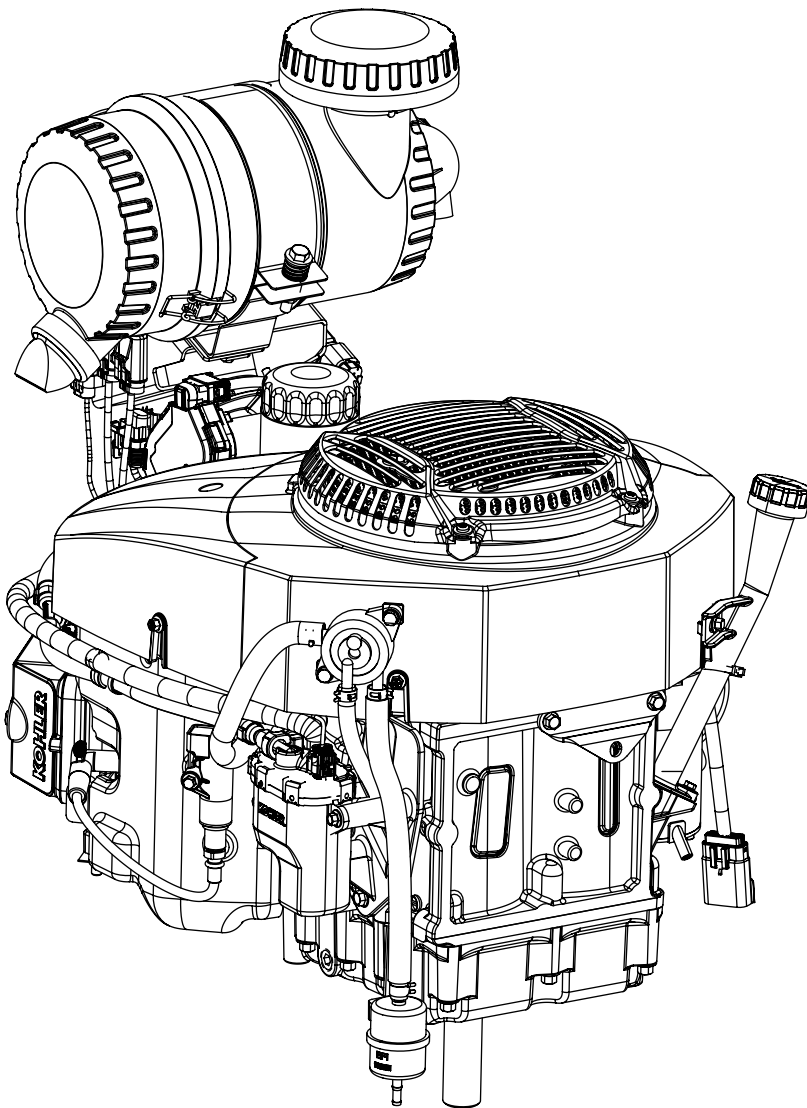


Command PRO

ECV936, ECV938

Service Manual



Kohler Engines
is now Rehlko.



2	Safety
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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.

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.

	⚠ 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.	

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

	⚠ WARNING Carbon Monoxide can cause severe nausea, fainting or death. Avoid inhaling exhaust fumes. Never run engine indoors or in enclosed spaces.
Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.	

	⚠ 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.	

	⚠ 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.	

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

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

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

	⚠ WARNING Explosive Fuel can cause fires and severe burns. Fuel 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.	

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 Rehlko authorized dealer found at engines.rehlko.com or 1-800-544-2444 (U.S. and Canada).

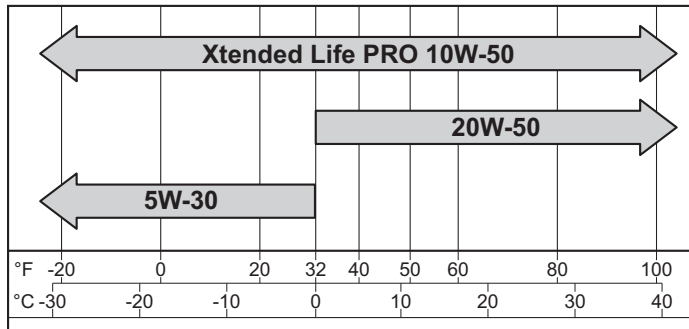
MAINTENANCE SCHEDULE	
Every 100 Hours or Annually ¹	
Change oil. Oil filter is recommended.	Lubrication System
Check oil cooler fins, clean as necessary (if equipped).	
Remove cooling shrouds and clean cooling areas.	Air Cleaner/Intake
Check air cleaner element.	
Every 200 Hours	
Change oil filter.	Lubrication System
Every 300 Hours ²	
Change oil and filter (Xtended Life PRO 10W-50 oil and Xtended Life PRO filter only.)	Lubrication System
Replace unique Electronic Fuel Injection (EFI) fuel filter.	
Every 600 Hours ¹	
Replace heavy-duty air cleaner element and inner element.	Air Cleaner/Intake
Replace spark plugs and set gap.	Electrical System
¹ Perform these procedures more frequently under severe, dusty, dirty conditions.	
² Option only if using Xtended Life PRO oil and filter.	

REPAIRS/SERVICE PARTS

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

OIL RECOMMENDATIONS

We recommend use of Rehlko 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:

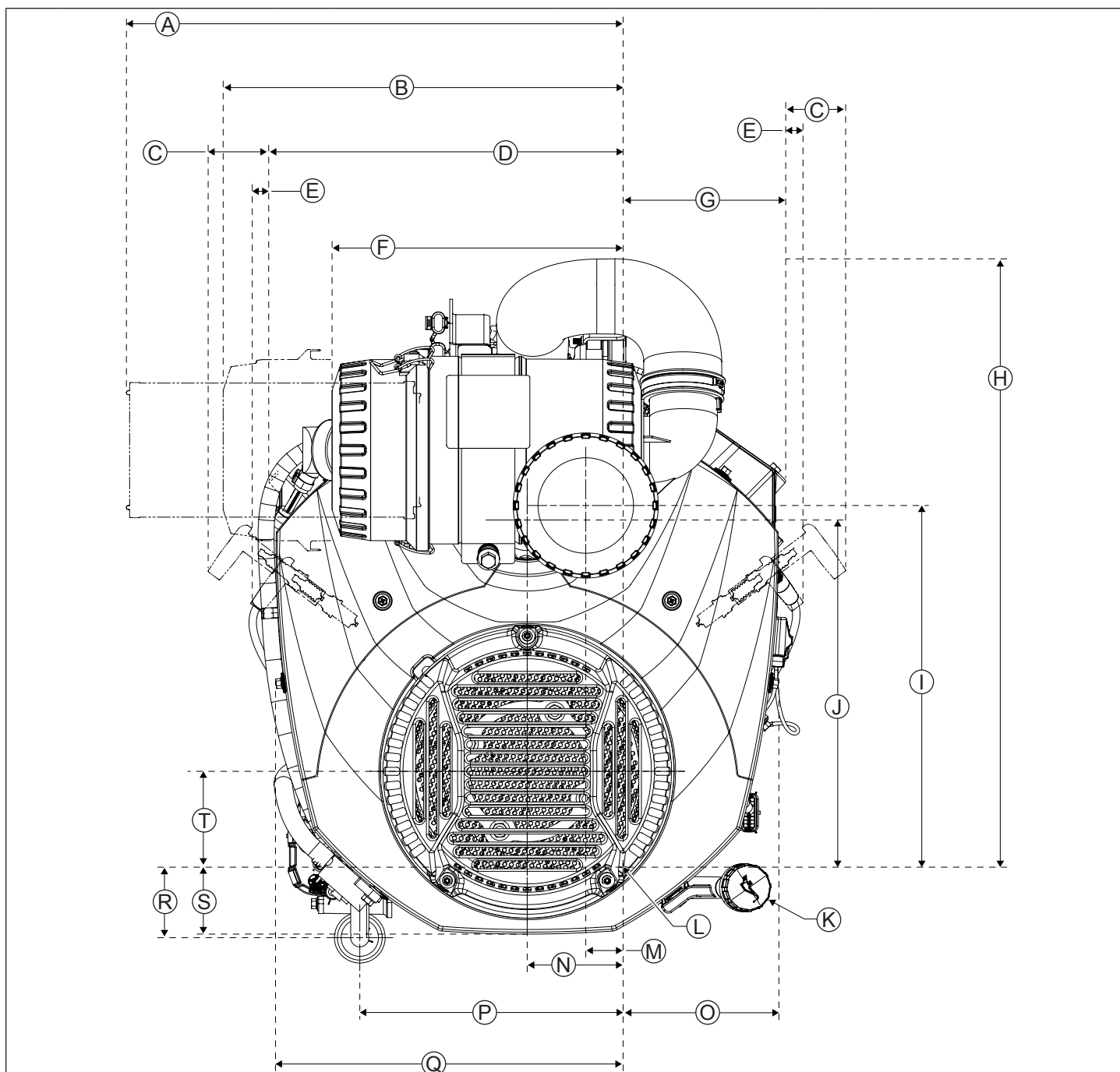
- Clean, fresh, unleaded gasoline.
- Octane rating of 87 (R+M)/2 or higher.
- Research Octane Number (RON) 90 octane minimum.
- Gasoline up to 10% ethyl alcohol, 90% unleaded is acceptable.
- Methyl Tertiary Butyl Ether (MTBE) and unleaded gasoline blend (max 15% MTBE by volume) are approved.
- Do not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

