED
GREY
1
10
9
18
BLACK
BLACK
10A
Fuse
10A
Fuse
DARK BLUE
RED/BLACK
DARK GREEN
RED/BLACK
RED/BLACK
BLACK
RED/BLACK
PURPLE
PURPLE
YELLOW
RED/BLACK
DARK GREEN
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A B
A B C
A B C
1 2
A B C D
1 2 3
1 2 3
1 2
A B
1 2
3 4
Fuel
Injector
#1
Fuel
Injector
#2
Ignition
Coil
#1
Ignition
Coil
#2
Crankshaft
Position
Sensor
Oxygen
Sensor
Throttle
Position
Sensor
Manifold
Absolute
Pressure
Sensor
Oil
Temperature
Sensor
Intake
Air
Temperature
Sensor
Diagnostic
Connector

Crankshaft Position Sensor

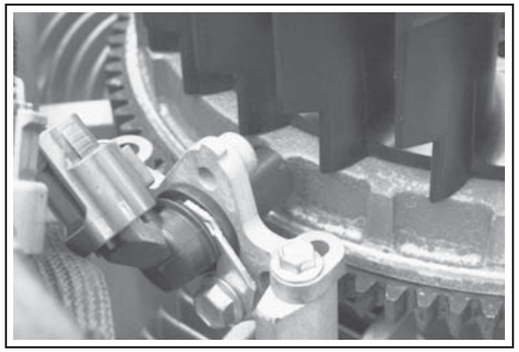


Figure 5-3. Crankshaft Position Sensor.

General

The crankshaft position sensor is essential to engine operation; constantly monitoring the rotation and speed (RPM) of the crankshaft. There are 23 consecutive teeth cast into the flywheel. One tooth is missing and is used to reference the crankshaft position for the ECU. The inductive crankshaft position sensor is mounted **0.20-0.70 mm (0.008-0.027 in.)** from the flywheel.

During rotation, an AC voltage pulse is created within the sensor for each passing tooth. The ECU calculates engine speed from the time interval between the consecutive pulses. The gap from the missing tooth creates an interrupted input signal, corresponding to specific crankshaft position near BDC for cylinder #1. This signal serves as a reference for the control of ignition timing by the ECU. Synchronization of the inductive speed pickup and crankshaft position takes place during the first two revolutions each time the engine is started. The sensor must be properly connected at all times. If the sensor becomes disconnected for any reason, the engine will quit running.

Service

The crankshaft position sensor is a sealed, non-serviceable assembly. If Fault Code diagnosis indicates a problem within this area, test and correct as follows.

1. Check the mounting and air gap of the sensor. It must be **0.20-0.70 mm (0.008-0.027 in.)**.

2. Inspect the wiring and connections for damage or problems.

3. Make sure the engine has resistor type spark plugs.

4. Disconnect the Black connector from the ECU.

5. Connect an ohmmeter between the #4 and #13 pin terminals. A resistance value of **325-395** Ω at room temperature (20°C, 68°F) should be obtained. If resistance is correct, check the mounting, air gap, flywheel teeth (damage, run-out, etc.), and flywheel key.

6. Disconnect the crankshaft position sensor connector from the wiring harness. Test resistance between the terminals. A reading of **325-395** Ω should again be obtained.

   a. If the resistance is incorrect, remove the screws securing the sensor to the mounting bracket and replace the sensor.

   b. If the resistance in step 5 was incorrect, but the resistance of the sensor alone was correct, test the wire harness circuits between the sensor connector terminals and the corresponding pin terminals (#4 and #13) in the main connector. Correct any observed problem, reconnect the sensor, and perform step 5 again.

7. When fault is corrected and engine starts, clear fault codes following the ECU Reset procedure. See page 5.10.

Throttle Position Sensor (TPS)

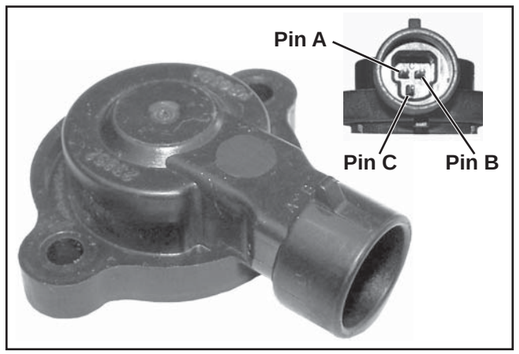


Figure 5-4. Throttle Position Sensor with Pinout.

General

The throttle position sensor (TPS) is used to indicate throttle plate angle to the ECU. Since the throttle (by way of the governor) reacts to engine load, the angle of the throttle plate is directly related to the load on the engine.

Mounted on the throttle body and operated directly off the end of the throttle shaft, the TPS works as a potentiometer, varying the voltage signal to the ECU in direct correlation to the angle of the throttle plate. This signal, along with the other sensor signals, is processed by the ECU and compared to the internal preprogrammed maps to determine the required fuel and ignition settings for the amount of load.

The correct position of the TPS is established and set at the factory. Do not loosen the TPS or alter the mounting position unless absolutely required by fault code diagnosis. If the TPS is loosened or repositioned, the appropriate TPS Learn Procedure **must** be performed to re-establish the baseline relationship between the ECU and the TPS.

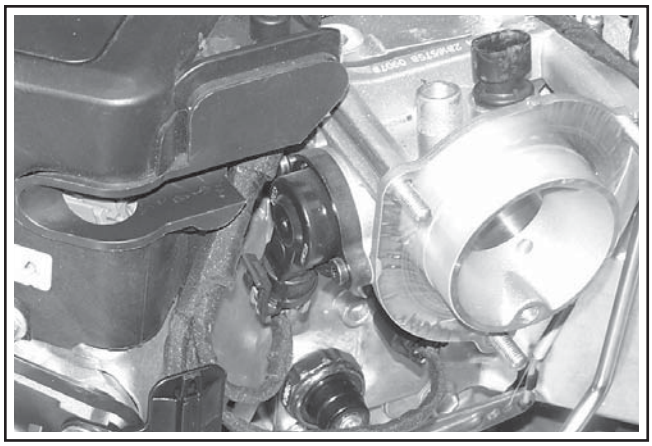


Figure 5-5. TPS Location.

Service

The TPS is a sealed, non-serviceable assembly. If diagnosis indicates a bad sensor, complete replacement is necessary. If a blink code indicates a problem with the TPS, it can be tested as follows:

1. Counting the number of turns, back out the idle speed adjusting screw (counterclockwise) until the throttle plates can be closed completely. Write this number down for reference later.

2. Disconnect the Black connector from the ECU, but leave the TPS mounted to the throttle body.

3. a. Use an ohmmeter and connect the red (positive) ohmmeter lead to Black pin 12 terminal and the black (negative) ohmmeter lead to Black pin 10 terminal to test.

   b. Hold the throttle closed and check the resistance. It should be **1400-1800 Ω**.

4. Leave the leads connected to the pin terminals as described in step 3. Rotate the throttle shaft slowly to the full throttle position. Monitor the dial during rotation for indication of any momentary short or open circuits. Note the resistance at the full throttle position. It should be **4600-5200 Ω** without a stop pin, or **3200-4100 Ω** with a stop pin.

5. Disconnect the main wiring harness connector from the TPS, leaving the TPS assembled to the throttle body. Refer to the following chart and perform the resistance checks indicated between the terminals in the TPS switch, with the throttle in the positions specified. Pin location shown in Figure 5-4.

Throttle Position	Between Terminal	Resistance Value (Ω)	Continuity
Closed	A & C	1400-1800	Yes
Full with Stop Pin	A & C	3200-4100	Yes
Full without Stop Pin	A & C	4600-5200	Yes
Any	A & B	3000-7000	Yes

   If the resistance values in steps 3, 4, and 5 are within specifications, go to step 6.

   If the resistance values are not within specifications, or a momentary short or open circuit was detected during rotation (step 4), the TPS needs to be replaced, go to step 7.

6. Check the TPS circuits (input, ground) between the TPS plug and the main harness connector for continuity, damage, etc. The input pin is 12 and the ground is pin 10.

   a. Repair or replace as required.

   b. Turn the idle speed screw back in to its original setting.

   c. Reconnect connector plugs, start engine and retest system operation.

7. Remove the two mounting screws from the TPS. Save the screws for reuse. Remove and discard the faulty TPS. Install the replacement TPS and secure with the original mounting screws.

   a. Reconnect the Black and TPS connector plugs.

   b. Perform the TPS Learn Procedure integrating the new sensor to the ECU.

ECU Reset and TPS Learn Procedure

Any service to the ECU, TPS/Throttle Body (including idle speed increase over 300 RPM), or the fuel pump module should include ECU Reset.

This will clear all trouble codes, all closed loop learned offsets, all max values, and all timers besides the permanent hour meter.

The system will NOT reset when the battery is disconnected!

ECU Reset Procedure

1. Turn key OFF.

2. Install Red wire jumper (Figure 5-6) from Kohler EFI service kit on to service port (connect the white wire to the black wire in the 4 way diagnostic port).

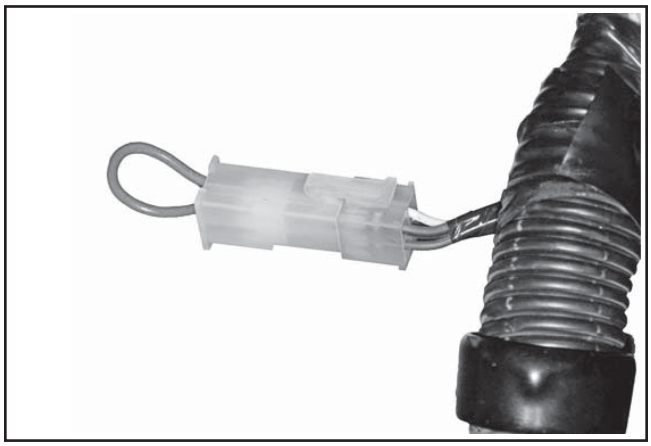


Figure 5-6. Service Port and Jumper Connector.

3. Turn key ON, then OFF and count 10 seconds.

4. Turn key ON, then OFF and count to 10 seconds a second time.

5. Remove the jumper, ECU is reset. A TPS Learn Procedure **must** be performed after the ECU Reset.

TPS Learn Procedure

1. Turn idle screw clockwise one full turn prior to key ON after ECU Reset.

2. Start engine, run at low idle until engine is warm.

3. Idle speed must be above 1500 RPM. If below 1500 RPM, turn idle screw up to 1700 RPM and then shut down engine and perform ECU Reset again.

4. Adjust idle speed down to 1500 RPM. Allow engine to dwell at 1500 RPM for about 3 seconds.

5. After this, adjust the idle speed to the final specified speed setting.

6. Turn the key OFF and count to 10 seconds.

Learn is complete and the engine is ready for operation.

Engine (Oil) Temperature Sensor

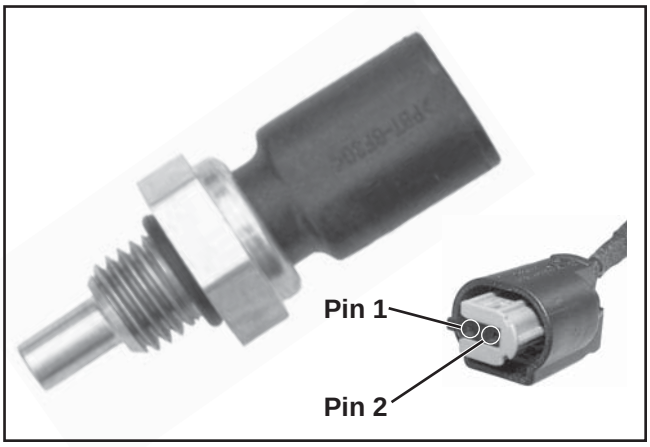


Figure 5-7. Engine (Oil) Temperature Sensor.

General

The engine (oil) temperature sensor (Figure 5-7) is used by the system to help determine fuel requirements for starting (a cold engine needs more fuel than one at or near operating temperature).

Mounted in the breather cover, it has a temperature-sensitive resistor that extends into the oil flow. The resistance changes with oil temperature, altering the voltage sent to the ECU. Using a table stored in its memory, the ECU correlates the voltage drop to a specific temperature. Using the fuel delivery maps, the ECU then knows how much fuel is required for starting at that temperature.

Service

The temperature sensor is a sealed, non-serviceable assembly. A faulty sensor must be replaced. If a blink code indicates a problem with the temperature sensor, it can be tested as follows:

1. Remove the temperature sensor from the breather cover and cap or block the sensor hole.

2. Wipe the sensor clean and allow it to reach room temperature (25°C, 77°F).

3. Unplug the Black connector from the ECU.

4. With the sensor still connected, check the temperature sensor circuit resistance between the Black pin 10 and 14 terminals. The value should be **9000-11000** Ω.

5. Unplug the sensor from the wire harness and check the sensor resistance separately across the two pins. Resistance value should again be **9000-11000** Ω.

   a. If the resistance is out of specifications, replace the temperature sensor.

   b. If it is within specifications, proceed to Step 6.

6. Check the circuits (input, ground), from the wire harness connector to the sensor plug for continuity, damage, etc. Connect one ohmmeter lead to Black pin 14 in the wire harness connector (as in step 4). Connect the other lead to terminal #1 in the sensor plug (see Figure 5-7). Continuity should be indicated. Repeat the test between Black pin 10 and terminal #2 in the sensor plug.

Intake Air Temperature Sensor

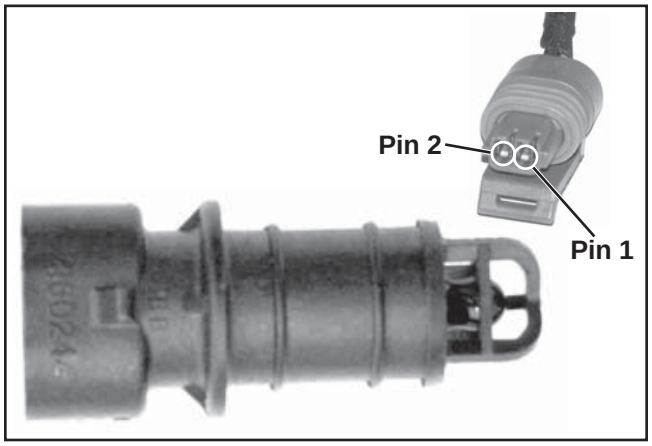


Figure 5-8. Intake Air Temperature Sensor.

General

The Intake Air Temperature (IAT) sensor is a thermally sensitive resistor that exhibits a change in electrical resistance with a change in its temperature.

When the sensor is cold, the resistance of the sensor is high, and the voltage signal is high. As the sensor warms up, the resistance drops and voltage signal decreases. From the voltage signal, the ECU can determine the temperature of the intake air.

The purpose of an air temperature sensor is to help the ECU calculate air density. The higher the air temperature gets the less dense the air becomes. As the air becomes less dense the ECU knows that it needs to lessen the fuel flow to achieve the correct air/fuel ratio. If the fuel ratio was not changed the engine would become rich, possibly losing power and consuming more fuel.

Service

The intake air temperature sensor is a non-serviceable component. Complete replacement is required if it is faulty. The sensor and wiring harness can be checked as follows.

1. Remove the temperature sensor from the throttle body.

2. Allow it to reach room temperature (20°C, 68°F).

3. Unplug the Black connector from the ECU.

4. With the sensor still connected, check the temperature sensor circuit resistance between the Black pin 10 and 8 pin terminals. The value should be **3100-3900** Ω.

5. Unplug the sensor from the wire harness and check the sensor resistance separately across the two pins. Resistance value should again be **3100-3900** Ω.

   a. If the resistance is out of specifications, replace the temperature sensor.

   b. If it is within specifications, proceed to Step 6.

6. Check the circuits (input, ground), from the main harness connector to the sensor plug for continuity, damage, etc. Connect one ohmmeter lead to Black pin 8 in the main harness connector (as in step 4). Connect the other lead to terminal #1 in the sensor plug (see Figure 5-8). Continuity should be indicated. Repeat the test between Black pin 10 and terminal #2 in the sensor plug.

Oxygen Sensor

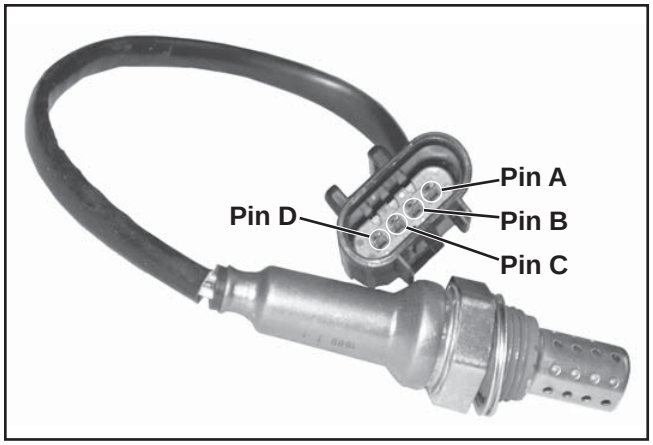


Figure 5-9. Oxygen Sensor.

General

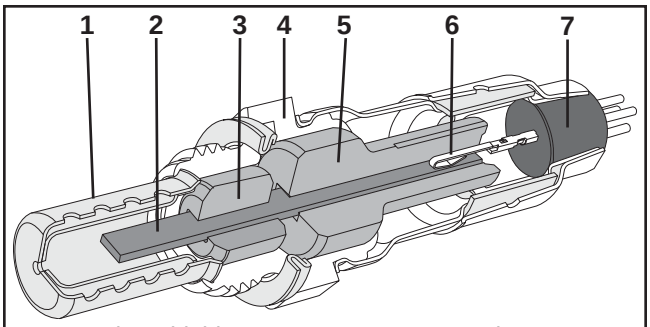
The oxygen sensor functions like a small battery, generating a voltage signal to the ECU based upon the difference in oxygen content between the exhaust gas and the ambient air.

The tip of the sensor, protruding into the exhaust gas, is hollow (see cutaway Figure 5-10). The outer portion of the tip is surrounded by the exhaust gas, with the inner portion exposed to the ambient air. When the oxygen concentration on one side of the tip is different than that of the other side, a voltage signal up to 1.0 volt is generated and sent to the ECU. The voltage signal tells the ECU if the engine is straying from the ideal fuel mixture, and the ECU then adjusts the injector pulse accordingly.

The oxygen sensor functions after being heated to a minimum of 400°C (752°F). A heater inside the sensor heats the electrode to the optimum temperature in about 10 seconds. The oxygen sensor receives the ground through the wire, eliminating the need for proper grounding through the muffler. If problems indicate a bad oxygen sensor, check all connections and wire harness. The oxygen sensor can also be contaminated by leaded fuel, certain RTV and/or other silicone compounds, fuel injector cleaners, etc. Use only those products indicated as O_2 Sensor Safe.

Service

The temperature must be controlled very accurately and gas constituents measured to a high degree of accuracy for absolute sensor measurements. Since this requires laboratory equipment, it is not possible to distinguish a marginally **in specification** sensor from a marginally **out of specification** sensor with simple field diagnostic equipment. Furthermore, as with most devices, intermittent problems are difficult to diagnose. Still, with a good understanding of the system and the sensor, it is possible to diagnose many sensor problems in the field.



1. Protection Shield
2. Planar Element and Heater
3. Lower Insulator
4. Stainless Steel Housing
5. Upper Insulator
6. Terminal Connection to Element
7. High Temp Water Seal

Figure 5-10. Cutaway of Oxygen Sensor.

Using diagnostic software connected to the ECU is a useful technique for observing sensor performance. However, the user must understand that such software reads a signal generated by the ECU. If there is an ECU or wiring problem, the readings could be misinterpreted as a sensor problem. The digital nature of the signal to the software means that it is not reading the continuous output of the sensor. A voltmeter can also be used as an effective tool in diagnosing sensors. It is advisable to use an electronic meter such as a digital voltmeter. Simple mechanical meters may place a heavy electrical load on the sensor and cause inaccurate readings. Since the resistance of the sensor is highest at low temperatures, such meters will cause the largest inaccuracies when the sensor is in a cool exhaust.

Visual Inspection

1. Look for a damaged or disconnected sensor-to-engine harness connection.

2. Look for damage to the sensor lead wire or the associated engine wiring due to cutting, chaffing or melting on a hot surface.

3. Disconnect the sensor connector and look for corrosion in the connector.

4. Try reconnecting the sensor and observe if the problem has cleared.

5. Correct any problems found during the visual check.

Sensor Signal Observation

If the visual examination shows no problems, connect the sensor back to the engine harness.

NOTE: Do not cut into or pierce the sensor or engine wiring to make this connection. The sensor produces a very small signal. Corrosion or damage to the wiring could lead to an incorrect signal because of repairs or contamination to the sensor.

1. Using a voltmeter or diagnostic software observe the voltage before the engine is started. With the key ON, the voltage should read about 1.0 volt. This voltage is generated by the ECU. If it is not present, disconnect the sensor and observe the voltage at the harness connector. If the voltage is now present, there is a short in the sensor or associated wiring and corrective action should be taken. If the voltage still is not present, there is a problem with the ECU or engine harness.

2. Reconnect the sensor and start the engine. Run the engine at sufficient speed to bring the sensor up to operating temperature. Maintain for 1 to 2 minutes to ensure that the engine has gone closed loop. Once in closed loop, the sensor voltage should cycle between about 100 to 250 mv and 700 to 900 mv. If this cycling is not observed, a determination must be made. If the problem is with the engine or the sensor.

3. Check engine harness for battery voltage on the heater circuit.

NOTE: Using the diagnostic software, the wiring and ECU integrity can be checked by grounding the signal wire; the output of the sensor, read on the software, should be around 4 mv.

Removal Inspection

1. If the sensor has heavy deposits on the lower shield, the engine, oil, or fuel may be the source.

2. If heavy carbon deposits are observed, incorrect engine fuel control may be occurring.

3. If the sensor is at room temperature, measure between the signal leads, the black wire (Pin C) and grey wire (Pin D) attached to the sensor (see Figure 5-9). If the resistance is less than one megohm, the sensor has an internal short.

4. With the sensor at room temperature measure the heater circuit resistance, purple wire (Pin A) and white wire (Pin B), resistance should be 8.1-11.1 Ω.

5. If a damaged sensor is found, identify the root cause, which may be elsewhere in the application. The table on the following page summarizes sensor symptoms and corrections. It includes items, which apply to both diagnostics and application system design.

6. A special "dry to touch" anti-seize compound is applied to all new oxygen sensors at the factory. If the recommended mounting thread sizes are used, this material provides excellent anti-seize capabilities and no additional anti-seize is needed. If the sensor is removed from the engine and reinstalled, the anti-seize compound should be reapplied. Use a oxygen sensor safe type anti-seize compound. It should be applied according to the directions on the label.

NOTE: Apply the anti-seize compound only to the threads. Anti-seize compound will affect sensor performance if it gets into the lower shield of the sensor.

Oxygen Sensor Symptoms and Corrections

CONDITION	POSSIBLE CAUSE	CORRECTION
Low voltage output	Shorted sensor or sensor circuit Shorted lead wire Wiring shorted to ground	Replace sensor or repair wiring
	Contamination of air reference	Remove source of external contamination, protect air reference area
	Air leak at sensor or gasket, sensor upper shield damage	Use recommended torque at installation, replace gasket or sensor Revise application exhaust Shield sensor from damage
High voltage output	Silica poisoning	Replace sensor
	Contaminated gasoline	Use high quality fuel
	Engine problem; misfire	Correct cause of misfire
	Excessive rich air/fuel ratio	Correct air/fuel ratio
	Wiring shorted to voltage	Repair wiring
Open circuit, no activity from sensor	Broken element Sensor dropped Hard blow to engine or exhaust system Defective sensor Thermal shock	Replace sensor
Slow time response	Open heater circuit Improper handling Carbon deposits	Replace sensor
	Improper fueling	Correct fueling
	Incorrect or contaminated fuel	Use high quality fuel
	Excessive engine oil consumption causing exhaust contamination or other exhaust side contamination	Correct engine condition
	Heater circuit open/shorted or out of specification	Repair short in harness wires, replace sensor

Manifold Absolute Pressure Sensor

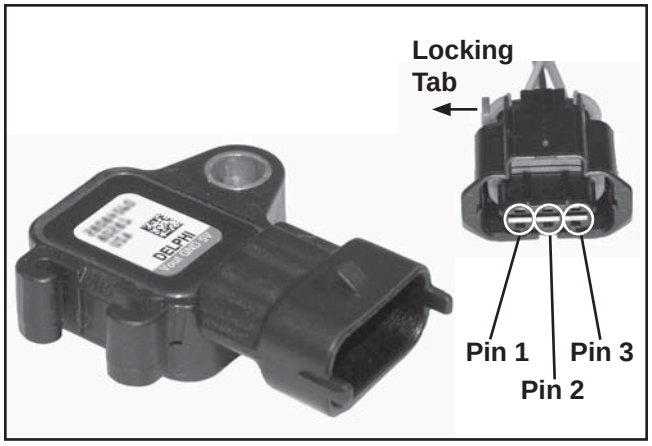


Figure 5-11. Manifold Absolute Pressure Sensor and Connector.

General

The manifold absolute pressure (MAP) sensor provides immediate manifold pressure information to the ECU. The MAP measures the difference in pressure between the outside atmosphere and the vacuum level inside the intake manifold and monitors pressure in the manifold as the primary means of detecting load. The data is used to calculate air density and determine the engine's mass air flow rate, which in turn determines the required ideal fueling. The MAP also stores instant barometric pressure reading when the key is turned ON.

Service

The manifold absolute pressure sensor is a sealed, non-serviceable assembly. A faulty sensor must be replaced. If a blink code indicates a problem with the manifold absolute pressure sensor, it can be tested as follows:

1. Make sure all connections are making proper contact and are free of dirt and debris. Remove the blower housing. Slide the locking tab out and pull off the manifold absolute pressure connector. Turn the key switch to ON and check with a volt meter by contacting the red lead to pin 1 and the black lead to pin 2. See Figure 5-11 for pin location. There should be 5 volts present, indicating the ECU and wiring harness are functioning.

2. Check continuity in wire harness. Ohms between Pin 3 at the sensor connector and Black pin 11 connector at ECU should be near zero ohms. If no continuity is measured or very high resistance, replace wire harness.

3. Check to make sure the intake manifold is not loose and the MAP sensor is not loose. Loose parts would allow a vacuum leak, making the MAP sensor report misleading information to the ECU.

   a. Tighten all hardware and perform an ECU Reset and a TPS Learn Procedure to see if the MIL will display a fault with the MAP sensor again. If the MIL finds a fault with the MAP sensor, replace it.

Fuel Injectors

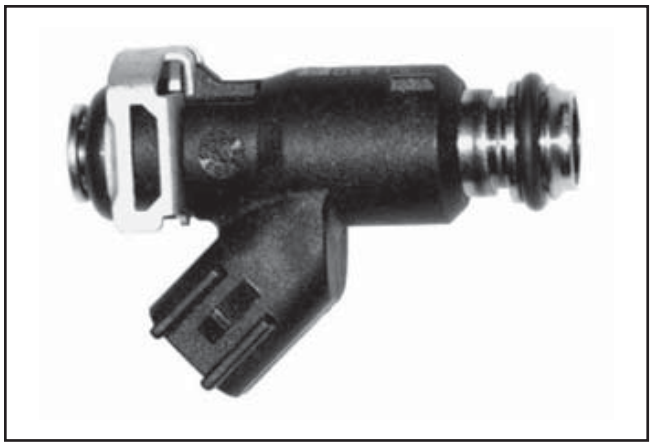


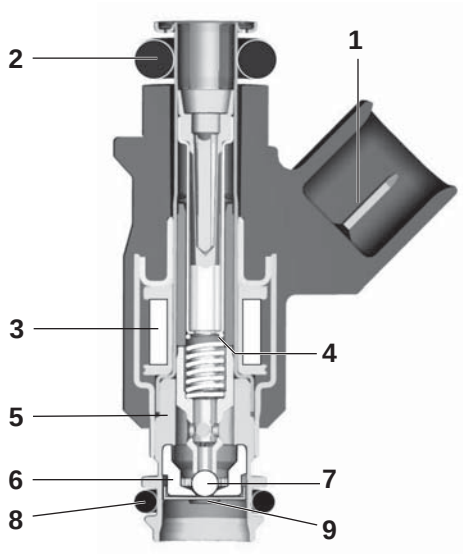
Figure 5-12. Fuel Injector.

General

The fuel injectors mount into the intake manifold, and the high pressure fuel line attaches to them at the top end. Replaceable O-rings on both ends of the injector prevent external fuel leakage and also insulate it from heat and vibration. A special clip connects each injector to the high pressure fuel line and holds it in place. The O-rings and retaining clip should be replaced any time the fuel injector is separated from its normal mounting position. DO NOT reuse existing O-rings or retaining clips as fuel leakage may result.

When the key switch is on, the fuel pump module will pressurize the high pressure fuel line to 39 psi, and voltage is present at the injector. At the proper instant, the ECU completes the ground circuit, energizing the injector. The valve needle in the injector is opened electromagnetically, and the pressure in the high pressure fuel line forces fuel down through the inside. The director plate at the tip of the injector contains a series of calibrated openings which directs the fuel into the manifold in a cone-shaped spray pattern.

The injectors have sequential fueling that open and close once every other crankshaft revolution. The amount of fuel injected is controlled by the ECU and determined by the length of time the valve needle is held open, also referred to as the injection duration or pulse width. The time the injector is open (milliseconds) may vary in duration depending on the speed and load requirements of the engine.



1. Electrical Connection
2. Upper O-ring
3. Solenoid Winding
4. Armature
5. Valve Housing
6. Valve Seat
7. Valve End
8. Lower O-ring
9. Director Plate

Figure 5-13. Fuel Injector Details.

Service

Injector problems typically fall into three general categories: electrical, dirty/clogged, or leakage. An electrical problem usually causes one or both of the injectors to stop functioning. Several methods may be used to check if the injectors are operating.

1. With the engine running at idle, listen for a buzzing or clicking sound.

2. Disconnect the electrical connector from an injector and listen for a change in idle performance (only running on one cylinder) or a change in injector noise or vibration.

If an injector is not operating, it can indicate either a bad injector, or a wiring/electrical connection problem. Check as follows:

NOTE: Do not apply voltage to the fuel injector(s). Excessive voltage will burn out the injector(s). Do not ground the injector(s) with the ignition ON. Injector(s) will open/turn on if relay is energized.

1. Disconnect the electrical connector from both injectors. Plug a 12 volt noid light (part of EFI Service Kit, see Section 2) into one connector.

Figure 5-14. Volt Noid Light.

2. Make sure all safety switch requirements are met. Crank the engine and check for flashing of the test light. Turn key OFF for at least 10 seconds between tests to allow ECU to go to sleep and reawake. Repeat test at other connector.

NOTE: When cranking engine with injectors disconnected, fault codes will be registered in the ECU and will need to be cleared using software fault clear or an ECU Reset and TPS Learn Procedure.

   a. If flashing occurs, use an ohmmeter (Rx1 scale) and check the resistance of each injector across the two terminals. Proper resistance is **11-13** Ω. If injector resistance is correct, check whether the connector and injector terminals are making a good connection. If the resistance is not correct, replace the injector.

Check all electrical connections, connectors, and wiring harness leads if resistance is incorrect.

Injector leakage is very unlikely, but in those rare instances it can be internal (past the tip of the valve needle), or external (weeping around the injector O-rings). See Figure 5-15. The loss of system pressure from the leakage can cause hot restart problems and longer cranking times. To check for leakage it will be necessary to loosen or remove the blower housing which may involve removing the engine from the unit.

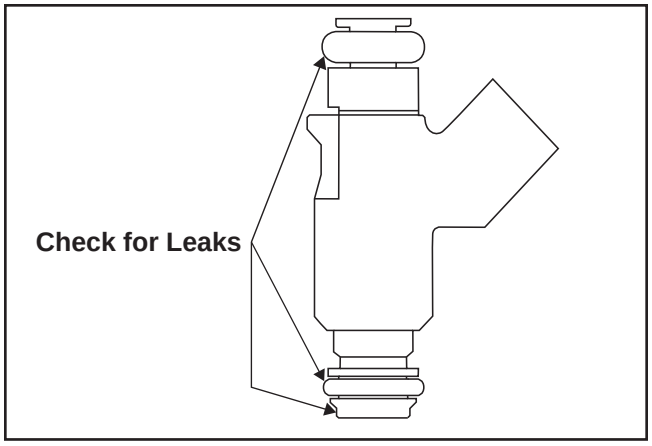


Figure 5-15. Injector Inspection Points.

1. Engine must be cool. Depressurize fuel system as stated on page 5.2.
2. Disconnect spark plug leads from spark plugs.
3. Remove the air cleaner by removing the two top screws and the three nuts securing the air cleaner base to the throttle body. Service air cleaner components as required.
4. Remove the flywheel grass screen if it overlaps the blower housing.
5. Remove the two oil cooler mounting screws.
6. Remove the two screws for the pulse pump.
7. Remove the fuse bracket if equipped.
8. Remove one screw securing the ECU bracket into the blower housing.
9. Remove the top nut, washer and spring for the throttle control shaft and the two screws for the throttle control bracket.
10. Remove oil separator mounting hardware if equipped.
11. Disconnect the breather tube on top of the throttle body.
12. Disconnect the vent hose underneath the throttle body.
13. Disconnect the rectifier-regulator connector.
14. Remove the blower housing mounting screws. Note the location of the plated (silver) screw attaching the rectifier-regulator ground bracket. To gain access to the screw behind the dipstick tube, remove the dipstick tube screw and pull the tube out. Remove the blower housing.
15. Thoroughly clean the area around and including the throttle body/manifold and the injectors.
16. Disconnect the throttle linkage and linkage spring from the governor lever. Disconnect the TPS lead from the harness.
17. Remove the manifold mounting bolts and separate the throttle body/manifold from the engine leaving the TPS, high pressure fuel line, injectors and fuel line connections intact. Discard the old gaskets.
18. Position the manifold assembly over an appropriate container to capture fuel and turn the key switch ON to activate the fuel pump and pressurize the system. Do not turn switch to START position.
19. If either injector exhibits leakage of more than two to four drops per minute from the tip, or shows any sign of leakage around the outer shell, turn the ignition switch OFF and replace the injector as follows.
20. Depressurize the fuel system following the procedure in the fuel warning on page 5.2.
21. Clean any dirt accumulation from the sealing/mounting area of the faulty injector(s) and disconnect the electrical connector(s).
22. Pull the retaining clip off the top of the injector(s). Remove the screw holding the injector(s) from the manifold.

23. Reverse the appropriate procedures to install the new injector(s) and reassemble the engine. Use new O-rings and retaining clips any time an injector is removed (new replacement injectors include new O-rings and retaining clips). Lubricate O-rings lightly with clean engine oil. Use the installation tool provided with the O-rings to install the new upper O-ring. Place the tool into the fuel injector inlet. Place one side of the O-ring into the O-ring groove and roll the O-ring over the tool onto the fuel injector. Torque the screw securing the fuel injector caps and blower housing mounting screws to **7.3 N·m (65 in. lb.)**, and the intake manifold and air cleaner mounting screws to **10.5 N·m (93 in. lb.)**. An ECU Reset will need to be completed. Follow the instructions on page 5.10.

Injector problems due to dirt or clogging are generally unlikely due to the design of the injectors, the high fuel pressure, and the detergent additives in the gasoline. Symptoms that could be caused by dirty/clogged injectors include rough idle, hesitation/stumbling during acceleration, or triggering of fault codes related to fuel delivery. Injector clogging is usually caused by a buildup of deposits on the director plate, restricting the flow of fuel, resulting in a poor spray pattern. Some contributing factors to injector clogging include higher than normal operating temperatures, short operating intervals, and dirty, incorrect, or poor quality fuel. Cleaning of clogged injectors is not recommended; they should be replaced. Additives and higher grades of fuel can be used as a preventative measure if clogging has been a problem.

Ignition System

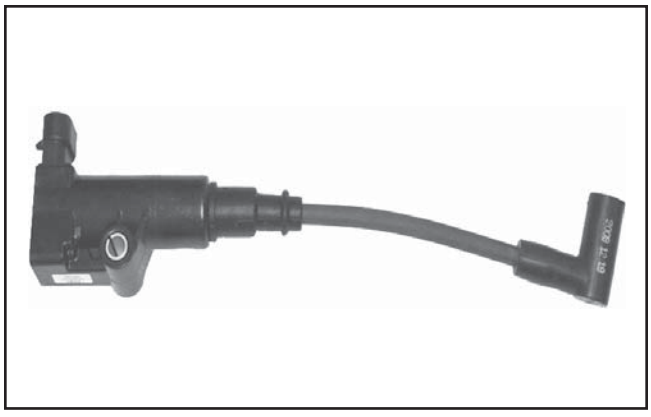


Figure 5-16. Ignition Coil.

General

A high-voltage, solid-state, battery ignition system is used with the EFI system. The ECU controls the ignition output and timing through transistorized control of the primary current delivered to the coils. Based on input from the crankshaft position sensor, the ECU determines the correct firing point for the speed at which the engine is running. At the proper instant, it interrupts the flow of primary current in the coil, causing the electromagnetic flux field to collapse. The flux collapse induces an instantaneous high voltage in the coil secondary which is strong enough to bridge the gap on the spark plug. Each coil fires every other revolution.

Service

If a coil is determined to be faulty, replacement is necessary. An ohmmeter may be used to test the wiring and coil windings.

NOTE: **Do not** ground the coils with the ignition ON as they may overheat or spark.

NOTE: Always disconnect the spark plug lead from the spark plug before performing the following tests.

Testing

1. Using an ohmmeter set on the Rx1 scale, check the resistance in circuits as follows:

   a. Disconnect the Black connector from the ECU to check the number one cylinder coil (starter side). Test between Black pin 1 and Black pin 15.

   b. Disconnect the Grey connector from the ECU to check the number two cylinder coil (oil filter side). Test between Grey pin 10 and Grey pin 17. A reading of **0.5-0.8** Ω in each test indicates that the wiring and coil primary circuits are OK.

   c. If reading(s) are not within specified range, check and clean connections and retest.

   d. If reading(s) are still not within the specified range, test the coils separately from main harness as follows:

      1) Remove the screw retaining the coil to the housing and disconnect the primary leads connector.

2) Connect an ohmmeter set on the Rx1 scale to the primary terminals of the coil. Primary resistance should be **0.5-0.8** Ω.

3) Connect an ohmmeter set on the Rx10K scale between the spark plug boot terminal and the B+ primary terminal. Secondary resistance should be **6400-7800** Ω.

4) If the secondary resistance is not within the specified range, the coil is faulty and needs to be replaced.

NOTE: If the ignition coil(s) are disabled and an ignition fault is registered, the system will automatically disable the corresponding fuel injector drive signal. The fault must be corrected to the ignition coil and the ECU power (switch) must be turned OFF for 10 seconds for the injector signal to return. This is a safety measure to prevent bore washing and oil dilution.

Spark Plugs

EFI engines are equipped with Champion® RC12YC resistor spark plugs. Equivalent alternate brand plugs can also be used, but must be resistor plugs or permanent damage to the ECU will occur, in addition to affecting operation. Proper spark plug gap is **0.76 mm (0.030 in.)**.

Battery Charging System

EFI engines are equipped with either a 20 or 25 amp charging system to accommodate the combined electrical demands of the ignition system and the specific application. Charging system troubleshooting information is provided in Section 7.

Fuel Components

Fuel Pump

General

An electric fuel pump module and a lift pump (two types) are used to transfer fuel in the EFI system. See Figures 5-17 and 5-18. The two types of lift pumps are a pulse fuel pump and a mechanical fuel pump. The pumping action is created by either the oscillation of positive and negative pressures within the crankcase through a hose, or by direct lever/pump actuation off rocker arm movement. The pumping action causes the diaphragm on the inside of the pump to pull fuel in on its downward stroke and to push it into the fuel pump module on its upward stroke. Internal check valves prevent fuel from going backward through the pump. The fuel pump module receives the fuel from the lift pump, increases and regulates the pressure for the fuel injectors.

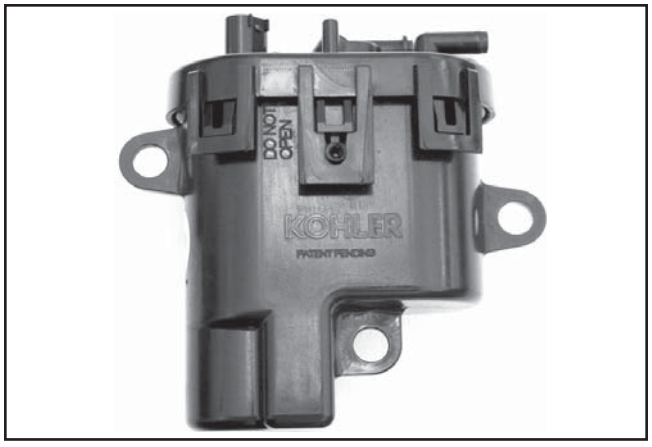


Figure 5-17. Fuel Pump Module.

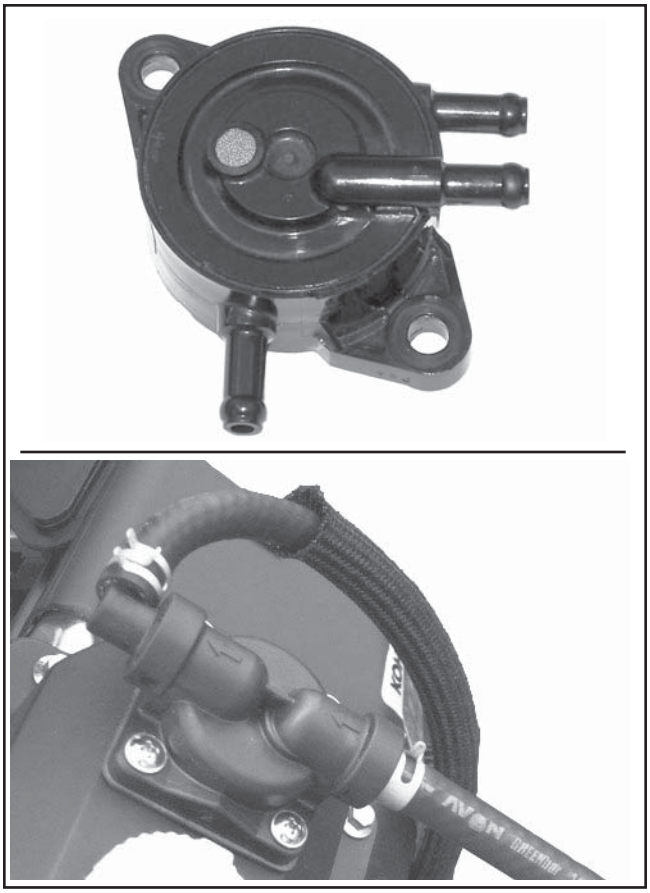


Figure 5-18. Pulse and Mechanical Fuel Pump.

The fuel pump module is rated for a minimum output of 13.5 liters per hour and regulated at 270 kilo pascals (39 psi).

When the key switch is turned ON and all safety switch requirements are met, the ECU activates the fuel pump module for about six seconds, which pressurizes the system for start-up. If the key switch is not promptly turned to the start position, the engine fails to start, or the engine is stopped with the key switch ON (as in the case of an accident), the ECU switches off the pump preventing the continued delivery of fuel. In this situation, the MIL will go on, but it will go back off after 4 cranking revolutions if system function is OK. Once the engine is running, the fuel pump remains on.

Service

The fuel pump module is not serviceable and must be replaced if determined to be faulty. If a fuel pump problem is suspected, make certain the pump is being activated, all electrical connections are properly secured, the fuses are good, and a minimum of 7.0 volts is being supplied. If during cranking, voltage drops below 7.0 volts, a reduction of fuel pressure may occur resulting in a lean starting condition. If required, testing of the fuel pump may be conducted.

1. Relieve fuel pressure at the fuel pump module following the instructions on page 5.2. The fuel pump module may need to be loosened or pulled away from the engine. Disconnect the fuel coupler from the fuel pump module and insert the pressure test jumper (from Kohler EFI Service Kit) between the high pressure fuel line and the fuel pump module.

2. Connect the black hose of Pressure Tester (part of EFI Service Kit, see Section 2). Route the clear hose into a portable gasoline container or the equipment fuel tank.

3. Turn on the key switch to activate the pump and check the system pressure on the gauge. It may take several key cycles to compress the air introduced into the system and reach regulated pressure. If system pressure of 39 psi ± 3 is observed, the wiring, fuel pump, and regulator are working properly. Turn key switch OFF and depress the valve button on the tester to relieve the system pressure.

   a. If the pressure is too high, replace the fuel pump module.

   b. If the pressure is too low, replace the fuel pump module.

4. If the pump did not activate (step 3), disconnect the plug from the fuel pump. Connect a DC voltmeter across the terminals in the plug, turn on the key switch and observe if a minimum of 7 volts is present during the six second prime process.

5. If no voltage is observed, connect the red lead of meter to the red wire of the plug and the black lead to a good ground while the key is still ON.

6. If voltage is between 7 and 14, turn key switch OFF and connect an ohmmeter between the terminals on the pump to check for continuity.

   a. If there was no continuity between the pump terminals, replace the fuel pump.

   b. If the voltage was below 7, test the wiring harness.

7. If voltage at the plug was good, and there was continuity across the pump terminals, reconnect the plug to the pump, making sure you have a good connection. Turn on the key switch and listen for the pump to activate.

   a. If the pump starts, repeat steps 2 and 3 to verify correct pressure.

   b. If the pump still does not operate, replace it.

NOTE: The fuel pump module pins are coated with a thin layer of electrical grease to prevent fretting and corrosion. Do not attempt to remove electrical grease from the fuel pump module pins.

Fuel Filter

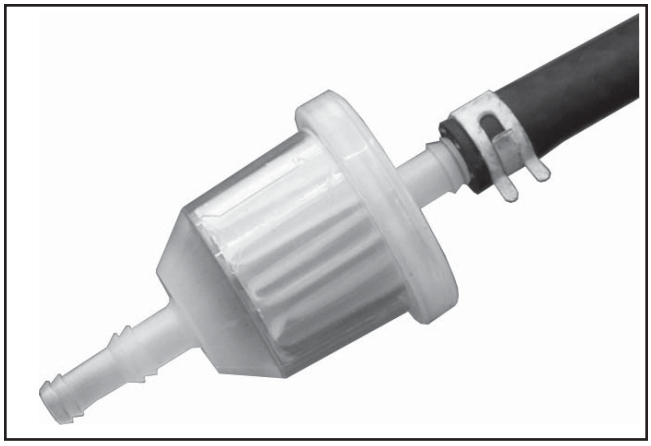


Figure 5-19. In-Line Fuel Filter.

General

The precision components inside the fuel pump module are not serviceable. DO NOT attempt to open the fuel pump module. Damage to the components will result and the warranty will be void. Because the fuel pump module is not serviceable, the engines are equipped with a special 10-micron EFI fuel filter to prevent harmful contamination from entering the module. See Figure 5-19.

If there are two filters in the system, the one before the lift pump will be a standard 51-75 micron filter, and the one after the lift pump will be the special 10-micron filter. Be sure to use an approved 10-micron filter for replacement.

Service

Periodically inspect the filter and replace **every 200 operating hours** or more frequently under extremely dusty or dirty conditions. Use only a genuine Kohler filter and install it according to the directional arrows. Failure to use the proper filter can result in engine damage and void the warranty.

High Pressure Fuel Line

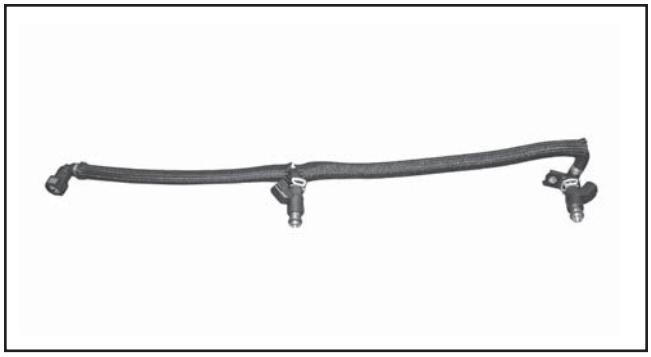


Figure 5-20. High Pressure Fuel Line with Fuel Injectors.

General

The high pressure fuel line is an assembly of hoses, injector caps and a fuel connector to the fuel pump module. The high pressure fuel line feeds fuel to the top of the injectors through the injector caps. The caps are fastened to the intake manifold and the injectors are locked into place. A small retaining clip provides a secondary lock.

The high pressure fuel line is serviced as a complete assembly to prevent tampering and safety hazards. The components are not individually serviceable.

These engines use low permeation rated fuel lines, certified to comply with California and U.S. EPA evaporative emission requirements. Fuel lines that do not meet these requirements may not be used. Order replacement hose through a Kohler Service Center.

⚠ CAUTION:

Low permeation high-pressure fuel line with an SAE 30R9 or 30R12 rating (1/4 in. I.D.) is required for safe and reliable operation due to higher operating pressure of the EFI system. Low permeation low-pressure fuel line with a SAE 30R7 rating (1/4 in. I.D.) may only be used between the fuel tank and lift pump, between the lift pump and fuel pump module, or as otherwise configured in the application.

Service
The high pressure fuel line is mounted to the intake manifold. No specific servicing is required unless operating conditions indicate that it needs replacement. It can be detached by removing the two mounting screws, wire ties, and the injector retaining clips. Thoroughly clean the area around all joints and relieve any pressure before starting any disassembly by following the instruction on page 5.2.

Purge Port and Vent Hose Assembly

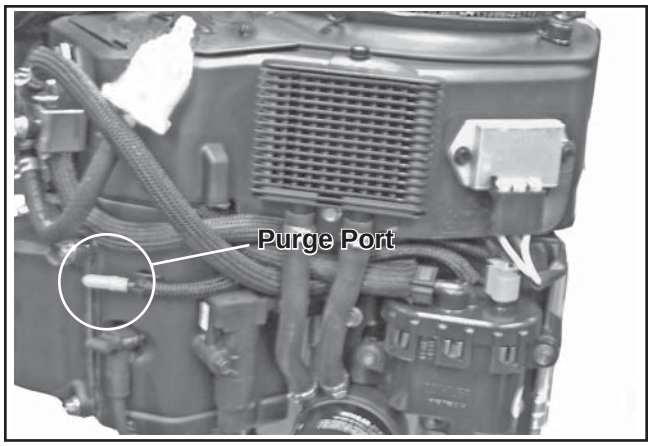


Figure 5-21. Purge Port Location.

General
The vent hose assembly is intended to vent fuel vapor out of the fuel pump module and direct the fuel vapor into the throttle body. All EFI engines are equipped with an engine mounted purge port on the #2 cylinder barrel baffle. This capped purge port can be used by the OEM to vent fuel tanks or used in conjunction with a carbon canister kit for Tier III evaporative emissions compliance. The purge port connects to the vent hose assembly and directs all fuel vapor into the throttle body. If the purge port remains unused, the port must remain capped to prevent dirt from entering the engine. See Figure 5-21.

Service
No specific servicing is required for the vent hose assembly or purge port unless operating conditions indicate replacement is required. All components are serviced individually. Abrasion sleeves on hoses should be reused or replaced when servicing vent hoses. Please note vent hose routing and replicate after service or component replacement to prevent pinching or abrasion of the vent hoses.

Throttle Body/Intake Manifold Assembly

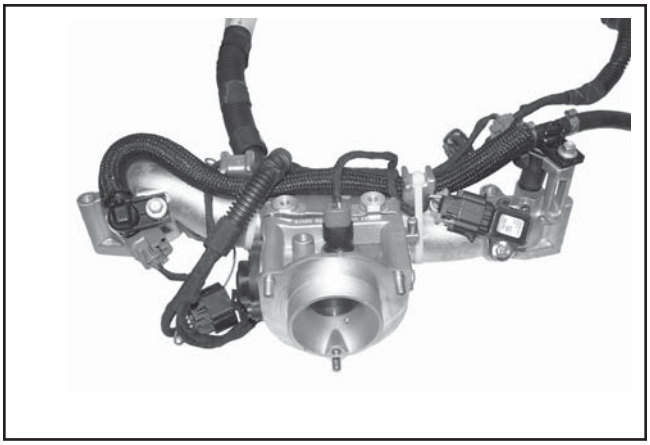


Figure 5-22. Throttle Body/Intake Manifold Details.

General
The EFI engines have no carburetor, so the throttle function (regulate incoming combustion airflow) is achieved with a throttle valve in a separate throttle body attached to the intake manifold. The throttle body/intake manifold provides mounting for the fuel injectors, throttle position sensor, intake air temperature sensor, high pressure fuel line, idle speed screw, and air cleaner assembly. See Figure 5-22.

Service
The throttle body is serviced as an assembly, with the throttle shaft, TPS, throttle plate, and idle speed adjusting screw installed. The throttle shaft rotates on needle bearings (non-serviceable), capped with seals to prevent air leaks.

NOTE: ECU Reset is required if the throttle body is replaced.

Idle Speed Adjustment (RPM)

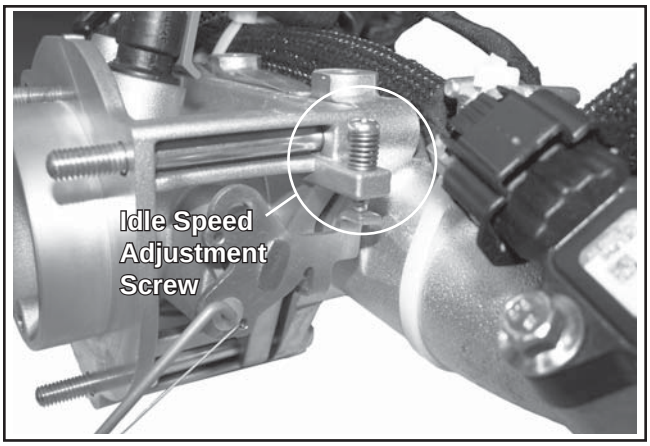


Figure 5-23. Idle Speed Adjustment.

