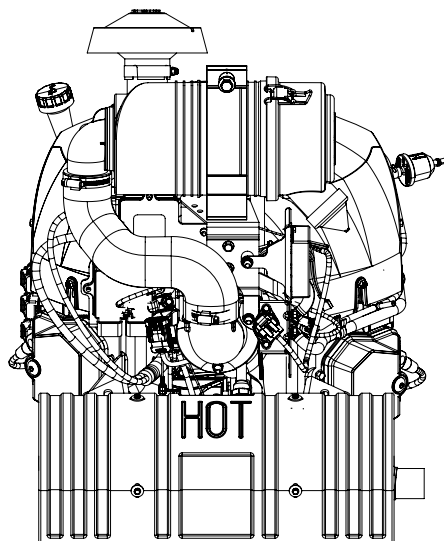


KOHLER® Command PRO

ECV940 & ECV980

Service Manual



IMPORTANT: Read all safety precautions and instructions carefully before operating equipment. Refer to operating instruction of equipment that this engine powers.

Ensure engine is stopped and level before performing any maintenance or service.

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Safety


SAFETY PRECAUTIONS


⚠ WARNING: A hazard that could result in death, serious injury, or substantial property damage.


⚠ CAUTION: A hazard that could result in minor personal injury or property damage.


NOTE: is used to notify people of important installation, operation, or maintenance information.

	<p>⚠ WARNING</p> <p>Explosive Fuel can cause fires and severe burns.</p> <p>Do not fill fuel tank while engine is hot or running.</p>
<p>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. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.</p>	


	<p>⚠ WARNING</p> <p>Rotating Parts can cause severe injury.</p> <p>Stay away while engine is in operation.</p>
<p>Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate engine with covers, shrouds, or guards removed.</p>	


	<p>⚠ WARNING</p> <p>Carbon Monoxide can cause severe nausea, fainting or death.</p> <p>Avoid inhaling exhaust fumes.</p>
<p>Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.</p>	


	<p>⚠ WARNING</p> <p>Accidental Starts can cause severe injury or death.</p> <p>Disconnect and ground spark plug lead(s) before servicing.</p>
<p>Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug lead(s). 2) Disconnect negative (-) battery cable from battery.</p>	


	<p>⚠ WARNING</p> <p>Hot Parts can cause severe burns.</p> <p>Do not touch engine while operating or just after stopping.</p>
<p>Never operate engine with heat shields or guards removed.</p>	


	<p>⚠ WARNING</p> <p>Cleaning Solvents can cause severe injury or death.</p> <p>Use only in well ventilated areas away from ignition sources.</p>
<p>Carburetor cleaners and solvents are extremely flammable. Follow cleaner manufacturer's warnings and instructions on its proper and safe use. Never use gasoline as a cleaning agent.</p>	

	<p>⚠ CAUTION</p> <p>Electrical Shock can cause injury.</p> <p>Do not touch wires while engine is running.</p>
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	<p>⚠ CAUTION</p> <p>Damaging Crankshaft and Flywheel can cause personal injury.</p>
<p>Using improper procedures can lead to broken fragments. Broken fragments could be thrown from engine. Always observe and use precautions and procedures when installing flywheel.</p>	

	<p>⚠ CAUTION</p> <p>Failure to utilize or reassemble debris screen as designed could result in debris screen failure and serious personal injury.</p>
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	<p>⚠ WARNING</p> <p>High Pressure Fluids can puncture skin and cause severe injury or death.</p> <p>Do not work on fuel system without proper training or safety equipment.</p>
<p>Fluid puncture injuries are highly toxic and hazardous. If an injury occurs, seek immediate medical attention.</p>	

	<p>⚠ WARNING</p> <p>Explosive Fuel can cause fires and severe burns.</p> <p>Fuel system ALWAYS remains under HIGH PRESSURE.</p>
<p>Wrap a shop towel completely around fuel pump module connector. Press release button(s) and slowly pull connector away from fuel pump module allowing shop towel to absorb any residual fuel in high pressure fuel line. Any spilled fuel must be completely wiped up immediately.</p>	

MAINTENANCE INSTRUCTIONS

	⚠ WARNING	Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug lead(s). 2) Disconnect negative (–) battery cable from battery.
	Accidental Starts can cause severe injury or death. Disconnect and ground spark plug lead(s) before servicing.	

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 dealer.

MAINTENANCE SCHEDULE

Every 100 Hours or Annually¹

• Change oil. Oil filter is recommended.	Lubrication System
• Remove cooling shrouds and clean cooling areas.	Air Cleaner/Intake

Every 150 Hours¹

• Check air cleaner element.	Air Cleaner/Intake
• Replace unique Electronic Fuel Injection (EFI) fuel filter.	
• Check oil cooler fins, clean as necessary.	Lubrication System

Every 200 Hours

• Change oil filter.	Lubrication System
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Every 300 Hours

• Replace air cleaner element and check inner element.	Air Cleaner/Intake
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Every 500 Hours or Annually¹

• Replace spark plugs and set gap.	Electrical System
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Every 600 Hours

• Replace air cleaner inner element.	Air Cleaner/Intake
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¹ Perform these procedures more frequently under severe, dusty, dirty conditions.

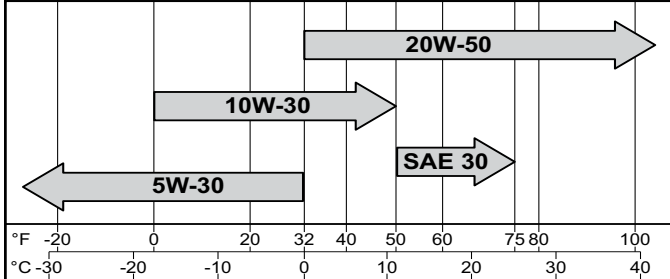
REPAIRS/SERVICE PARTS

Kohler genuine service parts can be purchased from Kohler authorized dealers. To find a local Kohler authorized dealer visit KohlerEngines.com or call 1-800-544-2444 (U.S. and Canada).

Maintenance

OIL RECOMMENDATIONS

We recommend use of Kohler oils for best performance. Other high-quality detergent oils (including synthetic) of API (American Petroleum Institute) service class SJ or higher are acceptable. Select viscosity based on air temperature at time of operation as shown in table below.



FUEL RECOMMENDATIONS



WARNING

Explosive Fuel can cause fires and severe burns.

Do not fill fuel tank while engine is hot or running.

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. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.

NOTE: E15, E20 and E85 are NOT approved and should NOT be used; effects of old, stale or contaminated fuel are not warrantable.

Fuel must meet these requirements:

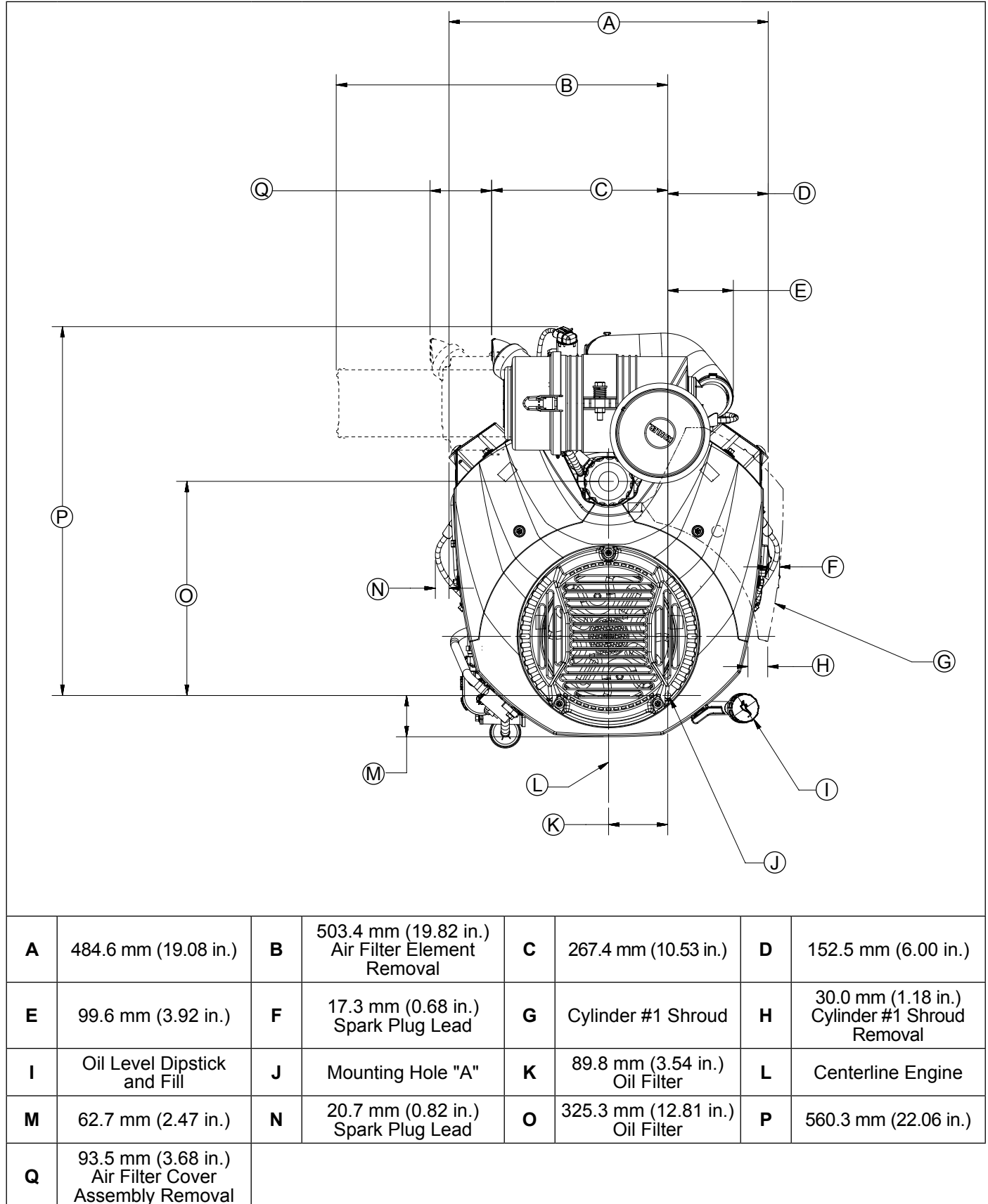
- Clean, fresh, unleaded gasoline.
- Octane rating of 87 (R+M)/2 or higher.
- Research Octane Number (RON) 90 octane minimum.
- Gasoline up to 10% ethyl alcohol, 90% unleaded is acceptable.
- Methyl Tertiary Butyl Ether (MTBE) and unleaded gasoline blend (max 15% MTBE by volume) are approved.
- Do not add oil to gasoline.
- Do not overfill fuel tank.
- Do not use gasoline older than 30 days.

STORAGE

If engine will be out of service for 2 months or more follow procedure below.

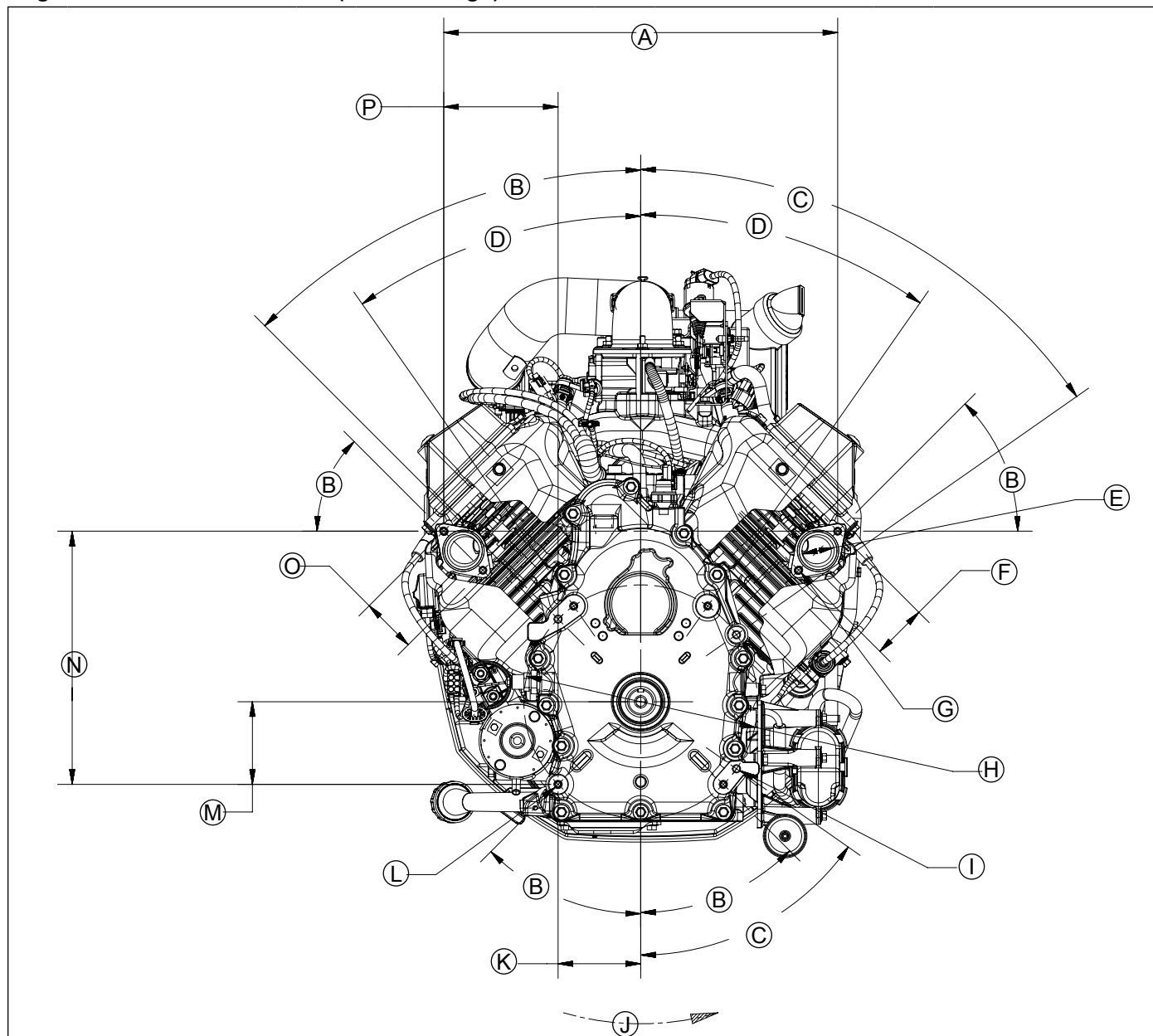
1. Add Kohler PRO Series fuel treatment or equivalent to fuel tank. Run engine 2-3 minutes to get stabilized fuel into fuel system (failures due to untreated fuel are not warrantable).
2. Change oil while engine is still warm from operation. Remove spark plug(s) and pour about 1 oz. of engine oil into cylinder(s). Replace spark plug(s) and crank engine slowly to distribute oil.
3. Disconnect negative (-) battery cable.
4. Store engine in a clean, dry place.

Engine Dimensions - Flywheel Side



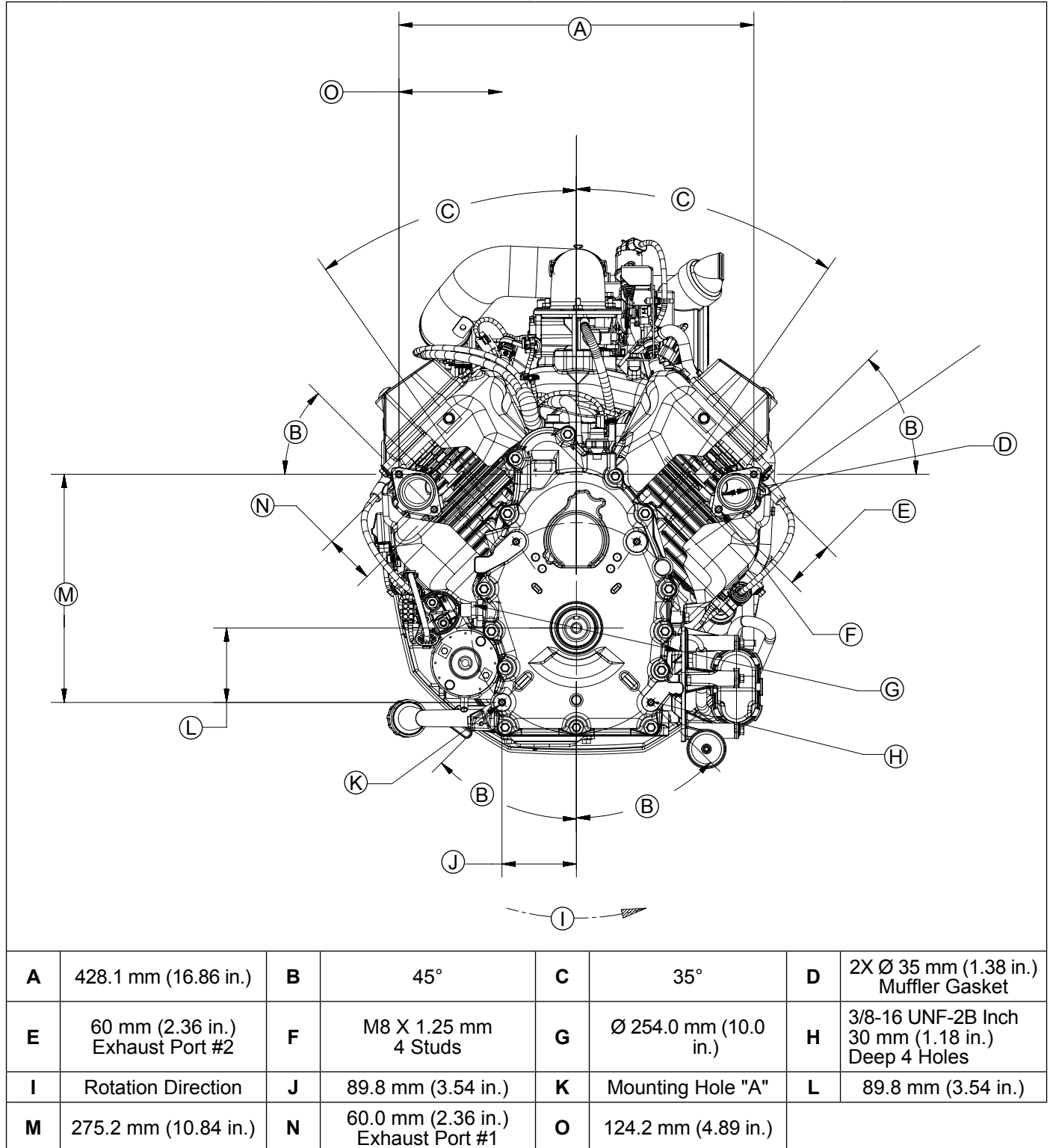
Specifications

Engine Dimensions - PTO Side (Earlier Design)



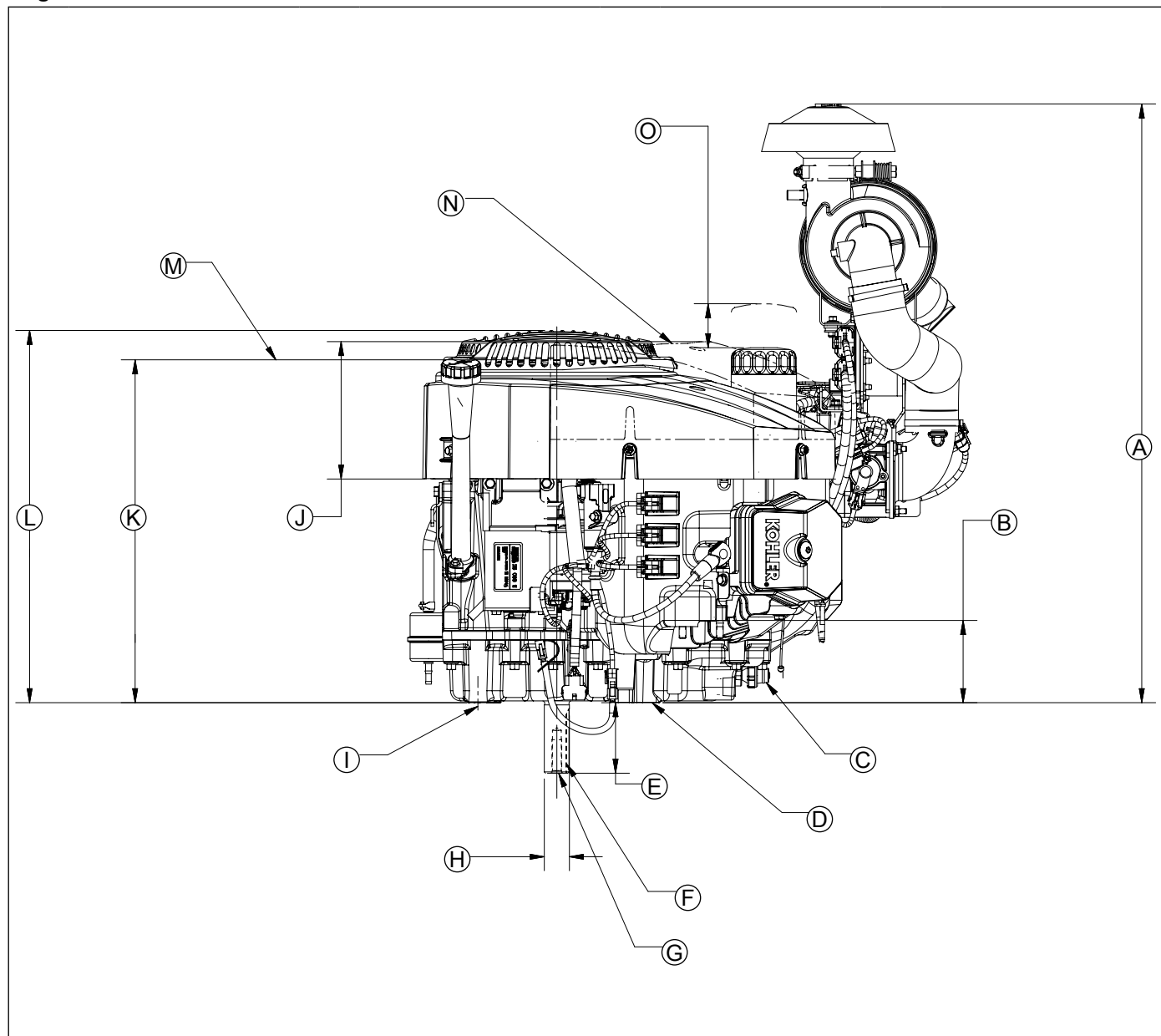
A	428.1 mm (16.86 in.)	B	45°	C	55°	D	35°
E	2X Ø 35 mm (1.38 in.) Muffler Gasket	F	60 mm (2.36 in.) Exhaust Port #2	G	M8 X 1.25 mm 4 Studs	H	Ø 254.0 mm (10.0 in.)
I	M8 X 1.25-6H 25 mm (0.98 in.) Deep 7 Holes	J	Rotation Direction	K	89.8 mm (3.54 in.)	L	Mounting Hole "A"
M	89.8 mm (3.54 in.)	N	275.2 mm (10.84 in.)	O	60.0 mm (2.36 in.) Exhaust Port #1	P	124.2 mm (4.89 in.)

Engine Dimensions - PTO Side (Later Design)



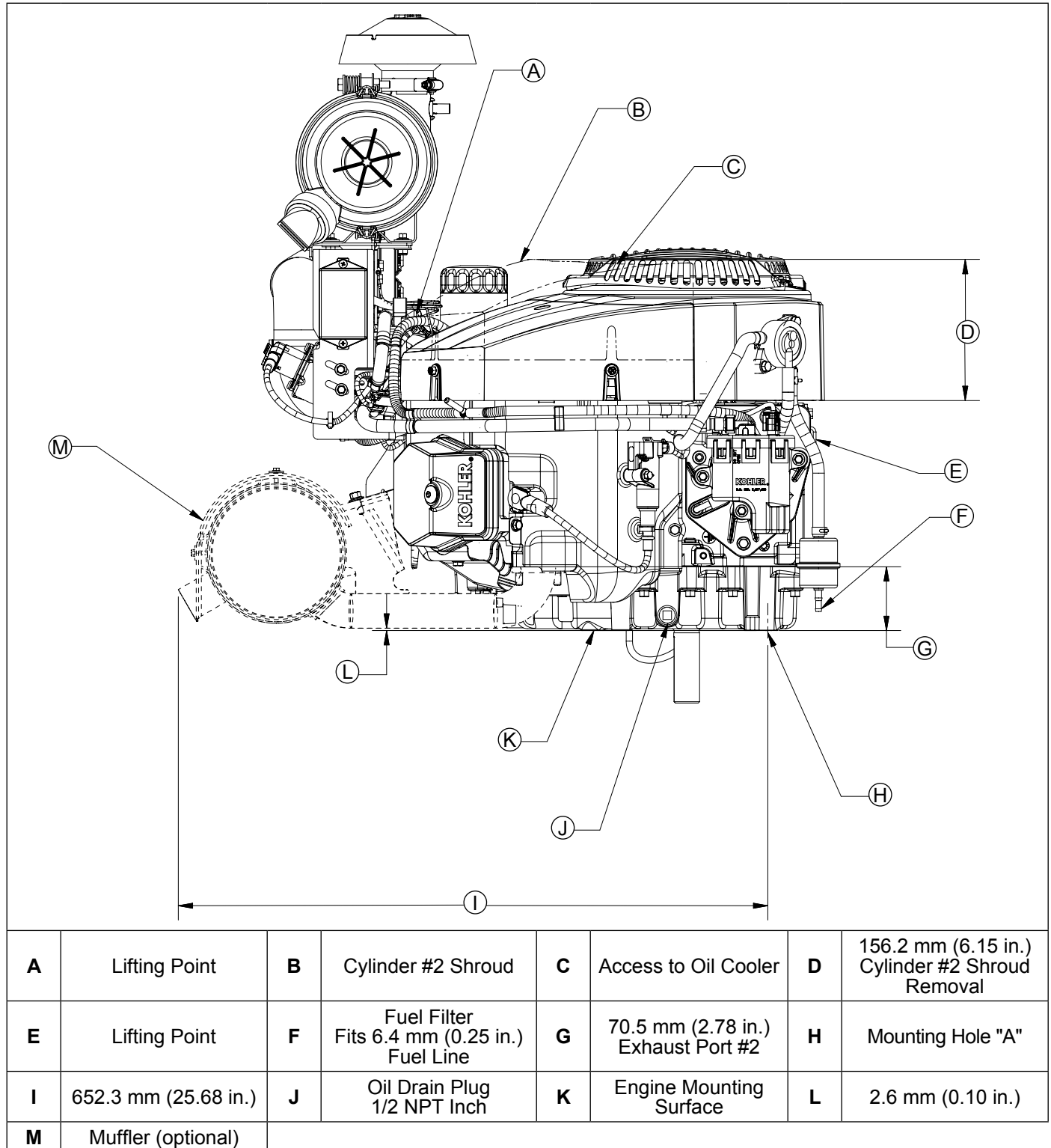
Specifications

Engine Dimensions - Starter Side



A	680.8 mm (26.80 in.)	B	93.5 mm (3.68 in.) Exhaust Port #1	C	Oil Pressure Switch	D	Engine Mounting Surface
E	80.2 mm (3.16 in.)	F	6.4 mm (0.25 in.) Square Keyway	G	7/16-20 UNF-2B Inch 38.1 mm (1.50 in.) Deep	H	Ø 28.6 mm (1.13 in.)
I	Mounting Hole "A"	J	156.2 mm (6.15 in.) Cylinder #1 Shroud Removal	K	389.8 mm (15.35 in.)	L	423.2 mm (16.66 in.)
M	Grass Screen	N	Cylinder #1 Shroud	O	50.0 mm (1.97 in.) Oil Filter Removal		

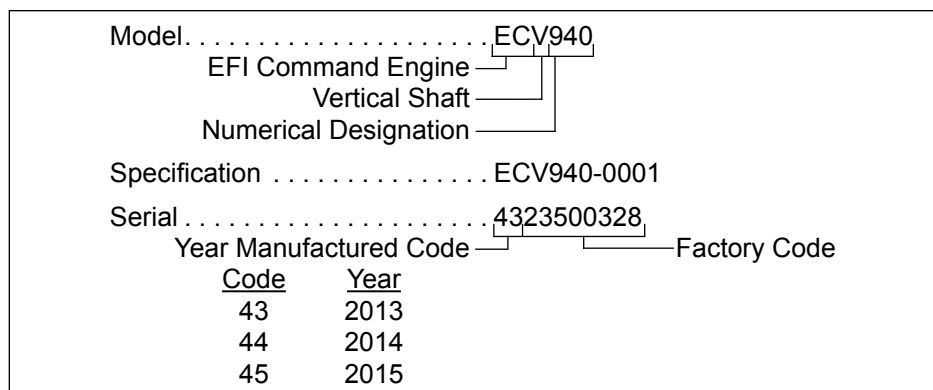
Engine Dimensions - Opposite Starter Side



Specifications

ENGINE IDENTIFICATION NUMBERS

Kohler engine identification numbers (model, specification and serial) should be referenced for efficient repair, ordering correct parts, and engine replacement.



GENERAL SPECIFICATIONS^{3,6}

	ECV940	ECV980
Bore	90 mm (3.54 in.)	
Stroke	78.5 mm (3.1 in.)	
Displacement	999 cc (61 cu. in.)	
Oil Capacity (refill)	1.9 L (2 U.S. qt.)	
Maximum Angle of Operation (@ full oil level) ⁴	25°	

TORQUE SPECIFICATIONS^{3,5}

	ECV940	ECV980
Blower Housing and Sheet Metal		
M6 Screw	10.7 N·m (95 in. lb.)	
New, Untapped Hole (casting)	7.3 N·m (65 in. lb.)	
Used, Tapped Hole (casting)	2.5 N·m (22 in. lb.)	
New, Extruded Hole (sheet metal)	2.0 N·m (18 in. lb.)	
Used, Extruded Hole (sheet metal)	2.5 N·m (22 in. lb.)	
Mounting Clip (valley baffle)		

Intake Manifold and Air Cleaner

Intake Manifold Mounting Fastener (torque in 2 increments)	first to 16.9 N·m (150 in. lb.) finally to 22.6 N·m (200 in. lb.)
Air Cleaner Elbow to Throttle Body Mounting Nut	7.9 N·m (70 in. lb.)
Air Cleaner Bracket Mounting Screw (into intake manifold)	11.3 N·m (100 in. lb.)
GCU Bracket to Intake Manifold & Air Cleaner Bracket	11.3 N·m (100 in. lb.)
Ground Lead to Air Cleaner Bracket	5.6 N·m (50 in. lb.)
Fuel Injector Cap Fastener	7.3 N·m (65 in. lb.)
Manifold Absolute Pressure (MAP) Sensor Fastener (Engines with Separate MAP and Intake Air Temperature Sensors)	7.3 N·m (65 in. lb.)
Temperature/Manifold Absolute Pressure (TMAP) Sensor Fastener (Engines with Combined Sensor)	7.3 N·m (65 in. lb.)

³ Values are in Metric units. Values in parentheses are English equivalents.

⁴ Exceeding maximum angle of operation may cause engine damage from insufficient lubrication.

⁵ Lubricate threads with engine oil prior to assembly.

⁶ Any and all horsepower (hp) references by Kohler are Certified Power Ratings and per SAE J1940 & J1995 hp standards. Details on Certified Power Ratings can be found at KohlerEngines.com.

TORQUE SPECIFICATIONS^{3,5}

ECV940

ECV980

Connecting Rod

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

Breather Cover Fastener	12.4 N·m (110 in. lb.)
Oil Drain Plug	21.4 N·m (16 ft. lb.)
Oil Temperature Sensor	7.3 N·m (65 in. lb.)
Dipstick Tube Screw	7.7 N·m (68 in. lb.)

Cylinder Head

Fastener (torque in 2 increments) Head Bolt	first to 23.7 N·m (210 in. lb.) finally to 46.9 N·m (415 in. lb.)
Pipe Plug 3/4 in.	28.5 N·m (252 in. lb.)
Rocker Arm Stud (AVT)	11.3 N·m (100 in. lb.)
Rocker Arm Screw (Non-AVT)	15.5 N·m (137 in. lb.)
Setscrew, AVT pivot locking	7.7 N·m (69 in. lb.)

Debris Screen

Fastener	9.9 N·m (88 in. lb.)
Hex Stud	21.5 N·m (190 in. lb.)
Mounting Screw - Hex Flange Screw	20.3 N·m (180 in. lb.)
Mounting Screw - Button Head Cap Screw	9.9 N·m (88 in. lb.)
Front Drive Shaft Screw (into flywheel)	24.4 N·m (216 in. lb.)

Flywheel

Fan Fastener Screw - Truss Head	10.4 N·m (92 in. lb.)
Fan Fastener Screw - Hex Head	9.9 N·m (88 in. lb.)
Flywheel Retaining Screw	69.8 N·m (51 ft. lb.)

Fuel Pump

Module Baffle to Crankcase Fastener	11.9 N·m (105 in. lb.)
Module to Baffle Fastener	9.2 N·m (81 in. lb.)
Pulse Pump Screw (to blower housing)	2.8 N·m (25 in. lb.)

Governor (Electronic)

Governor Control Unit (GCU) to GCU Bracket	2.1 N·m (19 in. lb.)
Digital Linear Actuator (DLA) Bracket to GCU Bracket	10.2 N·m (90 in. lb.)
DLA to DLA Bracket Screw	7.3 N·m (65 in. lb.)

Governor (Mechanical)

Lever Nut	7.1 N·m (63 in. lb.)
Yoke Mounting Screw	2.2 N·m (20 in. lb.)

Ignition

Spark Plug	27 N·m (20 ft. lb.)
Coil Fastener	5.1 N·m (45 in. lb.)
Electronic Control Unit (ECU) to Bracket Screw	6.2 N·m (55 in. lb.)
Rectifier-Regulator Fastener	2.5 N·m (22 in. lb.)

³ Values are in Metric units. Values in parentheses are English equivalents.

⁵ Lubricate threads with engine oil prior to assembly.

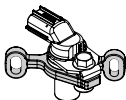
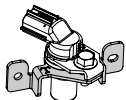
Specifications

TORQUE SPECIFICATIONS^{3,5}

ECV940

ECV980

Igniton Continued

<div> <div>Crankshaft Position Sensor Earlier Design Bracket</div>  </div>	
Crankshaft Position Sensor to Bracket Screw	11.3 N·m (100 in. lb.)
Crankshaft Position Sensor Bracket to Crankcase Screw	9.7 N·m (86 in. lb.)
<div> <div>Crankshaft Position Sensor Later Design Bracket</div>  </div>	
Crankshaft Position Sensor to Bracket Screw	6.8 N·m (60 in. lb.)
Crankshaft Position Sensor Bracket to Crankcase Screw	7.3 N·m (65 in. lb.)

Lifter Feed Chamber Cover

Screw	6.6 N·m (58 in. lb.)
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Muffler

Retaining Nut	24.4 N·m (216 in. lb.)
Screw, intermittent bracket (into weld nut)	13.6 N·m (120 in. lb.)
M6 Screw	9.9 N·m (88 in. lb.)
M8 Screw	24.4 N·m (216 in. lb.)

Oil Cooler

Mounting Screw	2.3 N·m (21 in. lb.)
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Oil Filter Adapter/Housing

Mounting Screw	23.7 N·m (210 in. lb.)
Oil Filter Nipple	17.8 N·m (158 in. lb.)

Oil Pan

Fastener	25.6 N·m (227 in. lb.)
Oil Temperature Sensor	13.6 N·m (120 in. lb.)
Oil Temperature Sensor Reducer Bushing	17.6 N·m (156 in. lb.)
Oil Temperature Sensor Nut	2.3 N·m (20 in. lb.)

Oil Pickup Screen

Mounting Screw	11.3 N·m (100 in. lb.) into a new hole 7.7 N·m (68 in. lb.) into a used hole
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Oil Pump

Mounting Screw	9.9 N·m (88 in. lb.)
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Oil SentryTM

Pressure Switch	10.7 N·m (95 in. lb.)
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Solenoid (starter)

Mounting Hardware	4.0-6.0 N·m (35-53 in. lb.)
Nut, Positive (+) Brush Lead	8.0-11.0 N·m (71-97 in. lb.)

³ Values are in Metric units. Values in parentheses are English equivalents.

⁵ Lubricate threads with engine oil prior to assembly.

Specifications

TORQUE SPECIFICATIONS^{3,5}

ECV940

ECV980

Starter Assembly

Thru Bolt	5.6-9.0 N·m (49-79 in. lb.)
Mounting Screw	16 N·m (142 in. lb.)
Brush Holder Mounting Screw	2.5-3.3 N·m (22-29 in. lb.)

Stator

Mounting Screw	9.3 N·m (82 in. lb.)
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Throttle Control Bracket

Fastener	9.9 N·m (88 in. lb.)
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Valve Cover

Fastener	13.6 N·m (120 in. lb.)
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CLEARANCE SPECIFICATIONS³

ECV940

ECV980

Camshaft

End Play	0.3/1.3 mm (0.011/0.051 in.)
Running Clearance	0.025/0.063 mm (0.0010/0.0025 in.)
Bore I.D. New Max. Wear Limit	20.000/20.025 mm (0.7874/0.7884 in.) 20.038 mm (0.7889 in.)
Bearing Surface O.D. New Max. Wear Limit	19.962/19.975 mm (0.7859/0.7864 in.) 19.959 mm (0.7858 in.)
Cam Lobe Profile (minimum dimension, measured from base circle to top of lobe) Exhaust	35 mm (1.3779 in.)
Intake	34.1 mm (1.3425 in.) 35 mm (1.3779 in.)

Connecting Rod

Crankpin End I.D. @ 70°F New Max. Wear Limit	44.030/44.037 mm (1.7334/1.7337 in.) 0.070 mm (0.0028 in.)
Connecting Rod-to-Crankpin Running Clearance New Max. Wear Limit	0.030/0.055 mm (0.0012/0.0022 in.) 0.070 mm (0.0028 in.)
Connecting Rod-to-Crankpin Side Clearance	0.30/0.59 mm (0.0118/0.0232 in.)
Connecting Rod-to-Piston Pin Running Clearance	0.015/0.028 mm (0.0006/0.0011 in.)
Piston Pin End I.D. @ 70°F New Max. Wear Limit	19.015/19.023 mm (0.7486/0.7489 in.) 19.036 mm (0.7494 in.)

Crankcase

Governor Cross Shaft Bore I.D. (Mechanical Governor) New Max. Wear Limit	8.025/8.050 mm (0.3159/0.3169 in.) 8.088 mm (0.3184 in.)
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Crankshaft

End Play (free) Thrust Bearing (Flange) Non-Thrust Bearing	0.30/1.50 mm (0.011/0.059 in.) 0.20/0.94 mm (0.008/0.037 in.)
------------------------------------------------------------------	------------------------------------------------------------------

³ Values are in Metric units. Values in parentheses are English equivalents.

Specifications

CLEARANCE SPECIFICATIONS³

ECV940

ECV980

Crankshaft Continued

Bore (in crankcase) New	45.043/45.068 mm (1.7733/1.7743 in.)
Crankshaft Bore (in crankcase)-to-Crankshaft Running Clearance New	0.043/0.090 mm (0.0017/0.0035 in.)
Bore (in oil pan) New, Without Bearing	50.025/50.00 mm (1.9694/1.9685 in.)
Crankshaft to Sleeve Bearing (in oil pan) Running Clearance New	0.040/0.167 mm (0.0015/0.0065 in.)
Oil Pan End Main Bearing Journal O.D. - New O.D. - Max. Wear Limit Max. Taper Max. Out-of-Round	44.978/45.00 mm (1.770/1.771 in.) 44.90 mm (1.767 in.) 0.022 mm (0.0009 in.) 0.025 mm (0.0010 in.)
Connecting Rod Journal O.D. - New O.D. - Max. Wear Limit Max. Taper Max. Out-of-Round Width	43.982/44.000 mm (1.731/1.732 in.) 43.97 mm (1.731 in.) 0.018 mm (0.0007 in.) 0.025 mm (0.0010 in.) 53.00/53.09 mm (2.0866/2.0901 in.)
T.I.R. PTO End, Crank in Engine Entire Crank, in V-Blocks	0.279 mm (0.0110 in.) 0.10 mm (0.0039 in.)
Flywheel End Main Bearing Journal O.D. - New O.D. - Max. Wear Limit Max. Taper Max. Out-of-Round	44.978/45.00 mm (1.770/1.771 in.) 44.90 mm (1.767 in.) 0.022 mm (0.0009 in.) 0.025 mm (0.0010 in.)

Crankshaft Bearing (PTO)

New (installed) Max. Wear Limit	45.040/45.145 mm (1.773/1.777 in.) 45.158 mm
------------------------------------	-------------------------------------------------

Cylinder Bore

I.D. New Max. Wear Limit Max. Taper Max. Out-of-Round	90.000/90.025 mm (3.543/3.544 in.) 90.075 mm (3.546 in.) 0.013 mm (0.00051 in.) 0.013 mm (0.00051 in.)
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Cylinder Head

Max. Out-of-Flatness	0.076 mm (0.003 in.)
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Governor (Mechanical)

Governor Cross Shaft-to-Crankcase Running Clearance	0.025/0.087 mm (0.0009/0.0034 in.)
Cross Shaft O.D. New Max. Wear Limit	7.963/8.000 mm (0.3135/0.3149 in.) 7.936 mm (0.3124 in.)
Governor Gear Shaft-to-Governor Gear Running Clearance	0.070/0.160 mm (0.0027/0.0063 in.)
Gear Shaft O.D. New Max. Wear Limit	5.990/6.000 mm (0.2358/0.2362 in.) 5.977 mm (0.2353 in.)