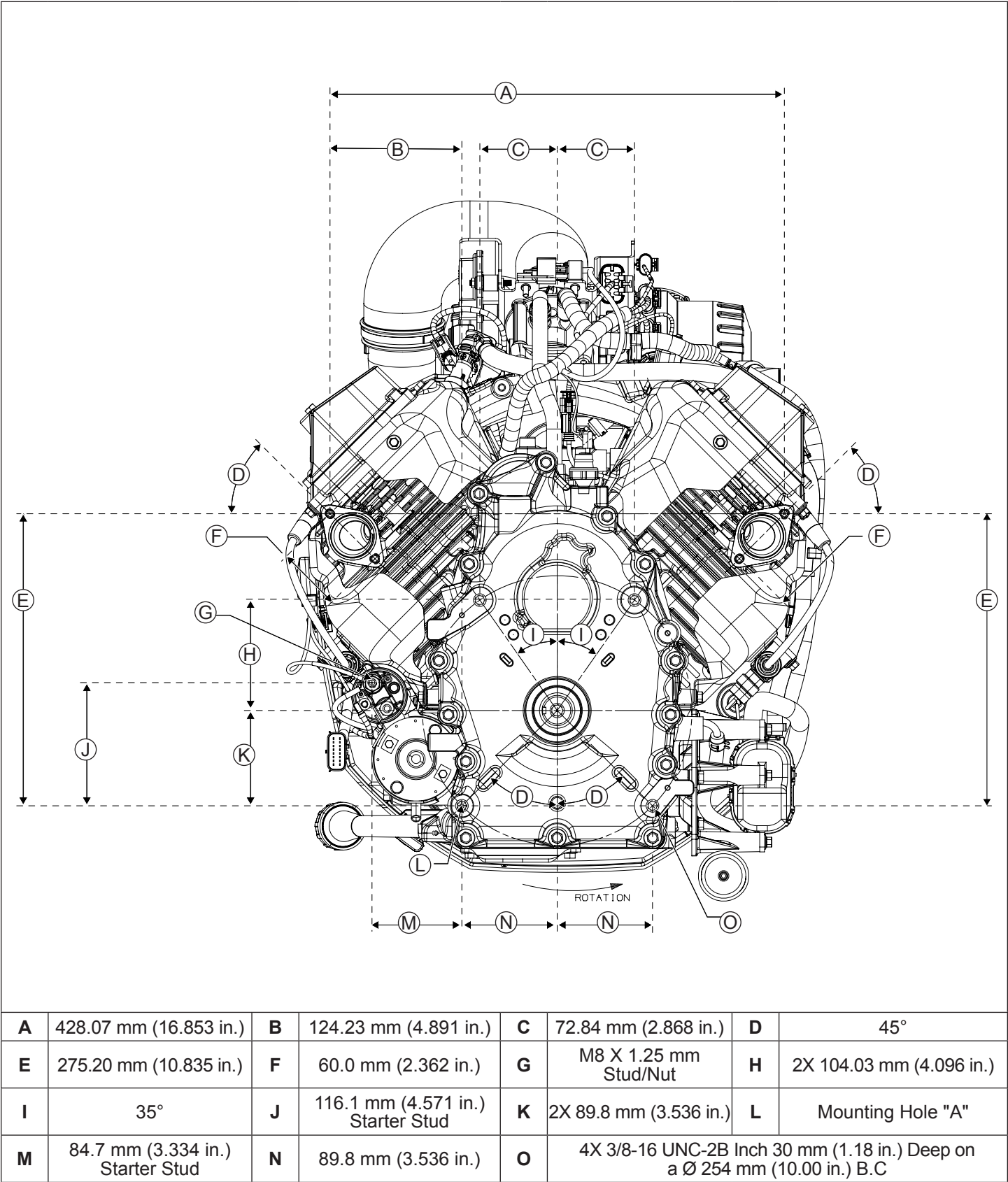
1. Add PRO Series fuel treatment or equivalent to fuel tank. Run engine 2-3 minutes to get stabilized fuel into fuel system (failures due to untreated fuel are not warrantable).
2. Change oil while engine is still warm from operation. Remove spark plug(s) and pour about 1 oz. of engine oil into cylinder(s). 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

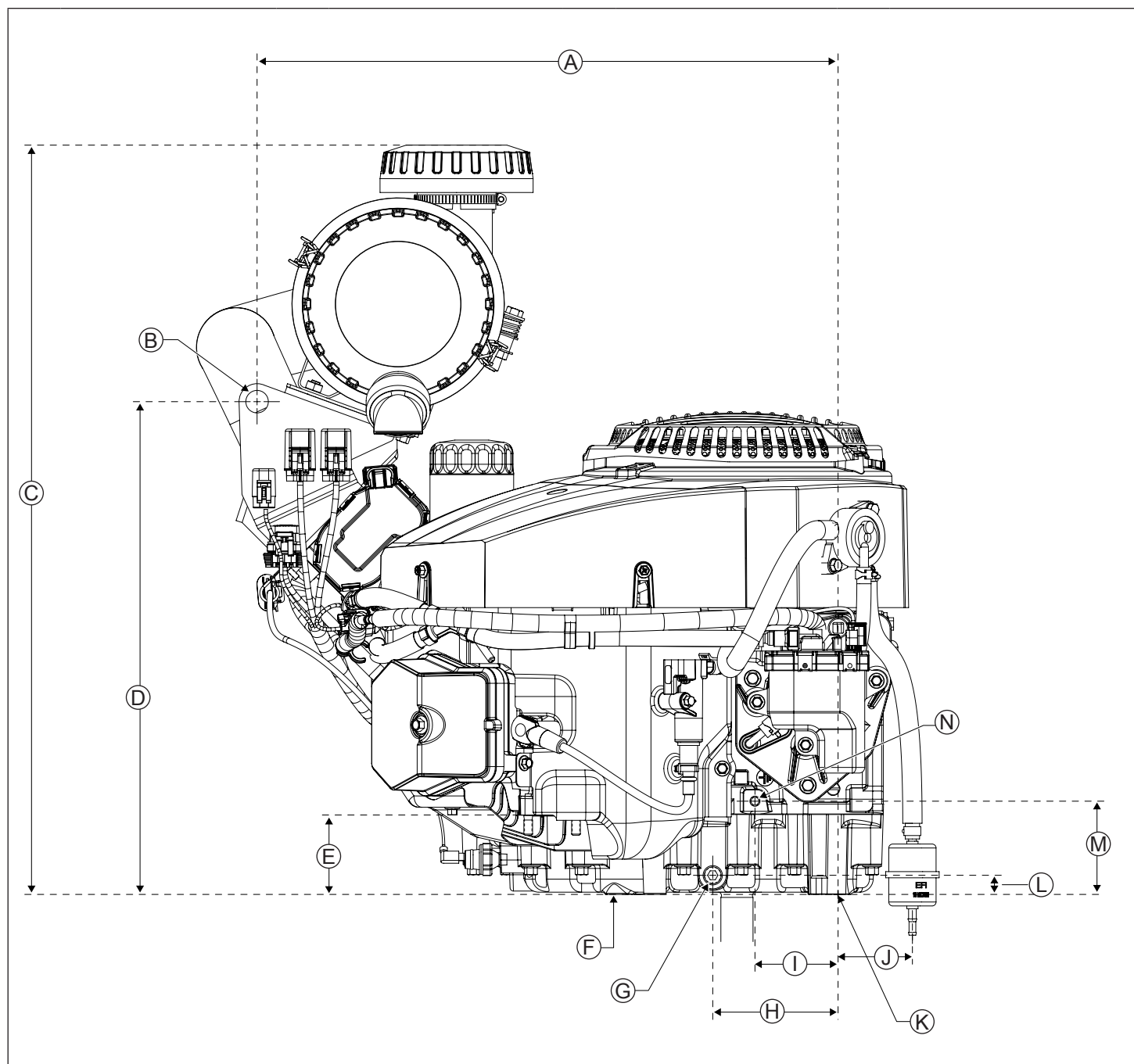


A	465.1 mm (18.313 in.) Air Filter Element Removal	B	374.5 mm (14.746 in.) Air Filter Cover Removal	C	56.7 mm (2.23 in.) Spark Plug Boot Removal	D	331.9 mm (13.06 in.) Valve Cover
E	16.2 mm (0.638 in.) Spark Plug Boot	F	272.5 mm (10.730 in.)	G	152.3 mm (5.996 in.) Valve Cover	H	569.9 mm (22.439 in.)
I	338.8 mm (13.340 in.) Hood, Inlet	J	325.3 mm (12.807 in.) Oil Filter	K	Oil Fill & Dipstick (Yellow)	L	Mounting Hole "A" (In Oil Pan)
M	35.0 mm (1.376 in.) Hood, Inlet	N	89.8 mm (3.536 in.) Oil Filter	O	145.9 mm (5.744 in.) Blower Housing	P	246.6 mm (9.707 in.) Fuel Filter
Q	325.5 mm (12.816 in.) Blower Housing	R	68.1 mm (2.601 in.) Fuel Filter	S	62.7 mm (2.468 in.) Blower Housing	T	89.8 mm (3.536 in.)

Engine Dimensions - PTO Side (Earlier Design)