General

The idle speed is the only adjustment that may be performed on the EFI system. The standard idle speed setting for EFI engines is **1500 RPM**, but certain applications might require a different setting. Check the equipment manufacturer's recommendation.

For starting and warm up, the ECU will adjust the fuel and ignition timing, based upon ambient temperature, engine temperature, and loads present. In cold conditions, the idle speed will probably be different than normal for a few moments. Under other conditions, the idle speed may actually start lower than normal, but gradually increase to the established setting as operation continues. **Do not** attempt to circumvent this warm up period, or readjust the idle speed during this time. The engine must be completely warmed up, in closed loop operating mode for accurate idle adjustment.

Adjustment Procedure

1. Make sure there are no fault codes present in the ECU memory.

2. Start the engine and allow it to fully warm up and establish closed looped operation (approximately 5-10 min.).

3. Place the throttle control in the idle/slow position and check the idle speed with a tachometer. Turn the idle speed screw in or out as required to obtain **1500 RPM**, or the idle speed specified by the equipment manufacturer. See Figure 5-23.

4. If the idle speed is adjusted up over **1800 RPM**, you must first decrease idle RPM to **1500 RPM** and then up to final idle speed setting for the TPS to be properly learned by the ECU.

5. The idle speed adjustment can affect the high idle speed setting. Move the throttle control to the full throttle position and check the high idle speed. Adjust as necessary to **3750 RPM**, or the speed specified by the equipment manufacturer.

Initial Governor Adjustment

The initial governor adjustment is especially critical on EFI engines because of the accuracy and sensitivity of the electronic control system. Incorrect adjustment can result in overspeed, loss of power, lack of response, or inadequate load compensation. If you encounter any of these symptoms and suspect them to be related to the governor setting, the following should be used to check and/or adjust the governor and throttle linkage.

If the governor/throttle components are all intact, but you think there may be a problem with the adjustment, follow Procedure A to check the setting. If the governor lever or the throttle body was loosened or removed, go immediately to Procedure B to perform the initial adjustment.

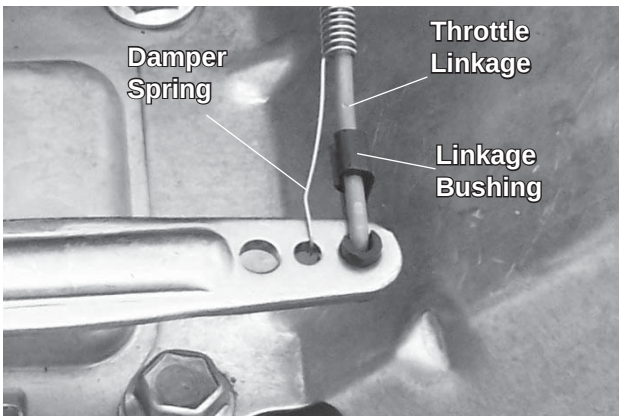


Figure 5-24. Throttle Linkage/Governor Lever Connection.

A. Checking the Initial Adjustment

1. Unsnap the plastic linkage bushing attaching the throttle linkage to the governor lever. See Figure 5-24. Unhook the damper spring from the lever, separate the linkage from the bushing, and remove the bushing from the lever. Mark the hole position and unhook the governor spring from the governor lever.

2. Pivot the throttle shaft and plate assembly into the Full Throttle position. Use a locking pliers (needle nose works best) to temporarily clamp the plate to the stop boss. Alternatively, there may be a stop pin instead of the stop boss. See Figure 5-25.

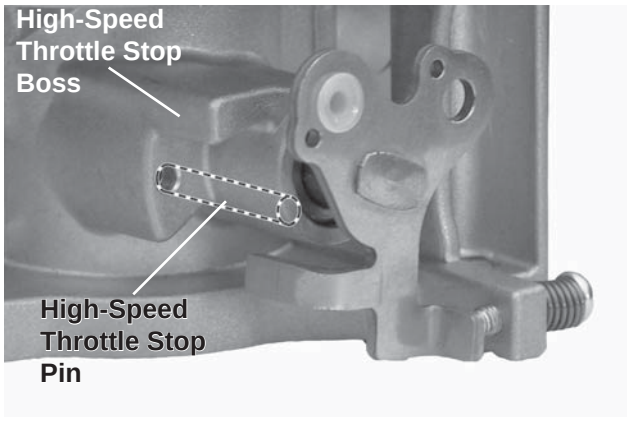


Figure 5-25. Throttle Details.

3. Rotate the governor lever and shaft counterclockwise until it stops. Use only enough pressure to hold it in that position.

4. Check how the end of the throttle linkage aligns with the bushing hole in the governor lever. See Figure 5-26. It should fall in the center of the hole. If it doesn't, perform the adjustment procedure as follows.

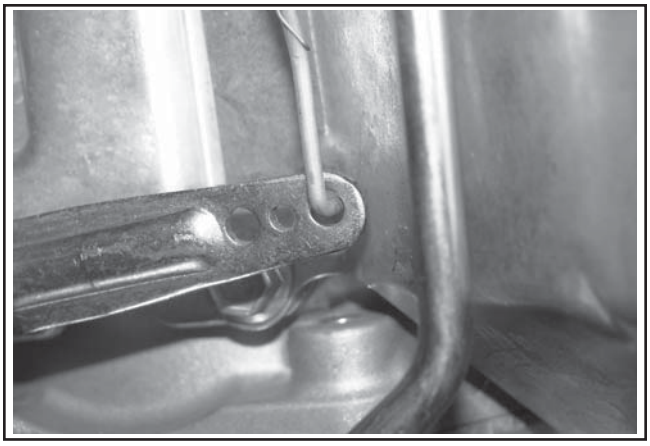


Figure 5-26. Throttle Link in Center of Hole.

B. Setting the Initial Adjustment

1. Check the split where the clamping screw goes through the governor lever. See Figure 5-27. There should be a gap of at least 1/32 in. If the tips are touching and there is no gap present, the lever should be replaced. If not already installed, position the governor lever on the cross shaft, but leave the clamping screw loose.

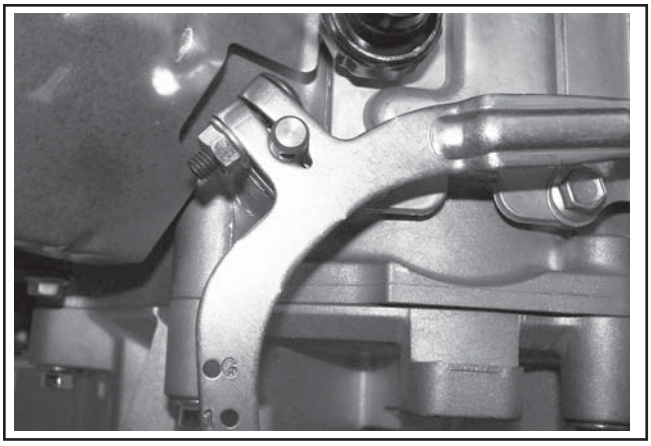


Figure 5-27. Checking Split of Clamp.

2. Follow the instructions in Step 2 of Checking the Initial Adjustment, then reattach the throttle linkage to the governor lever with the bushing clip. It is not necessary to reattach the damper or governor springs at this time.

3. Insert a nail or Allen wrench into the hole in the top of the cross shaft. Using light pressure, rotate the governor shaft **counterclockwise** as far as it will turn, then torque the hex nut on the clamping screw to **6.8 N·m (63 in. lb.)**. See Figure 5-28. Make sure that the governor arm has not twisted up or down after the nut has been tightened.

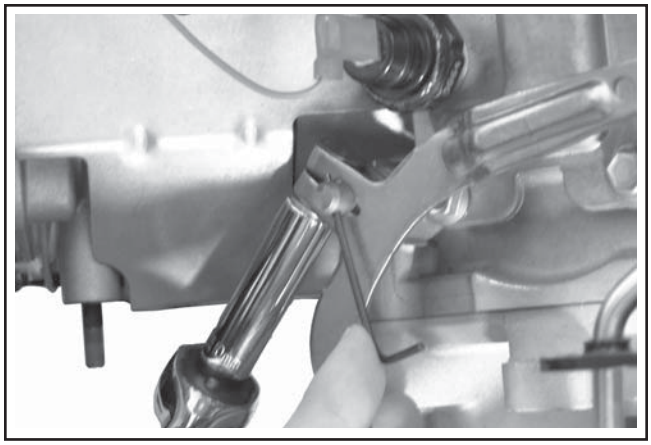


Figure 5-28. Adjusting Governor Shaft.

4. Verify that the governor has been set correctly. With the linkage still retained in the Full Throttle position (Step 2), unsnap the bushing clip, separate the linkage from the bushing, and remove the bushing from the lever. Follow Steps 3 and 4 in Checking the Initial Adjustment.

5. Reconnect the dampening spring into its governor lever hole from the bottom. Reinstall the bushing and reattach the throttle linkage. See Figure 5-24. Reattach the governor spring in the marked hole.

6. Start the engine and allow it to fully warm up and establish closed loop operation (approximately 5-10 min.). Check the speed settings and adjust as necessary, first the low idle speed, and then the high-speed setting.

NOTE: Throttle body and air cleaner assembly must be securely fastened with three hex flange nuts to the intake manifold prior to attempting to set the governor.

Troubleshooting

General

When troubleshooting a problem on an engine with EFI, basic engine operating problems must be eliminated first before faulting the EFI system components. What appears to be an EFI problem could be something as simple as a fuel tank with debris in the bottom or a plugged vent. Be sure the engine is in good mechanical operating condition and all other systems are operating properly before attempting to troubleshoot the EFI system.

Troubleshooting Guide

Engine starts hard or fails to start when cold

1. Fuel pump not running
2. Faulty spark plugs
3. Old/stale fuel
4. Incorrect fuel pressure
5. Crankshaft position sensor loose or faulty
6. TPS set incorrect (ECU Reset and TPS Learn)
7. TPS faulty
8. Engine temp sensor faulty
9. Faulty coils
10. Low system voltage
11. Faulty injectors
12. Faulty battery
13. Loose or corroded connections

Engine starts hard or fails to start when hot

1. Faulty spark plugs
2. Fuel pump not running
3. Fuel pressure low
4. Insufficient fuel delivery
5. TPS set incorrect (ECU Reset and TPS Learn)
6. Crankshaft position sensor loose or faulty
7. TPS faulty
8. Engine temp sensor faulty
9. Faulty injectors

Engine stalls or idles roughly (cold or warm)

1. Faulty spark plugs
2. Insufficient fuel delivery
3. TPS set incorrect
4. TPS faulty
5. Faulty engine temperature sensor
6. Faulty injectors

Engine misses, hesitates, or stalls under load

1. Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty/restricted
2. Dirty air cleaner
3. Insufficient fuel pressure or fuel delivery
4. Vacuum (intake air) leak
5. Improper governor setting, adjustment or operation
6. TPS faulty, mounting problem or TPS Learn Procedure incorrect
7. Bad coil(s), spark plug(s), or wires

Low Power

1. Faulty/malfunctioning ignition system
2. Dirty air filter
3. Insufficient fuel delivery
4. Improper governor adjustment
5. Plugged/restricted exhaust
6. One injector not working
7. Basic engine problem exists
8. TPS faulty or mounting exists
9. Throttle plate in throttle body not fully opening to WOT stop (if so equipped)

Fuel System

⚠ WARNING: Fuel System Under Pressure!

The fuel system operates under high pressure. System pressure must be relieved through the fuel connector and the fuel pump module (see page 5.2) prior to servicing or removal of any fuel system components. Do not smoke or work near heaters or other fire hazards. Have a fire extinguisher handy and work only in a well-ventilated area.

The function of the fuel system is to provide sufficient delivery of fuel at the system operating pressure of 39 psi ± 3. If an engine starts hard, or turns over but will not start, it may indicate a problem with the EFI fuel system. A quick test will verify if the system is operating.

1. Disconnect and ground the spark plug leads.

2. Complete all safety interlock requirements and crank the engine for approximately 3 seconds.

3. Remove the spark plugs and check for fuel at the tips.

    a. If there is fuel at the tips of the spark plugs the fuel pump and injectors are operating.

    b. If there is no fuel at the tips of the spark plugs, check the following:

        1) Make sure the fuel tank contains clean, fresh, proper fuel.

        2) Make sure that the vent in the fuel tank is open.

        3) Make sure the fuel tank valve (if so equipped) is fully opened.

        4) Make sure the battery is supplying proper voltage.

        5) Check that the fuses are good, and that no electrical or fuel line connections are damaged or broken.

        6) Test fuel pump module operation as described earlier under Fuel Pump – Service.

Fault Codes

The ECU continuously monitors engine operation against preset performance limits. If the operation is outside the limits, the ECU activates the MIL, if equipped, and stores a diagnostic code in its fault memory. If the component or system returns to proper function, the ECU will turn off the MIL. If the MIL stays illuminated, it warns the customer a fault is currently happening, and dealer service is required. Upon receipt, the dealer technician can access the fault code(s) to help determine what portion of the system is malfunctioning. The 4-digit fault codes available are listed on page 5.28.

The codes are accessed through the key switch and displayed as blinks or flashes of the MIL. Access the codes as follows:

1. Check that the battery voltage is above 11 volts.

2. Start with the key switch OFF.

3. Turn the key switch to the ON and OFF, then ON and OFF, then ON, leaving it on in the third sequence. Do not start the engine. The time between sequences must be less than 2.5 seconds.

4. The MIL will blink a series of times. The number of times the MIL blinks represents a number in the blink code.

5. A sequence of four digits make up a fault code. There is a one (1) second pause between the blinks of a fault code. There is a three (3) second pause between separate fault codes. After the fault code(s) are blinked a two digit 61 is blinked to indicate the program has completed.

    a. It's a good idea to write down the codes as they appear, as they may not be in numerical sequence.

    b. Code 61 will always be the last code displayed, indicating the end of code transmission. If code 61 appears immediately, no other fault codes are present.

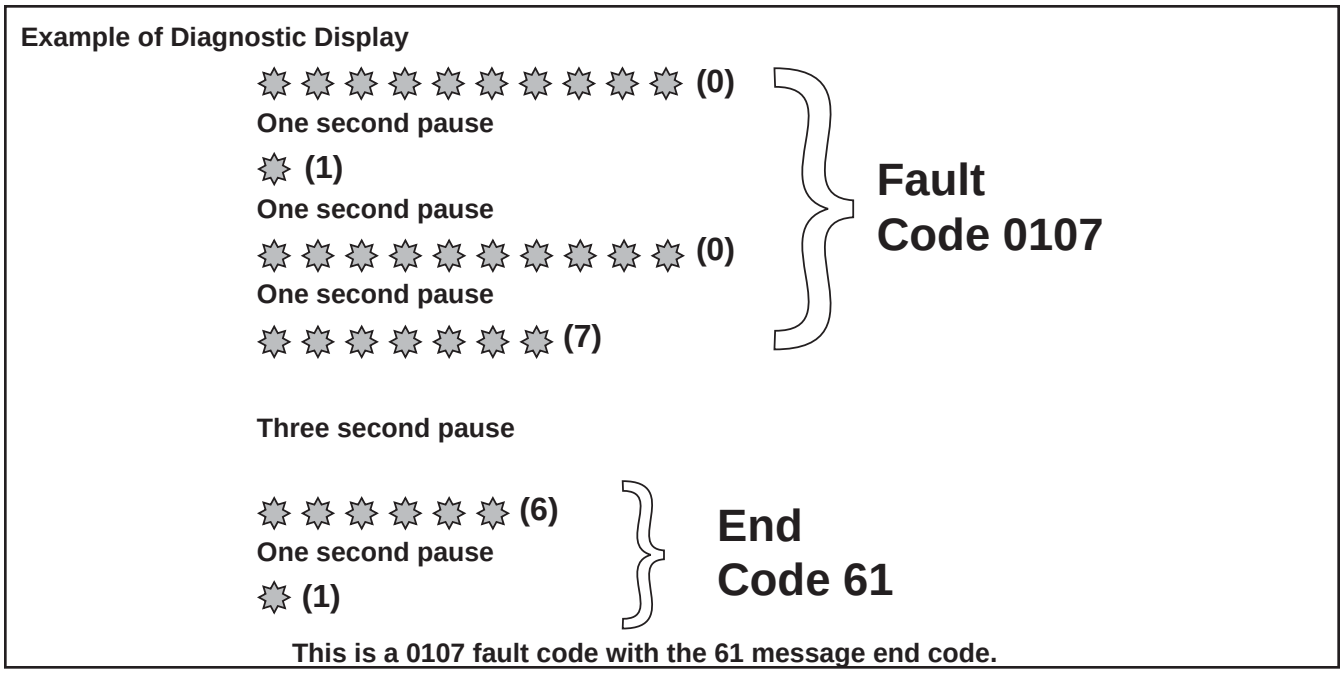


Figure 5-29.

After the problem has been corrected, the fault codes may be cleared by following the ECU Reset and TPS Learn Procedures.

The chart on the following page lists the fault codes, and what they correspond to. Following the chart is a list of the individual codes with an explanation of what triggers them, what symptoms might be expected, and the probable causes.

A MIL may not be provided with the engine. If the equipment manufacturer has not added a MIL to the equipment, one can be added easily for quick diagnostics. The main engine to vehicle connection will have a tan wire which is the ground for the MIL. Either incandescent or LED type bulbs can be used for the MIL as long as they do not draw more than 0.1 amps. The bulb needs to be rated at 1.4 Watts or less, or needs to have a total resistance of 140 Ω or more. LEDs typically draw less than 0.03 amps. Attach +12 volts to the positive terminal of the bulb and attach the ground terminal of the bulb to the tan wire.

Diagnostic Code Summary

Fault Code	Connection or Failure Description
0031	Oxygen Sensor Heater Circuit High Voltage
0032	Oxygen Sensor Heater Circuit Low Voltage
0107	Manifold Absolute Pressure Sensor Circuit Low Voltage or Open
0108	Manifold Absolute Pressure Sensor Circuit High Voltage
0112	Intake Air Temperature Sensor Circuit Low Voltage
0113	Intake Air Temperature Sensor Circuit High Voltage or Open
0117	Coolant/Oil Temperature Sensor Circuit Low Voltage
0118	Coolant/Oil Temperature Sensor Circuit High Voltage or Open
0122	Throttle Position Sensor Circuit Low Voltage or Open
0123	Throttle Position Sensor Circuit High Voltage
0131	Oxygen Sensor 1 Circuit Low Voltage, or Open
0132	Oxygen Sensor 1 Circuit High Voltage
0171	Maximum Adaptation Limit Exceeded
0172	Minimum Adaptation Limit Exceeded
0174	Lean Fuel Condition at High Load (Open Loop)
0201	Injector 1 Circuit Malfunction
0202	Injector 2 Circuit Malfunction
0230	Fuel Pump Module Circuit Low Voltage or Open
0232	Fuel Pump Module Circuit High Voltage
0336	Crankshaft Position Sensor Noisy Signal
0337	Crankshaft Position Sensor No Signal
0351	Cylinder 1 Ignition Coil Malfunction
0352	Cylinder 2 Ignition Coil Malfunction
0562	System Voltage Low
0563	System Voltage High
61	End of Code Transmission

Code:	0031
Component:	Oxygen Sensor Heater
Fault:	O2S Heater Circuit High Voltage

Condition: System voltage too high, shorted connection or faulty sensor.

Possible Causes:
1. Oxygen Sensor Related
   a. Sensor connector or wiring problem.
   b. Sensor damaged.
   c. Pin circuit wiring or connectors at Black 7.

2. ECU Related
   a. ECU-to-harness connection problem.

Code:	0032
Component:	Oxygen Sensor Heater
Fault:	O2S Heater Circuit Low Voltage

Condition: System voltage too low, open connection or faulty sensor.

Possible Causes:
1. Engine Wiring Harness Related
   a. Pin circuit wiring or connectors.
      1. ECU Black pin 7.
      2. Broken wire.

2. Oxygen Sensor Related
   a. Sensor connector or wiring problem.

3. Poor system ground from ECU to engine or battery to engine.

Code:	0107
Component:	Manifold Absolute Pressure Sensor
Fault:	MAP Circuit Low Voltage or Open

Condition: Intake manifold leak, open connection or faulty sensor.

Possible Causes:
1. MAP Sensor Related
   a. Sensor malfunction.
   b. Vacuum leaks from loose manifold or sensor.

2. Wire Harness Related
   a. Poor grounding or open circuit.
   b. Wire harness and connectors loose, damaged or corroded.
   c. Pin circuit wiring or connectors at Black 10, 11 and 16.

3. Bad TPS Learn.

Code:	0108
Component:	Manifold Absolute Pressure Sensor
Fault:	MAP Circuit High Voltage

Condition: Intake manifold leak, shorted connection or faulty sensor.

Possible Causes:
1. MAP Sensor Related
   a. Sensor malfunction.
   b. Vacuum leaks from loose manifold or sensor.

2. Wire Harness Related
   a. Poor grounding.
   b. Pin circuit wiring or connectors at Black 11.

3. Bad TPS Learn.

Code:	0112
Component:	Intake Air Temperature Sensor
Fault:	Intake Air Temperature Sensor Circuit Low Voltage

Condition: Shorted connection, faulty sensor or shorted wire.

Possible Causes:
1. Temperature Sensor Related
   a. Sensor wiring or connection.

2. Engine Wiring Harness Related
   a. Pin circuits Black 10 and Black 8 may be damaged or routed near noisy signal (coils, alternator, etc.).
   b. ECU-to-harness connection problem.

Code:	0113
Component:	Intake Air Temperature Sensor
Fault:	Intake Air Temperature Sensor Circuit High Voltage or Open

Condition: Shorted connection, faulty sensor, broken wire or connection.

Possible Causes:
1. Temperature Sensor Related
   a. Sensor wiring or connection.

2. Engine Wiring Harness Related
   a. Pin circuits ECU Black pin 10 and 8 may be damaged.
   b. ECU-to-harness connection problem or broken wire.

Code:	0117
Component:	Coolant/Oil Sensor
Fault:	Coolant/Oil Temperature Sensor Circuit Low Voltage

Condition: Shorted connection, faulty sensor or shorted wire.

Possible Causes:
1. Temperature Sensor Related
   a. Sensor wiring or connection.

2. Engine Wiring Harness Related
   a. Pin circuits Black 10 and Black 14 maybe damaged or routed near noisy signal (coils, stator, etc.).
   b. ECU-to-harness connection problem.

Code:	0118
Component:	Coolant/Oil Sensor
Fault:	Coolant/Oil Temperature Sensor Circuit High Voltage or Open

Condition: Shorted connection, faulty sensor, open connection or broken wire.

Possible Causes:
1. Temperature Sensor Related
   a. Sensor wiring or connection.

2. Engine Wiring Harness Related
   a. Pin circuits ECU Black pin 10 and 14 may be damaged.
   b. ECU-to-harness connection problem or broken wire.

3. System Related
   a. Engine is operating above the 176°C (350°F) temperature sensor limit.

Code:	0122
Component:	Throttle Position Sensor (TPS)
Fault:	TPS Circuit Low Voltage or Open

Condition: Open connection, broken wire or faulty sensor.

Possible Causes:
1. TPS Related
   a. TPS bad or worn internally.

2. Engine Wiring Harness Related
   a. Broken or shorted wire in harness.
      1. ECU Black pin 10 to TPS pin 1.
      2. ECU Black pin 12 to TPS pin 3.
      3. ECU Black pin 16 to TPS pin 2.

3. Throttle Body Related
   a. Throttle shaft inside TPS worn, broken, or damaged.
   b. Throttle plate loose or misaligned.
   c. Throttle plate bent or damaged allowing extra airflow past, or restricting movement.

4. ECU Related
   a. Circuit providing voltage or ground to TPS damaged.
   b. TPS signal input circuit damaged.

Code:	0123
Component:	Throttle Position Sensor (TPS)
Fault:	TPS Circuit High Voltage

Condition: Shorted connection or faulty sensor.

Possible Causes:
1. TPS Sensor Related
   a. Sensor connector or wiring.
   b. Sensor output affected or disrupted by dirt, grease, oil, wear.
   c. Sensor loose on throttle body manifold.

2. Throttle Body Related
   a. Throttle shaft or bearings worn/damaged.

3. Engine Wiring Harness Related
   a. ECU pins Black 10, 12 and 16 damaged (wiring, connectors).
   b. ECU pins Black 10, 12 and 16 routed near noisy electrical signal (coils, alternator).
   c. Intermittent 5 volt source from ECU (pin Black 16).
   d. ECU-to-harness connection problem.

Code:	0131
Component:	Oxygen Sensor
Fault:	O2S 1 Circuit Low Voltage

Condition: Open connection, broken wire or faulty sensor.

Possible Causes:
1. Oxygen Sensor Related
   a. Sensor connector or wiring problem.
   b. Sensor contaminated, corroded or damaged.
   c. Poor ground path.
   d. Pin circuit wiring or connectors. ECU Black pin 10 or 17.

2. TPS Learn Procedure Incorrect
   a. Lean condition (check oxygen sensor signal with VOA and see Oxygen Sensor section).

3. Engine wiring harness related such as a cut wire, broken or pinched.

Code:	0132
Component:	Oxygen Sensor
Fault:	O2S 1 Circuit High Voltage

Condition: Shorted connection or faulty sensor.

Possible Causes:
1. Oxygen Sensor Related
   a. Sensor connector or wiring problem.
   b. Sensor contaminated or damaged.
   c. Poor ground path.
   d. Pin circuit wiring or connectors. ECU Black pin 10 or Black pin 17.

2. Engine Wiring Harness Related
   a. Difference in voltage between sensed voltage and actual sensor voltage.
   b. Short in wire harness.

Code:	0171
Component:	Fuel System
Fault:	Maximum adaptation limit exceeded

Condition: Fuel inlet screen/filter plugged, low pressure at high pressure fuel line, TPS malfunction, shorted connection, faulty sensor, low fuel or wrong fuel type.

Possible Causes:
1. Oxygen Sensor Related
   a. Corrosion or poor connection.
   b. Sensor contaminated or damaged.
   c. Air leak into exhaust.
   d. Poor ground path.
   e. Pin circuit wiring or connectors.
      1. ECU Black pin 10 or Black pin 17.

2. TPS Sensor Related
   a. Throttle plate position incorrect during Learn procedure.
   b. TPS problem or malfunction.

3. Engine Wiring Harness Related
   a. Difference in voltage between sensed voltage and actual sensor voltage.
   b. Problem in wiring harness.
   c. ECU-to-harness connection problem.

4. Systems Related
   a. Ignition (spark plug, plug wire, ignition coil).
   b. Fuel (fuel type/quality, injector, fuel pressure too low, fuel pump module or lift pump).
   c. Combustion air (air cleaner dirty/restricted, intake leak, throttle bores).
   d. Base engine problem (rings, valves).
   e. Exhaust system leak (muffler, flange, oxygen sensor mounting boss, etc.).
   f. Fuel in the crankcase oil.

Code:	0172
Component:	Fuel System
Fault:	Minimum adaptation limit exceeded

Condition: Too high pressure at high pressure fuel line, TPS malfunction, shorted connection, faulty sensor or fuel pump module failure.

Possible Causes:
1. Oxygen Sensor Related
   a. Sensor connector or wiring.
   b. Sensor contaminated or damaged.
   c. Poor ground path.
   d. Pin circuit wiring or connectors. ECU Black pin 10 or 17.

2. TPS Sensor Related
   a. Throttle plate position incorrect during Learn procedure.
   b. TPS problem or malfunction.

3. Engine Wiring Harness Related
   a. Difference in voltage between sensed voltage and actual sensor voltage.
   b. Problem in wiring harness.
   c. ECU-to-harness connection problem.

4. Systems Related
   a. Ignition (spark plug, plug wire, ignition coil).
   b. Fuel (fuel type/quality, injector, fuel pressure too high, fuel pump module or lift pump).
   c. Combustion air (air cleaner dirty/restricted).
   d. Base engine problem (rings, valves).
   e. Fuel in the crankcase oil.
   f. Fuel pump module is over filled.
   g. Lift pump diaphragm is ruptured.

Code:	0174
Component:	Fuel System
Fault:	Lean fuel condition

Condition: Fuel inlet screen/filter plugged, low pressure at high pressure fuel line, TPS malfunction, shorted connection or faulty sensor.

Possible Causes:
1. TPS Learn Incorrect
   a. Lean condition (check oxygen sensor signal with VOA and see Oxygen Sensor section).

2. Engine Wiring Harness Related
   a. Pin circuit wiring or connectors. ECU pin Black 10, 12, 16 and 17.

3. Low Fuel Pressure
   a. Plugged filters.
   b. Bad lift pump.

4. Oxygen Sensor Related
   a. Sensor connector or wiring problem.
   b. Exhaust leak.
   c. Poor ground.

5. Poor system ground from ECU to engine, causing rich running while indicating lean.

6. Fuel pump module connection. See Fuel Components.

Code:	0201
Component:	Fuel Injector
Fault:	Injector 1 Circuit Malfunction

Condition: Injector damaged or faulty, shorted or open connection.

Possible Causes:
1. Injector Related
   a. Injector coil shorted or opened.

2. Engine Wiring Harness Related
   a. Broken or shorted wire in harness. ECU pin Black 5.
   b. Wiring from Ignition.

3. ECU Related
   a. Circuit controlling injector #1 damaged.

Code:	0202
Component:	Fuel Injector
Fault:	Injector 2 Circuit Malfunction

Condition: Injector damaged or faulty, shorted or open connection.

Possible Causes:
1. Injector Related
   a. Injector coil shorted or opened.

2. Engine Wiring Harness Related
   a. Broken or shorted wire in harness. ECU pin Black 6.
   b. Wiring from Ignition.

3. ECU Related
   a. Circuit controlling injector #2 damaged.

Code:	0230
Component:	Fuel Pump
Fault:	Circuit Low Voltage or Open

Condition: Shorted or open connection.

Possible Causes:
1. Fuel Pump Related
   a. Fuel pump module open or shorted internally.

2. Engine Wiring Harness related
   a. Broken or shorted wire in harness. ECU pin Black 9 or Grey 17.

3. ECU Related
   a. The ECU is damaged.

Code:	0232
Component:	Fuel Pump
Fault:	Circuit High Voltage

Condition: Shorted connection.

Possible Causes:
1. Fuel Pump Related
   a. Fuel pump module damaged internally.

2. Charging Output System Too High.

Code:	0336
Component:	Crankshaft Position Sensor
Fault:	Crankshaft Position Sensor Noisy Signal

Condition: Air gap incorrect, loose sensor, faulty/bad battery, shorted or faulty connection, faulty sensor or faulty sensor grounding.

Possible Causes:
1. Crankshaft Position Sensor Related
   a. Sensor connector or wiring.
   b. Sensor loose or air gap incorrect.

2. Crankshaft Position Sensor Wheel Related
   a. Damaged teeth.
   b. Gap section not registering.

3. Engine Wiring Harness Related
   a. Pin circuit wiring or connectors. ECU pin Black 4 and Black 13.
   b. ECU-to-harness connection problem.

4. Ignition System Related
   a. Non-resistor spark plug(s) used.
   b. Faulty or disconnected ignition coil or secondary lead.

Code:	0337
Component:	Crankshaft Position Sensor
Fault:	Crankshaft Position Sensor No Signal

Condition: Air gap incorrect, loose sensor, open or shorted connection or faulty sensor.

Possible Causes:
1. Crankshaft Position Sensor Related
   a. Sensor connector or wiring.
   b. Sensor loose or air gap incorrect.

2. Crankshaft Position Sensor Wheel Related
   a. Damaged teeth.

3. Engine Wiring Harness Related
   a. Pin circuit wiring or connectors. ECU pin Black 4 or Black 13.
   b. ECU-to-harness connection problem.

4. If code is stored in fault history and starts normally. Clear code, no other service required.

Code:	0351
Component:	Ignition Coil
Fault:	Cylinder 1 Ignition Coil Malfunction

Condition: Broken wire in harness (may not be visible), shorted connection or faulty sensor.

Possible Causes:
1. Engine Wiring Harness Related
   a. Connection to ignition or fuse.
   b. Pin circuit wiring or connectors. ECU pin Black 1.
   c. ECU-to-harness connection problem.

2. Ignition System Related
   a. Incorrect spark plug(s) used.
   b. Poor connection to spark plug.

Code:	0352
Component:	Ignition Coil
Fault:	Cylinder 2 Ignition Coil Malfunction

Condition: Broken wire in harness (may not be visible), shorted connection or faulty sensor.

Possible Causes:
1. Engine Wiring Harness Related
   a. Connection to ignition or fuse.
   b. Pin circuit wiring or connectors. ECU pin Grey 10.
   c. ECU-to-harness connection problem.

2. Ignition System Related
   a. Incorrect spark plug(s) used.
   b. Poor connection to spark plug.

Code:	0562
Component:	System Voltage
Fault:	System Voltage Low

Condition: Faulty voltage regulator, bad fuse or shorted connection.

Possible Causes:
1. Corroded Connections

2. Bad Stator

3. Bad Battery
   a. Low output charging system.
   b. Poor magnet in flywheel.
   c. Bad or missing fuse.

Code:	0563
Component:	System Voltage
Fault:	System Voltage High

Condition: Faulty voltage regulator or shorted connection.

Possible Causes:

1. Faulty Rectifier-Regulator
2. Bad Stator.
3. Bad Battery.

Code:	61
Fault:	End of Code Transmission

Troubleshooting Flow Chart

The following flow chart provides an alternative method of troubleshooting the EFI system. The chart will enable you to review the entire system in about 10-15 minutes. Using the chart, the accompanying diagnostic aids (listed after the chart), and any signaled fault codes, you should be able to quickly locate any problems within the system. See Figure 5-30.

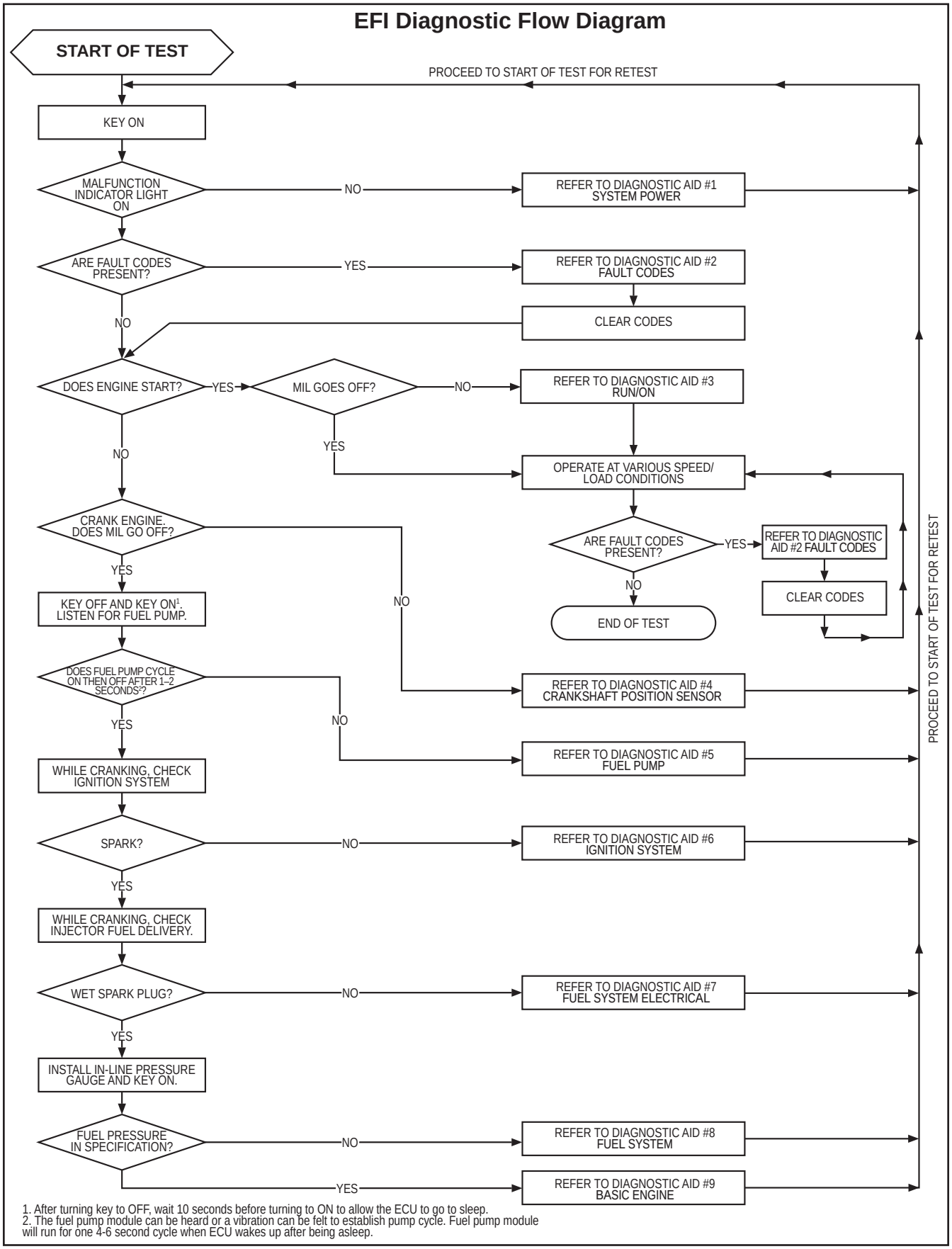


Figure 5-30. Troubleshooting Flow Chart.

Flow Chart Diagnostic Aids

Diagnostic Aid #1 SYSTEM POWER
(MIL does not illuminate when key is turned ON)

NOTE: MIL is installed by vehicle OEM. Twelve volt supply to bulb will be part of vehicle wire harness. Kohler key switch model will have MIL on engine with 12V supply to bulb.

Possible causes:
1. Battery
2. Main system fuse
3. MIL light bulb burned out
4. MIL electrical circuit problem
   Pin circuits Grey 3.
5. Ignition switch
6. Permanent ECU power circuit problem
   Pin circuit Black 18.
7. Switched ECU power circuit problem
   Pin circuit Black 15.
8 ECU grounds
9. ECU

Diagnostic Aid #2 FAULT CODES
(Refer to detailed fault code listing before flow chart and servicing information for the respective components)

Code 0031 - Oxygen Sensor Heater Circuit High Voltage
Code 0032 - Oxygen Sensor Heater Circuit Low Voltage
Code 0107 - Manifold Absolute Pressure Sensor Circuit Low Voltage or Open
Code 0108 - Manifold Absolute Pressure Sensor Circuit High Voltage
Code 0112 - Intake Air Temperature Sensor Circuit Low Voltage
Code 0113 - Intake Air Temperature Sensor Circuit High Voltage or Open
Code 0117 - Coolant/Oil Temperature Sensor Circuit Low Voltage
Code 0118 - Coolant/Oil Temperature Sensor Circuit High Voltage or Open
Code 0122 - TPS Circuit Low Voltage or Open
Code 0123 - TPS Circuit High Voltage
Code 0131 - O2S 1 Circuit Low Voltage or Open
Code 0132 - O2S 1 Circuit High Voltage
Code 0171 - Maximum adaptation limit exceeded
Code 0172 - Minimum adaptation limit exceeded
Code 0174 - Lean fuel condition at high load or open loop
Code 0201 - Injector 1 Circuit Malfunction
Code 0202 - Injector 2 Circuit Malfunction
Code 0230 - Fuel Pump Module Circuit Low Voltage or Open
Code 0232 - Fuel Pump Module Circuit High Voltage
Code 0336 - Crankshaft Position Sensor Noisy Signal
Code 0337 - Crankshaft Position Sensor No Signal
Code 0351 - Cylinder 1 Ignition Coil Malfunction
Code 0352 - Cylinder 2 Ignition Coil Malfunction
Code 0562 - System Voltage Low
Code 0563 - System Voltage High
Code 61 - End of Code Transmission.

Diagnostic Aid #3 RUN/ON
(MIL remains ON while engine is running)*

Possible causes:
1. All current fault codes will turn on MIL when engine is running.

NOTE: Either incandescent or LED type bulbs can be used for the MIL as long as they do not draw more than 0.1 amps. The bulb needs to be rated at 1.4 Watts or less, or needs to have a total resistance of 140 Ω or more. LEDs typically draw less than 0.03 amps.

Diagnostic Aid #4 CRANKSHAFT POSITION SENSOR
(MIL does not turn off during cranking)

Possible causes:
1. Crankshaft position sensor
2. Crankshaft position sensor circuit problem, pin circuits Black 4 and Black 13.
3. Crankshaft position sensor/toothed wheel air gap
4. Toothed wheel
5. Flywheel key sheared
6. ECU

Diagnostic Aid #5 FUEL PUMP
(fuel pump not turning on)

Possible causes:
1. Main fuse
2. Fuel pump circuit problem, pin circuits Black 9 and Grey 17.
3. Fuel pump module

Diagnostic Aid #6 IGNITION SYSTEM
(no spark)

Possible causes:
1. Spark plug
2. Plug wire
3. Coil
4. Coil circuit(s), pin circuits Grey 10 and Black 1.
5. ECU grounds

6. ECU
7. Vehicle safety interlocks, ground signal on safety wire.

Diagnostic Aid #7 FUEL SYSTEM ELECTRICAL
(no fuel delivery)

Possible causes:
1. No fuel
2. Air in high pressure fuel line
3. Fuel valve shut OFF
4. Fuel filter/line plugged
5. Injector circuit(s), pin circuits Black 5 and Black 6
6. Injector
7. ECU grounds
8. ECU
9. Lift pump not working

Diagnostic Aid #8 FUEL SYSTEM
(fuel pressure)

Possible causes for low fuel system pressure:
1. Low fuel
2. Fuel filter plugged
3. Fuel supply line plugged
4. Lift fuel pump - insufficient fuel supply
5. Fuel pump (lift or module) - internally plugged

Possible causes for high fuel system pressure:
1. Pressure regulator not functioning properly inside fuel pump module.

Diagnostic Aid #9 BASIC ENGINE
(cranks but will not run)

Possible causes:
1. Refer to basic engine troubleshooting charts within service manual sections 3, 5, and 7.

Section 6
Lubrication System

General

This engine uses a full pressure lubrication system, delivering oil under pressure to the crankshaft, camshaft, and connecting rod bearing surfaces. In addition to lubricating the bearing surfaces, the lubrication system supplies oil to the hydraulic valve lifters.

A high-efficiency gerotor pump is located in the oil pan. The oil pump maintains high oil flow and oil pressure, even at low speeds and high operating temperatures. A pressure relief valve in the oil pan limits the maximum pressure of the system.

Service

The oil pan must be removed to service the oil pump or oil pickup. Refer to the appropriate procedures in Sections 8 and 9.

Oil Recommendations

Using the proper type and weight of oil in the crankcase is extremely important; so is checking oil daily and changing the oil and filter regularly.

Use high-quality detergent oil of **API (American Petroleum Institute) service class SJ or higher.** Select the viscosity based on the air temperature at the time of operation as shown in the following table.

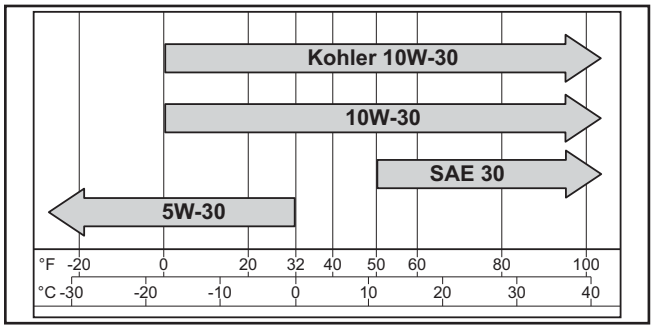


Figure 6-1. Viscosity Grade Table.

NOTE: Using other than service class SJ or higher oil, or extending oil change intervals longer than recommended can cause engine damage.

NOTE: Synthetic oils meeting the listed classifications may be used with oil changes performed at the recommended intervals. However, to allow piston rings to properly seat, a new or rebuilt engine should be operated for at least 50 hours using standard petroleum based oil before switching to synthetic oil.

A logo or symbol on oil containers identifies the API service class and SAE viscosity grade. See Figure 6-2.

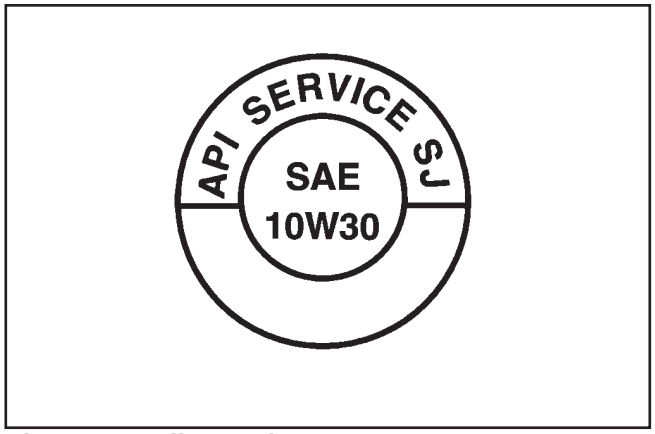


Figure 6-2. Oil Container Logo.

The top position of the symbol shows service class such as **API SERVICE CLASS SJ**. The symbol may show additional categories such as **SH, SG/CC, or CD**. The center portion shows the viscosity grade such as SAE 10W-30. If the bottom portion shows "Energy Conserving", it means that oil is intended to improve fuel economy in passenger car engines.

Check Oil Level

The importance of checking and maintaining the proper oil level in the crankcase cannot be overemphasized. Check oil **BEFORE EACH USE** as follows:

1. Make sure the engine is stopped, level, and is cool so the oil has had time to drain into the sump.

2. Clean the area around and beneath the oil fill cap/dipstick before removing it. This will help keep dirt, debris, and other foreign matter out of the engine. See Figure 6-3.

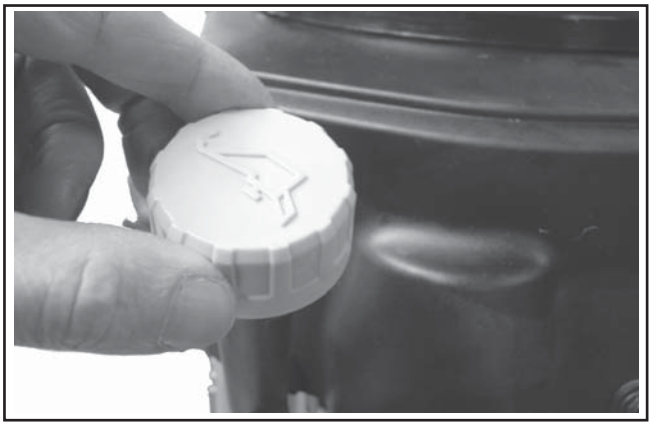


Figure 6-3. Oil Fill Cap/Dipstick.

3. Unscrew and remove the oil fill cap/dipstick; wipe off oil. Reinsert the dipstick into the oil fill tube and rest the cap on the tube. Do not thread the cap onto the tube.

4. Remove the oil fill cap/dipstick and check oil level is correct. The correct oil level is between the **F** and **L** marks on the dipstick. See Figure 6-4.

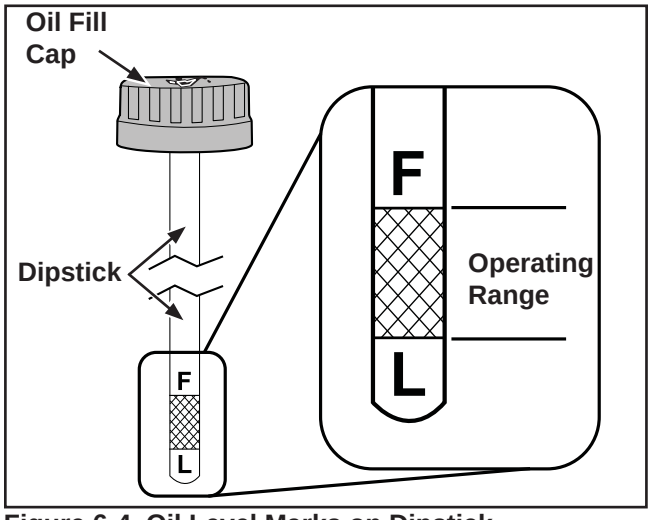


Figure 6-4. Oil Level Marks on Dipstick.

5. If the level is low, add oil of the proper type (Refer to **Oil Recommendations** on page 6.1) and to the correct level. Always check the level before adding more oil.

   NOTE: To prevent extensive engine wear or damage, always maintain the oil level within the *Operating Rang*e.

6. Reinstall the oil fill cap/dipstick and tighten on oil fill tube.

Oil Disposal

Protect and respect the environment. Dispose of oil at your local recycling center or municipal collection center in accordance with local ordinances.

Changing Oil and Oil Filter

Changing Oil

Change oil after every **100 hours** of operation (more frequently under severe conditions). Refill with oil as specified in the Viscosity Grades Table. See Figure 6-1. Change the oil while the engine is still warm. The oil will flow more freely and carry away more impurities. Make sure the engine is level when filling, checking, or changing the oil.

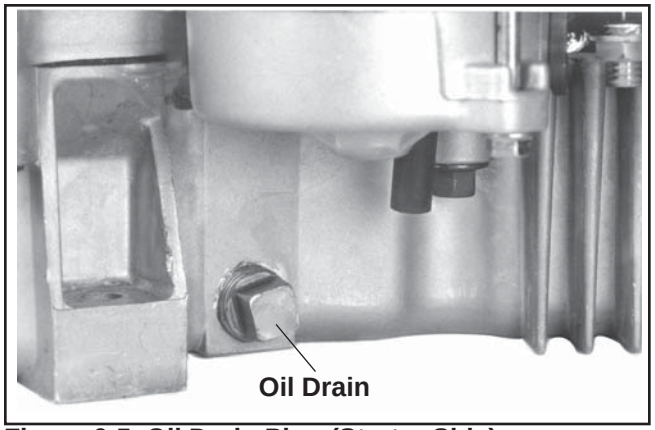


Figure 6-5. Oil Drain Plug (Starter Side).

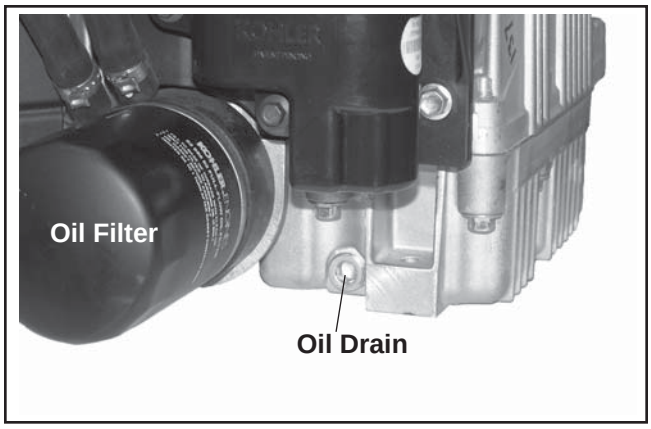


Figure 6-6. Oil Drain Plug (Oil Filter Side).

Change the oil as follows:

1. To keep dirt, debris, etc., out of the engine, clean the area around the oil fill cap/dipstick before removing it. See Figure 6-3.

2. Remove one of the oil drain plugs and the oil fill cap/dipstick. Allow ample time for complete drainage. See Figures 6-4 and 6-5.

3. Reinstall the drain plug and torque to **13.6 N·m (10 ft. lb.)**.

4. Fill the crankcase, with new oil of the proper type, to the **F** mark on the dipstick. Refer to **Oil Recommendations**. Always check the level with the dipstick before adding more oil.

5. Reinstall the oil fill cap/dipstick and tighten securely.

Changing Oil Filter

Replace the oil filter at least every other oil change (every 200 hours of operation). Always use a genuine Kohler oil filter. Replace the oil filter as follows:

1. Drain the oil from the engine crankcase. Remove one of the oil drain plugs and the oil fill cap/dipstick. Allow ample time for complete drainage. See Figures 6-3, 6-5, and 6-6.

2. Allow the oil filter to drain.

3. Before removing the oil filter, clean the area around the oil filter to keep dirt and debris out of the engine. Remove the old filter. Wipe off the surface where the filter mounts.

4. Place a new replacement filter in a shallow pan with the open end up. Pour new oil, of the proper type, in through the threaded center hole. Stop pouring when the oil reaches the bottom of the threads. Allow a minute or two for the oil to be absorbed by the filter material.

5. Apply a thin film of clean oil to the rubber gasket on the new filter.

6. Install the new oil filter to the filter adapter or oil cooler. Refer to the oil filter for installation instructions.

7. Reinstall the drain plug. Make sure it is tightened to **13.6 N·m (10 ft. lb.)** torque.

8. Fill the crankcase with new oil, of the proper type, to the F mark on the dipstick.

9. Test run the engine to check for leaks. Stop the engine, allow a minute for the oil to drain down, and recheck the level on the dipstick. Make sure oil level is up to but not over the F mark on the dipstick.

Service Oil Cooler

Some engines are equipped with an optional oil cooler. Inspect and clean oil cooler every 100 hours of operation (more frequently under severe conditions). Oil cooler must be kept free of debris. To service the oil cooler, clean the outside of fins with a brush or compressed air. Remove the hardware holding the cooler unit to the blower housing. Clean the inside of the cooler with a brush or compressed air. See Figure 6-7. After cleaning, reinstall the oil cooler to the blower housing with the mounting hardware.