³ Values are in Metric units. Values in parentheses are English equivalents.

CLEARANCE SPECIFICATIONS³

ECV940

ECV980

Ignition

Spark Plug Gap	0.76 mm (0.030 in.)
Crankshaft Position Sensor Air Gap (only on earlier design sensor bracket)	0.2/0.7 mm (0.008/0.027 in.)
Crankshaft Position Sensor Max. Air Gap (only on later design sensor bracket)	2.794 mm (0.110 in.)

Piston, Piston Rings, and Piston Pin

Piston-to-Piston Pin Running Clearance	0.006/0.018 mm (0.0002/0.0007 in.)
Pin Bore I.D. New Max. Wear Limit	19.006/17.013 mm (0.7482/0.7485 in.) 19.025 mm (0.7490 in.)
Pin O.D. New Max. Wear Limit	18.995/19.000 mm (0.7478/0.7480 in.) 18.994 mm (0.7478 in.)
Top Compression Ring-to-Groove Side Clearance	0.04/0.08 mm (0.0015/0.0031 in.)
Middle Compression Ring-to-Groove Side Clearance	0.04/0.08 mm (0.0015/0.0031 in.)
Oil Control Ring-to-Groove Side Clearance	0.03/0.19 mm (0.0011/0.0074 in.)
Top and Center Compression Ring End Gap New Bore Used Bore (max.)	0.30/0.55 mm (0.011/0.021 in.) 0.94 mm (0.037 in.)

Piston, Piston Rings, and Piston Pin Continued

Thrust Face O.D. ⁷ New Max. Wear Limit	89.953/89.967 mm (3.5414/3.5420 in.) 89.925 mm (3.540 in.)
Piston Thrust Face-to-Cylinder Bore ⁷ Running Clearance New	0.033/0.071 mm (0.0013/0.0028 in.)

Valves and Valve Lifters






Hydraulic Valve Lifter to Crankcase Running Clearance	0.012/0.050 mm (0.0004/0.0019 in.)
Intake Valve Stem-to-Valve Guide Running Clearance	0.038/0.076 mm (0.0015/0.0030 in.)
Exhaust Valve Stem-to-Valve Guide Running Clearance	0.050/0.088 mm (0.0020/0.0035 in.)
Intake Valve Guide I.D. New Max. Wear Limit	7.038/7.058 mm (0.2771/0.2779 in.) 7.135 mm (0.2809 in.)
Exhaust Valve Guide I.D. New Max. Wear Limit	7.038/7.058 mm (0.2771/0.2779 in.) 7.159 mm (0.2819 in.)
Guide Reamer Size Standard 0.25 mm O.S.	7.048 mm (0.2775 in.) 7.298 mm (0.2873 in.)
Nominal Valve Face Angle	45°

³ Values are in Metric units. Values in parentheses are English equivalents.






⁷ Measure 11 mm (0.4331 in.) above bottom of piston skirt at right angles to piston pin.

Specifications

GENERAL TORQUE VALUES

English Fastener Torque Recommendations for Standard Applications				
Bolts, Screws, Nuts and Fasteners Assembled Into Cast Iron or Steel				Grade 2 or 5 Fasteners Into Aluminum
Size	 Grade 2	 Grade 5	 Grade 8	 
Tightening Torque: N·m (in. lb.) ± 20%				
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.) ± 20%				
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)	142.5 (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	149.5 (110)	244.1 (180)	352.6 (260)	—
5/8-18	189.8 (140)	311.9 (230)	447.5 (330)	—
3/4-10	199.3 (147)	332.2 (245)	474.6 (350)	—
3/4-16	271.2 (200)	440.7 (325)	637.3 (470)	—

Metric Fastener Torque Recommendations for Standard Applications						
Size	Property Class					Noncritical Fasteners Into Aluminum
	 4.8	 5.8	 8.8	 10.9	 12.9	
Tightening Torque: N·m (in. lb.) ± 10%						
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.) ± 10%						
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 (56)	131.5 (97)	184.4 (136)	219.7 (162)	94.9 (70)

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

Certain quality tools are designed to help you perform specific disassembly, repair, and reassembly procedures. By using these tools, 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 a list of tools and their source.

SEPARATE TOOL SUPPLIERS

Kohler Tools
Contact your local Kohler 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.
Alcohol Content Tester For testing alcohol content (%) in reformulated/oxygenated fuels.	Kohler 25 455 11-S
Camshaft Endplay Plate For checking camshaft endplay.	SE Tools KLR-82405
Camshaft Seal Protector (Aegis) For protecting seal during camshaft installation.	SE Tools KLR-82417
Cylinder Leakdown Tester For checking combustion retention and if cylinder, piston, rings, or valves are worn. Individual component available: Adapter 12 mm x 14 mm (Required for leakdown test on XT-6 engines)	Kohler 25 761 05-S Design Technology Inc. DTI-731-03
Dealer Tool Kit (Domestic) Complete kit of Kohler required tools. Components of 25 761 39-S Ignition System Tester Cylinder Leakdown Tester Oil Pressure Test Kit Rectifier-Regulator Tester (120 V AC/60Hz)	Kohler 25 761 39-S Kohler 25 455 01-S Kohler 25 761 05-S Kohler 25 761 06-S Kohler 25 761 20-S
Dealer Tool Kit (International) Complete kit of Kohler required tools. Components of 25 761 42-S Ignition System Tester Cylinder Leakdown Tester Oil Pressure Test Kit Rectifier-Regulator Tester (240 V AC/50Hz)	Kohler 25 761 42-S Kohler 25 455 01-S Kohler 25 761 05-S Kohler 25 761 06-S Kohler 25 761 41-S
Digital Vacuum/Pressure Tester For checking crankcase vacuum. Individual component available: Rubber Adapter Plug	Design Technology Inc. DTI-721-01 Design Technology Inc. DTI-721-10
Electronic Fuel Injection (EFI) Diagnostic Software For Laptop or Desktop PC.	Kohler 25 761 23-S
EFI Service Kit For troubleshooting and setting up an EFI engine. Components of 24 761 01-S Fuel Pressure Tester Noid Light 90° Adapter In-line "T" Fitting Code Plug, Red Wire Code Plug, Blue Wire Shrader Valve Adapter Hose	Kohler 24 761 01-S Design Technology Inc. DTI-019 DTI-021 DTI-023 DTI-035 DTI-027 DTI-029 DTI-037
Flywheel Puller For properly removing flywheel from engine.	SE Tools KLR-82408

Tools and Aids

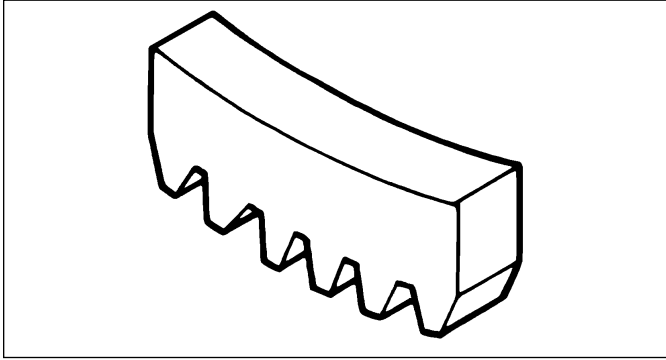
TOOLS

Description	Source/Part No.
Hydraulic Valve Lifter Tool For removing and installing hydraulic lifters.	Kohler 25 761 38-S
Ignition System Tester For testing output on all systems, including CD.	Kohler 25 455 01-S
Inductive Tachometer (Digital) For checking operating speed (RPM) of an engine.	Design Technology Inc. DTI-110
Offset Wrench (K and M Series) For removing and reinstalling cylinder barrel retaining nuts.	Kohler 52 455 04-S
Oil Pressure Test Kit For testing/verifying oil pressure on pressure lubricated engines.	Kohler 25 761 06-S
Rectifier-Regulator Tester (120 volt current) Rectifier-Regulator Tester (240 volt current) For testing rectifier-regulators. Components of 25 761 20-S and 25 761 41-S CS-PRO Regulator Test Harness Special Regulator Test Harness with Diode	Kohler 25 761 20-S Kohler 25 761 41-S Design Technology Inc. DTI-031 DTI-033
Spark Advance Module (SAM) Tester For testing SAM (ASAM and DSAM) on engines with SMART-SPARK™.	Kohler 25 761 40-S
Starter Servicing Kit (All Starters) For removing and reinstalling drive retaining rings and brushes. Individual component available: Starter Brush Holding Tool (Solenoid Shift)	SE Tools KLR-82411 SE Tools KLR-82416
Triad/OHC Timing Tool Set For holding cam gears and crankshaft in timed position while installing timing belt.	Kohler 28 761 01-S
Valve Guide Reamer (K and M Series) For properly sizing valve guides after installation.	Design Technology Inc. DTI-K828
Valve Guide Reamer O.S. (Command Series) For reaming worn valve guides to accept replacement oversize valves. Can be used in low-speed drill press or with handle below for hand reaming.	Kohler 25 455 12-S
Reamer Handle For hand reaming using Kohler 25 455 12-S reamer.	Design Technology Inc. DTI-K830

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	Loctite® 51360
Kohler Electric Starter Drive Lubricant (Inertia Drive)	Kohler 52 357 01-S
Kohler 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.	Kohler 25 597 07-S Loctite® 5910® Loctite® Ultra Black 598™ Loctite® Ultra Blue 587™ Loctite® Ultra Copper 5920™
Spline Drive Lubricant	Kohler 25 357 12-S

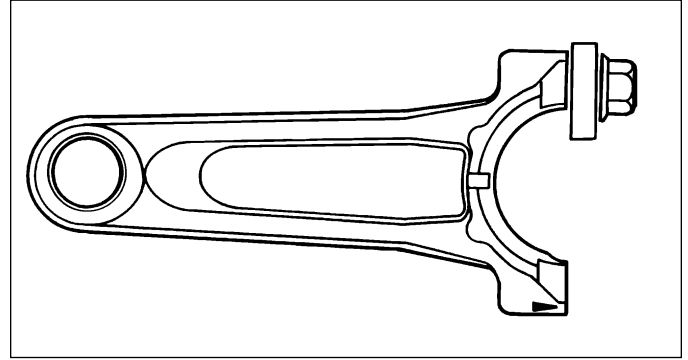
FLYWHEEL HOLDING TOOL



A flywheel holding tool can be made out of an old junk flywheel ring gear and used in place of a strap wrench.

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

ROCKER ARM/CRANKSHAFT TOOL



A spanner wrench to lift rocker arms or turn 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 rod cap.
2. Remove studs of a Posi-Lock rod or grind off aligning steps of a Command rod, so joint surface is flat.
3. Find a 1 in. long cap screw with correct thread size to match threads in connecting rod.
4. Use a flat washer with correct I.D. to slip on cap screw and approximately 1 in. O.D. Assemble cap screw and washer to joint surface of rod.

Troubleshooting

TROUBLESHOOTING GUIDE

When troubles occur, be sure to check 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 and vary by engine specification. Use these to locate causing factors.

Engine Cranks But Will Not Start

- Battery connected backwards.
- Blown fuse.
- Carburetor solenoid malfunction.
- Choke not closing.
- Clogged fuel line or fuel filter.
- Diode in wiring harness failed in open circuit mode.
- DSAI or DSAM malfunction.
- Empty fuel tank.
- Faulty electronic control unit.
- Faulty ignition coil(s).
- Faulty spark plug(s).
- Fuel pump malfunction-vacuum hose clogged or leaking.
- Fuel shut-off valve closed.
- Ignition module(s) faulty or improperly gapped.
- Insufficient voltage to electronic control unit.
- Interlock switch is engaged or faulty.
- Key switch or kill switch in OFF position.
- Low oil level.
- Quality of fuel (dirt, water, stale, mixture).
- SMART-SPARK™ malfunction.
- Spark plug lead(s) disconnected.

Engine Starts But Does Not Keep Running

- Faulty carburetor.
- Faulty cylinder head gasket.
- Faulty or misadjusted choke or throttle controls.
- Fuel pump malfunction-vacuum hose clogged or leaking.
- Intake system leak.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Quality of fuel (dirt, water, stale, mixture).
- Restricted fuel tank cap vent.

Engine Starts Hard

- Clogged fuel line or fuel filter.
- Engine overheated.
- Faulty ACR mechanism.
- Faulty or misadjusted choke or throttle controls.
- Faulty spark plug(s).
- Flywheel key sheared.
- Fuel pump malfunction-vacuum hose clogged or leaking.
- Interlock switch is engaged or faulty.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Low compression.
- Quality of fuel (dirt, water, stale, mixture).
- Weak spark.

Engine Will Not Crank

- Battery is discharged.
- Faulty electric starter or solenoid.
- Faulty key switch or ignition switch.
- Interlock switch is engaged or faulty.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Pawls not engaging in drive cup.
- Seized internal engine components.

Engine Runs But Misses

- Carburetor adjusted incorrectly.
- Engine overheated.
- Faulty spark plug(s).
- Ignition module(s) faulty or improperly gapped.
- Incorrect crankshaft position sensor air gap.
- Interlock switch is engaged or faulty.
- Loose wires or connections that intermittently ground ignition kill circuit.
- Quality of fuel (dirt, water, stale, mixture).
- Spark plug lead(s) disconnected.
- Spark plug lead boot loose on plug.
- Spark plug lead loose.

Engine Will Not Idle

- Engine overheated.
- Faulty spark plug(s).
- Idle fuel adjusting needle(s) improperly set.
- Idle speed adjusting screw improperly set.
- Inadequate fuel supply.
- Low compression.
- Quality of fuel (dirt, water, stale, mixture).
- Restricted fuel tank cap vent.

Engine Overheats

- Cooling fan broken.
- Excessive engine load.
- Fan belt failed/off.
- Faulty carburetor.
- High crankcase oil level.
- Lean fuel mixture.
- Low cooling system fluid level.
- Low crankcase oil level.
- Radiator, and/or cooling system components clogged, restricted, or leaking.
- Water pump belt failed/broken.
- Water pump malfunction.

Engine Knocks

- Excessive engine load.
- Hydraulic lifter malfunction.
- Incorrect oil viscosity/type.
- Internal wear or damage.
- Low crankcase oil level.
- Quality of fuel (dirt, water, stale, mixture).

Engine Loses Power

- Dirty air cleaner element.
- Engine overheated.
- Excessive engine load.
- Restricted exhaust.
- Faulty spark plug(s).
- High crankcase oil level.
- Incorrect governor setting.
- Low battery.
- Low compression.
- Low crankcase oil level.
- Quality of fuel (dirt, water, stale, mixture).

Engine Uses Excessive Amount of Oil

- Loose or improperly torqued fasteners.
- Blown head gasket/overheated.
- Breather reed broken.
- Clogged, broken, or inoperative crankcase breather.
- Crankcase overfilled.
- Incorrect oil viscosity/type.
- Worn cylinder bore.
- Worn or broken piston rings.
- Worn valve stems/valve guides.

Oil Leaks from Oil Seals, Gaskets

- Breather reed broken.
- Clogged, broken, or inoperative crankcase breather.
- Loose or improperly torqued fasteners.
- Piston blow by, or leaky valves.
- Restricted exhaust.

EXTERNAL ENGINE INSPECTION


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

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

- Check for buildup of dirt and debris on crankcase, cooling fins, grass screen, and other external surfaces. Dirt or debris on these areas can cause overheating.
- Check for obvious fuel and oil leaks, and damaged components. Excessive oil leakage can indicate a clogged or inoperative breather, worn or damaged seals or gaskets, or loose fasteners.
- Check air cleaner cover and base for damage or indications of improper fit and seal.
- Check air cleaner element. Look for holes, tears, cracked or damaged sealing surfaces, or other damage that could allow unfiltered air into engine. A dirty or clogged element could indicate insufficient or improper maintenance.
- Check carburetor throat for dirt. Dirt in throat is further indication that air cleaner was not functioning properly.
- Check if oil level is within operating range on dipstick. If it is above, sniff for gasoline odor.
- Check condition of oil. Drain oil into a container; it 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 over rich fuel settings, weak ignition, overextended oil change interval or wrong weight or type of oil was used.

CLEANING ENGINE


	⚠ WARNING
	<p>Cleaning Solvents can cause severe injury or death.</p> <p>Use only in well ventilated areas away from ignition sources.</p>
<p>Carburetor cleaners and solvents are extremely flammable. Follow cleaner manufacturer's warnings and instructions on its proper and safe use. Never use gasoline as a cleaning agent.</p>	

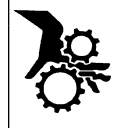
After inspecting external condition of engine, clean engine thoroughly before disassembly. Clean individual components as engine is disassembled. Only clean parts can be accurately inspected and gauged for wear or damage. There are many commercially available cleaners that will quickly remove grease,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

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

Troubleshooting

CRANKCASE VACUUM TEST

	<p>⚠ WARNING</p> <p>Carbon Monoxide can cause severe nausea, fainting or death. Avoid inhaling exhaust fumes.</p>
<p>Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.</p>	

	<p>⚠ WARNING</p> <p>Rotating Parts can cause severe injury. Stay away while engine is in operation.</p>
<p>Keep hands, feet, hair, and clothing away from all moving parts to prevent injury. Never operate engine with covers, shrouds, or guards removed.</p>	

A partial vacuum should be present in crankcase when engine is operating. Pressure in 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. Complete instructions are provided in kits.

To test crankcase vacuum with manometer:

1. Insert rubber stopper into oil fill hole. Be sure pinch clamp is installed on hose and use tapered adapters to connect hose between stopper and one manometer tube. Leave other tube open to atmosphere. Check that water level in manometer is at 0 line. Make sure pinch clamp is closed.
2. Start engine and run no-load high speed.
3. Open clamp and note water level in tube.
Level in engine side should be a minimum of 10.2 cm (4 in.) above level in open side.
If level in engine side is less than specified (low/no vacuum), or level in engine side is lower than level in open side (pressure), check for conditions in table below.
4. Close pinch clamp before stopping engine.

To test crankcase vacuum with vacuum/pressure gauge:

1. Remove dipstick or oil fill plug/cap.
2. Install adapter into oil fill/dipstick tube opening, upside down over end of a small diameter dipstick tube, or directly into engine if a tube is not used. Insert barbed gauge fitting into hole in stopper.
3. Run engine and observe gauge reading.
Analog tester—needle movement to left of 0 is a vacuum, and movement to right indicates a pressure.
Digital tester—depress test button on top of tester.
Crankcase vacuum should be a minimum of 10.2 cm (4 in.) of water. If reading is below specification, or if pressure is present, check table below for possible causes and conclusions.

Condition	Conclusion
Crankcase breather clogged or inoperative.	<p>NOTE: If breather is integral part of valve cover and cannot be serviced separately, replace valve cover and recheck pressure.</p> <p>Disassemble breather, clean parts thoroughly, check sealing surfaces for flatness, reassemble, and recheck pressure.</p>
Seals and/or gaskets leaking. Loose or improperly torque fasteners.	Replace all worn or damaged seals and gaskets. Make sure all fasteners are tightened securely. Use appropriate torque valves and sequences when necessary.
Piston blow by or leaky valves (confirm by inspecting components).	Recondition piston, rings, cylinder bore, valves and valves guides.
Restricted exhaust.	Check exhaust screen/spark arrestor (if equipped). Clean or replace as needed. Repair or replace any other damaged/restricted muffler or exhaust system parts.

COMPRESSION TEST

For Command Twins:

A compression test is best performed on a warm engine. Clean any dirt or debris away from base of spark plug(s) before removing them. Be sure choke is off, and throttle is wide open during test. Compression should be at least 160 psi and should not vary more than 15% between cylinders.

All other models:

These engines are equipped with an automatic compression release (ACR) mechanism. It is difficult to obtain an accurate compression reading because of ACR mechanism. As an alternative, use cylinder leakdown test described below.

CYLINDER LEAKDOWN TEST

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

Cylinder leakdown tester is a relatively simple, inexpensive leakdown tester for small engines. This tester includes a quick-connect for attaching adapter hose and a holding tool.

1. Run engine for 3-5 minutes to warm it up.
2. Remove spark plug(s) and air filter from engine.
3. Rotate crankshaft until piston (of cylinder being tested) is at top dead center (TDC) of compression stroke. Hold engine in this position while testing. Holding tool supplied with tester can be used if PTO end of crankshaft is accessible. Lock holding tool onto crankshaft. Install a 3/8 in. breaker bar into hole/slot of holding tool, so it is perpendicular to both holding tool and crankshaft PTO.

If flywheel end is more accessible, use a breaker bar and socket on flywheel nut/screw to hold it in position. An assistant may be needed to hold breaker bar during testing. If 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 engine cannot rotate off of TDC in either direction.

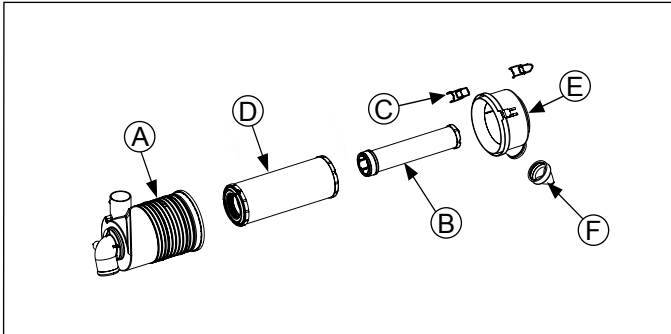
4. Install adapter into spark plug hole, but do not attach it to tester at this time.
5. Turn regulator knob completely counterclockwise.
6. Connect an air source of at least 50 psi to tester.
7. Turn regulator knob clockwise (increase direction) until gauge needle is in yellow set area at low end of scale.
8. Connect tester quick-connect to adapter hose. While firmly holding engine at TDC, gradually open tester valve. Note gauge reading and listen for escaping air at combustion air intake, exhaust outlet, and crankcase breather.

Condition	Conclusion
Air escaping from crankcase breather.	Ring or cylinder worn.
Air escaping from exhaust system.	Defective exhaust valve/improper seating.
Air escaping from intake.	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.

Air Cleaner/Intake

AIR CLEANER

These systems are CARB/EPA certified and components should not be altered or modified in any way.



A	Air Cleaner Housing	B	Inner Element
C	Retaining Clip	D	Element
E	End Cap	F	Dust Ejector Valve

NOTE: Operating engine with loose or damaged air cleaner components could cause premature wear and failure. Replace all bent or damaged components.

NOTE: Paper element cannot be blown out with compressed air.

1. Unhook retaining clips and remove end cap(s).
2. Check and clean inlet screen (if equipped).
3. Pull air cleaner element out of housing and replace. Check condition of inner element; replace when dirty.
4. Check all parts for wear, cracks, or damage, and that ejector area is clean.
5. Install new element(s).
6. Reinstall end cap(s) with dust ejector valve/screen down; secure with retaining clips.

BREATHER TUBE


Ensure both ends of breather tube are properly connected.

AIR COOLING

	⚠ WARNING
	Hot Parts can cause severe burns. Do not touch engine while operating or just after stopping.
	Never operate engine with heat shields or guards removed.

NOTE: Operating engine with a restricted air intake screen or radiator, damaged/ broken fan assembly, or missing fan shroud will cause engine damage due to over heating.

Proper cooling is essential. To prevent over heating, clean screens, cooling fins, and other external surfaces of engine. Avoid spraying water at wiring harness or any electrical components. See Maintenance Schedule.

	⚠ WARNING
	Explosive Fuel can cause fires and severe burns. Do not fill fuel tank while engine is hot or running.
	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. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.

Typical electronic fuel injection (EFI) system and related components include:

- 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). Earlier engines have a contacting (brushes) TPS. Later engines have a contactless (magnetic) TPS.
- Crankshaft position sensor.
- Oxygen sensor.
- Earlier engines have a separate manifold absolute pressure sensor (MAP) and an intake air temperature (IAT) sensor (located in throttle body).
- Later engines have a combined temperature/manifold absolute pressure (TMAP) sensor.
- Malfunction indicator light (MIL) - optional.
- Wire harness assembly & affiliated wiring.

FUEL RECOMMENDATIONS

Refer to Maintenance.

FUEL LINE

Low permeation fuel line must be installed on all Kohler Co. engines to maintain EPA and CARB regulatory compliance.

OPERATION

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

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

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

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

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

- Oil temperature is greater than 50-60°C (122-140°F).
- Oxygen sensor has warmed sufficiently to provide a signal (minimum 400°C, 752°F).
- Engine operation is at a steady state (not starting, warming up, accelerating, etc.).

During closed loop operation ECU has ability to readjust and learn adaptive controls, providing compensation for changes in overall engine condition and operating environment, so it will be able to maintain ideal air/fuel ratio. This system requires a minimum engine oil temperature greater than 60-70°C (140-158°F) to properly adapt. These adaptive values are maintained as long as 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 system operates in an open loop mode. In open loop operation oxygen sensor output is used to ensure engine is running rich, and controlling adjustments are based on primary sensor signals and programmed maps only. This system operates open loop whenever three conditions for closed loop operation (above) are not being met.

ECU is brain or central processing computer of entire EFI system. During operation, sensors continuously gather data which is relayed through wiring harness to input circuits within ECU. Signals to 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.

EFI SYSTEM

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

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

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 ECU. If maximum RPM limit (4500) is exceeded, ECU suppresses injection signals, cutting off fuel flow. This process repeats itself in rapid succession, limiting operation to preset maximum.

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

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

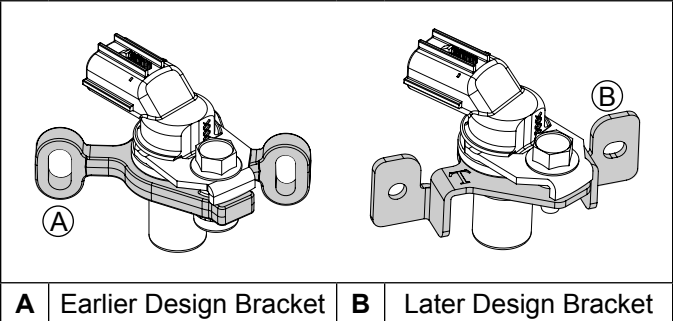
EFI system is a 12 VDC negative ground system, designed to operate down to a minimum of 6.0 volts. If system voltage drops below this level, operation of voltage sensitive components such as ECU, fuel pump, ignition coils, and injectors will be intermittent or disrupted, causing erratic operation or 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 wiring harness or connections. Even small amounts of corrosion or oxidation on terminals can interfere with milliamp currents used in system operation.

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

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

Crankshaft Position Sensor Bracket



Crankshaft position sensor is essential to engine operation; constantly monitoring rotation and speed (RPM) of crankshaft. There are 23 consecutive teeth cast into flywheel. One tooth is missing and is used to reference crankshaft position for ECU. Inductive crankshaft position sensor with earlier design bracket is mounted 0.20-0.70 mm (0.008-0.027 in.) from flywheel. Later design bracket requires no adjustment.

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

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

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

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

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

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

Earlier engines have a separate intake air temperature (IAT) sensor (located in throttle body) and a manifold absolute pressure (MAP) sensor. Later engines have a combined temperature/manifold absolute pressure (TMAP) sensor.

Intake Air Temperature (IAT) sensor is a thermally sensitive resistor that exhibits a change in electrical resistance with a change in its temperature. When sensor is cold, resistance of sensor is high. As sensor warms up, resistance drops and voltage signal increases. From voltage signal, ECU can determine temperature of intake air.

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

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

Later engines have a Temperature/Manifold Absolute Pressure (TMAP) sensor. This is an integrated sensor that checks both intake air temperature and manifold absolute pressure. This combined sensor is located in intake manifold.

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

Tip of sensor, protruding into exhaust gas, is hollow. Outer portion of tip is surrounded by exhaust gas, with inner portion exposed to ambient air. When oxygen concentration on one side of tip is different than that of other side, a voltage signal up to 1.0 volt is generated and sent to ECU. Voltage signal tells ECU if engine is straying from ideal fuel mixture, and ECU then adjusts injector pulse accordingly.

Oxygen sensor functions after being heated to a minimum of 400°C (752°F). A heater inside sensor heats electrode to optimum temperature in about 10 seconds. Oxygen sensor receives ground through wire, eliminating need for proper grounding through muffler. If problems indicate a bad oxygen sensor, check all connections and wire harness. 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 O2 Sensor Safe.

Fuel injectors mount into intake manifold, and high pressure fuel line attaches to them at top end. Replaceable O-rings on both ends of injector prevent external fuel leakage and also insulate it from heat and vibration. A special clip connects each injector to high pressure fuel line and holds it in place. O-rings and retaining clip must be replaced any time fuel injector is separated from its normal mounting position.

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

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

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

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

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

Fuel pump module is rated for a minimum output of 13.5 liters per hour and regulated at 270 kilopascals (39 psi).

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

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

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

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

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

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

EFI engines have no carburetor, so throttle function (regulate incoming combustion airflow) is achieved with a throttle valve in a separate throttle body attached to intake manifold. Throttle body/intake manifold provides mounting for fuel injectors, throttle position sensor, either a separate MAP sensor and an intake air temperature sensor, or a TMAP sensor, high pressure fuel line, idle speed screw, and air cleaner assembly.

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

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

IMPORTANT NOTES!

- Cleanliness is essential and must be maintained at all times when servicing or working on 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 system.
- Always depressurize fuel system through fuel connector on fuel pump module before disconnecting or servicing any fuel system components.
- Never attempt to service any fuel system component while engine is running or ignition switch is ON.
- Do not use compressed air if 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 ECU wiring harness connector or any individual components with ignition on. This can send a damaging voltage spike through ECU.
- Do not allow battery cables to touch opposing terminals. When connecting battery cables attach positive (+) cable to positive (+) battery terminal first, followed by negative (–) cable to negative (–) battery terminal.
- Never start engine when cables are loose or poorly connected to battery terminals.
- Never disconnect battery while engine is running.
- Never use a quick battery charger to start engine.
- Do not charge battery with key switch ON.
- Always disconnect negative (–) battery cable before charging battery, and also unplug harness from ECU before performing any welding on equipment.

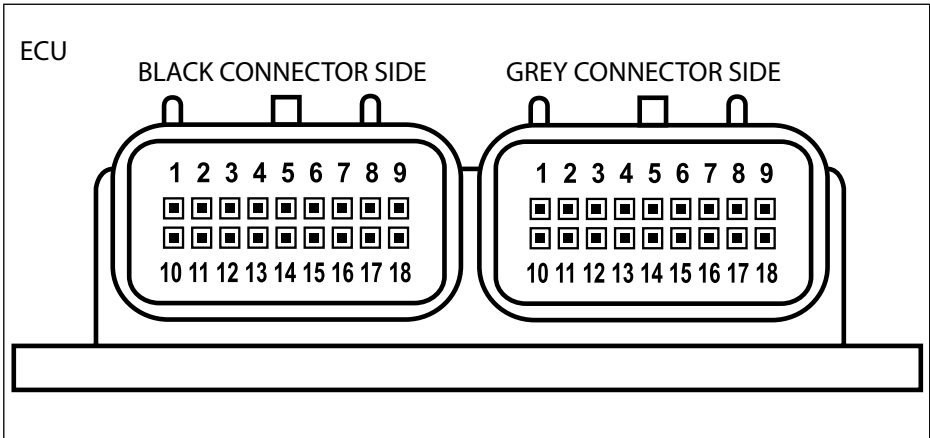
ELECTRICAL COMPONENTS

Electronic Control Unit (ECU)

Pinout of ECU

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

Grey Connector Side	
Pin #	Description
1	Not Used
2	Not Used
3	Malfunction Indicator Light (MIL) Ground
4	Not Used
5	Not Used
6	GCU Tach Output (Electronic Governor)
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 ECU

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

All operating and control functions within ECU are preset. No internal servicing or readjustment may be performed. If a problem is encountered, and you determine ECU to be faulty, contact your source of supply.

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

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

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

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

This system will NOT reset when battery is disconnected!

ECU Reset Procedure

1. Turn key/ignition OFF.
2. Install Red wire jumper from Kohler EFI service kit on to service port (connect white wire to black wire in 4 way diagnostic port).
3. Turn key/ignition ON, then OFF and count 10 seconds.
4. Turn key/ignition ON, then OFF and count to 10 seconds a second time.
5. Remove Red wire jumper. Turn key/ignition ON, then OFF and count to 10 seconds a third time. ECU is reset.

A TPS Learn Procedure **must** be performed after ECU reset.

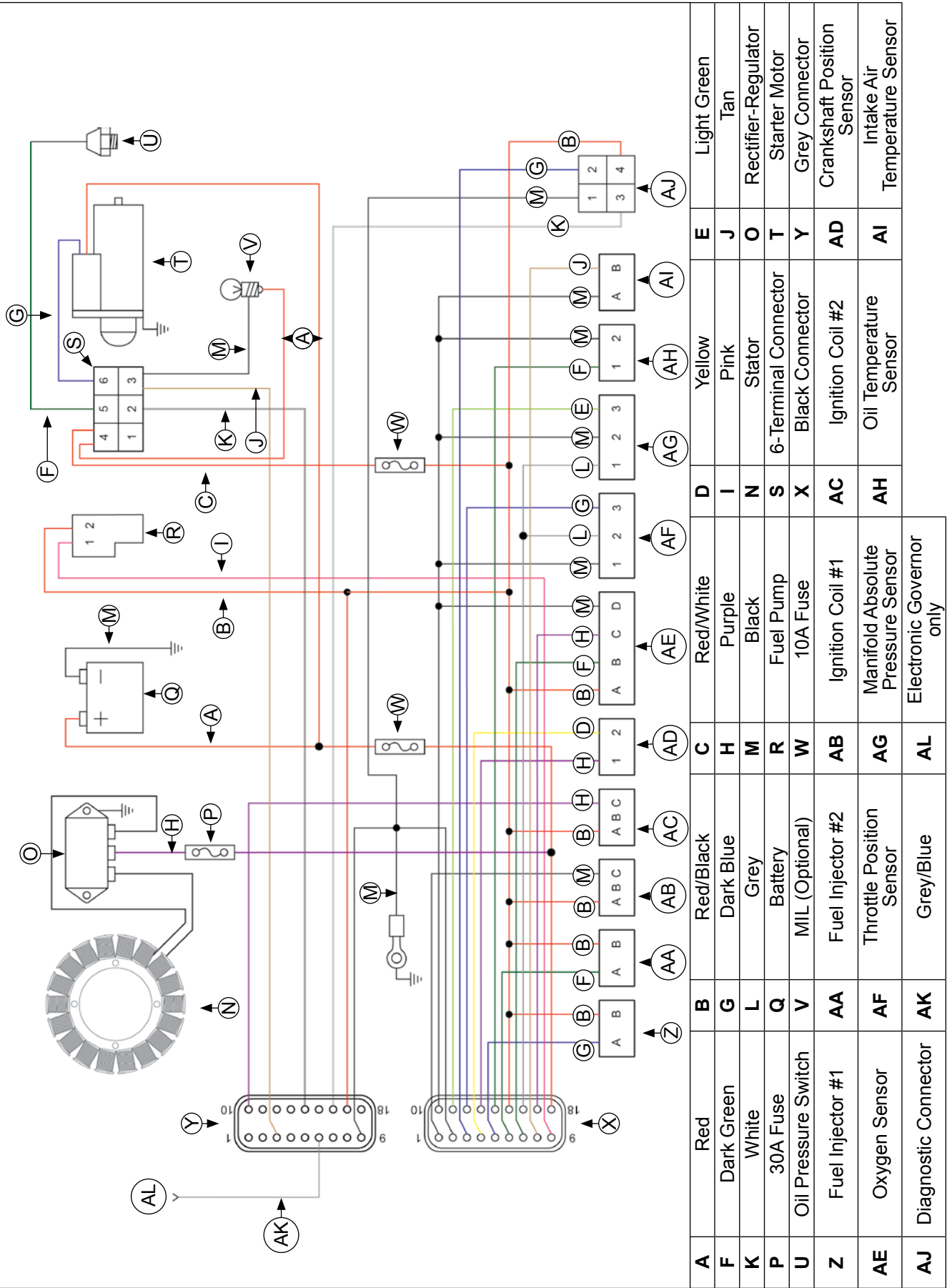
TPS Learn Procedure

1. Turn idle screw clockwise one full turn prior to key/ignition 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 idle speed to final specified speed setting.
6. Turn key/ignition OFF and count to 10 seconds.

Learn procedure is complete.

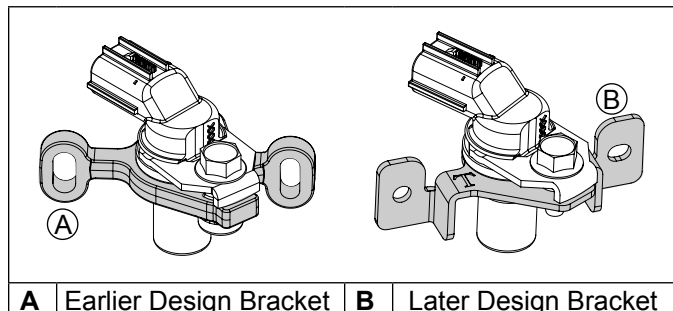
Wiring Harness

EFI Wiring Diagram 6-Terminal Connector (engines with separate MAP sensor and intake air temperature sensor)



A	Red	B	Red/Black	C	Red/White	D	Yellow	E	Light Green
F	Dark Green	G	Dark Blue	H	Purple	I	Pink	J	Tan
K	White	L	Grey	M	Black	N	Stator	O	Rectifier-Regulator
P	30A Fuse	Q	Battery	R	Fuel Pump	S	6-Terminal Connector	T	Starter Motor
U	Oil Pressure Switch	V	MIL (Optional)	W	10A Fuse	X	Black Connector	Y	Grey Connector
Z	Fuel Injector #1	AA	Fuel Injector #2	AB	Ignition Coil #1	AC	Ignition Coil #2	AD	Crankshaft Position Sensor
AE	Oxygen Sensor	AF	Throttle Position Sensor	AG	TMAP Sensor	AH	Oil Temperature Sensor	AI	Diagnostic Connector
AJ	Grey/Blue	AK	Electronic Governor only						

Crankshaft Position Sensor



A sealed, non-serviceable assembly. If Fault Code diagnosis indicates a problem within this area, test and correct as follows.

- Check mounting and air gap of crankshaft position sensor.
Earlier design bracket has slots to set air gap of 0.20-0.70 mm (0.008-0.027 in.).
Later design bracket is not adjustable, but if gap is greater than 2.794 mm (0.110 in.) check bracket or sensor for damage.
- Inspect wiring and connections for damage or problems.
- Make sure engine has resistor type spark plugs.
- Disconnect Black connector from ECU.
- Connect an ohmmeter between #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 mounting, air gap, flywheel teeth (damage, run-out, etc.), and flywheel key.
- Disconnect crankshaft position sensor connector from wiring harness. Test resistance between terminals. A reading of 325-395 Ω should again be obtained.
 - If resistance is incorrect, remove screws securing sensor to mounting bracket and replace sensor.
 - If resistance in step 5 was incorrect, but resistance of sensor alone was correct, test wire harness circuits between sensor connector terminals and corresponding pin terminals (#4 and #13) in main connector. Correct any observed problem, reconnect sensor, and perform step 5 again.
- When fault is corrected and engine starts, clear fault codes following ECU Reset procedure.

Throttle Position Sensor (TPS)

Earlier engines were built with a contacting (brush) type TPS. Later engines are built with a contactless (magnet) type TPS. Both designs have same three wires attached; a 5 volt supply, a ground, and a signal wire. However, these designs are not interchangeable. Follow proper testing information based on sensor type.

Contacting (Brush) Type TPS Resistance Table

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

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 TPS, it can be tested as follows:

- Counting number of turns, back out idle speed adjusting screw (counterclockwise) until throttle plates can be closed completely. Write this number down for reference later.
- Disconnect Black connector from ECU, but leave TPS mounted to throttle body.
- Use an ohmmeter and connect red (positive) ohmmeter lead to Black pin 12 terminal and black (negative) ohmmeter lead to Black pin 10 terminal to test.
 - Hold throttle closed and check resistance. It should be 1400-1800 Ω .
- Leave leads connected to pin terminals as described in step 3. Rotate throttle shaft slowly to full throttle position. Monitor dial during rotation for indication of any momentary short or open circuits. Note resistance at full throttle position. It should be 4600-5200 Ω without a stop pin, or 3200-4100 Ω with a stop pin.
- Disconnect main wiring harness connector from TPS, leaving TPS assembled to throttle body. Refer to Resistance Table and perform resistance checks indicated between terminals in TPS switch, with throttle in positions specified.
If resistance values in steps 3, 4, and 5 are within specifications, go to step 6.
If resistance values are not within specifications, or a momentary short or open circuit was detected during rotation (step 4), TPS needs to be replaced, go to step 7.
- Check TPS circuits (input, ground) between TPS plug and main harness connector for continuity, damage, etc. Input pin is 12 and ground is pin 10.
 - Repair or replace as required.
 - Turn idle speed screw back in to its original setting.
 - Reconnect connector plugs, start engine and retest system operation.
- Remove two mounting screws from TPS. Save screws for reuse. Remove and discard faulty TPS. Install replacement TPS and secure with original mounting screws.
 - Reconnect Black and TPS connector plugs.
 - Perform TPS Learn Procedure integrating new sensor to ECU.