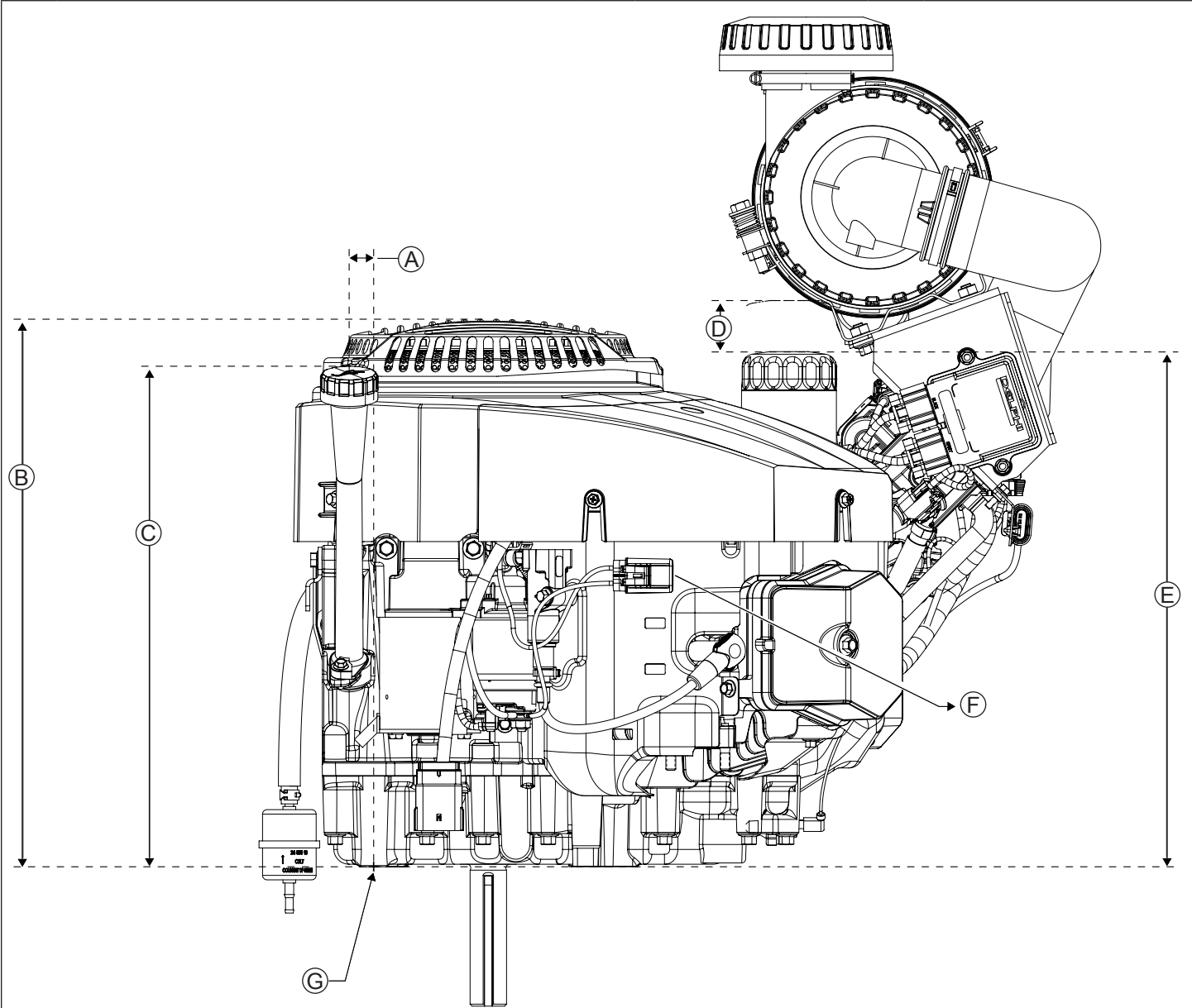


Engine Dimensions - Fuel Pump Module Side



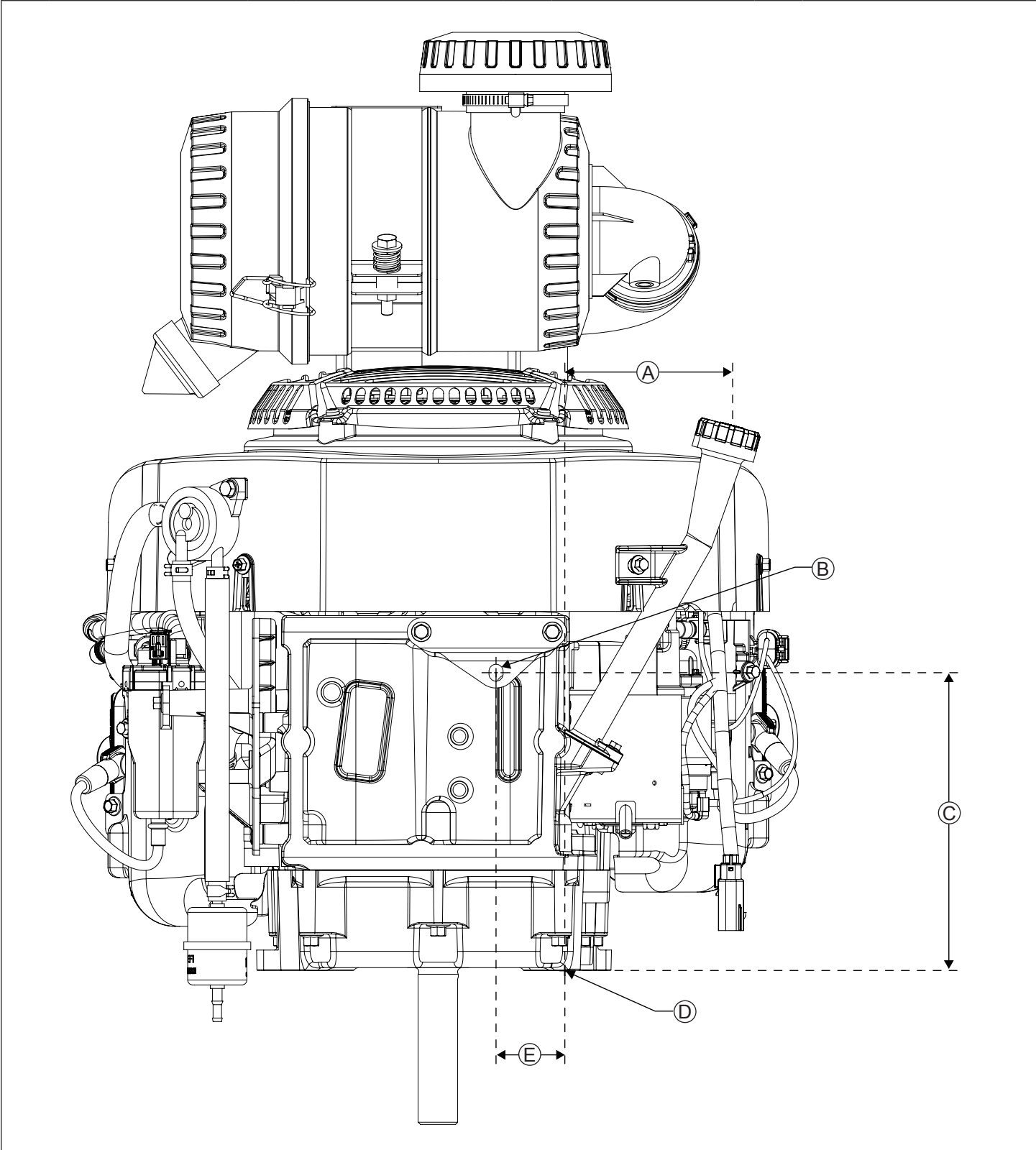
A	516.1 mm (20.317 in.)	B	Lift Hook Location #1	C	665.8 mm (26.213 in.)	D	437.8 mm (17.238 in.)
E	70.59 mm (2.779 in.) Exhaust Port #2	F	Engine Mounting Surface	G	Oil Drain Plug 3/8 Inch NPTF	H	111.3 mm (4.382 in.)
I	73.8 mm (2.906 in.)	J	66.1 mm (2.601 in.) Fuel Filter	K	Mounting Hole "A" (In Oil Pan)	L	17.0 mm (0.669 in.)
M	82.8 mm (3.261 in.)	N	M8 x 1.25 20 mm (0.79 in.) Deep Customer Ground Location				

Engine Dimensions - Opposite Fuel Pump Module Side



A	19.2 mm (0.756 in.)	B	429.1 mm (16.893 in.)	C	392.2 mm (15.442 in.)	D	40.0 mm (1.575 in.) Oil Filter Removal
E	403.7 mm (15.893 in.)	F	Charing Fuse	G	Mounting Hole "A"		

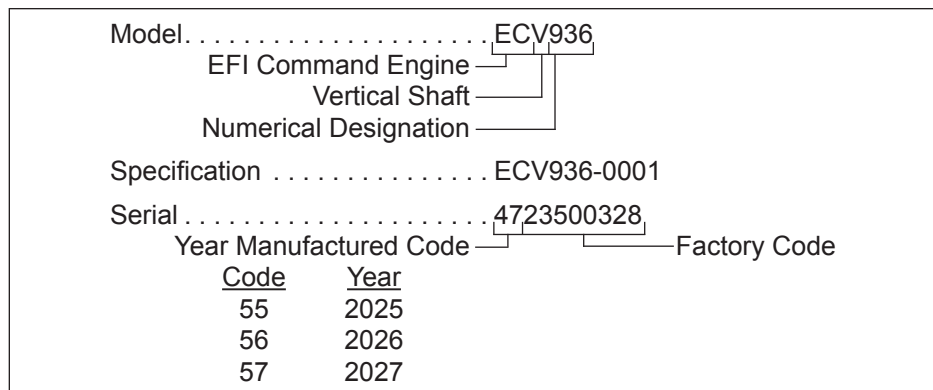
Engine Dimensions - Front View



A	119.1 mm (4.688 in.)	B	Lift Hook Location #2	C	211.3 mm (8.320 in.)	D	Mounting Hole "A"
E	48.8 mm (1.921 in.)						

ENGINE IDENTIFICATION NUMBERS

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



GENERAL SPECIFICATIONS^{3,6}

	ECV936	ECV938
Bore	90 mm (3.54 in.)	
Stroke	78.5 mm (3.1 in.)	
Displacement	999 cc (61 cu. in.)	
Oil Capacity (refill)	1.9-2.6 L (2.0-2.7 U.S. qt.)	
Maximum Angle of Operation (@ full oil level) ⁴	25°	

TORQUE SPECIFICATIONS^{3,5}

TORQUE SPECIFICATIONS ^{3,5}		ECV936	ECV938
Blower Housing and Sheet Metal			
M6 Screw			
New, Untapped Hole (casting)		10.7 N·m (95 in. lb.)	
Used, Tapped Hole (casting)		7.3 N·m (65 in. lb.)	
New, Extruded Hole (sheet metal)		2.5 N·m (22 in. lb.)	
Used, Extruded Hole (sheet metal)		2.0 N·m (18 in. lb.)	
Mounting Clip (valley baffle)		2.5 N·m (22 in. lb.)	
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 Bracket Mounting Screw (into intake manifold)		11.3 N·m (100 in. lb.)	
Ground Lead to Air Cleaner Bracket		5.6 N·m (50 in. lb.)	
HDAC Bracket to HDAC Screw		7.9 N·m (70 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 Rehiko are Certified Power Ratings and per SAE J1940 & J1995 hp standards. Details on Certified Power Ratings can be found at Engines.rehiko.com.

TORQUE SPECIFICATIONS^{3,5}

ECV936

ECV938

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.)
Engine (Oil) Temperature Sensor Lead	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 Screw	15.5 N·m (137 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.)

Ignition

Spark Plug	27 N·m (20 ft. lb.)
Coil Fastener	10.2 N·m (90 in. lb.)
Electronic Control Unit (ECU) to Bracket Screw	6.2 N·m (55 in. lb.)
ECU to Isolation Mount Nut (ETB)	2 N·m (18 in. lb.)
ECU Bracket to HDAC Screw (ETB)	7.9 N·m (70 in. lb.)
ECU Bracket to HDAC Bracket Screw (ETB)	4.5 N·m (5.1 in. lb.)
Fuse Bracket to HDAC Bracket Nut (ETB)	7.9 N·m (70 in. lb.)
Rectifier-Regulator Fastener (Standard Charging System)	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.