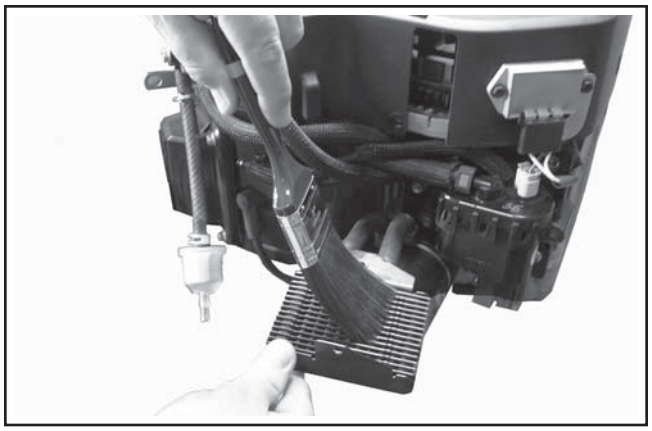


Figure 6-7. Blower Housing Mounted Oil Cooler.

Oil Sentry™

General

Some engines are equipped with an optional Oil Sentry™ switch. This switch is designed to prevent the engine from being started in a low oil or no oil condition. The Oil Sentry™ may not shut down a running engine before damage occurs. In some applications this switch may activate a warning signal. Read your equipment manual for more information.

The pressure switch is designed to make contact as the oil pressure decreases below 2-5 psi depending upon the application and switch specified.

On stationary or unattended applications (pumps, generators, etc.), the pressure switch can be used to ground the ignition module to stop the engine. On vehicular applications (lawn tractors, mowers, etc.) the pressure switch can only be used to activate a **low oil** warning light or signal.

NOTE: Make sure the oil level is checked BEFORE EACH USE and is maintained up to the **F** mark on the dipstick. This includes engines equipped with Oil Sentry™.

Installation

The Oil Sentry™ pressure switch is installed into the breather cover. See Figure 6-8.

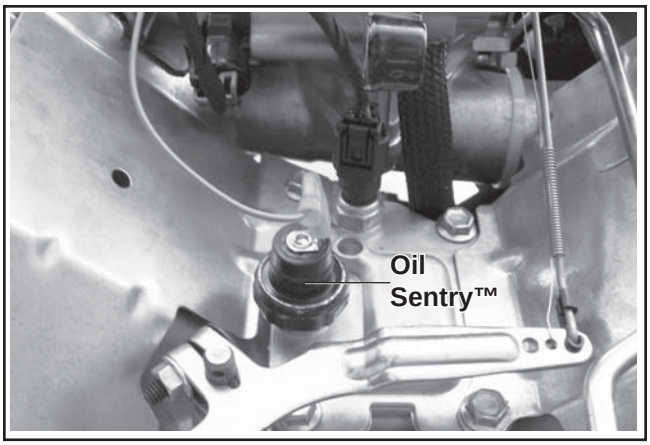


Figure 6-8. Location of Oil Sentry™ Switch.

On engines not equipped with Oil Sentry™ the installation hole is sealed with a 1/8-27 N.P.T.F. pipe plug.

To install the switch, follow these steps:

1. If no sealant is preapplied, apply **pipe sealant with Teflon®** (Loctite® 592™ PST® Thread Sealant or equivalent) to the threads of the switch.

2. Install the switch into the tapped hole in the breather cover. See Figure 6-8.

3. Torque the switch to **4.5 N·m (40 in. lb.)**.

4. Attach lead to switch terminal.

Testing the Switch

Compressed air, a pressure regulator, pressure gauge and a continuity tester are required to test the switch.

Normally Closed Switch

1. Connect the continuity tester across the blade terminal and the metal case of the switch. With **0 psi** pressure applied to the switch, the tester should indicate **continuity (switch closed)**.

2. Gradually increase the pressure to the switch. As pressure increases through the range of **2.0/5.0 psi,** the tester should indicate a change to **no continuity (switch open)**. The switch should remain open as the pressure is increased to **90 psi maximum**.

3. Gradually decrease the pressure through the range of **2.0/5.0 psi**. The tester should indicate a change to **continuity (switch closed) down to 0 psi**.

4. Replace the switch if it does not operate as specified.

Normally Open Switch

1. Connect the continuity tester across the blade terminal and the metal case of the switch. With **0 psi** pressure applied to the switch, the tester should indicate **no continuity (switch open)**.

2. Gradually increase the pressure to the switch. As pressure increases through the range of **2.0/5.0 psi,** the tester should indicate a change to **continuity (switch closed)**. The switch should remain closed as the pressure is increased to **90 psi maximum**.

3. Gradually decrease the pressure through the range of **2.0/5.0 psi**. The tester should indicate a change to **no continuity (switch open) down to 0 psi**.

Section 7
Electrical System and Components

This section covers the operation, service, and repair of the electrical system components. Systems and components covered in this section are:

- Spark Plugs
- Battery and Charging System
- Electric Starter

Spark Plugs

Engine misfire or starting problems are often caused by a spark plug that has improper gap or is in poor condition.

The engine is equipped with the following spark plugs:

Type: The standard spark plug is a Champion® RC12YC (Kohler Part No. 12 132 02-S). RFI compliant engines use a Champion® XC12YC (Kohler 25 132 14-S) spark plug. A high-performance spark plug, Champion® Platinum 3071 is also available. Equivalent alternate brand plugs can also be used.
Gap: 0.76 mm (0.030 in.)
Thread Size: 14 mm
Reach: 19.1 mm (3/4 in.)
Hex Size: 15.9 mm (5/8 in.)

Spark Plug Service

Remove the spark plugs after every **200 hours** of operation. Check their condition and either reset the gap or replace with new plugs as necessary. To service the plugs, perform the following steps:

1. Before removing a spark plug, clean the area around the base of the plug to keep dirt and debris out of the engine.

2. Remove the plug and check its condition. See **Inspection** following this procedure. Replace the plug if necessary.

   NOTE: Do not clean spark plugs in a machine using abrasive grit. Some grit could remain in the spark plug and enter the engine, causing extensive wear and damage.

3. Check the gap using a wire feeler gauge. Adjust the gap to **0.76 mm (0.030 in.)** by carefully bending the ground electrode. See Figure 7-1.

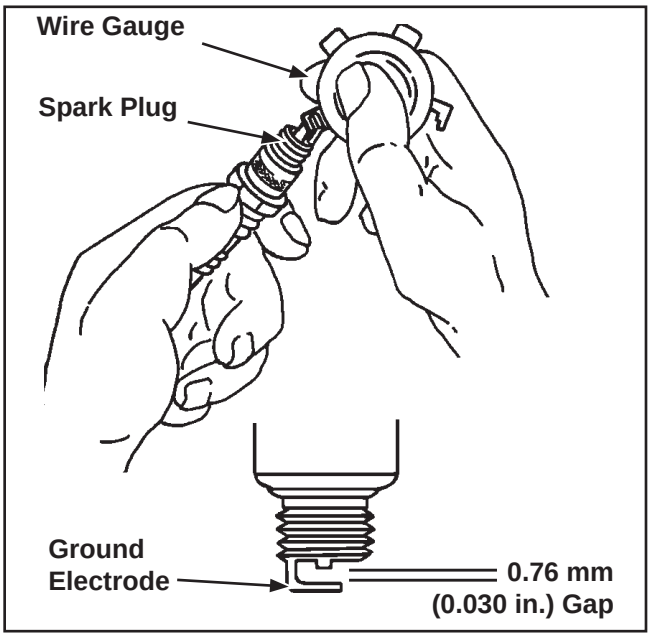


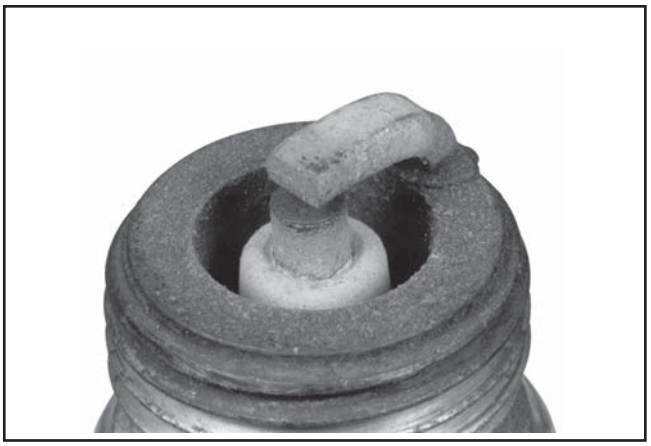
Figure 7-1. Servicing Spark Plug.

4. Reinstall the spark plug into the cylinder head and torque to **24.4-29.8 N·m (18-22 ft. lb.)**.

Inspection

Inspect each spark plug as it is removed from the cylinder head. The deposits on the tip are an indication of the general condition of the piston rings, valves, and fuel injection system.

Normal and fouled plugs are shown in the following photos:

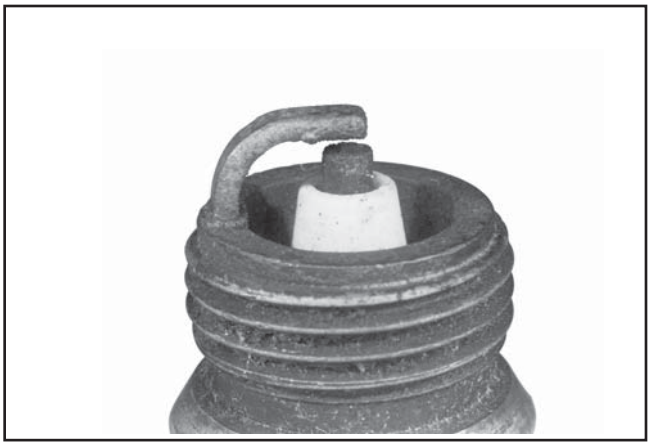


Normal: A plug taken from an engine operating under normal conditions will have light tan or grey colored deposits. If the center electrode is not worn, a plug in this condition could be set to the proper gap and reused.

Carbon Fouled: Soft, sooty, black deposits indicate incomplete combustion caused by a restricted air cleaner, over-rich fuel mixture, weak ignition, or poor compression.

Worn: On a worn plug, the center electrode will be rounded and the gap will be greater than the specified gap. Replace a worn spark plug immediately.

Wet Fouled: A wet plug is caused by excess fuel or oil in the combustion chamber. Excess fuel could be caused by a restricted air cleaner or rich air/fuel ratio. Oil in the combustion chamber is usually caused by a restricted air cleaner, a breather problem, or worn piston rings, cylinder walls or valve guides.



Overheated: Chalky, white deposits indicate very high combustion temperatures. This condition is usually accompanied by excessive gap erosion. Lean air/fuel ration, an intake air leak, or incorrect spark timing are normal causes for high combustion temperatures.

Battery

General

A 12-volt battery with 400 cold cranking amps is generally recommended for starting in all conditions. A smaller capacity battery is often sufficient if an application is started only in warmer temperatures. Refer to the following table for minimum cold cranking amp (cca) capacities, based on anticipated ambient temperatures. The actual cold cranking requirement depends on engine size, application, and starting temperatures. The cranking requirements increase as temperatures decrease and battery capacity shrinks. Refer also to the operating instructions for the piece of equipment for specific battery requirements.

Battery Size Recommendations

Temperature	Battery Required
Above 32°F (0°C)	200 cca minimum
0°F to 32°F (-18°C to 0°C)	250 cca minimum
-5°F to 0°F (-21°C to -18°C)	300 cca minimum
-10°F (-23°C) or below	400 cca minimum

If the battery charge is not sufficient to turn over the engine, recharge the battery.

Battery Maintenance

Regular maintenance is necessary to prolong battery life.

WARNING: Explosive Gas!

Batteries produce explosive hydrogen gas while being charged. To prevent a fire or explosion, charge batteries only in well ventilated areas. Keep sources of ignition away from the battery at all times. Keep batteries out of the reach of children. Remove all jewelry when servicing batteries.

Before disconnecting the negative (-) ground cable, make sure all switches are OFF. If ON, a spark will occur at the ground cable terminal, which could cause an explosion if hydrogen gas or gasoline vapors are present.

1. Regularly check the level of electrolyte. Add distilled water as necessary to maintain the recommended level.

   NOTE: Do not overfill the battery. Poor performance or early failure due to loss of electrolyte will result.

2. Keep the cables, terminals, and external surfaces of the battery clean. A build-up of corrosive acid or grime on the external surfaces can cause the battery to self-discharge. Self-discharge occurs rapidly when moisture is present.

3. Wash the cables, terminals, and external surfaces with a mild baking soda and water solution. Rinse thoroughly with clear water.

   NOTE: Do not allow the baking soda solution to enter the cells, as this will destroy the electrolyte.

Battery Test

To test the battery, you will need a DC voltmeter. Perform the following steps (see Figure 7-2):

1. Connect the voltmeter across the battery terminals.

2. Crank the engine. If the battery drops below 9 volts while cranking, the battery is too small, discharged, or faulty.

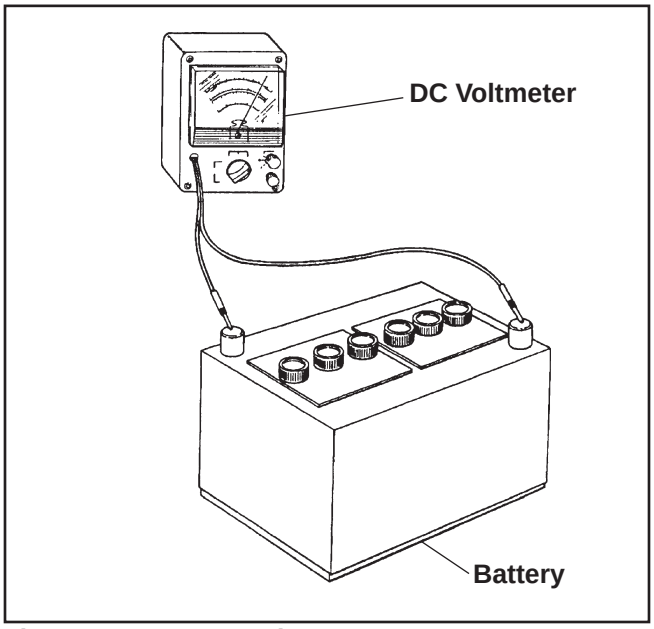


Figure 7-2. Battery Voltage Test.

Battery Charging System

General

These engines are equipped with a 20 or 25 amp regulated charging system. See Figure 7-3 for the 20/25 amp charging system diagram.

NOTE: Observe the following guidelines to avoid damage to the electrical system and components:

- Make sure the battery polarity is correct. A negative (-) ground system is used.
- Disconnect the rectifier-regulator plug and/or the wiring harness plug before doing any electric welding on the equipment powered by the engine. Also, disconnect all other electrical accessories in common ground with the engine.
- Prevent the stator (AC) leads from touching or shorting while the engine is running. This could damage the stator.

Stator

The stator is mounted on the crankcase behind the flywheel. Follow the procedures in **Section 8 - Disassembly** and **Section 10 - Reassembly** if stator replacement is necessary.

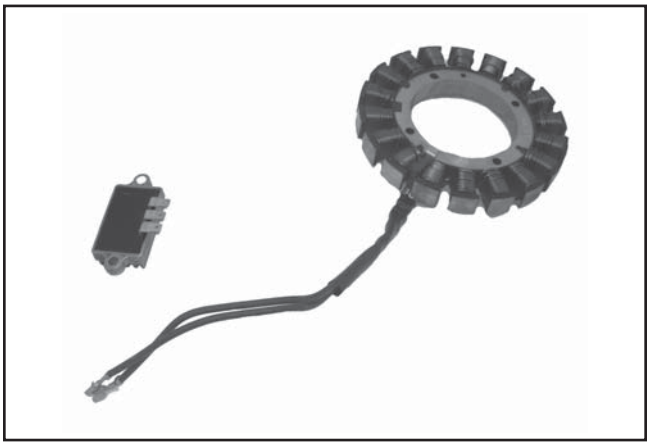


Figure 7-4. 20 Amp Stator and Rectifier-Regulator.

20/25 Amp Regulated Charging System

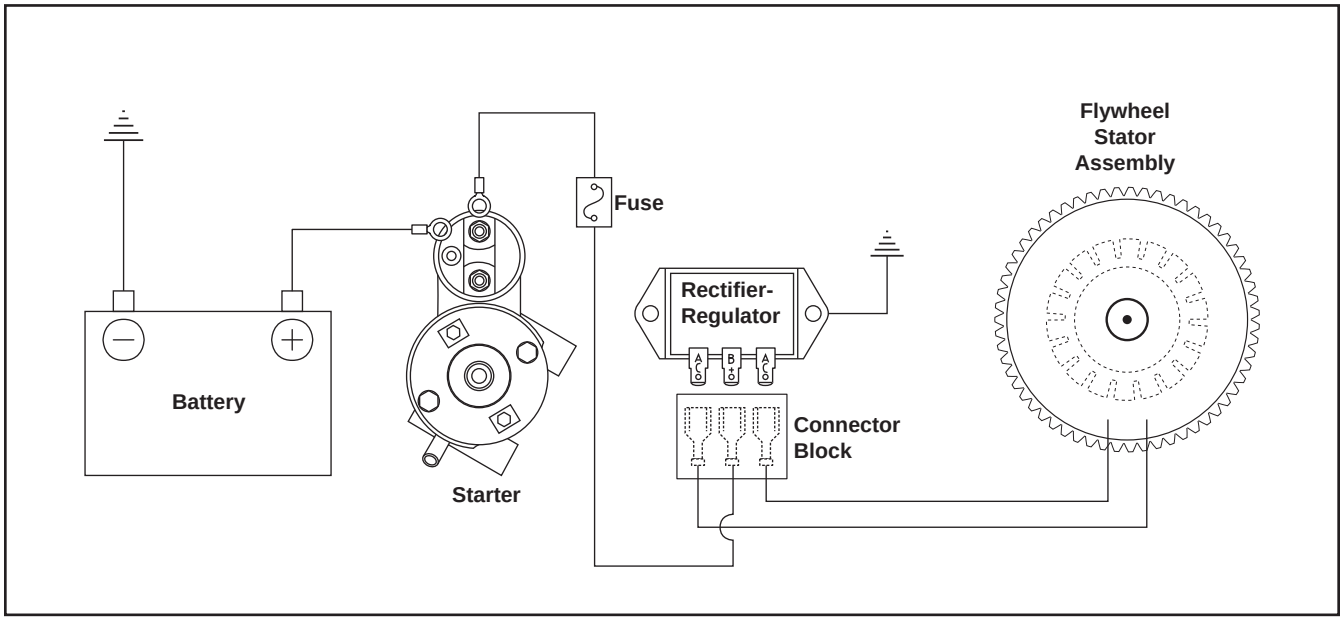


Figure 7-3. Wiring Diagram - 20/25 Amp Regulated Battery Charging System.

Rectifier-Regulator

The rectifier-regulator is mounted on the blower housing. See Figure 7-5. To replace it, disconnect the connector, remove the two mounting screws, and metal grounding strap.

NOTE: When installing the rectifier-regulator, take note of the terminal markings and install the connector accordingly.

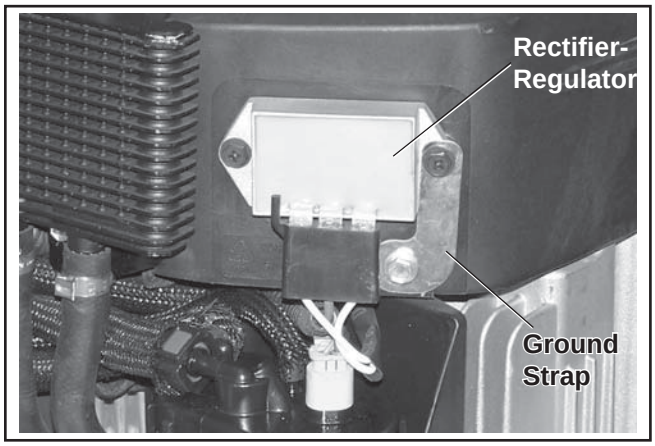


Figure 7-5. Rectifier-Regulator.

Testing of the rectifier-regulator may be performed as follows, using the Rectifier-Regulator Tester, (see Section 2).

NOTE: Disconnect all electrical connections attached to the rectifier-regulator. Testing may be performed with the rectifier-regulator mounted or loose. The figures show the part removed from the engine for clarity. Repeat the applicable test procedure **two or three times** to determine the condition of the part.

1. Connect the tester ground lead (with spring clamp) to the body of the rectifier-regulator.

2. Connect the red lead from the tester to the middle terminal labeled B+.

3. Connect the two black leads from the tester to both of the outer AC terminals on the rectifier-regulator. See Figure 7-6.

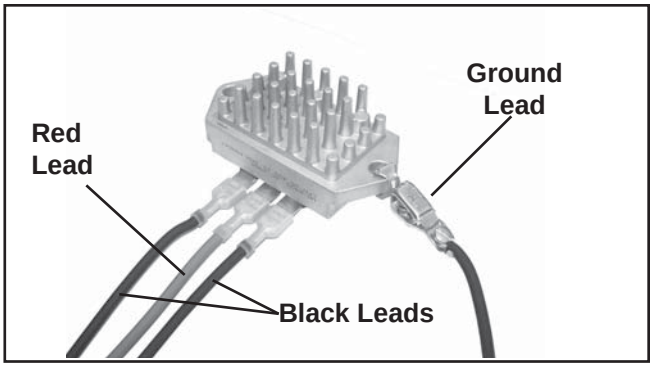


Figure 7-6. Connecting Leads to Rectifier-Regulator.

4. Plug the tester into the proper AC outlet/power supply for tester being used. Turn on the power switch. The **POWER** light should be lit and one of the four status lights may be lit as well. See Figure 7-7. This **does not** represent the condition of the part.

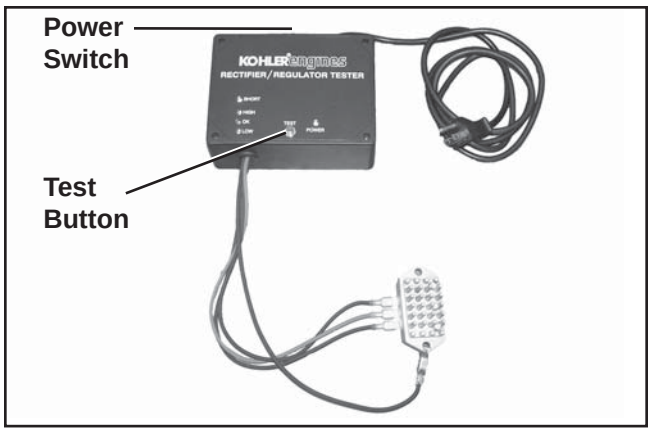


Figure 7-7. Testing the Rectifier-Regulator with a Tester.

5. Press the **TEST** button until a **click** is heard and then release. See Figure 7-7. Momentarily one of the four status lights will illuminate indicating the **partial condition** of the part.

   a. If the **OK** (green) light comes on the part is good and may be used.

   b. If any other light is displayed* the rectifier-regulator is faulty and should not be used.

*NOTE: A flashing **LOW** light can also occur as a result of an inadequate ground lead connection. Make certain the connection location is clean and the clamp is secure.

Troubleshooting Guide

20/25 Amp Battery Charging Systems

When problems occur in keeping the battery charged or the battery charges at too high a rate, the problem can usually be found somewhere in the charging system or with the battery.

NOTE: **Always zero ohmmeter on each scale before testing** to ensure accurate readings. Voltage tests should be made with the engine running at 3600 RPM - no load. **The battery must be good and fully charged.**

Problem	Test	Conclusion
No Charge to Battery	1. Trace B+ lead from rectifier-regulator to key switch, or other accessible connection. Disconnect it from switch or connection. Connect an ammeter from loose end of B+ lead to positive terminal of battery. Connect DC voltmeter from loose end of B+ lead to negative terminal of battery. With engine running at 3600 RPM, read voltage on voltmeter. If voltage is 13.8 volts or more, place a minimum load of 5 amps* on battery to reduce voltage. Observe ammeter. *NOTE: Turn on lights, if 60 watts or more. Or place a 2.5 ohm, 100 watt resistor across battery terminals.	1. If voltage is 13.7-14.7 and charge rate increases when load is applied, the charging system is OK and battery was fully charged. If voltage is less than 13.8 or charge rate does not increase when load is applied, test rectifier-regulator for proper ground. Using an ohmmeter set to the Rx1 scale, check the resistance from the rectifier-regulator housing to the battery ground. Resistance should be less than 1 ohm. As an alternative, connect a jumper lead from rectifier-regulator housing to the battery ground and retest charging voltage. If charge voltage measures 13.7-14.7 volts, the charging system is functioning. If resistance is greater than 1 ohm or charge voltage is less than 13.7, then re-establish ground between the ground strap and mounting screw. If voltage is less than 13.8 or charge rate does not increase when load is applied, test stator (Tests 2 and 3). If the voltage is low and does not increase, and there is no charging/amperage output, disconnect and reconnect the rectifier-regulator plug and retest. a. If the ammeter shows charge for a short time but then drops back to zero, the rectifier-regulator is functioning correctly but the battery is faulty. Replace the battery. b. If no amperage/charge rate appears during the retest, go to step 2.
	2. Remove connector from rectifier-regulator. With engine running at 3600 RPM, measure AC voltage across stator leads using an AC voltmeter.	2. If voltage is 28 volts or more, stator is OK. Rectifier-regulator is faulty. Replace the rectifier-regulator. If voltage is less than 28 volts, stator is probably faulty and should be replaced. Test stator further using an ohmmeter (Test 3).
	3a. With engine stopped, measure the resistance across stator leads using an ohmmeter.	3a. If resistance is 0.064/0.2 ohms, the stator is OK. If the resistance is infinity ohms, stator is open. Replace stator.
	3b. With the engine stopped, measure the resistance from each stator lead to ground using an ohmmeter.	3b. If the resistance is infinity ohms (no continuity), the stator is OK (not shorted to ground). If resistance (or continuity) is measured, the stator leads are shorted to ground. Replace stator.

Battery Continuously Charges at High Rate	1. Perform same test as step 1 above.	1. If the voltage is 14.7 volts or less the charging system is **OK**. The battery is unable to hold a charge. Service battery or replace as necessary. If voltage is more than 14.7 volts, the rectifier-regulator is faulty. Replace rectifier-regulator.

Fuses

This engine has three (3) **blade type** automotive fuses. Replacement fuses must have the same rating as the blown fuse. Use the fuse chart below to determine the correct fuse.

Wire Color	Fuse Rating
2 Purple Wires	30-amp Fuse
1 Red Wire with Black Stripe 1 Red Wire with White Stripe	10-amp Fuse
2 Red Wires	10-amp Fuse

To Replace a Fuse:

1. Shut engine off and remove key.
2. Locate the fuse holders.
3. Remove the fuse cover and pull out fuse.
4. Inspect the fuse for a solid fusible link or a broken fusible link. Replace the fuse if the fusible link is broken. If you are not sure if the fusible link is broken, replace the fuse.
5. Insert the fuse into the fuse holder until it is seated properly. Install the fuse cover.

Electric Starting Motors

These engines use solenoid shift starters.

Starting Motor Precautions

NOTE: Do not crank the engine continuously for more than 10 seconds at a time. If the engine does not start, allow a 60-second cool-down period between starting attempts. Failure to follow these guidelines can burn out the starter motor.

NOTE: If the starter cranks the engine but does not start the engine, the engine rotation must be allowed to come to a complete stop before attempting to restart the engine again. If the starter is engaged while the flywheel is rotating, the starter pinion and flywheel ring gear may clash, resulting in damage to the starter.

NOTE: If the starter does not crank the engine, shut off the starter immediately. Do not make further attempts to start the engine until the condition is corrected.

NOTE: Do not drop the starter or strike the starter frame. Doing so can damage the starter.

Starter Removal and Installation

Refer to the **Disassembly** and **Reassembly** Sections for starter removal and installation procedures.

Troubleshooting Guide - Starting Difficulties

Problem	Possible Fault	Correction
Starter Does Not Energize	Battery	1. Check the specific gravity of battery. If low, recharge or replace battery as necessary.
	Wiring	1. Clean corroded connections and tighten loose connections. 2. Replace wires in poor condition and with frayed or broken insulation.
	Starter Switch or Solenoid	1. By-pass the switch or solenoid with a jumper wire. If starter cranks normally, replace the faulty components. **Solenoid Shift Starters:** Perform individual solenoid test procedure. See pages 7.16 and 7.17.
Starter Energizes But Turns Slowly	Battery	1. Check the specific gravity of battery. If low, recharge or replace battery as necessary.
	Brushes	1. Check for excessively dirty or worn brushes and commutator. Clean using a coarse cloth (not emery cloth). 2. Replace brushes if excessively or unevenly worn.
	Transmission or Engine	1. Make sure the clutch or transmission is disengaged or placed in neutral. This is especially important on equipment with hydrostatic drive. The transmission must be exactly in neutral to prevent resistance which could keep the engine from starting. 2. Check for seized engine components such as the bearings, connecting rod, and piston.

Solenoid Shift Electric Starters

Operation – Solenoid Shift Starter

When power is applied to the starter the electric solenoid moves the drive pinion out onto the drive shaft and into mesh with the flywheel ring gear. When the pinion reaches the end of the drive shaft it rotates the flywheel and cranks the engine.

When the engine starts and the start switch is released the starter solenoid is deactivated, the drive lever moves back, and the drive pinion moves out of mesh with the ring gear into the retracted position.

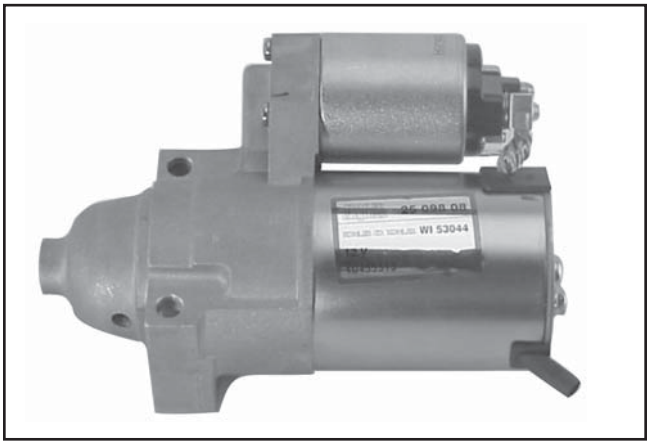


Figure 7-8. Completed Delco-Remy Starter.

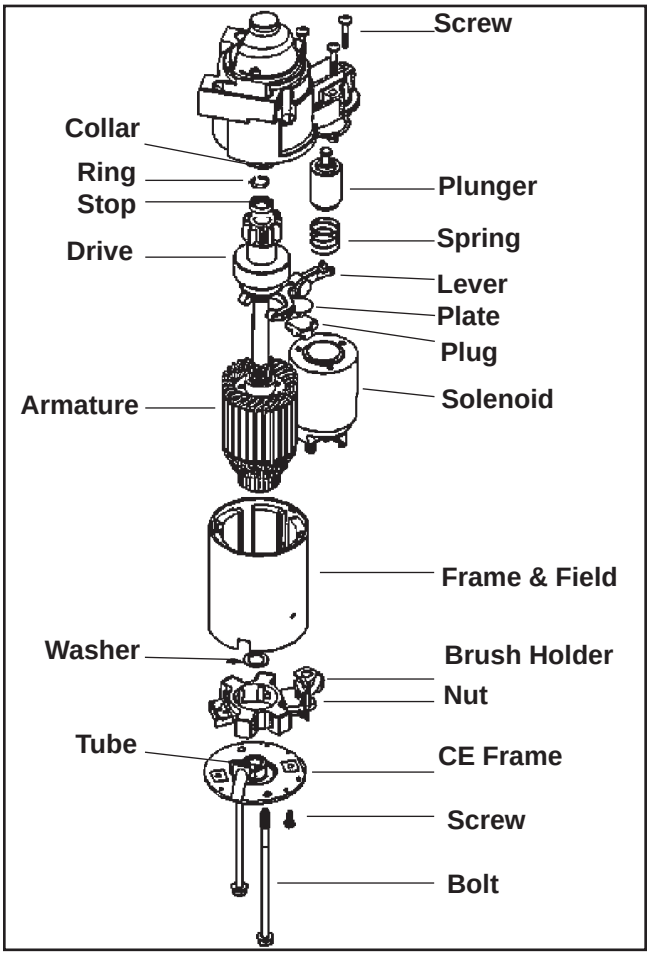


Figure 7-9. Delco-Remy Starter.

Starter Disassembly

1. Remove the hex nut and disconnect the positive (+) brush lead/bracket from the solenoid terminal.

2. Remove the three screws securing the solenoid to the starter. See Figure 7-10.

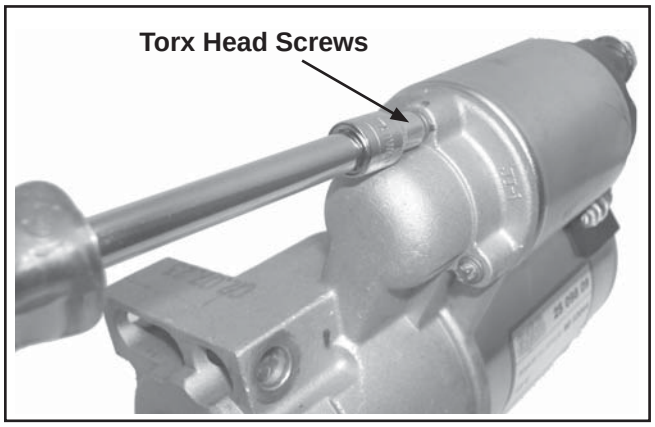


Figure 7-10. Removing Solenoid Screws.

NOTE: Test procedure for checking starter solenoid on pages 7.16 and 7.17.

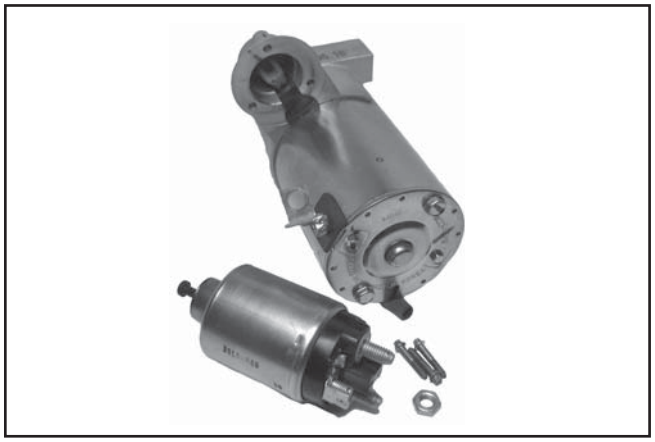


Figure 7-11. Solenoid Removed from Starter.

3. Remove the two thru (larger) bolts. See Figure 7-12.

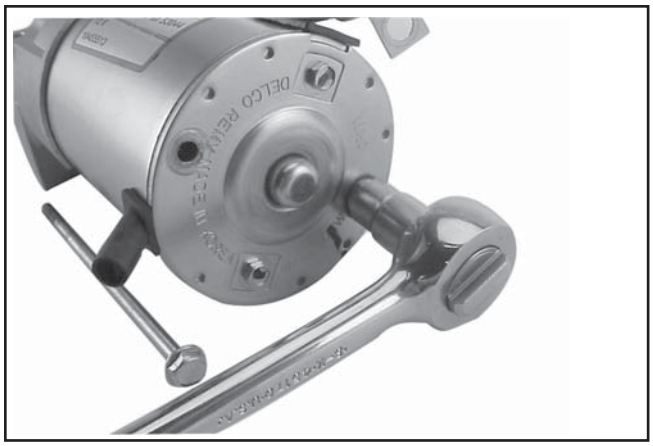


Figure 7-12. Removing Thru Bolts.

4. Remove the commutator end plate assembly, containing the brush holder, brushes, springs, and locking caps. Remove the thrust washer from inside the commutator end. See Figure 7-13.

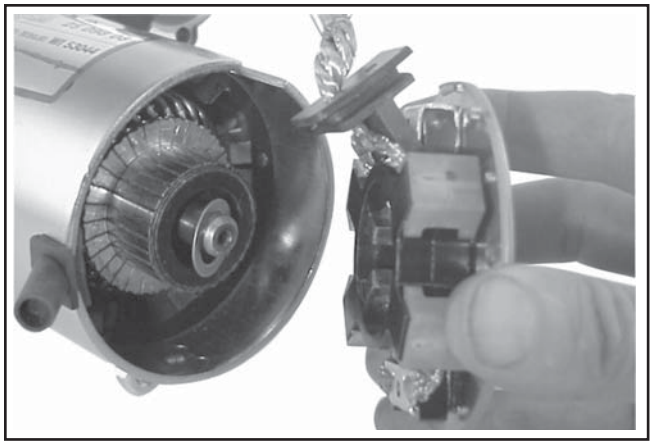


Figure 7-13. Removing Commutator End Plate Assembly.

5. Remove the frame from the armature and drive end cap. See Figure 7-14.

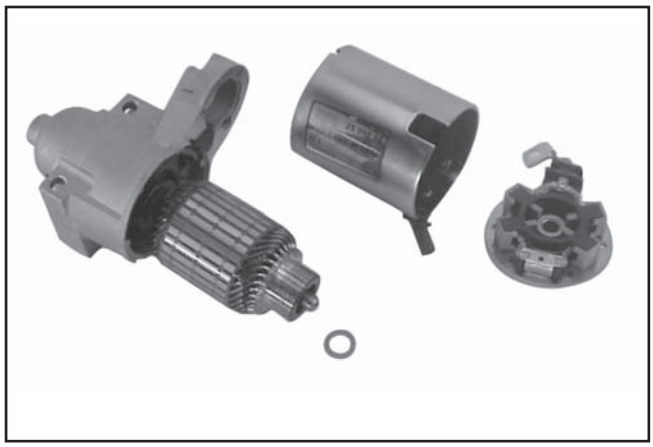


Figure 7-14. Starter Frame Removed.

6. Remove the rubber grommet and backing plate from the end cap. See Figure 7-15.

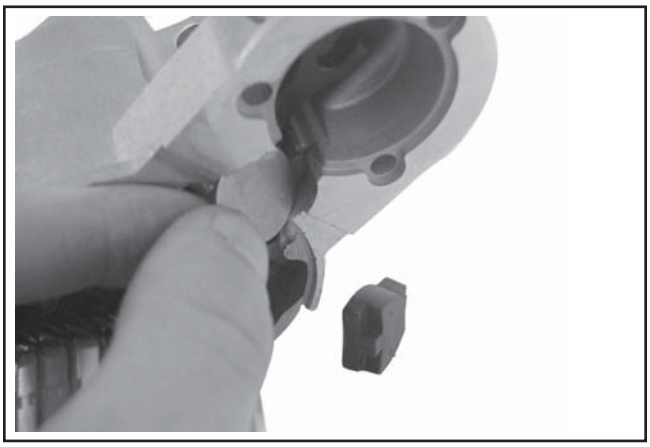


Figure 7-15. Rubber Grommet and Bushing Plate.

7. Take out the drive lever and pull the armature out of the drive end cap. See Figure 7-16.

8. Remove the thrust washer from the armature shaft. See Figure 7-16.

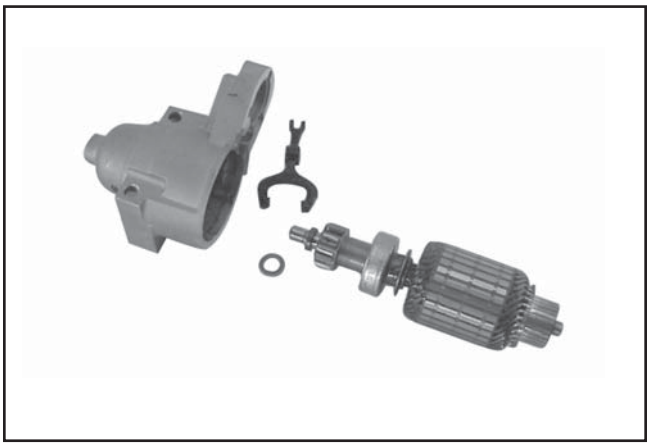


Figure 7-16. Armature and Lever Removed.

9. Push the stop collar down to expose the retaining ring. See Figure 7-17.

Figure 7-17. Retaining Ring Detail.

10. Remove the retainer from the armature shaft. Save the stop collar.

NOTE: Do not reuse the old retainer.

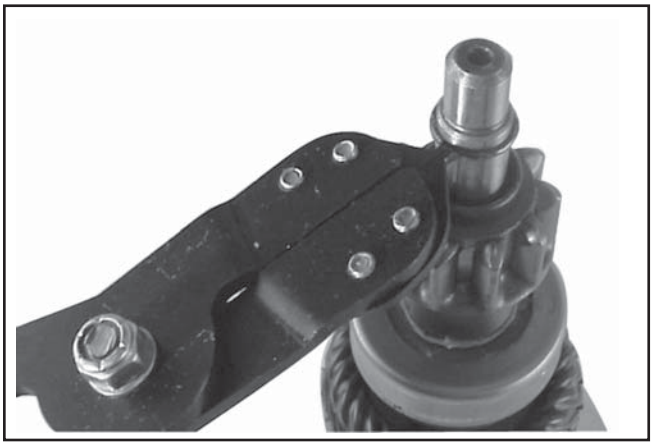


Figure 7-18. Removing Retaining Ring.

11. Remove the drive pinion assembly from the armature.

12. Clean the parts as required.

NOTE: **Do not** soak the armature or use solvent when cleaning. Wipe clean using a soft cloth, or use compressed air.

Inspection

Drive Pinion

Check and inspect the following areas:

a. The pinion teeth for abnormal wear or damage.

b. The surface between the pinion and the clutch mechanism for nicks, or irregularities which could cause seal damage.

c. Check the drive clutch by holding the clutch housing and rotating the pinion. The pinion should rotate in one direction only.

Brushes and Springs

Inspect both the springs and brushes for wear, fatigue, or damage. Measure the length of each brush. The minimum length for each brush is **7.6 mm (0.300 in.)**. See Figure 7-19. Replace the brushes if they are worn undersize, or their condition is questionable.

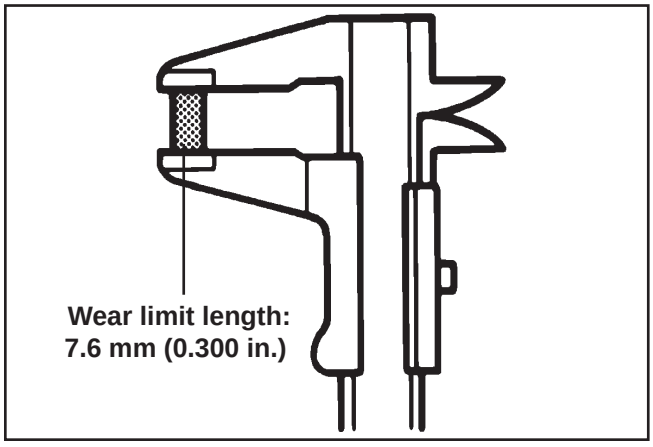


Figure 7-19. Checking Brushes.

Armature

1. Clean and inspect the commutator (outer surface). The mica insulation must be lower than the commutator bars (undercut) to ensure proper operation of the commutator. See Figure 7-20.

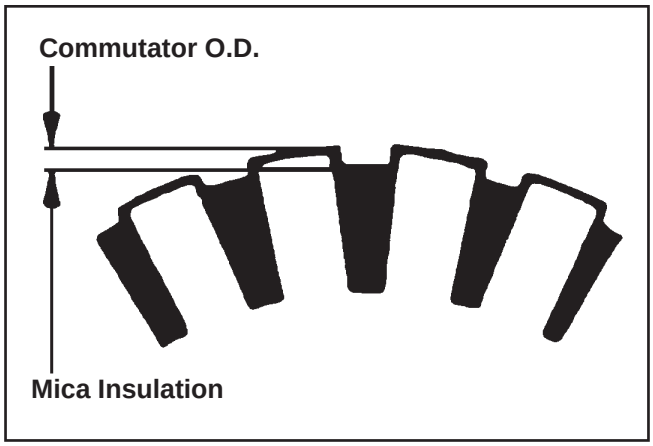


Figure 7-20. Commutator Mica Inspection.

2. Use an ohmmeter set to the Rx1 scale. Touch the probes between two different segments of the commutator, and check for continuity. See Figure 7-21. Test all the segments. Continuity must exist between all or the armature is bad.

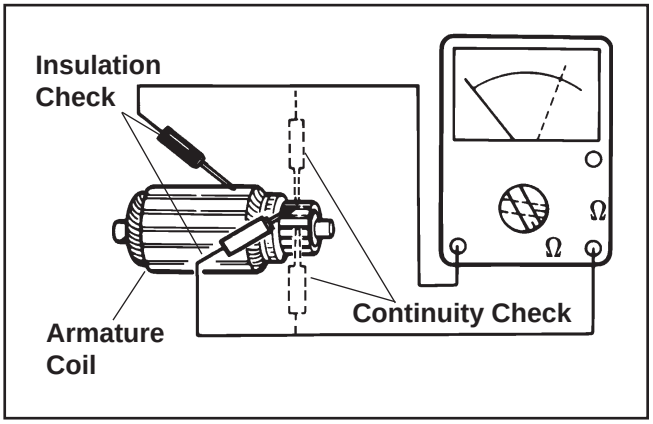


Figure 7-21. Checking Armature.

3. Check for continuity between the armature coil segments and the commutator segments. See Figure 7-21. There should be no continuity. If continuity exists between any two, the armature is bad.

4. Check the armature windings/insulation for shorting.

Shift Fork

Check that the shift fork is complete, and the pivot and contact areas are not excessively worn, cracked or broken.

Brush Replacement

The brushes and springs are serviced as a set (4). Use Kohler Brush and Spring Kit, if replacement is necessary.

1. Perform steps 1-5 in **Starter Disassembly**.

2. Remove the two screws securing the brush holder assembly to the end cap (plate). Note the orientation for reassembly later. See Figure 7-22. Discard the old brush holder assembly.

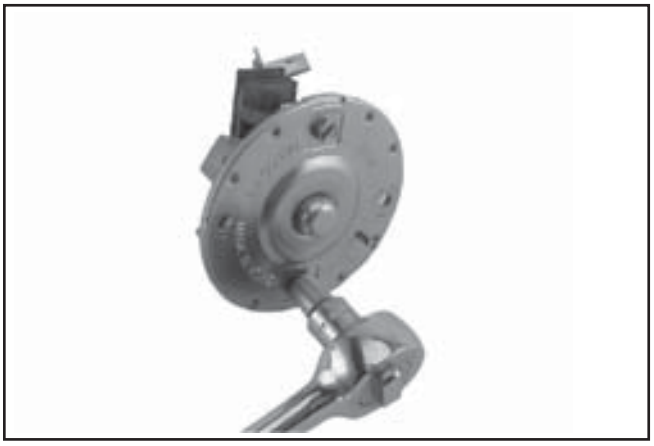


Figure 7-22. Removing Brush Holder.

3. Clean the component parts as required.

4. The new brushes and springs come preassembled in a brush holder with a protective sleeve that will also serve as an installation tool. See Figure 7-23.

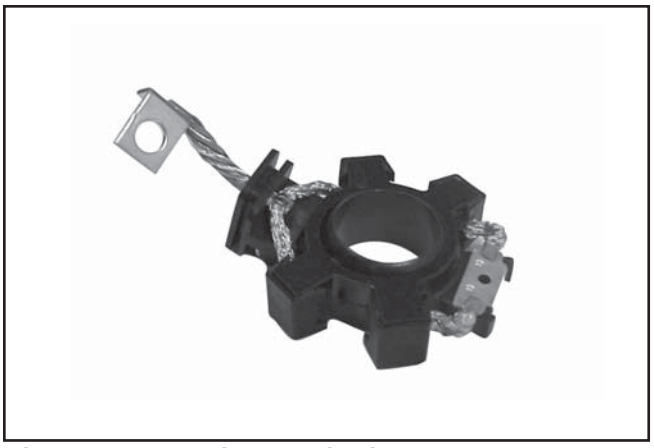


Figure 7-23. Service Brush Kit.

5. Perform Steps 10-13 in the **Starter Reassembly** sequence. Installation must be done after the armature, drive lever, and frame are installed, if the starter has been disassembled.

Starter Service

Clean the drive lever and armature shaft. Apply Kohler electric starter drive lubricant (see Section 2) (Versilube G322L or Mobil Temp SHC 32) to the lever and shaft. Clean and check the other starter parts for wear or damage as required.

Starter Reassembly

1. Apply drive lubricant (see Section 2) to the armature shaft splines. Install the drive pinion onto the armature shaft.

2. Install and assemble the stop collar/retainer assembly. See Figure 7-24.

   a. Install the stop collar down onto the armature shaft with the counter bore (recess) up.

   b. Install a new retainer in the larger (rear) groove of the armature shaft. Squeeze with a pliers to compress it in the groove.

   c. Slide the stop collar up and lock it into place, so the recess surrounds the retainer in the groove. If necessary, rotate the pinion outward on the armature splines against the retainer to help seat the collar around the retainer.

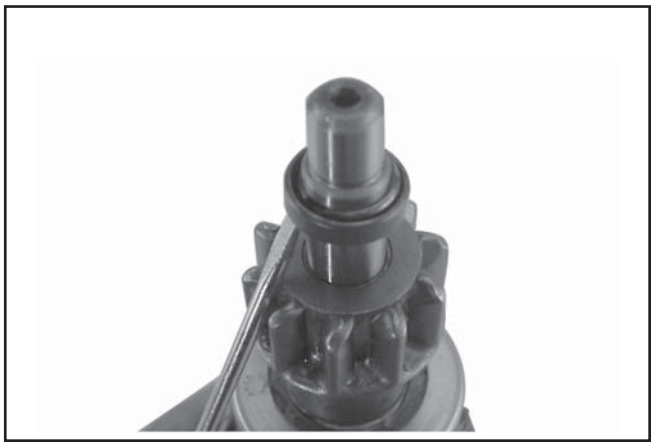


Figure 7-24. Installing Stop Collar and Retainer.

NOTE: Always use a new retainer. Do not reuse old retainers, which have been removed.

3. Install the offset thrust (stop) washer so the smaller **offset** of the washer faces the retainer/collar. See Figure 7-25.

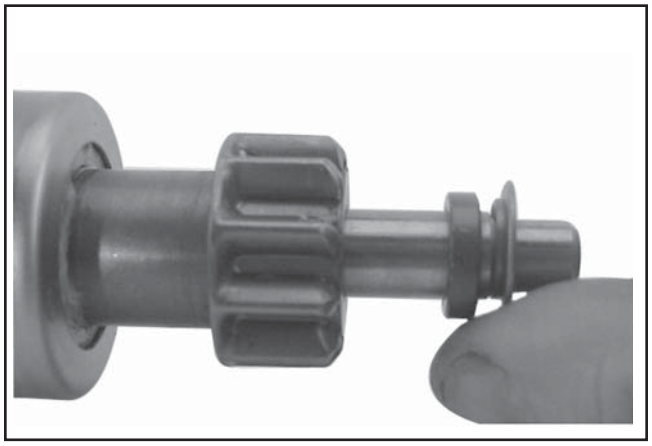


Figure 7-25. Installing Thrust Washer.

4. Apply a small amount of oil to the bearing in the drive end cap, and install the armature with the drive pinion.

5. Lubricate the fork end and center pivot of the drive lever with drive lubricant (see Section 2). Position the fork end into the space between the captured washer and the rear of the pinion.

6. Slide the armature into the drive end cap, and at the same time seat the drive lever into the housing.

NOTE: Correctly installed, the center pivot section of the drive lever will be flush or below the machined surface of the housing which receives the backup washer. See Figure 7-26.

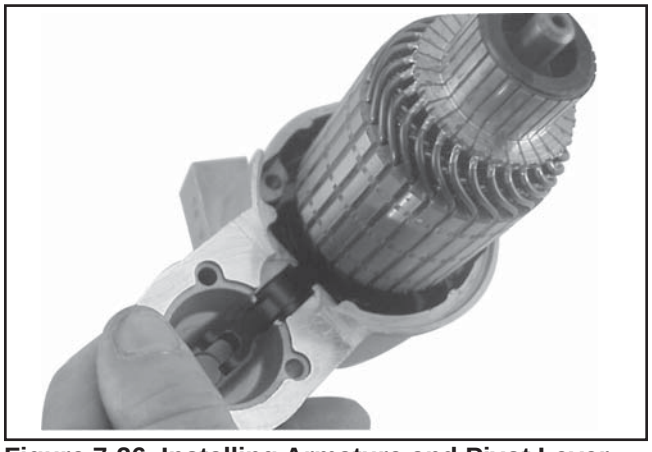


Figure 7-26. Installing Armature and Pivot Lever.

7. Install the backing plate, followed by the rubber grommet, into the matching recess of the drive end cap. The molded recesses in the grommet should be **out**, matching and aligned with those in the end cap. See Figure 7-27.

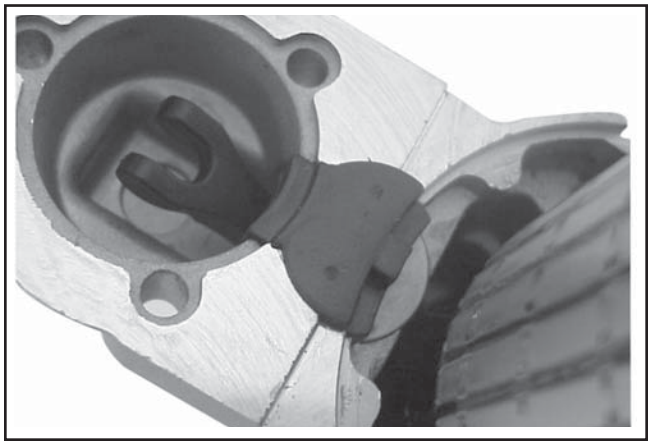


Figure 7-27. Installing Backing Plate and Grommet.