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Contactless (Magnet) Type TPS

TPS is a sealed, non-serviceable assembly. If diagnosis indicates a bad sensor, complete replacement is necessary. Magnet that sensor detects is separate, and can be replaced or reused. If a blink code indicates a problem with TPS, it can be tested as follows:

Diagnostics of sensor: ECU will still have electrical faults captured in fault codes: P0122 & P0123. These electrical faults still have same meaning as with prior sensor, P0122 detecting low voltage, open circuit, and P0123 for high voltage conditions between ECU, wire harness, and sensor. Tip: when working with any electrical connection, remember to keep connections clean & dry. This is best accomplished by cleaning connection thoroughly prior to disassembly. Contaminated sensor connections can cause premature engine faults. Functionally testing sensor can no longer be done with simple resistance checks. If either of these two faults is present or a TPS fault is suspected, recommended diagnostic test is as follows:

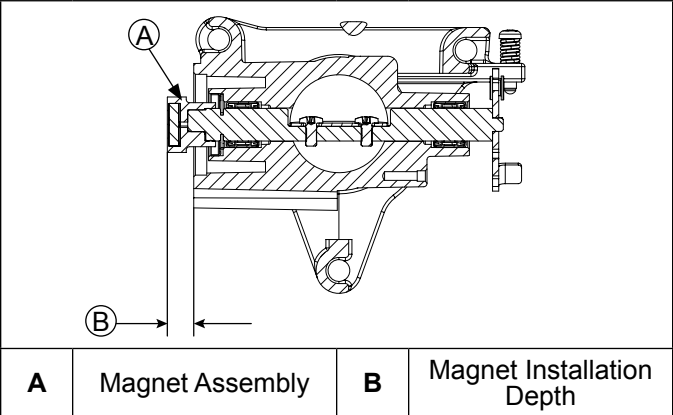
If a computer with diagnostic software is available

Observe throttle percent and raw TPS values through diagnostic software. With diagnostic software communicating to ECU and key ON engine not running, these values can be observed while throttle is moved from closed to full open position. There should be a smooth and repeatable throttle percent value starting at closed position reading between 0 (about 6.5%) to WOT position reading 93 (100%). If one of these values is outside of specified range and output transitions in a smooth manner, reset ECU and run test again. Since there is no longer any wear elements inside sensor, most likely faults will be in electrical connections between sensor and wire harness and wire harness to ECU. With service software communicating to ECU and engine not running, a small load or gentle back and forth motion can be applied to connectors or wires just outside connectors to detect a faulty connection.

If only a volt meter is available

Measure voltage supply to sensor from ECU. This voltage should be 5.00 +/- 0.20 volts. This can be measured by gently probing terminals B & C on harness side with TPS connector removed from TPS and key ON. This will generate a P0122 fault that can be cleared with an ECU reset. If voltage is low, battery, harness and ECU should be investigated. If supply voltage is good, plug sensor back into harness. Probe sensor signal wire with volt meter, terminal A at TPS or pin Black 12 at ECU. This signal should start between 0.6-1.2 volts at low idle and grow smoothly as throttle is opened to 4.3-4.8 volts at full open (WOT). Since there is no longer any wear elements inside sensor, most likely faults will be in electrical connections between sensor and wire harness and wire harness to ECU.

Replace magnet assembly



Magnet assembly is captured in a small plastic housing that is press fit to end of throttle shaft. This generally does not need replacement. If replacement is required, can be replaced as follows:

1. Remove sensor from throttle body, exposing round magnet assembly.
2. A pair of flat blade screw drivers or a spanner tool can be used to pry this off shaft. Caution should be used to avoid damage to machined flat surface that sensor seals against. Also, make sure throttle blade is in full open position to avoid driving throttle blade into throttle bore causing damage to blade and/or bore.
3. When replacing magnet assembly, alignment is critical. There is a D-shaped drive feature on end of shaft and a matching pocket in magnet assembly. On outer diameter of magnet assembly is a notch that aligns with center of flat feature of D. Align this notch and flat of D feature in shaft and preassemble parts.
4. With throttle blade in full open position (WOT), press magnet assembly fully on to throttle shaft. Full insertion can be checked by measuring height from throttle body sensor mounting face to end of magnet assembly. This should be no more than 8.6 mm (0.338 in). Installation process requires significant force, so take care that all parts are aligned. Tapping magnet assembly on can fracture/damage brittle magnet within assembly and throttle body assembly and is NOT RECOMMENDED.

Engine (Oil) Temperature Sensor

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

1. Remove temperature sensor from breather cover and cap or block sensor hole.
2. Wipe sensor clean and allow it to reach room temperature (25°C, 77°F).
3. Unplug Black connector from ECU.
4. With sensor still connected, check temperature sensor circuit resistance between Black pin 10 and 14 terminals. Value should be 9000-11000 Ω.
5. Unplug sensor from wire harness and check sensor resistance separately across two pins. Resistance value should again be 9000-11000 Ω.
 - a. If resistance is out of specifications, replace temperature sensor.
 - b. If it is within specifications, proceed to Step 6.
6. Check circuits (input, ground), from wire harness connector to sensor plug for continuity, damage, etc. Connect one ohmmeter lead to Black pin 14 in wire harness connector (as in step 4). Connect other lead to terminal #1 in sensor plug. Continuity should be indicated. Repeat test between Black pin 10 and terminal #2 in sensor plug.

Earlier engines have a separate intake air temperature (IAT) sensor (located in throttle body) and a manifold absolute pressure (MAP) sensor (located in intake manifold).

Intake Air Temperature Sensor

A non-serviceable component. Complete replacement is required if it is faulty. Sensor and wiring harness can be checked as follows.

1. Remove temperature sensor from throttle body.
2. Allow it to reach room temperature (20°C, 68°F).
3. Unplug Black connector from ECU.
4. With sensor still connected, check temperature sensor circuit resistance between Black pin 10 and 8 pin terminals. Value should be 3100-3900 Ω.
5. Unplug sensor from wire harness and check sensor resistance separately across two pins. Resistance value should again be 3100-3900 Ω.
 - a. If resistance is out of specifications, replace temperature sensor.
 - b. If it is within specifications, proceed to Step 6.
6. Check circuits (input, ground), from main harness connector to sensor plug for continuity, damage, etc. Connect one ohmmeter lead to Black pin 8 in main harness connector (as in step 4). Connect other lead to terminal #1 in sensor plug. Continuity should be indicated. Repeat test between Black pin 10 and terminal #2 in sensor plug.

Manifold Absolute Pressure Sensor (MAP)

A sealed, non-serviceable assembly. A faulty sensor must be replaced. If a blink code indicates a problem with 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 blower housing. Slide locking tab out and pull off manifold absolute pressure connector. Turn key switch to ON and check with a volt meter by contacting red lead to pin 1 and black lead to pin 2. There should be 5 volts present, indicating ECU and wiring harness are functioning.
2. Check continuity in wire harness. Ohms between Pin 3 at 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 intake manifold is not loose and MAP sensor is not loose. Loose parts would allow a vacuum leak, making MAP sensor report misleading information to ECU.
 - a. Tighten all hardware and perform an ECU Reset and a TPS Learn Procedure to see if MIL will display a fault with MAP sensor again. If MIL finds a fault with MAP sensor, replace it.

Later engines have a combined temperature/manifold absolute pressure (TMAP) sensor (located in intake manifold).

Temperature/Manifold Absolute Pressure (TMAP) Sensor

A sealed non-serviceable integrated sensor that checks both intake air temperature and manifold absolute pressure. Complete replacement is required if it is faulty. Sensor and wiring harness can be checked as follows.

If a blink code indicates a problem with Intake Air Temperature (TMAP) Sensor Circuit (P0112 or P0113), it can be tested as follows:

1. Remove TMAP sensor from intake manifold.
2. Allow it to reach room temperature (20°C, 68°F).
3. Unplug Black connector from ECU.
4. With sensor still connected, check temperature sensor circuit resistance between Black pin 10 and 8 pin terminals. Value should be 1850-2450 Ω.
5. Unplug sensor from wire harness and check sensor resistance separately across pin. Resistance value should again be 1850-2450 Ω.
 - a. If resistance is out of specifications, check local temperature. Sensor resistance will go down as temperature is higher. Replace TMAP sensor if determined to be faulty.
 - b. If it is within specifications, proceed to Step 6.

EFI SYSTEM

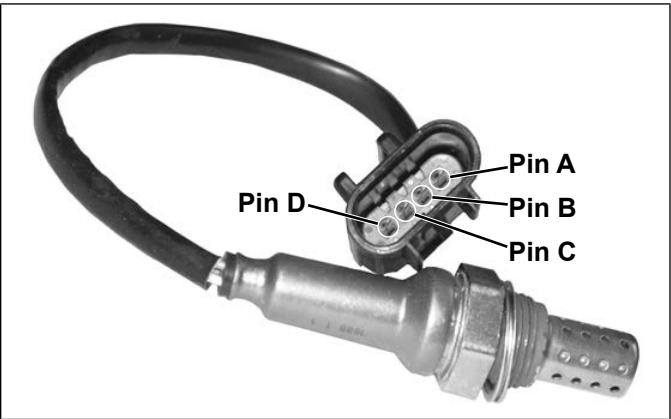
- 6. Check circuits (input, ground), from main harness connector to sensor plug for continuity, damage, etc. Connect one ohmmeter lead to Black pin 8 in main harness connector (as in step 4). Connect other lead to terminal #3 in sensor plug. Continuity should be indicated. Repeat test between Black pin 10 and terminal #4 in sensor plug.
- 7. Reinstall sensor.

If a blink code indicates a problem with Manifold Absolute Pressure (TMAP) Sensor Circuit (P0107 or P0108), it can be tested as follows:

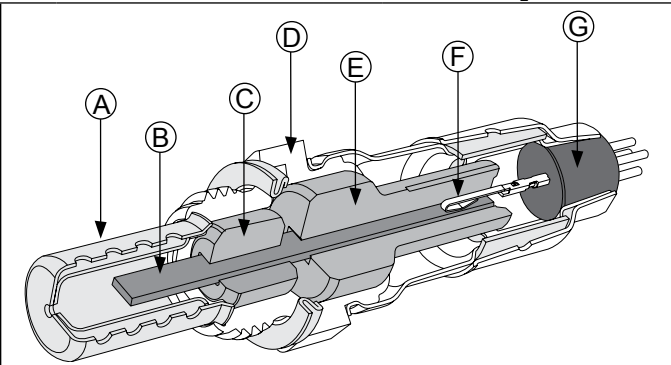
- 1. Make sure all connections are making proper contact and are free of dirt and debris. Slide locking tab out and pull off TMAP connector. Turn key switch to ON and check with a volt meter by contacting red lead to pin 1 and black lead to pin 2. There should be 5 volts present, indicating ECU and wiring harness are functioning.
- 2. Check continuity in wire harness. Ohms between Pin 3 at 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 intake manifold is not loose and TMAP sensor is not loose. Loose parts would allow a vacuum leak, making TMAP sensor report misleading information to ECU.
 - a. Tighten all hardware and perform an ECU Reset and a TPS Learn Procedure to see if MIL will display a fault with sensor again. If MIL finds a fault with TMAP sensor, replace it.

Oxygen Sensor (O₂)

Components



Cutaway Oxygen Sensor Components (O₂)



A	Protection Shield	B	Planar Element and Heater
C	Lower Insulator	D	Stainless Steel Housing
E	Upper Insulator	F	Terminal Connection to Element
G	High Temp Water Seal		

Temperature must be controlled very accurately and gas constituents measured to a high degree of accuracy for absolute sensor measurements. This requires laboratory equipment to determine a good or bad sensor in field. Furthermore, as with most devices, intermittent problems are difficult to diagnose. Still, with a good understanding of system and sensor, it is possible to diagnose many sensor problems in field.

Using diagnostic software connected to ECU is a useful technique for observing sensor performance. However, user must understand that such software reads a signal generated by ECU. If there is an ECU or wiring problem, readings could be misinterpreted as a sensor problem. Digital nature of signal to software means that it is not reading continuous output of 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 sensor and cause inaccurate readings. Since resistance of sensor is highest at low temperatures, such meters will cause largest inaccuracies when 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 sensor lead wire or associated engine wiring due to cutting, chaffing or melting on a hot surface.
3. Disconnect sensor connector and look for corrosion in connector.
4. Try reconnecting sensor and observe if problem has cleared.
5. Correct any problems found during visual check.

Sensor Signal Observation

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

1. Using a voltmeter, observe voltage between Pin C and Pin D before engine is started. With key ON, and sensor unplugged, voltage should read about 5.0 volts. With sensor attached, using diagnostic software, voltage should read about 1.0 volt. This voltage is generated by ECU. If it is not present, there is a short in associated wiring and corrective action should be taken. If voltage still is not present, there is a problem with ECU or engine harness.
2. Reconnect sensor and start engine. Run engine at sufficient speed to bring sensor up to operating temperature. Maintain for 1 to 2 minutes to ensure that engine has gone closed loop. Once in closed loop, sensor voltage should cycle between about 100 to 250 mv (low speed idle) and 700 to 900 mv (high speed no load). If this cycling is not observed, a determination must be made, if problem is with engine or sensor.
3. Check engine harness for battery voltage on heater circuit.

Removal Inspection

NOTE: Apply anti-seize compound only to threads.

Anti-seize compound will affect sensor performance if it gets into lower shield of sensor.

1. If sensor has heavy deposits on lower shield, engine, oil, or fuel may be source.
2. If heavy carbon deposits are observed, incorrect engine fuel control may be occurring.
3. If sensor is at room temperature, measure between signal leads, black wire (Pin C) and grey wire (Pin D) attached to sensor. If resistance is less than one megohm, sensor has an internal short.
4. With sensor at room temperature measure 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 root cause, which may be elsewhere in application. Refer to Troubleshooting-Oxygen Sensor (O₂) table.
6. A special "dry to touch" anti-seize compound is applied to all new oxygen sensors at factory. If recommended mounting thread sizes are used, this material provides excellent anti-seize capabilities and no additional anti-seize is needed. If sensor is removed from engine and reinstalled, anti-seize compound should be reapplied. Use an oxygen sensor safe type anti-seize compound. It should be applied according to directions on label.

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Troubleshooting-Oxygen Sensor (O₂)

Condition	Possible Cause	Conclusion
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.	Check for high fuel pressure Leaking injector Liquid fuel in vent line
	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.

Fuel Injectors



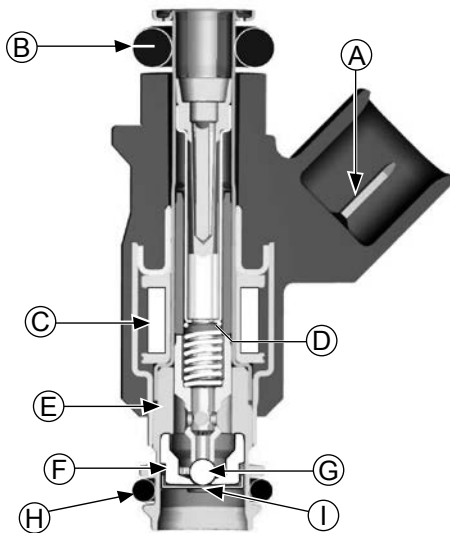
WARNING

Explosive Fuel can cause fires and severe burns.

Fuel system ALWAYS remains under HIGH PRESSURE.

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

Details



A	Electrical Connection	B	Upper O-ring
C	Solenoid Winding	D	Armature
E	Valve Housing	F	Valve Seat
G	Valve End	H	Lower O-ring
I	Director Plate		

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

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

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

1. With engine running at idle, listen for a buzzing or clicking sound.
2. Disconnect 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:

1. Disconnect electrical connector from both injectors. Plug a 12 volt noid light into one connector.
2. Make sure all safety switch requirements are met. Crank engine and check for flashing of 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.
 - a. If flashing occurs, use an ohmmeter (Rx1 scale) and check resistance of each injector across two terminals. Proper resistance is 11-13 Ω . If injector resistance is correct, check whether connector and injector terminals are making a good connection. If resistance is not correct, replace 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 tip of valve needle), or external (weeping around injector O-rings). Loss of system pressure from leakage can cause hot restart problems and longer cranking times. To check for leakage it will be necessary to loosen or remove blower housing which may involve removing engine from unit. Refer to Disassembly for removal of injector.

1. Remove manifold mounting bolts and separate throttle body/manifold from engine leaving TPS, high pressure fuel line, injectors and fuel line connections intact. Discard old gaskets.
2. Position manifold assembly over an appropriate container to capture fuel and turn key switch ON to activate fuel pump and pressurize system. Do not turn switch to START position.

NOTE: 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 fuel pump module pins.

3. If either injector exhibits leakage of more than two to four drops per minute from tip, or shows any sign of leakage around outer shell, turn ignition switch OFF and replace injector as follows.
4. Depressurize fuel system.
5. Clean any dirt accumulation from sealing/mounting area of faulty injector(s) and disconnect electrical connector(s).
6. Pull retaining clip off top of injector(s). Remove screw holding injector(s) from manifold.

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7. Reverse appropriate procedures to install new injector(s) and reassemble 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 installation tool provided with O-rings to install new upper O-ring. Place tool into fuel injector inlet. Place one side of O-ring into O-ring groove and roll O-ring over tool onto fuel injector. Torque screw securing fuel injector caps and blower housing mounting screws to 7.3 N·m (65 in. lb.), and intake manifold and air cleaner mounting screws to 11.3 N·m (100 in. lb.). An ECU Reset will need to be completed.

Injector problems due to dirt or clogging are generally unlikely due to design of injectors, high fuel pressure, and detergent additives in 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 director plate, restricting 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 Coil

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

NOTE: Do not ground primary coil with ignition ON as they may overheat or spark.

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

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



Testing

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

1. To check cylinder coil 1 (starter side), disconnect Black connector from ECU and test between Black pins 1 and 15. To check cylinder coil 2 (oil filter side), disconnect Grey connector from ECU and test between Grey pins 10 and 17. Wiring and coil primary circuits are OK if readings are 0.5-0.8 Ω .
2. If reading(s) are not within specified range, check and clean connections and retest.
3. If reading(s) are still not within specified range, test coils separately from main harness as follows:
 - a. Remove screw retaining coil to housing and disconnect primary leads connector.

- b. Connect an ohmmeter set on Rx1 scale to primary terminals of coil. Primary resistance should be 0.5-0.8 Ω .
- c. Connect an ohmmeter set on Rx10K scale between spark plug boot terminal and B+ primary terminal. Secondary resistance should be 6400-7800 Ω .
- d. If secondary resistance is not within specified range, coil is faulty and needs to be replaced.

FUEL COMPONENTS

	 WARNING
	Explosive Fuel can cause fires and severe burns. Fuel system ALWAYS remains under HIGH PRESSURE.
Wrap a shop towel completely around fuel pump module connector. Press release button(s) and slowly pull connector away from fuel pump module allowing shop towel to absorb any residual fuel in high pressure fuel line. Any spilled fuel must be completely wiped up immediately.	

Fuel Pump Module (FPM)

Fuel pump module is not serviceable and must be replaced if determined to be faulty. If a fuel pump problem is suspected, make certain pump is being activated, all electrical connections are properly secured, 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 fuel pump may be conducted.

1. Relieve fuel pressure at fuel pump module. Fuel pump module may need to be loosened or pulled away from engine. Disconnect fuel coupler from fuel pump module and insert pressure test jumper (from Kohler EFI Service Kit) between high pressure fuel line and fuel pump module.
2. Connect black hose of Pressure Tester. Route clear hose into a portable gasoline container or equipment fuel tank.
3. Turn on key switch to activate pump and check system pressure on gauge. It may take several key cycles to compress air introduced into system and reach regulated pressure. If system pressure of 39 psi \pm 3 is observed, wiring, fuel pump, and regulator are working properly. Turn key switch OFF and depress valve button on tester to relieve system pressure.
 - a. If pressure is too high or too low, replace fuel pump module.
4. If pump did not activate (step 3), disconnect plug from fuel pump. Connect a DC voltmeter across terminals in plug, turn on key switch and observe if a minimum of 7 volts is present during six second prime process.
5. If no voltage is observed, connect red lead of meter to red wire of plug and black lead to a good ground while key is still ON.

6. If voltage is between 7 and 14, turn key switch OFF and connect an ohmmeter between terminals on pump to check for continuity.
 - a. If there was no continuity between pump terminals, replace fuel pump.
 - b. If voltage was below 7, test wiring harness.
7. If voltage at plug was good, and there was continuity across pump terminals, reconnect plug to pump, making sure you have a good connection. Turn on key switch and listen for pump to activate.
 - a. If pump starts, repeat steps 2 and 3 to verify correct pressure.
 - b. If pump still does not operate, replace it.

High Pressure Fuel Line

High pressure fuel line is mounted to intake manifold. No specific servicing is required unless operating conditions indicate that it needs replacement. Thoroughly clean area around all joints and relieve any pressure before starting any disassembly. Detach by removing two mounting screws, wire ties, and injector retaining clips.

Purge Port and Vent Hose Assembly

No specific servicing is required for 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 vent hoses. Only Kohler replacement parts can be used because fitting is specific to system and must be maintained. Visit KohlerEngines.com for recommended Kohler replacement parts.

Throttle Body/Intake Manifold Assembly

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

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

TROUBLESHOOTING

Troubleshooting Guide

Condition	Possible Cause
Engine Starts Hard or Fails to Start When Cold.	Fuel pump not running.
	Faulty spark plugs.
	Old/stale fuel.
	Incorrect fuel pressure.
	Crankshaft position sensor loose or faulty.
	TPS set incorrect (ECU Reset and TPS Learn).
	TPS faulty.
	Engine temp sensor faulty.
	Faulty coils.
	Low system voltage.
	Faulty injectors.
	Faulty battery.
	Loose or corroded connections.

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Troubleshooting Guide

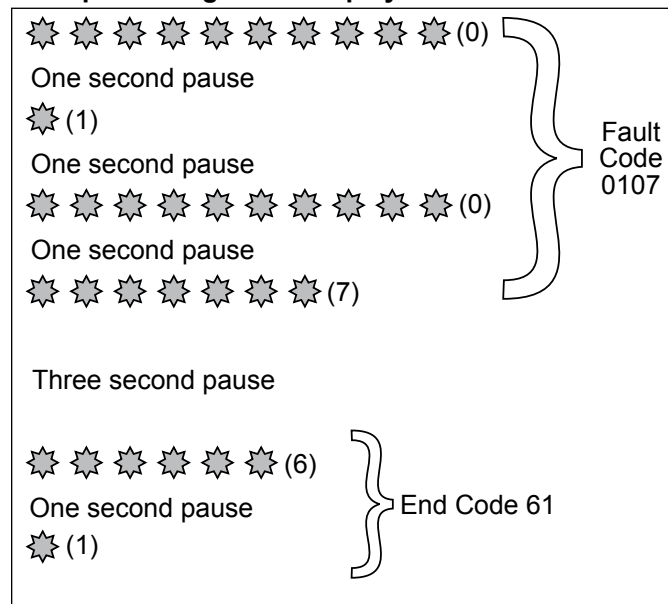
Condition	Possible Cause
Engine Starts Hard or Fails to Start When Hot.	Faulty spark plugs.
	Fuel pump not running.
	Fuel pressure low.
	Insufficient fuel delivery.
	TPS set incorrect (ECU Reset and TPS Initialization).
	Crankshaft position sensor loose or faulty.
	TPS faulty.
	Engine temp sensor faulty.
	Faulty injectors.
Engine Stalls or Idles Roughly (cold or warm).	Faulty spark plugs.
	Insufficient fuel delivery.
	TPS set incorrect.
	TPS faulty.
	Faulty engine temperature sensor.
Engine Misses, Hesitates, or Stalls Under Load.	Faulty injectors.
	Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty/restricted.
	Dirty air cleaner.
	Insufficient fuel pressure or fuel delivery.
	Vacuum (intake air) leak.
	Improper governor setting, adjustment or operation.
	TPS faulty, mounting problem or TPS Initialization Procedure incorrect.
Low Power	Bad coil(s), spark plug(s), or wires.
	Faulty/malfunctioning ignition system.
	Dirty air filter.
	Insufficient fuel delivery.
	Improper governor adjustment.
	Plugged/restricted exhaust.
	One injector not working.
	Basic engine problem exists.
	TPS faulty or mounting exists.
	Throttle plate in throttle body not fully opening to WOT stop (if equipped).

Function Test

	<p>⚠ WARNING</p> <p>High Pressure Fluids can puncture skin and cause severe injury or death.</p> <p>Do not work on fuel system without proper training or safety equipment.</p>
	<p>Fluid puncture injuries are highly toxic and hazardous. If an injury occurs, seek immediate medical attention.</p>

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

1. Disconnect and ground spark plug leads.
2. Complete all safety interlock requirements and crank engine for approximately 3 seconds.
3. Remove spark plugs and check for fuel at tips.
 - a. If there is fuel at tips of spark plugs fuel pump and injectors are operating.
 - b. If there is no fuel at tips of spark plugs, check following:
 1. Make sure fuel tank contains clean, fresh, proper fuel.
 2. Make sure that vent in fuel tank is open.
 3. Make sure fuel tank valve (if equipped) is fully opened.
 4. Make sure battery is supplying proper voltage.
 5. Check that 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.

Fault Codes**Example of Diagnostic Display****Diagnostic Fault Code Summary**

Fault Code	Connection or Failure Description
0031	Oxygen Sensor Heater Circuit Low Voltage
0032	Oxygen Sensor Heater Circuit High Voltage
0107	Manifold Absolute Pressure (MAP or TMAP) Sensor Circuit Low Voltage or Open
0108	Manifold Absolute Pressure (MAP or TMAP) Sensor Circuit High Voltage
0112	Intake Air Temperature (IAT or TMAP) Sensor Circuit Low Voltage
0113	Intake Air Temperature (IAT or TMAP) 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

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Fault Code	Connection or Failure Description
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
1693	Tach Output (ECU) Low
1694	Tach Output (ECU) High
61	End of Code Transmission

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

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

1. Check that battery voltage is above 11 volts.
2. Start with key switch OFF.
3. Turn key switch to ON and OFF, then ON and OFF, then ON, leaving it on in third sequence. Do not start engine. Time between sequences must be less than 2.5 seconds.
4. MIL will blink a series of times. Number of times MIL blinks represents a number in blink code.
5. A sequence of four digits make up a fault code. There is a one (1) second pause between blinks of a fault code. There is a three (3) second pause between separate fault codes. After fault code(s) are blinked a two digit 61 is blinked to indicate program has completed.
 - a. It's a good idea to write down codes as they appear, as they may not be in numerical sequence.
 - b. Code 61 will always be last code displayed, indicating end of code transmission. If code 61 appears immediately, no other fault codes are present.

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

Diagnostic Fault Code Summary lists fault codes, and what they correspond to. Diagnostic Code Summary is a list of individual codes with an explanation of what triggers them, what symptoms might be expected, and probable causes.

A MIL may not be provided with engine. If equipment manufacturer has not added a MIL to equipment, one can be added easily for quick diagnostics. Main engine to vehicle connection will have a tan wire which is ground for MIL. Either incandescent or LED type bulbs can be used for MIL as long as they do not draw more than 0.1 amps. 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 positive terminal of bulb and attach ground terminal of bulb to tan wire.

Diagnostic Code Summary

Code 0031

Component:	Oxygen Sensor Heater
Fault:	O2S Heater Circuit Low Voltage
Condition:	System voltage too low, open connection or faulty sensor.
Conclusion:	<p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuit wiring or connectors. ECU black pin 7 or broken wire. <p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring problem. <p>Poor system ground from ECU to engine or battery to engine.</p>

Code 0032

Component:	Oxygen Sensor Heater
Fault:	O2S Heater Circuit High Voltage
Condition:	System voltage too high, shorted connection or faulty sensor.
Conclusion:	<p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring problem. • Sensor damaged. • Pin circuit wiring or connectors at Black 7. <p>ECU Related</p> <ul style="list-style-type: none"> • ECU-to-harness connection problem.

Code 0107

Component:	Manifold Absolute Pressure (MAP or TMAP) Sensor
Fault:	MAP or TMAP Circuit Low Voltage or Open
Condition:	Intake manifold leak, open connection or faulty sensor.
Conclusion:	<p>MAP or TMAP Sensor Related</p> <ul style="list-style-type: none"> • Sensor malfunction. • Vacuum leaks from loose manifold or sensor. <p>Wire Harness Related</p> <ul style="list-style-type: none"> • Poor grounding or open circuit. • Wire harness and connectors loose, damaged or corroded. • Pin circuit wiring or connectors at Black 10, 11 and 16. <p>Bad TPS Learn.</p>

Code 0108

Component:	Manifold Absolute Pressure (MAP or TMAP) Sensor
Fault:	MAP or TMAP Circuit High Voltage
Condition:	Intake manifold leak, shorted connection or faulty sensor.
Conclusion:	<p>MAP or TMAP Sensor Related</p> <ul style="list-style-type: none"> • Sensor malfunction. • Vacuum leaks from loose manifold or sensor. <p>Wire Harness Related</p> <ul style="list-style-type: none"> • Poor grounding. • Pin circuit wiring or connectors at Black 11. <p>Bad TPS Learn.</p>

Code 0112

Component:	Intake Air Temperature (IAT or TMAP) Sensor
Fault:	Intake Air Temperature (IAT or TMAP) Sensor Circuit Low Voltage
Condition:	Shorted connection, faulty sensor or shorted wire.
Conclusion:	<p>Temperature (IAT or TMAP) Sensor Related</p> <ul style="list-style-type: none"> • Sensor wiring or connection. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuits Black 10 and Black 8 may be damaged or routed near noisy signal (coils, alternator, etc.). • ECU-to-harness connection problem.

Code 0113

Component:	Intake Air Temperature (IAT or TMAP) Sensor
Fault:	Intake Air Temperature (IAT or TMAP) Sensor Circuit High Voltage or Open
Condition:	Shorted connection, faulty sensor, broken wire or connection.
Conclusion:	<p>Temperature (IAT or TMAP) Sensor Related</p> <ul style="list-style-type: none"> • Sensor wiring or connection. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuits ECU Black pin 10 and 8 may be damaged. • 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.
Conclusion:	<p>Temperature Sensor Related</p> <ul style="list-style-type: none"> • Sensor wiring or connection. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuits Black 10 and Black 14 maybe damaged or routed near noisy signal (coils, stator, etc.). • 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.
Conclusion:	<p>Temperature Sensor Related</p> <ul style="list-style-type: none"> • Sensor wiring or connection. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuits ECU Black pin 10 and 14 may be damaged. • ECU-to-harness connection problem or broken wire. <p>System Related</p> <ul style="list-style-type: none"> • Engine is operating above 176°C (350°F) temperature sensor limit.

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Code 0122

Component:	Throttle Position Sensor (TPS)
Fault:	TPS Circuit Low Voltage or Open
Condition:	Open connection, broken wire or faulty sensor.
Conclusion:	<p>TPS Related</p> <ul style="list-style-type: none"> • TPS bad or worn internally. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Broken or shorted wire in harness. <ul style="list-style-type: none"> ECU Black pin 10 to TPS pin 1. ECU Black pin 12 to TPS pin 3. ECU Black pin 16 to TPS pin 2. <p>Throttle Body Related</p> <ul style="list-style-type: none"> • Throttle shaft inside TPS worn, broken, or damaged. • Throttle plate loose or misaligned. • Throttle plate bent or damaged allowing extra airflow past, or restricting movement. <p>ECU Related</p> <ul style="list-style-type: none"> • Circuit providing voltage or ground to TPS damaged. • TPS signal input circuit damaged.

Code 0123

Component:	Throttle Position Sensor (TPS)
Fault:	TPS Circuit High Voltage
Condition:	Shorted connection or faulty sensor.
Conclusion:	<p>TPS Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring. • Sensor output affected or disrupted by dirt, grease, oil, wear. • Sensor loose on throttle body manifold. <p>Throttle Body Related</p> <ul style="list-style-type: none"> • Throttle shaft or bearings worn/damaged. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • ECU pins Black 10, 12 and 16 damaged (wiring, connectors). • ECU pins Black 10, 12 and 16 routed near noisy electrical signal (coils, alternator). • Intermittent 5 volt source from ECU (pin Black 16). • ECU-to-harness connection problem.

Code 0131

Component:	Oxygen Sensor
Fault:	O2S 1 Circuit Low Voltage
Condition:	Open connection, broken wire or faulty sensor.
Conclusion:	<p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring problem. • Sensor contaminated, corroded or damaged. • Poor ground path. • Pin circuit wiring or connectors. <ul style="list-style-type: none"> ECU Black pin 10 or 17. <p>TPS Learn Procedure Incorrect</p> <ul style="list-style-type: none"> • Lean condition (check oxygen sensor signal with VOA and see Oxygen Sensor section). <p>Engine wiring harness related such as a cut wire, broken or pinched.</p>

Code 0132

Component:	Oxygen Sensor
Fault:	O2S 1 Circuit High Voltage
Condition:	Shorted connection or faulty sensor.
Conclusion:	<p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring problem. • Sensor contaminated or damaged. • Poor ground path. • Pin circuit wiring or connectors. <ul style="list-style-type: none"> ECU Black pin 10 or Black pin 17. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Difference in voltage between sensed voltage and actual sensor voltage. • 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.
Conclusion:	<p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Corrosion or poor connection. • Sensor contaminated or damaged. • Air leak into exhaust. • Poor ground path. • Pin circuit wiring or connectors. ECU Black pin 10 or Black pin 17. <p>TPS Sensor Related</p> <ul style="list-style-type: none"> • Throttle plate position incorrect during Learn procedure. • TPS problem or malfunction. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Difference in voltage between sensed voltage and actual sensor voltage. • Problem in wiring harness. • ECU-to-harness connection problem. <p>Systems Related</p> <ul style="list-style-type: none"> • Ignition (spark plug, plug wire, ignition coil). • Fuel (fuel type/quality, injector, fuel pressure too low, fuel pump module or lift pump). • Combustion air (air cleaner dirty/restricted, intake leak, throttle bores). • Base engine problem (rings, valves). • Exhaust system leak (muffler, flange, oxygen sensor mounting boss, etc.). • Fuel in 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.
Conclusion:	<p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring. • Sensor contaminated or damaged. • Poor ground path. • Pin circuit wiring or connectors. ECU Black pin 10 or 17. <p>TPS Sensor Related</p> <ul style="list-style-type: none"> • Throttle plate position incorrect during Learn procedure. • TPS problem or malfunction. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Difference in voltage between sensed voltage and actual sensor voltage. • Problem in wiring harness. • ECU-to-harness connection problem. <p>Systems Related</p> <ul style="list-style-type: none"> • Ignition (spark plug, plug wire, ignition coil). • Fuel (fuel type/quality, injector, fuel pressure too high, fuel pump module or lift pump). • Combustion air (air cleaner dirty/restricted). • Base engine problem (rings, valves). • Fuel in crankcase oil. • Fuel pump module is over filled. • Lift pump diaphragm is ruptured.

EFI SYSTEM

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.
Conclusion:	<p>TPS Learn Incorrect</p> <ul style="list-style-type: none"> Lean condition (check oxygen sensor signal with VOA and see Oxygen Sensor). <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> Pin circuit wiring or connectors. ECU pin Black 10, 12, 16 and 17. <p>Low Fuel Pressure</p> <ul style="list-style-type: none"> Plugged filters. Bad lift pump. <p>Oxygen Sensor Related</p> <ul style="list-style-type: none"> Sensor connector or wiring problem. Exhaust leak. Poor ground. <p>Poor system ground from ECU to engine, causing rich running while indicating lean.</p> <p>Fuel pump module connection. See Fuel Components.</p>

Code 0201

Component:	Fuel Injector
Fault:	Injector 1 Circuit Malfunction
Condition:	Injector damaged or faulty, shorted or open connection.
Conclusion:	<p>Injector Related</p> <ul style="list-style-type: none"> Injector coil shorted or opened. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> Broken or shorted wire in harness. ECU pin Black 5. Wiring from Ignition. <p>ECU Related</p> <ul style="list-style-type: none"> Circuit controlling injector #1 damaged.

Code 0202

Component:	Fuel Injector
Fault:	Injector 2 Circuit Malfunction
Condition:	Injector damaged or faulty, shorted or open connection.
Conclusion:	<p>Injector Related</p> <ul style="list-style-type: none"> Injector coil shorted or opened. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> Broken or shorted wire in harness. ECU pin Black 6. Wiring from Ignition. <p>ECU Related</p> <ul style="list-style-type: none"> Circuit controlling injector #2 damaged.

Code 0230

Component:	Fuel Pump
Fault:	Circuit Low Voltage or Open
Condition:	Shorted or open connection.
Conclusion:	<p>Fuel Pump Related</p> <ul style="list-style-type: none"> Fuel pump module open or shorted internally. <p>Engine Wiring Harness related</p> <ul style="list-style-type: none"> Broken or shorted wire in harness. ECU pin Black 9 or Grey 17. <p>ECU Related</p> <ul style="list-style-type: none"> ECU is damaged.

Code 0232

Component:	Fuel Pump
Fault:	Circuit High Voltage
Condition:	Shorted connection.
Conclusion:	<p>Fuel Pump Related</p> <ul style="list-style-type: none"> Fuel pump module damaged internally. <p>Charging Output System Too High.</p>

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.
Conclusion:	<p>Crankshaft Position Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring. • Sensor loose or air gap incorrect. <p>Crankshaft Position Sensor Wheel Related</p> <ul style="list-style-type: none"> • Damaged teeth. • Gap section not registering. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuit wiring or connectors. • ECU pin Black 4 and Black 13. • ECU-to-harness connection problem. <p>Ignition System Related</p> <ul style="list-style-type: none"> • Non-resistor spark plug(s) used. • 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.
Conclusion:	<p>Crankshaft Position Sensor Related</p> <ul style="list-style-type: none"> • Sensor connector or wiring. • Sensor loose or air gap incorrect. <p>Crankshaft Position Sensor Wheel Related</p> <ul style="list-style-type: none"> • Damaged teeth. <p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Pin circuit wiring or connectors. • ECU pin Black 4 or Black 13. • ECU-to-harness connection problem. <p>If code is stored in fault history and starts normally. Clear code, no other service required.</p>

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.
Conclusion:	<p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Connection to ignition or fuse. • Pin circuit wiring or connectors. • ECU pin Black 1. • ECU-to-harness connection problem. <p>Ignition System Related</p> <ul style="list-style-type: none"> • Incorrect spark plug(s) used. • 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.
Conclusion:	<p>Engine Wiring Harness Related</p> <ul style="list-style-type: none"> • Connection to ignition or fuse. • Pin circuit wiring or connectors. • ECU pin Grey 10. • ECU-to-harness connection problem. <p>Ignition System Related</p> <ul style="list-style-type: none"> • Incorrect spark plug(s) used. • Poor connection to spark plug.

Code 0562

Component:	System Voltage
Fault:	System Voltage Low
Condition:	Faulty voltage regulator, bad fuse or shorted connection.
Conclusion:	<p>Corroded Connections</p> <p>Bad Stator</p> <p>Bad Battery</p> <ul style="list-style-type: none"> • Low output charging system. • Poor magnet in flywheel. • Bad or missing fuse.

Code 0563

Component:	System Voltage
Fault:	System Voltage High
Condition:	Faulty voltage regulator or shorted connection.
Conclusion:	<p>Faulty Rectifier-Regulator</p> <p>Bad Stator.</p> <p>Bad Battery.</p>

EFI SYSTEM

Code 1693

Component:	Tach Output (ECU)
Fault:	Tach Circuit Low
Condition:	Tachometer output circuit short to ground.
Conclusion:	Bad Tach Wire (grounded). GCU circuit short to ground.

Code 1694

Component:	Tach Output (ECU)
Fault:	Tach Circuit High
Condition:	Tachometer output circuit short to battery.
Conclusion:	ECU or GCU circuit error.

Code 61

Component:	End of Code Transmission
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Troubleshooting Flow Chart

Flow chart provides an alternative method of troubleshooting EFI system. Chart will enable you to review entire system in about 10-15 minutes. Using chart, accompanying diagnostic aids (listed chart), and any signaled fault codes, you should be able to quickly locate any problems within system.

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.

Conclusion

- Battery
- Main system fuse
- MIL light bulb burned out
- MIL electrical circuit problem
Pin circuits Grey 3.
- Ignition switch
- Permanent ECU power circuit problem
Pin circuit Black 18.
- Switched ECU power circuit problem
Pin circuit Black 15.
- ECU grounds
- ECU

Diagnostic Aid #2 FAULT CODES

Refer to Diagnostic Fault Code Summary.

Diagnostic Aid #3 RUN/ON

(MIL remains ON while engine is running)*

Condition

NOTE: Either incandescent or LED type bulbs can be used for MIL as long as they do not draw more than 0.1 amps. 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.

*All current fault codes will turn on MIL when engine is running.