TORQUE SPECIFICATIONS^{3,5}

ECV936

ECV938

Rectifier-Regulator Power Studs/Nuts (High Output Charging System)	4.0 N·m (35 in. lb.)
Rectifier-Regulator Terminal Block Cover Fastener (High Output Charging System)	2.8 N·m (25 in. lb.)

Crankshaft Position Sensor

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.)
Harness Ground Wire to #1 Crankcase Post Screw	9.7 N·m (86 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.)
Oxygen Sensor 22 mm (7/8 in.) wrench size	50.1 N·m (37 ft. lb.)

Oil Cooler (if equipped)

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.)
Engine (Oil) Temperature Sensor	13.6 N·m (120 in. lb.)
Engine (Oil) Temperature Sensor Reducer Bushing	17.6 N·m (156 in. lb.)
Engine (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.

TORQUE SPECIFICATIONS^{3,5}

ECV936

ECV938

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 Body

Mounting Stud	3.7 N·m (32 in. lb.)
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Throttle Control Bracket

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

Aluminum Valve Cover Fastener Into New Head	Torque to 26 N·m (230 in. lb.) to ensure seal seats in valve cover groove. Back off screw to zero and then torque screw again to 18.1 N·m (160 in. lb.).
Into Used Head	Torque to 16.4 N·m (145 in. lb.) to ensure seal seats in valve cover groove. Back off screw to zero and then torque screw again to 16.4 N·m (145 in. lb.).
Plastic Valve Cover Fastener	13.6 N·m (120 in. lb.)

CLEARANCE SPECIFICATIONS³

ECV936

ECV938

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.)

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

CLEARANCE SPECIFICATIONS³

ECV936

ECV938

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.)
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.)

Crankshaft (continued)

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.)

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

CLEARANCE SPECIFICATIONS³

ECV936

ECV938

Crankshaft Bearing (PTO)

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

Cylinder Bore

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

Cylinder Head

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

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

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.	19.006/17.013 mm (0.7482/0.7485 in.)
New	19.025 mm (0.7490 in.)
Max. Wear Limit	
Pin O.D.	18.995/19.000 mm (0.7478/0.7480 in.)
New	18.994 mm (0.7478 in.)
Max. Wear Limit	
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	0.30/0.55 mm (0.011/0.021 in.)
New Bore	0.94 mm (0.037 in.)
Used Bore (max.)	

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

CLEARANCE SPECIFICATIONS³

	ECV936	ECV938
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.

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

Tools and Aids

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.

NOTE: Not all tools listed are required to service this engine.

SEPARATE TOOL SUPPLIERS

Rehlko Tools
Contact your local Rehlko 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.	Rehlko 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
Dual Gauge 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)	Rehlko 25 761 46-S Design Technology Inc. DTI-731-03
Dealer Tool Kit Complete kit of Rehlko required tools. Components of 25 761 58-S Dual Gauge Cylinder Leakdown Test Tool Oil Pressure Test Kit	Rehlko 25 761 58-S Rehlko 25 761 46-S Rehlko 25 761 06-S
EFI Service Kit For troubleshooting and setting up an EFI engine. Components of 24 761 01-S Fuel Pressure Tester Shrader Valve Adapter Hose Noid Light 90° Adapter (Shrader) Code Plug, Red Wire Code Plug, Blue Wire Code Plug, Yellow Wire CAN Bus Reset Tool, Green Wire Wire Probe Set (2 pieces regular wire with clip; 1 piece fused wire) Hose Removal Tool, Dual Size/End (also sold as individual Rehlko tool) K-Line Adapter Jumper Lead Wiring Harness	Rehlko 24 761 01-S Design Technology Inc. DTI-019 DTI-037 DTI-021 DTI-023 DTI-027 DTI-029 DTI-028 DTI-030 DTI-031 DTI-033 Rehlko 25 176 23-S
Flywheel Puller For properly removing flywheel from engine.	SE Tools KLR-82408
Flywheel Anchor Bolts, Washers, Nuts Tool Used with Flywheel Puller to properly removing flywheel from 5400 Series engine.	Rehlko 25 086 753-S
Hose Removal Tool, Dual Size/End (also available in EFI Service Kit) Used to properly remove fuel hose from engine components.	Rehlko 25 455 20-S
Inductive Tachometer (Digital) For checking operating speed (RPM) of an engine.	Design Technology Inc. DTI-110
Jumper Lead Tool For use with Stepper Motor Controller Tool to test rotary stepper motor.	Rehlko 25 518 43-S
Mobile KDS Gen 2 (Wireless) Module (New CAN Bus/ETB Capable) Replaces the previous Rehlko 25 761 45-S mobile Android or iOS EFI diagnostics. Components of 25 761 55-S 7 Pin to DB9 Cable 7 Pin to 4 Pin Adapter K-Line Adapter Jumper Lead Wiring Harness	Rehlko 25 761 55-S Rehlko 25 761 48-S Rehlko 25 761 53-S Rehlko 25 176 23-S

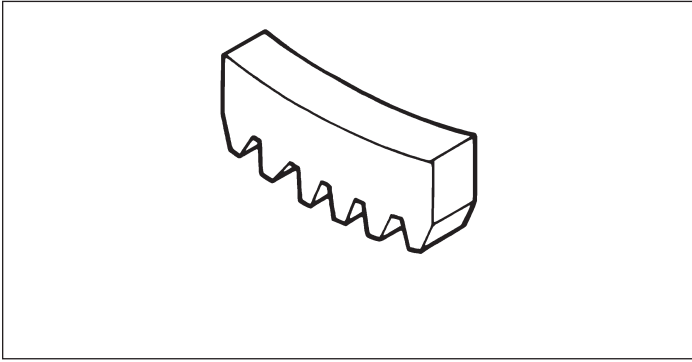
TOOLS

Description	Source/Part No.
Mobile (Wireless) CAN Bus Cable Upgrade Kit Updates the previous Rehlko 25 761 45-S mobile (wireless) Android or iOS tool to allow CAN Bus/ETB communications and the ability to perform diagnostics. Components of 25 761 56-S 7 Pin to DB9 Cable 7 Pin to 4 Pin Adapter K-Line Adapter Jumper Lead Wiring Harness	Rehlko 25 761 56-S Rehlko 25 761 48-S Rehlko 25 761 53-S Rehlko 25 176 23-S
Oil Pressure Test Kit For testing/verifying oil pressure on pressure lubricated engines.	Rehlko 25 761 06-S
Reamer Handle For hand reaming using Rehlko 25 455 12-S reamer.	Design Technology Inc. DTI-K830
Rehlko® Diagnostic System (KDS) Gen 2 For Laptop or Desktop PC. Components of 25 761 50-S Engine Communication Module 7 Pin to DB9 Cable USB Module to PC Cable 7 Pin to 4 Pin Adapter K-Line Adapter Jumper Lead Wiring Harness	Rehlko 25 761 50-S Rehlko 25 761 47-S Rehlko 25 761 48-S Rehlko 25 761 49-S Rehlko 25 761 53-S Rehlko 25 176 23-S
Replacement Cable and Adapter Kit For laptop or desktop PC or mobile (wireless). Components of 25 761 57-S 7 Pin to DB9 Cable 7 Pin to 4 Pin Adapter	Rehlko 25 761 57-S Rehlko 25 761 48-S Rehlko 25 761 53-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
Stepper Motor Controller Tool For testing operation of stepper motor/Digital Linear Actuator (DLA).	Rehlko 25 455 21-S
Triad/OHC Timing Tool Set For holding cam gears and crankshaft in timed position while installing timing belt.	Rehlko 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.	Rehlko 25 455 12-S

AIDS

Description	Source/Part No.
Camshaft Lubricant (Valspar ZZ613)	Rehlko 25 357 14-S
Dielectric Grease	Loctite® 51360
P80 Emulsion Lubricant	Rehlko 25 357 80-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. Permatex® the Right Stuff® 1 Minute Gasket™ or Loctite® Nos. 5900® or 5910® are recommended for best sealing characteristics.	Rehlko 25 597 07-S Loctite® 5910® Loctite® Ultra Black 598™ Loctite® Ultra Blue 587™ Loctite® Ultra Copper 5920™ Permatex® the Right Stuff® 1 Minute Gasket™
Spline Drive Lubricant	Rehlko 25 357 12-S

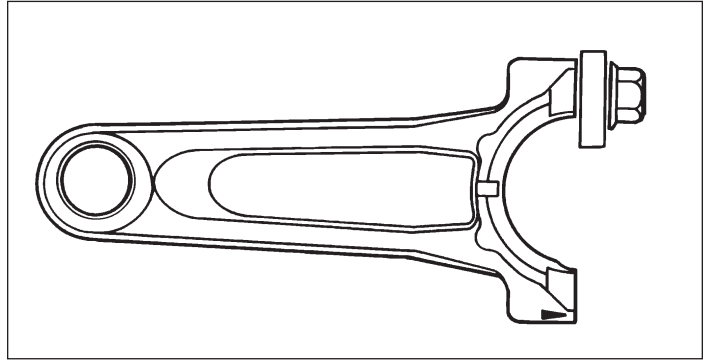
FLYWHEEL HOLDING TOOL



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 capscrew with correct thread size to match threads in connecting rod.
4. Use a flat washer with correct I.D. to slip on capscrew and approximately 1 in. O.D. Assemble capscrew and washer to joint surface of rod.

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 EFI engine troubles are listed below and vary by engine specification. These systems should be checked **before** more indepth troubleshooting begins. Once these systems are eliminated then additional troubleshooting can begin. Thorough diagnosis of a Rehiko EFI engine requires the use of Special Tools to scan for DTC's, read live sensor data and measure fuel pressure. These Special Tools are listed in the Tools and Aids section of this service manual. Failure to use these special tools may lead to misdiagnosis and unnecessary parts replacement.

Engine Cranks But Will Not Start

- Battery connected backwards.
- Blown fuse.
- Clogged fuel line or fuel filter.
- 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.
- 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).
- Spark plug lead(s) disconnected.

Engine Starts But Does Not Keep Running

- Faulty cylinder head gasket.
- Faulty or misadjusted 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 (Retractable Start).
- Faulty or misadjusted 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 (Retractable Start).
- Seized internal engine components.