8. Install the frame, with the small notch forward, onto the armature and drive end cap. Align the notch with the corresponding section in the rubber grommet. Install the drain tube in the rear cutout, if it was removed previously. See Figure 7-28.

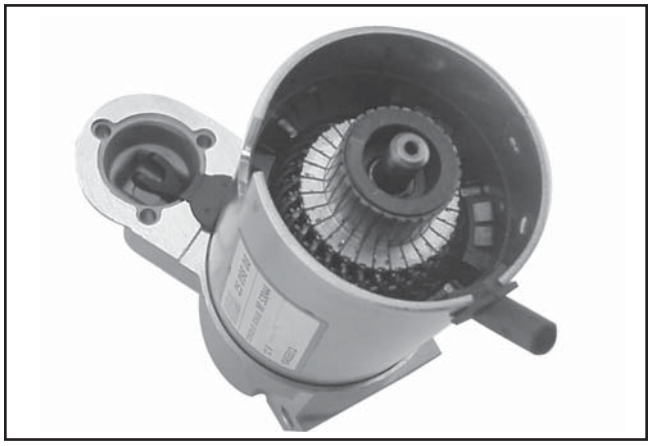


Figure 7-28. Installing Frame and Drain Tube.

9. Install the flat thrust washer onto the commutator end of the armature shaft. See Figure 7-29.

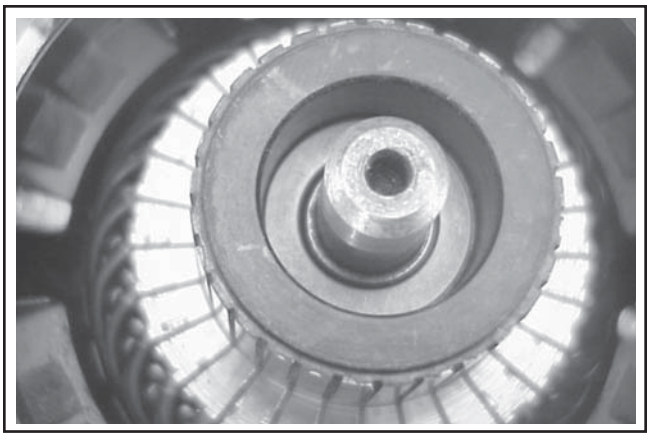


Figure 7-29. Installing Thrust Washer.

10. Starter reassembly when **replacing** the Brushes/ Brush Holder Assembly:

    a. Hold the starter assembly vertically on the end housing, and carefully position the assembled brush holder assembly, with the supplied protective tube, against the end of the commutator/armature. The mounting screw holes in the metal clips must be **up/out.** Slide the brush holder assembly down into place around the commutator, and install the positive (+) brush lead grommet in the cutout of the frame. See Figure 7-30. The protective tube may be saved and used for future servicing.

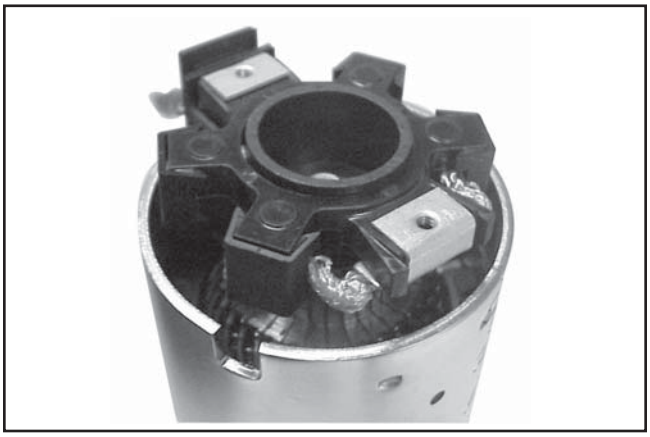


Figure 7-30. Installing Brush Holder Assembly with Supplied Tube.

Starter reassembly when **not replacing** the Brushes/ Brush Holder Assembly:

a. Carefully unhook the retaining caps from over each of the brush assemblies. Do not lose the springs. See Figure 7-31.

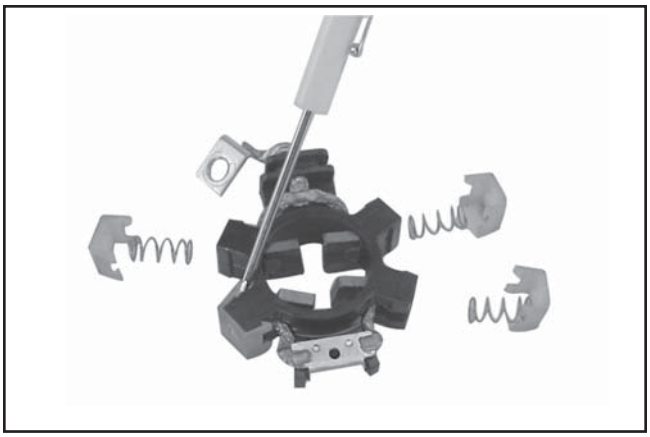


Figure 7-31. Removing Retaining Clips.

b. Position each of the brushes back in their slots so they are flush with the I.D. of the brush holder assembly. Insert the Brush Installation Tool with extension, or use the tube described above from a prior brush installation, through the brush holder assembly, so the holes in the metal mounting clips are **up/out**.

c. Install the brush springs and snap on the four retainer caps. See Figure 7-32.

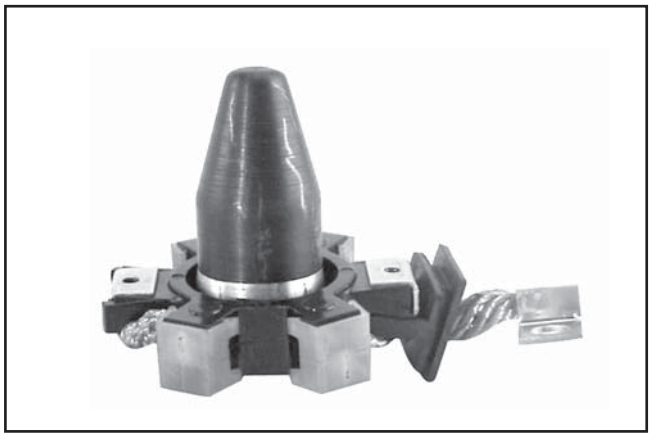


Figure 7-32. Brush Installation Tool with Extension.

d. Hold the starter assembly vertically on the end housing, and carefully place the tool (with extension) and assembled original brush holder assembly onto the end of the armature shaft. Slide the brush holder assembly down into place around the commutator, install the positive (+) brush lead grommet in the cutout of the frame. See Figure 7-33.

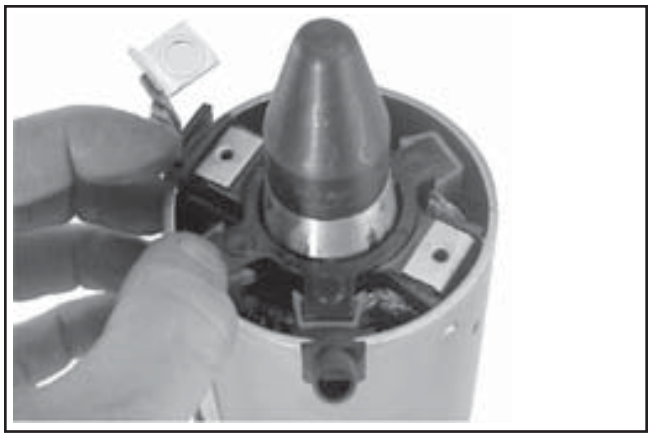


Figure 7-33. Installing Brush Holder Assembly using Tool with Extension.

11. Install the end cap onto the armature and frame, aligning the thin raised rib in the end cap with the corresponding slot in the grommet of the positive (+) brush lead.

12. Install the two thru bolts, and the two brush holder mounting screws. Torque the thru bolts to **5.6-9.0 N·m (49-79 in. lb.)**. Torque the brush holder mounting screws to **2.5-3.3 N·m (22-29 in. lb.)**. See Figures 7-34 and 7-35.

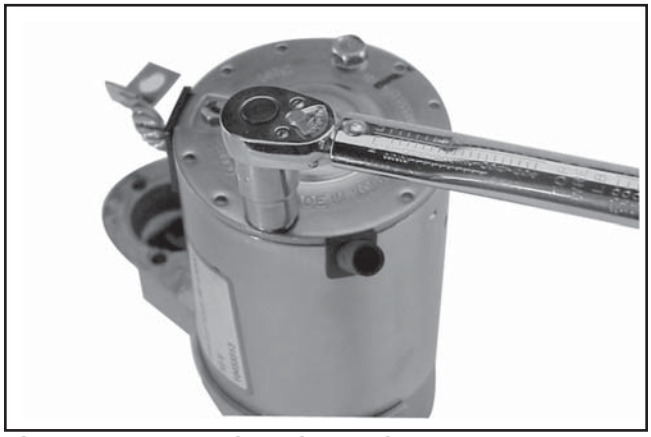


Figure 7-34. Torquing Thru Bolts.

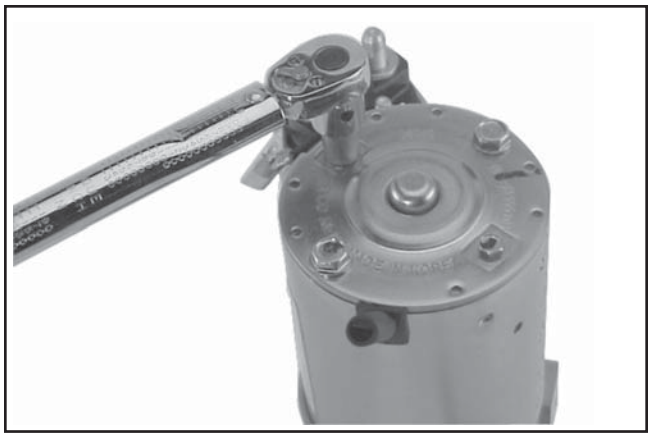


Figure 7-35. Torquing Brush Holder Screws.

13. Hook the plunger behind the upper end of the drive lever, and install the spring into the solenoid. Insert the three mounting screws through the holes in the drive end cap. Use these to hold the solenoid gasket in position, then mount the solenoid. Torque the screws to **4.0-6.0 N·m (35-53 in. lb.)**.

14. Connect the positive (+) brush lead/bracket to the solenoid and secure with the hex nut. Torque the nut to **8-11 N·m (71-97 in. lb.)**. Do not overtighten. See Figure 7-36.

Figure 7-36. Positive (+) Brush Lead Connection.

Solenoid Test Procedure

Solenoid Shift Style Starters
Disconnect all leads from the solenoid including the positive brush lead attached to the lower stud terminal. Remove the mounting hardware and separate the solenoid from the starter for testing.

Test 1. Solenoid Pull-In Coil/Plunger Actuation.
Use a 12 volt power supply and two test leads. Connect one lead to the flat spade **START** terminal on the solenoid. Momentarily* connect the other lead to the lower large post terminal. See Figure 7-37. When the connection is made the solenoid should energize (audible click), and the plunger retract. Repeat the test several times. If the solenoid fails to activate, it should be replaced.

*NOTE: DO NOT leave the 12 volt test leads connected to the solenoid for any time over what is necessary for performing each of the individual tests. Internal damage to the solenoid may otherwise occur.

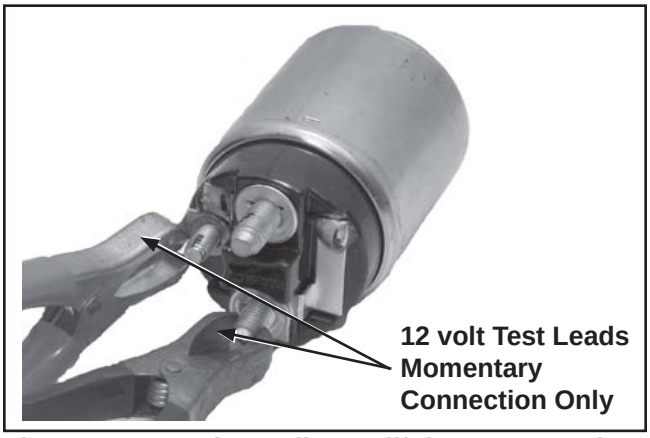


Figure 7-37. Testing Pull-In Coil/Plunger Actuation.

Test 2. Solenoid Pull-In Coil/Contact Continuity.
Use an ohmmeter set to the audible or Rx2K scale, and connect the two ohmmeter leads to the two large post terminals. Perform the preceding test (1) and check for continuity. See Figure 7-38. The ohmmeter should indicate continuity, if no continuity is indicated the solenoid should be replaced. Repeat test several times to confirm condition.

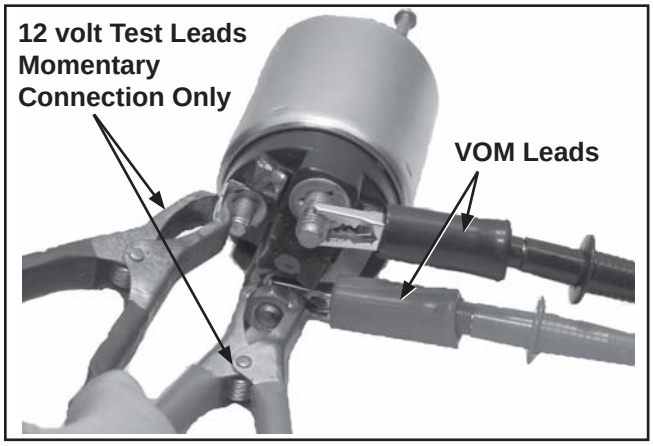


Figure 7-38. Testing Pull-In Coil/Solenoid Contact Continuity.

Test 3. Solenoid Hold-In Coil Function Test.
Connect one 12 volt test lead to the flat spade **START** terminal on the solenoid, and the other lead to the body or mounting surface of the solenoid. Then, manually push the plunger **in** and check if the **Hold-In** coil holds the plunger retracted. See Figure 7-39.

Do not allow the test leads to remain connected to the solenoid for a prolonged period of time. If the plunger fails to stay retracted, the solenoid should be replaced.

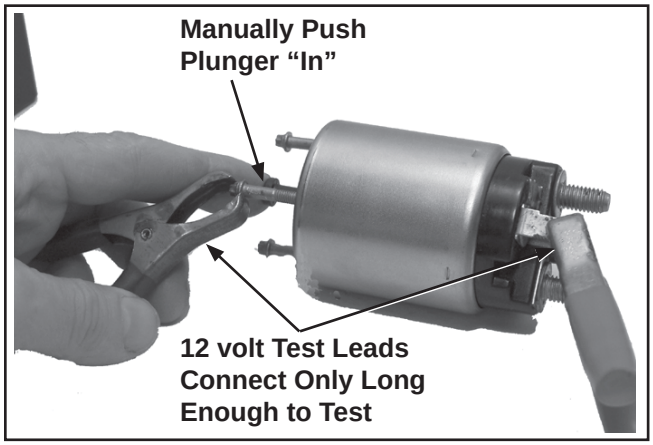


Figure 7-39. Testing Hold-In Coil/Function Test.

Test 4. Solenoid Hold-In Coil/Contact Continuity. Use an ohmmeter set to the audible or Rx2K scale, and connect the two ohmmeter leads to the two large post terminals. Perform the preceding test (3) and check for continuity. See Figure 7-40. The meter should indicate continuity, if no continuity is indicated the solenoid should be replaced. Repeat test several times to confirm condition.

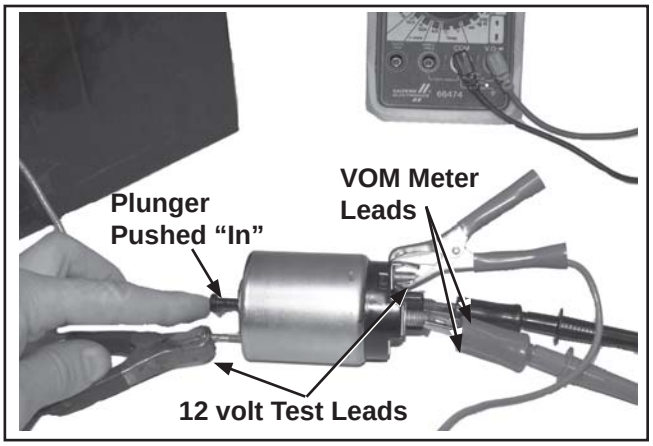


Figure 7-40. Testing Hold-In Coil/Solenoid Contact Continuity.

Section 8
Disassembly

⚠ WARNING

Accidental Starts can cause severe injury or death.
Disconnect and ground spark plug lead(s) before servicing.

Accidental Starts!

Disabling engine. Accidental starting can cause severe injury or death. Before working on the engine or equipment, disable the engine as follows: 1) Disconnect the spark plug lead(s). 2) Disconnect negative (–) battery cable from battery.

General

Clean all parts thoroughly as the engine is disassembled. Only clean parts can be accurately inspected and gauged for wear or damage. There are many commercially available cleaners that will quickly remove grease, oil and grime from engine parts. When such a cleaner is used, follow the manufacturer's instructions and safety precautions carefully.

Make sure all traces of the cleaner are removed before the engine is reassembled and placed into operation. Even small amounts of these cleaners can quickly break down the lubricating properties of engine oil.

Typical Disassembly Sequence

The following sequence is suggested for complete engine disassembly. The sequence can be varied to accommodate options or special equipment.

1. Disconnect spark plug leads.
2. Shut off fuel supply.
3. Drain oil from crankcase and remove oil filter.
4. Remove oil cooler.
5. Remove muffler.
6. Remove air cleaner assembly.
7. Remove throttle control panel.
8. Remove external governor controls.
9. Remove lift fuel pump and fuel pump module.
10. Remove throttle body.
11. Remove electronic control unit.
12. Remove electronic control unit bracket and electric starter motor.
13. Remove oil separator and hardware.
14. Remove grass screen.
15. Remove outer baffles and blower housing.
16. Remove Oil Sentry™.
17. Remove inner baffles and breather cover.
18. Remove valve covers.
19. Remove crankshaft position sensor.
20. Remove manifold absolute pressure sensor.
21. Remove fuel injectors.
22. Remove intake manifold.
23. Remove spark plugs.
24. Remove cylinder heads and hydraulic lifters.
25. Remove fan and flywheel.
26. Remove stator and backing plate.
27. Remove oil pan assembly.
28. Remove camshaft.
29. Remove governor cross shaft.
30. Remove connecting rods with pistons and rings.
31. Remove crankshaft.
32. Remove flywheel end oil seal.

Disconnect Spark Plug Leads

1. Disconnect the leads from the spark plugs. See Figure 8-1.

   NOTE: Pull on boot only, to prevent damage to spark plug lead.

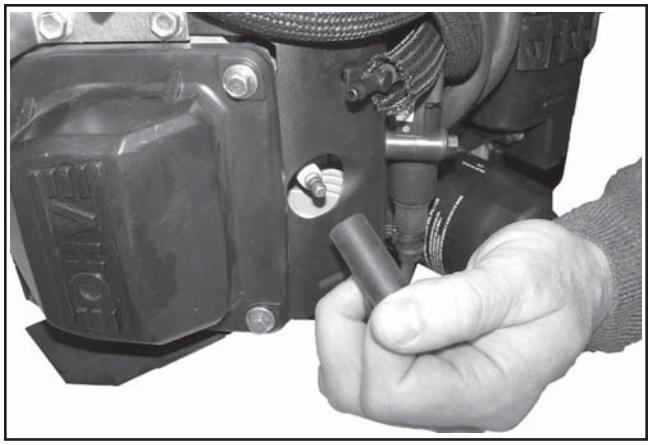


Figure 8-1. Disconnect Spark Plug Leads.

Shut Off Fuel Supply

Drain Oil From Crankcase and Remove Oil Filter

1. Remove oil fill cap/dipstick and one of the oil drain plugs. See Figure 8-2.

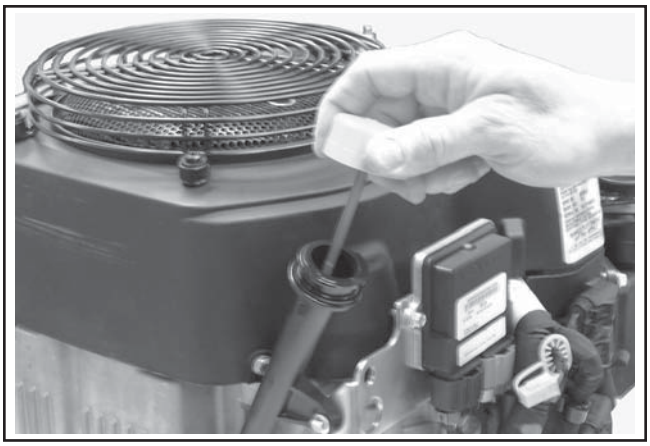


Figure 8-2. Removing Oil Fill Cap/Dipstick.

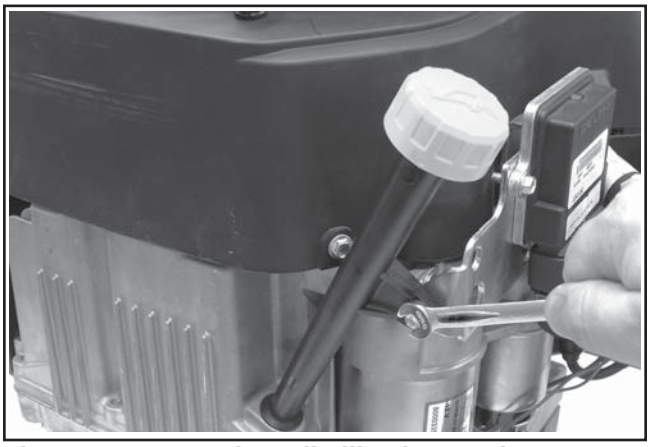


Figure 8-3. Removing Oil Fill Tube Bracket.

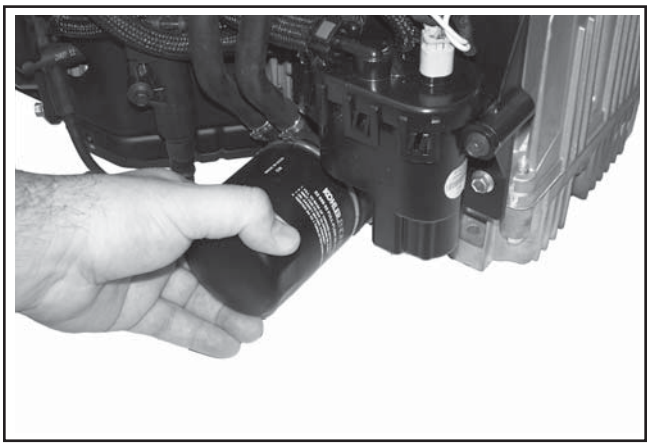


Figure 8-4. Removing Oil Filter.

2. Allow ample time for the oil to drain from the crankcase and oil filter.

3. Remove the mounting screw and detach the oil fill tube. See Figure 8-3.

4. Remove and discard the oil filter. See Figure 8-4.

Remove Oil Cooler

The oil cooler can now be removed from the engine.

1. Use a 8 mm Allen wrench to remove the oil filter threaded nipple.

2. Separate the filter adapter from the oil pan, leaving the oil lines attached. Remove the two hex flange screws mounting the oil cooler to the blower housing. Remove the cooler, lines, and filter adapter as an assembly.

Remove Muffler

1. Remove the exhaust system and attaching hardware from the engine. On engines equipped with a port liner, remove it now.

Remove Air Cleaner Assembly

Heavy-Duty Air Cleaner

1. Remove the hex flange nuts securing the air cleaner to the mounting studs. See Figure 8-5.

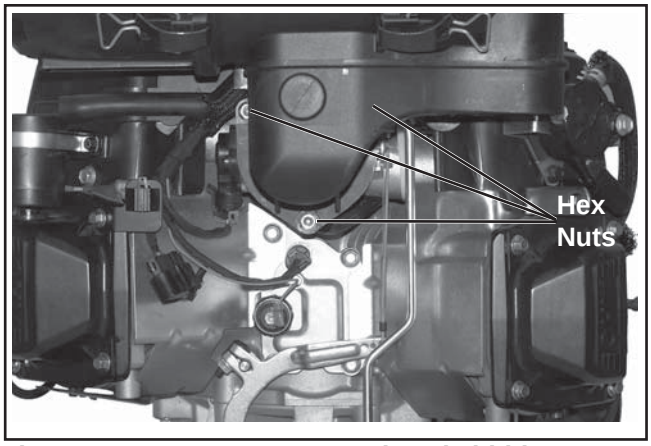


Figure 8-5. Remove Hex Nuts (one is hidden behind the elbow).

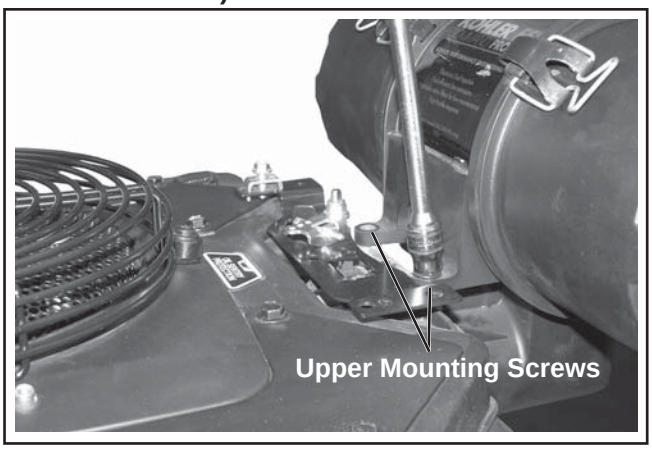


Figure 8-6. Removing Upper Mounting Screws.

2. Remove the two upper screws securing the air cleaner to the mounting bracket and remove the air cleaner assembly. See Figure 8-6.

Low-Profile Air Cleaner (Optional)

1. Loosen the cover-retaining knob, and remove the cover. See Figure 8-7.

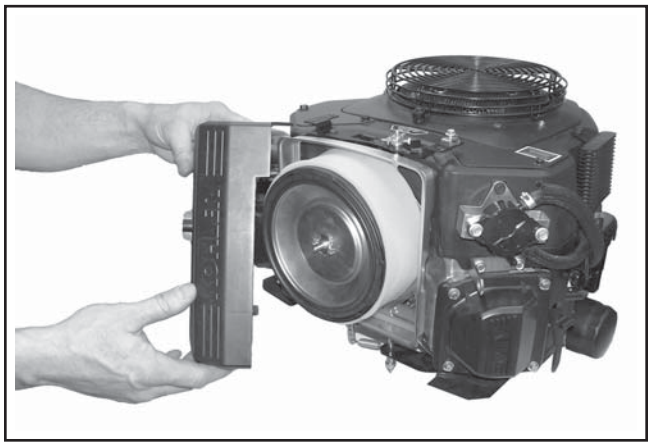


Figure 8-7. Removing Low-Profile Air Cleaner Cover.

2. Remove the wing nut from the element cover.

3. Remove the element cover, element and precleaner. See Figure 8-8.

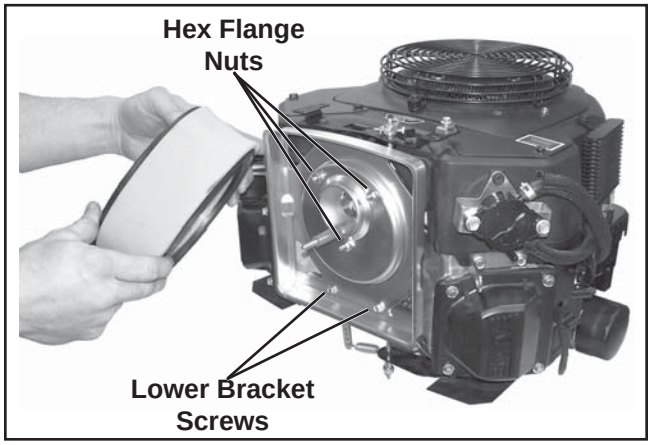


Figure 8-8. Removing Low-Profile Element and Precleaner.

4. Remove the three hex flange nuts securing the air cleaner base. See Figure 8-8. Two additional lower hex flange screws must be removed from the lower air cleaner support bracket.

5. Remove the base.

Remove Top Mount Control Panel

1. Remove the throttle control shaft nut on top of the throttle shaft and remove the throttle control lever and spring. See Figure 8-9.

2. Remove the two screws fastening the control panel and remove the panel from the blower housing. See Figure 8-9.

3. Remove the lower throttle control bracket from the cylinder head.

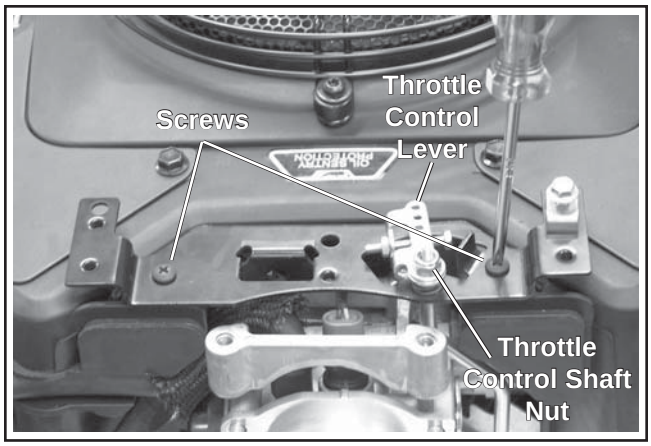


Figure 8-9. Removing Throttle Control Panel.

Remove Bottom Mount Control Panel (If So Equipped)

1. Remove the governor lever spring.

2. Remove the four hex flange screws fastening the throttle panel and remove the panel from the cylinder heads. See Figure 8-10.

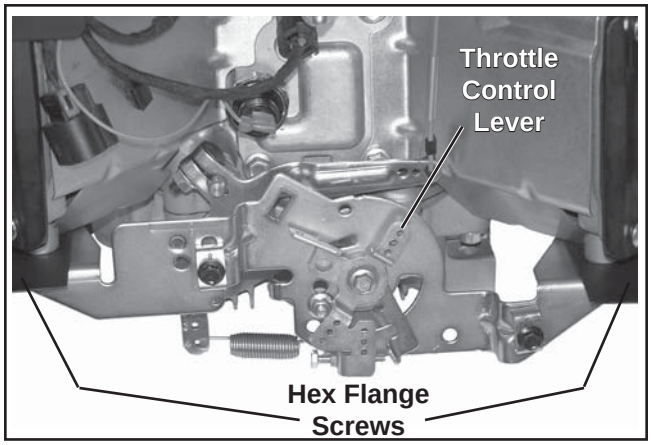


Figure 8-10. Removing Throttle Control Panel.

Remove External Governor Controls

1. Disconnect the governor spring attached to the governor lever. See Figure 8-11. Note the hole location for reassembly.

2. Disconnect the throttle linkage spring, remove the throttle linkage bushing, and throttle linkage from the governor lever. See Figure 8-11.

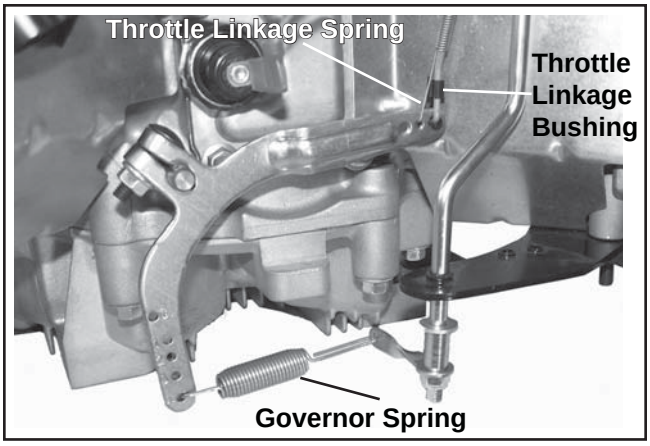


Figure 8-11. Governor Spring and Throttle Linkage.

3. Loosen the hex flange nut and remove the governor lever from the cross shaft. See Figure 8-12.

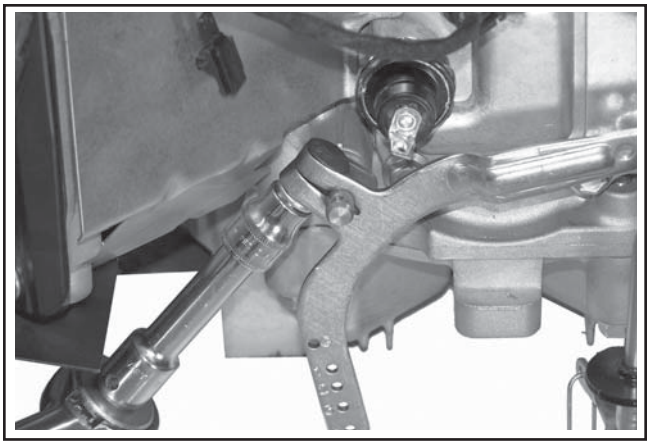


Figure 8-12. Removing Governor Lever.

Remove Lift Fuel Pump and Fuel Pump Module

⚠ WARNING

Explosive Fuel can cause fires and severe burns.
Do not fill the fuel tank while the engine is hot or running.

Explosive Fuel!

Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Do not fill the fuel tank while the engine is hot or running, since spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Do not start the engine near spilled fuel. Never use gasoline as a cleaning agent.

⚠ WARNING

Explosive Fuel can cause fires and severe burns.
Fuel systems ALWAYS remains under HIGH PRESSURE.

Fuel Fire and Burns!

Wrap a shop towel completely around the fuel pump module connector. Press the release button(s) and slowly pull the connector away from the fuel pump module allowing the shop towel to absorb any residual fuel in the high pressure fuel line. Any spilled fuel must be completely wiped up immediately.

Lift Fuel Pump

1. Disconnect the inlet and outlet fuel lines at the lift pump. See Figure 8-13.

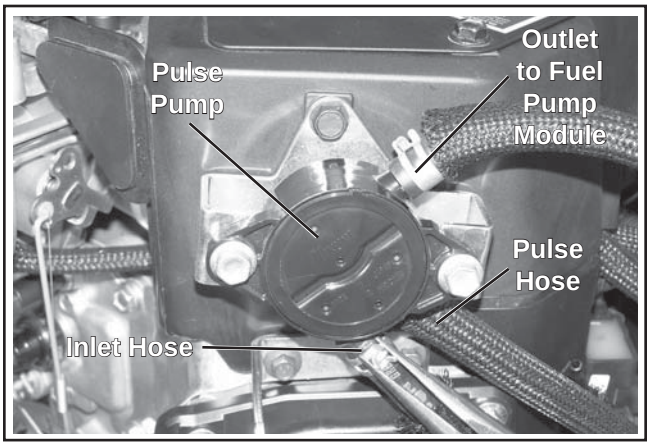


Figure 8-13. Lift Fuel Pump Details.

2. Disconnect the pulse (vacuum) hose at the lift fuel pump from the crankcase.

3. Remove the two hex flange screws securing the lift fuel pump to the bracket.

Fuel Pump Module

1. Remove the three screws securing the fuel pump module.

2. Lift the grey locking tab and squeeze the tab to disconnect the electrical connector. See Figure 8-14.

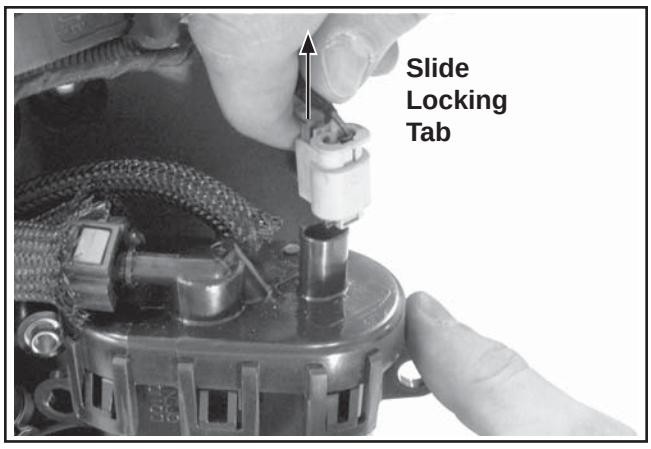


Figure 8-14. Disconnect Electrical Connector.

3. Disconnect the vent hose from the top of the fuel pump module. See Figure 8-15.

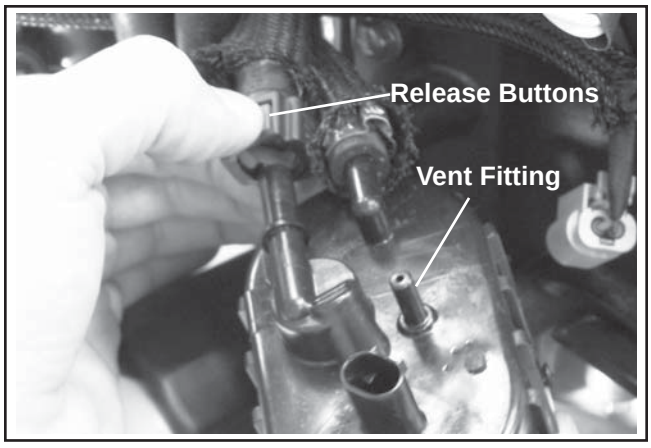


Figure 8-15. Slowly Pull Connector.

4. Wrap a shop towel completely around the high pressure fuel line connector.

5. Press the release button(s) and slowly pull the connector away from the fuel pump module allowing the shop towel to absorb any residual fuel in the high pressure fuel line. Any spilled fuel must be completely wiped up immediately. See Figure 8-15.

NOTE: Figure 8-15 depicts removing the connector without a shop towel wrapped around it for instructional purposes only.

6. Using a side cutter or similar tool, cut the Oetiker Clamp off to remove the inlet fuel line. A new Oetiker Clamp will need to be used for reinstall. See Figure 8-16.

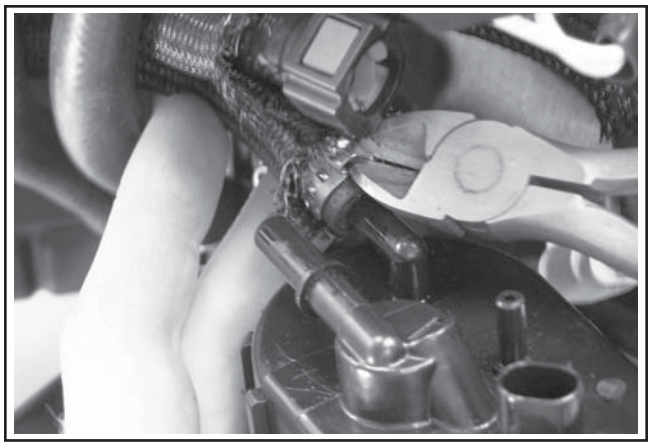


Figure 8-16. Remove Oetiker Clamp.

7. Remove three screws securing the Fuel Pump Module Baffle which the pump was mounted to.

Remove Throttle Body

1. Disconnect the intake air temperature sensor. See Figure 8-17.

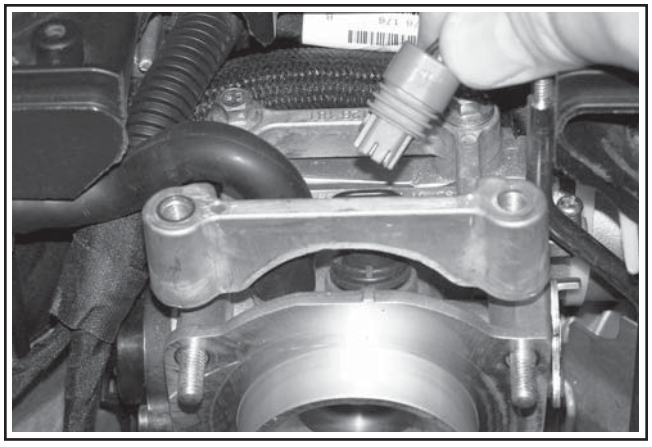


Figure 8-17. Disconnect Intake Air Temperature Sensor.

2. Disconnect the breather tube. See Figure 8-18.

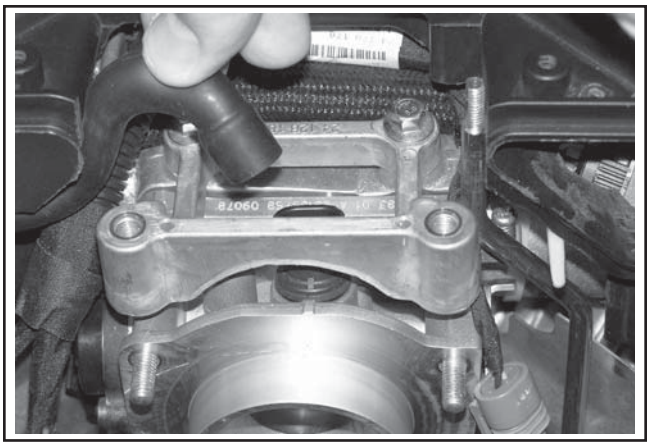


Figure 8-18. Disconnect Breather Tube.

3. Disconnect the throttle position sensor connector. See Figure 8-19.

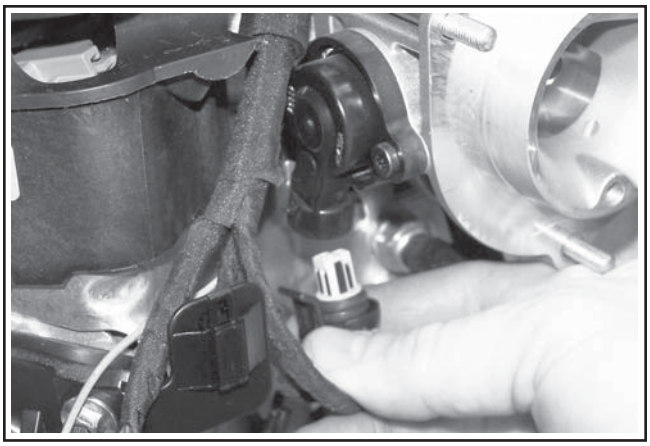


Figure 8-19. Disconnecting the Throttle Position Sensor.

4. Disconnect the vent hose from beneath the throttle body. See Figure 8-20.

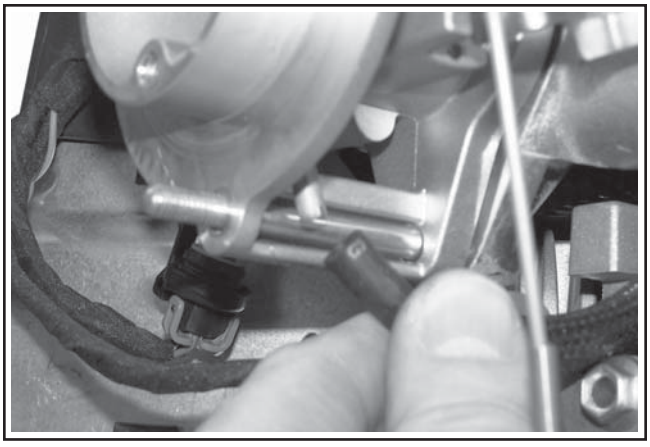


Figure 8-20. Disconnect the Vent Hose.

5. If equipped, remove the two screws securing the heavy-duty air cleaner bracket, take off the bracket and slide the throttle body off the intake manifold. See Figure 8-21.

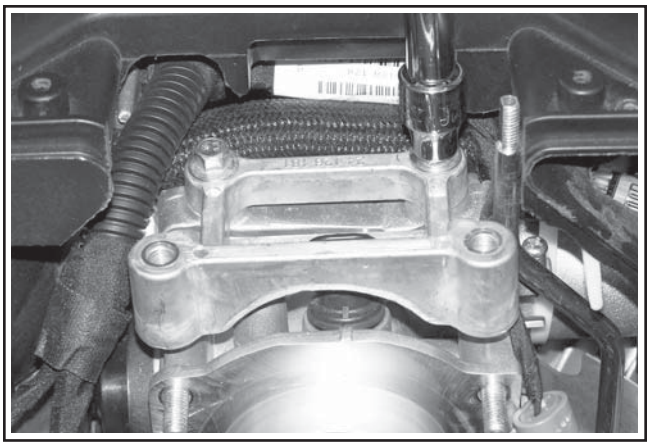


Figure 8-21. Remove Air Cleaner Bracket Screws.

Remove the Electronic Control Unit (ECU)

1. Remove the two hex flange screws securing the ECU to the bracket. See Figure 8-22.

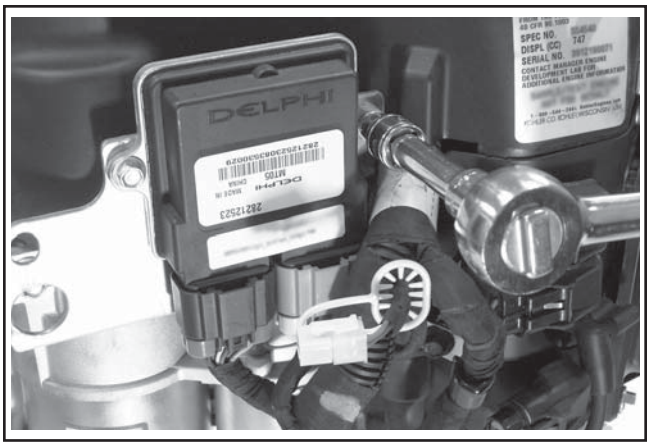


Figure 8-22. Remove ECU Screws.

2. Disconnect the Black and Grey electrical connectors from the ECU. See Figure 8-23.

Figure 8-23. Disconnect ECU Electrical Connectors.

Remove Electric Starter Motor and Electronic Control Unit Bracket

1. Disconnect the leads from the starter.

2. Remove the two hex flange screws. See Figure 8-24.

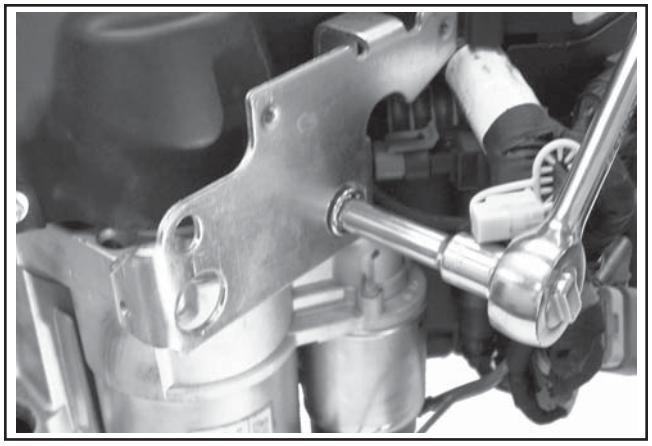


Figure 8-24. Removing Electric Starter Motor.

Remove Oil Separator and Hardware

1. Remove the two screws securing the oil separator assembly, pulling the assembly out and away from the valve cover. See Figure 8-25.

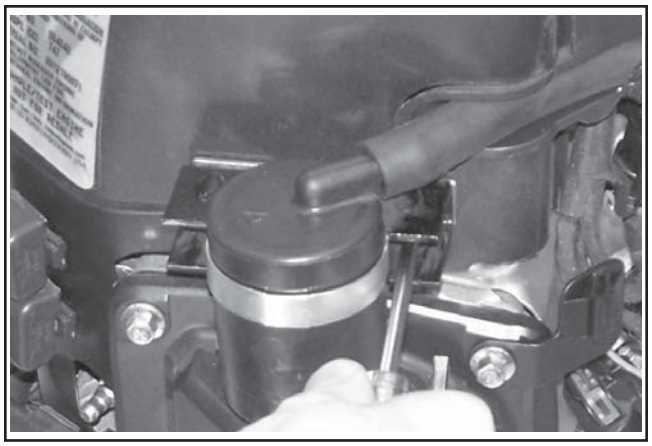


Figure 8-25. Remove Oil Separator Assembly.

Remove Grass Screen

1. Remove the four socket head cap screws securing the metal grass screen and remove the screen. See Figure 8-26

Figure 8-26. Remove Grass Screen.

2. Remove the four spacers, paying attention to the curvature of the spring washers between the spacers and the fan.

NOTE: The fan will be loose, but cannot be removed until after the blower housing is removed.

3. If there is a plastic grass screen attached to the fan, remove the four screws securing the grass screen. Removing the screen will expose the four screws fastening the fan to the flywheel. See Figure 8-27 and Figure 8-28.

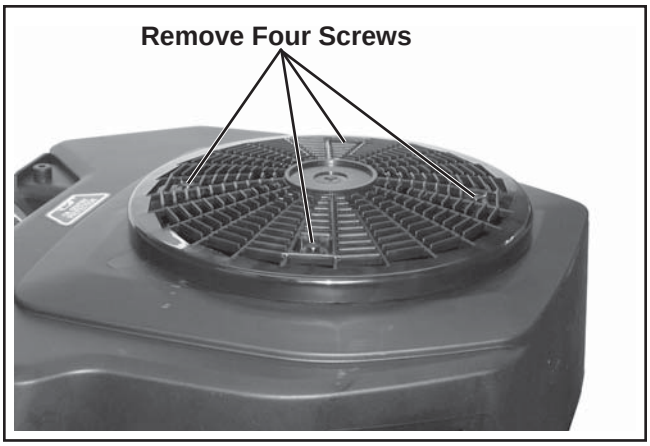


Figure 8-27. Plastic Grass Screen.

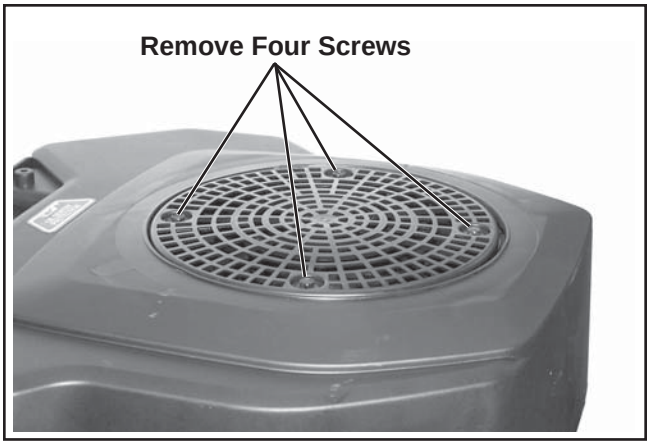


Figure 8-28. Plastic Grass Screen.

Remove Outer Baffles and Blower Housing

1. Disconnect the plug from the rectifier-regulator. See Figure 8-29.

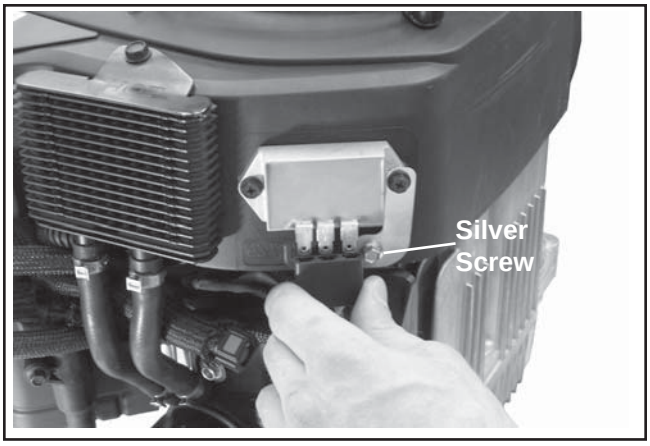


Figure 8-29. Disconnect Plug from Rectifier-Regulator.

2. Remove the silver plated rectifier-regulator ground strap screw fastened to the crankcase. The rectifier-regulator does not have to be detached from the blower housing.

3. Disconnect the three fuse connectors attached to the outer baffle on the starter side. Allowing them to hang is fine.

NOTE: Some engines may have two fuses mounted to a bracket above the ECU and a third in-line fuse near the rectifier-regulator.

4. Remove the three (each side) hex flange screws securing the outer baffles. Note the location of any lifting strap and the position of the two short screws (one each side on bottom) for reassembly. See Figure 8-30. The coil and any hoses may remain attached to the baffle after being unplugged or disconnected.

5. Remove the outer baffles. See Figure 8-30.

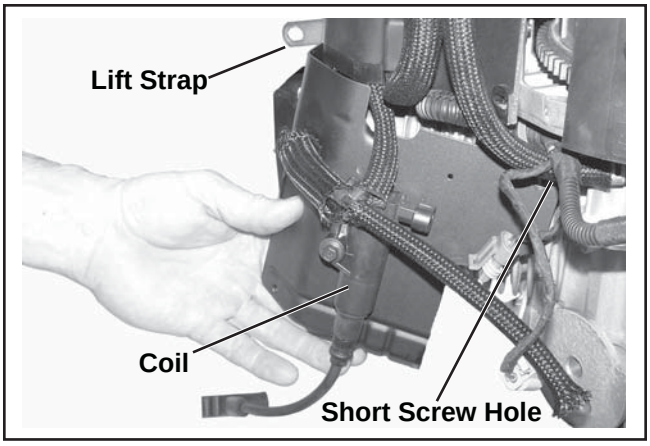


Figure 8-30. Note Location of Short Screws.

6. Remove the remaining hex flange screws securing the blower housing. Remove the blower housing. See Figure 8-31.

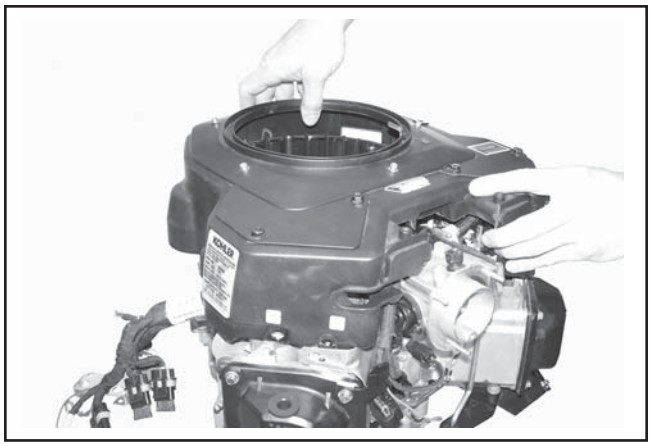


Figure 8-31. Removing Blower Housing.