Diagnostic Aid #4 CRANKSHAFT POSITION SENSOR

(MIL does not turn off during cranking)

Condition

- Crankshaft position sensor
- Crankshaft position sensor circuit problem, pin circuits Black 4 and Black 13.
- Crankshaft position sensor/toothed wheel air gap
- Toothed wheel
- Flywheel key sheared
- ECU

Diagnostic Aid #5 FUEL PUMP

(fuel pump not turning on)

Condition

- Main fuse
- Fuel pump circuit problem, pin circuits Black 9 and Grey 17.
- Fuel pump module

Diagnostic Aid #6 IGNITION SYSTEM

(no spark)

Condition

- Spark plug
- Plug wire
- Coil
- Coil circuit(s), pin circuits Grey 10 and Black 1.
- ECU grounds
- ECU
- Vehicle safety interlocks, ground signal on safety wire.

Diagnostic Aid #7 FUEL SYSTEM ELECTRICAL

(no fuel delivery)

Condition

- No fuel
- Air in high pressure fuel line
- Fuel valve shut OFF
- Fuel filter/line plugged
- Injector circuit(s), pin circuits Black 5 and Black 6
- Injector
- ECU grounds
- ECU
- Lift pump not working

Diagnostic Aid #8 FUEL SYSTEM

(fuel pressure)

Low Fuel Pressure-Condition

- Low fuel
- Fuel filter plugged
- Fuel supply line plugged
- Lift fuel pump - insufficient fuel supply
- Fuel pump (lift or module) - internally plugged
- Pressure regulator not functioning properly inside fuel pump module.

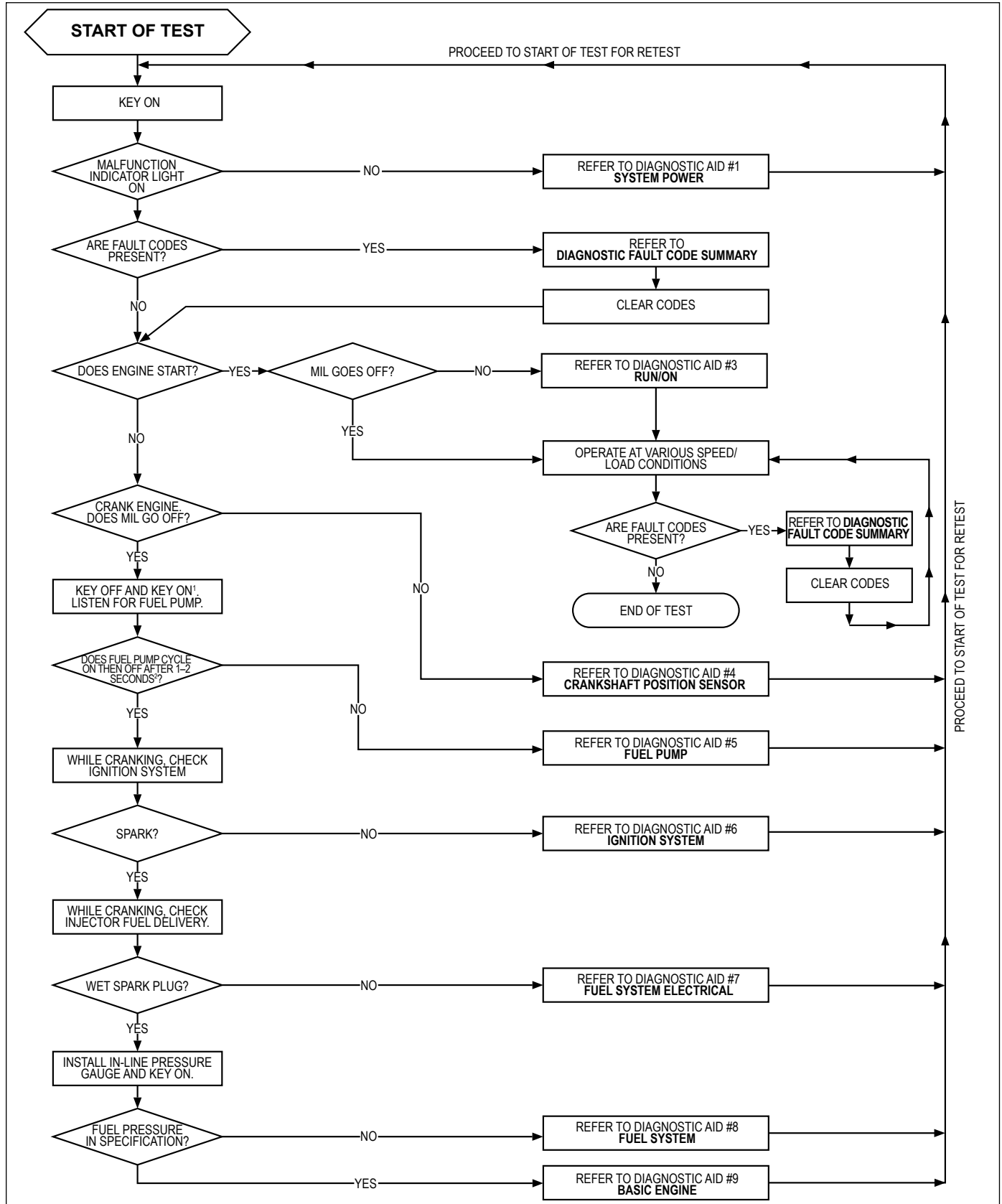
Diagnostic Aid #9 BASIC ENGINE

(cranks but will not run)

Condition

- Refer to basic engine troubleshooting charts within Troubleshooting.

EFI Diagnostic Flow Diagram



1. After turning key to OFF, wait 10 seconds before turning to ON to allow ECU to go to sleep.
2. Fuel pump module can be heard or a vibration can be felt to establish pump cycle. Fuel pump module will run for one 4-6 second cycle when ECU wakes up after being asleep.

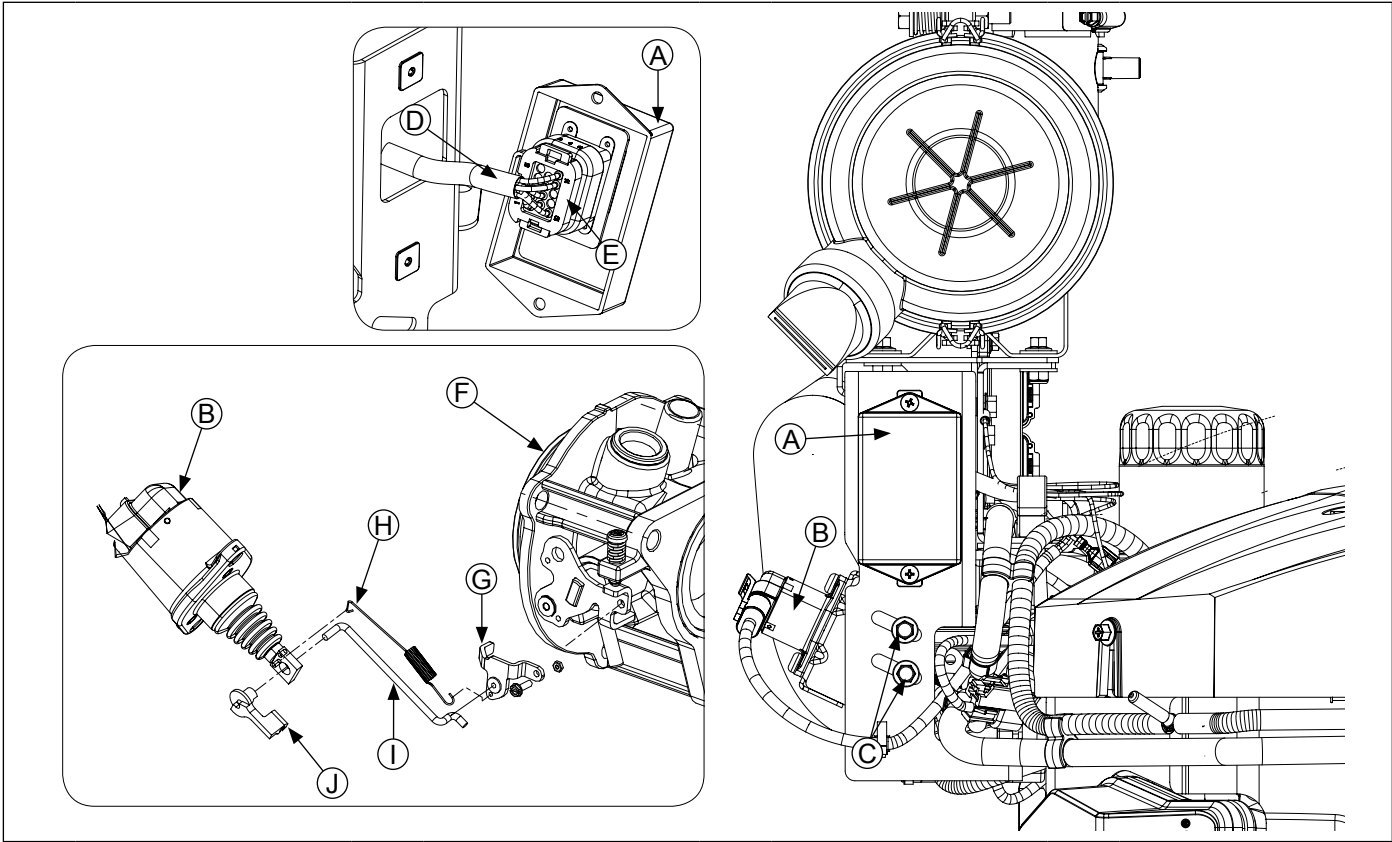
Governor System

GOVERNOR

These engines are equipped with an electronic governor or a mechanical governor.

ELECTRONIC GOVERNOR

Components



A	Governor Control Unit (GCU)	B	Digital Linear Actuator (DLA)	C	DLA Throttle Plate Mounting Screws	D	Wiring Harness
E	Connector	F	Throttle Body Assembly	G	Throttle Body Lever Adapter	H	Linkage Spring
I	Throttle Linkage	J	Plastic Linkage Retaining Clip				

Electronic governor regulates engine speed at varying loads. Typical electronic governor includes:

- Digital linear actuator (DLA).
- Throttle linkage.
- Linkage spring.
- Linkage retaining clip.
- Governor control unit (GCU).

Digital Linear Actuator (DLA)

Energizing bi-directional digital linear actuator coils in proper sequence, causes threaded shaft to move out of, or back into rotor, in precise linear increments. When power is removed, actuator shaft remains in position. DLA must initialize (fully extend) to move throttle plate to closed position, and partially open for starting. Correct adjustment of DLA is critical to achieve full range of throttle plate movement. See Adjustment.

Governor control unit (GCU) senses engine speed by pulse voltage inputs from EFI ECU module. GCU regulates engine speed by variable input voltage from a customer-supplied source.

NOTE: Actual speeds depend on application. Refer to equipment manufacturer's recommendations.

Potentiometer Specifications

Wiper Voltage	Engine Speed (RPM)
0-1	Low Speed Endpoint
1-9	Variable Speed Endpoint
9-16	High Speed Endpoint

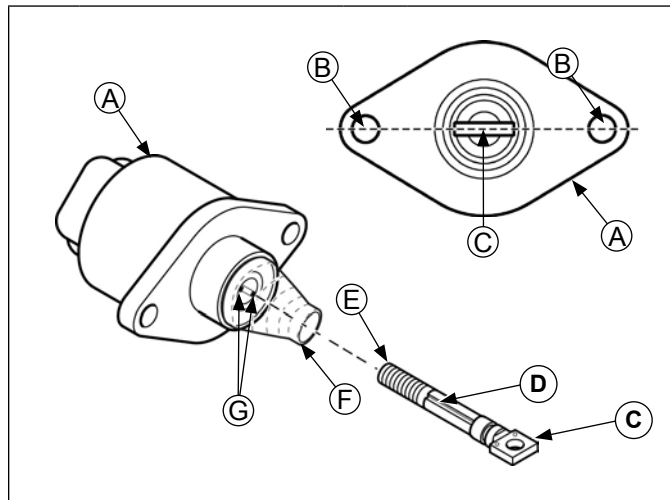
Linkage

NOTE: Throttle linkage spring must be in place and installed correctly to ensure proper throttle operation and performance.

Throttle linkage spring will fully open throttle plate if linkage becomes detached from DLA. This will create an overspeed condition causing engine to shut down. DLA shaft will have to be manually screwed back into body, and then retracted before reassembling linkage.

Adjustment

DLA Details



A	DLA	B	Mounting Holes
C	Clevis	D	Keyway
E	Clevis Shaft	F	Rubber Boot
G	Keys		

DLA must be in fully retracted position during assembly. Full range of throttle plate movement will not be achieved if DLA is partially extended when assembled. Loosen DLA mounting plate screws located on side of actuator plate. With throttle linkage secured with a retaining clip at end of DLA shaft, slide DLA bracket assembly back until throttle plate is fully open. Torque mounting plate screws to 10.2 N·m (90 in. lb.).

Proper link/spring assembly is critical. Insert spring hook tab of spring through DLA clevis hole until it exits opposite side, and tab of spring is allowed to snap into position. Hook opposite "hook" end of spring through throttle body lever adapter hole before inserting z-bend of link into throttle body lever adapter. Pay close attention not to stretch/over extend spring or damage to spring may occur.

If clevis shaft becomes overextended or disconnected from actuator reinstall as follows:

1. Disconnect linkage and remove DLA from bracket.
2. Remove clevis shaft completely out of DLA.
3. Reinstall rubber boot onto DLA if required.

4. Place clevis shaft into actuator. Rotate clevis shaft clockwise 3 full turns, applying slight pressure, until you feel clevis shaft keyway make contact with key in actuator. When clevis shaft is installed properly flat of clevis will be aligned with two mounting holes.

NOTE: Continuing to rotate clevis shaft after it has made contact with keyway will damage keyway or actuator.

5. Confirm that key and keyway are in alignment, by hand, press clevis shaft into actuator. It will take a reasonable amount of pressure to do this. If shaft will not move inward, do not force it. Remove clevis shaft and repeat previous step.
6. Reinstall DLA into bracket, torque screws to 7.3 N·m (65 in. lb.), and connect linkage.

GCU/Harness Diagnostics and Troubleshooting

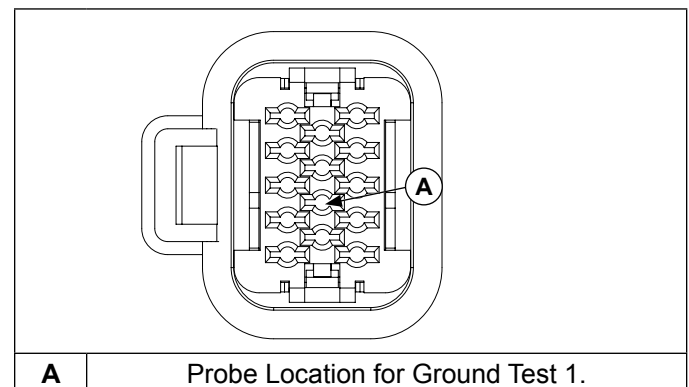
NOTE: It is important to use proper sized probes to perform these tests. Probes that are incorrect size can damage connector or harness plug.

Ground and Power Tests

1. Switch key to OFF position.
2. Remove GCU from bracket and unplug wiring harness.

These two tests check for power and ground supply to GCU. If either test fails, check if harness, electrical connections, or electrical system need repair.

Test 1 Probe Location

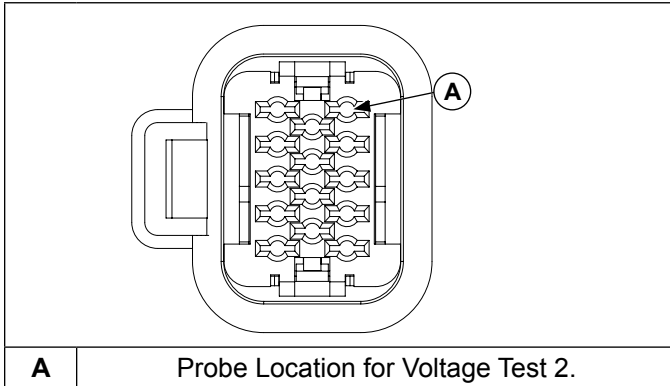


Test 1: Identify probe location in connector. Using a continuity tester, check for a good ground. If ground is faulty, inspect unit ground, battery ground, connectors, and wiring harness. Clean or fix connections or replace any faulty parts.

If test 1 checks OK, locate probe location in connector, and check using test 2.

Governor System

Test 2 Probe Location



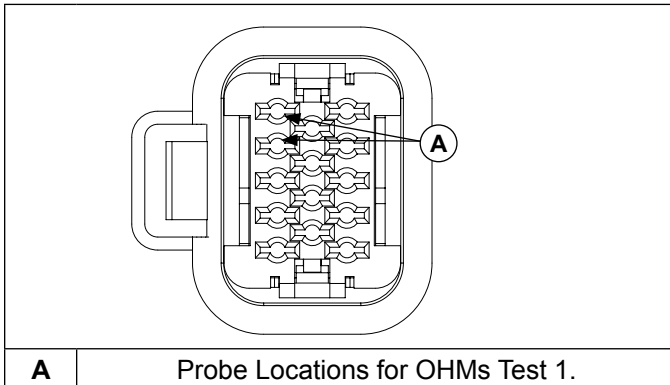
Test 2: Identify probe location in connector. Using a 12 volt meter test for voltage. Turn key switch to ON position. Voltage should be within +/- 1 volt of battery voltage. If voltage is within +/- 1 volt of battery voltage, harness is OK, replace GCU. If not within +/- 1 volt of battery voltage, check connections and replace wiring harness if necessary.

Ohms Tests

1. Remove GCU from bracket and unplug wiring harness.

These two tests are for measuring resistance of DLA circuit that sends a signal to GCU. If either test fails, DLA is no good and should be replaced. If both tests are good, DLA is neither shorted or open, it is good. Another component, connection, or input is most likely at fault.

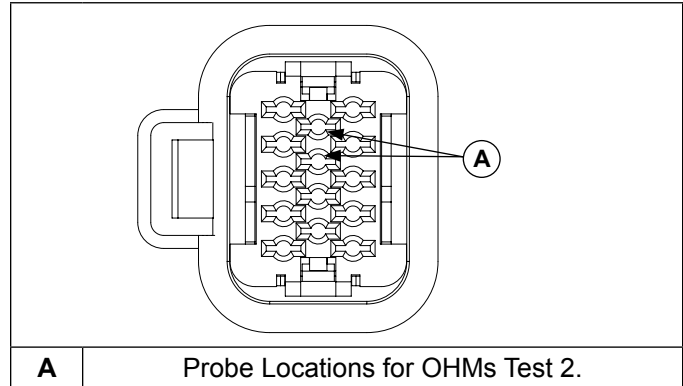
Test 1 Probe Location



Test 1: Identify probe locations in connector. Using a digital multi-meter set to lowest scale (0-200 ohms), place probes onto harness making sure of a good connection. Resistance should be between 47.7 and 58.3 ohms.

If test 1 checks OK, locate wire ends in connector and check using test 2.

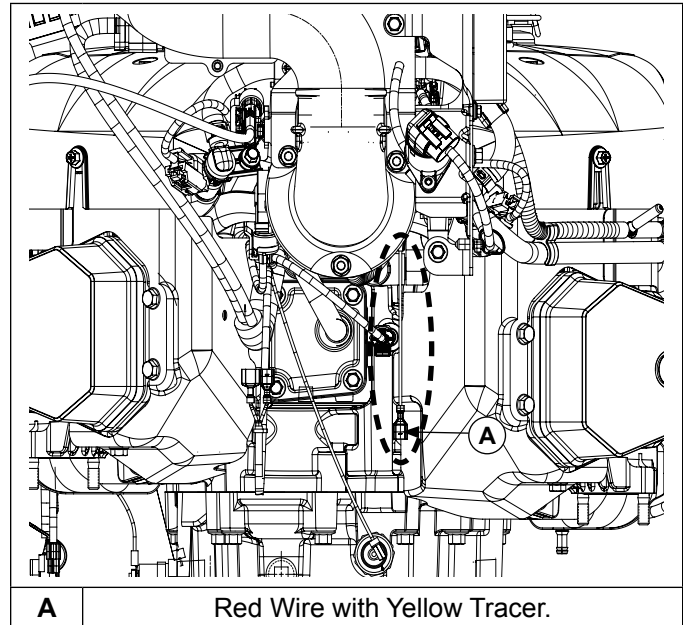
Test 2 Probe Location



Test 2: Identify probe locations in connector. Using a digital multi-meter set to lowest scale (0-200 ohms), place probes onto harness making sure of a good connection. Resistance should be between 47.7 and 58.3 ohms.

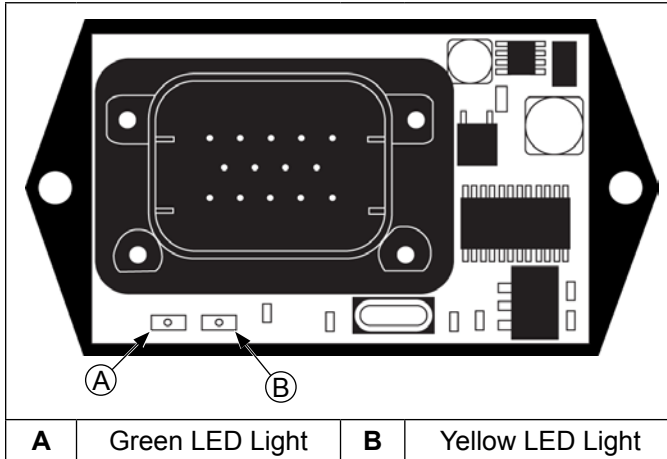
If either test 1 or 2 fail resistance test, fault could also be caused by a break/cut in wiring harness. Inspect and test for a potential harness issue prior to replacing DLA assembly.

Speed Control Input



This connection is a single wire red with yellow tracer.

GCU Blink Code Tests



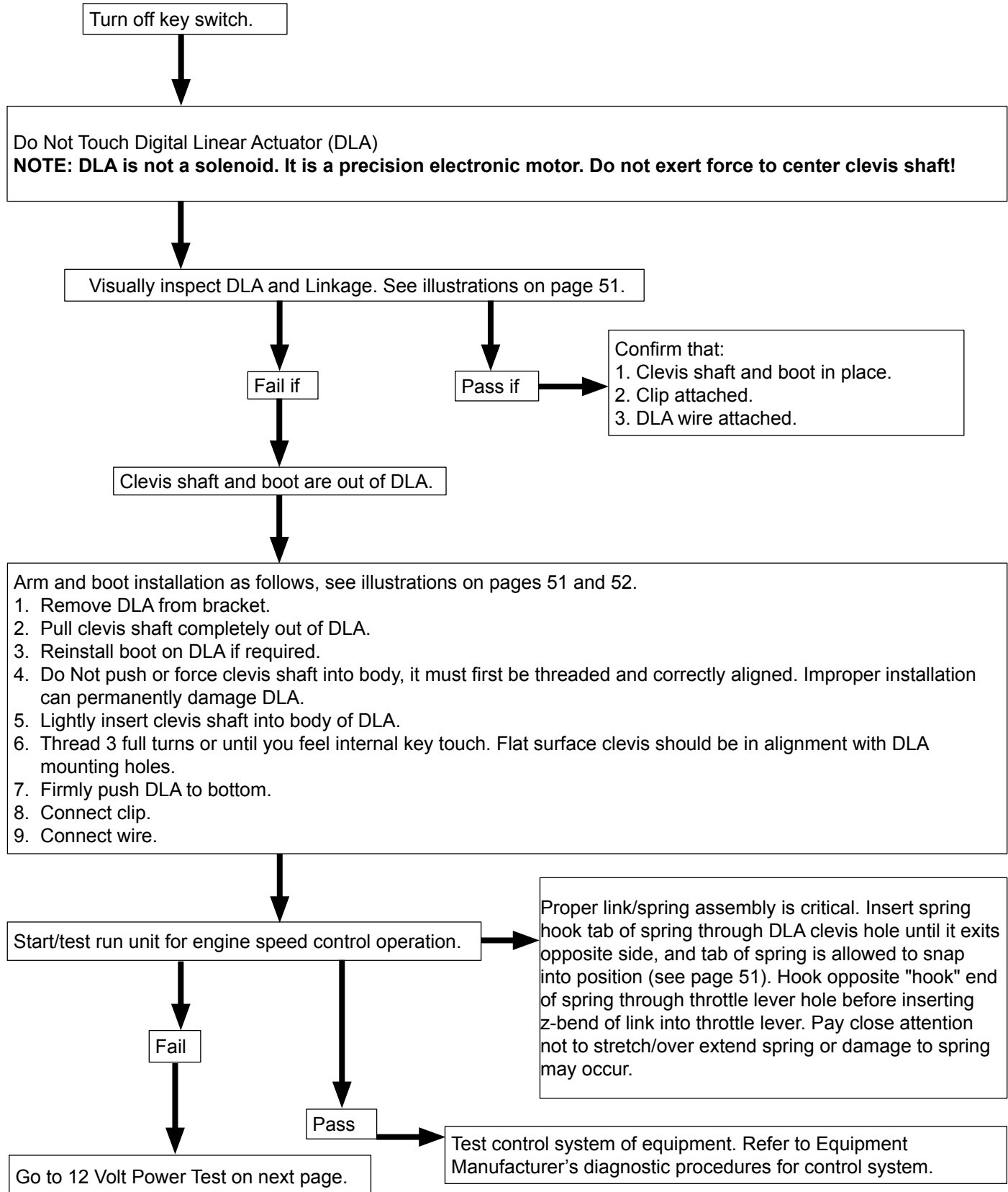
Speed control issues can also be diagnosed utilizing on-board Blink Code diagnostic lights equipped in GCU. These GCUs store blink codes/trouble codes, that can be quickly diagnosed using blink code charts.

GCU Blink Codes for Software Stored Codes - Activated when key is turned to ON position.					
Failure Condition	Possible Causes	Response	Response Time	LED Diagnostics	
				Yellow LED	Green LED
Speed Error				BLINKS	ON
Watchdog Interrupt	RFI interference	Ground to kill, close throttle plate		BLINKS	BLINKS
	Overtemp				
	Software bug				
	Lightning				
Overspeed (Over 4500 RPM for 0.5 seconds sustained)	External noise on ECU input	Ground to kill, close throttle plate	1 second delay	ON	ON
	Frozen throttle plate				
	DLA failure				
	Mechanical bindage				
Excessive Battery Voltage (> 18v for 0.5 seconds)	Open battery voltage on B+ 24 V battery (not compatible with system, 12 V battery only)	Ground to kill, close throttle plate	0.5 seconds	OFF	ON

Governor System

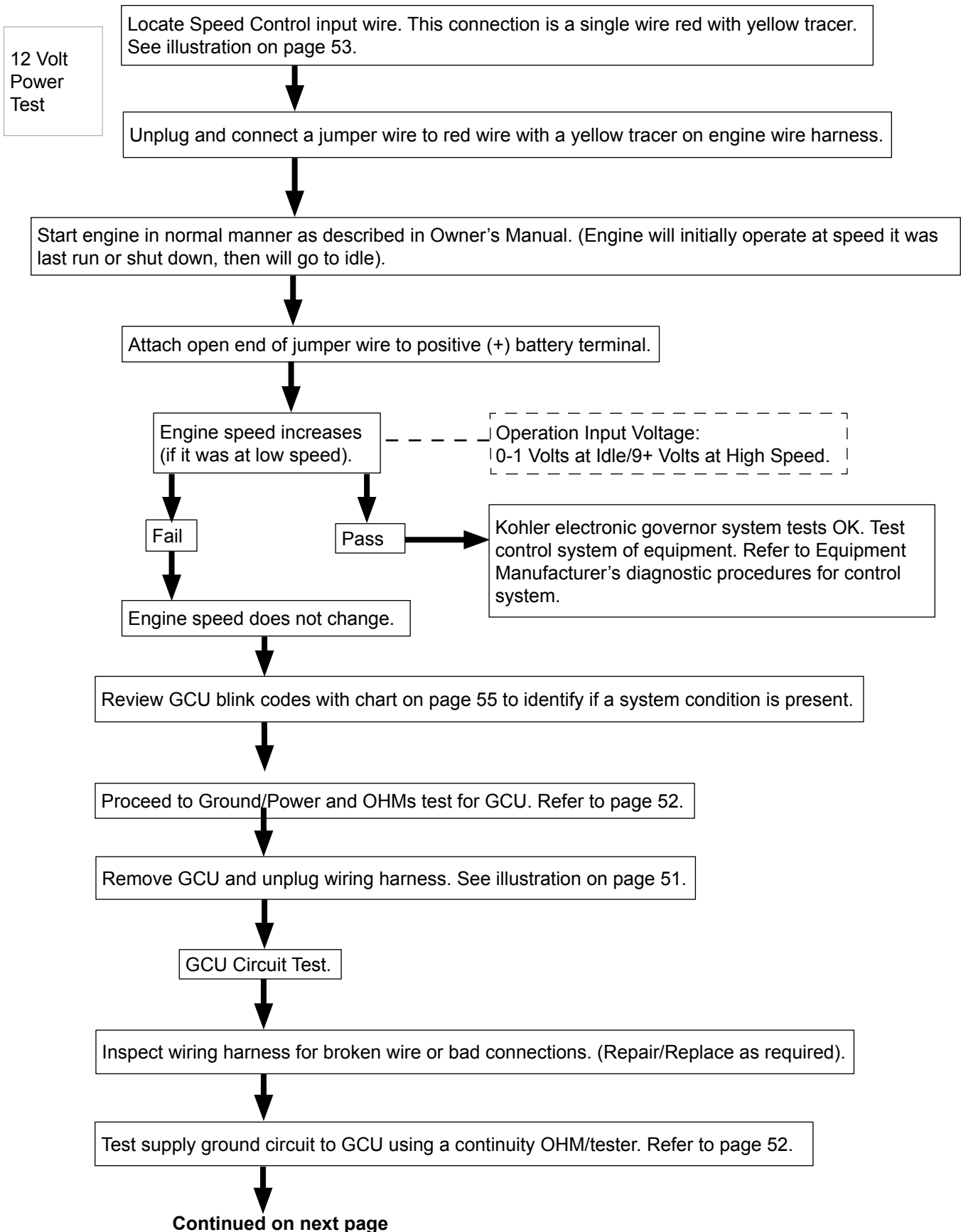
GCU Blink Codes for Software Running Codes - Activated when engine is running.					
Failure Condition	Possible Causes	Response	Response Time	LED Diagnostics	
				Yellow LED	Green LED
Running Normally		None		BLINKS	BLINKS
RPM Too High	Mechanical bindage	None		ON	BLINKS
RPM Too Low	Mechanical bindage	None		ON	BLINKS
Missing Pulse (Normal RPM)	Faulty ECU Faulty ECU wiring			BLINKS	ON
Missing Pulse (RPM Too High)	Faulty ECU Faulty ECU wiring			ON	ON
Missing Pulse (RPM Too Low)	Faulty ECU Faulty ECU wiring			OFF	ON
Sleep Mode	Power at GCU with no ECU pulses (left in run mode)	System shutdown	30 minutes	OFF	OFF
Watchdog Interrupt	RFI interference	Ground to kill, close throttle plate	N/A	BLINKS	OFF
	Overtemp				
	Software bug				
	Lightning				
Overspeed (Over 4500 RPM for 0.5 seconds sustained)	External noise on ECU input				
	Frozen throttle plate				
	DLA failure				
	Mechanical bindage		1 second delay	ON	OFF
Excessive Battery Voltage (> 18v for 0.5 seconds)	Open battery voltage on B+ 24 V battery (not compatible with system, 12 V battery only)	Ground to kill, close throttle plate	0.5 seconds	OFF	OFF

Electronic Governor Troubleshooting Flow Chart



Governor System

Electronic Governor Troubleshooting Flow Chart Continued



Electronic Governor Troubleshooting Flow Chart Continued

Turn key switch to ON position. Test supply voltage to GCU using volt meter. Refer to page 53 (battery voltage +/- 1 volt) **Note: Prevent Damage to Connector. Do Not Use Oversized Probe Tips.**

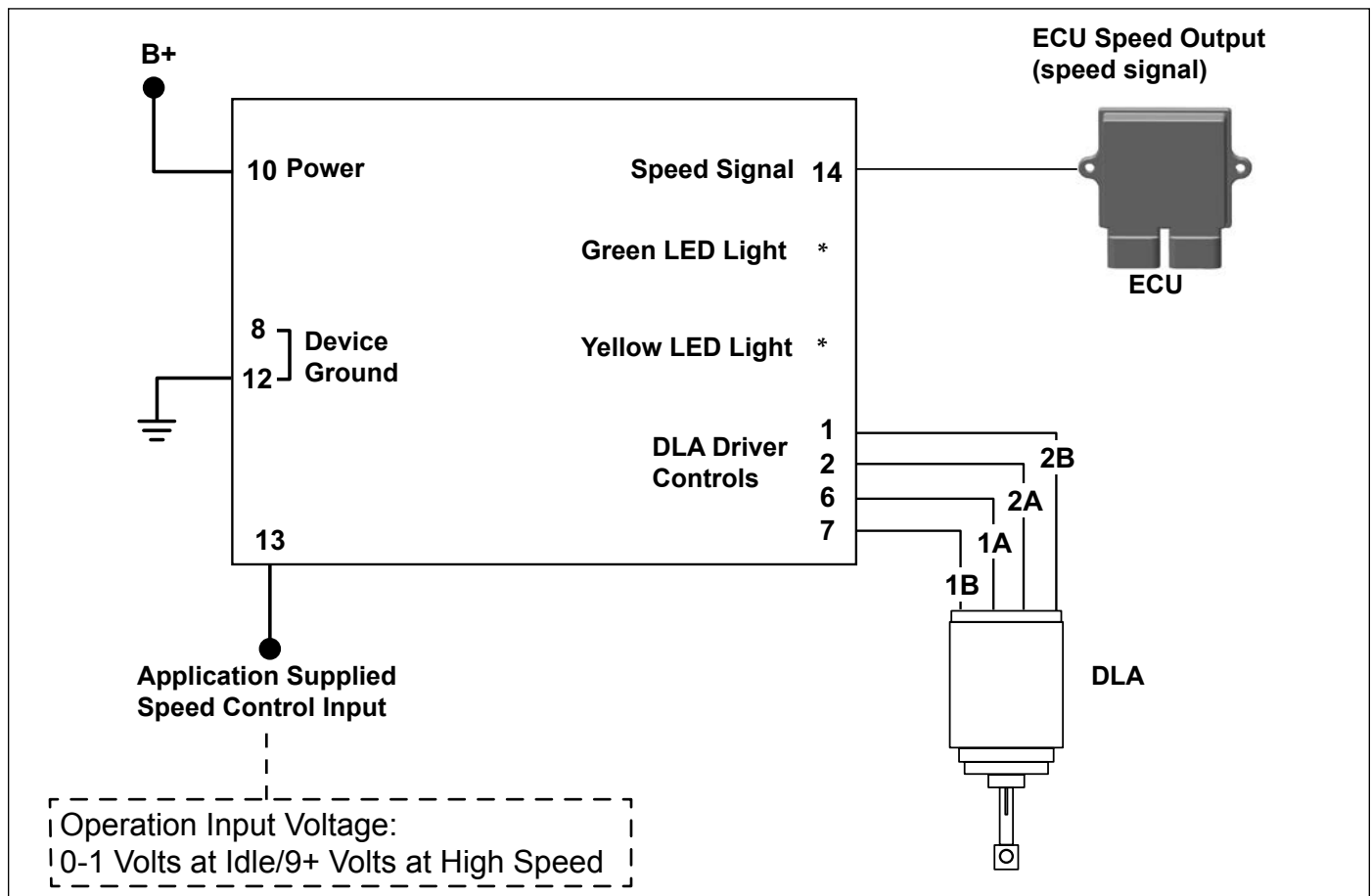
Proceed to DLA Circuit Test.

Test 1: Identify wire ends in connector. Using a digital multi-meter set to lowest scale (0-200 ohms) place probes onto harness making sure of a good connection. Resistance should be between 47.7 and 58.3 ohms. Refer to page 53.

Test 2: Identify wire ends in connector. Using a digital multi-meter set to lowest scale (0-200 ohms) place probes onto harness making sure of a good connection. Resistance should be between 47.7 and 58.3 ohms. Refer to page 53.

If either test fails, DLA is no good and should be replaced. If both tests are good, DLA is neither shorted or open, and should be good. Another component, connection, or input is most likely at fault.

Basic Electrical Diagram of Electronic Governor System



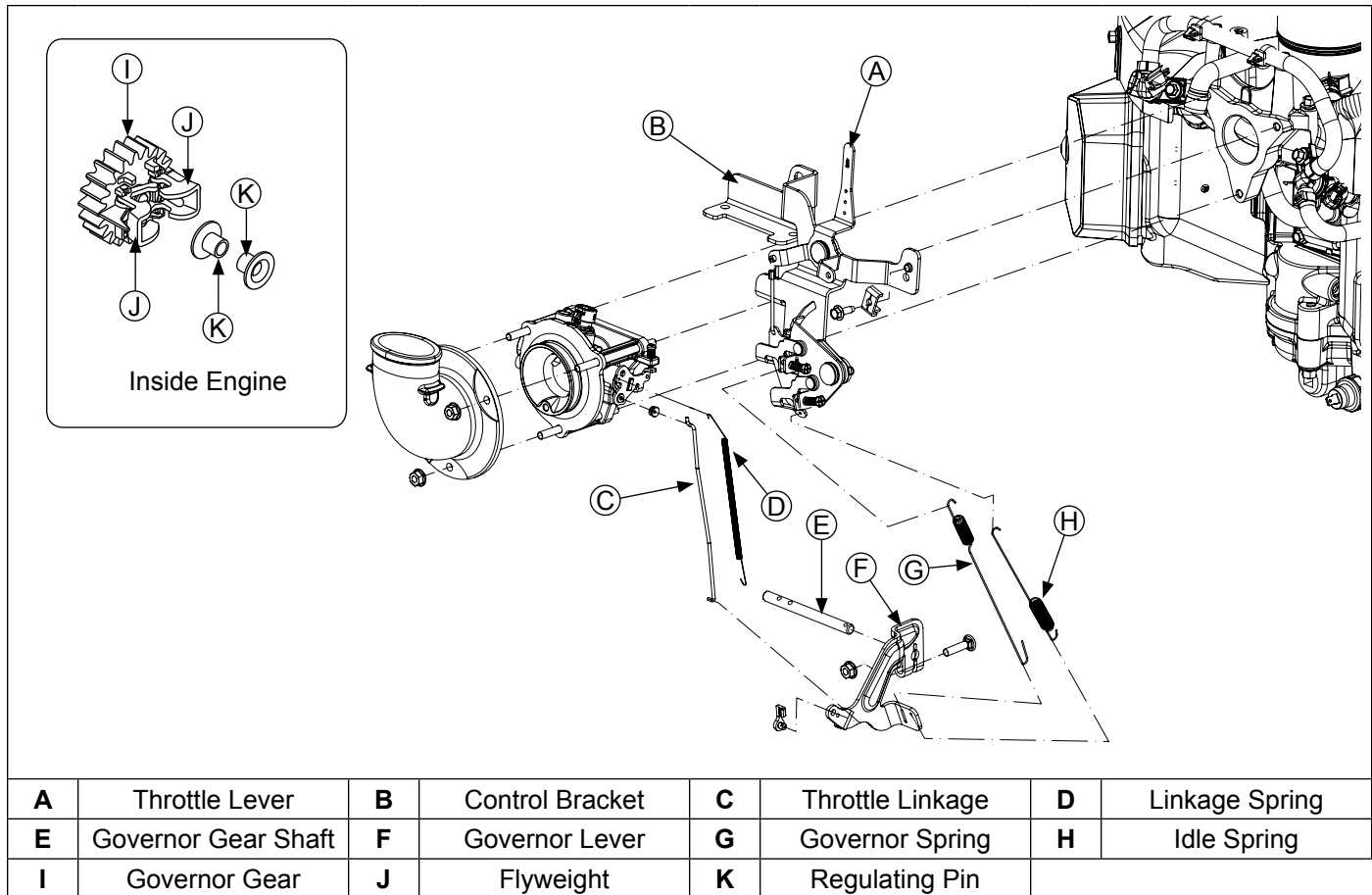
Governor System

MECHANICAL GOVERNOR

Governed speed setting is determined by position of throttle control. It can be variable or constant, depending on engine application.

Governor is designed to hold engine speed constant under changing load conditions. Governor gear/flyweight mechanism is mounted inside crankcase and is driven off gear on camshaft.

Components



This governor design works as follows:

- Centrifugal force acting on rotating governor gear assembly causes flyweights to move outward as speed increases. Governor spring tension moves them inward as speed decreases.
- As flyweights move outward, they cause regulating pin to move outward.
- Regulating pin contacts tab on cross shaft causing shaft to rotate.
- One end of cross shaft protrudes through crankcase. Rotating action of cross shaft is transmitted to throttle lever of throttle body through external linkage.
- When engine is at rest, and throttle is in FAST position, tension of governor spring holds throttle plate open. When engine is operating, governor gear assembly is rotating. Force applied by regulating pin against cross shaft tends to close throttle plate. Governor spring tension and force applied by regulating pin balance each other during operation, to maintain engine speed.
- When load is applied and engine speed and governor gear speed decreases, governor spring tension moves governor lever to open throttle plate wider. This allows more fuel into engine, increasing engine speed. As speed reaches governed setting, governor spring tension and force applied by regulating pin will again offset each other to hold a steady engine speed.