Engine Runs But Misses

- Engine overheated.
- Faulty spark plug(s).
- Ignition coil(s) faulty.
- Incorrect crankshaft position sensor air gap (only on engines with earlier design bracket with slots allowing adjustment).
- 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 speed adjusting screw improperly set (this is not a feature on engines equipped with an electronic throttle body).
- 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.
- High crankcase oil level.
- Lean fuel mixture.
- Low crankcase oil level.
- Cooling system components clogged or restricted.

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 (on engines equipped with electronic throttle body governor is digitally controlled and not adjustable).
- 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 throttle body 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
	Cleaning Solvents can cause severe injury or death. Use only in well ventilated areas away from ignition sources.
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.	

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.

CRANKCASE VACUUM TEST

	⚠ WARNING
	Carbon Monoxide can cause severe nausea, fainting or death. Avoid inhaling exhaust fumes. Never run engine indoors or in enclosed spaces.
Engine exhaust gases contain poisonous carbon monoxide. Carbon monoxide is odorless, colorless, and can cause death if inhaled.	

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

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 (inches of water gauge only). 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 (inches of water gauge only):

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.	NOTE: If breather is integral part of valve cover and cannot be serviced separately, replace valve cover and recheck pressure. Disassemble breather, clean parts thoroughly, check sealing surfaces for flatness, reassemble, and recheck pressure.
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

NOTE: This engine utilizes an Engine Control Unit (ECU) controlled Electronic Throttle Body (ETB). The ETB precisely regulates airflow and is typically not fully open during normal engine cranking, which would restrict maximum airflow and result in an inaccurate (low) compression reading. Rehiko® Diagnostic System (KDS) Gen 2 must be used to accurately measure compression.

NOTE: Rehiko® Diagnostic System (KDS) Gen 2 system tests as mentioned within this manual, are available to dealers only. Special tests are not activated within KDS tool for non Rehiko dealers.

A compression test is best performed on a warm engine. Clean any dirt or debris away from base of spark plug before removing it. **Be sure battery is fully charged and throttle is wide open during test.** Some models (retractable start) 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.

Step-by-Step Procedure

1. Preparation: Warm the engine to operating temperature. Disconnect high pressure fuel pump electrical connector from high pressure fuel pump module. A trouble code will be set and will be cleared during a later step. Clean dirt/debris from base of spark plugs before removing them.
2. Access: Remove all spark plugs and install compression tester gauge.
3. Wide Open Throttle (WOT) Command:
Connect the Diagnostic System (KDS).
Select Engine and Navigate to the "Tests" function.
Select "Compression Test" and follow on screen instructions.
4. Test: Crank the engine (typically 4-6 compression strokes) until the gauge peaks. Record the reading.
5. Completion: Complete all listed steps in "Compression Test" shown on KDS.
6. Results: Compression should be at least 160 psi and should not vary more than 15% between cylinders.

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.

Dual Gauge Test Procedure

1. Run engine until oil temperature reaches and maintains 150°F (66°C) or more for a minimum of 5 minutes. Ideally, engine should be run under normal load conditions.
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 from kit 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 engine cannot rotate off TDC in either direction.
4. Connect an air source (at least 100 PSI) to tool.
5. Turn regulator knob clockwise (increase direction). Confirm both gauges read approximately the same air pressure from 0 to 80 PSI. Note any discrepancies between gauges for leakage calculation. Release pressure by turning regulator knob completely counterclockwise before proceeding.
6. Install adapter hose into spark plug hole of cylinder being tested. Use 12 mm x 14 mm adapter if required.
7. Firmly hold engine at TDC. Connect other end of adapter hose to tool quick connect. Turn regulator knob clockwise (increase direction) until left gauge needle reads 20 PSI.

NOTE: When piston is at TDC, little to no holding force should be required when air pressure is applied to cylinder. If excess holding force is required, this indicates piston is not at TDC. Readjust as necessary before proceeding.

8. Slowly turn regulator knob clockwise until left hand gauge maintains selected test pressure (see chart below).

Left Gauge Regulated Pressure Selection

80 PSI

Recommended for engines over 200 cc or those exhibiting high leakage at 35 PSI setting.

35 PSI

Recommended for single cylinder walk-behind push mower applications.

9. Compare right gauge reading to Test Pressure Chart on next page to identify percentage of leakage. Also refer to Leakdown Test Results chart on next page for colors, conditions, and action required.
10. For engines exhibiting leakage in yellow or red zone, repeat test procedure. Operate engine under normal load conditions prior to test. Confirm piston is at TDC during test.

NOTE: To prevent damage to gauge assembly, always turn pressure regulator knob to zero (counterclockwise) after each test.

Test Pressure Chart for Dual Gauge Tool

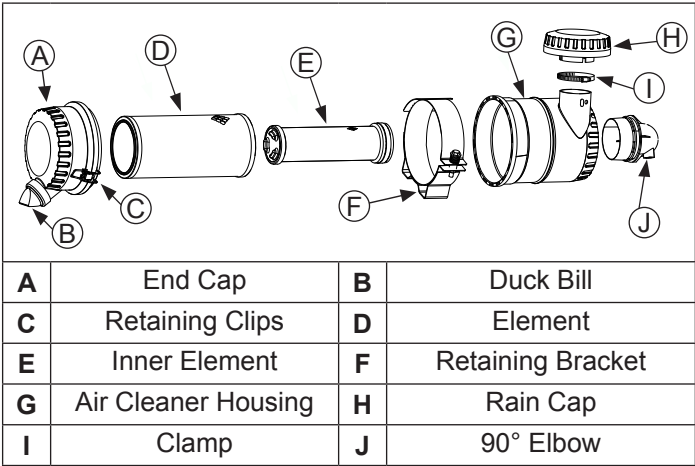
Left Gauge Regulated Pressure Selection	Right Gauge Reading in PSI										
80 PSI Recommended for engines over 200 cc or those exhibiting high leakage at 35 PSI setting.	80	72	64	56	48	40	32	24	16	8	0
35 PSI Recommended for single cylinder walk-behind push mower applications.	35	31.5	28	24.5	21	17.5	14	10.5	7	3.5	0
Percentage of leakage	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	Green Zone					Yellow Zone			Red Zone		

Leakdown Test Results

Test Result	Condition	Action
Gauge reading in low (green) zone.	Piston rings and cylinder in good condition.	No further action required.
Gauge reading in moderate (yellow) zone.	Air escaping from crankcase breather and/or dipstick tube.	Some wear present causing leakage from combustion chamber to crankcase. Repair not required at this time if breather system is functioning normally.
	Air escaping from exhaust.	Exhaust valve leakage present, possibly due to carbon deposits. Repair not required. Carbon cleaning could be performed to reduce leakage.
	Air escaping from intake.	Intake valve leakage present, possibly due to carbon deposits. Repair not required. Carbon cleaning could be performed to reduce leakage.
Gauge reading in high (red) zone. Confirm consecutive leakdown test has been performed AFTER engine has been operated under normal load conditions.	Air escaping from crankcase breather and/or dipstick tube.	Excess wear present causing leakage from combustion chamber to crankcase. Breather system will not function normally and will fail crankcase vacuum test if this condition is truly present. Engine disassembly and analysis required to determine root cause and correction.
	Air escaping from exhaust.	Excess exhaust valve leakage present, possibly due to carbon deposits and/or valve to seat sealing issues. Carbon cleaning may reduce leakage. Valve grind and/or component replacement may be necessary. Excess oil consumption and/or excess heat is a suspect cause and must be resolved to prevent reoccurrence.
	Air escaping from intake.	Excess intake valve leakage present, possibly due to carbon deposits and/or valve to seat sealing issues. Carbon cleaning may reduce leakage. Valve grind and/or component replacement may be necessary. Excess oil consumption through intake valve and/or excess heat is a suspect cause and must be resolved to prevent reoccurrence. Inspect breather system components and intake valve stem sealing.

AIR CLEANER

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



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 duck bill 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. Inspect for any debris visible through flywheel cooling holes (if equipped) and clean as necessary. 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.
- Electronic throttle body (ETB)/intake manifold.
- Electronic control unit (ECU).
- Ignition coils.
- Engine temperature sensor.
- Throttle position sensor (TPS) is contactless and not serviceable.
- Crankshaft position sensor.
- Oxygen sensor.
- Temperature/manifold absolute pressure (TMAP) sensor.
- Malfunction indicator light (MIL)-optional.
- 30 Amp fuse (charging system).
- Refer to equipment manual for fuse detail in OEM supplied wiring harness (high output charging system).
- 10 Amp fuse (ignition switch).
- 10 Amp fuse (battery power).
- Wire harness assembly & affiliated wiring.

FUEL RECOMMENDATIONS

Refer to Maintenance.

FUEL LINE

Low permeation fuel line must be installed on all Rehiko 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.

NOTE: Replacement ECUs are shipped unprogrammed (blank). The ECU **MUST** be programmed/flushed with the correct engine-specific calibration file using the Rehiko Diagnostic System (KDS) software. Failure to program/flash the ECU will result in a no-start condition.

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 Electronic Control Unit (ECU) which manages system operation, determining best combination of fuel mixture, ignition timing, throttle opening and/or engine RPM for current operating conditions.

ETB engines feature an ECU that uses CAN BUS/J1939 communication protocols and may be linked to other electronic control modules installed on the application. Refer to the equipment manufacturer's manual for confirmation of additional modules and operational details

Native fault codes on ETB engines are transmitted in J1939 protocol. For consistency and familiarity, Rehiko service literature and the diagnostic tool continue to display and reference the equivalent SAE P-code (example: P0122).

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, operator requested engine 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:

- Engine 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 temperature greater than 50-60°C (122-140°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.

EFI System-Electronic Throttle Body (ETB)

ECU is brain or central processing computer of entire EFI and ETB/electronic governor 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, requested customer speed input, oil temperature, intake air temperature, exhaust oxygen levels, manifold absolute pressure, and battery voltage.

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, ignition timing, and ETB throttle opening.

ECU continually performs a diagnostic check of itself, each sensor, 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 codes using the Rehiko Diagnostic System (KDS) Gen 2, 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 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.

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 or customer speed input/ETB throttle opening) reacts to engine load, angle of throttle plate is directly related to load on engine.

TPS is sealed and not serviced separately. Mounted on electronic 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.

TPS auto-learn is an automated process. No adjustment is required.