Remove Oil Sentry™

1. Disconnect the lead from the Oil Sentry™ switch.

2. Remove the Oil Sentry™ switch from the breather cover. See Figure 8-32.

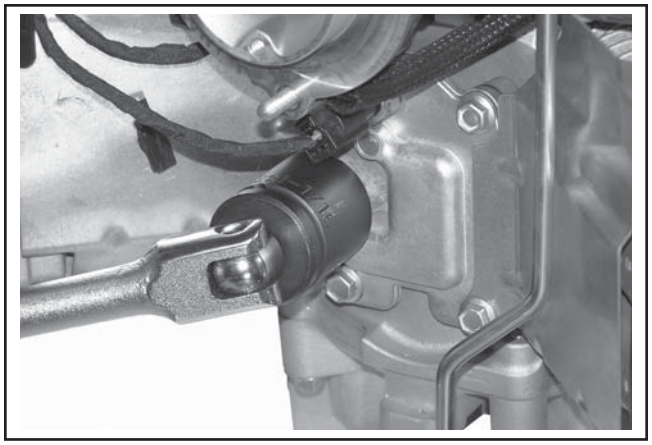


Figure 8-32. Removing Oil Sentry™ Switch.

NOTE: This is optional. Removing the Oil Sentry is not required to remove the breather cover.

Remove Inner Baffles and Breather Cover

1. Remove the four hex flange screws securing the inner baffles to the crankcase.

2. Remove the inner (valley) baffles. See Figure 8-33.

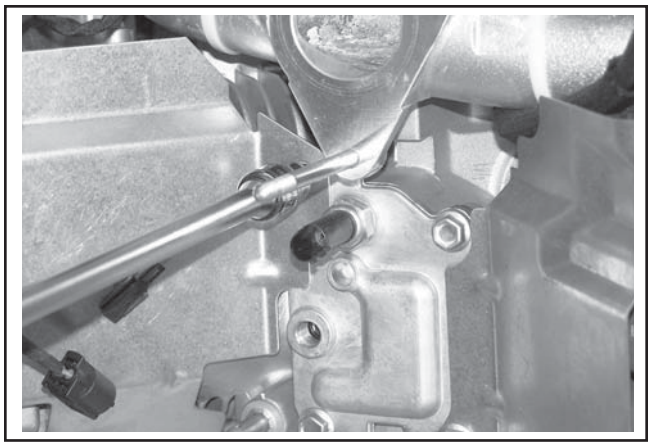


Figure 8-33. Removing Inner Baffles.

3. Disconnect and remove the oil temperature sensor. See Figure 8-34.

NOTE: This is optional. Removing the oil temperature sensor is not required to remove the breather cover or inner baffles.

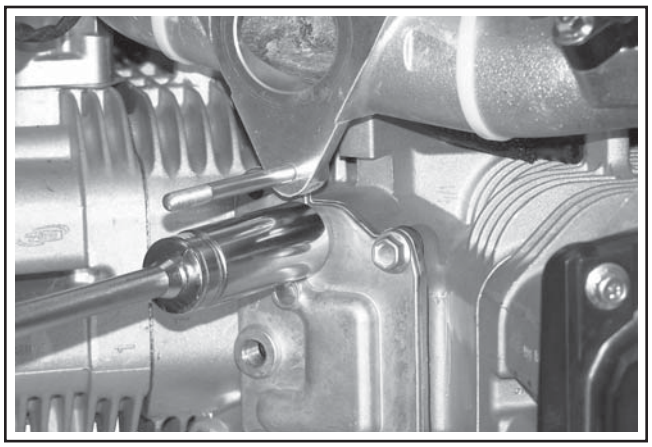


Figure 8-34. Remove the Oil Temperature Sensor.

4. Remove the two remaining hex flange screws from the breather cover. See Figure 8-35.

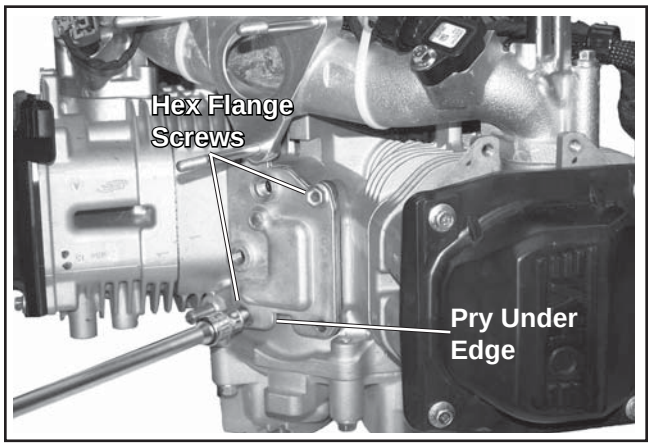


Figure 8-35. Remove Breather Cover Screws.

5. Pry under the protruding edge of the breather cover with a screwdriver to break the gasket seal. See Figure 8-35. Do not pry on the sealing surfaces as it could cause damage resulting in leaks.

6. Remove the breather cover and gasket. See Figure 8-36.

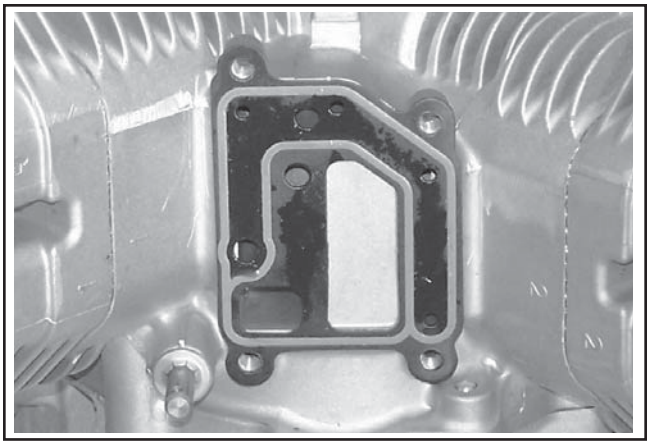


Figure 8-36. Removing Breather Cover Gasket.

Remove Valve Covers

1. Remove the four hex flange screws securing each valve cover. Note valve cover differences for proper location in reassembly. Ensure any brackets removed are reassembled in the same location. See Figure 8-37.

2. The covers should lift off without prying.

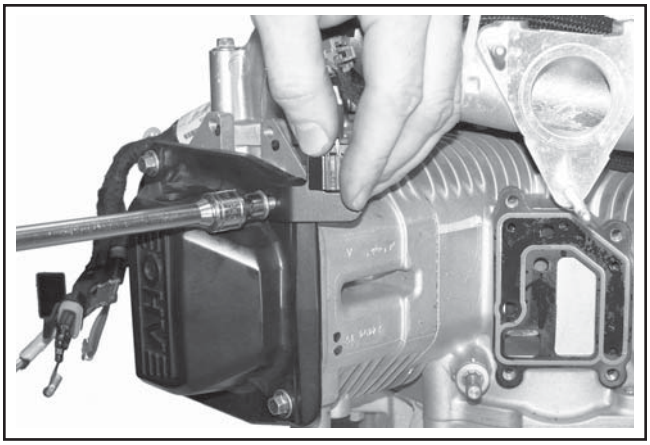


Figure 8-37. Removing Valve Cover.

Remove Crankshaft Position Sensor

1. Disconnect the electrical connector to the crankshaft position sensor. See Figure 8-38.

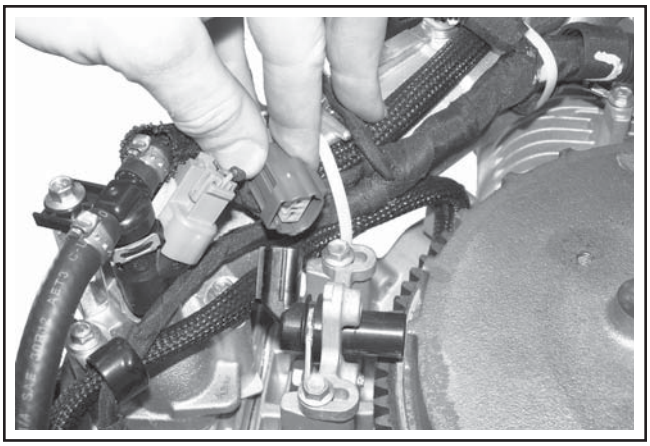


Figure 8-38. Disconnect Crankshaft Position Sensor.

2. Remove the two hex flange screws securing the crankshaft position sensor. See Figure 8-39.

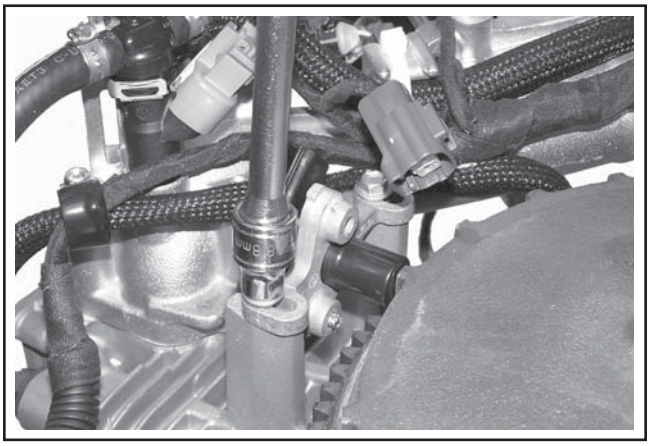


Figure 8-39. Remove the Crankshaft Position Sensor.

Remove the Manifold Absolute Pressure (MAP) Sensor

1. With a screwdriver, slide the locking tab on the electrical connector. See Figure 8-40.

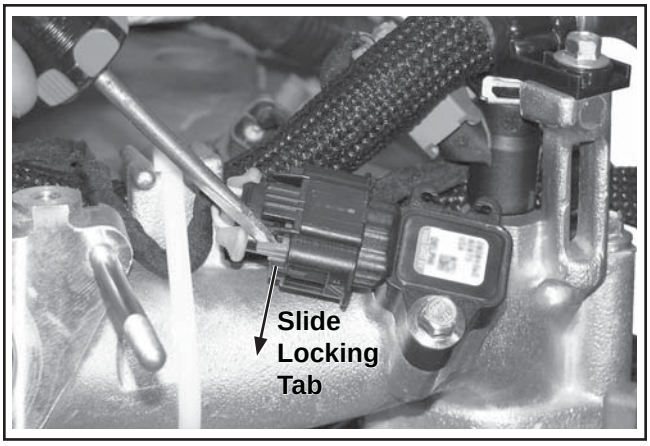


Figure 8-40. Slide Locking Tab on Connector.

2. Detach the connector.

3. Remove the hex flange screw and pull the MAP sensor out of the intake manifold. See Figure 8-41.

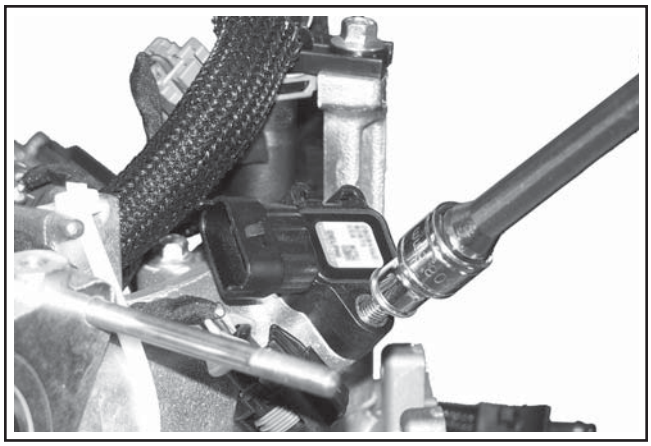


Figure 8-41. Remove MAP Screw.

Remove Fuel Injectors

1. Disconnect the electrical connector. See Figure 8-42.

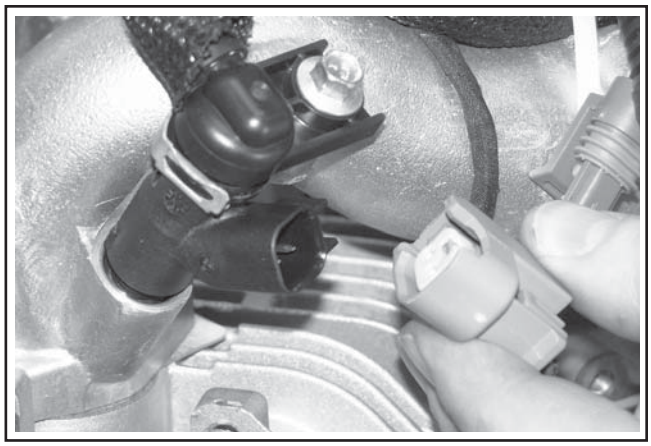


Figure 8-42. Remove Connector.

2. Remove the hex flange screw and pull the injector out of the intake manifold for each injector. See Figure 8-43.

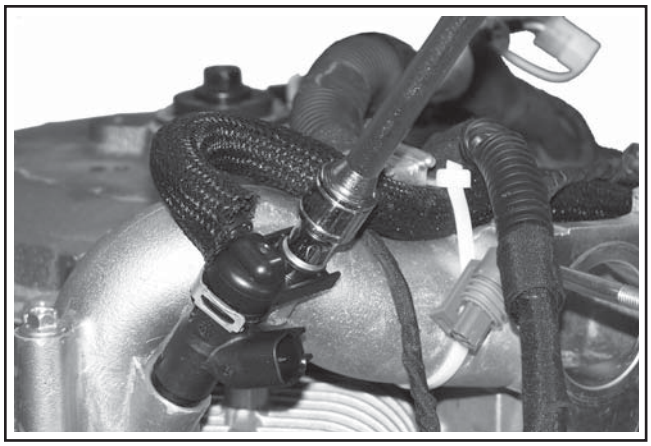


Figure 8-43. Remove Fuel injector.

3. When removed, pull off the metal retaining clip connecting the fuel injector to the fuel injector cap. See Figure 8-44. There may be some fuel left in the high pressure fuel line. Any spilled fuel must be completely wiped up immediately.

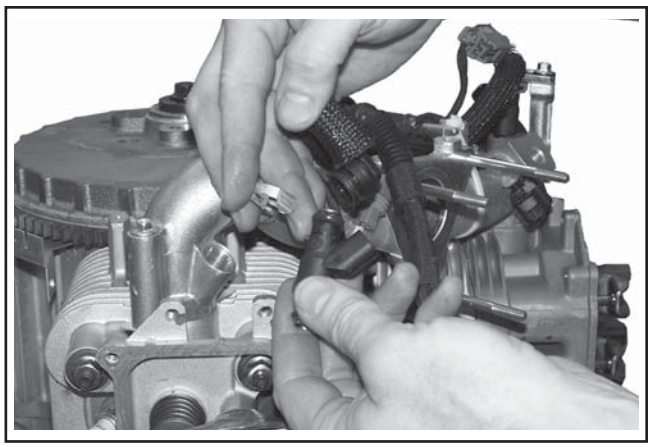


Figure 8-44. Remove Retaining Clip.

Remove Intake Manifold

1. Remove the hex flange screw securing a ring terminal which is part of the wiring harness. See Figure 8-45.

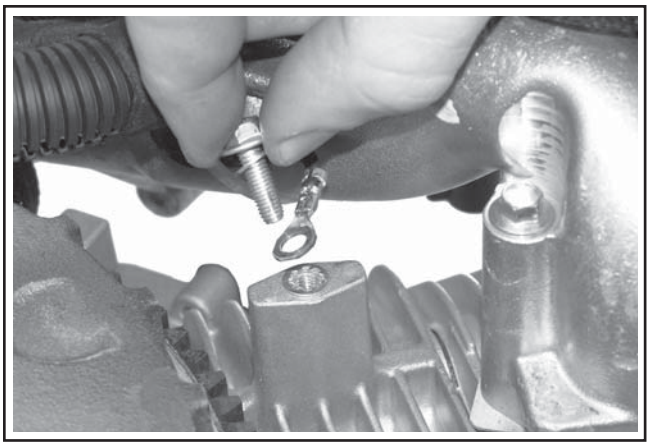


Figure 8-45. Remove Screw for Ground Terminal.

2. Remove the four hex flange screws securing the intake manifold to the cylinder heads. Note which screw location holds the wiring clamp. See Figure 8-46.

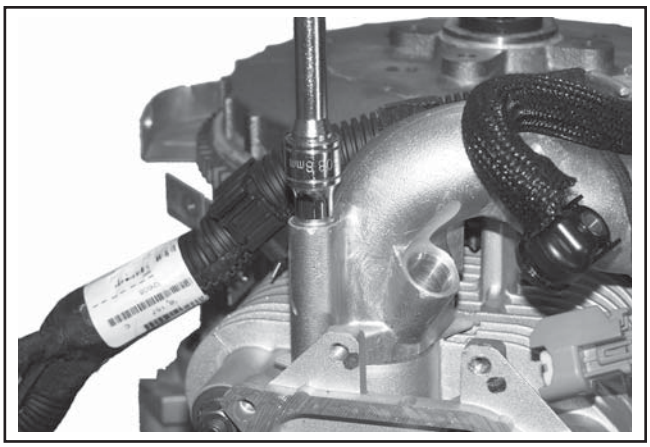


Figure 8-46. Remove Intake Manifold Screws.

3. Unclasp the wiring harness from the clip using a screwdriver. See Figure 8-47.

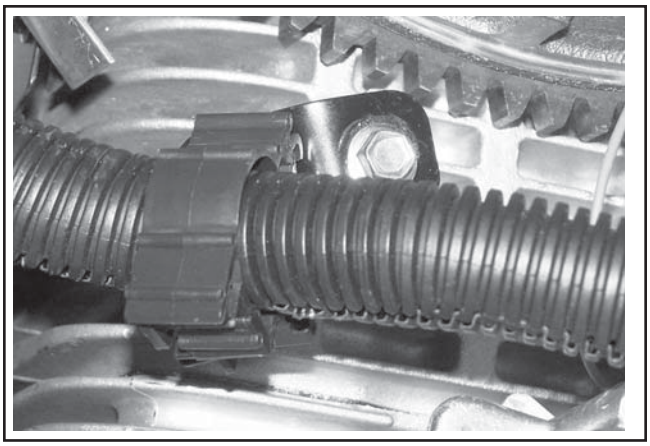


Figure 8-47. Wire Harness Clip.

4. Remove the intake manifold and the intake manifold gaskets. See Figure 8-48.

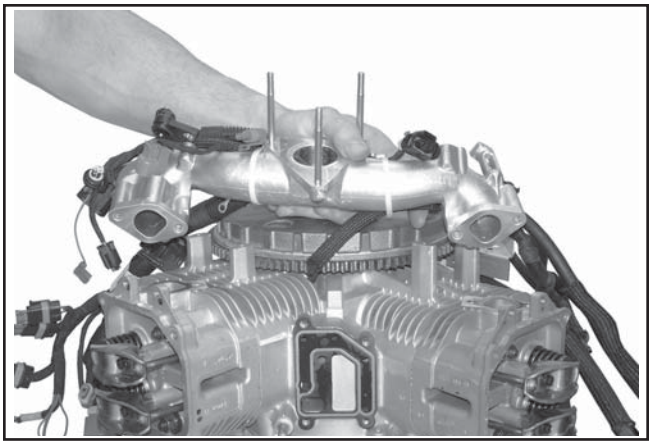


Figure 8-48. Removing Intake Manifold.

5. Leave the wiring harness attached to the manifold.

Remove Spark Plugs

1. Remove the spark plug from each cylinder head. See Figure 8-49.

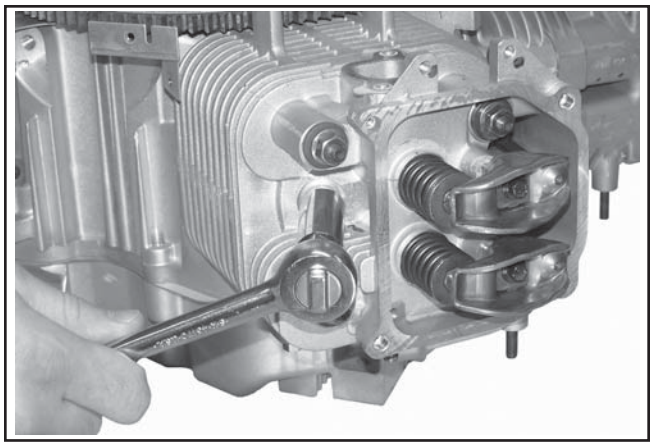


Figure 8-49. Removing Spark Plugs.

Remove Cylinder Heads and Hydraulic Lifters

NOTE: Cylinder heads are retained using either hex flange screws or hex flange nuts and washers on studs. Do not interchange or mix components.

1. Remove the four hex flange screws or hex nuts and washers securing each cylinder head. See Figure 8-50. Discard the screws or nuts and washers once removed. Do not reuse. Studs (if present) should only be removed if damaged or if cylinder reconditioning is necessary. Once removed, they must be replaced.

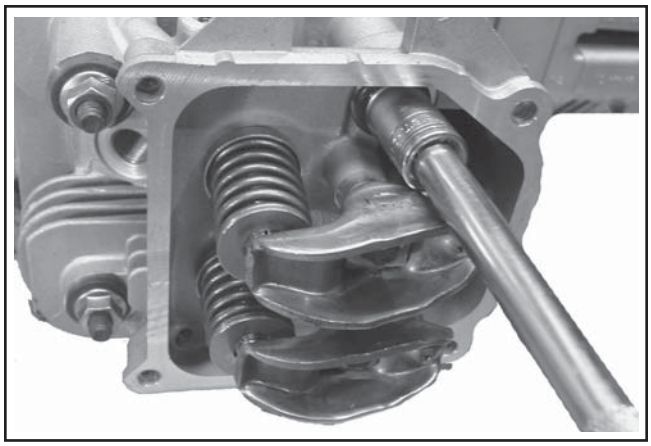


Figure 8-50. Removing Cylinder Head Fasteners.

2. Mark the location of the push rods as either intake or exhaust and cylinder 1 or 2. Push rods should always be reinstalled in the same positions.

3. Carefully remove the push rods, cylinder heads, and head gaskets. See Figure 8-51.

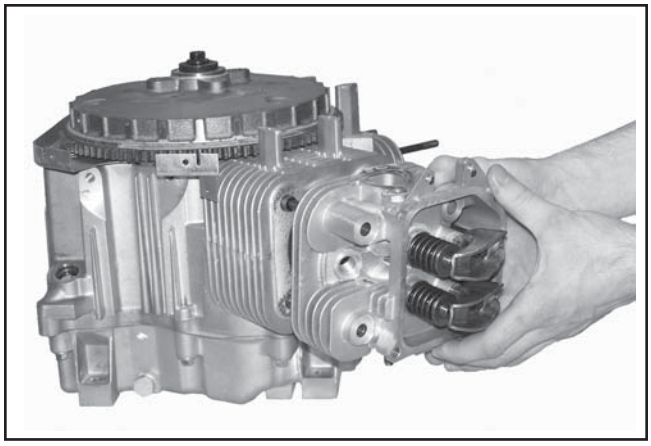


Figure 8-51. Removing Cylinder Head.

4. Remove the lifters from the lifter bores. Use a hydraulic lifter tool. Do not use a magnet to remove lifters. Mark the lifters by location, as either intake or exhaust, and cylinder 1 or 2. Hydraulic lifters should always be reinstalled in the same position. See Figure 8-52 and 8-53.

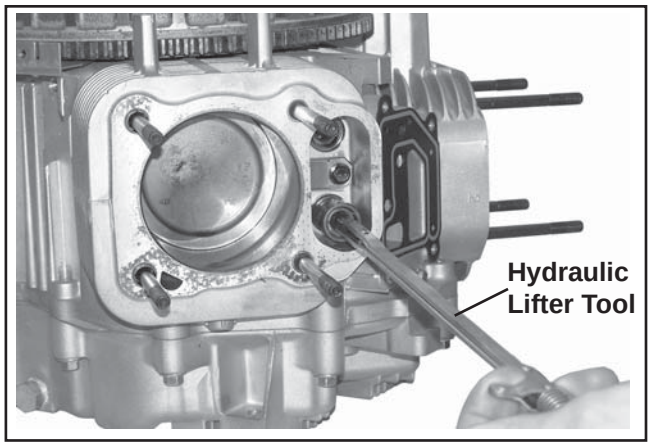


Figure 8-52. Removing Hydraulic Lifters.

Figure 8-53. Mark the Lifters By Location.

Disassemble Cylinder Heads

1. Remove the two hex flange screws, rocker arm pivots and rocker arms from the cylinder head. See Figure 8-54.

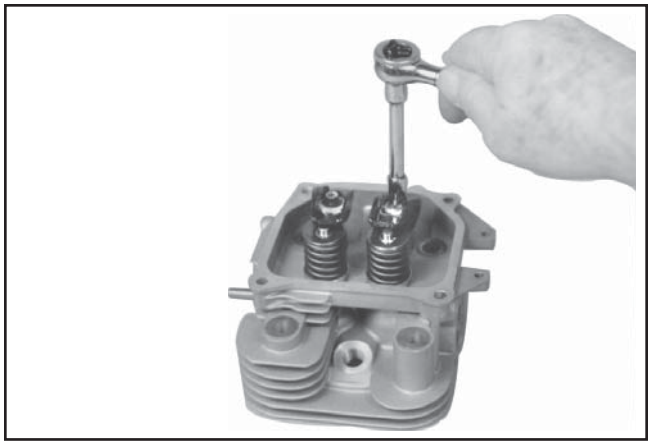


Figure 8-54. Removing Rocker Arm.

2. Compress the valve springs using a valve spring compressor. See Figure 8-55.

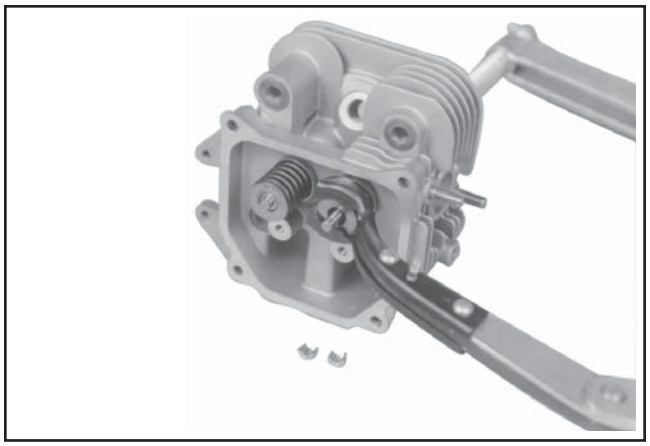


Figure 8-55. Removing Valves with Valve Spring Compressor.

3. Once the valve spring is compressed, remove the valve spring keepers, then remove the following items. See Figures 8-56 and 8-57:

   - Valve spring retainers
   - Valve springs
   - Valve spring caps
   - Intake and exhaust valves (mark position)
   - Valve stem seals (intake and exhaust)

NOTE: These engines use valve stem seals on the intake and exhaust valves. Use a new seal whenever the valve is removed or if the seal is deteriorated or damaged in any way. Never reuse an old seal.

4. Repeat the above procedure for the other cylinder head. Do not interchange parts from one cylinder head to the other.

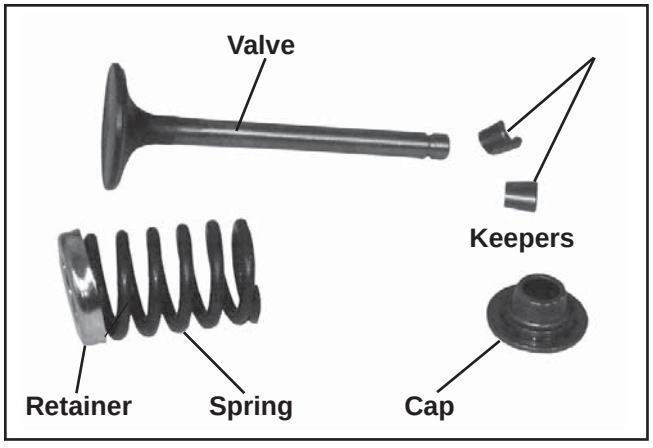


Figure 8-56. Valve Components.

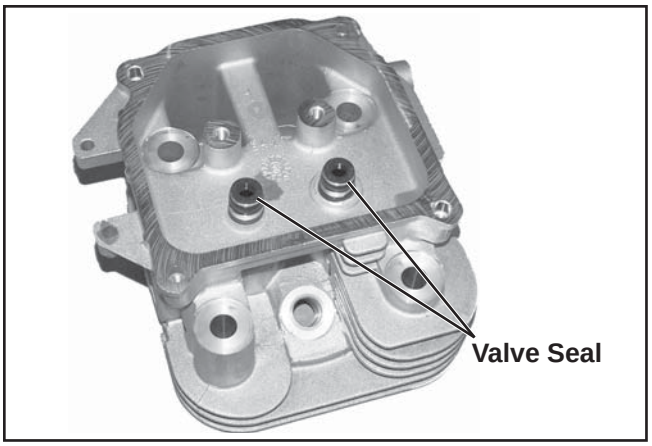


Figure 8-57. Valve Seal Location.

Remove Fan and Flywheel

1. Remove the four shoulder bolts securing the fan if still attached and remove fan.

2. Use a flywheel strap wrench or holding tool (see Section 2) to hold the flywheel and loosen the hex flange screw securing the flywheel to the crankshaft. See Figure 8-58.

   NOTE: Always use a flywheel strap wrench or holding tool to hold the flywheel when loosening or tightening the flywheel screw. **Do not** use any type of bar or wedge to hold the flywheel. Use of such tools could cause the flywheel to become cracked or damaged.

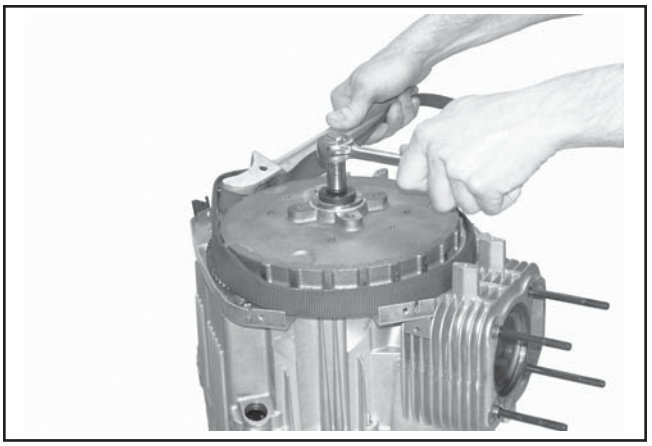


Figure 8-58. Removing Flywheel Fastener Using Strap Wrench.

3. Remove the hex flange screw and washer.

4. Use a puller to remove the flywheel from the crankshaft. See Figure 8-59.

NOTE: Always use a flywheel puller to remove the flywheel from the crankshaft. **Do not** strike the crankshaft or flywheel, as these parts could become cracked or damaged. Striking the puller or crankshaft can cause the crank gear to move, affecting crankshaft endplay.

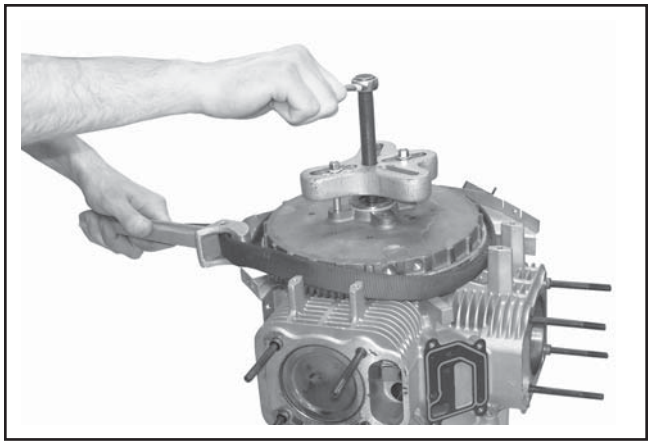


Figure 8-59. Removing Flywheel with a Puller.

5. Remove the woodruff key.

Remove Stator and Backing Plates

1. Remove the four screws securing the backing plate. See Figure 8-60. Remove the backing plate.

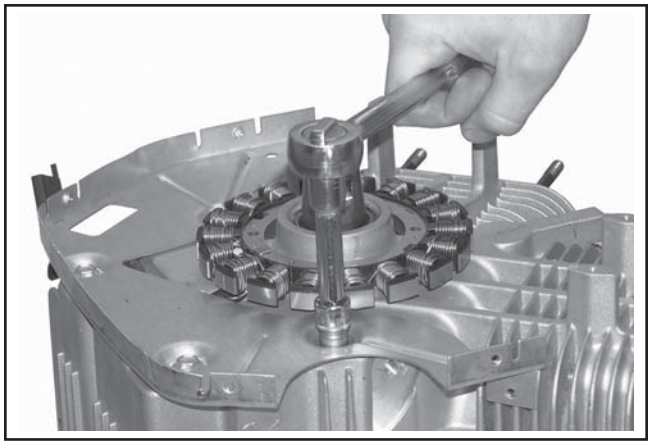


Figure 8-60. Removing Backing Plate.

2. Remove the two hex flange screws and the stator. See Figure 8-61. Note the position/routing of the stator lead.

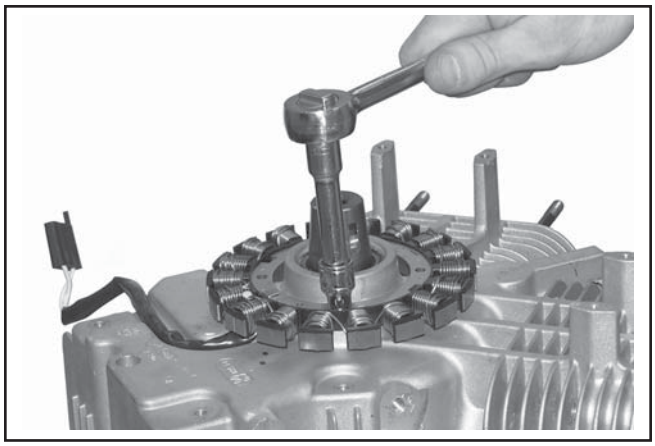


Figure 8-61. Removing Stator.

Remove Oil Pan Assembly

1. Remove the ten hex flange screws securing the oil pan to the crankcase. See Figure 8-62.

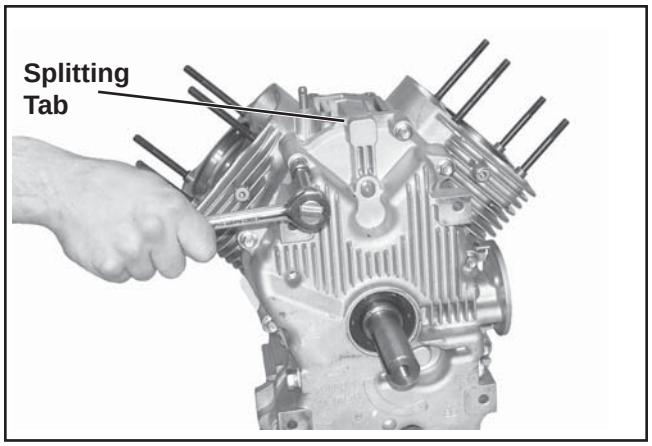


Figure 8-62. Removing Oil Pan Fasteners.

2. Locate the splitting tab cast into the perimeter of the oil pan. Insert the drive end of a 1/2 in. breaker bar between the splitting tab and the crankcase and turn it to loosen seal. See Figure 8-62. Do not pry on the sealing surfaces as this can cause leaks. Tap with a rubber mallet to finish removing the oil pan. Remove the oil seal and replace at reassembly.

Governor Gear Assembly

The governor gear assembly is located inside the oil pan. If service is required, refer to the service procedures under **Governor Gear Assembly** in Section 9.

Oil Pump Assembly

The oil pump is mounted inside the oil pan. If service is required, refer to the service procedures under **Oil Pump Assembly** in Section 9.

Remove Camshaft

1. Remove the camshaft and shim (if used). See Figure 8-63.

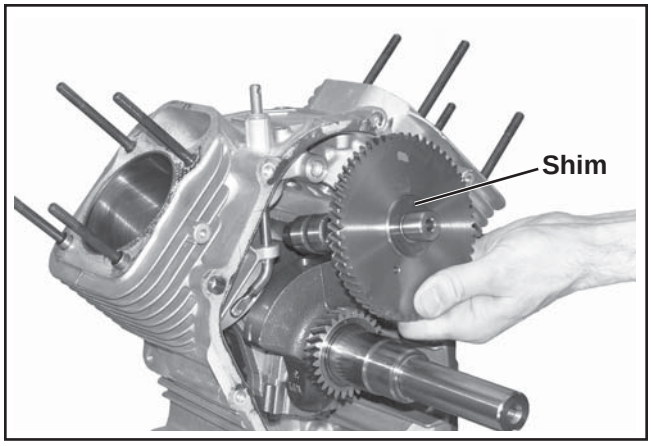


Figure 8-63. Removing Camshaft.

Remove Governor Cross Shaft

1. Remove the retainer and nylon washer, from the governor cross shaft. See Figure 8-64.

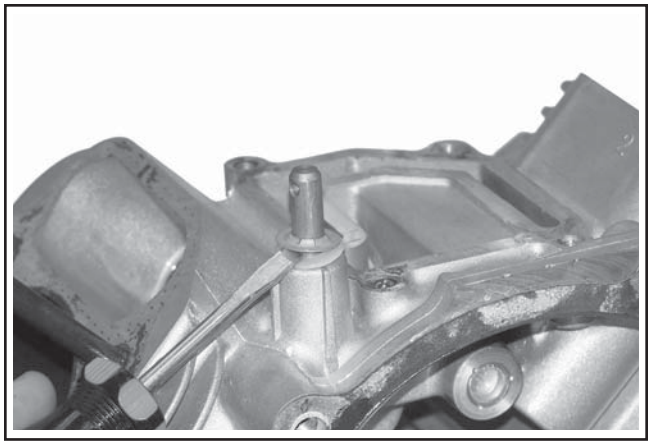


Figure 8-64. Removing Governor Cross Shaft Retainer.

2. Remove the cross shaft through the inside of the crankcase. See Figure 8-65.

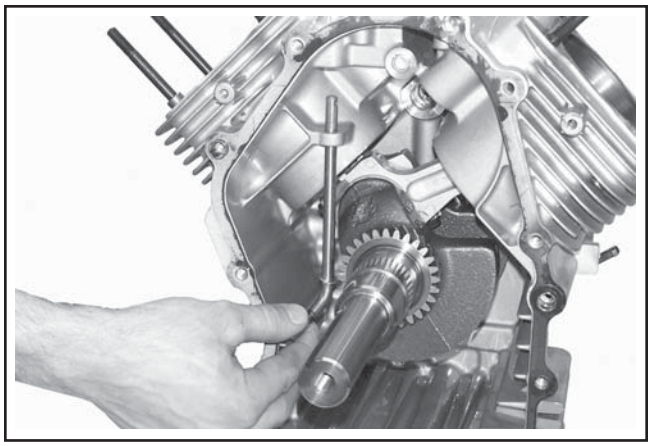


Figure 8-65. Removing Governor Cross Shaft.

Remove Connecting Rods with Pistons and Rings

1. Remove the two hex flange screws securing the closest connecting rod end cap. Remove the end cap. See Figure 8-66.

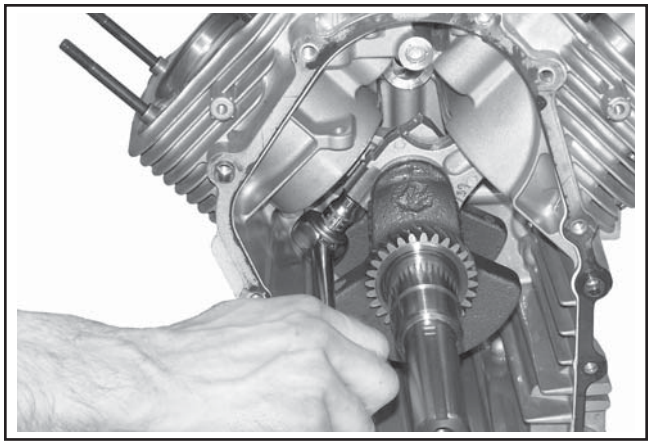


Figure 8-66. Removing Connecting Rod End Cap.

NOTE: If a carbon ridge is present at the top of either cylinder bore, use a ridge reamer tool to remove it before attempting to remove the piston.

2. Carefully remove the connecting rod and piston assembly from the cylinder bore. See Figure 8-67.

NOTE: The cylinders are numbered on the crankcase. Use the numbers to mark each end cap, connecting rod and piston for reassembly. **Do not** mix end caps and connecting rods.

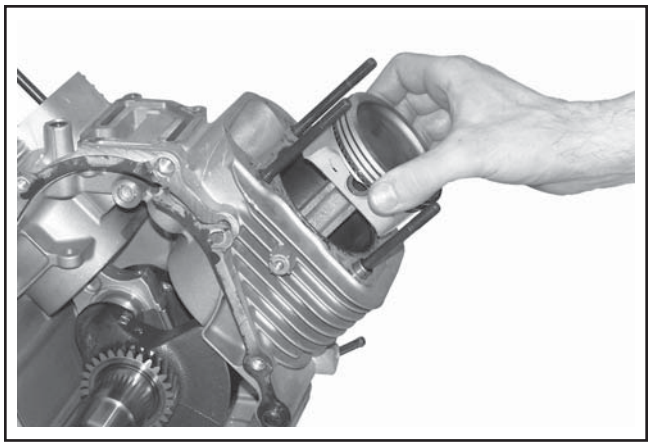


Figure 8-67. Removing Connecting Rod and Piston Assembly.

3. Repeat the above procedure for the other connecting rod and piston assembly.

4. Remove piston pin from piston for inspection. Use a small screwdriver to pry the pin retainer out of the groove. See Figure 8-68.

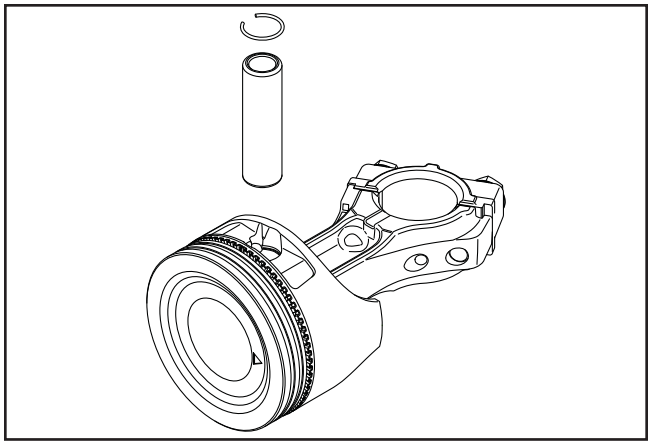


Figure 8-68. Remove Piston Pin.

Remove Crankshaft

1. Carefully pull the crankshaft from the crankcase. See Figure 8-69.

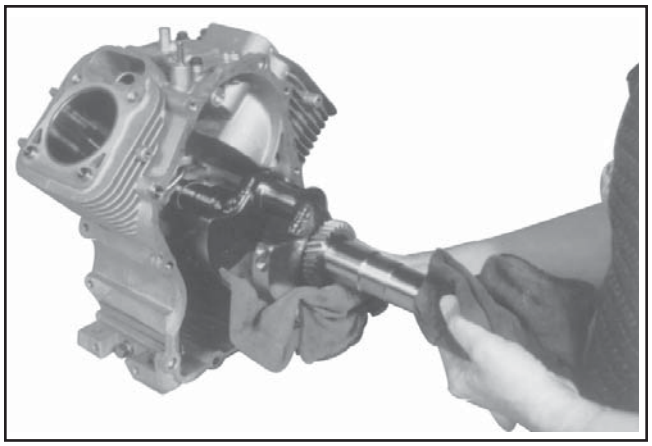


Figure 8-69. Removing Crankshaft.

Remove Flywheel End Oil Seal

1. Remove the oil seal from the crankcase. See Figure 8-70.

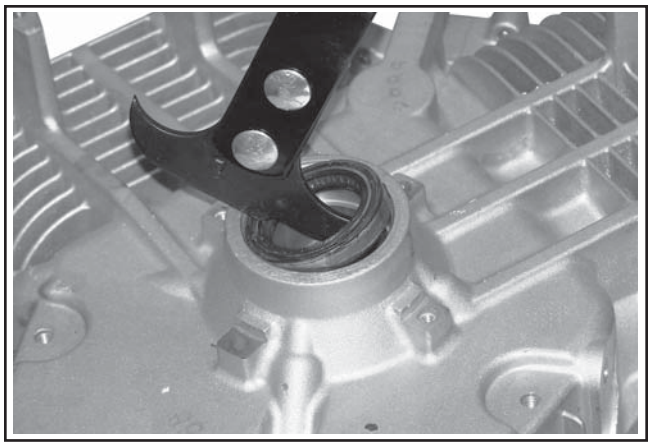


Figure 8-70. Removing Oil Seal.

Section 9
Inspection and Reconditioning

This section covers the operation, inspection, and repair/reconditioning of major internal engine components. The following components are not covered in this section. They are covered in sections of their own:

Air Cleaner, Section 4
Fuel Injection & External Governor, Section 5
Ignition, Charging & Electric Starter, Section 7

Clean all parts thoroughly. Only clean parts can be accurately inspected and gauged for wear or damage. There are many commercially available cleaners that will quickly remove grease, oil, and grime from engine parts. When such a cleaner is used, follow the manufacturer's instructions and safety precautions carefully. Make sure all traces of the cleaner are removed before the engine is reassembled and placed into operation. Even small amounts of these cleaners can quickly break down the lubricating properties of engine oil.

Use an aerosol gasket remover, paint stripper, or lacquer thinner to remove any old sealant. Apply the solvent, allow time for it to work, and then brush the surface with a **brass** wire brush. After the old sealant is removed, clean the surface with isopropyl alcohol, lacquer thinner, or aerosol electrical contact cleaner. **Do not** scrape the surfaces, as any scratches, nicks, or burrs can result in leaks. See Service Bulletin 252 for further information.

Refer to A Guide to Engine Rebuilding (TP-2150-A) for additional information. Measurement Guide (TP-2159-B) and Engine Inspection Data Record (TP-2435) are also available; use these to record inspection results.

Camshaft

Inspection and Service

Check the lobes of the camshaft for wear or damage. See Section 1 for minimum lift specifications. The measurement must be performed while the valve train is still assembled. Inspect the cam gear for badly worn, chipped or missing teeth. Replacement of the camshaft will be necessary if any of these conditions exist.

Crankshaft

Inspection and Service

Inspect the gear teeth of the crankshaft. If the teeth are badly worn, chipped, or some are missing, replacement of the crankshaft will be necessary.

Inspect the crankshaft bearing surfaces for scoring, grooving, etc. Measure the running clearance between the crankshaft journals and their respective bearing bores. Use an inside micrometer or telescoping gauge to measure the inside diameter of both bearing bores in the vertical and horizontal planes. Use an outside micrometer to measure the outside diameter of the crankshaft main bearing journals. Subtract the journal diameters from their respective bore diameters to get the running clearances. Check the results against the specifications in Section 1. If the running clearances are within specification, and there is no evidence of scoring, grooving, etc., no further reconditioning is necessary. If the bearing surfaces are worn or damaged, the crankcase and/or oil pan will need to be replaced.

Inspect the crankshaft keyways. If worn or chipped, replacement of the crankshaft will be necessary.

Inspect the crankpin for score marks or metallic pickup. Slight score marks can be cleaned with crocus cloth soaked in oil. If wear limits, as stated in **Specifications and Tolerances** are exceeded, it will be necessary to either replace the crankshaft or regrind the crankpin to **0.25 mm (0.010 in.)** undersize. If reground, a **0.25 mm (0.010 in.)** undersize connecting rod (big end) must then be used to achieve proper running clearance. Measure the crankpin for size, taper, and out-of-round.

NOTE: If the crankpin is reground, visually check to ensure that the fillet blends smoothly with the crankpin surface. See Figure 9-1.

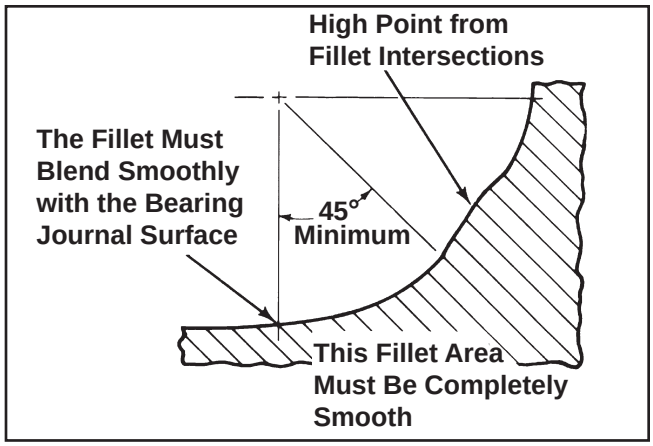


Figure 9-1. Crankpin Fillets.

The connecting rod journal can be ground one size under. When grinding the crankshaft, grinding stone deposits can get caught in the oil passages, which could cause severe engine damage. Removing the crankpin plug when the crankshaft is ground provides easy access for removing any grinding deposits that may collect in the oil passages.

Use the following procedure to remove and replace the plug.

Procedure to Remove Crankshaft Plug:

1. Drill a 3/16 in. hole through the plug in the crankshaft.

2. Thread a 3/4 in. or 1 in. long self-tapping screw with a flat washer into the drilled hole. The flat washer must be large enough to seat against the shoulder of the plug bore. See Figure 9-2.

3. Tighten the self-tapping screw until it draws the plug out of the crankshaft.

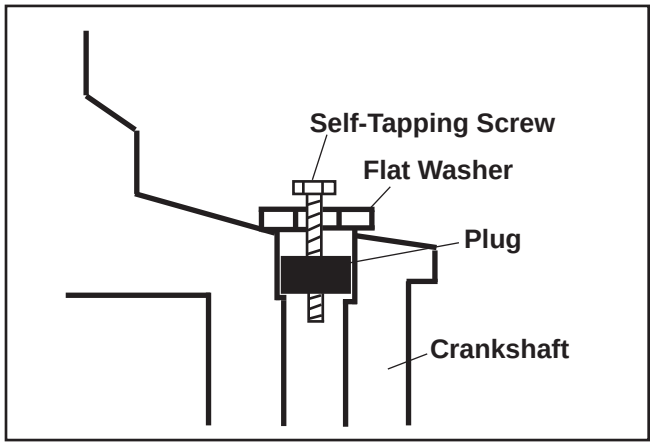


Figure 9-2. Removing Crankpin Plug.

Procedure to Install New Plug:

1. Use a single cylinder camshaft pin Part No. **47 380 09-S** as a driver and tap the plug into the plug bore until it seats at the bottom of the bore. Make sure the plug is tapped in evenly to prevent leakage.

Crankcase

Inspection and Service

Check all gasket surfaces to make sure they are free of gasket fragments. Gasket surfaces must also be free of deep scratches or nicks.

Check the cylinder bore for scoring. In severe cases, unburned fuel can cause scuffing and scoring of the cylinder wall. It washes the necessary lubricating oils off the piston and cylinder wall. As raw fuel seeps down the cylinder wall, the piston rings make metal to metal contact with the wall. Scoring of the cylinder wall can also be caused by localized hot spots resulting from blocked cooling fins or from inadequate or contaminated lubrication.

If the cylinder bore is badly scored, excessively worn, tapered, or out-of-round, resizing is necessary. Use an inside micrometer to determine the amount of wear (refer to **Specifications, Tolerances, and Special Torque Values** in Section 1), then select the nearest suitable oversize of either **0.25 mm (0.010 in.)** or **0.50 mm (0.020 in.)**. Resizing to one of these oversizes will allow usage of the available oversize piston and ring assemblies. First, resize using a boring bar, then use the following procedures for honing the cylinder.

Honing

While most commercially available cylinder hones can be used with either portable drills or drill presses, the use of a low speed drill press is preferred as it facilitates more accurate alignment of the bore in relation to the crankshaft crossbore. Honing is best accomplished at a drill speed of about **250 RPM** and **60 strokes** per minute. After installing coarse stones in hone, proceed as follows:

1. Lower hone into bore and after centering, adjust so that the stones are in contact with the cylinder wall. Use of a commercial cutting-cooling agent is recommended.

2. With the lower edge of each stone positioned even with the lowest edge of the bore, start drill and honing process. Move the hone up and down while resizing to prevent the formation of cutting ridges. Check the size frequently.

NOTE: Kohler pistons are custom-machined to exacting tolerances. When oversizing a cylinder, it should be machined exactly **0.25 mm (0.010 in.)** or **0.50 mm (0.020 in.)** over the new diameter (Section 1). The corresponding oversize Kohler replacement piston will then fit correctly.

3. When the bore is within **0.064 mm (0.0025 in.)** of the desired size, remove the coarse stones and replace them with burnishing stones. Continue with the burnishing stones until the bore is within **0.013 mm (0.0005 in.)** of the desired size and then use finish stones (220-280 grit) and polish the bore to its final size. A crosshatch should be observed if honing is done correctly. The crosshatch should intersect at approximately 23°-33° off the horizontal. Too flat an angle could cause the rings to skip and wear excessively, and too steep an angle will result in high oil consumption. See Figure 9-3.