Governor Adjustments

NOTE: Do not tamper with governor setting. Overspeed is hazardous and could cause personal injury.

Initial Adjustment Procedure

Make this adjustment whenever governor arm is loosened or removed from cross shaft. Adjust as follows:

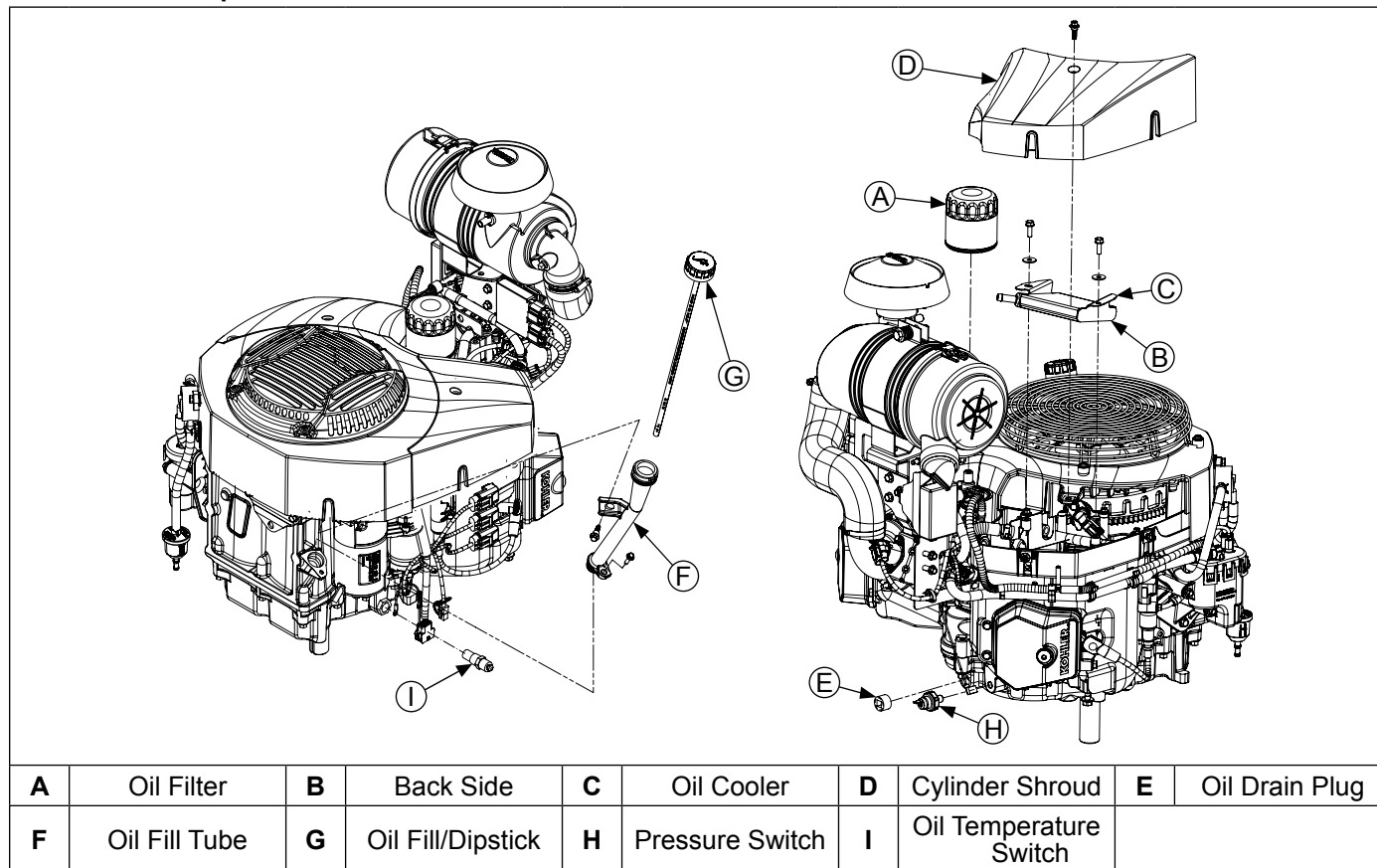
1. Make sure throttle linkage is connected to governor arm and throttle lever on throttle body.
2. Loosen nut holding governor lever to cross shaft.
3. Move governor lever toward throttle body as far as it will go (wide open throttle) and hold in this position.
4. Insert a long thin rod or tool into hole on cross shaft and rotate shaft clockwise (viewed from end) as far as it will turn, then torque nut to 7.1 N·m (63 in. lb.).

Lubrication System

This engine uses a full pressure lubrication system which delivers oil under pressure to crankshaft, camshaft, connecting rod bearing surfaces, and hydraulic valve lifters.

A high-efficiency gerotor oil pump maintains high oil flow and oil pressure, even at low speeds and high operating temperatures. A pressure relief valve limits maximum pressure of system. Oil pan must be removed to service oil pickup, pressure relief valve, and oil pump.

Lubrication Components



OIL RECOMMENDATIONS

Refer to Maintenance.

CHECK OIL LEVEL

NOTE: To prevent extensive engine wear or damage, never run engine with oil level below or above operating range indicator on dipstick.

Ensure engine is cool. Clean oil fill/dipstick areas of any debris.

1. Remove dipstick; wipe oil off.
2. Reinsert dipstick into tube; rest cap on tube, do not thread cap onto tube.
3. Remove dipstick; check oil level. Level should be at top of indicator on dipstick.
4. If oil is low on indicator, add oil up to top of indicator mark.
5. Reinstall and secure dipstick.

CHANGE OIL AND FILTER

Change oil while engine is warm.

1. Clean area around oil fill cap/dipstick and drain plug. Remove drain plug and oil fill cap/dipstick. Allow oil to drain completely.
2. Clean area around oil filter; remove filter; wipe off mounting surface. Reinstall drain plug and torque to 21.4 N·m (16 ft. lb.).
3. Place new filter in shallow pan with open end up. Fill with new oil until oil reaches bottom of threads. Allow 2 minutes for oil to be absorbed by filter material.
4. Apply a thin film of clean oil to rubber gasket on new filter.
5. Refer to instructions on oil filter for proper installation.
6. Fill crankcase with new oil. Level should be at top of indicator on dipstick.
7. Reinstall oil fill cap/dipstick and tighten securely.
8. Start engine; check for oil leaks. Stop engine; correct leaks. Recheck oil level.
9. Dispose of used oil and filter in accordance with local ordinances.

OIL COOLER

NOTE: Oil cooler is mounted under cylinder shroud. Removal of cylinder shroud is necessary to access oil cooler.

1. Clean fins with a brush or compressed air.
2. Remove screws securing oil cooler and tilt to clean back side.
3. Reinstall oil cooler and torque to 2.3 N·m (21 in. lb.).

OIL SENTRY™ (if equipped)

This switch is designed to prevent engine from starting in a low oil or no oil condition. 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 manuals for more information.

Oil Sentry™ pressure switch is installed in oil pan pressure port. On engines not equipped with Oil Sentry™ installation hole is sealed with a 1/8-27 N.P.T.F. pipe plug.

Installation

1. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to threads of switch.
2. Install switch into tapped hole in oil pan.
3. Torque switch to 10.7 N·m (95 in. lb.).

Testing

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

1. Connect continuity tester across blade terminal and metal case of switch. With 0 psi pressure applied to switch, tester should indicate continuity (switch closed).
2. Gradually increase pressure to switch. As pressure increases through range of 7-11 psi tester should indicate a change to no continuity (switch open). Switch should remain open as pressure is increased to 90 psi maximum.
3. Gradually decrease pressure through range of 7-11 psi. Tester should indicate a change to continuity (switch closed) down to 0 psi.
4. Replace switch if it does not operate as specified.

Electrical System

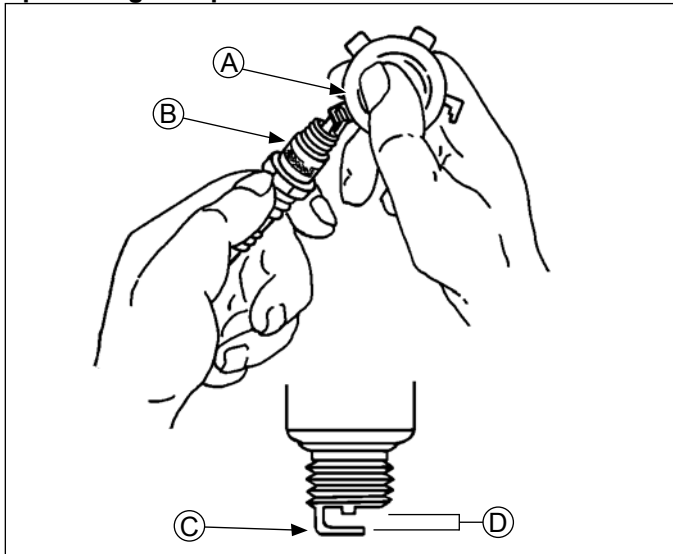
SPARK PLUGS



CAUTION

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

Spark Plug Component and Details



A	Wire Gauge	B	Spark Plug
C	Ground Electrode	D	Gap

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

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

Engine is equipped with following spark plugs:

Gap	0.76 mm (0.03 in.)
Thread Size	14 mm
Reach	19.1 mm (3/4 in.)
Hex Size	15.9 mm (5/8 in.)

Refer to Maintenance for Repairs/Service Parts.

Service

Clean out spark plug recess. Remove plug and replace.

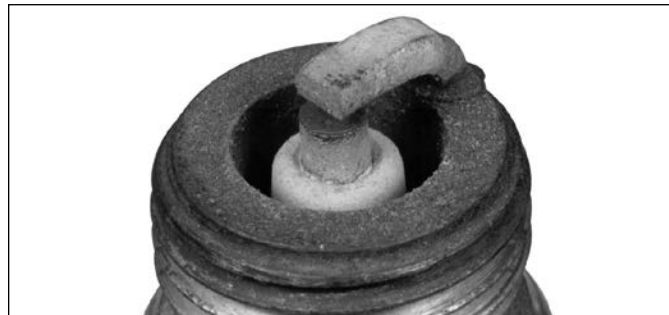
1. Check gap using wire feeler gauge. Adjust gap to 0.76 mm (0.03 in.).
2. Install plug into cylinder head.
3. Torque plug to 27 N·m (20 ft. lb.).

Inspection

Inspect each spark plug as it is removed from cylinder head. Deposits on tip are an indication of general condition of piston rings, valves, and carburetor.

Normal and fouled plugs are shown in following photos:

Normal



Plug taken from an engine operating under normal conditions will have light tan or gray colored deposits. If center electrode is not worn, plug can be set to proper gap and reused.

Worn



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

Wet Fouled



A wet plug is caused by excess fuel or oil in combustion chamber. Excess fuel could be caused by a restricted air cleaner, a carburetor problem, or operating engine with too much choke. Oil in combustion chamber is usually caused by a restricted air cleaner, a breather problem, worn piston rings, or valve guides.

Carbon Fouled



Soft, sooty, black deposits indicate incomplete combustion caused by a restricted air cleaner, over rich carburetion, weak ignition, or poor compression.

Overheated



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

BATTERY

A 12-volt battery with 400 cold cranking amps (cca) 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 following table for minimum capacities based on anticipated ambient temperatures. Actual cold cranking requirement depends on engine size, application, and starting temperatures. Cranking requirements increase as temperatures decrease and battery capacity shrinks. Refer to equipment's operating instructions 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 battery charge is insufficient to turn over engine, recharge battery.

Battery Maintenance

Regular maintenance is necessary to prolong battery life.

Battery Test

To test battery, follow manufacturer's instructions.

Electrical System

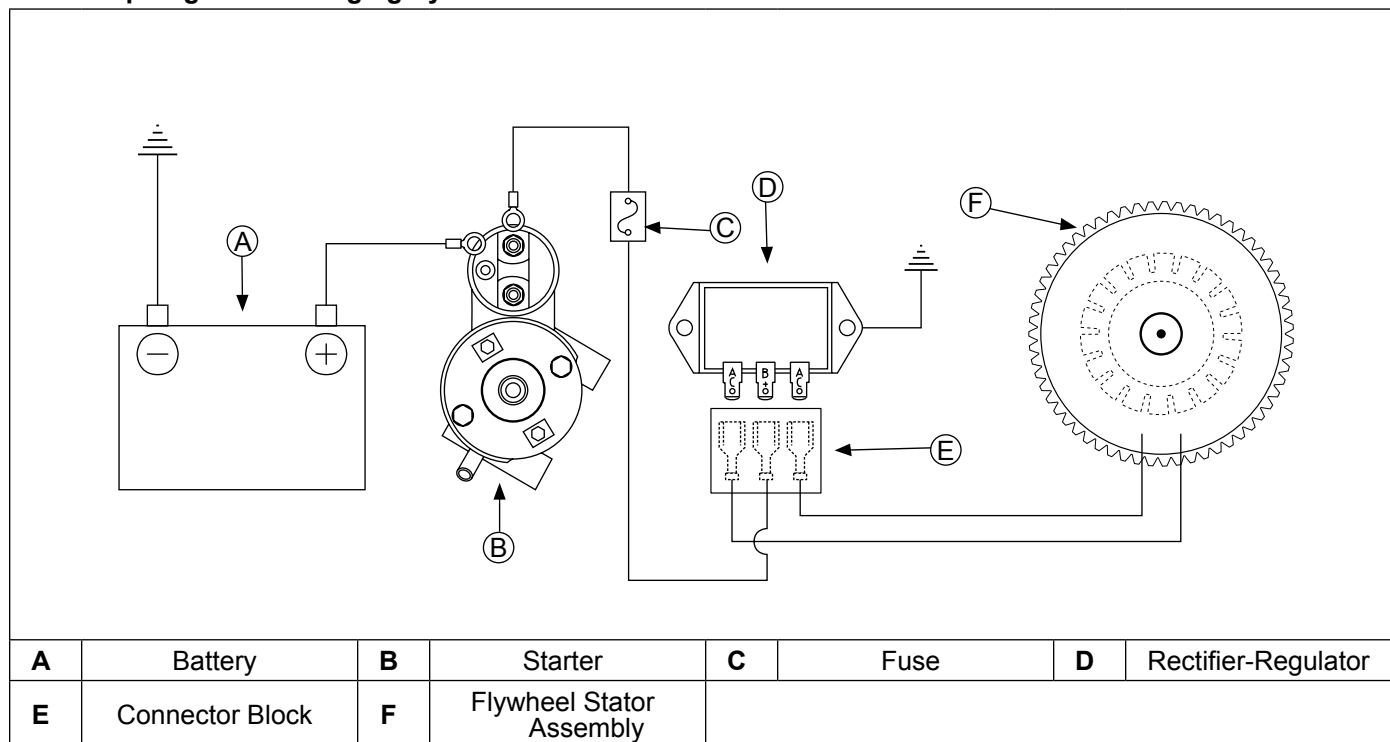
BATTERY CHARGING SYSTEM

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

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

These engines are equipped with a 20 or 25 amp regulated charging system.

20/25 Amp Regulated Charging System



Stator

Stator is mounted on crankcase behind flywheel. Follow procedures in Disassembly and Reassembly if stator replacement is necessary.

Rectifier-Regulator

NOTE: When installing rectifier-regulator, take note of terminal markings and install plug(s) accordingly.

NOTE: Disconnect all electrical connections attached to rectifier-regulator. Testing may be performed with rectifier-regulator mounted or loose. Repeat applicable test procedure 2 or 3 times to determine condition of part.

Rectifier-regulator is mounted on blower housing. To replace, disconnect plug(s), remove mounting screws, and ground wire or metal grounding strap.

Testing rectifier-regulator may be performed as follows, using appropriate rectifier-regulator tester.

To test 20/25 amp rectifier-regulators:

1. Connect tester ground lead (with spring clamp) to body of rectifier-regulator.
2. Connect red lead from tester to middle terminal labeled B+.
3. Connect black leads from tester to both outer AC terminals on rectifier-regulator.
4. Plug tester into proper AC outlet/power for tester being used. Turn on power switch. POWER light should be illuminated and one of four status lights may be lit as well. This does not represent condition of part.
5. Press TEST button until a click is heard and then release. Momentarily one of four status lights will illuminate indicating partial condition of part.

Condition	Conclusion
	20/25 amp
OK (green) light comes on and stays steady.	Disconnect tester black lead attached to 1 AC terminal and reconnect it to other AC terminal. Repeat test. If OK (green) light comes on again, part is good and may be used.
NOTE: A flashing LOW light can also occur as a result of an inadequate ground lead connection. Make certain connection location is clean and clamp is secure. Other lights come on.	Rectifier-regulator is faulty and should not be used.

Troubleshooting Guide

20/25 Amp Battery Charging System

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

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

To test charging system for no charge to battery:

1. Insert an ammeter in B+ lead from rectifier-regulator. With engine running at 3600 RPM and B+ (at terminal on rectifier-regulator) to ground using a DC voltmeter.

If voltage is 13.8 volts or more, place a minimum load of 5 amps (turn on lights if 60 watts or more, or place a 2.5 ohm, 100 watt resistor across battery terminals) on battery to reduce voltage. Observe ammeter.

Condition	Conclusion
Charge rate increases when load is applied.	Charging system is OK and battery was fully charged.
Charge rate does not increase when load is applied.	Test stator and rectifier-regulator (steps 2 and 3).

2. Remove connector from rectifier-regulator. With engine running at 3600 RPM, measure AC voltage across stator leads using an AC voltmeter.

Condition	Conclusion
Voltage is 28 volts or more.	Stator is OK. Rectifier-regulator is faulty; replace.
Voltage is less than 28 volts.	Stator is faulty; replace. Test stator further using an ohmmeter (steps 3 and 4).

3. With engine stopped, measure resistance across stator leads using an ohmmeter.

Condition	Conclusion
Resistance is 0.064/0.2 ohms.	Stator is OK.
Resistance is 0 ohms.	Stator is shorted; replace.
Resistance is infinity ohms.	Stator is open; replace.

4. With engine stopped, measure resistance from each stator lead to ground using an ohmmeter.

Condition	Conclusion
Resistance is infinity ohms (no continuity).	Stator is OK (not shorted to ground).
Resistance (or continuity) measured.	Stator leads are shorted to ground; replace.

To test charging system for battery continuously charging at high rate:

1. With engine running at 3600 RPM, measure voltage from B+ lead to ground using a DC voltmeter.

Condition	Conclusion
Voltage is 14.7 volts or less.	Charging system is OK. Battery is unable to hold charge; service or replace.
Voltage is more than 14.7 volts.	Faulty rectifier-regulator; replace.

Electrical System

FUSES

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

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

Fuse Replacement

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

NOTE: Do not crank engine continuously for more than 10 seconds. Allow a 60 second cool down period between starting attempts. Failure to follow these guidelines can burn out starter motor.

NOTE: If starter is engaged while flywheel is rotating, starter pinion and flywheel ring gear may clash and damage starter.

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

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

Engines in this series use solenoid shift starters.

Troubleshooting-Starting Difficulties

Condition	Possible Cause	Conclusion
Starter does not energize.	Battery	Check specific gravity of battery. If low, recharge or replace battery as necessary.
	Wiring	Clean corroded connections and tighten loose connections. Replace wires in poor condition and with frayed or broken insulation.
	Starter Switch or Solenoid	By-pass switch or solenoid with a jumper wire. If starter cranks normally, replace faulty components. Remove and perform individual solenoid test procedure.
Starter energizes but turns slowly.	Battery	Check specific gravity of battery. If low, recharge or replace battery as necessary.
	Brushes	Check for excessively dirty or worn brushes and commutator. Clean using a coarse cloth (not emery cloth). Replace brushes if excessively or unevenly worn.
	Transmission or Engine	Make sure clutch or transmission is disengaged or placed in neutral. This is especially important on equipment with hydrostatic drive. Transmission must be exactly in neutral to prevent resistance which could keep engine from starting. Check for seized engine components such as bearings, connecting rod, and piston.

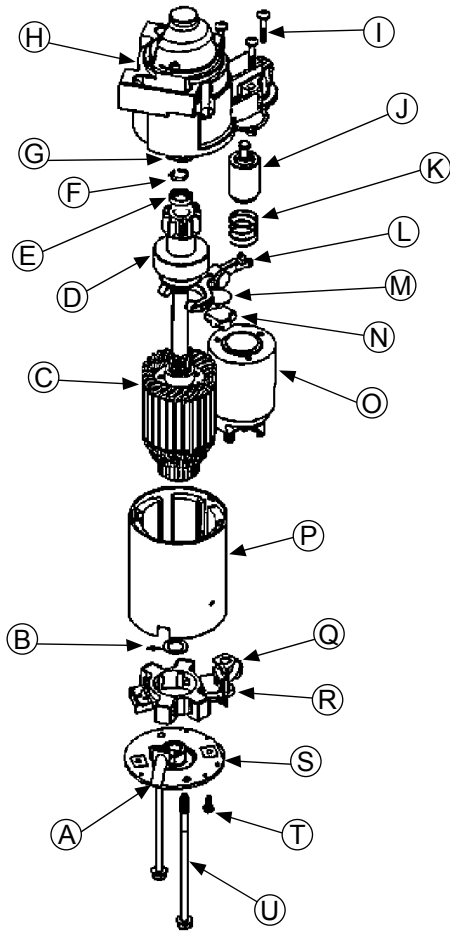
Starter System

SOLENOID SHIFT STARTERS

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

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

Solenoid Shift Starter Components



A	Tube	B	Washer
C	Armature	D	Drive
E	Stop	F	Retaining Ring
G	Collar	H	Drive End Cap
I	Screw	J	Plunger
K	Spring	L	Lever
M	Plate	N	Plug
O	Solenoid	P	Frame and Field
Q	Brush Holder	R	Nut
S	Commutator End Plate	T	Screw
U	Bolt		

Starter Disassembly

NOTE: Do not reuse old retainer.

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

1. Remove hex nut and disconnect positive (+) brush lead/bracket from solenoid terminal.
2. Remove head screws securing solenoid to starter.
3. Unhook plunger pin from drive lever. Remove gasket from recess in housing.
4. Remove thru (larger) bolts.
5. Remove commutator end plate assembly, containing brush holder, brushes, springs, and locking caps. Remove thrust washer from inside commutator end.
6. Remove frame from armature and drive end cap.
7. Remove drive lever pivot bushing and backing plate (if equipped) from end cap.
8. Take out drive lever and pull armature out of drive end cap.
9. Remove thrust washer from armature shaft.
10. Push stop collar down to expose retaining ring.
11. Remove retainer from armature shaft. Save stop collar.
12. Remove drive pinion assembly from armature.
13. Clean parts as required.

Inspection

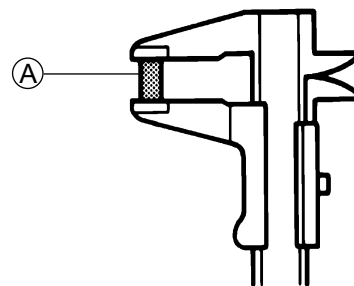
Drive Pinion

Check and inspect following areas:

- Pinion teeth for abnormal wear or damage.
- Surface between pinion and clutch mechanism for nicks or irregularities which could cause seal damage.
- Check drive clutch by holding clutch housing and rotating pinion. Pinion should rotate in only 1 direction.

Brushes and Springs

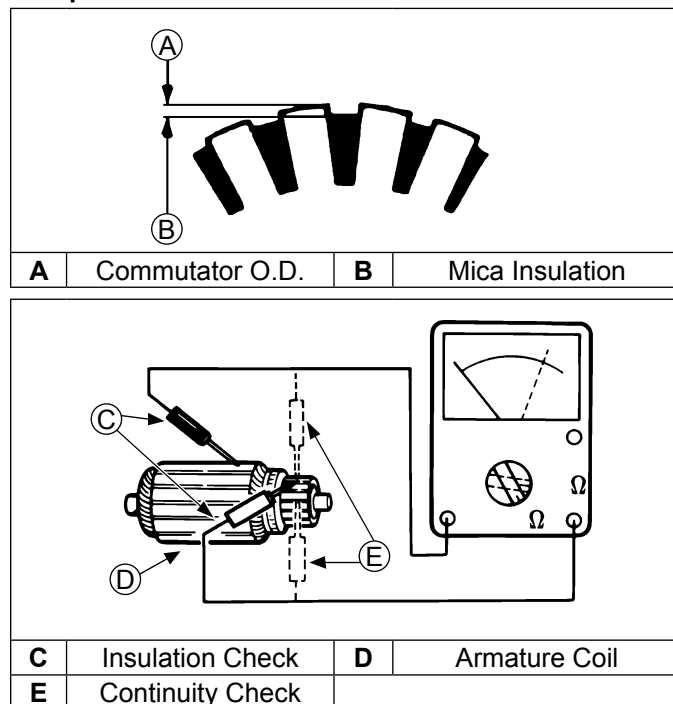
Detail



A	Wear Limit Length
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Inspect both springs and brushes for wear, fatigue, or damage. Measure length of each brush. Minimum length for each brush is 7.6 mm (0.300 in.). Replace brushes if they are worn, undersize, or condition is questionable.

Armature Components and Details



1. Clean and inspect commutator (outer surface). Mica insulation must be lower than commutator bars (undercut) to ensure proper operation of commutator.
2. Use an ohmmeter set to Rx1 scale. Touch probes between 2 different segments of commutator, and check for continuity. Test all segments. Continuity must exist between all or armature is bad.
3. Check for continuity between armature coil segments and commutator segments. There should be no continuity. If continuity exists between any 2 armature is bad.
4. Check armature windings/insulation for shorting.

Shift Fork

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

Brush Replacement

4 brushes and springs are serviced as a set. Use a new Kohler brush and spring kit if replacement is necessary.

1. Perform steps 1-5 in Starter Disassembly.
2. Remove screws securing brush holder assembly to end cap (plate). Note orientation for reassembly later. Discard old brush holder assembly.
3. Clean component parts as required.
New brushes and springs come preassembled in a brush holder with a protective sleeve that will also serve as an installation tool.
4. Perform steps 10-13 in Starter Reassembly sequence. If starter has been disassembled, installation must be done after armature, drive lever, and frame are installed.

Starter Reassembly

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

NOTE: Correctly installed, center pivot section of drive lever will be flush or below machined surface of housing.

1. Apply drive lubricant to armature shaft splines. Install drive pinion onto armature shaft.
2. Install and assemble stop collar/retainer assembly.
 - a. Install stop collar down onto armature shaft with counter bore (recess) up.
 - b. Install a new retainer in larger (rear) groove of armature shaft. Squeeze with a pliers to compress it in groove.
 - c. Slide stop collar up and lock it into place, so recess surrounds retainer in groove. If necessary, rotate pinion outward on armature splines against retainer to help seat collar around retainer.
3. Install offset thrust (stop) washer so smaller offset of washer faces retainer/collar.
4. Apply a small amount of oil to bearing in drive end cap, and install armature with drive pinion.
5. Lubricate fork end and center pivot of drive lever with drive lubricant. Position fork end into space between captured washer and rear of pinion.
6. Slide armature into drive end cap and at same time seat drive lever into housing.
7. Install rubber grommet into matching recess of drive end cap. Molded recesses in grommet should be out, matching and aligned with those in end cap.
8. Install frame, with small notch forward, onto armature and drive end cap. Align notch with corresponding section in rubber grommet. Install drain tube in rear cutout, if it was removed previously.
9. Install flat thrust washer onto commutator end of armature shaft.
10. Starter reassembly when replacing brushes/brush holder assembly:
 - a. Hold starter assembly vertically on end housing, and carefully position assembled brush holder assembly, with supplied protective tube, against end of commutator/armature. Mounting screw holes in metal clips must be up/out. Slide brush holder assembly down into place around commutator, and install positive (+) brush lead grommet in cutout of frame. Protective tube may be saved and used for future servicing.

Starter reassembly when not replacing brushes/brush holder assembly:

- a. Carefully unhook retaining caps from brush assemblies. Do not lose springs.
- b. Position brushes back in their slots so they are flush with I.D. of brush holder assembly. Insert brush installation tool (with extension), or use tube described above from a prior brush installation, through brush holder assembly, so holes in metal mounting clips are up/out.

Starter System

- c. Install brush springs and snap on retainer caps.
- d. Hold starter assembly vertically on end housing, and carefully place tool (with extension) and assembled original brush holder assembly onto end of armature shaft. Slide brush holder assembly down into place around commutator, install positive (+) brush lead grommet in cutout of frame.
11. Install end cap onto armature and frame, aligning thin raised rib in end cap with corresponding slot in grommet of positive (+) brush lead.
12. Install thru bolts and brush holder mounting screws. Torque bolts to 5.6-9.0 N·m (49-79 in. lb.) and brush holder mounting screws to 2.5-3.3 N·m (22-29 in. lb.).
13. Hook plunger behind upper end of drive lever and install spring into solenoid. Insert mounting screws through holes in drive end cap. Use these to hold solenoid gasket in position, then mount solenoid. Torque screws to 4.0-6.0 N·m (35-53 in. lb.).
14. Connect positive (+) brush lead/bracket to solenoid and secure with nut. Torque nut to 8-11 N·m (71-97 in. lb.). Do not overtighten.

Solenoid Tests

NOTE: DO NOT leave 12 volt test leads connected to solenoid for any time over what is necessary for performing each of individual tests. Internal damage to solenoid may occur.

Disconnect all leads from solenoid including positive brush lead attached to lower stud terminal. Remove mounting hardware and separate solenoid from starter for testing.

To test solenoid pull-in coil/plunger:

Actuation

1. Use a 12 volt power supply and 2 test leads.
2. Connect 1 lead to flat spade S/start terminal on solenoid. Momentarily connect other lead to lower large post terminal.

When connection is made solenoid should energize (audible click) and plunger retract. Repeat test several times.

Continuity

1. Use an ohmmeter set to audible or Rx2K scale, and connect 2 ohmmeter leads to 2 large post terminals.
2. Perform solenoid pull-in coil/plunger actuation test and check for continuity. Ohmmeter should indicate continuity. Repeat test several times.

To test solenoid hold-in coil:



Function

1. Connect a 12 volt test lead to flat spade S/start terminal on solenoid and other lead to body or mounting surface of solenoid.
2. Manually push plunger IN and check if coil holds plunger retracted. Do not allow test leads to remain connected to solenoid for a prolonged period of time.

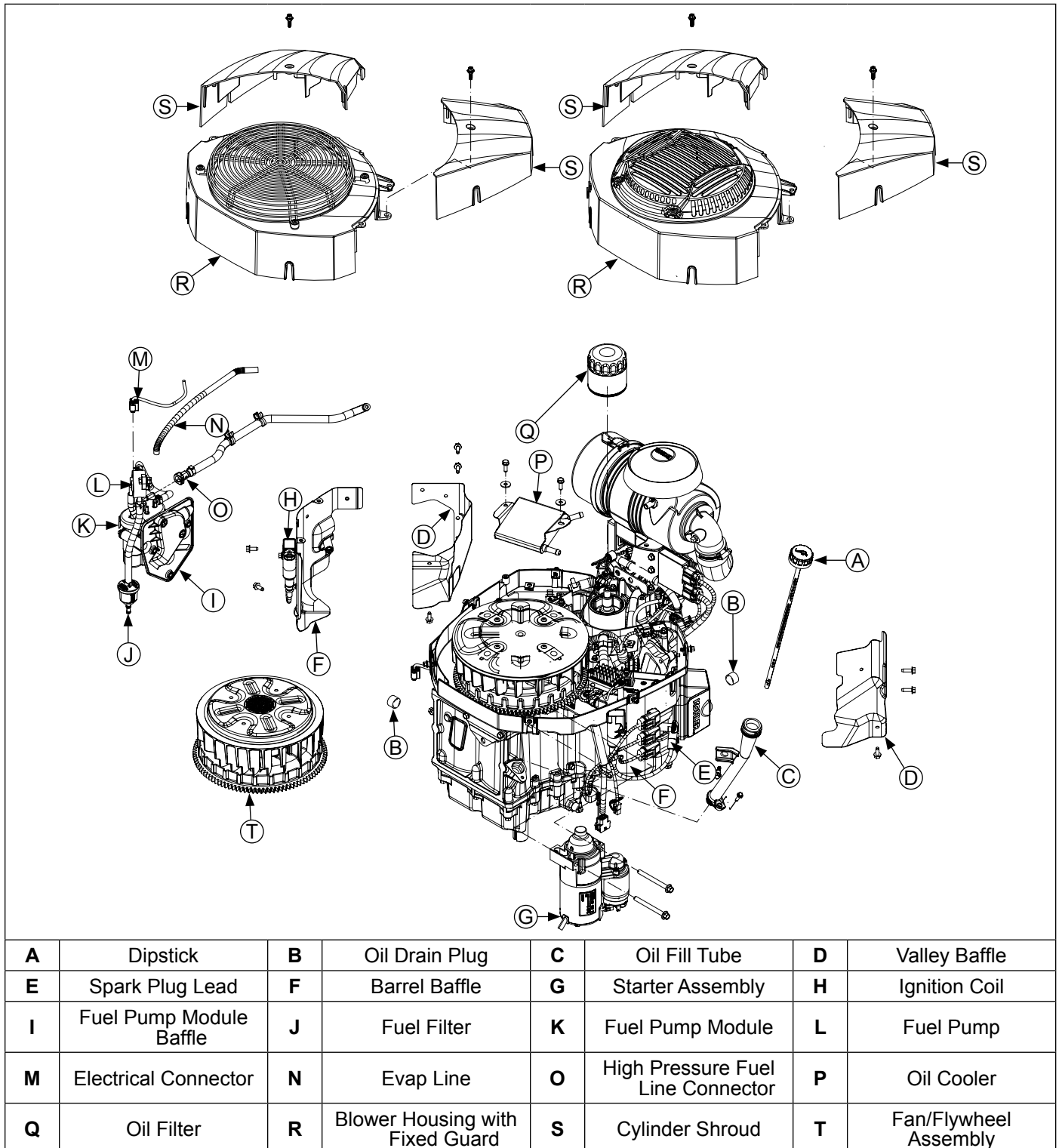
Continuity

1. Use an ohmmeter set to audible or Rx2K scale, and connect 2 ohmmeter leads to 2 large post terminals.
2. Perform preceding solenoid hold-in coil function test and check for continuity. Meter should indicate continuity. Repeat test several times.

Condition	Conclusion
Solenoid fails to activate.	Replace solenoid.
No continuity is indicated.	
Plunger fails to stay retracted.	

	 WARNING	
	Accidental Starts can cause severe injury or death.	
	Disconnect and ground spark plug lead(s) before servicing.	
		Before working on engine or equipment, disable engine as follows: 1) Disconnect spark plug lead(s). 2) Disconnect negative (–) battery cable from battery.

External Engine Components



Disassembly/Inspection and Service

Clean all parts thoroughly as 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 manufacturer's instructions and safety precautions carefully.

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

NOTE: This disassembly sequence removes some components in subassemblies to enable technician to perform internal engine servicing. Do not disconnect every EFI and electronic governor component.

Disconnect Spark Plug Leads

NOTE: Pull on boot only, to prevent damage to spark plug lead.

1. Disconnect leads from spark plugs.
2. Shut off fuel supply.

Drain Oil from Crankcase and Remove Oil Filter

1. Clean oil filter and housing area. Remove and discard oil filter.
2. Remove dipstick and 1 oil drain plug.
3. Allow ample time for oil to drain from crankcase.

Remove Muffler

Remove exhaust system and attaching hardware from engine. On engines equipped with a port liner, remove it now.

Remove Cylinder Shrouds and Blower Housing

1. Remove top mounting screw and loosen shoulder screws on each side. Lift off cylinder shrouds.
2. Remove mounting screws and separate blower housing from backing shroud assembly. One screw also secures oil fill/dipstick tube. Fixed guard (if equipped) may be removed with blower housing. If engine has pulse/lift pump mounted to blower housing, remove two mounting screws.
3. Remove lower mounting screw and pull oil fill tube out of crankcase.


Remove Electric Starter Motor

1. Disconnect leads from starter.
2. Remove screws and starter.

Remove #1 Barrel and Valley Baffles

1. Remove mounting screws from #1 barrel baffle. Disconnect wiring harness from coil (#1 starter side). Let barrel baffle hang (with coil installed).
2. Carefully remove clip securing wires to #1 valley baffle. Remove 3 screws, then valley baffle.

Remove Fuel Pump Module/Fuel Pump Assembly

	⚠ WARNING
	Explosive Fuel can cause fires and severe burns.
	Do not fill fuel tank while engine is hot or running.
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. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.	

1. Remove evap line & clips from fuel line clips and separate from fuel pump module.
2. Lift grey locking tab and squeeze to disconnect electrical connector from fuel pump module.
3. Wrap a shop towel completely around high pressure fuel line connector.
4. Press release button and slowly pull connector away from fuel pump module, allowing shop towel to absorb any residual fuel in high pressure fuel line. Any spilled fuel must be wiped up immediately.
5. Remove pulse line from crankcase fitting.
6. Remove 3 screws securing fuel pump module baffle to crankcase. Remove fuel pump module, baffle, and fuel pump keeping all fuel lines connected.

Separate parts only if additional service is required. Refer to page 90.

Do not cut any Oetiker clamps unless fuel lines and/or fuel filter are being replaced.

Remove Governor Springs, Linkage, and Lever (Mechanical Governor Only)

1. Unhook idle and governor springs from control bracket and governor lever. Note color, location, and position of each.
2. Disconnect throttle linkage and linkage spring from governor lever.
3. Loosen nut and remove governor lever from cross shaft.

Remove Oil Cooler

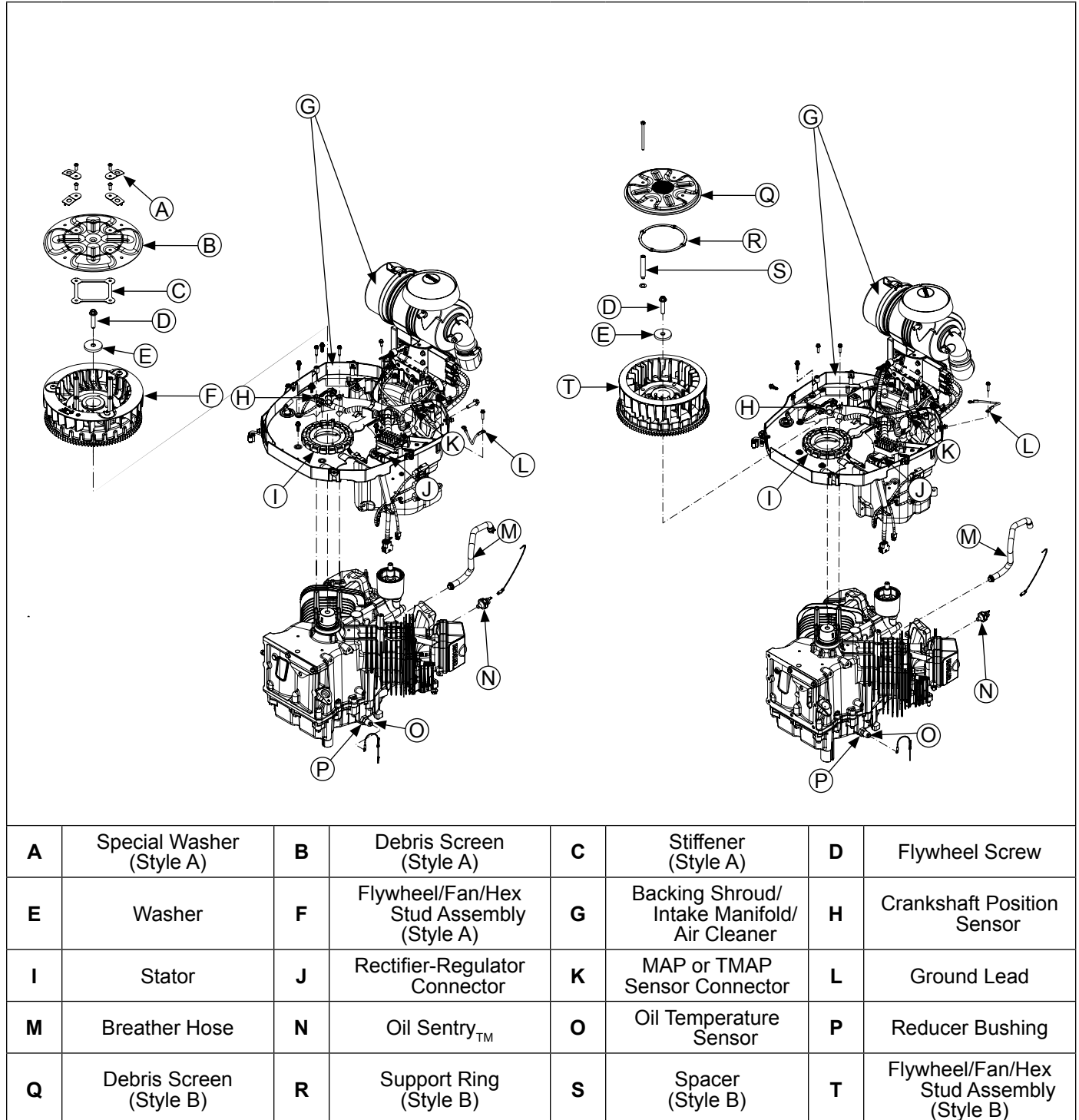
NOTE: New clamps are recommended any time disassembly is performed, or if clamps have been loosened (expanded) several times.