Engine 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.

Temperature/Manifold Absolute Pressure (TMAP) sensor is an integrated sensor that checks both intake air temperature and manifold absolute pressure.

Intake Air Temperature control 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 sensing air temperature 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 check provides immediate manifold pressure information to ECU. TMAP sensor 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.

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 protrudes into exhaust gas. When oxygen concentration on one side of tip is different than that of other side, a voltage signal up to 0.98 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 (during normal running).

ETB EFI engines are equipped with either a 20 amp or high output 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 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 (3.51 gallons) per hour and regulated at 270 kilopascals (39 psi).

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 electronic 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 evaporative emissions compliance. Purge port connects to vent hose assembly and directs all fuel vapor into electronic 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 electronic throttle body (ETB) attached to intake manifold. ETB is an assembly of three functional components: 1) A mechanical throttle body to control air flow to engine. 2) A DC electric motor and gear reduction to drive and position throttle blade. 3) A non-contact throttle position sensor to measure throttle position. This technology is common on many modern automobiles, including a return spring feature. Return spring will mechanically return throttle blade to a home position if power is lost or interrupted to drive motor. Home position is above normal low idle position, but typically is low RPM and very low load.

ETB (Electronic throttle body)/intake manifold provides mounting for fuel injectors, throttle position sensor, TMAP sensor, high pressure fuel line, and air cleaner assembly.

ETB Engine idle speed is not adjustable and is preset and controlled by ECU. Standard idle speed setting for EFI engines is 1500 RPM, but certain applications might require a different setting.

The ECU continuously monitors engine speed, load, temperatures, and other parameters via sensors, while receiving the primary speed request from the OEM controller through one of two possible interfaces:

- Analog voltage input (0–5 V)
- CANBUS communication

Consult OEM service information to confirm interface type.

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 be different than normal for a few moments. Idle speed typically starts higher than normal, but gradually decreases to established setting as operation continues. Engine must be completely warmed up, in closed loop operating mode for accurate idle check.

IMPORTANT NOTES!

- Thorough diagnosis of a Rehlko EFI engine requires the use of Special Tools to scan for DTC's, read live sensor data and measure fuel pressure. These Special Tools are listed in the Tools and Aids section of this service manual. Failure to use these special tools may lead to misdiagnosis and unnecessary parts replacement.
- 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.

REHLKO DIAGNOSTIC SYSTEM (see Tools and Aids)

- Software features: Reading/clearing DTCs (diagnostic trouble codes), live data streaming (sensors, RPM, temperatures, load, etc.), data logging, graphs, access to built-in service manuals, TPS (throttle position sensor) initialization/reset, oxygen sensor diagnostics, and system testing. Supports all Rehlko EFI engines equipped with 4 or 7-pin diagnostic connector
- Only the PC (Windows) version of the Rehlko Diagnostic System (Gen 2) is capable of flashing/programming a replacement ECU.
- Mobile (KDS) Gen 2 and the mobile apps (Android/iOS) do not support ECU flashing, but remain fully functional for reading/clearing codes, live data, TPS initialization, active tests, etc.
- Every diagnostic kit (PC and Mobile) includes a software license serial number and quick-start guide explaining the software installation and registration process.
- Tool Registration: Communication with an ETB (Electronic Throttle Body) engine requires tool registration per the instructions provided in the diagnostic kit. ETB engines are not listed in engine menu by default.
- Dealer Access Restriction: Access to advanced Special Test Functions is limited to authorized Rehlko dealers only. These features are not activated within the diagnostic tool for non-Rehlko dealer service centers.

ELECTRICAL COMPONENTS

Electronic Control Unit (ECU)

Pinout of ECU

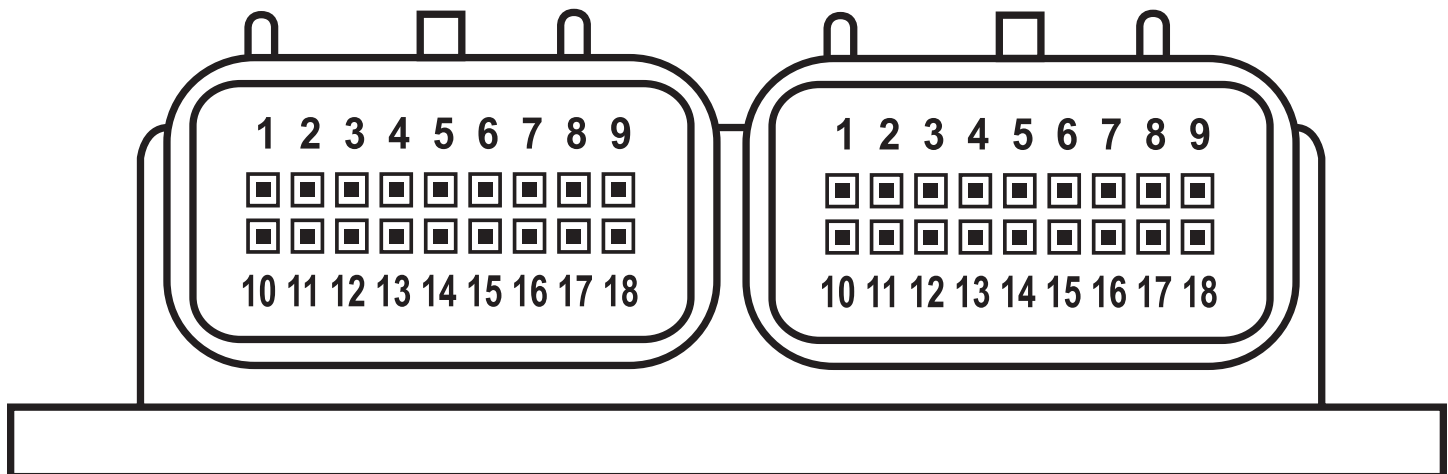
Black Connector Side	
Pin #	Description
1	Ignition Coil #1 Ground
2	Battery Ground
3	Not Used
4	Crankshaft Position Sensor Input High
5	Fuel Injector Output #1 Ground
6	Fuel Injector Output #2 Ground
7	Oxygen Sensor Heater
8	Intake Air Temperature (TMAP) Sensor Input
9	Fuel Pump Ground
10	Ground for TPS, TMAP, O2, and Temp sensors
11	Manifold Absolute Pressure (TMAP) sensor input
12	Throttle Position Sensor (TPS) input
13	Crankshaft Position Sensor Low
14	Engine Temperature Sensor input
15	Ignition Switch (Switched +12V)
16	Power for TPS and 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	Tach Out
7	CAN Low
8	CAN High
9	Battery Ground
10	Ignition Coil #2 Ground
11	ETB Motor High
12	ETB Motor Low
13	Desired Engine Speed Input (0-5V)
14	Safety Switch Ground
15	Not Used
16	ECU Reset
17	Fuel Pump Control (+12V)
18	Not Used

ECU

BLACK CONNECTOR SIDE

GREY CONNECTOR SIDE



EFI System-Electronic Throttle Body (ETB)

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. TPS to throttle shaft positioning is an automated process performed at key cycle and cannot be altered.

Any service to ECU, TPS/Electronic Throttle Body, or fuel pump module replacement should include ECU Reset.

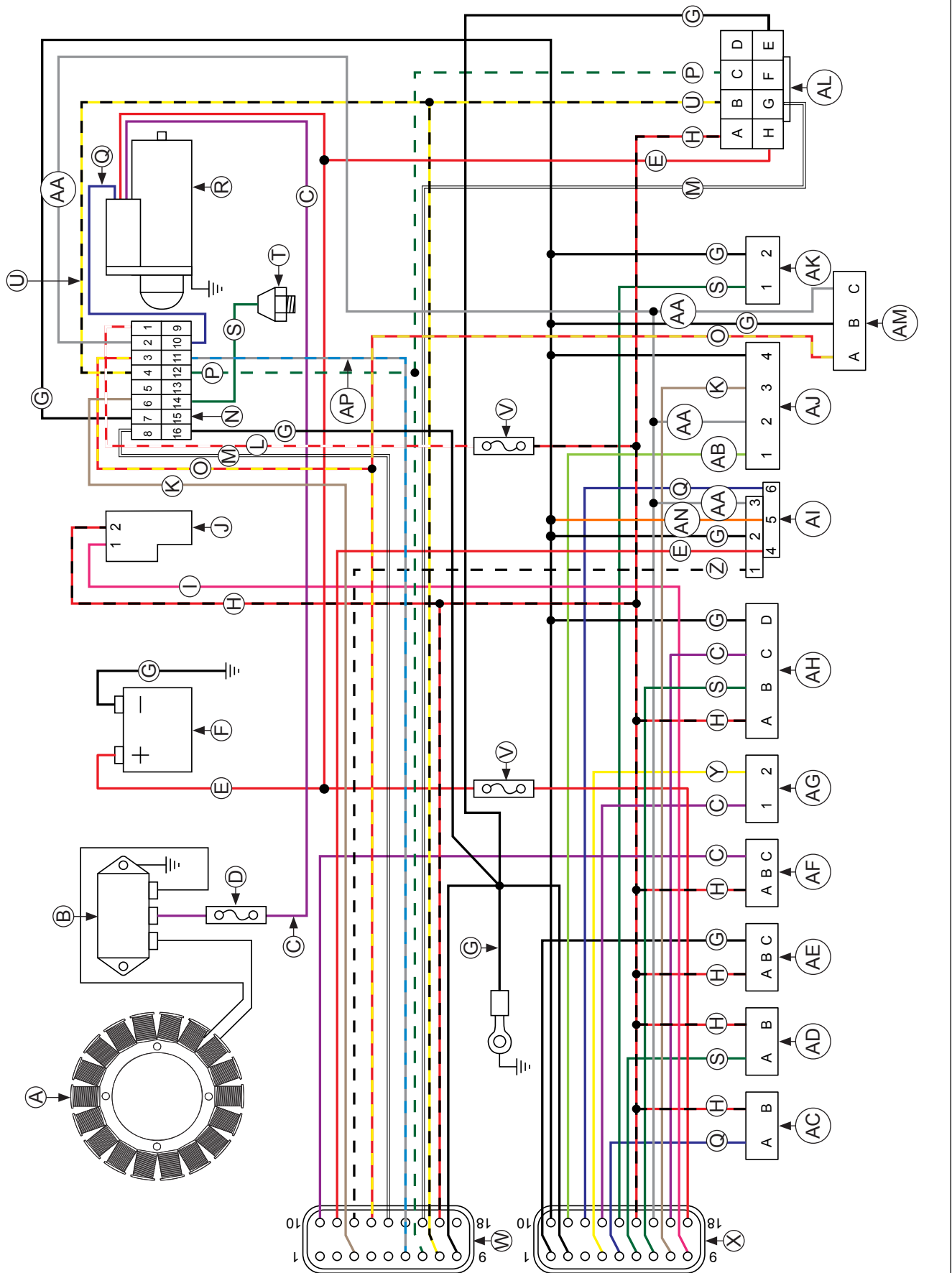
This will clear all trouble codes, all closed loop learned offsets, all max values, and all timers besides permanent hour meter.