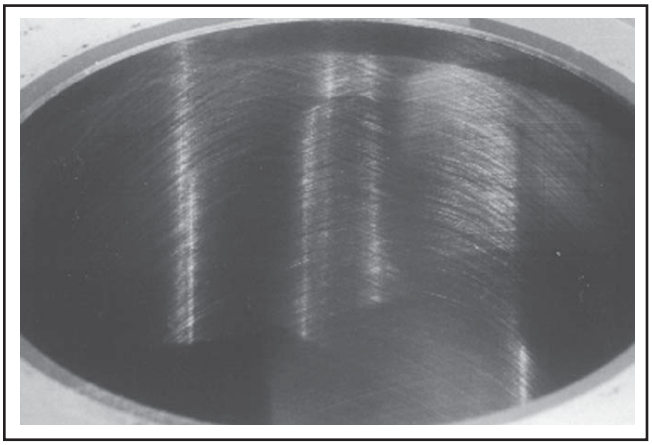


Figure 9-3. Cylinder Bore Crosshatch After Honing.

4. After resizing, check the bore for roundness, taper, and size. Use an inside micrometer, telescoping gauge, or bore gauge to take measurements. The measurements should be taken at three locations in the cylinder – at the top, middle, and bottom. Two measurements should be taken (perpendicular to each other) at each of the three locations.

Clean Cylinder Bore After Honing

Proper cleaning of the cylinder walls following boring and/or honing is very critical to a successful overhaul. Machining grit left in the cylinder bore can destroy an engine in less than one hour of operation after a rebuild.

The final cleaning operation should always be a thorough scrubbing with a brush and hot, soapy water. Use a strong detergent that is capable of breaking down the machining oil while maintaining a good level of suds. If the suds break down during cleaning, discard the dirty water and start again with more hot water and detergent. Following the scrubbing, rinse the cylinder with very hot, clear water, dry it completely, and apply a light coating of engine oil to prevent rusting.

Measuring Piston-to-Bore Clearance

Before installing the piston into the cylinder bore, it is necessary that the clearance be accurately checked. This step is often overlooked, and if the clearances are not within specifications, engine failure will usually result.

NOTE: Do not use a feeler gauge to measure piston-to-bore clearance–it will yield inaccurate measurements. Always use a micrometer.

Use the following procedure to accurately measure the piston-to-bore clearance:

1. Use a micrometer and measure the diameter of the piston **6 mm (0.24 in.)** above the bottom of the piston skirt and perpendicular to the piston pin. See Figure 9-4.

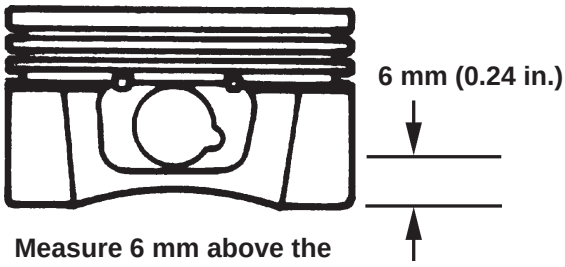


Figure 9-4. Measuring Piston Diameter.

2. Use an inside micrometer, telescoping gauge, or bore gauge and measure the cylinder bore. Take the measurement approximately **63.5 mm (2.5 in.)** below the top of the bore and perpendicular to the piston pin.

3. Piston-to-bore clearance is the difference between the bore diameter and the piston diameter (step 2 minus step 1).

Flywheel

Inspection

Inspect the flywheel for cracks, and the flywheel keyway for damage. Replace flywheel if it is cracked. Replace the flywheel, the crankshaft, and the key if the flywheel key is sheared or the keyway is damaged.

Inspect the ring gear for cracks or damage. Kohler does not provide ring gears as a serviceable part. Replace the flywheel if the ring gear is damaged.

Cylinder Head and Valves

Inspection and Service

After cleaning, check the flatness of the cylinder head and the corresponding top surface of the crankcase, using a surface plate or piece of glass and feeler gauge as shown in Figure 9-5. The maximum allowable out of flatness is **0.076 mm (0.003 in.)**.

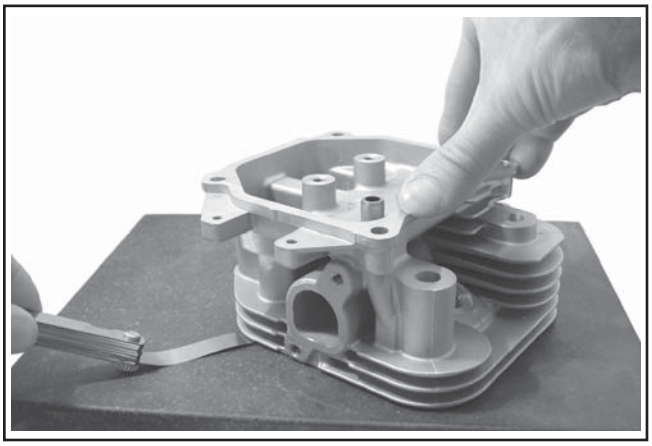
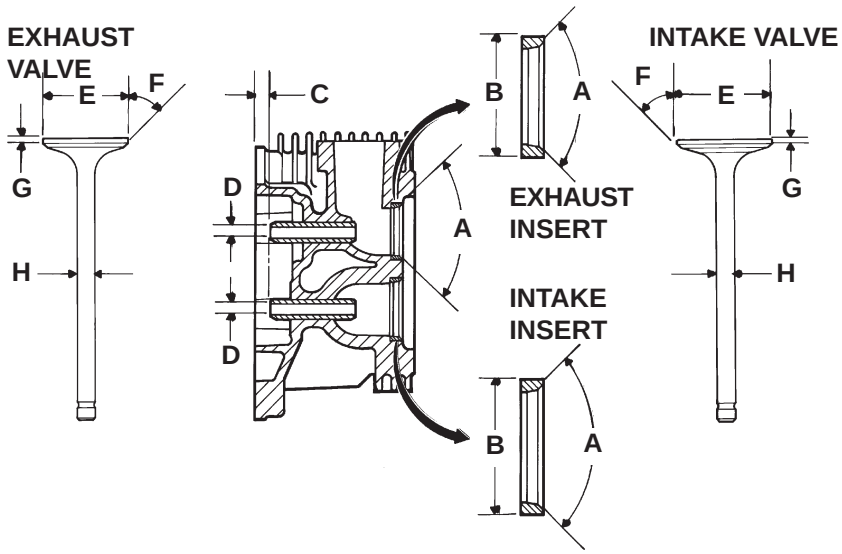


Figure 9-5. Checking Cylinder Head Flatness.

Carefully inspect the valve mechanism parts. Inspect the valve springs and related hardware for excessive wear or distortion. Check the valves and valve seat area or inserts for evidence of deep pitting, cracks, or distortion. Check clearance of the valve stems in the guides. See Figure 9-6 for valve details and specifications.



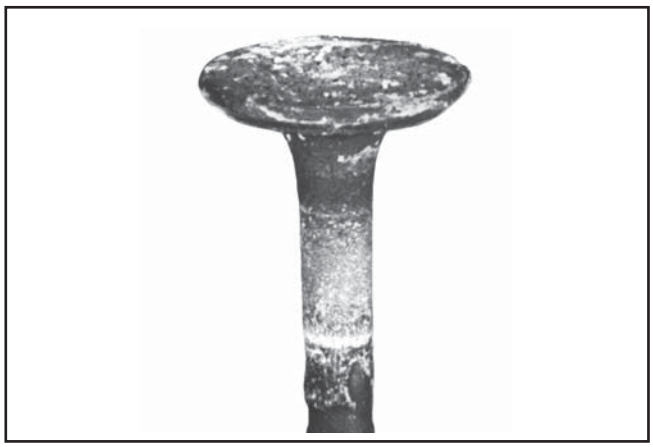
	Dimension	Intake	Exhaust
A	Seat Angle	89°	89°
B	Insert O.D.	36.987/37.013 mm (1.4562/1.4572 in.)	32.987/33.013 mm (1.2987/1.2997 in.)
C	Guide Depth	4 mm (0.1575 in.)	4 mm (0.1575 in.)
D	Guide I.D.	7.040/7.060 mm (0.2772/0.2780 in.)	7.040/7.060 mm (0.2772/0.2780 in.)
E	Valve Head Diameter	33.37/33.63 mm (1.3138/1.3240 in.)	29.37/29.63 mm (1.1563/1.1665 in.)
F	Valve Face Angle	45°	45°
G	Valve Margin (Min.)	1.5 mm (0.0591 in.)	1.5 mm (0.0591 in.)
H	Valve Stem Diameter	6.982/7.000 mm (0.2749/0.2756 in.)	6.970/6.988 mm (0.2744/0.2751 in.)

Figure 9-6. Valve Details.

Hard starting, or loss of power accompanied by high fuel consumption may be symptoms of faulty valves. Although these symptoms could also be attributed to worn rings, remove and check the valves first. After removal, clean the valve heads, faces, and stems with a power wire brush. Then, carefully inspect each valve for defects such as warped head, excessive corrosion, or worn stem end. Replace valves found to be in bad condition. A normal valve and valves in bad condition are shown in the accompanying illustrations.

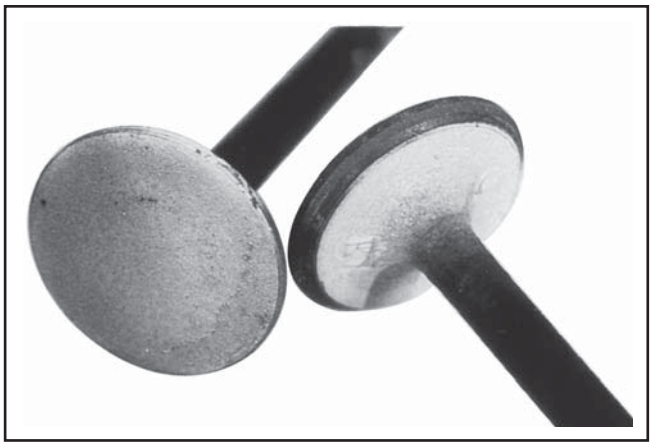
Normal: Even after long hours of operation a valve can be reconditioned and reused if the face and margin are in good shape. If a valve is worn to where the margin is less than 1/32 in. do not reuse it. The valve shown was in operation for almost 1000 hours under controlled test conditions.

Leakage: A poor grind on face or seat of valve will allow leakage resulting in a burned valve on one side only.



Bad Condition: The valve depicted here should be replaced. Note the warped head; margin damaged and too narrow. These conditions could be attributed to excessive hours or a combination of poor operating conditions.

Coking: Coking is normal on intake valves and is not harmful. If the seat is good, the valve could be reused after cleaning.



Excessive Combustion Temperatures: The white deposits seen here indicate very high combustion temperatures, usually due to a lean fuel mixture.

Stem Corrosion: Moisture in fuel or from condensation are the most common causes of valve stem corrosion. Condensation occurs from improper preservation during storage and when engine is repeatedly stopped before it has a chance to reach normal operating temperatures. Replace corroded valves.

Gum: Gum deposits usually result from using stale gasoline. Gum is a prevalent cause of valve sticking. The cure is to ream the valve guides and clean or replace the valves, depending on their condition.

Overheating: An exhaust valve subject to overheating will have a dark discoloration in the area above the valve guide. Worn guides and faulty valve springs may cause this condition. Also check for clogged air intake, and blocked fins when this condition is noted.

Valve Guides

If a valve guide is worn beyond specifications, it will not guide the valve in a straight line. This may result in burnt valve faces or seats, loss of compression, and excessive oil consumption.

To check valve guide-to-valve stem clearance, thoroughly clean the valve guide and, using a split-ball gauge, measure the inside diameter of the guide. Then, using an outside micrometer, measure the diameter of the valve stem at several points on the stem where it moves in the valve guide. Use the largest stem diameter to calculate the clearance by subtracting the stem diameter from the guide diameter. If the intake clearance exceeds **0.078 mm (0.0031 in.)** or the exhaust clearance exceeds **0.090 mm (0.0035 in.)**, determine whether the valve stem or guide is responsible for the excessive clearance.

The maximum (I.D.) wear on the intake valve guide is **7.134 mm (0.2809 in.)** while **7.159 mm (0.2819 in.)** is the maximum allowed on the exhaust guide. The guides are not removable but can be reamed **0.25 mm (0.010 in.)** oversize. Valves with 0.25 mm oversize stems must then be used.

If the guides are within limits but the valve stems are worn beyond limits, install new valves.

Valve Seat Inserts

Powder metal alloy intake and exhaust valve seat inserts are press-fitted into the cylinder head. The inserts are not replaceable but can be reconditioned if not too badly pitted or distorted. If cracked or badly warped, the cylinder head should be replaced.

Recondition the valve seat inserts following the instructions provided with the valve seat cutter being used. A typical cutter is shown in Figure 9-7. The final cut should be made with an 89° cutter as specified for the valve seat angle in Figure 9-6. Cutting the proper 45° valve face angle, as specified in Figure 9-6, and the proper valve seat angle (44.5°, half of the full 89° angle), will achieve the desired 0.5° (1.0° full cut) interference angle where the maximum pressure occurs on the outside diameters of the valve face and seat.

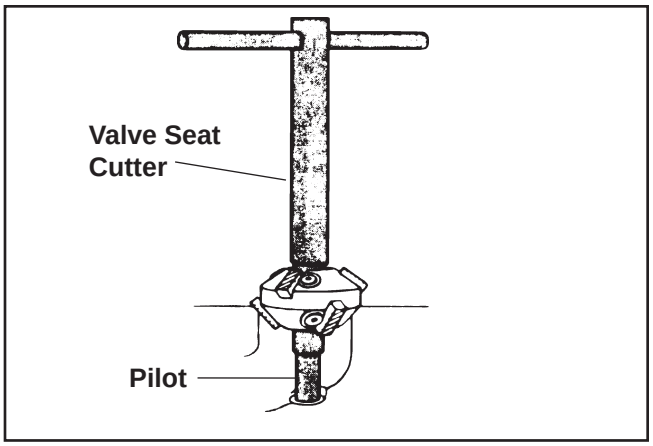


Figure 9-7. Typical Valve Seat Cutter.

Lapping Valves

Reground or new valves must be lapped in, to provide proper fit. Use a hand valve grinder with a suction cup for final lapping. Lightly coat the valve face with a "fine" grade of grinding compound, then rotate the valve on its seat with the grinder. Continue grinding until a smooth surface is obtained on the seat and on the valve face. Thoroughly clean the cylinder head in soap and hot water to remove all traces of grinding compound. After drying the cylinder head, apply a light coating of **SAE 10** oil to prevent rusting.

Valve Stem Seal

These engines use valve stem seals on the intake and exhaust valves. Always use a new seal when the valves are removed from the cylinder head. The seals should also be replaced if deteriorated or damaged in any way. **Never reuse an old seal.**

Pistons and Rings

Inspection

Scuffing and scoring of pistons and cylinder walls occurs when internal engine temperatures approach the welding point of the piston. Temperatures high enough to do this are created by friction, which is usually attributed to improper lubrication and/or overheating of the engine.

Normally, very little wear takes place in the piston boss-piston pin area. If the original piston and connecting rod can be reused after new rings are installed, the original pin can also be reused but new piston pin retainers are required. The piston pin is included as part of the piston assembly – if the pin boss in the piston or the pin are worn or damaged, a new piston assembly is required.

Ring failure is usually indicated by excessive oil consumption and blue exhaust smoke. When rings fail, oil is allowed to enter the combustion chamber where it is burned along with the fuel. High oil consumption can also occur when the piston ring end gap is incorrect because the ring cannot properly conform to the cylinder wall under this condition. Oil control is also lost when ring gaps are not staggered during installation.

When cylinder temperatures get too high, lacquer and varnish collect on pistons causing rings to stick, which results in rapid wear. A worn ring usually takes on a shiny or bright appearance.

Scratches on rings and pistons are caused by abrasive material such as carbon, dirt, or pieces of hard metal.

Detonation damage occurs when a portion of the fuel charge ignites spontaneously from heat and pressure shortly after ignition. This creates two flame fronts, which meet and explode to create extreme hammering pressures on a specific area of the piston. Detonation generally occurs from using low octane fuels.

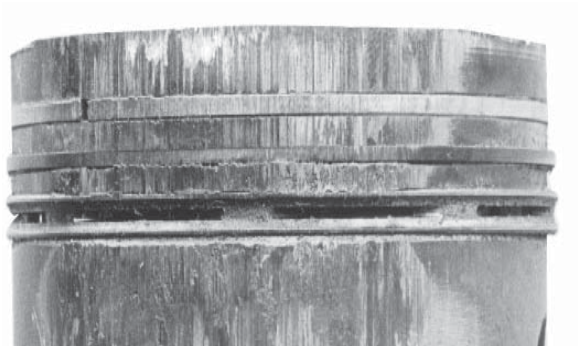
Preignition or ignition of the fuel charge before the timed spark can cause damage similar to detonation. Preignition damage is often more severe than detonation damage. Preignition is caused by a hot spot in the combustion chamber from sources such as glowing carbon deposits, blocked cooling fins, an improperly seated valve, or wrong spark plug(s).

See Figure 9-8 for some common types of piston and ring damage.

Stuck, Broken Rings

Abrasive Scratched Rings

Overheated or Deteriorated Oil



Scored Piston and Rings

Figure 9-8. Common Types of Piston Damage.

Replacement pistons are available in STD bore size, and 0.25 mm (0.010 in.), and 0.50 mm (0.020 in.) oversize. Replacement pistons include new piston ring sets and new piston pins.

Replacement ring sets are also available separately for STD, 0.25 mm (0.010 in.), and 0.50 mm (0.020 in.) oversize pistons. Always use new piston rings when installing pistons. Never use old rings.

Some important points to remember when servicing piston rings:

1. The cylinder bore must be deglazed before service ring sets are used.

2. If the cylinder bore does not need reboring and if the old piston is within wear limits and free of score or scuff marks, the old piston may be reused.

3. Remove the old rings and clean up the grooves. **Never reuse old rings.**

4. Before installing the new rings on the piston, place the top two rings, each in turn, in its running area in the cylinder bore and check the end gap. See Figure 9-9. Compare the ring gap to the specifications listed in Section 1.

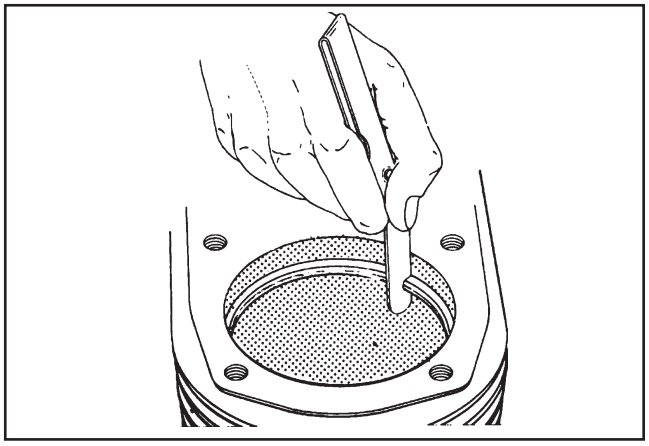


Figure 9-9. Measuring Piston Ring End Gap.

5. After installing the new compression (top and middle) rings on the piston, check the piston-to-ring side clearance. Compare the clearance to specifications listed in Section 1. If the side clearance is greater than specified, a new piston must be used. Refer to Figure 9-10.

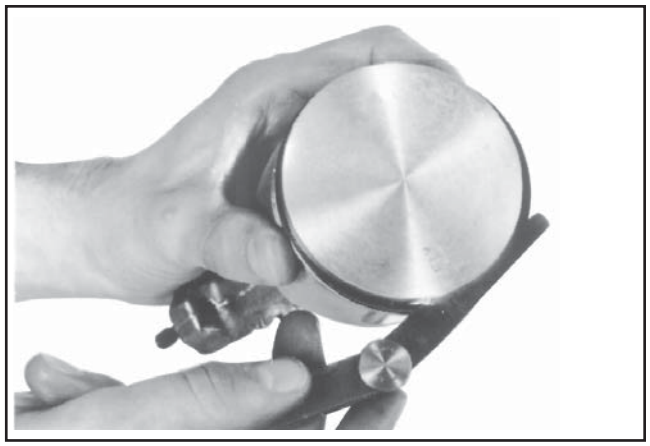


Figure 9-10. Measuring Piston Ring Side Clearance.

Install New Piston Rings

To install new piston rings, proceed as follows:

NOTE: Rings must be installed correctly. Ring installation instructions are usually included with new ring sets. Follow instructions carefully. Use a piston ring expander to install rings. See Figure 9-11. Install the bottom (oil control) ring first and the top compression ring last. Refer to Figure 9-12.

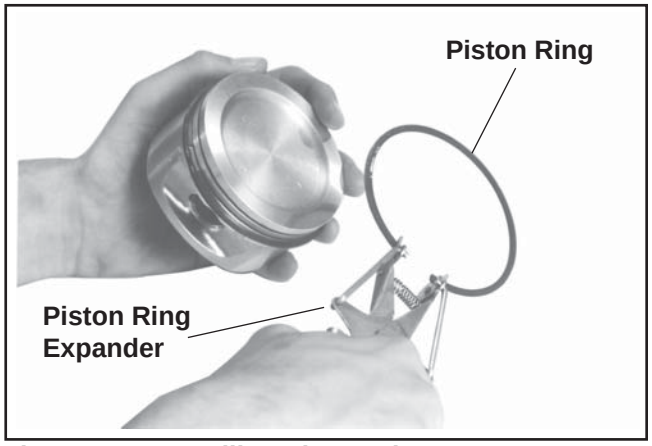


Figure 9-11. Installing Piston Rings.

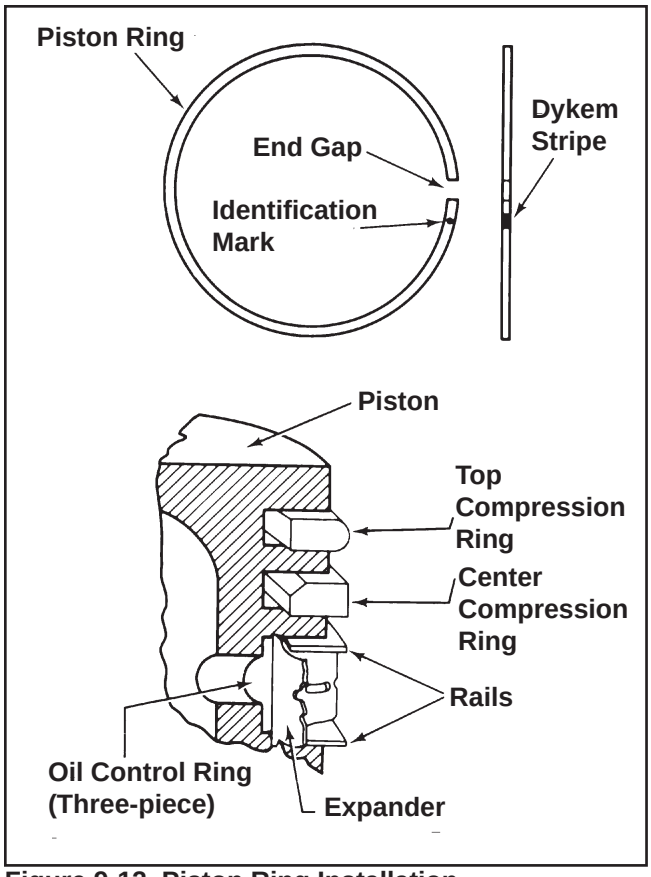


Figure 9-12. Piston Ring Installation.

1. Oil Control Ring (Bottom Groove): Install the expander and then the rails. Make sure the ends of the expander are not overlapped.

2. Middle Compression Ring (Center Groove): Install the center ring using a piston ring expander tool. Make sure the "identification" mark is up or the dykem stripe (if contained) is to the left of the end gap.

3. Top Compression Ring (Top Groove): Install the top ring using a piston ring expander. Make sure the "identification" mark is up or the dykem stripe (if contained), is to the left of the end gap.

Connecting Rods

Offset, stepped-cap connecting rods are used in all these engines.

Inspection and Service

Check the bearing area (big end) for excessive wear, score marks, running and side clearances (refer to Section 1, **Specifications, Tolerances, and Special Torque Values**). Replace the rod and cap if scored or excessively worn.

Service replacement connecting rods are available in STD crankpin size and **0.25 mm (0.010 in.)** undersize. The **0.25 mm (0.010 in.)** undersized rods have an identification marking on the lower end of the rod shank. Always refer to the appropriate parts information to ensure that correct replacements are used.

Hydraulic Lifters

Inspection

Check the base surface of the hydraulic lifters for wear or damage. If the lifters need to be replaced, apply a liberal coating of Kohler lubricant (see Section 2) to the base of each new lifter before it is installed.

"Bleeding" the Lifters

To prevent a possible bent push rod or broken rocker arm, it is important to "bleed" any excess oil out of the lifters before they are installed.

1. Cut a 50-75 mm (2-3 in.) piece from the end of an old push rod and chuck it in a drill press.

2. Lay a rag or shop towel on the table of the drill press and place the lifter, open end up, on the towel.

3. Lower the chucked push rod until it contacts the plunger in the lifter. Slowly "pump" the plunger two or three times to force the oil out of the feed hole in the side of the lifter.

Oil Pan Assembly

Inspection

Inspect the oil seal in the oil pan and remove it if it is worn or damaged. Refer to **Install Oil Seal in Oil Pan** in Section 10 for new oil seal installation.

Inspect the main bearing surface for wear or damage (refer to Section 1, **Specifications, Tolerances, and Special Torque Values**). Replace the oil pan assembly if required.

Governor Gear Assembly

Inspection

Inspect the governor gear teeth. Replace the gear if it is worn, chipped, or if any teeth are missing. Inspect the governor weights. They should move freely in the governor gear.

Disassembly

The governor gear **must** be replaced once it is removed from the oil pan.

NOTE: The governor gear is held onto the shaft by small molded tabs in the gear. When the gear is removed from the shaft, these tabs are destroyed and the gear must be replaced. Therefore, remove the gear **only** if absolutely necessary.

1. Remove the regulating pin and governor gear assembly. See Figure 9-13.

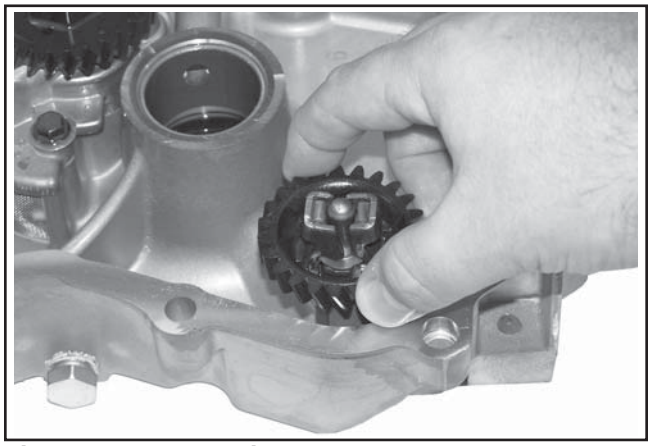


Figure 9-13. Removing Governor Gear.

2. Remove the locking tab thrust washer located under the governor gear assembly.

3. Carefully inspect the governor gear shaft and replace it only if it is damaged. After removing the damaged shaft, press or lightly tap the replacement shaft into the oil pan to the depth shown in Figure 9-14.

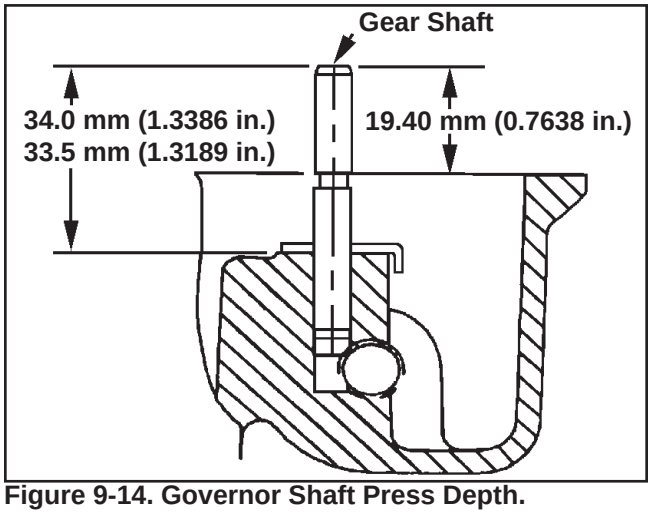


Figure 9-14. Governor Shaft Press Depth.

Reassembly

1. Install the locking tab thrust washer on the governor gear shaft with the tab down.

2. Position the regulating pin within the governor gear/flyweight assembly and slide both onto governor shaft.

Oil Pump Assembly

Disassembly

1. Remove the two hex flange screws.

2. Remove the oil pump assembly from the oil pan.

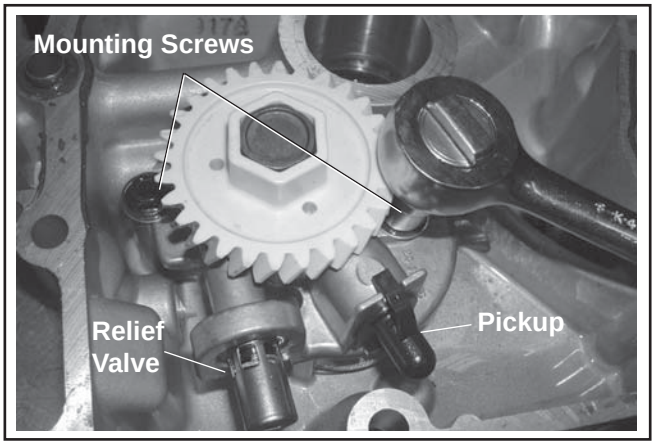


Figure 9-15. Removing Oil Pump.

3. Remove the oil pump rotor. Unhook the locking clip, and carefully pull it free from the oil pump housing.

   The relief valve is a one-piece style, staked to the oil pump housing. See Figure 9-16. Removal should not be attempted, nor is internal servicing possible. If a problem with the relief valve is encountered, the oil pump should be replaced.

Inspection

Inspect the oil pump housing, gear, and rotors for nicks, burrs, wear, or any visible damage. If any parts are worn or damaged, replace the oil pump.

Figure 9-16. Oil Pump, Plastic Oil Pickup, and One-Piece Relief Valve.

Reassembly

1. Install the oil pickup to the oil pump body. Lubricate the O-ring with oil and make sure it remains in the groove as the pickup is being installed.

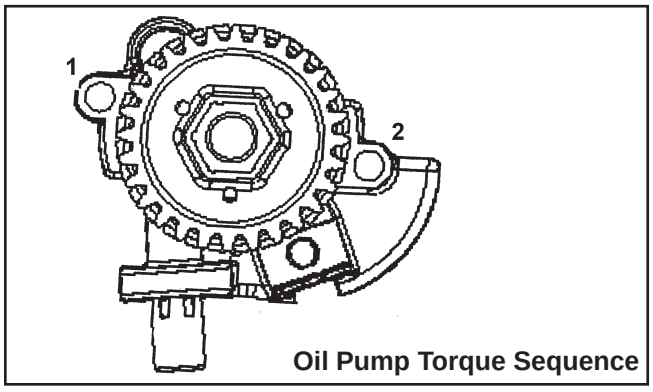
2. Install the rotor.

3. Install the oil pump body to the oil pan and secure with the two hex flange screws. Torque the hex flange screws as follows:

   a. Install fastener into location No. 1 and lightly tighten to position pump.

   b. Install fastener into location No. 2 and fully torque to the recommended value.

   c. Torque fastener in location No. 1 to the recommended value.



First Time Installation:	10.7 N·m (95 in. lb.)
All Reinstallations:	6.7 N·m (60 in. lb.)

4. After torquing, rotate the gear and check for freedom of movement. Make sure there is no binding. If binding occurs, loosen the screws, reposition the pump, retorque the hex flange screws and recheck the movement.

Crankcase Breather System

The breather system is designed to control the amount of oil in the head area and still maintain the necessary vacuum in the crankcase.

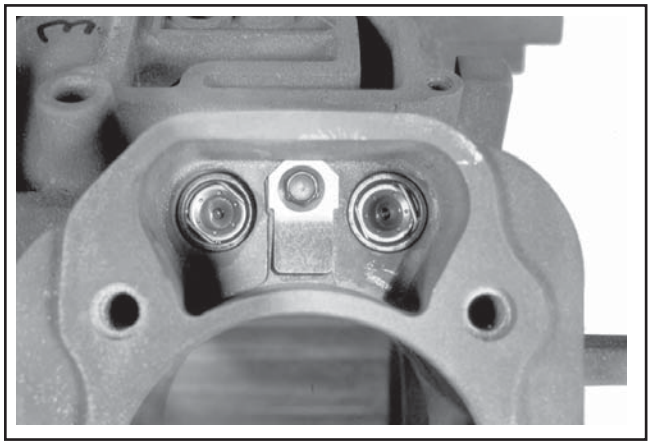


Figure 9-17. Crankcase with Breather Reed.

A spring steel reed and stop is mounted on each bank of the crankcase, between the lifter bores. See Figure 9-17. When the pistons move downward, air is pushed past the reeds into the cylinder head cavities. On the #2 cylinder, the upper end of the head is completely sealed by the rocker cover, so a low, positive pressure is created in the head cavity. The #1 rocker cover has a hole in it for venting. The bottom nipple of an oil separator canister is fitted into the hole with a grommet. From the top nipple of the canister, a breather hose goes back to the air cleaner base. The air moving into the #1 head cavity is filtered through the oil separator and then is drawn into the air intake. See Figure 9-18.

The upward travel of the pistons closes the reeds and creates a low vacuum in the lower crankcase. The combination of low pressure above and low vacuum below forces any accumulated oil out of the #2 head area into the crankcase. On the #1 bank you have atmospheric pressure above and vacuum below, again drawing any oil toward the crankcase.

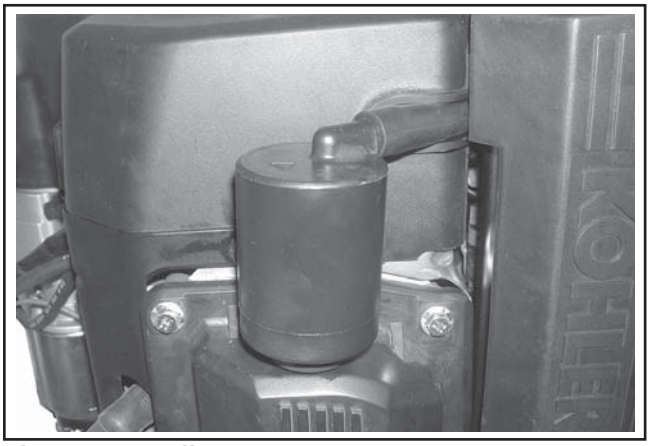


Figure 9-18. Oil Separator.

Governor Cross Shaft Oil Seal

If the governor cross shaft seal is damaged and/or leaks, replace it using the following procedure.

Remove the oil seal from the crankcase and replace it with a new one. Install the new seal to the depth shown in Figure 9-19 using a seal installer.

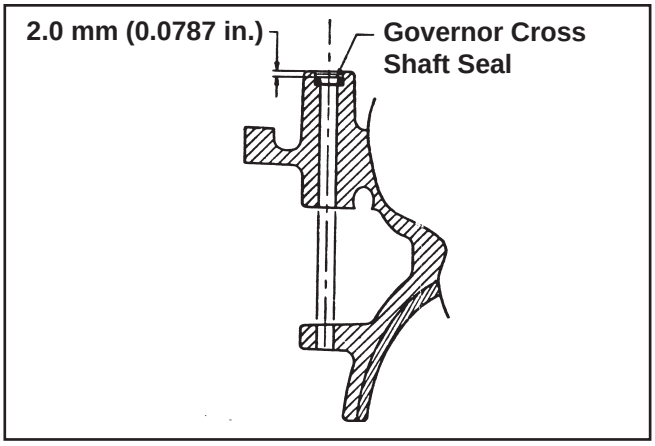


Figure 9-19. Installing Cross Shaft Oil Seal.

Section 10
Reassembly

General

NOTE: Make sure the engine is assembled using all specified torque values, tightening sequences, and clearances. Failure to observe specifications could cause severe engine wear or damage. Always use new gaskets. Apply a small amount of oil to the threads of critical fasteners before assembly, unless a Sealant or Loctite® is specified or preapplied.

Make sure all traces of any cleaner are removed before the engine is assembled and placed into operation. Even small amounts of these cleaners can quickly break down the lubricating properties of engine oil.

Check the oil pan, crankcase, and cylinder heads to be certain that all old sealing material has been removed. Use gasket remover, lacquer thinner, or paint remover to remove any remaining traces. Clean the surfaces with isopropyl alcohol, acetone, lacquer thinner, or electrical contact cleaner.

Typical Reassembly Sequence

The following sequence is suggested for complete engine reassembly. This procedure assumes that all components are new or have been reconditioned, and all component subassembly work has been completed. The sequence may vary to accommodate options or special equipment. Detailed procedures follow:

1. Install flywheel end oil seal.
2. Install crankshaft.
3. Install connecting rods with pistons and rings.
4. Install governor cross shaft.
5. Install camshaft.
6. Install oil pan assembly.
7. Install stator and backing plate.
8. Install flywheel and fan.
9. Install cylinder heads and hydraulic lifters.
10. Install push rods and rocker arms.
11. Install spark plugs.
12. Install intake manifold.
13. Install fuel injectors.
14. Install manifold absolute pressure sensor.
15. Install crankshaft position sensor.
16. Install valve covers.
17. Install breather cover and inner baffles.
18. Install oil temperature sensor.
19. Install Oil Sentry™.
20. Install blower housing and outer baffles.
21. Install grass screen.
22. Install oil separator and hardware.
23. Install electronic control unit bracket and electric starter motor.
24. Install electronic control unit.
25. Install throttle body.
26. Install lift fuel pump and fuel pump module.
27. Install external governor controls.
28. Install throttle control panel.
29. Install air cleaner assembly (see Section 4).
30. Install muffler.
31. Install oil cooler.
32. Install oil filter and fill crankcase with oil.
33. Connect spark plug leads.

Install Flywheel End Oil Seal

1. Make sure that the seal bore of the crankcase is clean and free of any nicks or burrs. See Figure 10-1.

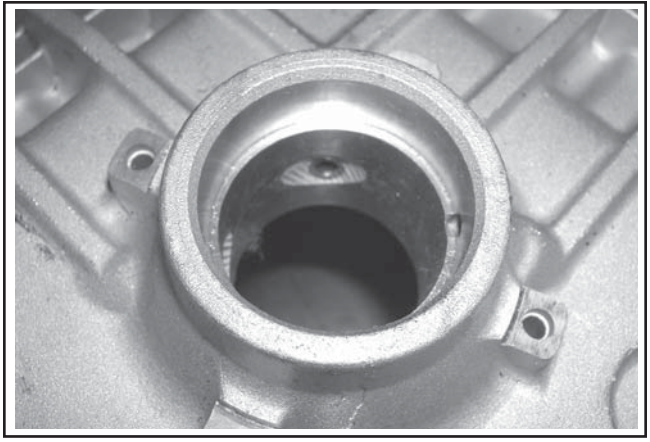


Figure 10-1. Seal Bore of Crankcase.

2. Apply a light coat of engine oil to the outside diameter of the oil seal.

3. Drive the oil seal into the crankcase using a seal driver. Make sure the oil seal is installed straight and true in the bore to the depth shown in Figure 10-2.

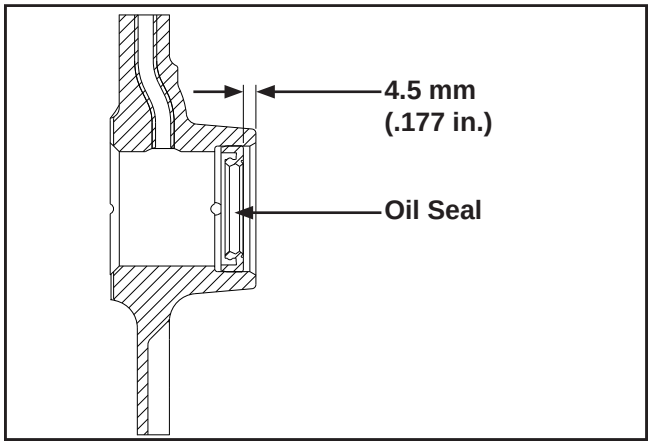


Figure 10-2. Installing Oil Seal in Crankcase.

Install Crankshaft

1. Lubricate the crankshaft journals and connecting rod bearing surfaces with engine oil.

2. Carefully slide the flywheel end of the crankshaft through the main bearing in the crankcase. See Figure 10-3.

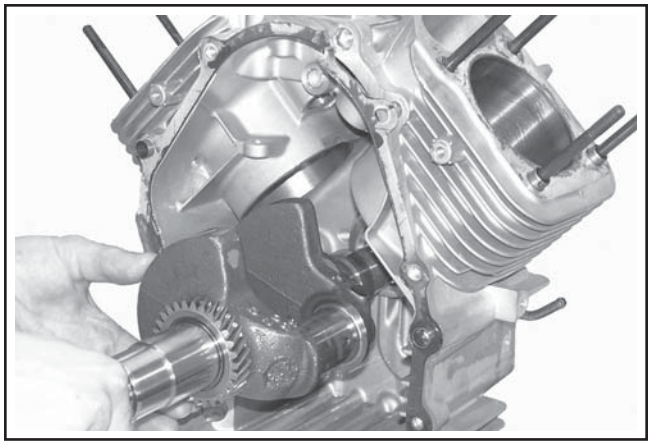


Figure 10-3. Installing Crankshaft.

Install Connecting Rods with Pistons and Rings

NOTE: The cylinders are numbered on the crankcase. Make sure to install the piston, connecting rod, and end cap into its appropriate cylinder bore as previously marked at disassembly. **Do not** mix the end caps and connecting rods.

NOTE: Proper orientation of the piston/connecting rod assemblies inside the engine is extremely important. Improper orientation can cause extensive wear or damage. Be certain the pistons and connecting rods are assembled exactly as shown in Figure 10-4.

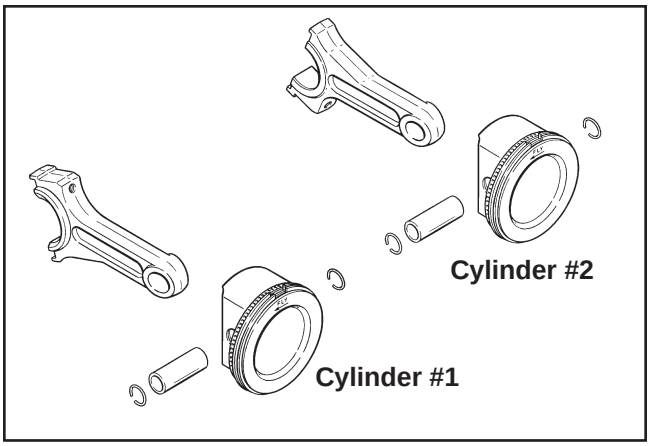


Figure 10-4. Proper Piston Connecting Rod Orientation.

1. Stagger the piston rings in the grooves until the end gaps are 120° apart. The oil ring rails should also be staggered.

2. Lubricate the cylinder bore, piston, and piston rings with engine oil. Compress the rings using a piston ring compressor.

3. Make sure the **Fly** stamping on the piston is facing towards the flywheel side of the engine. Use a hammer with a rubber grip and gently tap the piston into the cylinder as shown in Figure 10-5. Be careful that the oil ring rails do not spring free between the bottom of the ring compressor and the top of the cylinder.

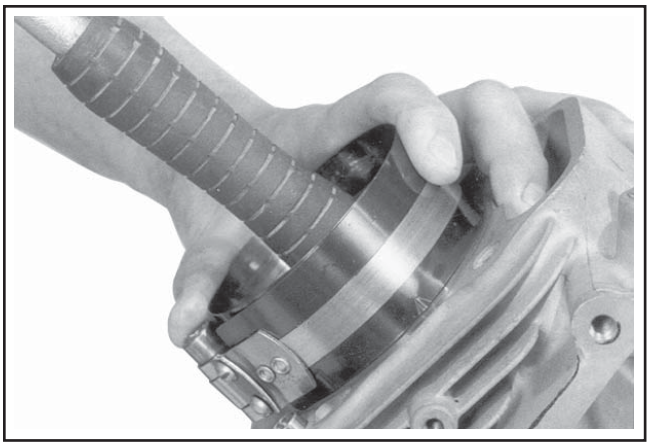


Figure 10-5. Installing Piston Assembly Using Ring Compressor Tool.

4. Install the inner rod cap to the connecting rod using the two hex flange screws. Torque in increments to **11.6 N·m (103 in. lb.)**. Illustrated instructions are provided in the service rod package. See Figure 10-6.

NOTE: Align the chamfer of the connecting rod with the chamfer of its mating end cap. When installed, the flat faces of the connecting rods should face each other. The faces with the raised rib should be toward the outside.

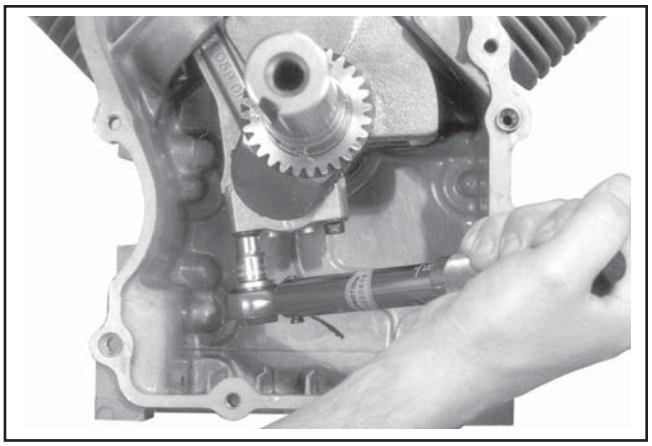


Figure 10-6. Torquing Connecting Rod End Cap.

5. Repeat the above procedure for the other connecting rod and piston assembly.

Install Governor Cross Shaft

1. Lubricate the governor cross shaft bearing surfaces in the crankcase with engine oil.

2. Slide the small lower washer onto the governor cross shaft and install the cross shaft from the inside of the crankcase.

3. Install the nylon washer onto the governor cross shaft, then start the push-on retaining ring. Hold the cross shaft up in position, place a **0.50 mm (0.020 in.)** feeler gauge on top of the nylon washer, and push the retaining ring down the shaft to secure. Remove the feeler gauge, which will have established the proper end play. See Figures 10-7 and 10-8.

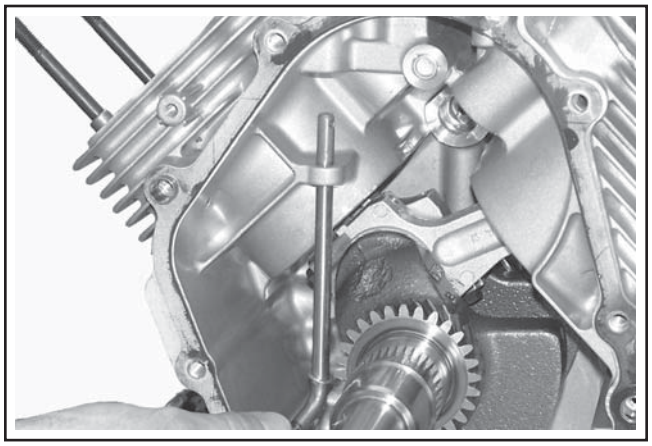


Figure 10-7. Installing Governor Cross Shaft.

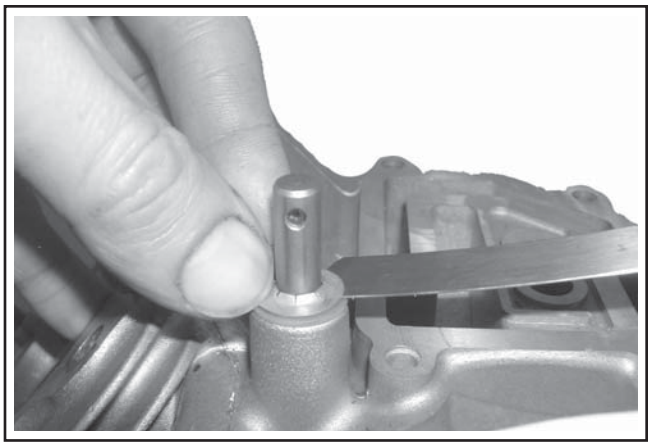


Figure 10-8. Setting Governor Cross Shaft End Play.

Install Camshaft

1. Liberally apply camshaft lubricant (see Section 2) to each of the cam lobes. Lubricate the camshaft bearing surfaces of the crankcase and camshaft with engine oil. See Figure 10-9.

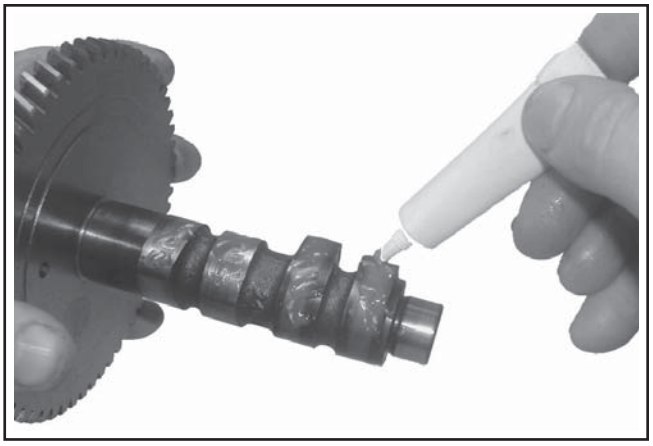


Figure 10-9. Apply Camshaft Lubricant to Cam Lobes.

2. Position the timing mark of the crankshaft gear at the 12 o'clock position.

3. Turn the governor cross shaft clockwise until the lower end of the shaft contacts the cylinder. Make sure the cross shaft remains in this position while installing the camshaft. See Figure 10-10.

4. Slide the camshaft into the bearing surface of the crankcase, positioning the timing mark of camshaft gear at the 6 o'clock position. Make sure the camshaft gear and crankshaft gear mesh with both timing marks aligned. See Figure 10-10.

5. Install the shim removed during disassembly onto the camshaft.

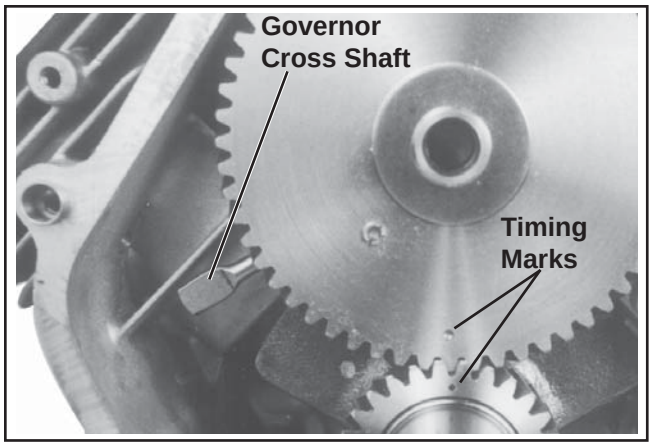


Figure 10-10. Aligning Crankshaft and Camshaft Timing Marks.

Oil Pump Assembly

The oil pump is mounted inside the oil pan. If service was required, and the oil pump was removed, refer to the assembly procedures under **Oil Pump Assembly** in Section 9.

Governor Gear Assembly

The governor gear assembly is located inside the oil pan. If service was required, and the governor was removed, refer to the assembly procedures under **Governor Gear Assembly** in Section 9.

Install Oil Seal in Oil Pan

1. Check to make sure that there are no nicks or burrs in the crankshaft bore of the oil pan.

2. Apply a light coat of engine oil to the outside diameter of the oil seal.

3. Drive the oil seal into the oil pan using a seal driver. Make sure the oil seal is installed straight and true in the bore, to the depth shown in Figures 10-11 and 10-12.

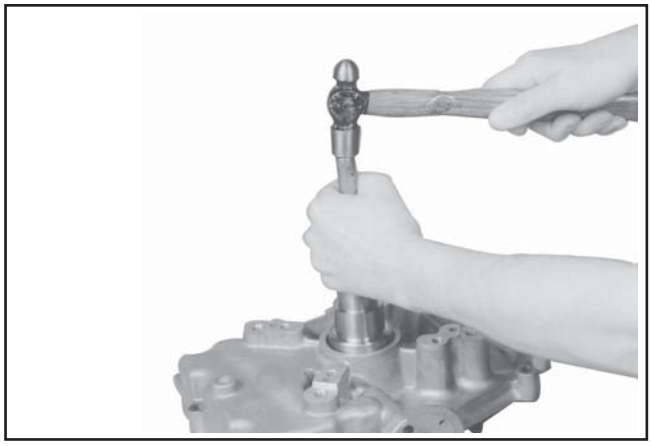


Figure 10-11. Installing Oil Seal in Oil Pan.

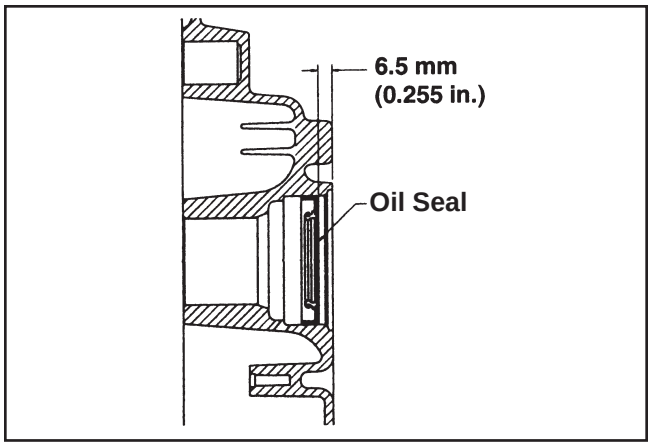


Figure 10-12. Oil Seal Depth in Oil Pan.