1. Remove oil cooler mounting screws. Do not lose any washers (if used).
2. Note orientation of clamps before disassembling for proper clearance during reassembly. Loosen clamps and disconnect hoses from oil cooler. Cap hoses as required to prevent dirt infiltration.

Remove #2 Barrel and Valley Baffles

1. Disconnect wiring harness lead from coil (#2 oil cooler side).
2. Carefully depress back of high pressure fuel line mounting clip and separate from #2 barrel baffle. Remove 5 screws (2 internal, 3 external), then remove barrel baffle (with coil installed).
3. Remove screws and #2 side valley baffle.
4. If necessary, carefully depress clip & remove coil from barrel baffle.

Flywheel/Backing Shroud/Intake and Throttle Body/Air Cleaner Assembly Components



Disassembly/Inspection and Service

Remove Crankshaft Position Sensor

1. Remove two bracket mounting screws and crankshaft position sensor from backing shroud. Keep leads in place and let bracket and crankshaft position sensor lay on backing shroud.
2. Unplug connector from rectifier-regulator. Remove wiring harness ground lead from rectifier-regulator mounting screw (outside edge). Rectifier-regulator does not need to be removed from backing shroud.
3. Remove lead from oil temperature sensor (in oil pan). Remove switch from oil pan only if replacing.
4. Remove screw securing harness bracket and ground lead to #1 cylinder boss.
5. Remove other end of ground lead from #1 cylinder boss screw. Be sure to keep washer.

Remove Debris Screen (Style A)

Remove screws and special washers securing debris screen to studs in flywheel; then remove stiffener. Hex studs and cooling fan can stay attached to flywheel.

Remove Debris Screen (Style B)

NOTE: Fan will be loose, but cannot be removed until after blower housing is removed.

1. Remove screws securing screen and remove screen.
2. Remove spacers, paying attention to curvature of spring washers between spacers and fan.

Remove Flywheel/Fan/Hex Stud Assembly

NOTE: Always use a flywheel strap wrench or holding tool to hold flywheel when loosening or tightening flywheel screw. Do not use any type of bar or wedge to hold flywheel. Use of such tools could cause flywheel to become cracked or damaged.

NOTE: Always use a flywheel puller to remove flywheel from crankshaft. Do not strike crankshaft or flywheel, as these parts could become cracked or damaged.

1. Use a flywheel strap wrench or holding tool to hold flywheel and loosen screw securing flywheel to crankshaft.
2. Remove screw and washer.
3. Use a puller to remove flywheel from crankshaft.
4. Remove woodruff key from crankshaft.

Inspection

Inspect flywheel for cracks and flywheel keyway for damage. Replace flywheel if it is cracked. Replace flywheel, crankshaft, and key if flywheel key is sheared or keyway is damaged.

Inspect ring gear for cracks or damage. Kohler does not provide ring gear as a serviceable part. Replace flywheel if ring gear is damaged.

Remove Backing Shroud Assembly

1. Remove screws securing stator to backing shroud. Keep leads in place and let stator lay on backing shroud.
2. Carefully slide lock tab outward. Press down on lock tab to release, then separate connectors.
3. Remove screws securing backing shroud to crankcase. Set backing shroud/harness assembly to #1 starter side.

Remove Intake and Throttle Body/Air Cleaner Assembly

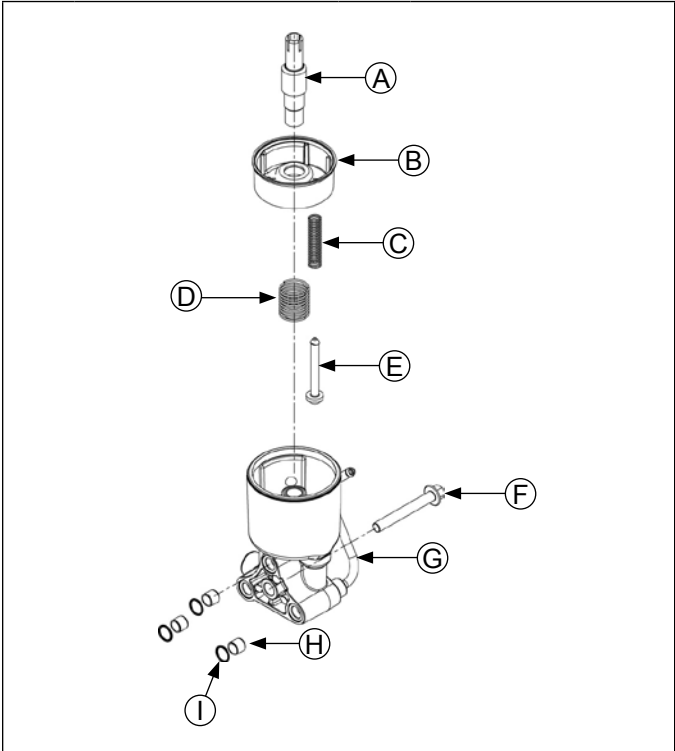
1. Disconnect lead from Oil Sentry™ switch. (Green wire, red terminal). Remove switch from oil pan only if replacing.
2. Disconnect oil temperature sensor connector. Unless sensor is damaged or malfunctioning, disassembly from crankcase is unnecessary.
3. Remove breather hose from breather cover. (Other end is connected to throttle body assembly.)
4. Loosen but do not remove throttle body/intake manifold. Support manifold and remove this assembly when final intake manifold bolt is taken out, along with backing plate assembly.

Assembly includes air cleaner, hose, elbow, throttle body, intake manifold, fuel rail assembly, injectors, MAP or TMAP sensor, intake air temperature sensor, ECU, and brackets. If equipped with electronic governor it also includes GCU, DLA, and electronic governor wiring harness.

Separate parts only if additional service is required. Refer to pages 88-90.

Remove Oil Filter Housing

Oil Filter Housing Components



A	Oil Filter Nipple	B	Cup
C	Valve Spring	D	Cup Spring
E	Oil Filter Valve	F	Screw
G	Oil Filter Housing	H	Pin
I	O-Ring		

NOTE: Further disassembly of oil filter housing assembly is not required unless being serviced individually. Follow substeps a, b, and c.

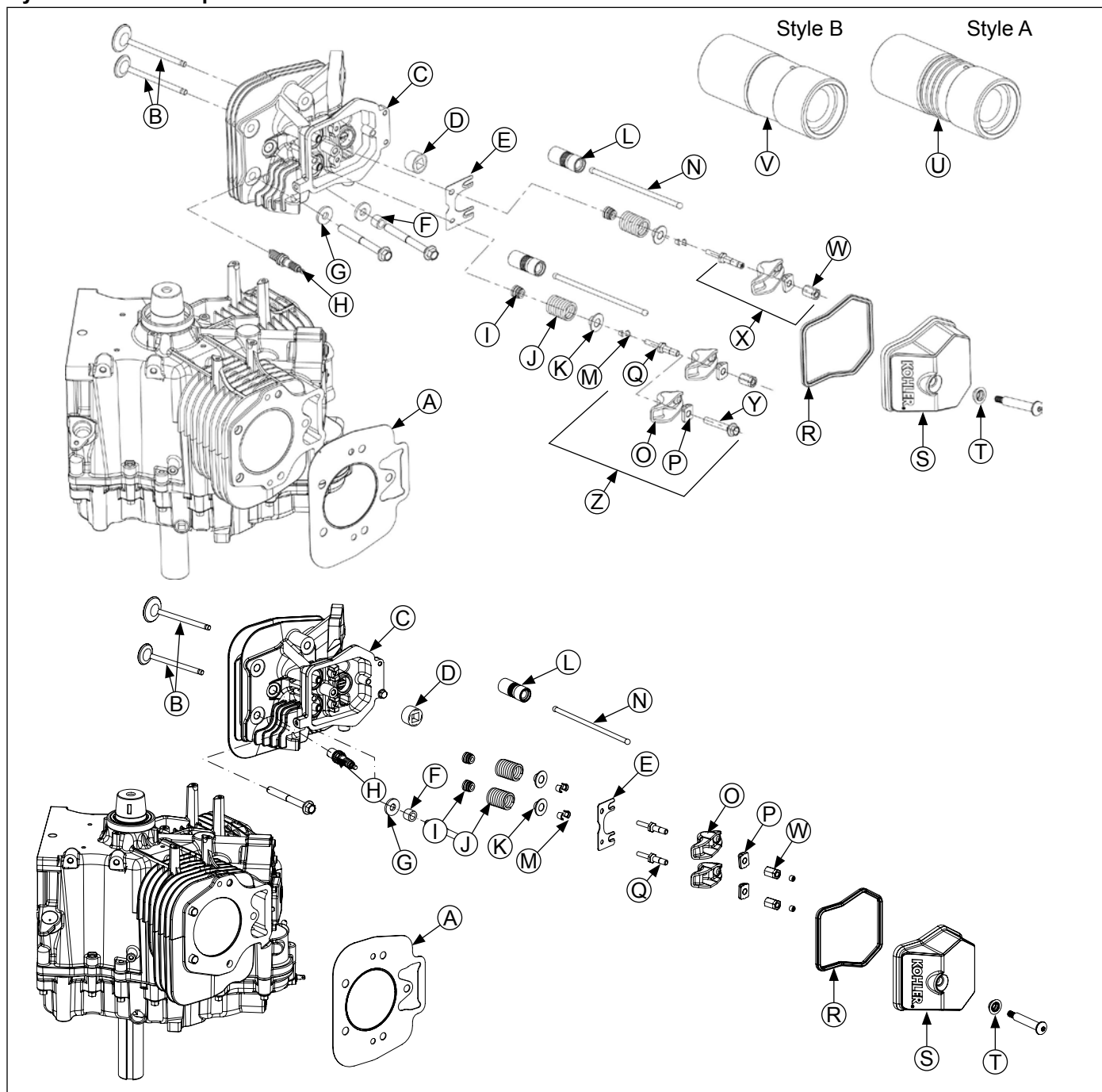
1. Remove screw securing oil filter housing and individual O-rings to crankcase. Carefully separate parts.

Perform following only if oil filter housing assembly requires individual servicing.

- a. Remove nipple from cup and oil filter housing.
- b. Remove oil filter cup and spring from housing.
- c. Remove rubber valve and spring from cup.

Disassembly/Inspection and Service

Cylinder Head Components



A	Gasket	B	Valve	C	Cylinder Head	D	Pipe Plug
E	Guide Plate	F	Spacer	G	Washer	H	Spark Plug
I	Valve Stem Seal	J	Valve Spring	K	Valve Spring Retainer	L	Hydraulic Lifter
M	Valve Spring Keeper	N	Push Rod	O	Rocker Arm	P	Rocker Arm Pivots
Q	Rocker Stud	R	Valve Cover Seal	S	Valve Cover	T	Grommet
U	Hydraulic Lifter Style A (Ribbed)	V	Hydraulic Lifter Style B (Smooth)	W	Adjusting Nut	X	Adjustable Valve Train (AVT)
Y	Rocker Arm Screw	Z	Non-adjustable Valve Train (Non-AVT)				

Remove Spark Plugs

Remove spark plug from each cylinder head.

Remove Valve Covers

1. Remove screw and grommet securing each valve cover.
2. Remove valve cover and seal from each cylinder head. Note locations of individual valve covers if they are different.

Remove Cylinder Heads and Hydraulic Lifters

NOTE: Exhaust lifters are located on output shaft side of engine while intake lifters are located on fan side of engine. Cylinder head number is embossed on outside of each cylinder head.

1. Non-adjustable Valve Train
 - a. Remove rocker arm screws, rocker arm pivots and rocker arms.Adjustable Valve Lash
 - a. Loosen set screws and remove adjusting nuts on rocker arm pivot studs.
 - b. Remove rocker arm pivot and rocker arms.
2. Remove pipe plug from cylinder head to access screw in center location.
3. Remove screws securing each cylinder head. Note locations of washers and spacer.
4. Mark position of push rods as either intake or exhaust and cylinder #1 or #2. Push rods should always be reinstalled in same positions.
5. Carefully remove push rods, cylinder head, and head gasket.
6. Repeat procedure for other cylinder head.

Disassemble Cylinder Heads

NOTE: These engines use valve stem seals on intake and exhaust valves. Use a new seal whenever valves are removed, or if seal is deteriorated in any way. Never reuse an old seal.

1. Non-adjustable Valve Train

Remove screws, rocker arm pivots, and rocker arms from cylinder head.

Adjustable Valve Train

Remove adjusters, rocker arm pivots, and rocker arms from cylinder head. Remove pivot studs and guide plate as required.

2. Compress valve springs using a valve spring compressor.
3. Once valve spring is compressed, remove following items:
 - Valve spring keepers.
 - Valve spring retainers.
 - Valve springs.
 - Valve spring caps.
 - Intake and exhaust valves (mark position).
 - Valve stem seals.
4. Repeat above procedure for other cylinder head. Do not interchange parts from 1 cylinder head to another.

7. Remove lifters from lifter bores. Use a hydraulic lifter tool. Do not use a magnet to remove lifters. Mark lifters by location, as either intake or exhaust and cylinder #1 or #2. Hydraulic lifters should always be reinstalled in same position.

Inspection

Check base surface of hydraulic lifters for wear or damage. If lifters need to be replaced, apply a liberal coating of Kohler lubricant to base of each new lifter before it is installed.

Bleeding Lifters Style A (Ribbed)

To prevent a possible bent push rod or broken rocker arm, it is important to bleed any excess oil out of lifters before they are installed.

1. Cut a 50-75 mm (2-3 in.) piece from end of an old push rod and chuck it in a drill press.
2. Lay a rag or shop towel on table of drill press and place lifter, open end up, on towel.
3. Lower chucked push rod until it contacts plunger in lifter. Slowly pump plunger 2 or 3 times to force oil out of feed hole in side of lifter.

Bleeding Lifters Style B (Smooth)

To prevent a possible bent push rod or broken rocker arm, it is important to bleed any excess oil out of lifters before they are installed.

1. Lay a rag or shop towel on table of drill press. Place an 8 mm (5/16 in.) socket on towel with well end up, then place open end of lifter on socket. Ensure socket does not contact lifter ball surface.
2. Place some material, such as wood, plastic, or aluminum on top of lifter to protect lifter finish.
3. Lower drill press chuck until it contacts material on lifter. Slowly pump lifter 2 or 3 times to force oil out of feed hole in side of lifter.

Disassembly/Inspection and Service

Inspection and Service Valve Details

EXHAUST VALVE		INTAKE VALVE	
Dimension		Intake	Exhaust
A	Seat Angle	89°	89°
B	Seat Taper	30°	30°
C	Guide Depth	8.5 mm (0.334 in.)	8.5 mm (0.334 in.)
D	Guide I.D.	7.038/7.058 mm (0.2771/0.2779 in.)	7.038/7.058 mm (0.2771/0.2779 in.)
E	Valve Head Diameter	38.625/38.685 mm (1.5206/1.5230 in.)	31.625/31.825 mm (1.2450/1.2549 in.)
F	Valve Face Angle	45°	45°
G	Valve Margin (Min.)	1.0 mm (0.0393 in.)	1.0 mm (0.0393 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.)

After cleaning, check flatness of cylinder head and corresponding top surface of crankcase using a surface plate or piece of glass and feeler gauge. Maximum allowable out of flatness is 0.076 mm (0.003 in.).

Carefully inspect valve mechanism parts. Inspect valve springs and related hardware for excessive wear or distortion. Check valves and valve seat area or inserts for evidence of deep pitting, cracks, or distortion. Check clearance of valve stems in guides.

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 valves first. After removal, clean valve heads, faces, and stems with a power wire brush.

Then, carefully inspect each valve for defects such as a warped head, excessive corrosion, or a worn stem end. Replace valves found to be in bad condition.

Valve Guides

If a valve guide is worn beyond specifications, it will not guide 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 valve guide and, using a split-ball gauge, measure inside diameter of guide. Then, using an outside micrometer, measure diameter of valve stem at several points on stem where it moves in valve guide. Use largest stem diameter to calculate clearance by subtracting stem diameter from guide diameter. If intake clearance exceeds 0.038/0.076 mm (0.0015/0.0030 in.) or exhaust clearance exceeds 0.050/0.088 mm (0.0020/0.0035 in.), determine if valve stem or guide is responsible for excessive clearance.

Maximum (I.D.) wear on intake valve guide is 7.135 mm (0.2809 in.) and 7.159 mm (0.2819 in.) for exhaust guide. 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 guides are within limits but valve stems are worn beyond limits, install new valves.

Valve Seat Inserts

Hardened steel alloy intake and exhaust valve seat inserts are press fitted into cylinder head. Inserts are not replaceable but can be reconditioned if not too badly pitted or distorted. If cracked or badly warped, cylinder head should be replaced.

Recondition valve seat inserts following instructions provided with valve seat cutter being used. Final cut should be made with an 89° cutter as specified for valve seat angle. Cutting proper 45° valve face angle as specified, and proper valve seat angle (44.5°, half of full 89° angle), will achieve desired 0.5° (1.0° full cut) interference angle where maximum pressure occurs on outside diameters of valve face and seat.

Lapping Valves

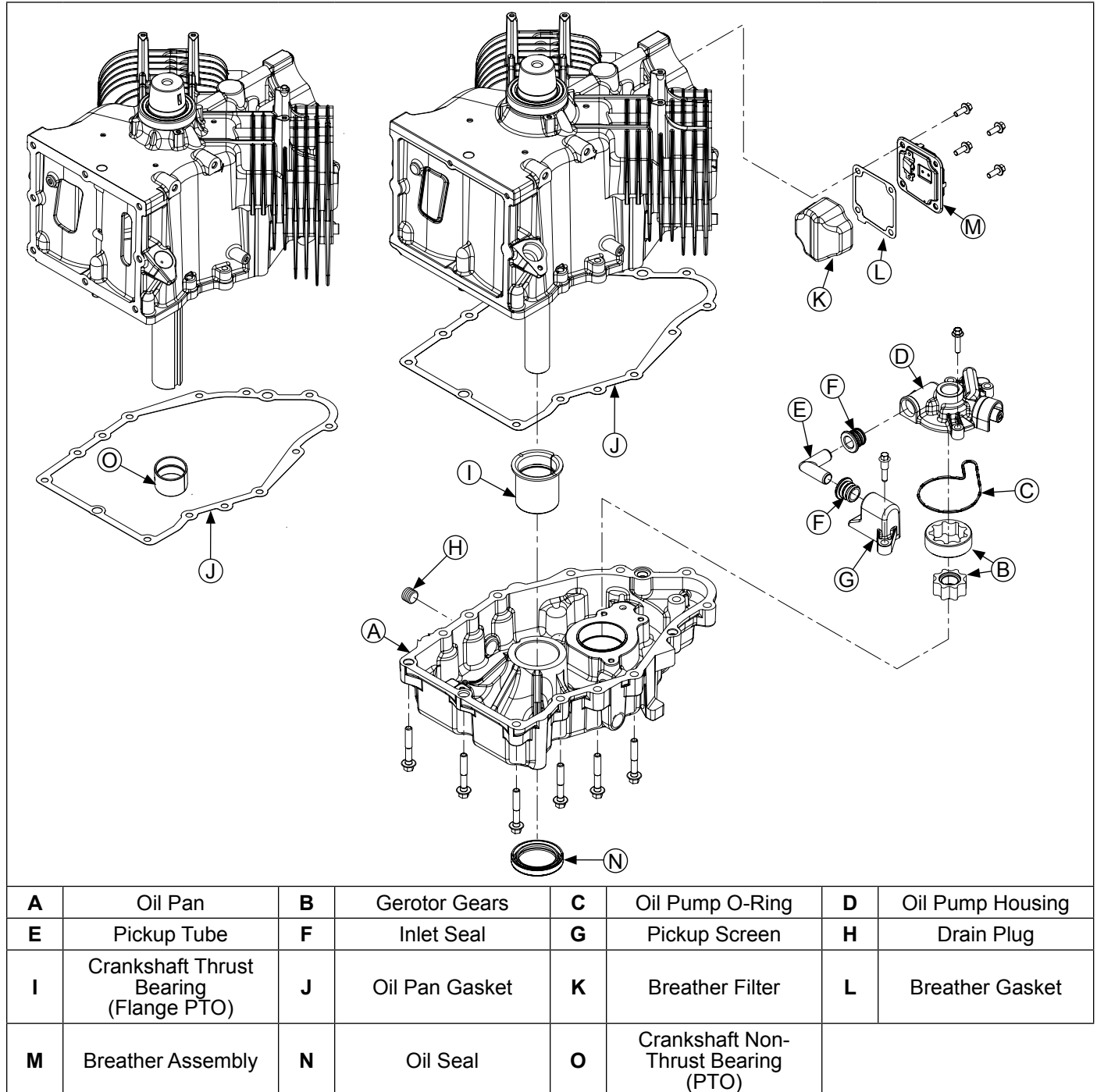
Reground or new valves must be lapped in, to provide proper fit. Use a hand valve grinder with a suction cup for final lapping. Lightly coat valve face with a fine grade

of grinding compound, then rotate valve on its seat with grinder. Continue grinding until a smooth surface is obtained on seat and on valve face. Thoroughly clean cylinder head in soap and hot water to remove all traces of grinding compound. After drying cylinder head, apply a light coating of SAE 10 oil to prevent rusting.

Valve Stem Seals

These engines use valve stem seals on intake and exhaust valves. Always use new seals when valves are removed from cylinder head. Seals should also be replaced if deteriorated or damaged in any way. Never reuse an old seal.

Breather/Oil Pan Components



Disassembly/Inspection and Service

Remove Breather Assembly

1. Carefully remove harness clip from #1 valley baffle (if not already removed).
2. Remove fasteners securing breather assembly and gasket to crankcase.
3. Carefully break gasket seal and remove breather and filter. Do not pry on sealing surfaces as it could cause damage resulting in leaks. Note assembly and orientation of parts.

Remove Oil Pan Assembly

1. Remove screws securing oil pan to crankcase.
2. Locate protruding tabs on oil pan. Carefully tap to break gasket seal. Do not pry on sealing surfaces as this could cause leaks. Separate oil pan from crankcase. Remove old gasket.

Inspection

Inspect oil seal in oil pan and remove it if it is worn or damaged.

Inspect crankshaft bearing surface for wear or damage. Replace bearing or oil pan assembly if required.

Oil Pump Assembly

Disassembly

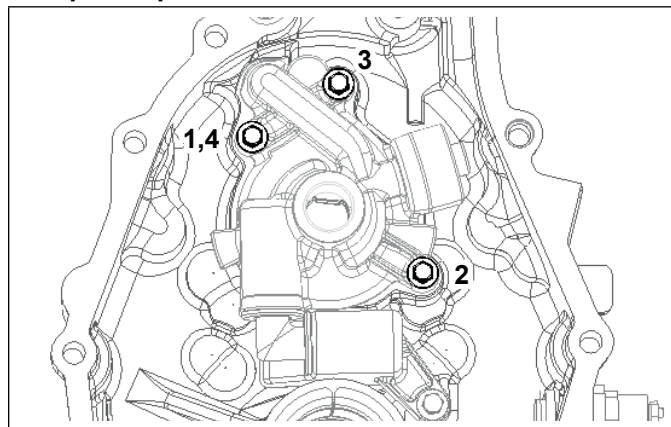
1. Remove screws securing oil pump housing including screw for pickup screen.
2. Remove oil pump housing and pickup screen from oil pan.
3. Remove oil pump gerotor gears from oil pan recess.
4. Remove oil pickup by pulling it free from oil pump body.
5. Relief valve is a one-piece style, staked to oil pump housing; removal should not be attempted, nor is internal servicing possible. If a problem with relief valve is encountered, oil pump should be replaced.

Inspection

Inspect oil pump housing, gerotor gears, and oil pan recess for nicks, burrs, wear, or any visible damage. Inspect inlet seal for pickup tube in housing. If any parts are worn or damaged, replace seal, oil pump or oil pan as required.

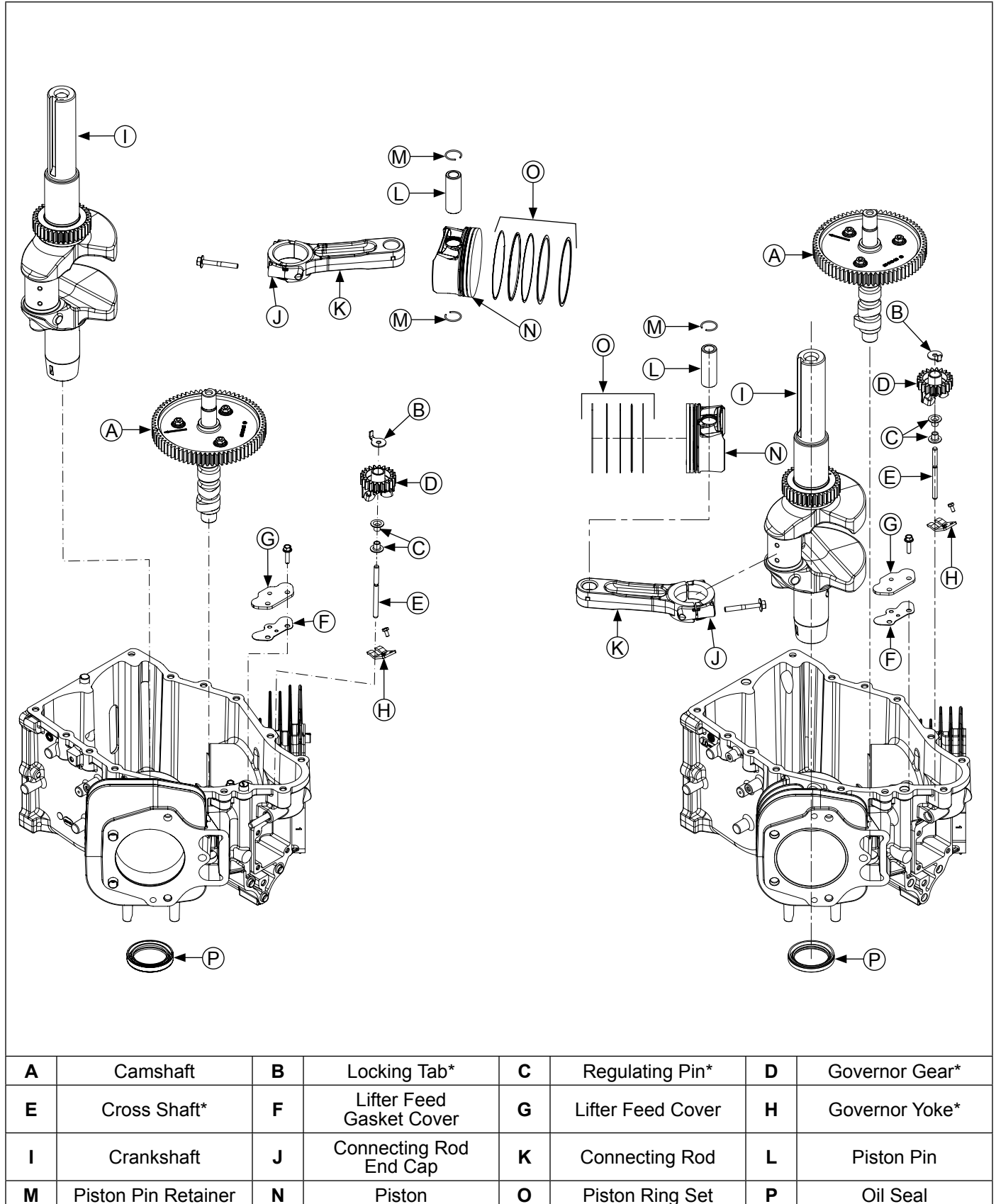
Reassembly

Torque Sequence



1. Make sure recess in oil pan for oil pump gerotor gears is clean.
2. Lubricate oil pump gerotor gears with grease (Lubriplate® 100 or equivalent), and install into recess.
3. Lightly lubricate with oil and install inlet seal into oil pump housing until it is fully seated.
4. Install O-ring in groove of oil pump housing. Use a small quantity of grease to hold it in place.
5. Lightly lubricate I.D. of inlet seal with oil and carefully insert end of pickup tube through seal into oil pump housing.
6. Install oil pump housing with pickup tube, over oil pump boss and gears. Align all 3 screw locations.
7. Check alignment of parts and torque oil pump housing screws 9.9 N·m (88 in. lb.) using sequence below:
 - a. Install fastener into screw location 1 and lightly tighten to position pump.
 - b. Install fastener into screw location 2 and fully torque to recommended value.
 - c. Install fastener into screw location 3 and fully torque to recommended value.
 - d. Finish torquing fastener in screw location 1 to recommended value.
8. Install and torque pickup screen mounting screw to 11.3 N·m (100 in. lb.) into new hole or 7.7 N·m (68 in. lb.) into used hole.

Crankcase Components



*Mechanical Governor only.

Disassembly/Inspection and Service

Remove Camshaft

Remove camshaft and shim (if used).

Inspection

Check lobes of camshaft for wear or damage. Inspect cam gear for badly worn, chipped, or missing teeth. Replacement of camshaft will be necessary if any of these conditions exist.

Remove Connecting Rods with Pistons and Rings

NOTE: If a carbon ridge is present at top of either cylinder bore, use a ridge reamer tool to remove ridge before attempting to remove piston.

NOTE: Cylinders are numbered on crankcase. Use numbers to mark each end cap, connecting rod and piston for reassembly. Do not mix end caps and connecting rods.

1. Remove screws securing closest connecting rod end cap. Remove end cap.
2. Carefully remove connecting rod and piston assembly from cylinder bore.
3. Repeat above procedures for other connecting rod and piston assembly.

Connecting Rods

Offset, stepped-cap connecting rods are used in these engines.

Inspection and Service

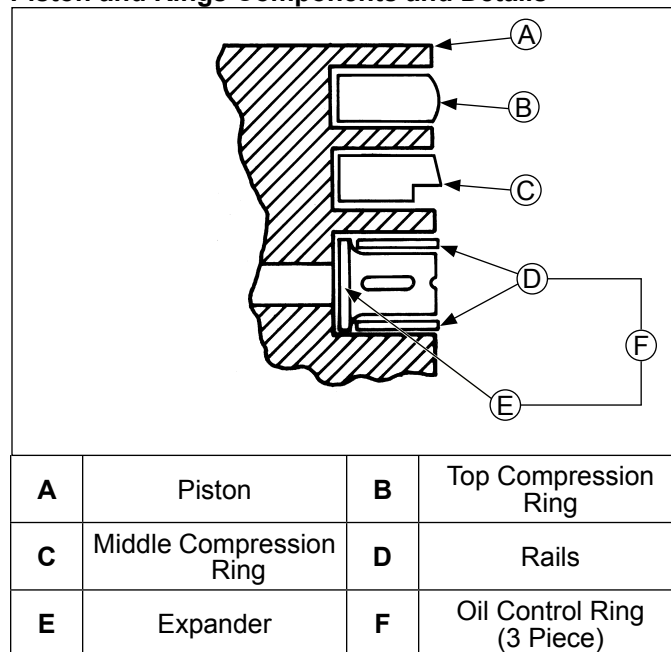
Check bearing area (big end) for excessive wear, score marks, running and side clearances. Replace rod and cap if scored or excessively worn.

Service replacement connecting rods are available in STD crankpin size and 0.25 mm (0.010 in.) undersize. Always refer to appropriate parts information to ensure that correct replacements are used.

Piston and Rings

Inspection

Piston and Rings Components and Details



Scuffing and scoring of pistons and cylinder walls occurs when internal engine temperatures approach welding point of piston. Temperatures high enough to do this are created by friction, which is usually attributed to improper lubrication and/or overheating of engine.

Normally, very little wear takes place in piston boss-piston pin area. If original piston and connecting rod can be reused after new rings are installed, original pin can also be reused but new piston pin retainers are required. Piston pin is included as part of piston assembly – if pin boss in piston or 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 combustion chamber where it is burned along with fuel. High oil consumption can also occur when piston ring end gap is incorrect because ring cannot properly conform to 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 fuel charge ignites spontaneously from heat and pressure shortly after ignition. This creates 2 flame fronts which meet and explode to create extreme hammering pressures on a specific area of piston. Detonation generally occurs from using low octane fuels.

Preignition or ignition of fuel charge before 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 combustion chamber from sources such as glowing carbon deposits, blocked cooling fins, an improperly seated valve, or wrong spark plug(s).

Replacement pistons are available in STD bore size, and in 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.

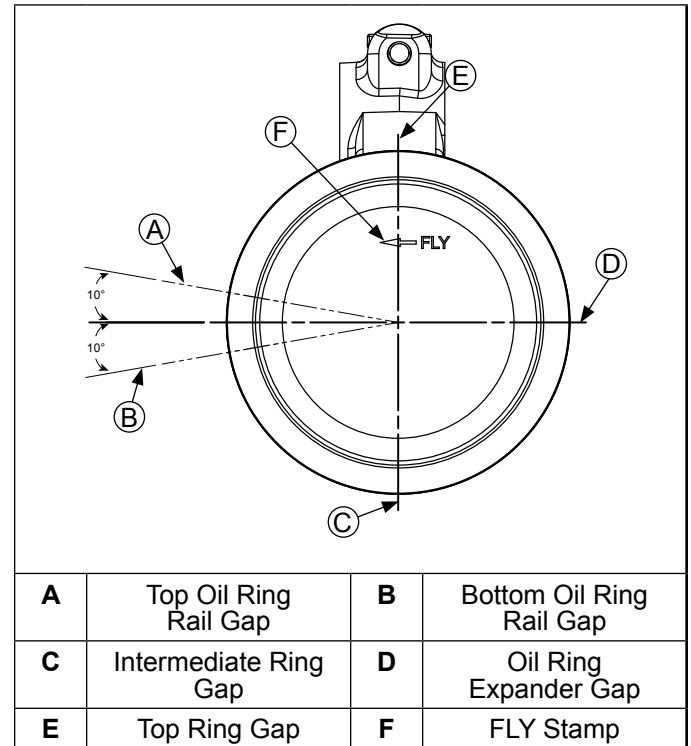
Replacement ring sets are also available separately for STD, 0.25 mm (0.010 in.), and 0.50 mm (0.020 in.) oversize pistons. Always use new piston rings when installing pistons. Never reuse old rings.

Some important points to remember when servicing piston rings:

1. Cylinder bore must be deglazed before service ring sets are used.
2. If cylinder bore does not need reboring and if old piston is within wear limits and free of score or scuff marks, old piston may be reused.
3. Remove old rings and clean up grooves. Never reuse old rings.
4. Before installing new rings on piston, place top 2 rings, each in turn, in its running area in cylinder bore and check end gap. Top and center compression ring end gap clearance is 0.30/0.55 mm (0.011/0.021 in.) with maximum wear limit of 0.94 mm (0.037 in.).
5. After installing new compression (top and middle) rings on piston, make sure ring-to-groove side clearance is 0.04/0.08 mm (0.0015/0.0031 in.). If side clearance is greater than specified, a new piston must be used.

Install New Piston Rings

Piston Ring Orientation



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. Install bottom (oil control) ring first and top compression ring last.

To install new piston rings, proceed as follows:

1. Oil control ring (bottom groove): Install expander and then rails. Make sure ends of expander are not overlapped.
2. Middle compression ring (center groove): Install center ring using a piston ring installation tool. Make sure identification mark is up or colored dye stripe (if contained), is to left of end gap.
3. Top compression ring (top groove): Install top ring using a piston ring expander. Make sure identification mark is up or colored dye stripe (if contained), is to left of end gap.

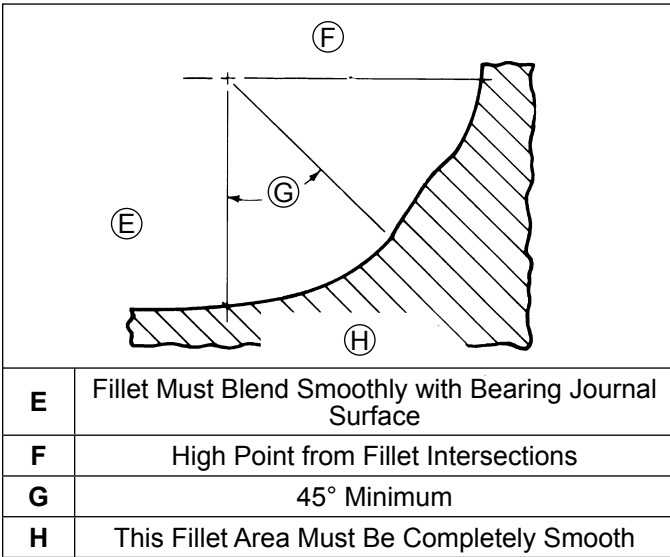
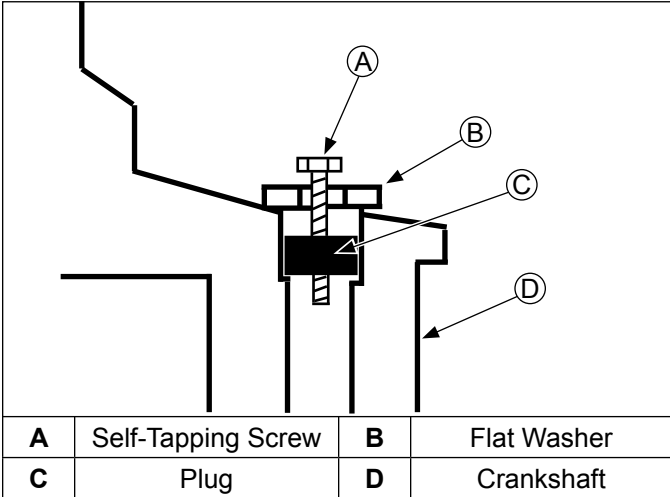
Disassembly/Inspection and Service

Remove Crankshaft

NOTE: If crankpin is reground, visually check to ensure that fillet blends smoothly with crankpin surface.

Carefully pull crankshaft from crankcase. Note thrust washers and shims if used.

Inspection and Service
Crankshaft Components and Details



Inspect gear teeth of crankshaft. If teeth are badly worn, chipped, or some are missing, replacement of crankshaft will be necessary.

Inspect crankshaft bearing surfaces for scoring, grooving, etc. A replaceable bearing is used in crankshaft bore of oil pan. Do not replace bearing unless it shows signs of damage, or is out of running clearance 0.040/0.167 mm (0.0015/0.0065 in.). If crankshaft turns easily, without noise, and there is no evidence of scoring, grooving, etc., on races or bearing surfaces, bearing can be reused.

Inspect crankshaft keyways. If they are worn or chipped, replacement of crankshaft will be necessary.

Inspect 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 Clearance Specifications, are exceeded, it will be necessary to replace crankshaft or regrind 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 crankpin for size, taper, and out-of-round.

Clearance Specifications-Connecting Rod Journal

O.D. - New	43.982/44.000 mm (1.731/1.732 in.)
O.D. - Max. Wear Limit	43.97 mm (1.731 in.)
Max. Taper	0.018 mm (0.0007 in.)
Max. Out-of-Round	0.025 mm (0.0010 in.)
Width	53.00/53.09 mm (2.0866/2.0901 in.)

Connecting rod journal can be ground 1 size under. When grinding a crankshaft, grinding stone deposits can get caught in oil passages, which could cause severe engine damage. Removing crankpin plug when crankshaft is ground provides easy access for removing any grinding deposits that may collect in oil passages.

Use following procedure to remove and replace plug.

Remove Crankshaft Plug

1. Drill a 3/16 in. hole through plug in crankshaft.
2. Thread a 3/4 in. or 1 in. long self-tapping screw with a flat washer into drilled hole. Flat washer must be large enough to seat against shoulder of plug bore.
3. Tighten self-tapping screw until it draws plug out of crankshaft.

Install New Crankshaft Plug

Use 1 single cylinder camshaft pin, as a driver and tap plug into plug bore until it seats at bottom of bore. Make sure plug is tapped in evenly to prevent leakage.

Remove Governor Gear Assembly (Mechanical Governor Only)

Governor gear is held onto shaft by small molded tabs in gear. When gear is removed from shaft, these tabs are destroyed and gear must be replaced. Therefore, remove gear only if absolutely necessary. If governor cross shaft, yoke, or gear condition does not require removal, governor gear may be left in place. If removal is necessary, perform as follows:

1. Remove locking tab thrust washer and note orientation.
2. Using a screwdriver, carefully pry upward to unseat governor gear assembly from governor gear shaft. Remove regulating pin and governor gear assembly.
3. Inspect governor gear shaft for wear or damage. Remove shaft only if replacement is needed.

Inspection

Governor gear is located within crankcase. Inspect governor gear teeth. Replace gear if it is worn, chipped, or if any teeth are missing. Inspect governor weights. They should move freely in governor gear.

Remove Governor Yoke, Cross Shaft, and Seal (Mechanical Governor Only)

1. Remove mounting screws securing yoke to governor cross shaft.
2. Pull governor cross shaft out of crankcase and remove seal.

Remove Lifter Feed Chamber Cover and Gaskets

Remove screws securing lifter feed chamber cover and gaskets. Carefully separate parts from crankcase.

Remove Flywheel End Oil Seal

Remove oil seal from crankcase using a seal puller.