This system will NOT reset when battery is disconnected!

ECU Reset Procedure

1. Turn key/ignition OFF.
2. Install Green colored wire jumper from Rehlko EFI service kit on to diagnostic port (or connect white wire to black wire (terminals G and E) in 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 Green colored wire jumper. Turn key/ignition ON, then OFF and count to 10 seconds a third time. ECU is reset.

ETB EFI Wiring Harness 20 Amp



EFI System-Electronic Throttle Body (ETB)

ETB EFI Wiring Harness 20 Amp Detail							
A	Stator	B	Rectifier-Regulator	C	Purple	D	30A Fuse
E	Red	F	Battery	G	Black	H	Red/Black
I	Pink	J	Fuel Pump Module	K	Tan	L	Red/White
M	White	N	16-Terminal Connector	O	Red/Yellow	P	Green/White
Q	Dark Blue	R	Starter Motor	S	Dark Green	T	Oil Pressure Switch
U	Yellow/Black	V	10A Fuse	W	Grey Connector	X	Black Connector
Y	Yellow	Z	Black/White	AA	Grey	AB	Light Green
AC	Fuel Injector #1	AD	Fuel Injector #2	AE	Ignition Coil #1	AF	Ignition Coil #2
AG	Crankshaft Position Sensor	AH	Oxygen Sensor	AI	Electronic Throttle Control	AJ	TMAP Sensor
AK	Engine Temperature Sensor	AL	Diagnostic Connector (8 Bay, 7 Pin)	AM	Throttle Position Sensor	AN	Orange
AO	Grey/Blue						

Troubleshooting Guide

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

EFI System-Electronic Throttle Body (ETB)

Fault Code Summary

Fault Code	Connection or Failure Description	SAE J1939 Fault Codes	
		SPN	FMI
P0031	Oxygen Sensor Heater Circuit Low Voltage	3056	5
P0032	Oxygen Sensor Heater Circuit High Voltage	3056	6
P0107	Manifold Absolute Pressure Sensor Circuit Low Voltage or Open	102	4
P0108	Manifold Absolute Pressure Sensor Circuit High Voltage	102	3
P0112	Intake Air Temperature Sensor Circuit Low Voltage	105	4
P0113	Intake Air Temperature Sensor Circuit High Voltage or Open	105	3
P0117	Engine Temperature Sensor Circuit Low Voltage	110	4
P0118	Engine Temperature Sensor Circuit High Voltage or Open	110	3
P0122	Throttle Position Sensor Circuit Low Voltage or Open	51	4
P0123	Throttle Position Sensor Circuit High Voltage	51	3
P0131	Oxygen Sensor 1 Circuit Low Voltage, or Open	3056	4
P0132	Oxygen Sensor 1 Circuit High Voltage	3056	3
P0171*	Maximum Adaptation Limit Exceeded	4237	0
P0172*	Minimum Adaptation Limit Exceeded	4237	1
P0174	Lean Fuel Condition at High Load (Open Loop)	4237	31
P0201	Injector 1 Circuit Malfunction	651	31
P0202	Injector 2 Circuit Malfunction	652	31
P0217	Overheat Condition	110	0
P0230	Fuel Pump Module Circuit Low Voltage or Open	1347	5
P0232	Fuel Pump Module Circuit High Voltage	1347	6
P0336	Crankshaft Position Sensor Noisy Signal	636	2
P0337	False Start Detected/CKP Sensor Signal	636	8
P0351	Cylinder 1 Ignition Coil Malfunction	1268	31
P0352	Cylinder 2 Ignition Coil Malfunction	1269	31
P0562	System Voltage Low	168	4
P0563	System Voltage High	168	3
P2100	Throttle Actuator Control Motor Circuit Open (Low Current Fault)	5419	5
P2119	Throttle Actuator Stuck	5419	7

NOTE: Any fault code marked with an asterisk (*) must be cleared using the ECU reset procedure See page 34.

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 occurring, and dealer service is required. Upon receipt, dealer technician can access fault code(s) to help determine what portion of system is malfunctioning.

MIL (Malfunction Indicator Lamp) activated Diagnostic Trouble Codes (DTCs) are retrieved using the Rehlko Diagnostic System (KDS) Gen 2 (see Tools and Aids.) via the 7-pin diagnostic connector on the engine.

KDS Gen 2 Tool Activation and Access:

- Tool Registration: To enable advanced features and additional engine families, including special test functions for ETB (Electronic Throttle Body), tool registration (per the instructions provided in the kit) is required.
- Dealer Access Restriction: Access to advanced Special Test Functions is limited to authorized Rehlko dealers only. These features are not activated within the KDS tool for non-Rehlko dealer service centers.

After problem has been corrected, fault codes may be cleared by using Clear Codes command on Rehlko Diagnostic System (KDS) Gen 2.

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.

Note: Special Tools are listed in the Tools and Aids section of this service manual. Failure to use these special tools may lead to misdiagnosis and unnecessary parts replacement.

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.

ECU circuit will flow small amount of current. This may dimly illuminate LED type bulb. On is bright. Resistor can be added in series if LED type bulb is used to eliminate glow.

Diagnostic Code Summary

Fault Code	SPN	FMI
Code P0031	3056	5

NOTE: Codes P0031 and P0032 may have been mistakenly activated by turning key ON with oxygen sensor disconnected. If either code status is inactive, that code may have set during assembly or a previous repair and may not be related to current event. Clear codes and retest to confirm. If code status is active, refer to Oxygen Sensor (O2) earlier in this section, to test and troubleshoot.

Component:	Oxygen Sensor Heater
Function:	Sensor heater ensures that sensor reaches operating temperature
Fault:	O2S Heater Circuit Low Voltage
Condition:	System voltage too low, open connection or faulty sensor.
Possible Causes:	Engine Wiring Harness Related - Pin circuit wiring or connectors. - ECU Black pin 7 or broken wire. Oxygen Sensor Related - Sensor connector or wiring problem. Poor system ground from ECU to engine or battery to engine.
Testing:	See Troubleshooting-Oxygen (O2) Sensor on page 46.

Fault Code	SPN	FMI
Code P0032	3056	6

NOTE: Codes P0031 and P0032 may have been mistakenly activated by turning key ON with oxygen sensor disconnected. If either code status is inactive, that code may have set during assembly or a previous repair and may not be related to current event. Clear codes and retest to confirm. If code status is active, refer to Oxygen Sensor (O2) earlier in this section, to test and troubleshoot.

Component:	Oxygen Sensor Heater
Function:	Sensor heater ensures that sensor reaches operating temperature
Fault:	O2S Heater Circuit High Voltage
Condition:	System voltage too high, shorted connection or faulty sensor.
Possible Causes:	Oxygen Sensor Related - Sensor connector or wiring problem. - Sensor damaged. - Pin circuit wiring or connectors at Black 7. ECU Related - ECU-to-harness connection problem.
Testing:	See Troubleshooting-Oxygen (O2) Sensor on page 46.

Fault Code	SPN	FMI
Code P0107	102	4

Component:	Manifold Absolute Pressure (TMAP)
Function:	Measures intake manifold pressure and transmits data to ECU
Fault:	MAP Circuit Low Voltage or Open
Condition:	Intake manifold leak, open connection or faulty sensor.
Possible Causes:	TMAP Sensor Related • Sensor malfunction. • Vacuum leaks from loose manifold or sensor. Wire Harness Related • Poor grounding or open circuit. • Wire harness and connectors loose, damaged or corroded. • Pin circuit wiring or connectors at Black 10, 11 and 16.
Testing	See Temperature/Manifold Absolute Pressure (TMAP) Sensor to right. Preferred Method: Use Rehlko Diagnostic System to confirm sensor function

Fault Code	SPN	FMI
Code P0108	102	3

Component:	Manifold Absolute Pressure (TMAP)
Function:	Measures intake manifold pressure and transmits data to ECU
Fault:	MAP Circuit High Voltage
Condition:	Intake manifold leak, shorted connection or faulty sensor.
Possible Causes:	TMAP Sensor Related • Sensor malfunction. • Vacuum leaks from loose manifold or sensor. Wire Harness Related • Poor grounding. • Pin circuit wiring or connectors at Black 11.
Testing	See Temperature/Manifold Absolute Pressure (TMAP) Sensor to right. Preferred Method: Use Rehlko Diagnostic System to confirm sensor function.

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 troubleshooting 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.
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.

Fault Code	SPN	FMI
Code P0112	105	4

Component:	Intake Air Temperature (TMAP)
Function:	Measures intake air temperature and transmits data to ECU
Fault:	Intake Air Temperature Sensor Circuit Low Voltage
Condition:	Shorted connection, faulty sensor or shorted wire.
Possible Causes:	TMAP Sensor Related • Sensor wiring or connection. Engine Wiring Harness Related • Pin circuits ECU Black pin 10 and Black 8 may be damaged or routed near noisy signal (coils, stator, etc.). • ECU-to-harness connection problem.
Testing:	See Temperature/Manifold Absolute Pressure (TMAP) Sensor to right. Preferred Method: Use Rehlko Diagnostic System to confirm sensor function.

Fault Code	SPN	FMI
Code P0113	105	3

Component:	Intake Air Temperature (TMAP)
Function:	Measures intake air temperature and transmits data to ECU
Fault:	Intake Air Temperature Sensor Circuit High Voltage or Open
Condition:	Shorted connection, faulty sensor, broken wire or connection.
Possible Causes:	TMAP Sensor Related • Sensor wiring or connection. Engine Wiring Harness Related • Pin circuits ECU Black pin 10 and 8 may be damaged. • ECU-to-harness connection problem or broken wire.
Testing:	See Temperature/Manifold Absolute Pressure (TMAP) Sensor to right. Preferred Method: Use Rehlko Diagnostic System to confirm sensor function.