Install Oil Pan Assembly

Most engines use an oil pan gasket. Optionally, RTV sealant is used as a gasket between the oil pan and the crankcase. When assembling the oil pan, only use a gasket if a gasket was removed. Likewise, if RTV was used, only replace with RTV. **Do Not** use both. Refer to Section 2 for a listing of approved sealants. Always use fresh sealant. Using outdated sealant can result in leakage.

1. Be sure the sealing surfaces have been cleaned and prepared as described at the beginning of Section 10 or in Service Bulletin 252.

2. Check to make sure that there are no nicks or burrs on the sealing surfaces of the oil pan or crankcase.

3. Use a new gasket or apply RTV.

   a. For an oil pan with a gasket:

      1. Before installing the gasket, check to make sure O-ring is present in counter bore around the dowel pin.

   b. For an oil pan with RTV:

      1. Apply a **1.5 mm (1/16 in.)** bead of sealant to the sealing surface of the oil pan. Verify O-ring is present. See Figure 10-13 for the sealant pattern.

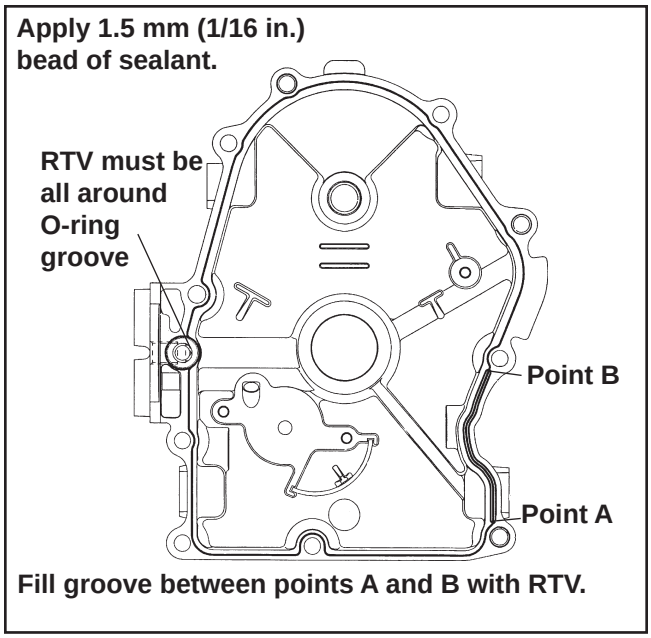


Figure 10-13. Oil Pan Sealant Pattern.

4. Make sure the end of the governor cross shaft is lying against the bottom of cylinder 1 inside the crankcase. See Figure 10-10.

5. Install the oil pan to the crankcase. Carefully seat the camshaft and the crankshaft into their mating bearings. Rotate the crankshaft slightly to help engage the oil pump and governor gear meshes.

6. Install the ten hex flange screws securing the oil pan to the crankcase. Torque the fasteners in the sequence shown in Figure 10-14 to **25.6 N·m (227 in. lb.)**. One of the ten mounting screws has a thread sealant patch. This screw is typically installed in the number 10 hole shown in Figure 10-14. Reapply pipe sealant with Teflon® (Loctite® 592™ PST® Thread Sealant or equivalent) to the number 10 oil pan screw as required. See Figure 10-15.

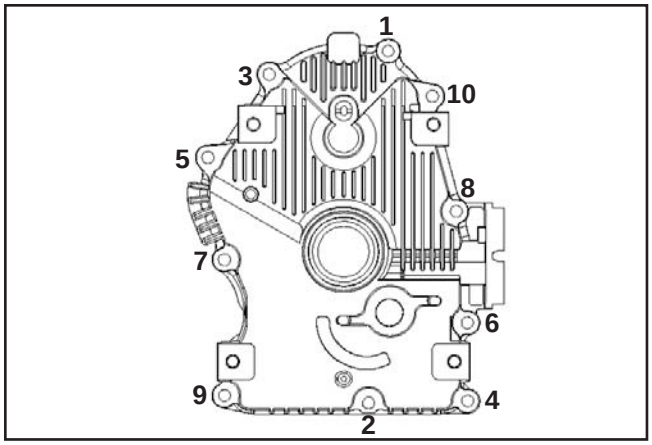


Figure 10-14. Oil Pan Fastener Torque Sequence.

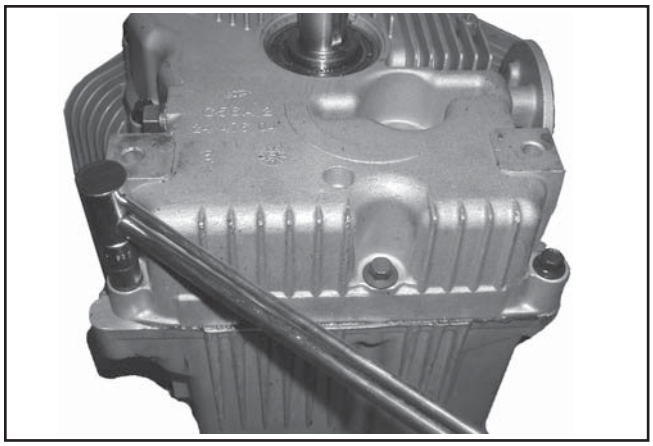


Figure 10-15. Torquing Oil Pan Fasteners.

Install Stator and Backing Plate

1. Apply pipe sealant with Teflon® (Loctite® 592™ PST® Thread Sealant or equivalent) to the stator mounting holes.

2. Position the stator aligning the mounting holes so that the leads are at the bottom, towards the crankcase.

3. Install and torque the two hex flange screws to **6.2 N·m (55 in. lb.)** for new holes or **4.0 N·m (35 in. lb.)** for used holes. See Figure 10-16.

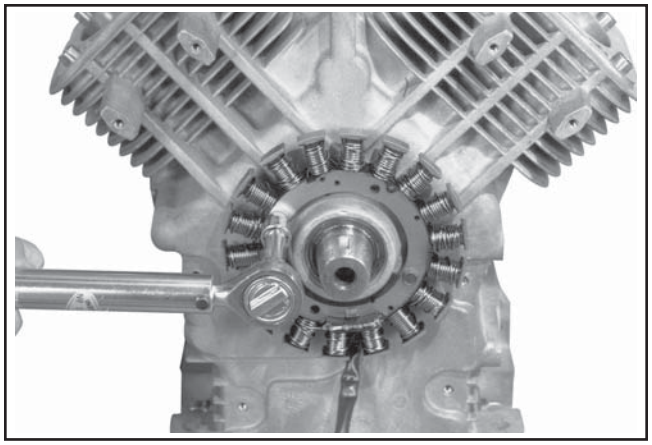


Figure 10-16. Torquing Stator Screws.

4. Route the stator leads in the crankcase channel, then install the backing plate. Secure with the four hex flange screws. See Figures 10-17 and 10-18. Torque the screws **10.7 N·m (95 in. lb.)** for new holes or **7.3 N·m (65 in. lb.)** for used holes.

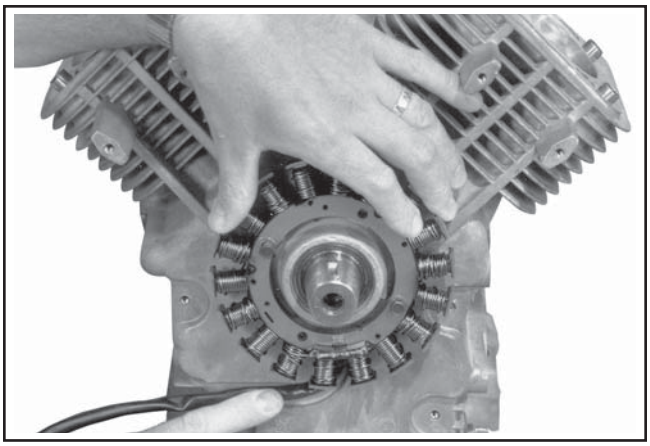


Figure 10-17. Route Stator Leads in Groove.

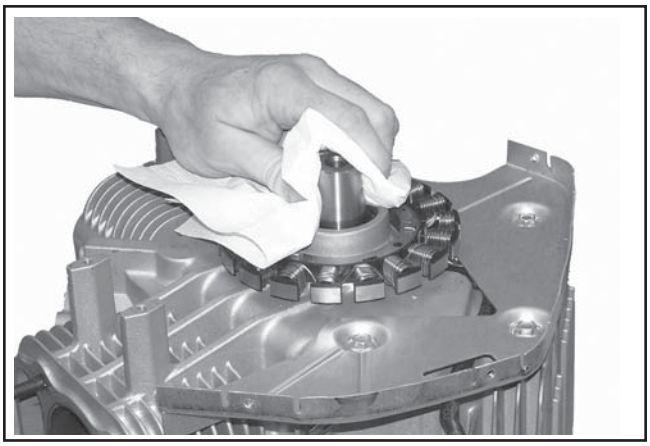


Figure 10-19. Clean and Dry Taper of Crankshaft.

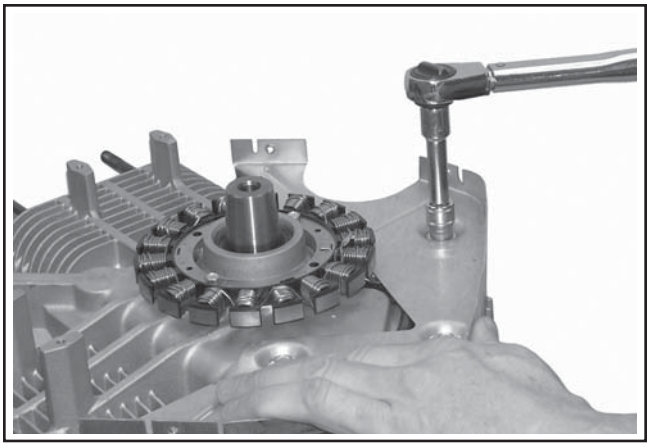


Figure 10-18. Installing Backing Plate.

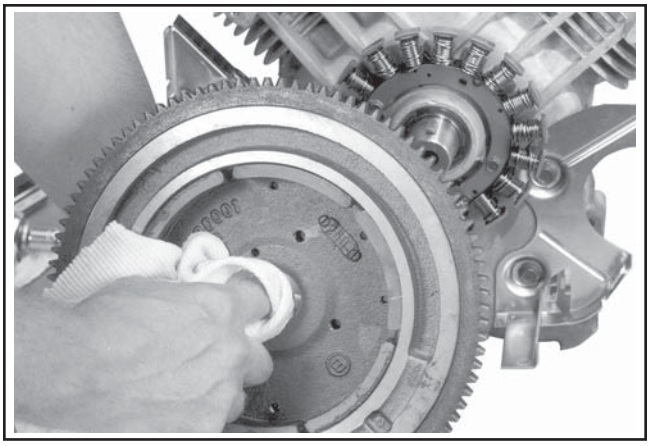


Figure 10-20. Clean and Dry Flywheel Hub.

Install Flywheel and Fan

⚠ WARNING: Damaging Crankshaft and Flywheel Can Cause Personal Injury!

Using improper procedures to install the flywheel can crack or damage the crankshaft and/or flywheel. This not only causes extensive engine damage, but can also cause personal injury, since broken fragments could be thrown from the engine. Always observe and use the following precautions and procedures when installing the flywheel.

NOTE: Before installing the flywheel, make sure the crankshaft taper and flywheel hub are clean, dry, and completely free of any lubricants. The presence of lubricants can cause the flywheel to be over stressed and damaged when the hex flange screw is torqued to specifications. See Figures 10-19 and 10-20.

1. Install the woodruff key into the keyway of the crankshaft. Make sure that the key is properly seated and parallel with the shaft taper.

   NOTE: Make sure the flywheel key is installed properly in the keyway. The flywheel can become cracked or damaged if the key is not properly installed.

2. Install the flywheel onto the crankshaft being careful not to shift the woodruff key. See Figure 10-21.

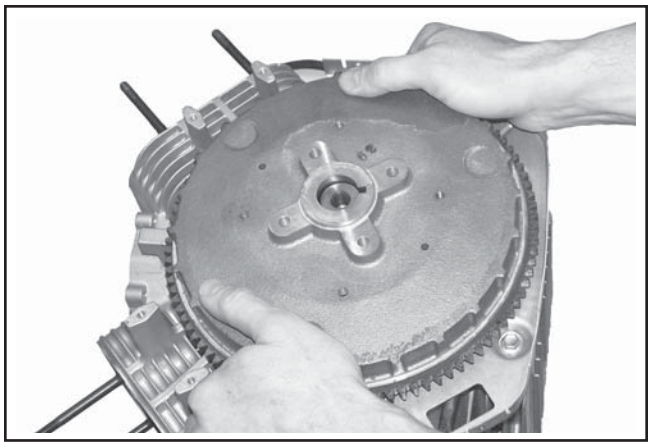


Figure 10-21. Carefully Align Keyway to Key.

3. Install the hex flange screw and washer.

4. Use a flywheel strap wrench or holding tool to hold the flywheel. Torque the hex flange screw securing the flywheel to the crankshaft to **71.6 N·m (52.8 ft. lb.)**. See Figure 10-22.

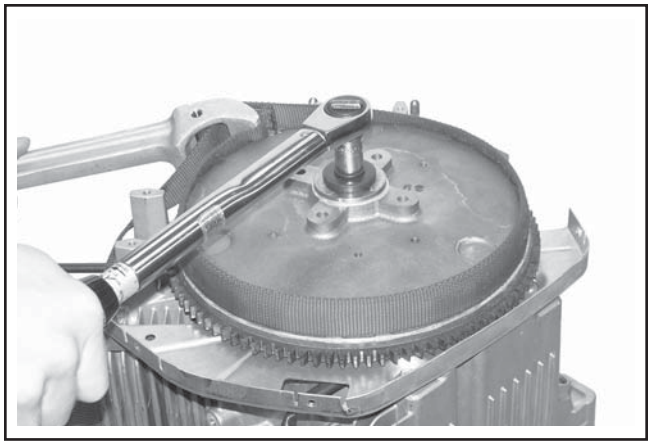


Figure 10-22. Installing and Torquing Flywheel Fastener.

Install Fan

1. Install the fan onto the flywheel using the four hex flange screws (engines with plastic grass screen). For engines with a metal grass screen, leave it loosely assembled.

NOTE: Position the locating tabs on the back of the fan into the locating holes of the flywheel. See Figure 10-23.

2. Torque the screws to **9.9 N·m (88 in. lb.)**.

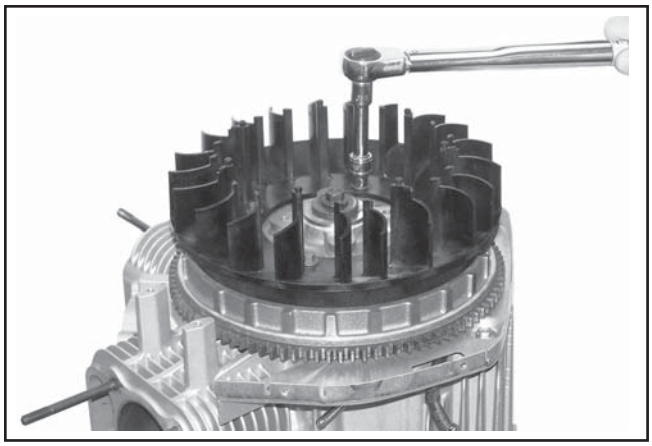


Figure 10-23. Installing Fan.

Install Cylinder Heads and Hydraulic Lifters

1. See **Servicing Hydraulic Lifters** in Section 9 for lifter preparation (bleed down) procedures.

2. Apply camshaft lubricant (see Section 2) to the bottom surface of each lifter. See Figure 10-24. Lubricate the hydraulic lifters and the lifter bores in the crankcase with engine oil.

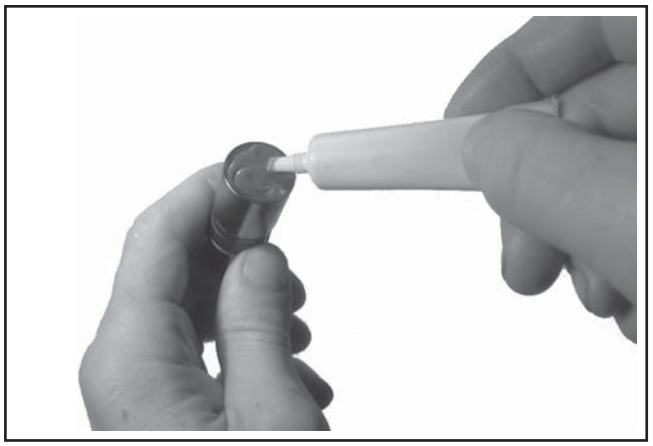


Figure 10-24. Applying Camshaft Lubricant to Bottom of Lifters.

3. Note the mark or tag identifying the hydraulic lifters as either intake or exhaust and cylinder 1 or cylinder 2. Install the hydraulic lifters into their appropriate locations in the crankcase. **Do not** use a magnet. See Figure 10-25.

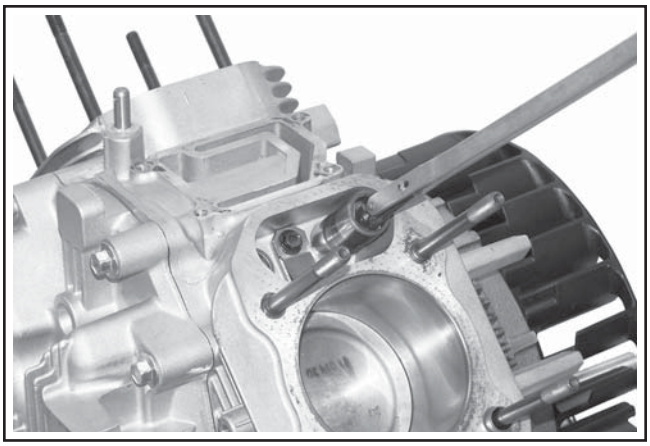


Figure 10-25. Installing Hydraulic Lifters.

NOTE: Hydraulic lifters should always be installed in the same position as before disassembly. The exhaust lifters are located on the output shaft (oil pan) side of the engine while the intake lifters are located on the fan side of the engine. The cylinder numbers are embossed on the top of the crankcase and each cylinder head. See Figure 10-26.

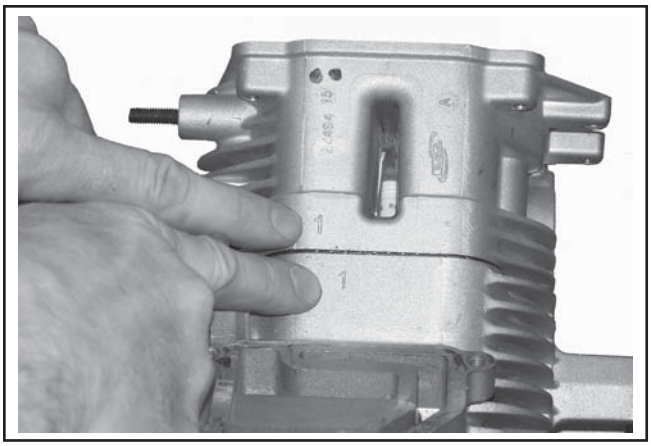


Figure 10-26. Match Numbers on Crankcase and Head.

4. If the breather reeds and stops were removed from the crankcase, reinstall them at this time and secure with the hex flange screw. Torque the screw to **4.0 N·m (35 in. lb.)**. See Figure 10-27.

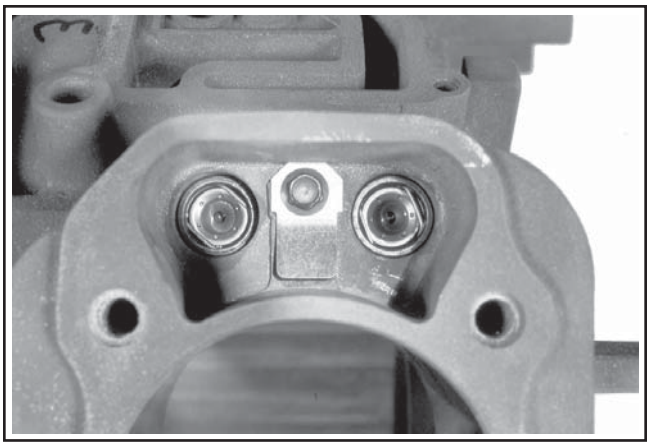


Figure 10-27. Installed Breather Reed.

Valve Stem Seals

These engines use valve stem seals on the intake valves and on the exhaust valves. Use a new seal whenever the valve is removed or if the seal is deteriorated or damaged in any way. Never reuse an old seal. See Figure 10-28.

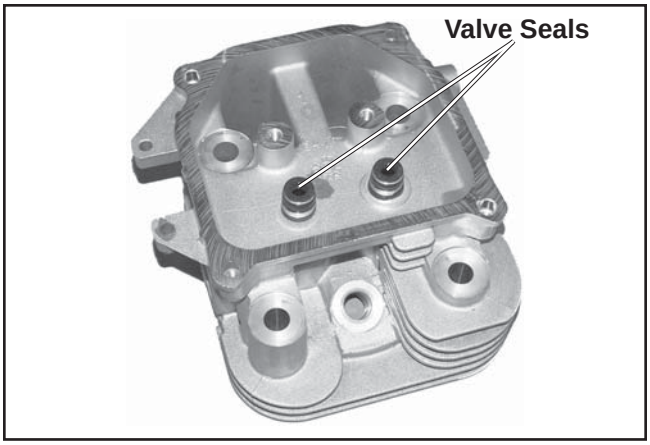


Figure 10-28. Valve Seal Location.

Assemble Cylinder Heads

Prior to installation, lubricate all components with engine oil, paying particular attention to the lip of the valve stem seal, valve stems, and valve guides. Install the following items in the order listed below using a valve spring compressor. See Figures 10-29 and 10-30.

- Intake and exhaust valves
- Valve spring retainers
- Valve springs
- Valve spring caps
- Valve spring keepers

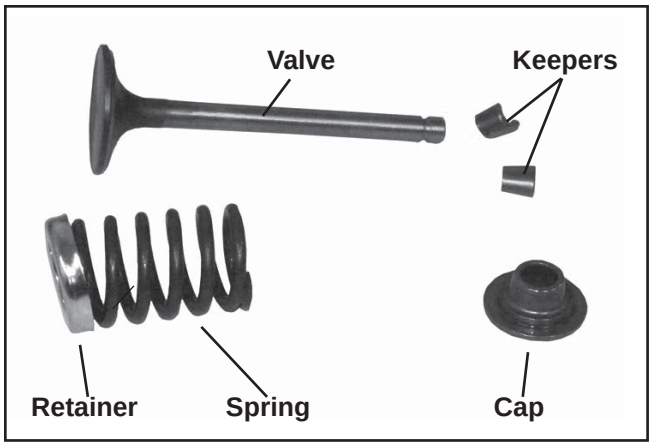


Figure 10-29. Valve Components.

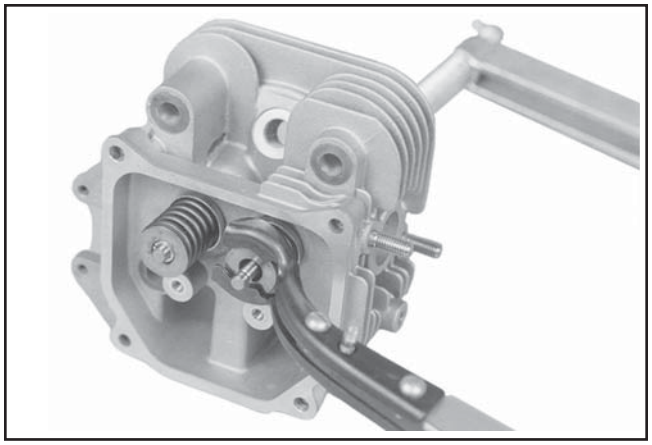


Figure 10-30. Installing Valves with Valve Spring Compressor.

Install Cylinder Heads

NOTE: Cylinder heads must be attached with the original type of mounting hardware, using either hex flange screws, or mounting studs with nuts and washers. Do not intermix the components.

1. Check to make sure there are no nicks or burrs on the sealing surfaces of the cylinder head or the crankcase.

Heads secured with mounting studs, nuts, and washers:

2. If all of the studs were left intact, go to Step 6. If any studs were disturbed or removed, install new studs as described in Step 3. Do not use/reinstall any loosened or removed studs.

3. Install new mounting stud(s) into the crankcase.

   a. Thread and lock two of the mounting nuts together on the smaller diameter threads.

   b. Thread the opposite end of the stud, with the preapplied locking compound, into the crankcase, until the specified height from the crankcase surface is achieved. See Figure 10-31. When threading in the studs, use a steady tightening motion without interruption until the proper height is obtained. Otherwise the frictional heat from the engaging threads may cause the locking compound to set up prematurely.

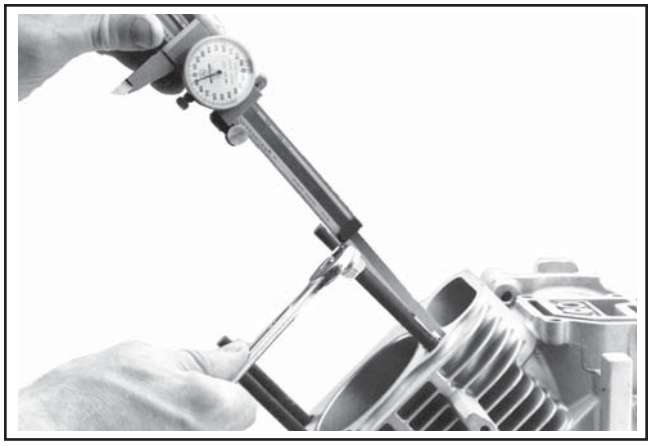


Figure 10-31. Installing New Mounting Studs to Specified Height.

The studs **closest** to the lifters must have an exposed height of **75 mm (2 15/16 in.)**.

The studs **furthest** from the lifters must have an exposed height of **69 mm (2 3/4 in.)**.

   c. Remove the nuts and repeat the procedure as required.

4. Check that the dowel pins are in place and install a new cylinder head gasket (part number facing up).

5. Install the cylinder head. Match the numbers on the cylinder heads and the crankcase. See Figure 10-26. Make sure the head is flat on the gasket and dowel pins.

6. Lightly lubricate the exposed (upper) threads of the studs with engine oil. Install a flat washer and hex nut onto each of the mounting studs. Torque the hex nuts in two stages; first to **16.9 N·m (150 in. lb.)**, then finally to **33.9 N·m (300 in. lb.)**, following the sequence in Figures 10-32 and 10-34.

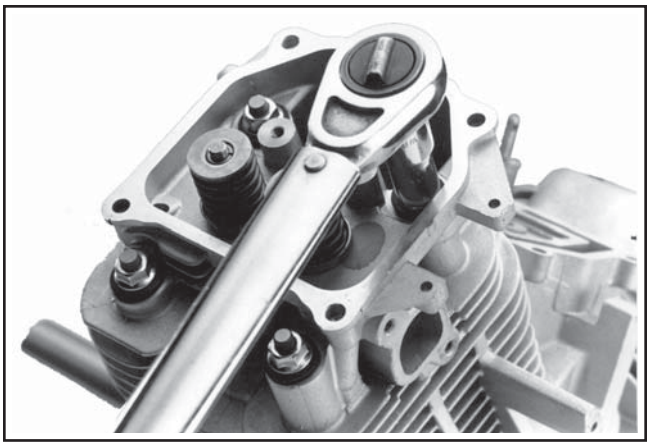


Figure 10-32. Torquing the Cylinder Head Mounting Nuts (Stud Design).

Heads secured with hex flange screws:

2. Install a new cylinder head gasket (part number facing up).

   NOTE: Match the numbers embossed on the cylinder heads and crankcase. See Figure 10-26.

3. Install the cylinder head and start the four hex flange screws. See Figure 10-33.

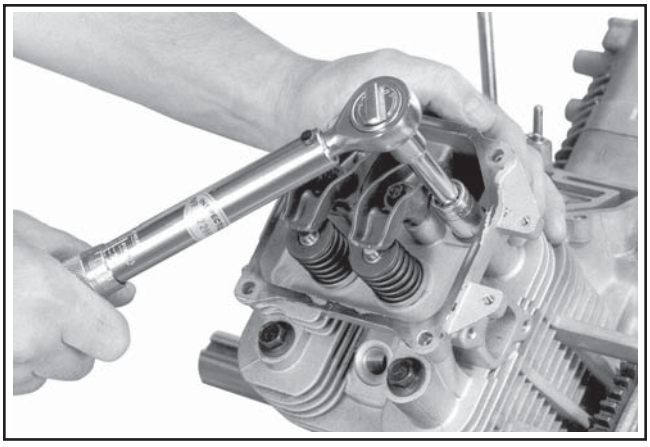


Figure 10-33. Torquing Cylinder Head Screws.

4. Torque the hex flange screws in two stages; first to **22.6 N·m (200 in. lb.)**, then finally to **41.8 N·m (370 in. lb.)**, following the sequence in Figure 10-34.

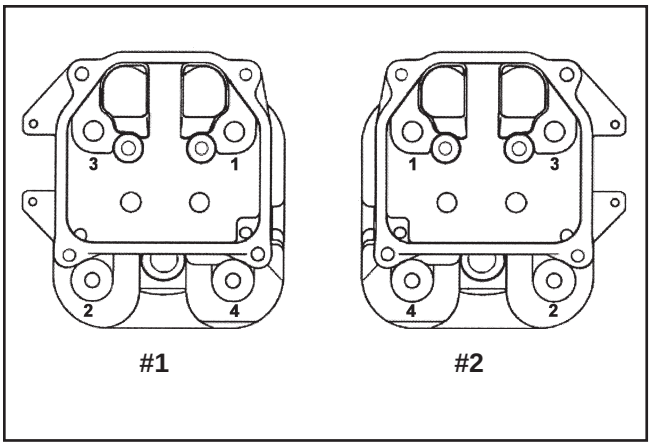


Figure 10-34. Cylinder Head Fastener Torque Sequence.

Install Push Rods and Rocker Arms

NOTE: Push rods should always be installed in the same position as before disassembly.

1. Note the mark or tag identifying the push rod as either intake or exhaust and cylinder #1 or #2. Dip the ends of the push rods in engine oil and install, making sure that each push rod ball seats in its hydraulic lifter socket. See Figure 10-35.

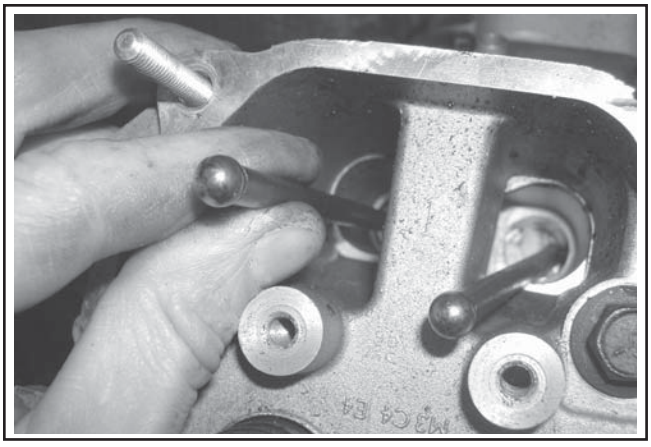


Figure 10-35. Install Push Rods in Their Original Position.

2. Apply grease to the contact surfaces of the rocker arms and rocker arm pivots. Install the rocker arms and rocker arm pivots on one cylinder head, and start the two hex flange screws.

3. Torque the hex flange screws to **11.9 N·m (105 in. lb.)**. See Figure 10-36.

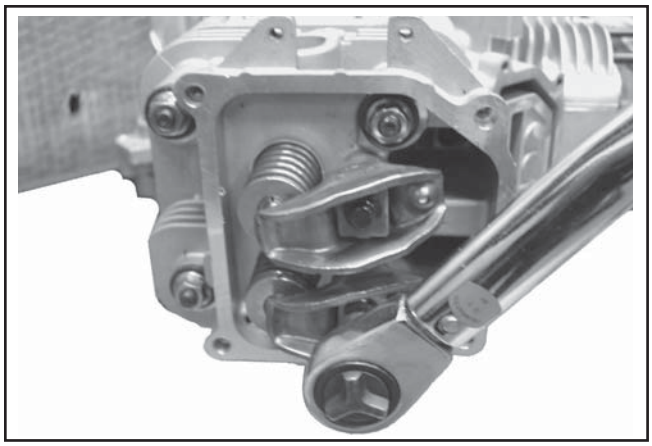


Figure 10-36. Torquing Rocker Arm Screws.

4. Use a spanner wrench or rocker arm lifting tool (see Section 2), to lift the rocker arms and position the push rods underneath. See Figure 10-37.

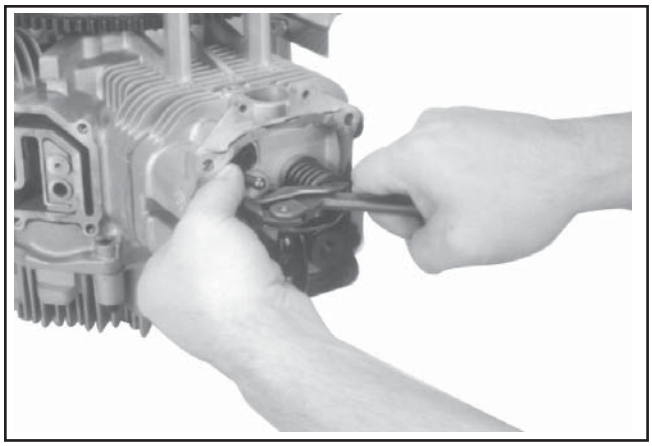


Figure 10-37. Using Spanner Wrench to Lift Rocker Arm Over Push Rod.

5. Repeat the above steps for the remaining cylinder. Do not interchange parts from the cylinder heads.

6. Rotate the crankshaft to check for free operation of the valve train. Check the clearance between the valve spring coils at full lift. Minimum allowable clearance is **0.25 mm (0.010 in.)**.

Check Assembly

Important: Rotate the crankshaft a minimum of two revolutions to check longblock assembly and overall proper operation.

Install Spark Plugs

1. Use new Champion® (or equivalent) spark plugs.

2. Set the gap at **0.76 mm (0.030 in.)**.

3. Install new plugs and torque to **24.4-29.8 N·m (18-22 ft. lb.**). See Figure 10-38.

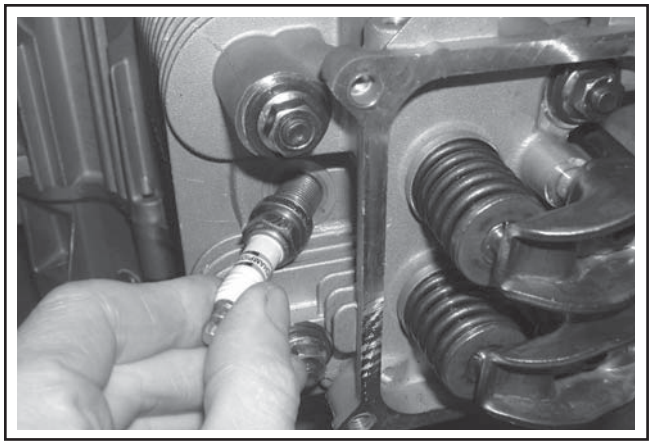


Figure 10-38. Installing Spark Plugs.

Install Intake Manifold

1. Install the intake manifold and new gaskets, with wiring harness attached, to the cylinder heads. Slide any wiring harness clips onto the appropriate bolts before installing. Make sure the gaskets are in the proper orientation. See Figures 10-39, and 10-40. Using the sequence shown in Figure 10-41, torque the four screws in two stages, first to **7.8 N·m (69 in. lb.)**, then to **10.5 N·m (93 in. lb.)**.

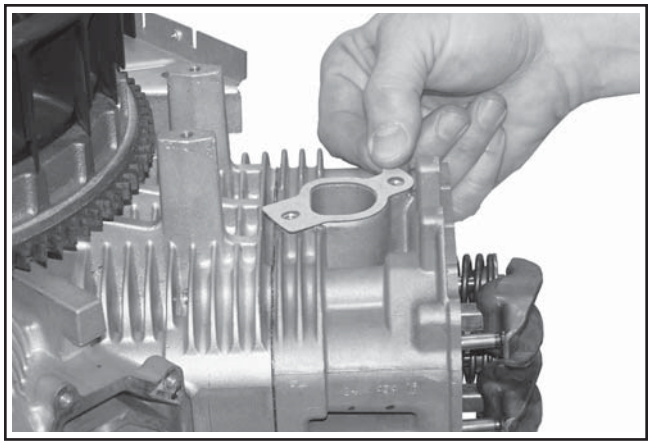


Figure 10-39. Installing Intake Manifold Gaskets.

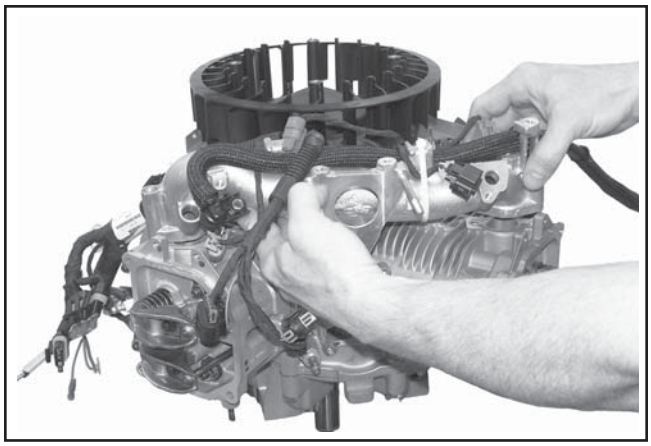


Figure 10-40. Installing Intake Manifold with Wiring Harness.

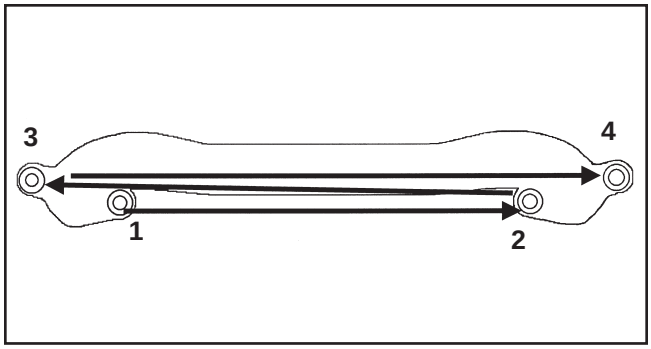


Figure 10-41. Intake Manifold Torque Sequence.

2. Install ground terminal to the crankcase post with a silver hex flange screw. Torque to **4.0 N·m (35 in. lb.)** into used holes or **6.2 N·m (55 in. lb.)** in new holes**.** See Figure 10-42.

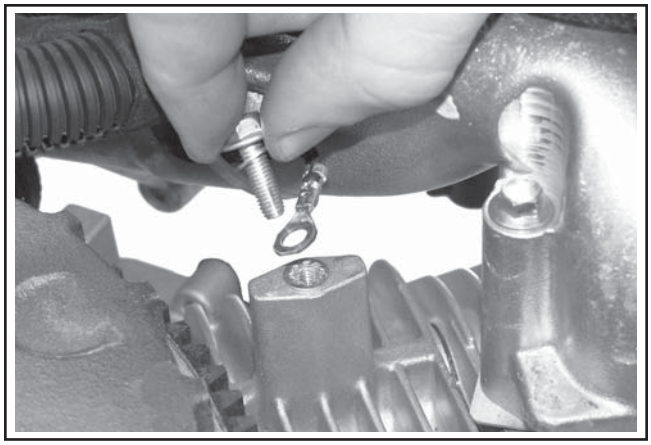


Figure 10-42. Install Ground Terminal.

3. Install the wire harness clip to the other crankcase post. Torque to **4.0 N·m (35 in. lb.)** into used holes or **6.2 N·m (55 in. lb.)** in new holes**.** See Figure 10-43.

4. Place wire harness conduit in clip and snap clip together.

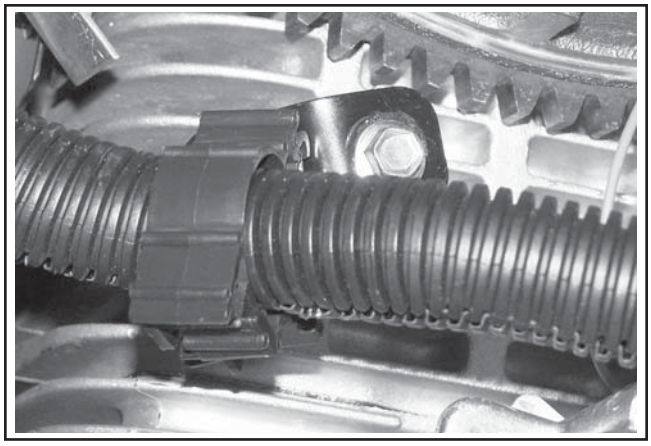


Figure 10-43. Install Wire Harness Clip.

Install Fuel Injectors

NOTE: Ensure all parts are clean, undamaged and free of debris and make sure the electrical connectors have the seal in place.

The O-rings and retaining clips should be replaced any time the fuel injector is separated from its normal mounting position.

1. Lightly lubricate the fuel injector O-rings with clean engine oil.

2. Push the retaining clip onto the fuel injector, aligning the clip as shown in Figure 10-44.

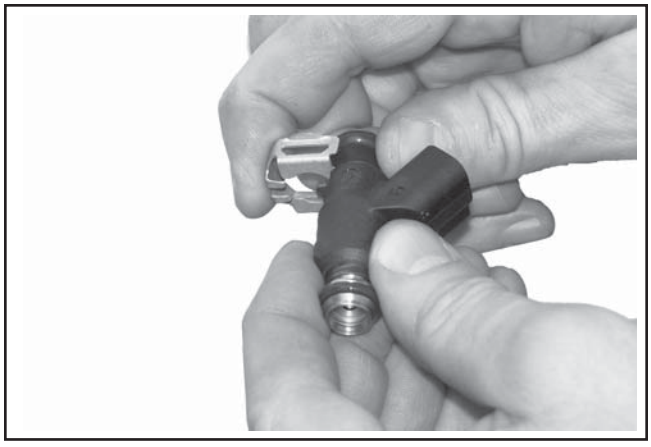


Figure 10-44. Install Fuel Injector Retaining Clip.

3. Press the fuel injector into the fuel injector cap until the retaining clip snaps into place.

4. Press the fuel injector into the bore in the intake manifold and rotate to original position.

5. Install the fuel injector cap hex flange screw into the intake manifold and torque to **7.3 N·m (65. in. lb.)**. See Figure 10-45.

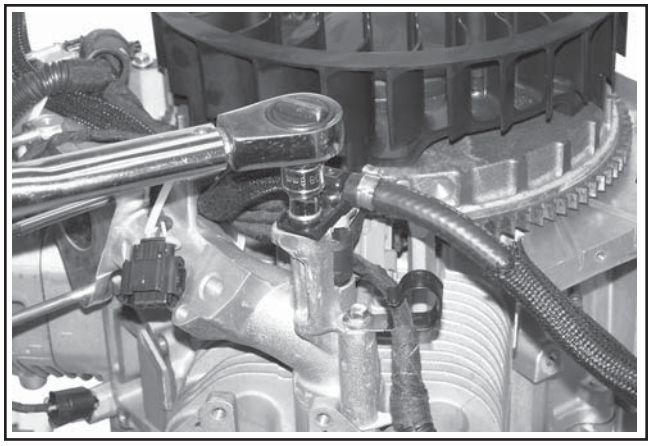


Figure 10-45. Torque Fuel Injector Cap Screw.

6. Push the electrical connector on the fuel injector making sure a good connection is made.

7. Repeat steps 1 through 6 for the other fuel injector.

Install Manifold Absolute Pressure (MAP) Sensor

NOTE: Ensure all parts are clean, undamaged and free of debris and make sure the electrical connector has the seal in place.

1. Lightly oil the MAP sensor O-ring and push the MAP sensor into the bore in the intake manifold.

2. Torque the hex flange screw to **7.3 N·m (65 in. lb.)**. See Figure 10-46.

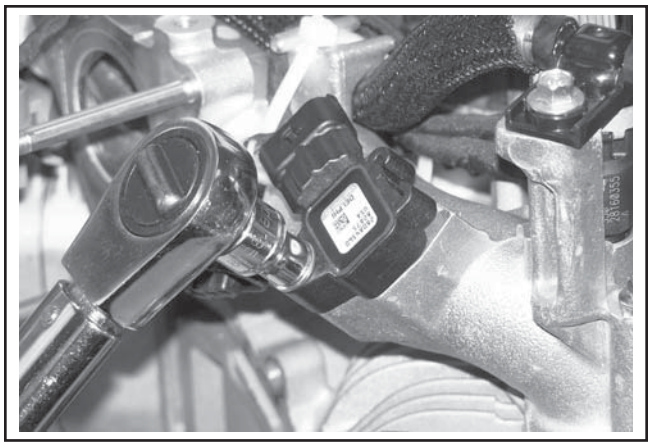


Figure 10-46. Torque the MAP Sensor Screw.

3. Push the electrical connector on the MAP sensor making sure a good connection is made.

Install Crankshaft Position Sensor

NOTE: Ensure all parts are clean, undamaged and free of debris and make sure the electrical connectors have the seal in place.

1. Install the crankshaft position sensor and bracket assembly to the crankcase posts.

2. Snug the hex flange screws and check the air gap of the sensor with a feeler gauge. It must be **0.20-0.70 mm (0.008-0.027 in.)**.

3. Torque the bracket screws to the crankcase to **4.0 N·m (35 in. lb.)** into used holes or **6.2 N·m (55 in. lb.)** into new holes. See Figure 10-47.

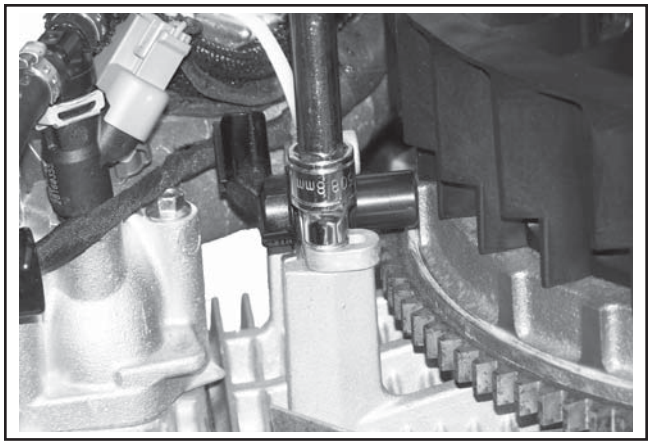


Figure 10-47. Torque Crankshaft Position Sensor.

4. Push the electrical connector on the crankshaft position sensor making sure a good connection is made.

Install Valve Covers

1. Make sure the sealing surfaces are clean.

2. Make sure there are no nicks or burrs on the sealing surfaces.

3. Install a new O-ring in the groove of each cover.

4. Position the covers on the cylinder heads. Locate the cover with the oil separator hole on the number 1 cylinder. Install the four hex flange screws in each cover and finger tighten.

5. Torque the valve cover fasteners to **6.2 N·m (55 in. lb.)** using the sequence shown in Figure 10-48.

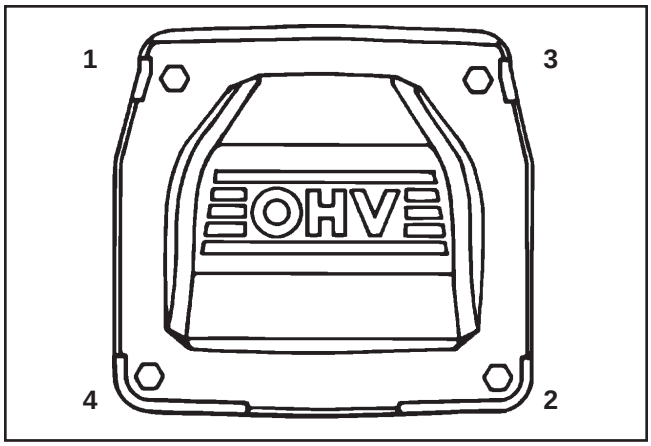


Figure 10-48. Valve Cover Fastener Torque Sequence.

Install Breather Cover and Inner Baffles

1. Be sure the sealing surfaces of the crankcase and breather cover are clean of old gasket material. **Do not** scrape the surfaces as this could result in leakage. Use a new gasket when installing the breather cover. See Figure 10-49.

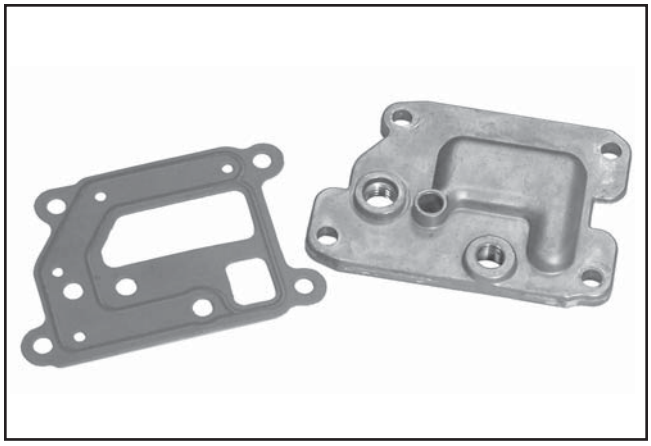


Figure 10-49. Breather Cover and Gasket.

2. Check to make sure there are no nicks or burrs on the sealing surfaces.

3. Position the breather gasket and cover on the crankcase. Install the first two hex flange screws in locations 3 and 4 shown in Figure 10-50. Finger tighten at this time.

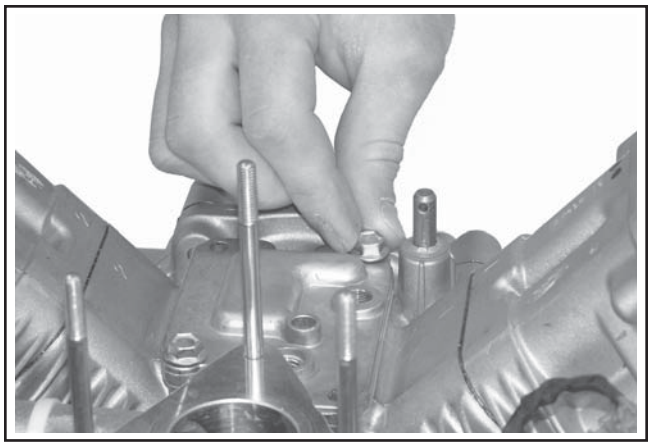


Figure 10-50. Installing Screws (Locations 3 and 4).

4. Install the inner baffles using the remaining two hex flange screws (see Figures 10-51 and 10-52) and finger tighten. **Do not** torque the screws at this time; they will be tightened after the blower housing and outer baffles are installed.

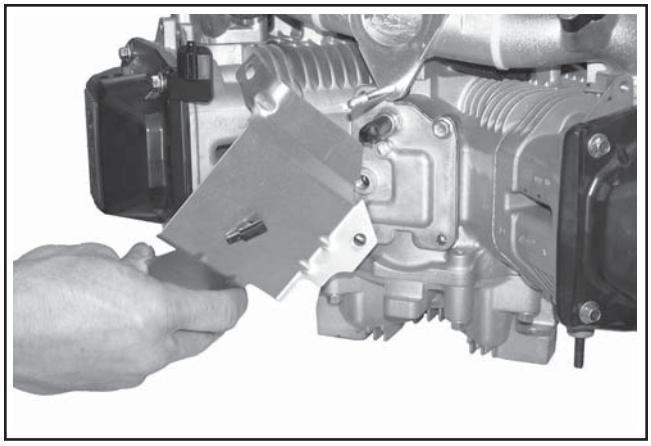


Figure 10-51. Installing Inner Baffles.

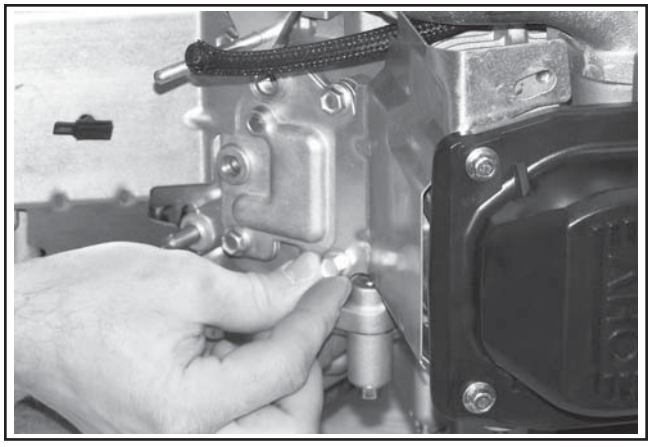


Figure 10-52. Finger Tighten Two Remaining Cover Screws.

Install Oil Temperature Sensor

NOTE: Ensure part is clean, undamaged and free of debris and make sure the electrical connector has the seal in place.

1. Lightly oil the oil temperature sensor O-ring and install the oil temperature sensor into the breather cover.

2. Torque the sensor to **7.3 N·m (65 in. lb.)**. See Figure 10-53.

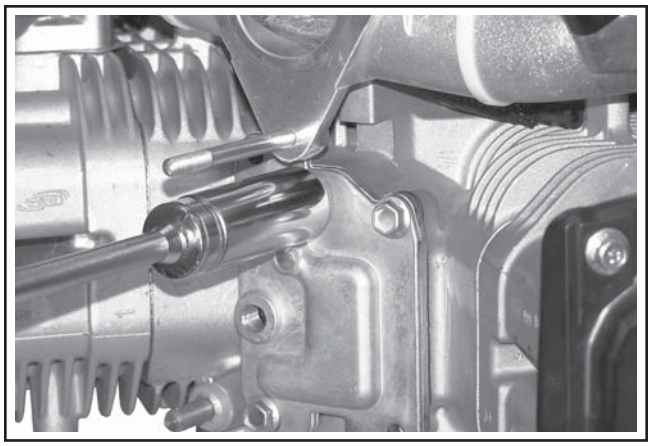


Figure 10-53. Torque Oil Temperature Sensor.