Crankcase

Inspection and Service

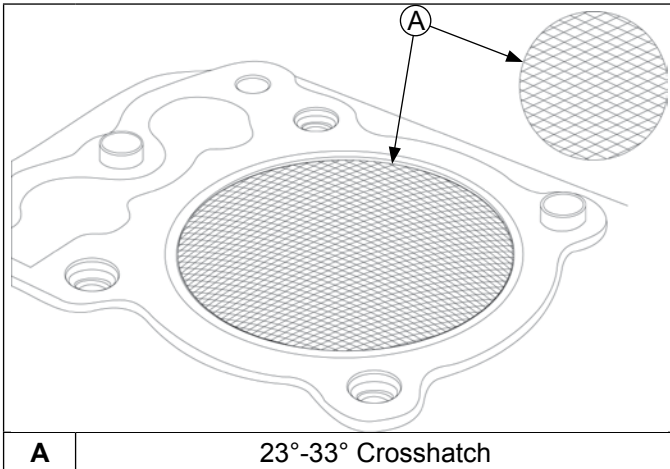
Check all gasket surfaces to make sure they are free of gasket fragments. Gasket surfaces must also be free of deep scratches or nicks.

Check cylinder bore for scoring. In severe cases, unburned fuel can cause scuffing and scoring of cylinder wall. It washes necessary lubricating oils off piston and cylinder wall. As raw fuel seeps down cylinder wall, piston rings make metal to metal contact with wall. Scoring of cylinder wall can also be caused by localized hot spots resulting from blocked cooling fins or from inadequate or contaminated lubrication.

If cylinder bore is badly scored, excessively worn, tapered, or out-of-round, resizing is necessary. Use an inside micrometer to determine amount of wear, then select nearest suitable oversize of either 0.25 mm (0.010 in.) or 0.50 mm (0.020 in.). Resizing to these oversizes will allow usage of available oversize piston and ring assemblies. Initially, resize using a boring bar, then use following procedures for honing cylinder.

Disassembly/Inspection and Service

Honing Detail



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 new diameter. corresponding oversize Kohler replacement piston will then fit correctly.

While most commercially available cylinder hones can be used with either portable drills or drill presses, use of a low speed drill press is preferred as it facilitates more accurate alignment of bore in relation to 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 stones are in contact with cylinder wall. Use of a commercial cutting-cooling agent is recommended.
2. With lower edge of each stone positioned even with lowest edge of bore, start drill and honing process. Move hone up and down while resizing to prevent formation of cutting ridges. Check size frequently.
3. When bore is within 0.064 mm (0.0025 in.) of desired size, remove coarse stones and replace them with burnishing stones. Continue with burnishing stones until bore is within 0.013 mm (0.0005 in.) of desired size and then use finish stones (220-280 grit) and polish bore to its final size. A crosshatch should be observed if honing is done correctly. Crosshatch should intersect at approximately 23°-33° off horizontal. Too flat an angle could cause rings to skip and wear excessively, and too steep an angle will result in high oil consumption.
4. After resizing, check bore for roundness, taper, and size. Use an inside micrometer, telescoping gauge, or bore gauge to take measurements. These measurements should be taken at 3 locations in cylinder – at top, middle, and bottom. There are 2 measurements that should be taken (perpendicular to each other) at all 3 locations.

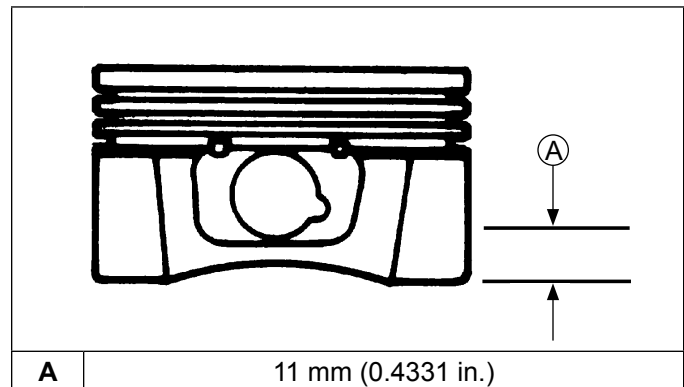
Clean Cylinder Bore After Honing

Proper cleaning of cylinder walls following boring and/or honing is very critical to a successful overhaul. Machining grit left in cylinder bore can destroy an engine in less than 1 hour of operation after a rebuild.

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 machining oil while maintaining a good level of suds. If suds break down during cleaning, discard dirty water and start again with more hot water and detergent. Following scrubbing, rinse 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

Piston Detail



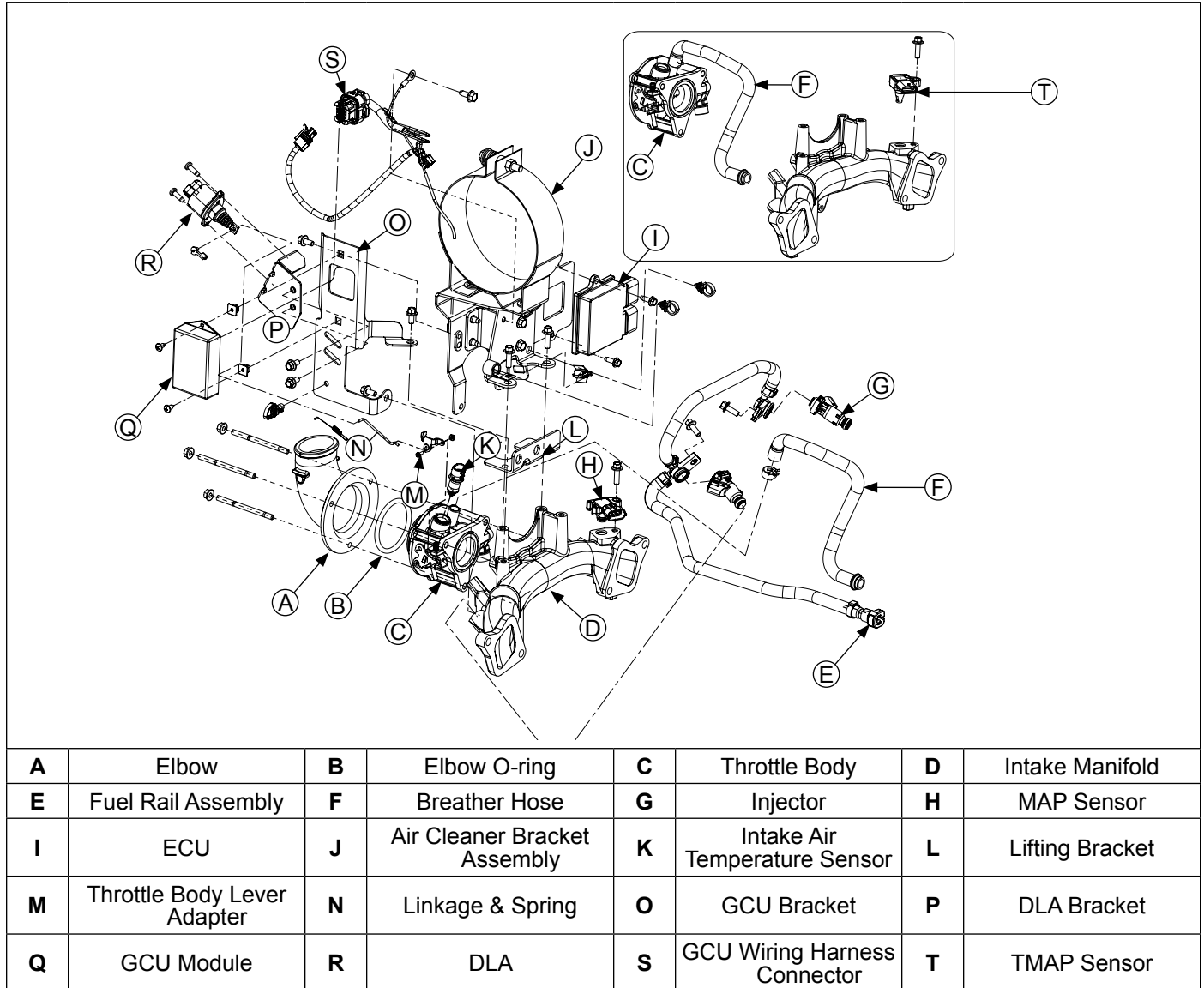
NOTE: Do not use a feeler gauge to measure piston-to-bore clearance; it will yield inaccurate measurements. Always use a micrometer.

Before installing piston into cylinder bore, it is necessary that clearance be accurately checked. This step is often overlooked, and if piston thrust face-to-cylinder bore running clearance is not within 0.033/0.071 mm (0.0013/0.0028 in.), engine failure will usually result.

Use following procedure to accurately measure piston-to-bore clearance:

1. Use a micrometer and measure diameter of piston 11 mm (0.4331 in.) above bottom of piston skirt and perpendicular to piston pin.
2. Use an inside micrometer, telescoping gauge, or bore gauge and measure cylinder bore. Take measurement approximately 63.5 mm (2.5 in.) below top of bore and perpendicular to piston pin.
3. Piston-to-bore clearance is difference between bore diameter and piston diameter (step 2 minus step 1).

Electronic Governor Intake and Throttle Body Assembly Components



Remove Throttle Body (Electronic Governor)

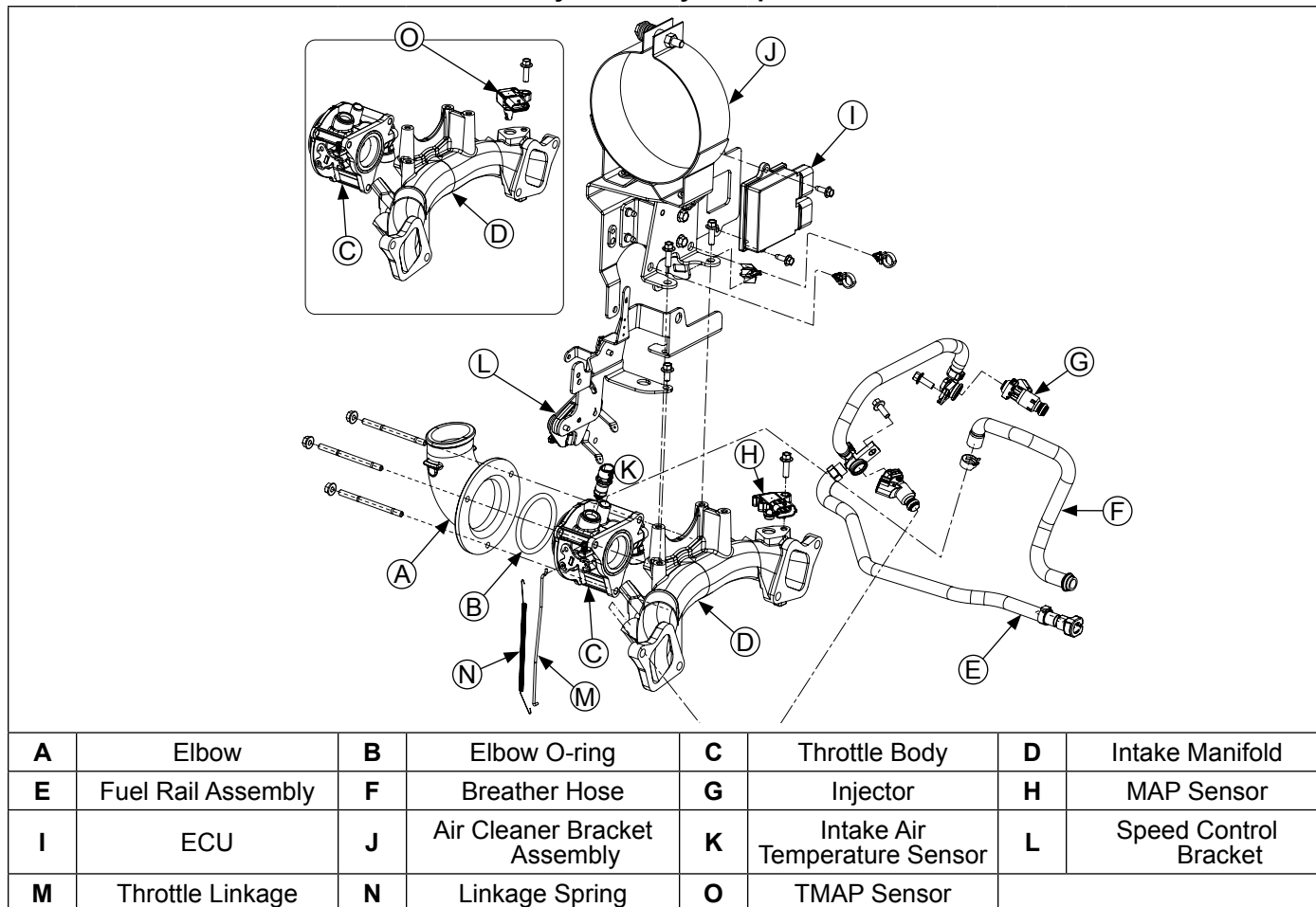
1. Disconnect TPS wire.
2. Loosen 2 screws securing lifting bracket and air cleaner bracket to intake manifold.
3. Remove nuts securing elbow and throttle body.
4. Remove 3 screws securing GCU bracket.
5. Disconnect link clip from outboard end of DLA; remove spring and linkage.
6. Carefully lift and move air cleaner brackets/ECU/GCU up on front section of engine. Secure temporarily to access and replace throttle body.
7. On earlier engines with separate intake air temperature (IAT) and MAP sensors, disconnect IAT sensor from throttle body.
8. Disconnect breather tube from throttle body.
9. Disconnect throttle position sensor connector.
10. Disconnect vent hose from bottom of throttle body.
11. Slide throttle body off studs.
12. Reverse procedure to reassemble, torque fasteners to proper specifications. Air cleaner bracket screws to 11.3 N·m (100 in. lb.); Air cleaner elbow to throttle body nuts to 7.9 N·m (70 in. lb.).

Remove GCU (Electronic Governor)

1. Remove screws securing GCU to GCU bracket.
2. Unplug wiring harness connector from GCU.
3. Reverse procedure to install. Torque screws to 2.1 N·m (19 in. lb.).

Disassembly/Inspection and Service

Mechanical Governor Intake and Throttle Body Assembly Components



Remove Throttle Body (Mechanical Governor)

1. Disconnect TPS wire.
2. Loosen 2 screws securing air cleaner bracket and speed control bracket to intake manifold.
3. Remove nuts securing elbow and throttle body.
4. Unhook idle and governor springs from control bracket and governor lever. Note location and position of each.
5. Disconnect throttle linkage and linkage spring from governor lever. Note location and position of each.
6. Carefully lift and move air cleaner brackets/ECU up on front section of engine. Secure temporarily to access and replace throttle body.
7. On earlier engines with separate intake air temperature (IAT) and MAP sensors, disconnect IAT sensor from throttle body.
8. Disconnect breather tube from throttle body.
9. Disconnect throttle position sensor connector.
10. Disconnect vent hose from bottom of throttle body.
11. Slide throttle body off studs.
12. Reverse procedure to reassemble, torque fasteners to proper specifications. Air cleaner bracket screws to 11.3 N·m (100 in. lb.); Air cleaner elbow to throttle body nuts to 7.9 N·m (70 in. lb.).

Remove ECU

1. Remove screws securing ECU to bracket.
2. Disconnect black and grey electrical connectors from ECU.
3. Reverse procedure to install. Torque screws to 6.2 N·m (55 in. lb.).


Remove Fuel Injectors

1. Disconnect electrical connector.
2. Remove screw for each injector and pull injector out of intake manifold.
3. When removed, pull metal retaining clip connecting fuel injector to fuel injector cap. There may be some fuel left in line. Any spilled fuel must be cleaned up immediately.
4. Reverse procedure to install. Torque fuel injector cap screws to 7.3 N·m (65 in. lb.).

Remove Manifold Absolute Pressure (MAP) Sensor or Temperature/Manifold Absolute Pressure (TMAP) Sensor

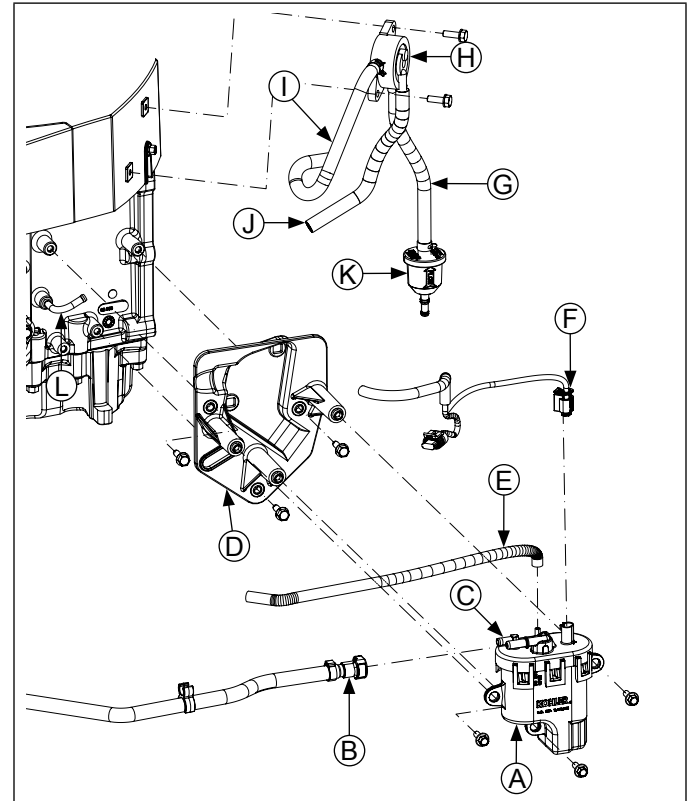
1. With a screwdriver, slide locking tab on electrical connector.
2. Carefully slide lock tab outward. Press down on lock tab to release, then separate connectors.
3. Remove screw and pull MAP or TMAP sensor out of intake manifold.
4. Reverse procedure to install. Torque screw to 7.3 N·m (65 in. lb.).

Remove Fuel Pump Module/Fuel Pump Assembly

	<p>⚠ WARNING</p>
	<p>Explosive Fuel can cause fires and severe burns.</p> <p>Do not fill fuel tank while engine is hot or running.</p>
<p>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. Spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Never use gasoline as a cleaning agent.</p>	

Fuel Pump Module/Fuel Pump was removed as an assembly. An exploded view of that assembly with steps to disassemble it follow.

Fuel Pump Module/Pump Assembly Components

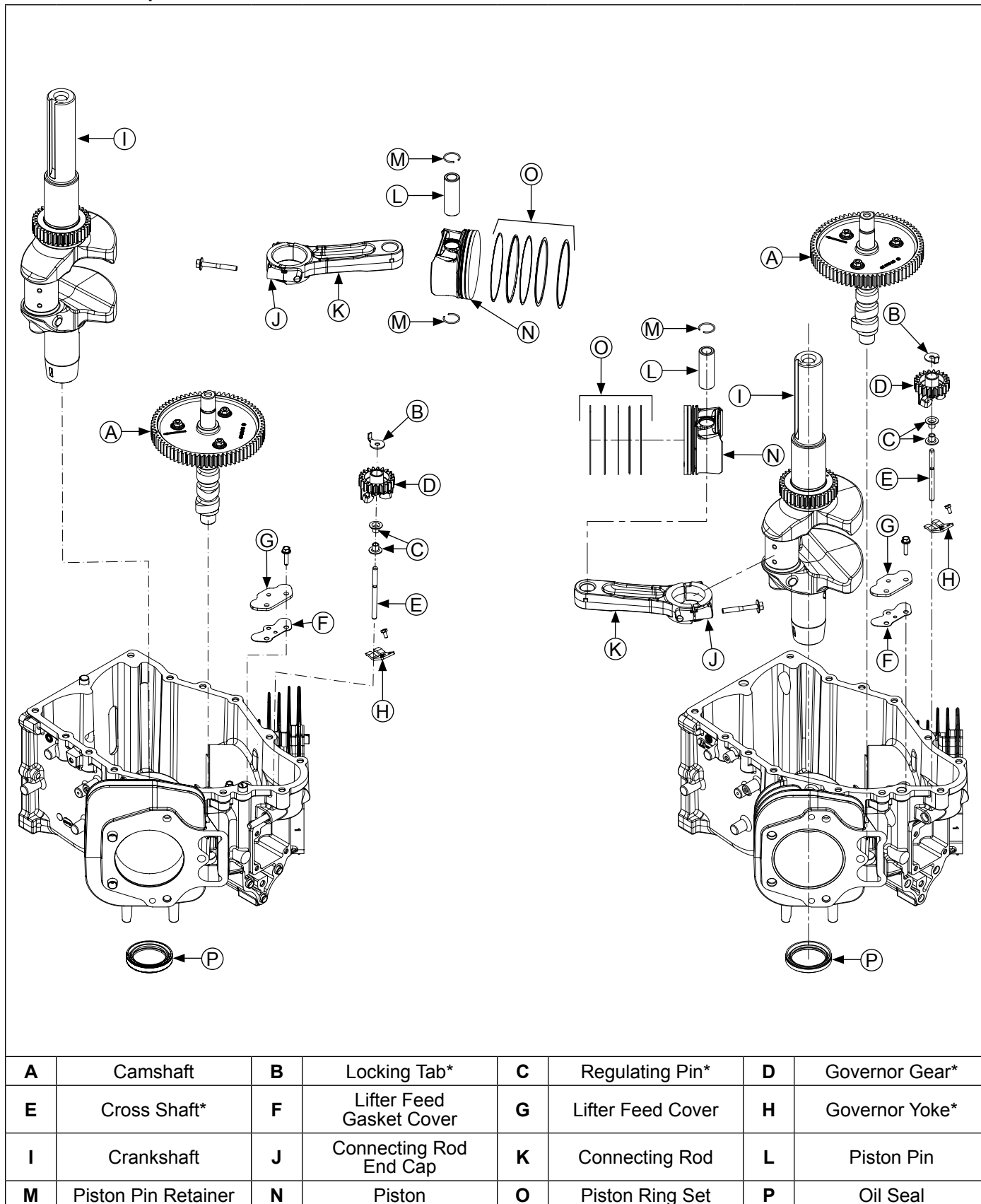


A	Fuel Pump Module	B	High Pressure Fuel Line Connector
C	Inlet Port	D	Fuel Pump Module Baffle
E	Evap Line	F	Electrical Connector
G	Inlet Line	H	Fuel Pump
I	Outlet Line	J	Pulse Line
K	Fuel Filter	L	Crankcase Fitting

1. Remove screws securing fuel pump module to baffle.
2. Using a side cutter or similar tool, cut Oetiker clamp to remove fuel line from fuel pump module inlet port.
3. Disconnect inlet, outlet, and pulse (vacuum) lines at fuel pump.

Reassembly

Crankcase Components



* Mechanical Governor only.

NOTE: Make sure engine is assembled using all specified torque values, torque 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 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 engine is assembled and placed into operation. Even small amounts of these cleaners can quickly break down lubricating properties of engine oil.

Check oil pan, crankcase, cylinder heads, and valve covers to be certain all old gasket material has been removed. Use gasket remover, lacquer thinner, or paint remover to remove any remaining traces. Clean surfaces with isopropyl alcohol, acetone, lacquer thinner, or electrical contact cleaner.

Install Flywheel End Oil Seal

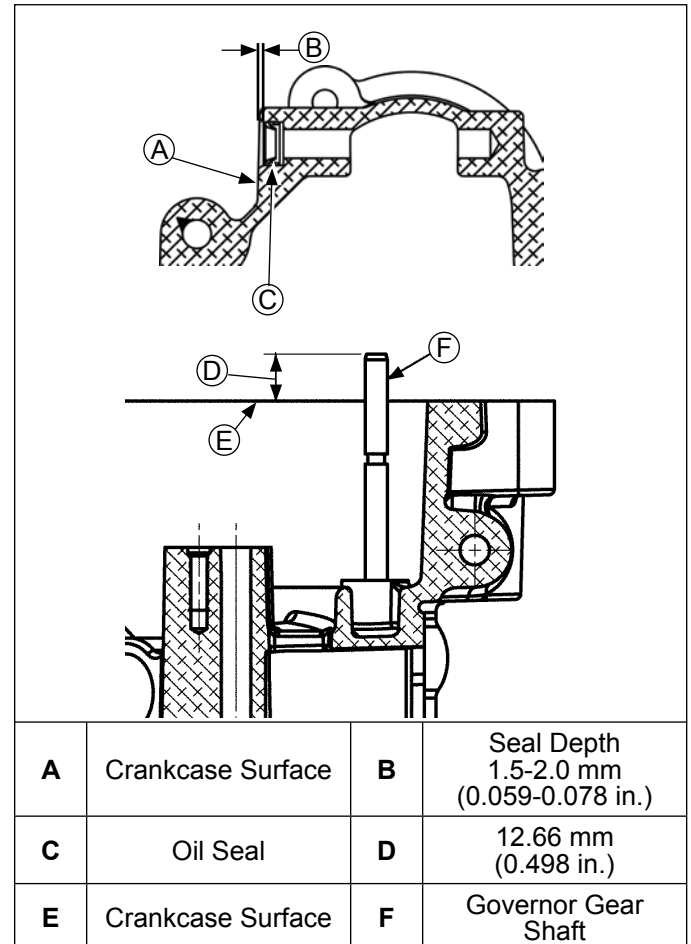
1. Make sure seal bore of crankcase is clean and free of any nicks or burrs.
2. Apply a light coat of clean engine oil to outside diameter of oil seal.
3. Install oil seal into crankcase using a seal driver. Make sure oil seal is installed straight and true in bore and tool bottoms against crankcase.

Install Lifter Feed Chamber Gasket and Cover

1. Install lifter feed chamber gasket, followed by lifter feed cover over lifter feed chamber.
2. Install screws. Make sure all parts are properly aligned. Torque screws to 6.6 N·m (58 in. lb.).

Install Governor Shafts, Seal, and Governor Gear (Mechanical Governor only)

Governor Components and Details



If governor shafts, seal, and/or governor gear were removed, reassemble as follows.

1. Lightly oil lip and outside diameter of new governor cross shaft seal. Install seal into crankcase to depth shown.
2. If governor gear shaft was removed, press or lightly tap replacement shaft into oil pan to depth shown.
3. Lubricate governor cross shaft bearing surfaces in crankcase with engine oil. Insert governor cross shaft end with flat cutout where governor yoke is secured, into crankcase and position shaft so that flat part is visible (up).
4. Attach governor yoke to cross shaft so curved section is up as marked. Secure with screws. If a thread locking compound is not preapplied, apply a small amount of Loctite® 266™ Threadlocker or equivalent, to screw threads before installing. Torque screws to 2.2 N·m (20 in. lb.).
5. Install first regulating pin with head down so it will contact yoke. Install governor gear with second regulating pin and flyweight assembly in/down onto governor shaft until it locks into position. Apply a small amount of grease to locking tab thrust washer and install on top of governor gear so tang is facing up in 6 o'clock position.

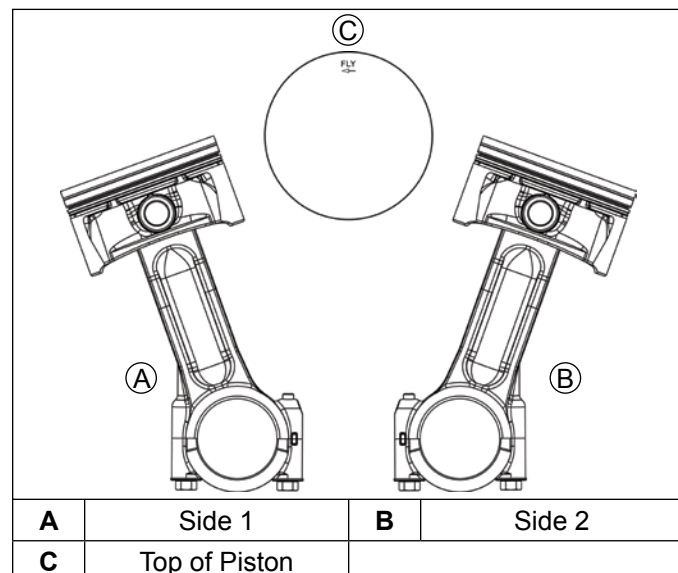
Reassembly

Install Crankshaft

Carefully slide flywheel end of crankshaft through oil seal in crankcase.

Install Connecting Rods with Pistons and Rings

Piston Details



NOTE: Cylinders are numbered on crankcase. Make sure to install piston, connecting rod and end cap into appropriate cylinder bore as previously marked at disassembly. Do not mix end caps and connecting rods.

NOTE: Proper orientation of piston/connecting rod assemblies inside engine is extremely important. Improper orientation can cause extensive wear or damage. Be certain pistons and connecting rods are assembled exactly as shown.

1. If piston rings were removed, refer to Disassembly/Inspection and Service procedure to install new rings.
2. Lubricate cylinder bore, piston, and piston rings with engine oil. Compress rings of piston side 1 using a piston ring compressor.
3. Lubricate crankshaft journals and connecting rod bearing surfaces with engine oil.
4. Make sure FLY stamping on piston is facing toward flywheel side of engine. Use a hammer with a rubber grip and gently tap piston into cylinder. Be careful oil ring rails do not spring free between bottom of ring compressor and top of cylinder.
5. Install inner rod cap to connecting rod using screws. Torque screws in increments to 11.6 N·m (103 in. lb.). Illustrated instructions are provided in service rod package.
Align chamfer of connecting rod with chamfer of its mating end cap. When installed, flat faces of connecting rods should face each other. Faces with raised rib should be toward outside.
6. Repeat this procedure for other connecting rod and piston assembly.

Install Camshaft

1. Liberally apply camshaft lubricant to each cam lobe. Lubricate camshaft bearing surfaces of crankcase and camshaft with engine oil.
2. Position timing mark of crankshaft gear at 12 o'clock position.
3. Slide camshaft into bearing surface of crankcase, positioning timing mark of camshaft gear at 6 o'clock position. Make sure camshaft gear and crankshaft gear mesh, with both timing marks aligned.

Determining Camshaft End Play

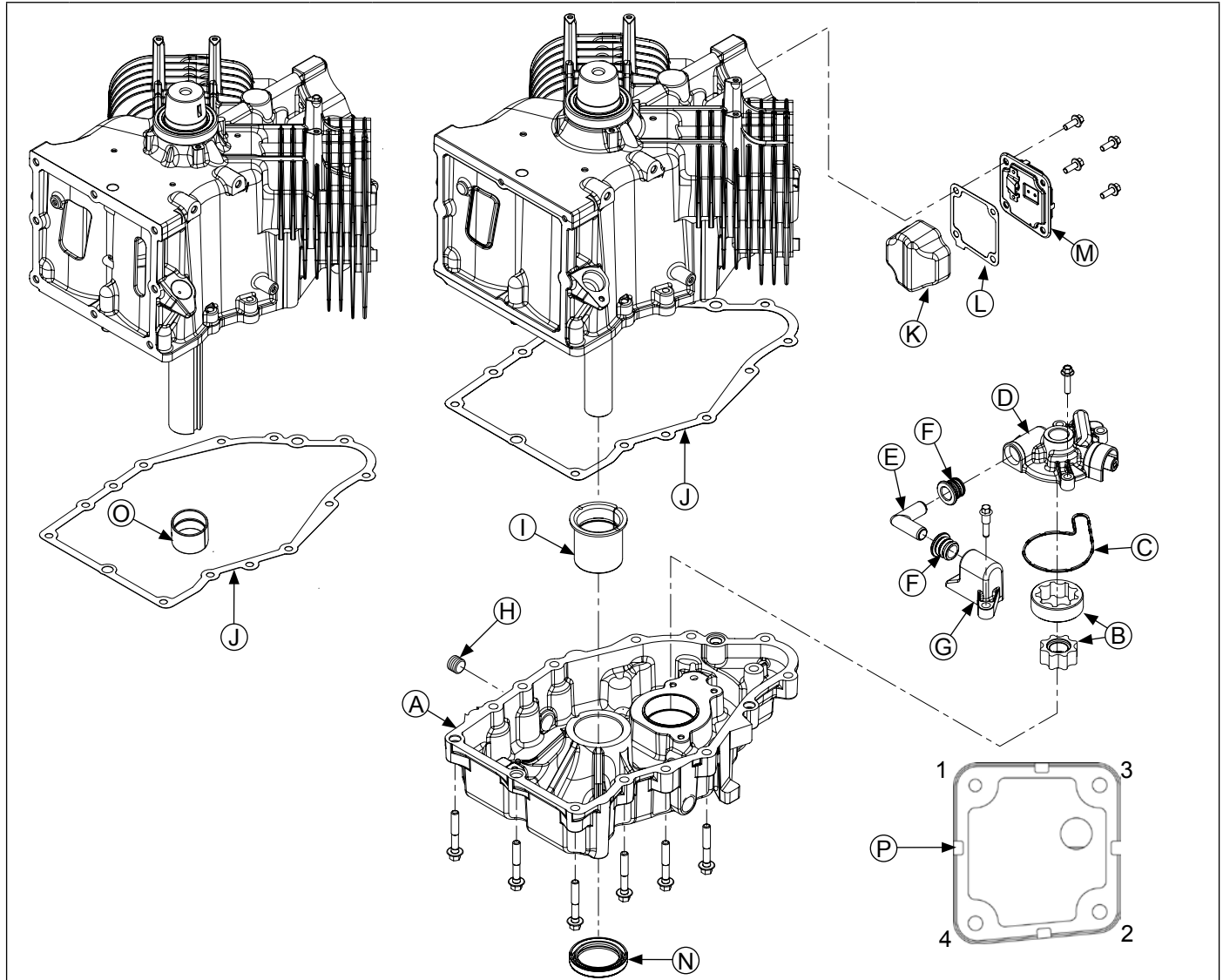
1. Place a new oil pan gasket into position on crankcase.
2. Position camshaft end play checking tool over camshaft. Use a feeler gauge to check end play between camshaft and end play checking tool. Camshaft endplay should be between 0.3/1.3 mm (0.011/0.051 in.).
3. No shim is typically used from factory. However, if camshaft end play is not within specified range, remove checking tool and shim as necessary.

Several color coded shims are available:

- White: 0.69215/0.73025 mm (0.02725/0.02875 in.)
Blue: 0.74295/0.78105 mm (0.02925/0.03075 in.)
Red: 0.79375/0.83185 mm (0.03125/0.03275 in.)
Yellow: 0.84455/0.88265 mm (0.03325/0.03475 in.)
Green: 0.89535/0.99345 mm (0.03525/0.03675 in.)
Gray: 0.94615/0.98425 mm (0.03725/0.03875 in.)
Black: 0.99695/1.03505 mm (0.03925/0.04075 in.)

4. Reinstall end play checking tool and recheck end play.

Breather/Oil Pan Components



A	Oil Pan	B	Gerotor Gears	C	Oil Pump O-Ring	D	Oil Pump Housing
E	Pickup Tube	F	Inlet Seal	G	Pickup Screen	H	Drain Plug
I	Crankshaft Thrust Bearing (Flange PTO)	J	Oil Pan Gasket	K	Breather Filter	L	Breather Gasket
M	Breather Assembly	N	Oil Seal	O	Crankshaft Non-Thrust Bearing (PTO)	P	Breather Fastener Torque Sequence

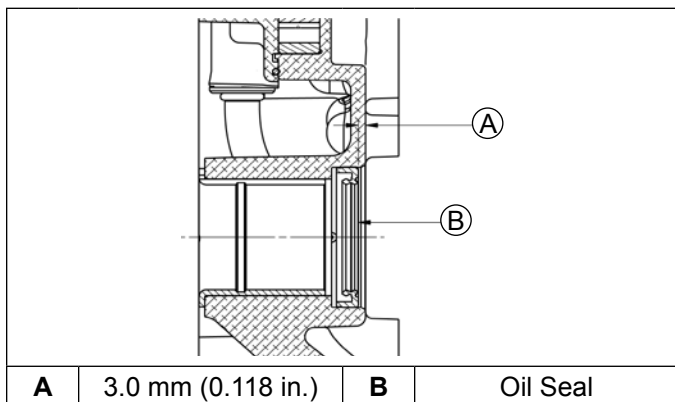
Install Oil Pan Seal and Crankshaft Bearing (PTO)

If bearing was removed in servicing, install a new bearing using an arbor press and driver.

1. Make sure oil pan bore for bearing is clean, dry and free of nicks or burrs.
2. Press crankshaft bearing (PTO) in place with notch oriented in 12 o'clock position using an arbor press and driver. Make sure bearing is fully seated against flange.
3. Apply a light coat of clean engine oil to inner surface of bearing.

Reassembly

PTO Oil Seal Details



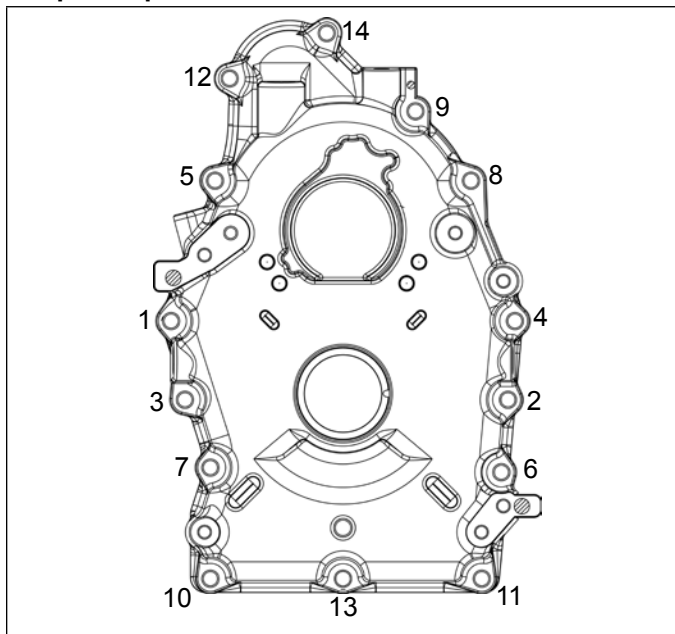
1. Check to make sure there are no nicks or burrs in crankshaft seal bore of oil pan.
2. Lightly oil outside diameter of oil seal.
3. Install oil seal into oil pan using a seal driver. Make sure oil seal is installed straight and true in bore to depth shown.

Oil Pump Assembly

Oil pump is mounted inside oil pan. If service was required and oil pump was removed, refer to Disassembly/Inspection and Service procedure.

Install Oil Pan Assembly

Torque Sequence



1. Make sure sealing surfaces of oil pan and crankcase are clean, dry, and free of any nicks or burrs. Install a new O-ring in oil pan.
2. Install a new oil pan gasket onto crankcase.
3. Make sure oil pump and oil pick up are installed in oil pan.
4. Ensure end of locking tab washer on governor gear is positioned outward in 6 o'clock position inside crankcase.
5. Orient flat of oil pump gear to match position of flat on camshaft. Install oil pan to crankcase. Carefully seat camshaft and crankshaft into their mating bearings. Rotate crankshaft slightly to help oil pump and governor gears mesh.
6. Lightly oil threads and install screws securing oil pan to crankcase. Torque fasteners in sequence shown to 25.6 N·m (227 in. lb.).

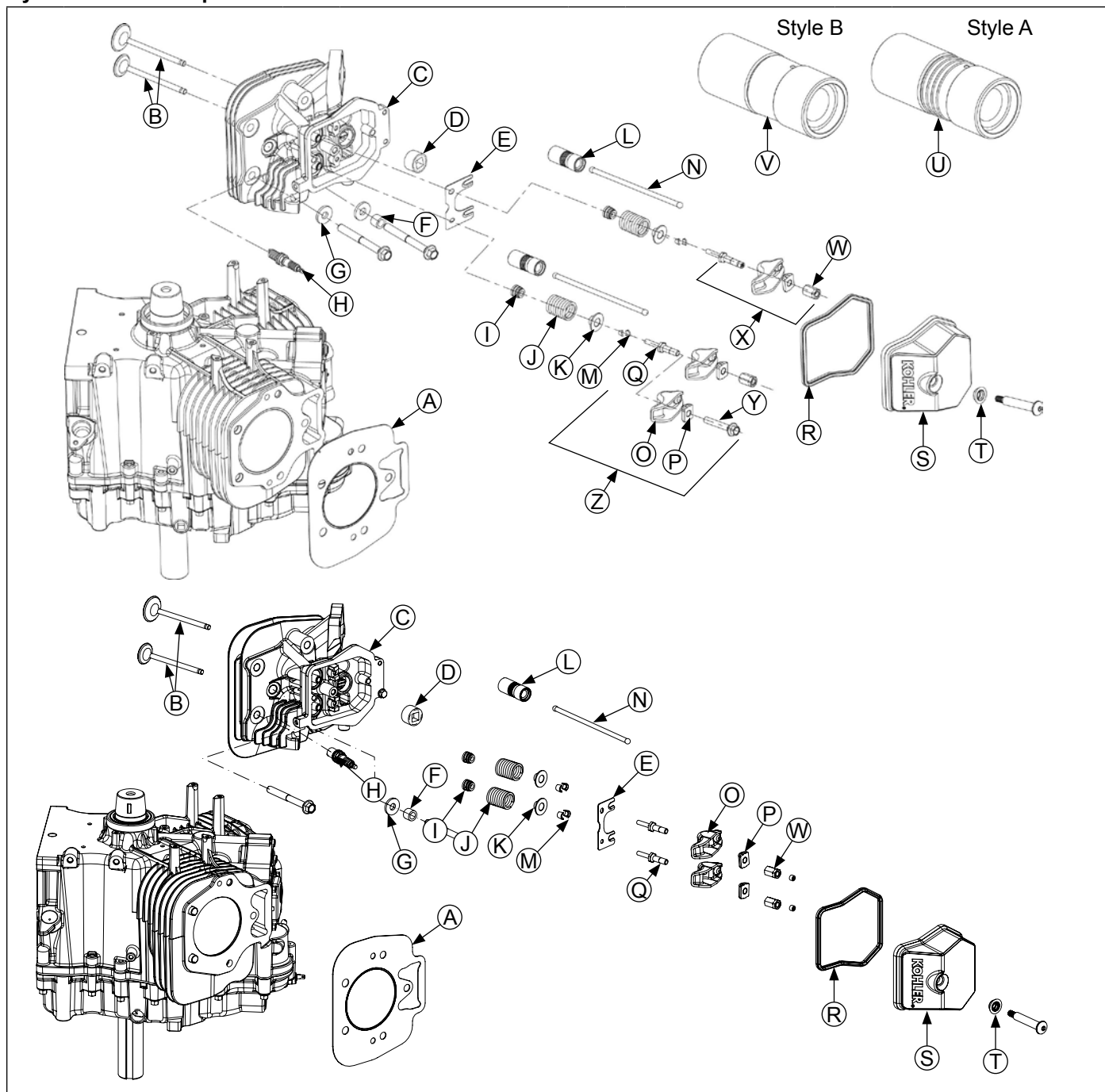
Check Crankshaft End Play

Set engine on base and use a dial indicator to check crankshaft end play to 0.30/1.50 mm (0.011/0.059 in.) for flange thrust bearing. Set engine crankshaft end play to 0.20/0.94 mm (0.008/0.037 in.) for non-thrust bearing.

Install Breather Assembly

1. Make sure sealing surfaces of crankcase and breather cover are clean and free of any nicks or burrs. Do not scrape surfaces, as this could result in leakage.
2. Install breather chamber gasket as shown. Assemble and install breather assembly components as illustrated. Make sure filter does not extend above top surface and all parts are properly aligned.
3. Install screws and torque to 12.4 N·m (110 in. lb.) following sequence.
4. Breather hose will be connected to cover in a later step.

Cylinder Head Components



A	Gasket	B	Valve	C	Cylinder Head	D	Pipe Plug
E	Guide Plate	F	Spacer	G	Washer	H	Spark Plug
I	Valve Stem Seal	J	Valve Spring	K	Valve Spring Retainer	L	Hydraulic Lifter
M	Valve Spring Keeper	N	Push Rod	O	Rocker Arm	P	Rocker Arm Pivots
Q	Rocker Stud	R	Valve Cover Seal	S	Valve Cover	T	Grommet
U	Hydraulic Lifter Style A (Ribbed)	V	Hydraulic Lifter Style B (Smooth)	W	Adjusting Nut	X	Adjustable Valve Train (AVT)
Y	Rocker Arm Screw	Z	Non-adjustable Valve Train (Non-AVT)				

Reassembly

Install Hydraulic Lifters

NOTE: Hydraulic lifters should always be installed in same position as they were disassembled. Exhaust lifters are located on output shaft side of engine while intake lifters are located on fan side of engine. Cylinder numbers are embossed on top of crankcase and each cylinder head.

1. Refer to Disassembly/Inspection and Service for lifter preparation (bleed down) procedures.
2. Apply camshaft lubricant to bottom surface of each lifter. Lubricate hydraulic lifters and lifter bores in crankcase with engine oil. Do not prime lifters.
3. Note mark or tag identifying hydraulic lifters as either intake or exhaust and cylinder 1 or cylinder 2. Install hydraulic lifters into their appropriate location in crankcase. Do not use a magnet.

Valve Stem Seals

These engines use valve stem seals on intake and exhaust valves. Always use new seals whenever valves are removed from cylinder head. Seals should also be replaced if worn or damaged. Never reuse an old seal.

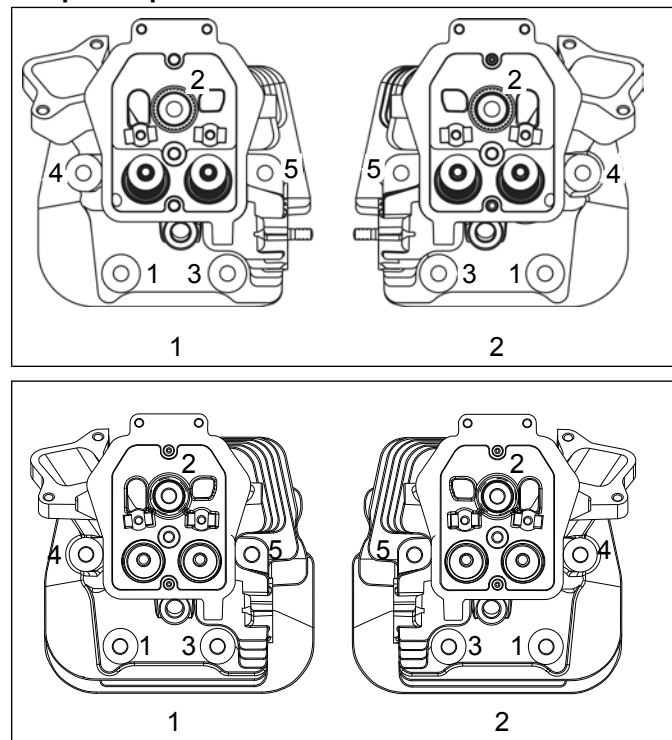
Assemble Cylinder Heads

Prior to installation, lubricate all components with engine oil, paying particular attention to lip of valve stem seal, valve stems, and valve guides. Install in order listed below using a valve spring compressor.

- Intake and exhaust valves
- Valve spring retainers.
- Valve springs.
- Valve spring keepers.
- Valve stem seals.
- Guide plate (AVT only).
- Pivot studs (AVT only).

Install Cylinder Heads

Torque Sequence



NOTE: Match numbers embossed on cylinder heads and crankcase.

1. Check to make sure there are no nicks or burrs on sealing surfaces of cylinder head or crankcase.
2. Check dowel pins are in place in 2 lower locations, and install a new cylinder head gasket, (printed side up).
3. Install cylinder head. Make sure head is flat on gasket and dowel pins. Install a flat washer on screws in locations 1 and 3. Install spacer followed by a flat washer on screw in location 5. Start 5 screws.
4. Torque screws in 2 stages, first to 23.7 N·m (210 in. lb.), finally to 46.9 N·m (415 in. lb.) following sequence shown.
5. Repeat procedure for opposite cylinder.
6. Make sure threads of pipe plugs for cylinder heads are clean and dry. Install a plug into each cylinder head above screw on location 2 and torque to 28.5 N·m (252 in. lb.).

Install Guide Plate, Pivot Studs, Push Rods and Rocker Arms

NOTE: Install push rod guide plate so flange is down (towards cylinder) on side 1, and up (away from cylinder) on side 2 (AVT only).

NOTE: Push rods should always be installed in same position as before in disassembly.

Non-adjustable Valve Train

1. Position rocker arm pivots in sockets of rocker arms. Insert screws through pivots, rocker arms, and guide plate. Start screws into cylinder head and finger tighten only at this time.
2. Note mark or tag identifying push rod as either intake or exhaust and cylinder 1 or 2. Dip ends of push rods in engine oil and install, making sure each push rod ball seats in its hydraulic lifter socket. Align rocker arms over valve stems. Hold rocker arm in position and torque screws to 15.5 N·m (137 in. lb.).

Adjustable Valve Train

1. Install push rod guide plate and rocker arm pivot studs onto cylinder heads if removed previously. Torque studs to 11.3 N·m (100 in. lb.).
2. Note mark or tag identifying push rod as either intake or exhaust and cylinder 1 or 2. Dip ends of push rods in engine oil and install, making sure each push rod ball seats in its hydraulic lifter socket.
3. Apply grease to contact surfaces of rocker arms and rocker arm pivots. Install rocker arms, rocker arm pivots, and adjusters on cylinder head 1.

Adjust Valve Clearance (AVT Only)

NOTE: It takes two hands to make lash adjustment. A clamping device or an assistant to hold lifter compressed while making adjustment will make process easier.

1. Turn adjusters in rocker arms by hand clockwise (down), only enough to capture push rods in recesses.
2. Rotate crankshaft to establish TDC on compression stroke for cylinder 1.

Check for:

- a. Compression will be felt through spark plug hole.
 - b. Keyway of crankshaft will be aligned with cylinder 1.
 - c. No rocker arm/push rod movement if crankshaft is rotated slightly back and forth. If they are moving, rotate crankshaft one full revolution.
3. Pre-Bled Lifters:
 - a. Apply downward pressure to push rod side of rocker arm to compress lifter and bottom internal plunger. Several manual compressions may be necessary. Hold in this position for step 3b.

- b. Insert a 0.406/0.483 mm (0.016/0.019 in.) feeler gauge between end of one valve and rocker arm. Turn adjuster until a slight drag is felt. Hold adjuster in this position and tighten locking setscrew. Torque setscrew to 7.7 N·m (69 in. lb.). After tightening recheck adjustment. Proper valve clearance is 0.406/0.483 mm (0.016/0.019 in.).

- c. Repeat procedure for other valve on this side.

Non-Bled Lifters (when cylinder heads and lifters are not removed):

- a. Turn 1 rocker arm adjusting nut from side 1 down until push rod is snug but can be rotated with drag. This is 0 lash.
 - b. Mark or note setting of adjustment nut, then turn (tighten) adjuster nut 3 complete revolutions clockwise, plus 3/4 turn, or a total of 3-3/4 turns.
 - c. Hold adjuster nut in this position and tighten locking setscrew. Torque setscrew to 7.7 N·m (69 in. lb.).
 - d. Repeat procedure for other valve on this side.
4. Viewed from PTO end, rotate crankshaft 270° (3/4 turn) counterclockwise and align crankshaft keyway with cylinder 2, which now puts that cylinder at TDC on compression stroke.
 5. Repeat steps 3-5 for setting valve clearance on cylinder 2.
 6. Rotate crankshaft to check for free operation of valve train. Check for clearance between valve spring coils at full lift, or bending of push rod(s) can occur. Minimum allowable clearance is 0.25 mm (0.010 in.).

Check Assembly

Rotate crankshaft a minimum of two revolutions to check assembly and overall proper operation.

Check if engine can be turned over completely and compression is noted. If it cannot (locks up at some point), return piston to TDC between intake and exhaust strokes first for one cylinder and then other waiting ten minutes to allow lifters to bleed down, then check for compression again.

Install Valve Covers

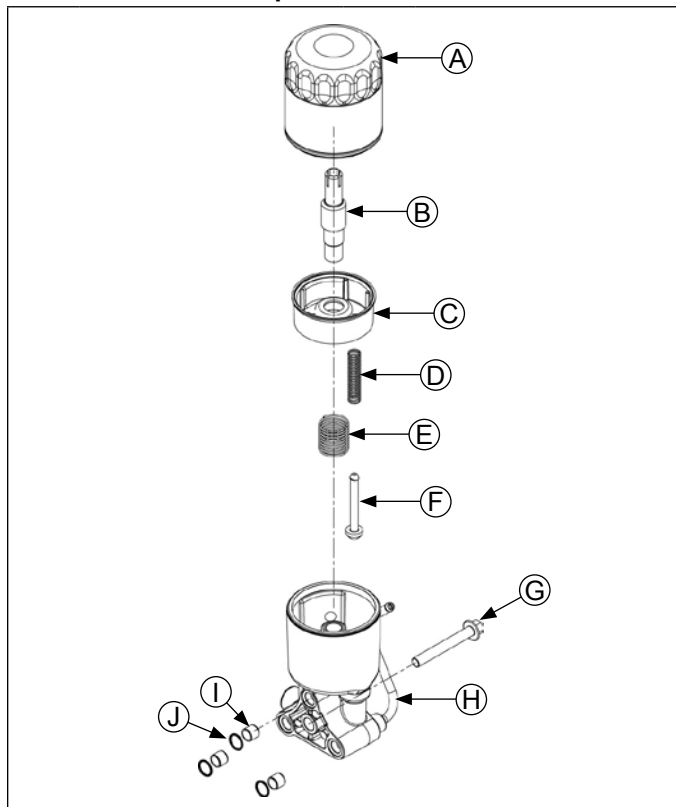
1. Make sure sealing surfaces are clean and free of any nicks or burrs.
2. Install and properly seat seal onto each valve cover.
3. Install valve covers on same side as they were originally installed.
4. Install a new grommet on each valve cover mounting screw. Start each screw into hole.
5. Check position of each cover and seal, then torque screws to 13.6 N·m (120 in. lb.).

Install Spark Plugs

1. Check gap using wire feeler gauge. Adjust gap to 0.76 mm (0.030 in.).
2. Install plug into cylinder head.
3. Torque plug to 27 N·m (20 ft. lb.).

Reassembly

Oil Cooler/Filter Components



A	Oil Filter	B	Oil Filter Nipple
C	Cup	D	Valve Spring
E	Cup Spring	F	Oil Filter Valve
G	Screw	H	Oil Filter Housing
I	Pin	J	O-Ring

Install Oil Filter Housing Assembly

Reassemble oil filter housing if disassembled previously.

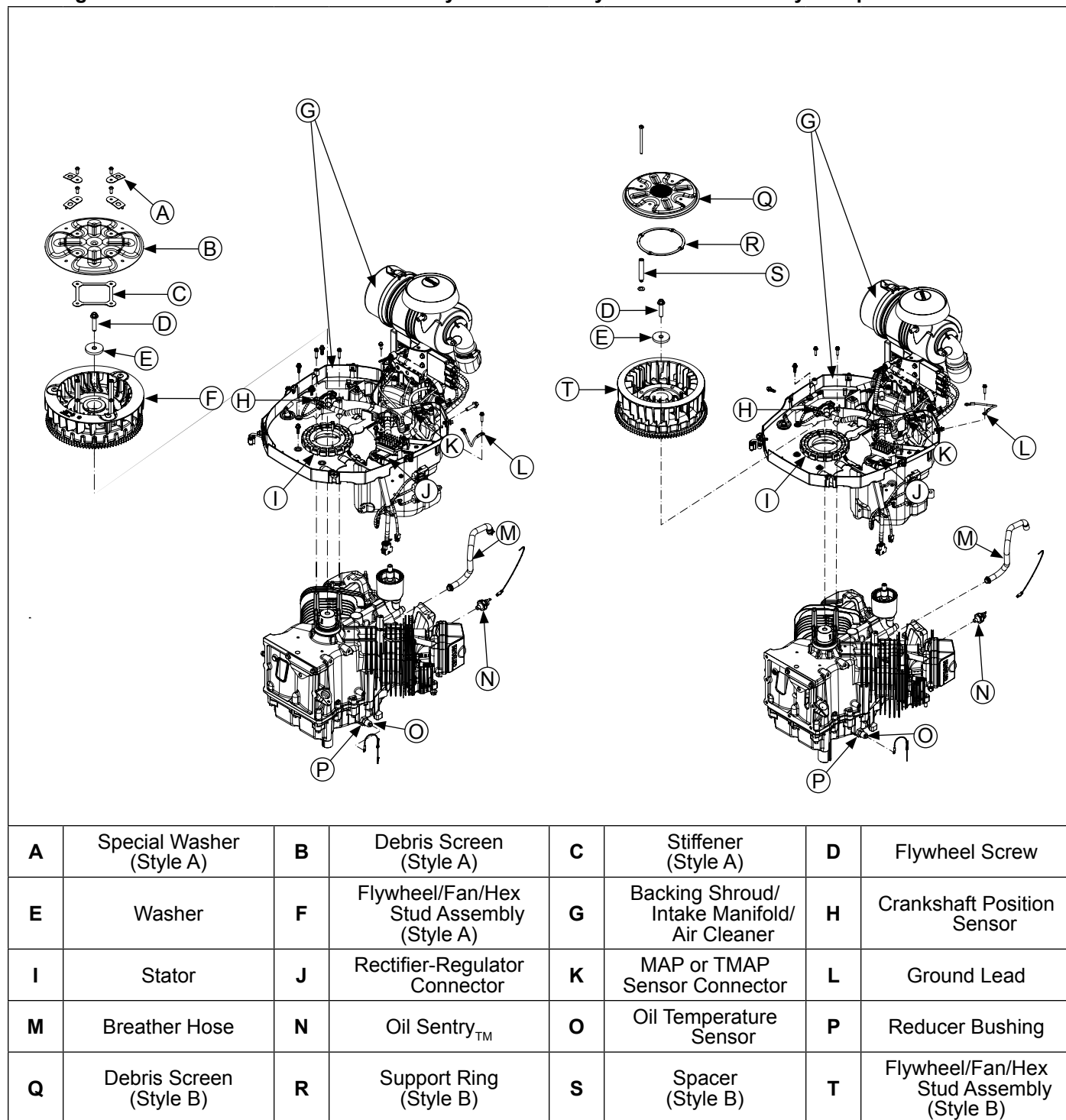
Reassembly

1. Install small spring onto rubber valve, and insert small end through corresponding hole in cup until properly seated.
2. Install larger spring into filter housing.
3. Insert oil filter cup, aligning cutout with corresponding section in housing.
4. Install nipple in housing and torque to 17.8 N·m (158 in. lb.).

Installation

1. Make sure all sealing surfaces are clean and all dowel pins are in position. Install or check new O-rings are around all oil filter adapter dowel pins.
2. Install oil filter housing assembly and secure with M8 screw. Make sure housing is flat on crankcase and all O-rings remain in position. Torque screw to 23.7 N·m (210 in. lb.)
3. Oil filter may be installed now or upon completion of engine assembly.

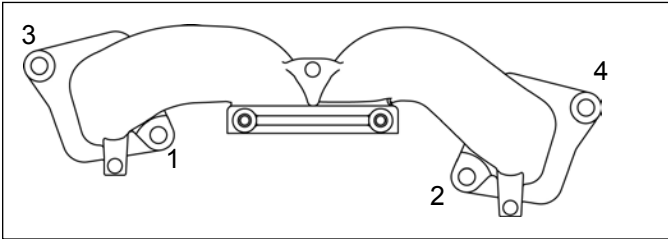
Backing Shroud/Intake Manifold/Throttle Body/Air Cleaner/Flywheel/Fan Assembly Components



Reassembly

Install Intake Manifold/Throttle Body//Air Cleaner/Backing Shroud Assembly

Intake Manifold Torque Sequence



1. Install new intake manifold gaskets on bolts so notched section is inward and points toward flywheel side. Loosely assemble intake manifold to heads; do not tighten at this time.
2. Set backing shroud assembly onto crankcase and start mounting screws. Torque screws in a crisscross pattern to 10.7 N·m (95 in. lb.) into new holes, or 7.3 N·m (65 in. lb.) into used holes.
3. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to stator mounting holes.
4. Position stator, aligning mounting holes so leads are at bottom and toward rectifier-regulator mount on cylinder 1 side.
5. Install and torque screws to 9.3 N·m (82 in. lb.).
6. Check that stator wires are under molded clips in backing shroud assembly.
7. Install dipstick tube with a new lower O-ring into crankcase. Secure with lower mounting screw. Torque screw to 7.7 N·m (68 in. lb.). Start upper screw but do not tighten until after blower housing is installed.
8. Torque intake manifold screws in 2 stages using sequence shown, first to 16.9 N·m (150 in. lb.), finally to 22.6 N·m (200 in. lb.).

Install Breather Hose

1. Lightly oil lower end of breather hose and install into hole in breather assembly. Cover should be situated between 2 raised rings of hose.
2. Connect Oil Sentry™ lead (green wire).
3. Install oil temp sensor connector.
4. Install MAP or TMAP sensor connector.

Install Oil Cooler

NOTE: New hose clamps are recommended for reassembly, or if clamps have been loosened (expanded) several times to avoid leakage.

1. Connect hoses between oil filter adapter and oil cooler. Secure with new clamps.
2. Align oil cooler with bosses in backing shroud assembly. Secure with screws and washers but do not tighten at this time.

Install Ground Lead and Rectifier-Regulator Connector

1. Attach ground lead to outer rectifier-regulator mounting screw and washer, then torque mounting screw to 2.5 N·m (22 in. lb.).
2. Install wiring harness clamp mounting bracket with harness ground lead to inboard #1 side cylinder boss.
3. Install rectifier-regulator connector.

Install Flywheel



CAUTION

Damaging Crankshaft and Flywheel can cause personal injury.

Using improper procedures can lead to broken fragments. Broken fragments could be thrown from engine. Always observe and use precautions and procedures when installing flywheel.

NOTE: Before installing flywheel make sure crankshaft taper and flywheel hub are clean, dry, and completely free of any lubricants. Presence of lubricants can cause flywheel to be overstressed and damaged when screw is torqued to specifications.

NOTE: Make sure flywheel key is installed properly in keyway. Flywheel can become cracked or damaged if key is not properly installed.

1. Install woodruff key into crankshaft keyway. Make sure key is properly seated and parallel with shaft taper.
2. Set flywheel/fan assembly onto crankshaft, being careful not to shift woodruff key.
3. Install screw and washer.
4. Use a flywheel strap wrench or holding tool to hold flywheel. Torque screw to 69.8 N·m (51 ft. lb.).

Install Fan (Style B)

NOTE: Position locating tabs on back of fan into locating holes of flywheel.

1. Install fan onto flywheel using screws (engines with plastic grass screen). Engines with a metal grass screen will leave fan loosely assembled.
2. Torque screws to 9.9 N·m (88 in. lb.).

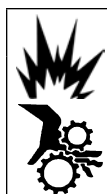
Install Crankshaft Position Sensor

NOTE: Ensure all parts are clean, undamaged, and free of debris; make sure electrical connectors have seal in place.

NOTE: On engines with earlier design bracket, an air gap must be set when installing. Later design brackets require no adjustment.

1. Install crankshaft position sensor and bracket assembly to crankcase posts.
2. On engines with earlier design bracket, snug screws and check air gap of sensor with a feeler gauge. It must be 0.20-0.70 mm (0.008-0.027 in.). Torque bracket screws to 9.7 N·m (86 in. lb.).
On engines with later design bracket, secure bracket assembly to crankcase posts. Torque bracket screws to 7.3 N·m (65 in. lb.)
3. Check electrical connector on crankshaft position sensor making sure a good connection is made.

Install Cooling Fan and Debris Screen (Style A)



CAUTION

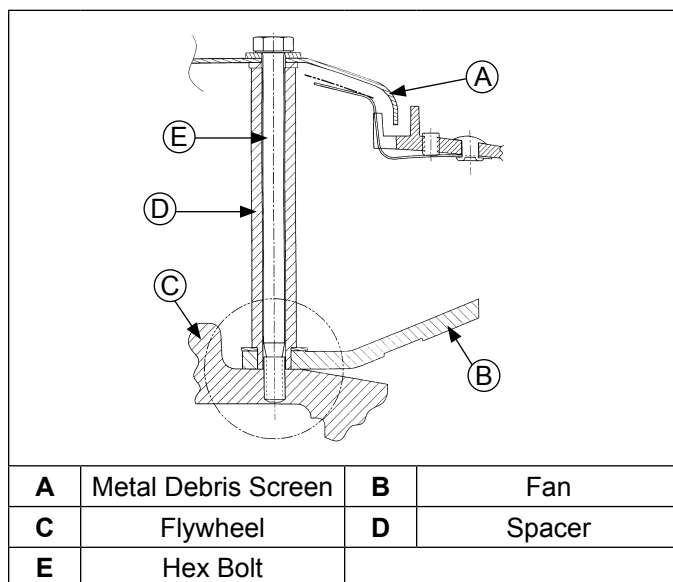
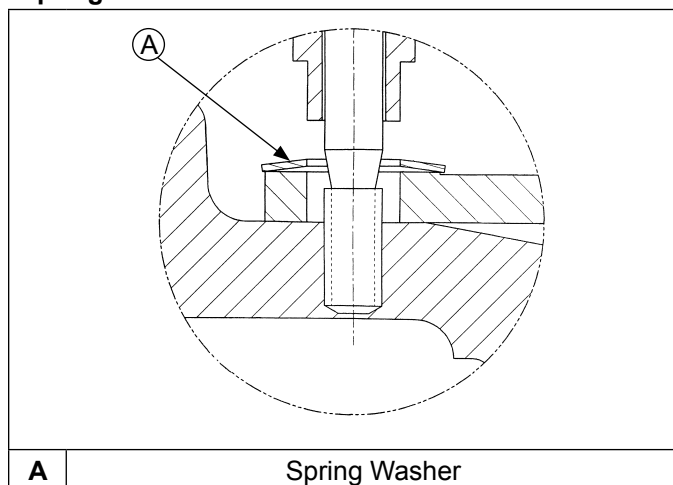
Failure to utilize or reassemble debris screen as designed could result in debris screen failure and serious personal injury.

If cooling fan was removed from flywheel perform step 1; if hex studs were removed from flywheel perform step 2; otherwise proceed to step 3.

1. Position cooling fan onto flywheel aligning mounting locations. Apply a small amount of Loctite® 243™ Threadlocker to threads and install long mounting screws. Torque screws to 10.4 N·m (92 in. lb.).
2. Apply a small amount of Loctite® 243™ Threadlocker to external threaded section, (unless new parts with preapplied locking compound are being used). Thread debris screen hex studs into mounting holes in flywheel. Torque each stud to 21.5 N·m (190 in. lb.).
3. Install stiffener followed by metal debris screen onto studs. Secure with special washers and mounting screws using Loctite® 243™ Threadlocker on threads. Torque hex flange screws to 20.3 N·m (180 in. lb.) and button head cap screws to 9.9 N·m (88 in. lb.).

Install Metal Debris Screen (Style B)

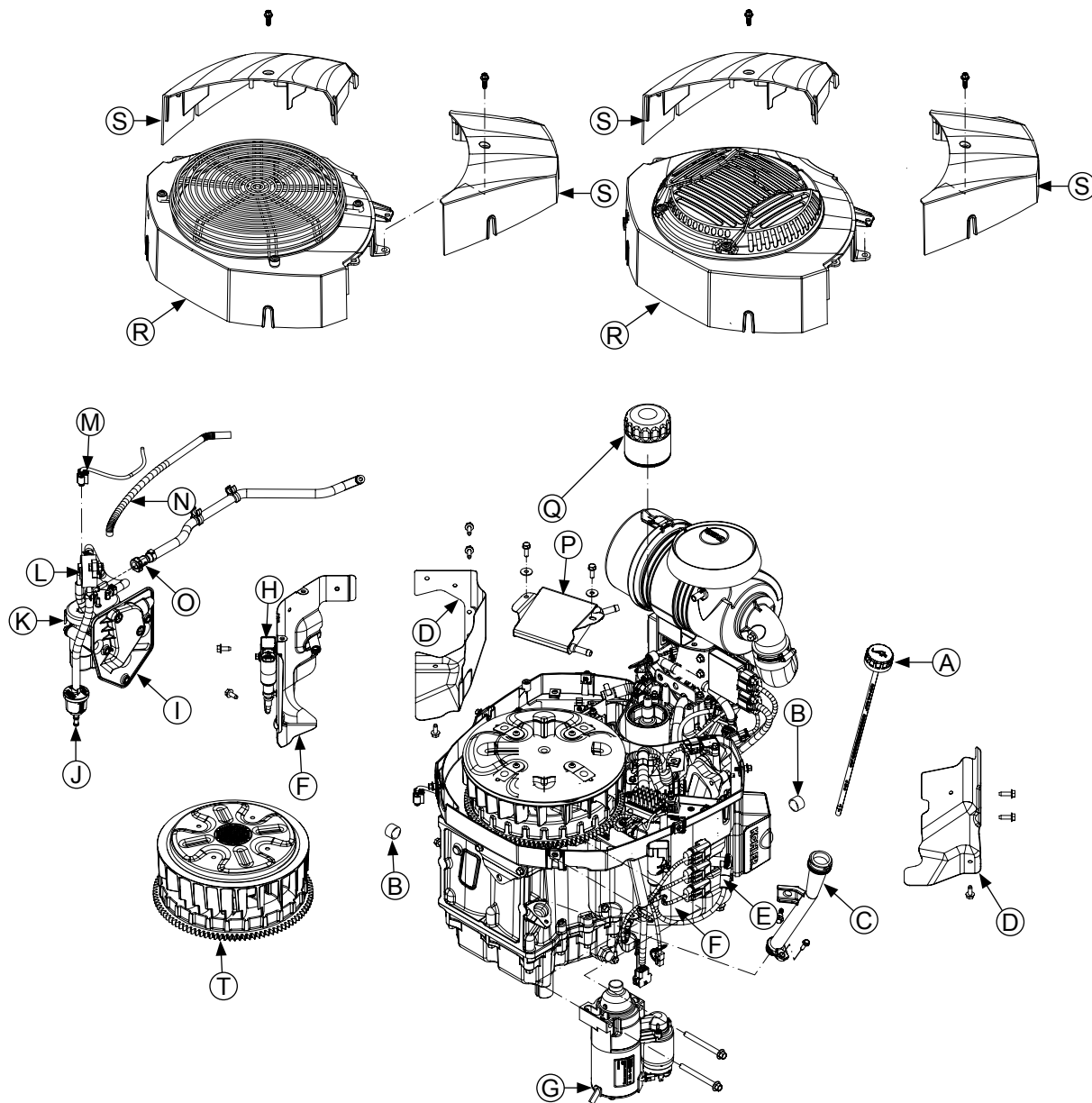
Spring Washer Details



1. Verify locating tabs on back of fan are inserted into locating holes on flywheel.
2. To assist assembly, find intake manifold studs with M6 thread at least 100 mm in length to be used as guide pins. Insert intake manifold studs through cooling fan mounting holes and thread them 4 or 5 turns into flywheel.
3. Install a spring washer on each stud with concave side down toward cooling fan.
4. Install a spacer on each stud with stepped end down. Smaller diameter should extend through spring washer and fan, so tip is resting on flywheel, and shoulder is resting on spring washer
5. Install support ring on studs, so it is resting on spacers. Then install metal screen on top of support ring.
6. Install a plain washers on each of screws. Apply Loctite® 242® to screw threads.
7. Carefully remove studs and replace with screws. Torque screws to 9.9 N·m (88 in. lb.). Repeat procedure for other studs and screws.

Reassembly

External Engine Components



A	Dipstick	B	Oil Drain Plug	C	Oil Fill Tube	D	Valley Baffle
E	Spark Plug Lead	F	Barrel Baffle	G	Starter Assembly	H	Ignition Coil
I	Fuel Pump Module Baffle	J	Fuel Filter	K	Fuel Pump Module	L	Fuel Pump
M	Electrical Connector	N	Evap Line	O	High Pressure Fuel Line Connector	P	Oil Cooler
Q	Oil Filter	R	Blower Housing with Fixed Guard	S	Cylinder Shroud	T	Fan/Flywheel Assembly

Install Valley and Cylinder Barrel Baffles

1. Install #1 side valley baffle and secure with 3 screws. Reinstall clip securing harness to baffle. Install #2 side valley baffle and secure with 3 screws. Torque M6 screws going into cylinder head and crankcase to 10.7 N·m (95 in. lb.) for new holes, or 7.3 N·m (65 in. lb.) for used holes.
2. Install cylinder barrel baffles. Make sure spark plug lead is routed through corresponding opening in each baffle. Start each screw. Torque M6 shoulder screws going through backing shroud assembly into extruded holes in baffles to 2.5 N·m (22 in. lb.) into new holes, or 2.0 N·m (18 in. lb.) into used holes. Torque M6 screws going into cylinder head and crankcase to 10.7 N·m (95 in. lb.) for new holes, or 7.3 N·m (65 in. lb.) for used holes.

Torque Oil Cooler Screws

1. Align oil cooler with bosses in backing shroud assembly. Torque screws to 2.3 N·m (21 in. lb.).

Install Fuel Pump Module/Fuel Pump Assembly

NOTE: Ensure all parts are clean, undamaged, and free of debris; make sure electrical connector has seal in place.

NOTE: Fuel pump module pins should be coated with a thin layer of electrical grease to prevent fretting and corrosion and may be reapplied if fuel pump module is being reused.

1. Orient fuel pump module baffle so pulse fitting in crankcase extends through cutout in baffle.
2. Connect pulse line (from fuel pump) to crankcase fitting.
3. Install screws to secure fuel pump module/baffle assembly to crankcase. Torque screws to 11.9 N·m (105 in. lb.). If fuel pump module was removed from baffle, after installing baffle, install fuel pump module to baffle and torque screws to 9.2 N·m (81 in. lb.).
4. Connect electrical connector to top of fuel pump module. Ensure grey locking tab is pulled out before connecting. Push connector onto terminal until a click is heard, then push in grey locking tab to lock connector.
5. Push high pressure fuel line connector onto fuel pump module fitting.
6. If Oetiker clamp was cut to remove inlet fuel line, slide a new Oetiker clamp onto fuel line and connect fuel line to fuel pump module. Only use an Oetiker clamp pliers to crimp Oetiker clamps. Oetiker clamp crimp must point up and away from top of fuel pump module and anti-abrasion sleeve must be positioned over Oetiker clamp.
7. Install connectors to #1 and #2 side ignition coils.
8. Orient/push line clamps into baffles. Push evap line into clips on high pressure fuel line. Connect evap line to vent fitting on fuel pump module.

Install Electric Starter

1. Install electric starter motor using screws.
2. Torque screws to 16 N·m (142 in. lb.).
3. Connect main power lead and solenoid lead.

Install Blower Housing/Guard Assembly

Align and install blower housing with fixed guard. Secure with screws. Torque screws to 2.5 N·m (22 in. lb.) into new holes, or 2.0 N·m (18 in. lb.) into used holes.

Install Fuel Pump

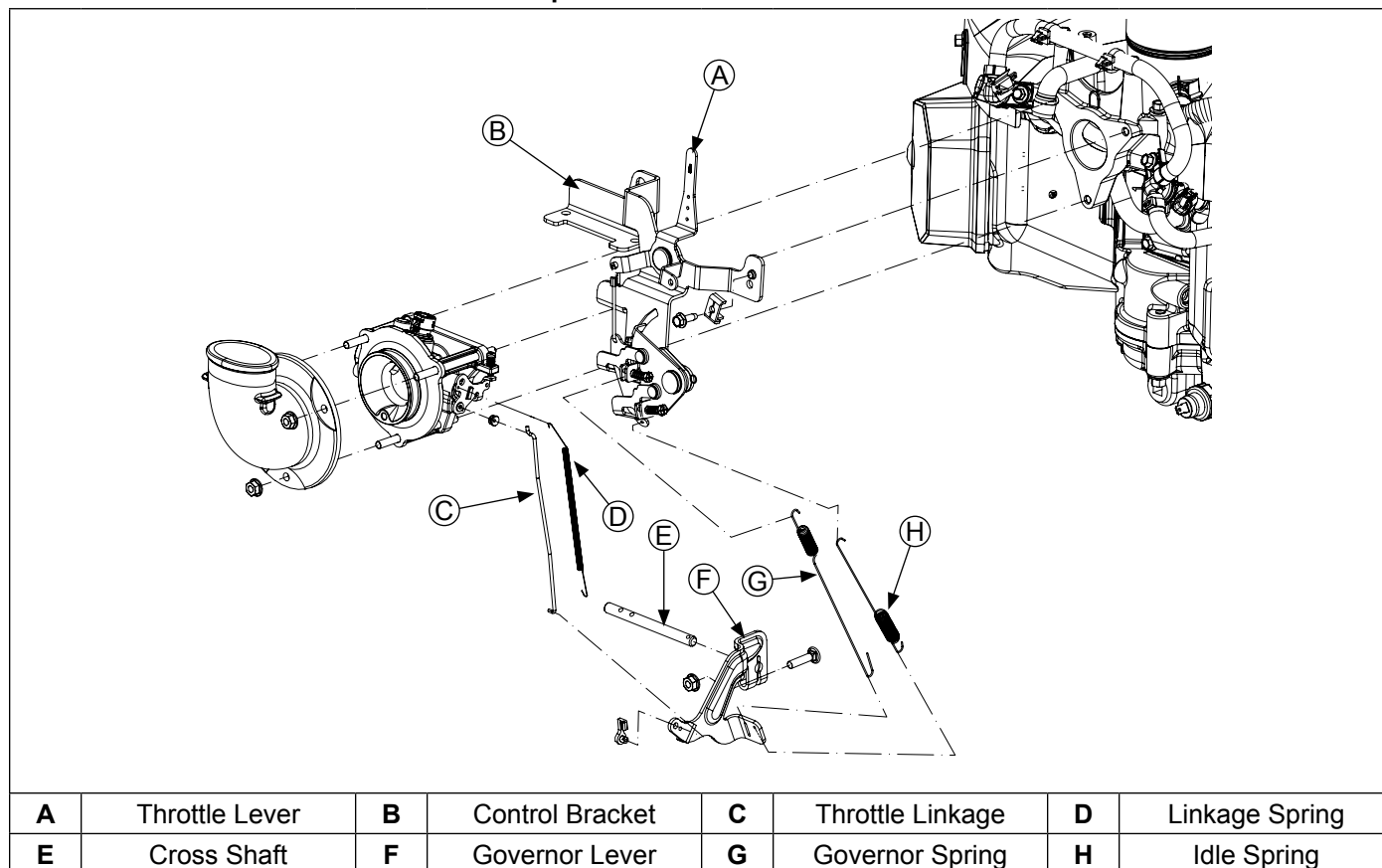
Install fuel pump to blower housing and secure with screws. Torque screws to 2.8 N·m (25 in. lb.).

Install Cylinder Shrouds

Install cylinder shrouds and secure with screws. Torque screws to 2.5 N·m (22 in. lb.) into new holes, or 2.0 N·m (18 in. lb.) into used holes.

Reassembly

Mechanical Governor Control Bracket Components



Install Governor Lever (Mechanical Governor Only)

Install governor lever onto governor shaft and connect throttle linkage with black clip.

Adjusting Mechanical Governor

1. Position governor lever so clamping area is inboard but completely on knurled area of governor cross shaft.
2. Move governor lever toward throttle body as far as it will go (wide-open throttle) and hold in position.
3. Insert a long thin rod or tool into hole on cross shaft and rotate shaft clockwise (viewed from end) as far as it will turn, then torque nut to 7.1 N·m (63 in. lb.).
4. Connect governor spring (with long looped end), to inner hole on governor lever and control bracket.
Connect governed idle spring to outer governor lever hole and control bracket.

Make sure springs do not contact valley baffle.

Install Oil Sentry™ (if equipped)

1. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to Oil Sentry™ threads switch and install it into 1/8 in. port in oil pan. Torque switch to 10.7 N·m (95 in. lb.).
2. Connect green wire lead to Oil Sentry™ terminal.

Install Muffler

1. Install new exhaust gaskets onto exhaust studs.
2. Install port liners (if equipped). Attach muffler and secure with nuts onto exhaust studs. Torque nuts to 24.4 N·m (216 in. lb.).
3. Install any attaching hardware and brackets. Torque M6 screws to 9.9 N·m (88 in. lb.), and M8 screws to 24.4 N·m (216 in. lb.).
4. Install spark arrestor (if used).

Install Oil Filter and Add Oil to Crankcase

NOTE: Make sure both oil drain plugs are installed and torqued to 21.4 N·m (16 ft. lb.). to prevent oil leakage.

1. Install oil drain plugs. Torque plugs to 21.4 N·m (16 ft. lb.).
2. Place new filter in shallow pan with open end up. Fill with new oil until oil reaches bottom of threads. Allow 2 minutes for oil to be absorbed by filter material.
3. Apply a thin film of clean oil to rubber gasket on new filter.
4. Refer to instructions on oil filter for proper installation.
5. Fill crankcase with new oil. Level should be at top of indicator on dipstick.
6. Reinstall oil fill cap/dipstick and tighten securely.

Connect Spark Plug Leads

Connect leads to spark plugs.

Prepare Engine for Operation

NOTE: If ECU, throttle body, TPS, or fuel pump module were replaced, an ECU Reset and TPS Learn is required. Refer to Electronic Fuel Injection (EFI) System section.

NOTE: If electronic governor and throttle body were removed or replaced, refer to Governor section for proper adjustment/assembly.

Engine is now completely reassembled. Before starting or operating engine, follow proceeding steps.

1. Make sure all hardware is tightened securely.
2. Make sure oil drain plugs, Oil Sentry™ pressure switch, and a new oil filter are installed.
3. Verify crankcase has been filled with correct amount, weight, and type of oil. Refer to oil recommendations and procedures in Maintenance, Specifications, and Lubrication System sections.
4. Turn on fuel supply.

Testing Engine

It is recommended engine be operated on a test stand or bench prior to installation in equipment.

1. Set engine up on a test stand. Install an oil pressure gauge. Start engine and check to be certain oil pressure (20 psi or more) is present. Run engine at idle for 2-3 minutes, then 5-6 minutes more between idle and midrange.
2. Adjust idle speed screw located on throttle body as necessary. Standard idle speed setting for EFI engines is 1500 RPM, but certain applications might require a different setting.
3. **Mechanical Governor:** Adjust governed idle and high speed (RPM) to required settings. Make sure maximum engine speed does not exceed 3900 RPM (no load).
3. **Electronic Governor:** Attach 12 volt jumper wire to speed control input red wire with yellow tracer. Engine speed should increase to high. Make sure maximum engine speed does not exceed 3900 RPM (no load). If engine speed does not increase, refer to Governor section for proper troubleshooting and diagnostics.



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