3. Push the electrical connector on the oil temperature sensor making sure a good connection is made.

Install Oil Sentry™ (If So Equipped)

1. Apply pipe sealant with Teflon® (Loctite® 592™ PST® Thread Sealant or equivalent) to the threads of the Oil Sentry™ switch and install it into the breather cover. See Figure 10-54. Torque to **4.5 N·m (40 in. lb.)**.

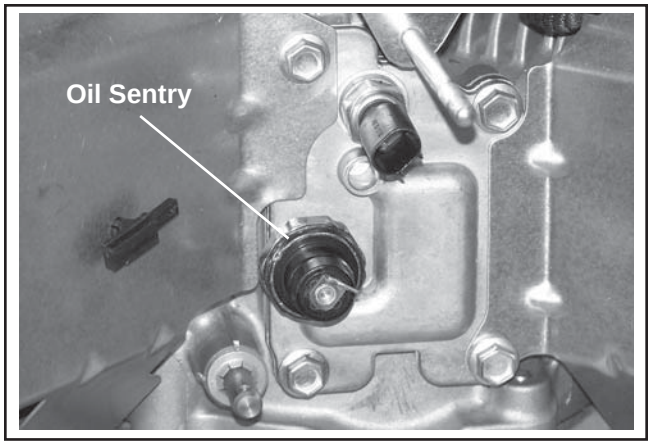


Figure 10-54. Oil Sentry™ Switch (If So Equipped).

2. Connect the wire lead (green) to the Oil Sentry™ terminal.

Install Blower Housing and Outer Baffles

NOTE: Do not completely tighten screws until all items are installed to allow shifting for hole alignment.

1. Slide the blower housing into position over the front edge of the inner baffles. See Figure 10-55. Start a few of the screws to hold it in place.

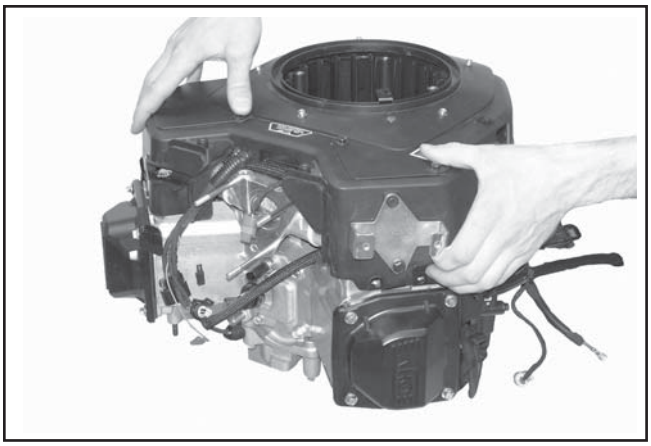


Figure 10-55. Installing Blower Housing.

2. Position the outer baffles and secure using the four M6 hex flange screws Install two M6 screws (20 mm long) into the intake port side of the cylinder heads, including any lifting strap. Install two M6 screws (16 mm long) into the exhaust port side of the cylinder head. Install the two short M5 screws (10 mm long) in the upper mounting holes of the outer baffles (into the backing plate). See Figures 10-56 and 10-57. Be sure any leads are routed out through the proper offsets or notches, so they will not be pinched between the blower housing and baffles.

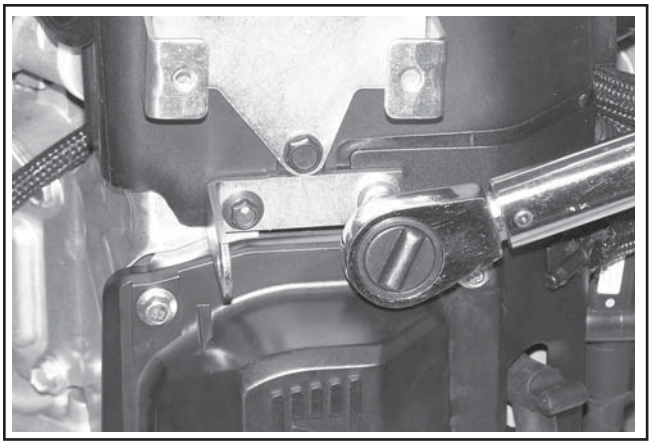


Figure 10-56. Tightening Outer Baffle Screws.

Figure 10-57. Tightening Short Screws for Outer Baffles.

3. Insert and tighten all remaining blower housing and baffle screws with the exception of the rectifier-regulator grounding bracket screw. Torque all blower housing and baffle M6 screws assembled into aluminum to **10.7 N·m (95 in. lb.)** for a new hole, or **7.3 N·m (65 in. lb.)** for a used hole. Torque all blower housing and baffle M5 screws assembled into sheet metal (backing plate) to **2.8 N·m (25 in. lb.)** for new holes, or **2.3 N·m (20 in. lb.)** for used holes.

4. Torque the four breather cover screws to **11.3 N·m (100 in. lb.)** into new holes or **7.3 N·m (65 in. lb.)** into used holes in the sequence shown in Figure 10-58. Note the first screw is torqued a second time.

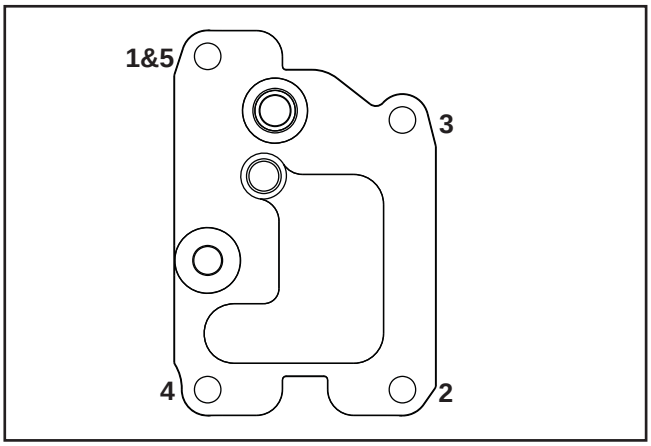


Figure 10-58. Breather Cover Fastener Torque Sequence.

Install Reconnect Rectifier-Regulator

1. Install the rectifier-regulator in the blower housing if removed previously, then secure grounding bracket against the outer side of the rectifier-regulator with a silver screw. See Figure 10-59.

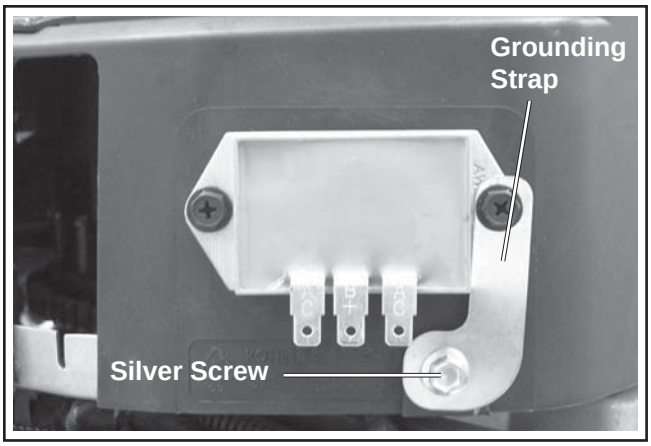


Figure 10-59. Rectifier-Regulator Ground Details.

2. Torque the two black rectifier-regulator hex flange screws to **1.4 N·m (12.6 in. lb.)** and the silver ground strap hex flange screw to **2.8 N·m (25 in. lb.)** into new holes or **2.3 N·m (20 in. lb.)** into used holes.

3. Connect the plug to the rectifier-regulator. If the purple wire was removed, verify the locking tang is raised on the terminal and push the wire terminal into the plug prior to connecting to the rectifier-regulator. See Figure 10-60.

NOTE: The rectifier-regulator middle terminal (B+) is offset (not equally spaced) from the outer terminals (AC). Verify the rectifier-regulator plug is assembled to match the terminal offset of the rectifier-regulator.

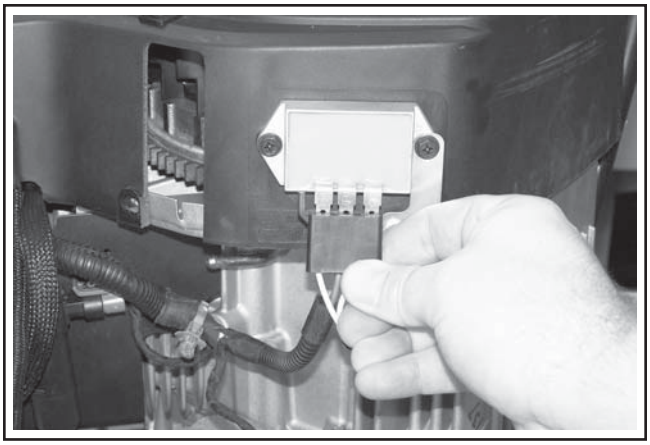


Figure 10-60. Attaching Rectifier-Regulator Plug.

Install Grass Screen

Metal Grass Screen

1. Verify the locating tabs on the back of the fan are inserted into the locating holes on the flywheel.

2. To assist assembly, find four intake manifold studs with M6 thread at least 100 mm in length to be used as guide pins. Insert the intake manifold studs through the cooling fan mounting holes and thread them 4 or 5 turns into the flywheel.

3. Install a spring washer on each stud with the concave side down toward the cooling fan. See Figure 10-61.

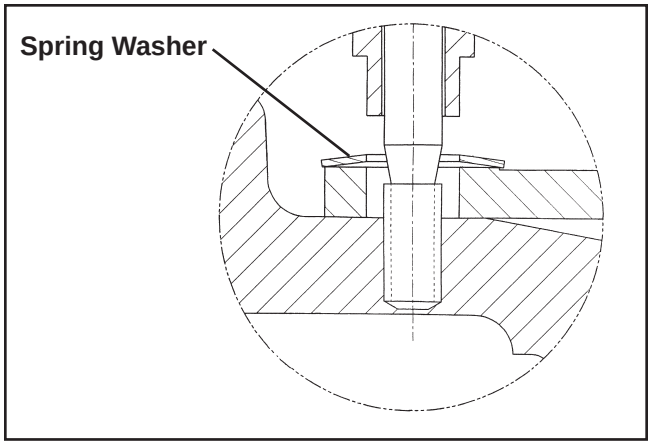


Figure 10-61. Spring Washer with Concave Side Down.

4. Install a spacer on each stud with the stepped end down. The smaller diameter should extend through the spring washer and fan, so the tip is resting on the flywheel, and the shoulder is resting on the spring washer. See Figure 10-62.

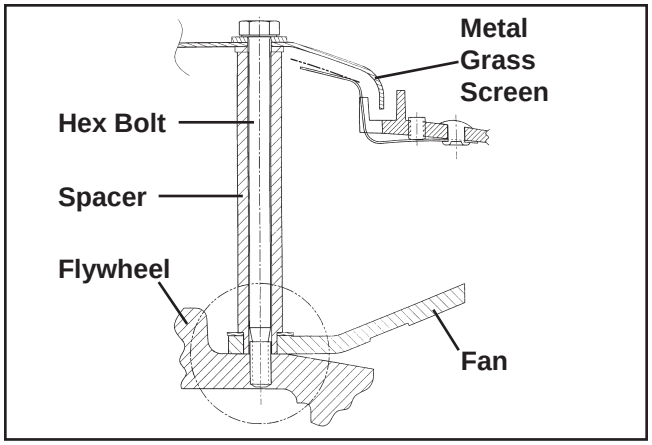


Figure 10-62. Spacer Shoulder Resting on Spring Washer.

5. Install the support ring on the studs, so it is resting on the spacers. Then install the metal screen on top of the support ring.

6. Install one of the plain washers on each of the hex cap screws. Apply Loctite® 242® to the hex cap screw threads.

7. Carefully remove two of the studs and replace with two of the hex cap screws. Torque the screws to **9.9 N·m (88 in. lb.)**. See Figure 10-63. Repeat the procedure for the other two studs and hex cap screws.

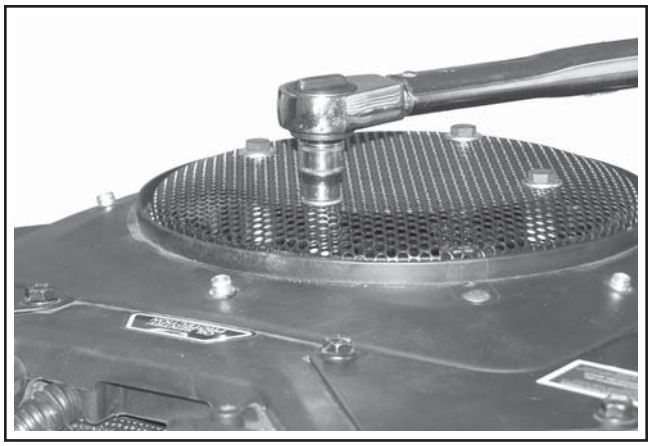


Figure 10-63. Torque Metal Grass Screen.

Plastic Grass Screen

1. Place the plastic grass screen on the fan and secure with four hex screws. Torque the four screws to **4.0 N·m (35 in. lb.)**. See Figures 10-64 and 10-65.

Figure 10-64. Torque Plastic Grass Screen Hex Screws.

Figure 10-65. Torque Plastic Grass Screen Hex Screws.

Install Oil Separator and Hardware

1. Ensure the rubber oil separator grommet is in good condition. Insert rubber grommet into valve cover. Push oil separator into the rubber grommet in the valve cover.

2. Secure the oil separator to the blower housing, placing the spacer and oil separator bracket against the blower housing and securing with the strap and two screws. Torque the screws to **2.3 N·m (20 in. lb.)**. See Figure 10-66.

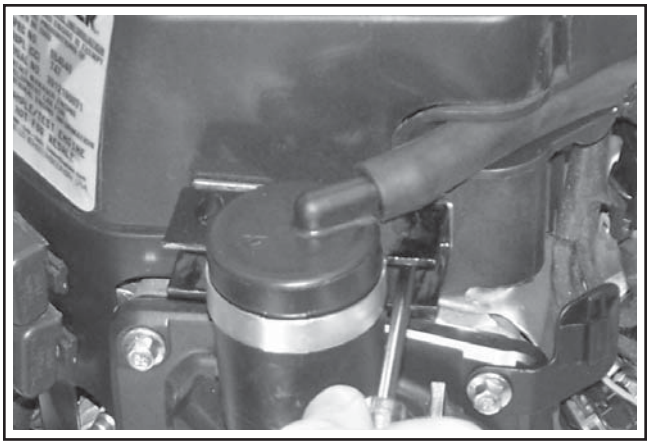


Figure 10-66. Install Oil Separator.

Install Electric Starter Motor and ECU Bracket

1. Install the electric starter motor using the two hex flange screws. Position the ECU bracket as shown. See Figure 10-67.

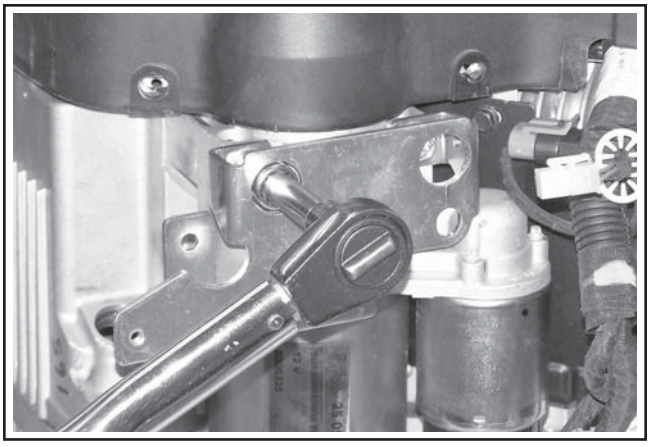


Figure 10-67. Installing Starter and ECU Bracket.

2. Torque the two hex flange screws to **16.0 N·m (142 in. lb.)**.

3. Connect the leads to the solenoid.

4. Install the dipstick tube and align the mounting hole with the threaded hole in the ECU bracket. Secure with the M5 hex flange screw. Torque the screw to **6.2 N·m (55 in. lb.)** into new holes or **4.0 N·m (35 in. lb.)** into used holes. See Figure 10-68.

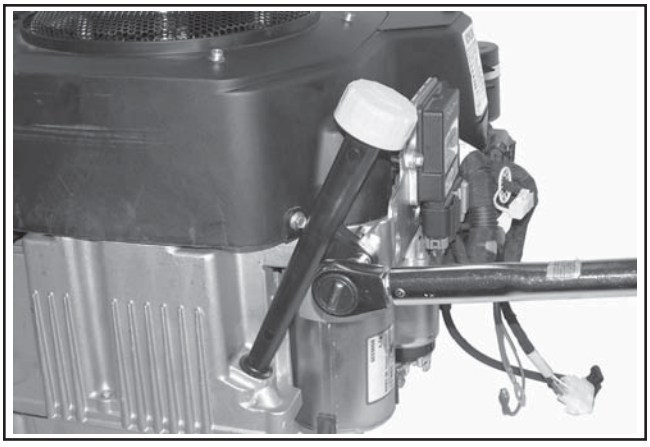


Figure 10-68. Installing Dipstick Tube.

Install Electronic Control Unit (ECU)

1. Install ECU to the ECU bracket using the two hex flange screws. Torque the M5 screws to **6.2 N·m (55 in. lb.)** into new holes or **4.0 N·m (35 in. lb.)** into used holes. See Figure 10-69.

2. Connect the Black and Grey electrical connectors. The connectors and ECU are keyed in such a way so they cannot be installed incorrectly.

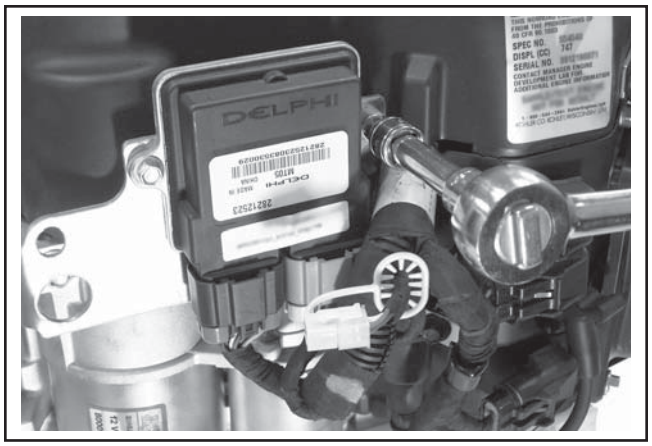


Figure 10-69. Torque ECU Screws.

NOTE: The ECU pins should be coated with a thin layer of electrical grease to prevent fretting and corrosion and may need to be reapplied if the ECU is being reused.

Install Throttle Body

1. Install a new throttle body O-ring prior to installation. Make sure all holes align and are open.

2. Install the throttle body, throttle position sensor, intake air temperature sensor, throttle linkage, spring and bushing, as an assembly. See Figure 10-70.

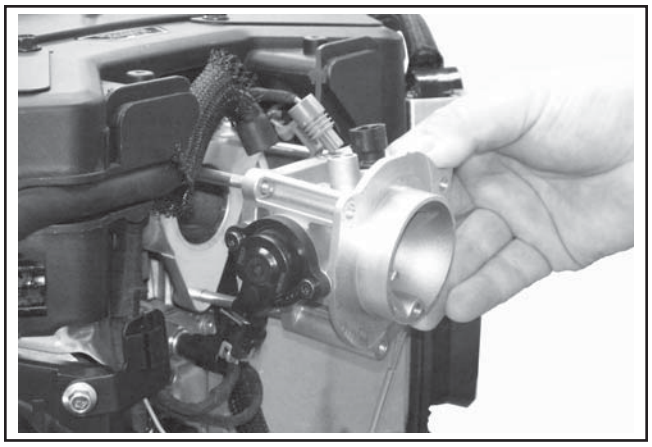


Figure 10-70. Installing Throttle Body Assembly.

3. Install the air cleaner bracket (models with heavy duty air cleaner only) to the throttle body with two hex flange screws. Torque the screws to **9.9 N·m (88 in. lb.)**. See Figure 10-71.

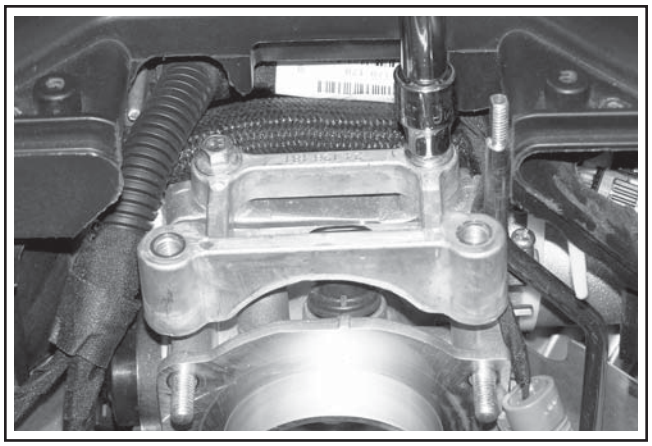


Figure 10-71. Install Air Cleaner Bracket.

4. Connect the breather separator hose to the top of the throttle body using a pliers to compress the spring clip. Route the hose through the housing by pressing the hose into the cutout of the blower housing. Position abrasion sleeve as shown. See Figure 10-72.

5. Push the electrical connector onto the intake air temperature sensor making sure a good connection is made by listening for a click. See Figure 10-72.

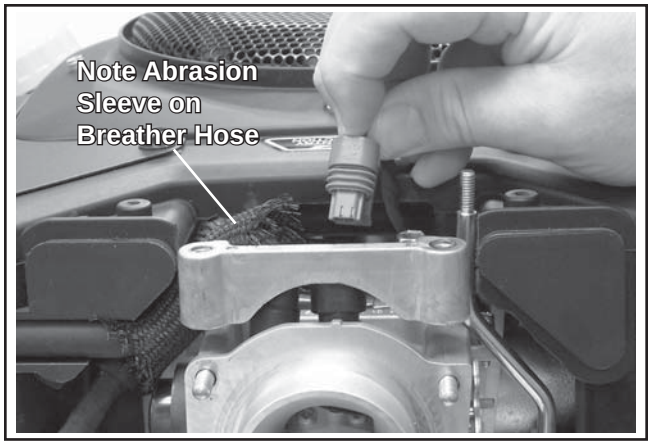


Figure 10-72. Install Breather Hose and Intake Air Temperature Sensor Connector.

6. Connect the 5/32 in. I.D. vent hose from the fuel pump module to the bottom of the throttle body.

7. Push electrical connector onto the throttle position sensor making sure a good connection is made. See Figure 10-73.

NOTE: Ensure all parts are clean, undamaged and free of debris and make sure the electrical connector has the seal in place.

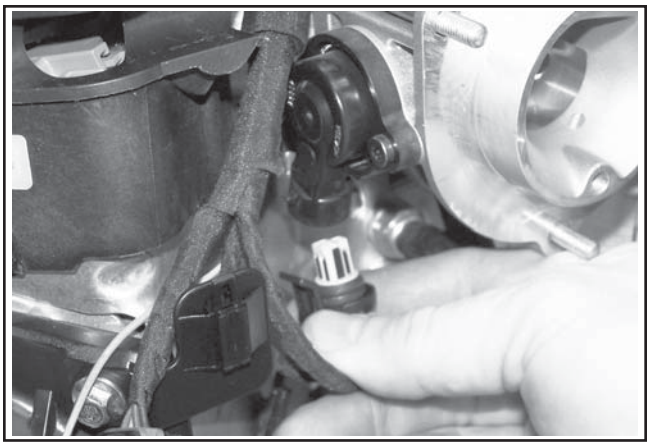


Figure 10-73. Connect the Throttle Position Sensor.

Install Lift Fuel Pump and Fuel Pump Module

WARNING

Explosive Fuel can cause fires and severe burns.
Do not fill the fuel tank while the engine is hot or running.

Explosive Fuel!

Gasoline is extremely flammable and its vapors can explode if ignited. Store gasoline only in approved containers, in well ventilated, unoccupied buildings, away from sparks or flames. Do not fill the fuel tank while the engine is hot or running, since spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Do not start the engine near spilled fuel. Never use gasoline as a cleaning agent.

1. Install the lift fuel pump and lines as an assembly. Connect the pulse line to the crankcase vacuum fitting. See Figures 10-74 and 10-75.

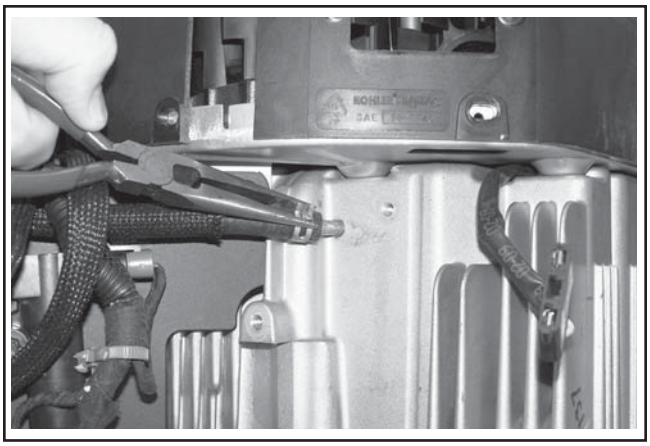


Figure 10-74. Install Pulse Line.

2. Install the lift fuel pump to the bracket on the housing using the two hex flange screws. Torque the M6 screws to **7.3 N·m (68 in. lb.)** in new holes or **6.2 N·m (55 in. lb.)** in used holes. See Figure 10-75.

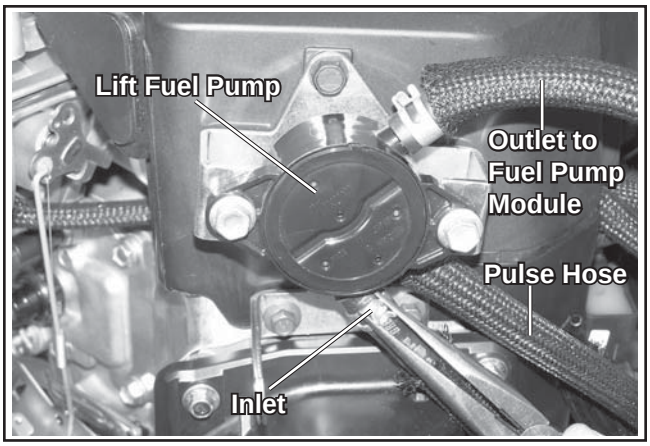


Figure 10-75. Reinstalled Lift Fuel Pump.

3. Connect the in-line 10 micron EFI fuel filter and hose to the inlet barb of the lift fuel pump and secure with the spring clamp.

NOTE: Some applications may have two in-line fuel filters. In those applications, connect the in-line 51-75 micron mesh fuel filter and hose to the inlet barb of the lift fuel pump and secure with a spring clamp. The in-line 10 micron EFI paper fuel filter and hose must be connected to the outlet barb of the lift fuel pump and secured with a spring clamp. See Figure 10-75.

4. Install the fuel pump module baffle to the crankcase using the three hex flange screws. Torque the screws to **11.9 N·m (105 in. lb.)**. See Figure 10-76.

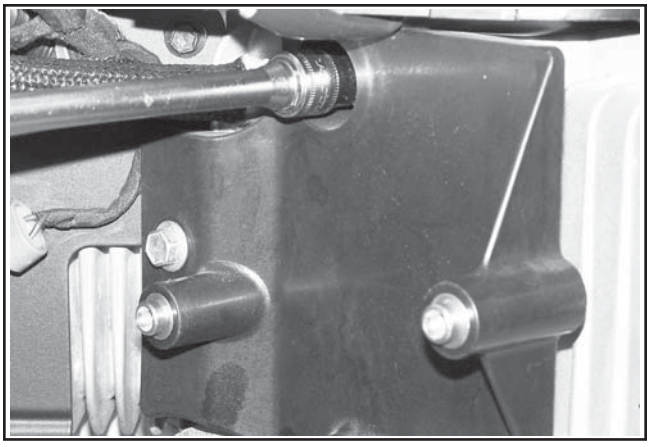


Figure 10-76. Install Fuel Pump Module Baffle.

NOTE: Ensure all parts are clean, undamaged and free of debris and make sure the electrical connector has the seal in place.

5. Push the high pressure fuel line connector onto the fuel pump module fitting.

6. If the Oetiker clamp was cut to remove the inlet fuel line, slide a new Oetiker clamp onto the fuel line and connect the fuel line. Only use an Oetiker clamp pliers to crimp Oetiker clamps. The Oetiker clamp crimp must point up, away from the top of the fuel pump module and the abrasion sleeve must be positioned over the Oetiker clamp.

7. Connect the electrical connector to the top of the fuel pump module. Ensure the grey locking tab is pulled out before connecting. Push the connector onto the terminal until a click is heard, then push in the grey locking tab to lock the connector. See Figure 10-77.

NOTE: The fuel pump module pins should be coated with a thin layer of electrical grease to prevent fretting and corrosion and may be reapplied if the fuel pump module is being reused.

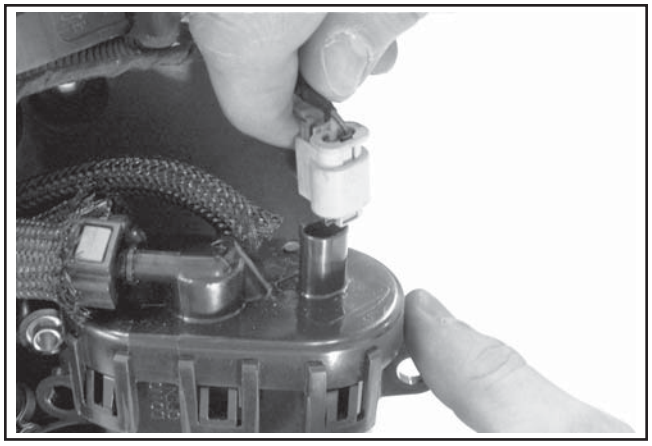


Figure 10-77. Connecting Fuel Pump Module Connector.

8. Install the fuel pump module to the baffle using the three hex flange screws. Torque the screws to **9.2 N·m (81 in. lb.)**. See Figure 10-78.

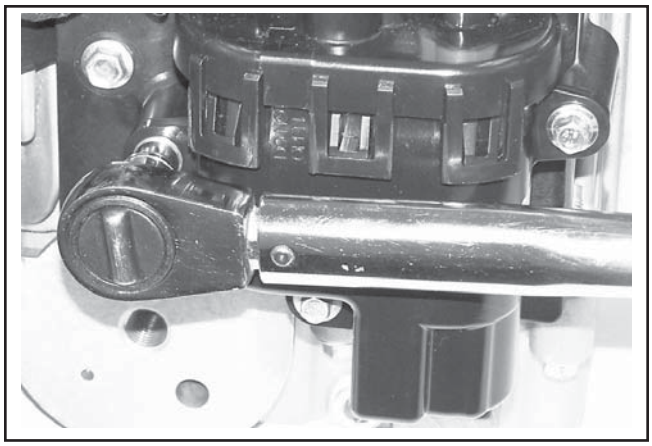


Figure 10-78. Install Fuel Pump Module.

Install External Governor Controls

1. Install the governor lever onto the governor cross shaft. See Figure 10-79.

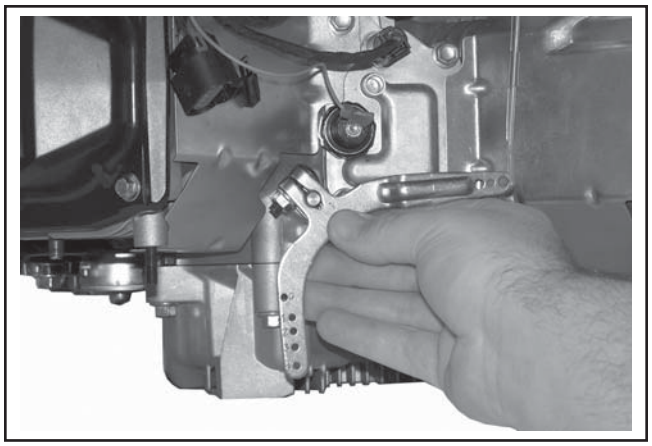


Figure 10-79. Install Governor Lever to Shaft.

2. Make sure the throttle linkage, linkage spring, black linkage bushing are connected to the governor lever and to the throttle lever on the throttle body. See Figure 10-80.

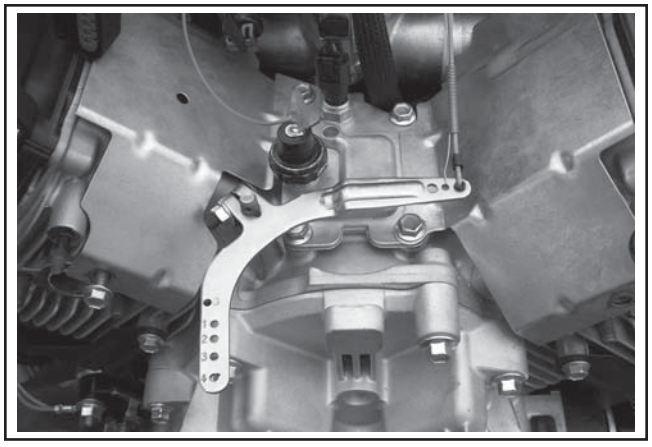


Figure 10-80. Throttle Linkage Details.

Install Throttle Control Panel

Assemble Top Mount Control Panel

1. Install the lower support control bracket with throttle control shaft. See Figure 10-81.

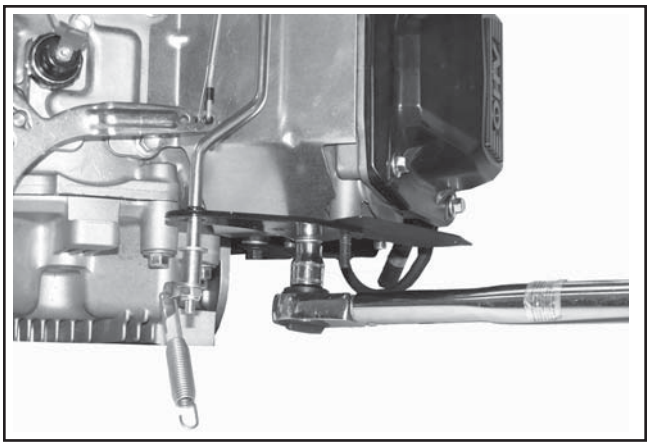


Figure 10-81. Installing Lower Support Control Bracket.

2. Install top mount control panel over throttle control shaft. Secure the control panel to the blower housing with the two screws. See Figure 10-82.

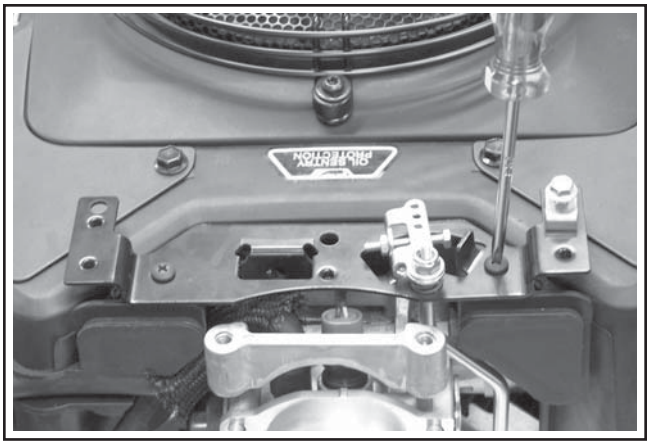


Figure 10-82. Installing Throttle Control Panel.

3. Assemble the throttle control lever and applicable hardware to the throttle control shaft.

4. Attach governor spring to the previously marked hole on the governor lever. See Figure 10-83.

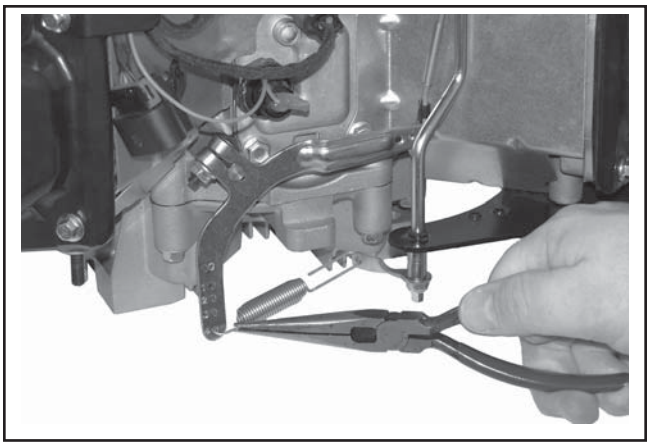


Figure 10-83. Connecting Governor Spring to Governor Lever.

Install Bottom Mount Control Panel (If So Equipped)

1. Install the bottom control panel and the air cleaner support bracket (if used) to the cylinder heads using the four hex flange screws. Torque the screws to **10.7 N·m (95 in. lb.)** into new holes, or **7.3 N·m (65 in. lb.)** into used holes. See Figure 10-84.

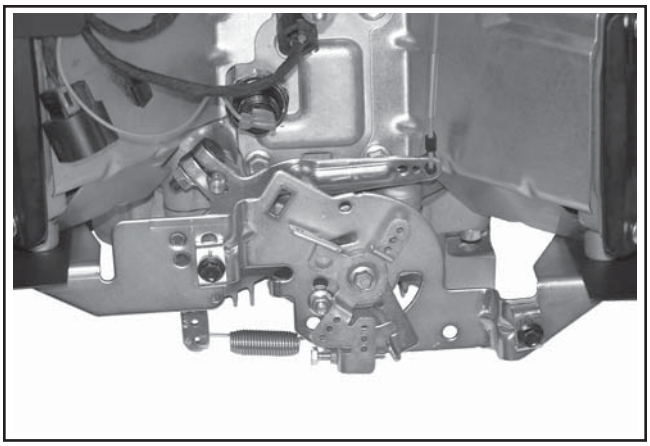


Figure 10-84. Bottom Mount Control Panel.

2. Connect the governor spring from the throttle control bracket to the previously marked hole in the governor lever.

NOTE: To identify the various parts and assembly of the throttle control panel, see Figure 10-85.

Item	Description
1	Bracket, speed control
2	Clamp, cable
3	Lever, throttle control (top)
4	Lever, throttle actuator (bottom)
5	Screw, M5x0.8x20
6	Washer, spring
7	Washer, flat (2)
8	Spring, return
9	Nut, M5x0.8 lock

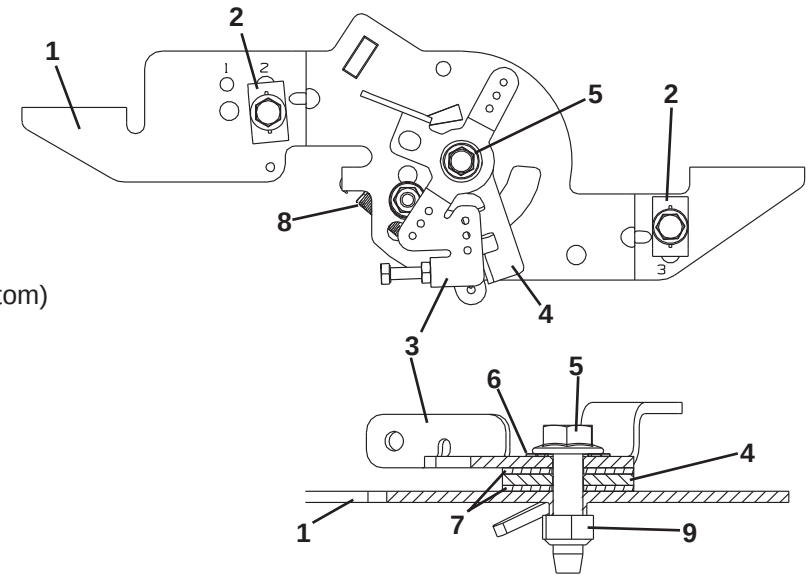


Figure 10-85. Throttle Control Bracket Detail.

Install Air Cleaner Assembly

Refer to Section 4 for the air cleaner reassembly procedure.

Heavy-Duty Air Cleaner

1. Install the air cleaner assembly onto the throttle body mounting studs. Secure and torque the hex flange nuts to **7.4-9.0 N·m (65.5-80 in. lb.)**. See Figure 10-86.

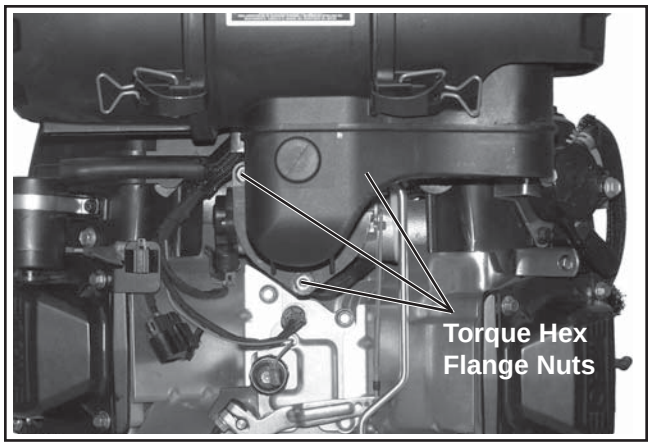


Figure 10-86. Torquing Hex Nuts.

2. Install and tighten the two upper mounting screws securing the air cleaner to the mounting bracket. Torque the screws to **9.9 N·m (88 in. lb.)**. See Figure 10-87.

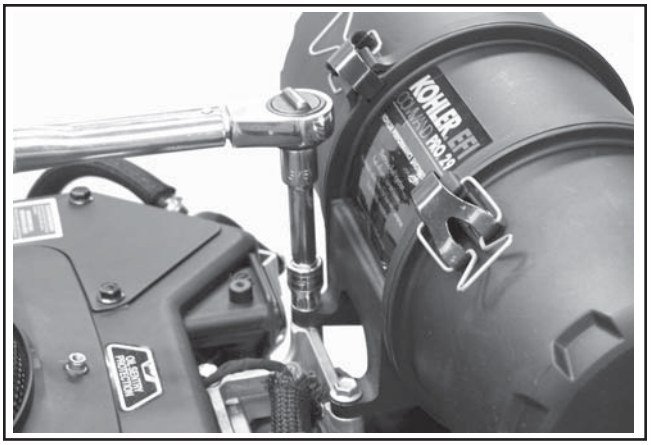


Figure 10-87. Installing Upper Mounting Screws.

Low-Profile Air Cleaner

1. Verify O-ring is present around the machined O.D. of the throttle body and place air cleaner base onto throttle body studs. Secure the air cleaner base using three hex flange nuts. Attach the air cleaner base bracket to the cylinder heads with four hex flange screws behind any control panel or bracket. Attach the air cleaner base to the lower bracket with the two M5 screws through the lower section of the base. Torque the hex flange nuts to **7.4-9.0 N·m (65.5-80 in. lb.)**, and the two lower M5 mounting screws to **2.3 N·m (20 in. lb.)**. See Figures 10-88 and 10-89.

Figure 10-88. Torquing Base Mounting Nuts.

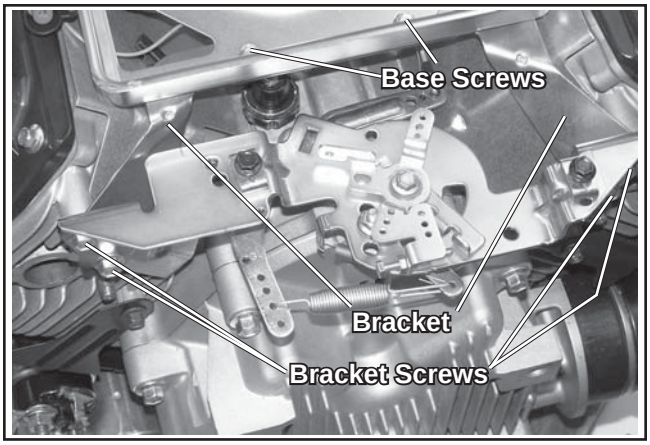


Figure 10-89. Low-Profile Air Cleaner and Bracket.

2. Install the air cleaner components as described in Section 4.

Setting Initial Governor Adjustment

1. Move the governor lever **toward** the throttle body as far as it will go (wide-open throttle) and hold in position.

2. Insert a nail into the hole on the cross shaft and rotate the shaft **counterclockwise** as far as it will turn, then torque the hex nut to **7.1 N·m (63 in. lb.)**. See Figure 10-90.

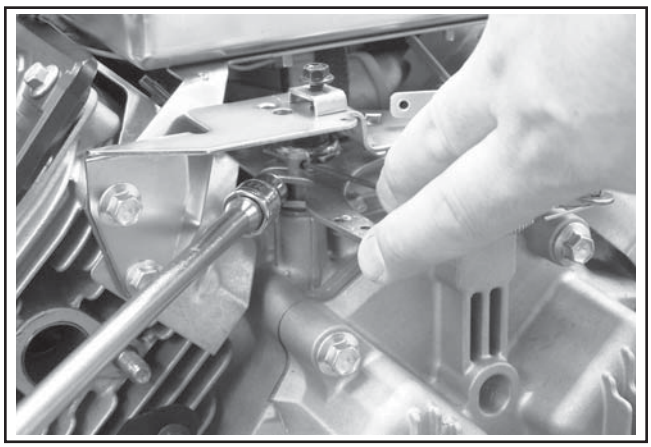


Figure 10-90. Setting Governor Adjustment.

Install Muffler

1. Install the port liners (if equipped). Install exhaust gaskets and the muffler. Install the oxygen sensor, torque to **50.1 N·m (37 ft. lb.),** and connect to wire harness.

2. Install remaining muffler support hardware (screws and nuts) and torque to **9.9 N·m (88 in. lb.)**.

3. Install the hex flange nuts to the exhaust studs. Torque hex flange nuts to **27.8 N·m (246 in. lb.)**.

Install Oil Cooler

1. Secure the adapter to the oil pan with the oil filter nipple. Torque the oil filter nipple to **28.5 N·m (21 ft. lb.)**.

2. Verify all fuel and vent hoses are routed properly and not pinched. Install the two hex flange screws to secure the oil cooler to the blower housing. Torque the top screw to **2.8 N·m (25 in. lb.)** and the lower screw to **2.3 N·m (20 in. lb.)**. See Figure 10-91**.**

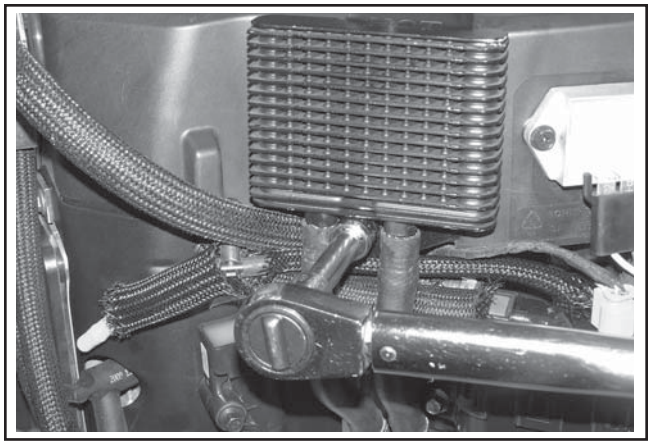


Figure 10-91. Install Oil Cooler.

Install Oil Filter and Fill Crankcase with Oil

NOTE: If testing oil pressure after completing reassembly, install the oil pressure adapter instead of the oil filter.

1. Prefill a new oil filter following the instructions in Section 6.

2. Apply a thin film of clean oil to the rubber gasket on the oil filter and thread the filter onto the adapter nipple. See Figure 10-92.

3. Refer to oil filter for specific installation instructions.

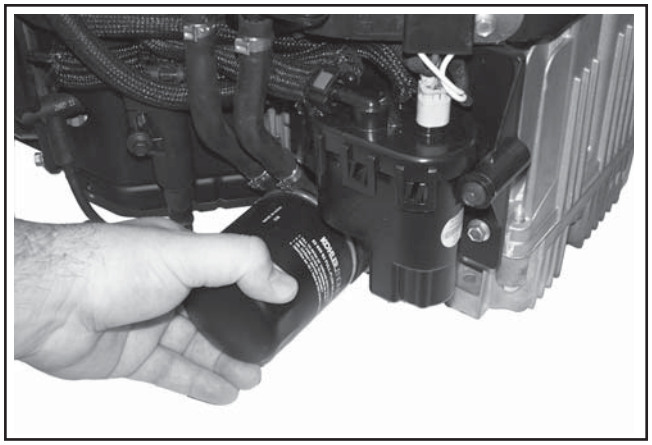


Figure 10-92. Installing and Tightening Oil Filter.

4. Install the oil drain plug(s). See Figure 10-93. Torque plug(s) to **13.6 N·m (10 ft. lb.)**.

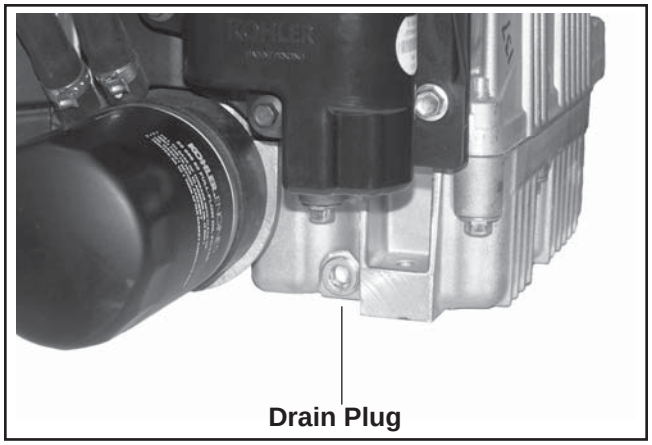


Figure 10-93. Install Oil Drain Plug(s).

NOTE: Make sure that both oil drain plugs are installed and torqued to the above specifications to prevent oil leakage.

5. Add oil to bring the level up to the **F** mark and reinstall the dipstick.

Connect Spark Plug Leads

1. Connect the leads to the spark plugs. See Figure 10-94.

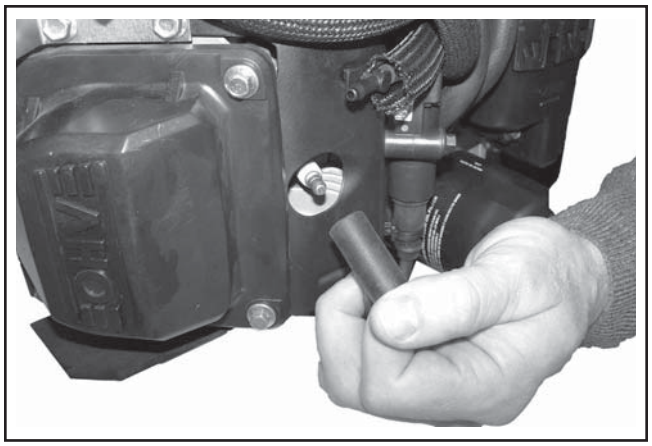


Figure 10-94. Connect Spark Plug Leads.

Prepare the Engine for Operation

The engine is now completely reassembled. Before starting or operating the engine, be sure to do the following.

1. Make sure all hardware is tightened securely.

2. Make sure the oil drain plugs, Oil Sentry® pressure switch, and a new oil filter are installed.

3. Fill the crankcase with the correct amount, weight, and type of oil. Refer to oil recommendations and procedures in the **Safety and General Information** and **Lubrication System** sections.

4. Adjust the idle speed adjusting screw as necessary. Refer to Section 5, **Electronic Fuel Injection System**.

5. Turn on fuel supply.

NOTE: If the ECU, throttle body, TPS or fuel pump module were replaced, an ECU Reset and TPS Learn is required. See Section 5 for the ECU Reset and TPS Learn procedure.

Sensitivity Adjustment

Governor sensitivity is adjusted by repositioning the governor spring in the holes of the governor lever. If speed surging occurs with a change in engine load, the governor is set too sensitive. If a big drop in speed occurs when normal load is applied, the governor should be set for greater sensitivity. See Figure 10-95 and adjust as follows:

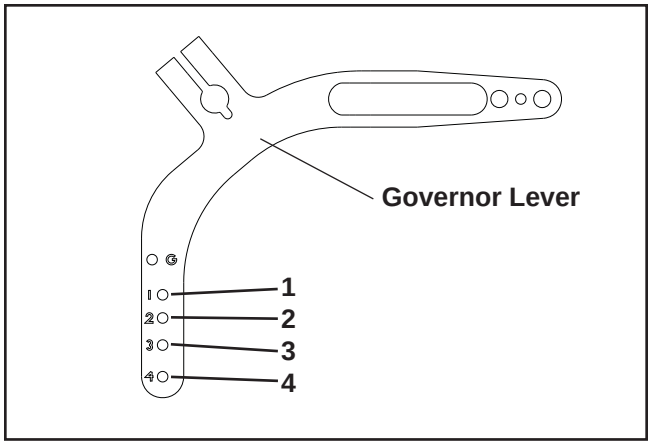


Figure 10-95. Governor Lever.

1. To increase the sensitivity, move the spring closer to the governor lever pivot point.

2. To decrease the sensitivity, move the spring away from the governor lever pivot point.

Testing the Engine

It is recommended that the engine be operated on a test stand or bench prior to installation in the piece of equipment.

1. Set the engine up on a test stand. Start engine, inspect for leaks and check to make certain that oil pressure (20 psi or more) is present. Run the engine at idle for 2-3 minutes, then 5-6 minutes more between idle and midrange.

2. Adjust the idle speed screw located on the throttle body as necessary. The standard idle speed setting for EFI engines is 1500 RPM, but certain applications might require a different setting.

3. Adjust the high-speed stop as necessary located on the control panel (if so equipped). Make sure the maximum engine speed does not exceed 4200 RPM (no load).

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