Temperature/Manifold Absolute Pressure (TMAP) Sensor

If troubleshooting 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 Procedure to see if MIL will display a fault with sensor again. If MIL finds a fault with TMAP sensor, replace it.

Fault Code	SPN	FMI
Code P0117	110	4

Component:	Engine Temperature Sensor
Function:	Continuously measures engine temperature and transmits data to ECU
Fault:	Engine Temperature Sensor Circuit Low Voltage
Condition:	Shorted connection, faulty sensor or shorted wire.
Possible Causes:	Temperature Sensor Related • Sensor wiring or connection. Engine Wiring Harness Related • Pin circuits ECU Black pin 10 and Black 14 may be damaged or routed near noisy signal (coils, stator, etc.). • ECU-to-harness connection problem.
Testing:	See Engine Temperature Sensor (Lead). Preferred Method: Use Rehlko Diagnostic System to confirm sensor function.

Fault Code	SPN	FMI
Code P0118	110	3

Component:	Engine Temperature Sensor
Function:	Continuously measures engine temperature and transmits data to ECU
Fault:	Engine Temperature Sensor Circuit High Voltage or Open
Condition:	Shorted connection, faulty sensor, open connection or broken wire.
Possible Causes:	Temperature Sensor Related • Sensor wiring or connection. Engine Wiring Harness Related • Pin circuits ECU Black pin 10 and 14 may be damaged. • ECU-to-harness connection problem or broken wire. System Related • Engine is operating above 176°C (350°F) temperature sensor limit.
Testing:	See Engine Temperature Sensor (Lead). Preferred Method: Use Rehlko Diagnostic System to confirm sensor function.

Engine Temperature Sensor (Lead)

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

1. Remove temperature sensor from crankcase next to 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.

Fault Code	SPN	FMI
Code P0122	51	4
Component:	Throttle Position Sensor (TPS)	
Function:	Monitors throttle plate angle and transmits data to ECU	
Fault:	TPS Circuit Low Voltage or Open	
Condition:	Open connection, broken wire or faulty sensor.	
Possible Causes:	TPS Related • TPS bad or worn internally. Engine Wiring Harness Related • Broken or shorted wire in harness. - ECU Black pin 10 to TPS pin 1. - ECU Black pin 12 to TPS pin 3. - ECU Black pin 16 to TPS pin 2. Throttle Body Related • 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. ECU Related • Circuit providing voltage or ground to TPS damaged. • TPS signal input circuit damaged.	
Testing:	See Throttle Position Sensor (TPS) troubleshooting. Preferred Method: Use Rehlko Diagnostic System to confirm sensor function.	

Fault Code	SPN	FMI
Code P0123	51	3
Component:	Throttle Position Sensor (TPS)	
Function:	Monitors throttle plate angle and transmits data to ECU	
Fault:	TPS Circuit High Voltage	
Condition:	Shorted connection or faulty sensor.	
Possible Causes:	TPS Sensor Related • Sensor connector or wiring. Throttle Body Related • Throttle shaft or bearings worn/damaged. Engine Wiring Harness Related • ECU pins Black 10, 12 and 16 damaged (wiring, connectors). • ECU pins Black 10, 12 and 16 routed near noisy electrical signal (coils, stator). • Intermittent 5 volt source from ECU (pin Black 16). • ECU-to-harness connection problem.	
Testing:	See Throttle Position Sensor (TPS) troubleshooting. Preferred Method: Use Rehlko Diagnostic System to confirm sensor function.	

Throttle Position Sensor (TPS) Troubleshooting

TPS is a sealed, non-serviceable internal part of electronic throttle body assembly. If diagnosis indicates a bad sensor, complete electronic throttle body replacement is necessary. 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. If a troubleshooting 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:

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

If Rehlko Diagnostic System (KDS) Gen 2 is available (see Tools and Aids) Refer to page 19.

Observe throttle percent and raw TPS values through diagnostic tool. With diagnostic tool communicating to ECU and key ON engine not running, these values can be observed using Throttle Position test within tool test options. Select Throttle Position Test, (see instructions within help (?) area of test.) Select desired percent of throttle opening. (For example, 50% requested opening will yield 50% TPS opening +/- 5%.) It is recommended to perform multiple tests in different throttle opening positions. (For example, 10%, 50%, and 100%.) If any of these tests are found to be outside of specified range, it is recommended to power engine down, wait 15 seconds, turn engine key switch power to ON position, and using diagnostic tool, repeat Throttle Opening Test. If values again are found to be outside of specified range, it is recommended to replace electronic throttle body assembly. If no results are found while performing this test, a small load or gentle back and forth motion can be applied to connectors or wires just outside connectors to detect a faulty connection.

EFI System-Electronic Throttle Body (ETB)

Fault Code	SPN	FMI
Code P0131	3056	4

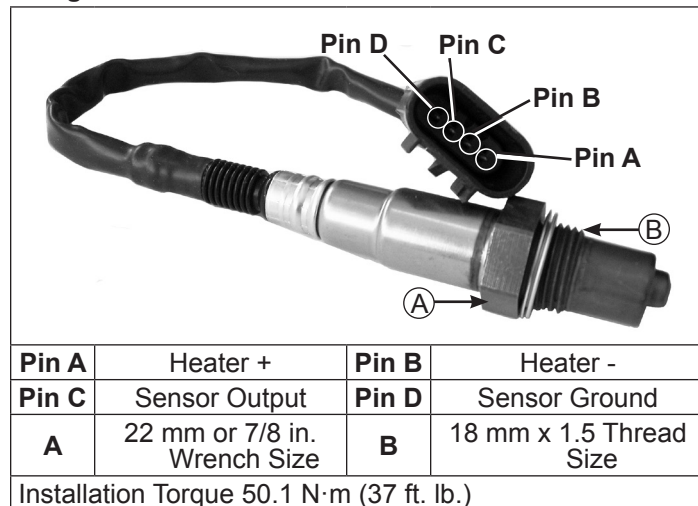
Component:	Oxygen Sensor
Function:	Measure exhaust oxygen content
Fault:	O2S 1 Circuit Low Voltage
Condition:	Open connection, broken wire or faulty sensor.
Possible Causes:	Oxygen Sensor Related • Sensor connector or wiring problem. • Sensor contaminated, corroded or damaged. • Poor ground path. • Pin circuit wiring or connectors. ECU Black pin 10 or 17. TPS Auto-Learn Incorrect • Lean condition (check oxygen sensor signal with VOA and see Oxygen Sensor). Engine wiring harness related such as a cut wire, broken or pinched.
Testing:	See troubleshooting starting on page 44.

Fault Code	SPN	FMI
Code P0132	3056	3

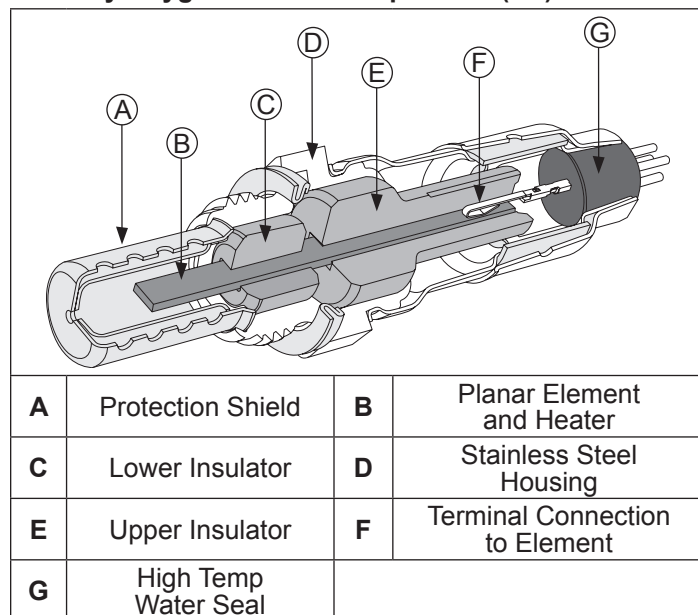
Component:	Oxygen Sensor
Function:	Measure exhaust oxygen content
Fault:	O2S 1 Circuit High Voltage
Condition:	Shorted connection or faulty sensor.
Possible Causes:	Oxygen Sensor Related • Sensor connector or wiring problem. • Sensor contaminated or damaged. • Poor ground path. • Pin circuit wiring or connectors. ECU Black pin 10 or Black pin 17. Engine Wiring Harness Related • Difference in voltage between sensed voltage and actual sensor voltage. • Short in wire harness.
Testing:	See troubleshooting starting on page 44.

Oxygen Sensor (O2)

Design Detail



Cutaway Oxygen Sensor Components (O2)

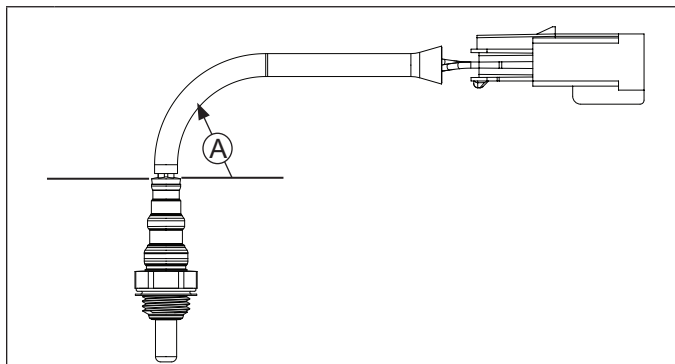


Absolute accuracy requires lab equipment, and intermittent faults remain difficult to pinpoint. However, solid system knowledge enables reliable diagnosis of most common faults.

Using Rehlko Diagnostic System (KDS) Gen 2, (see Tools and Aids), 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 diagnostic tool means that it is not reading continuous output of sensor. A voltmeter can also be used as an effective tool in diagnosing sensors.

Using "Adjust Injector Time" test within the diagnostic tool software will aid in testing operation of O2 sensor. See instructions within help (?) area of test.

Visual Inspection Sensor Wire Detail



- | | |
|----------|--|
| A | Keep a minimum of 25 mm (1.0 in.) radius at grommet. |
|----------|--|

NOTE: Always route harness away from hot exhaust and away from moving parts.

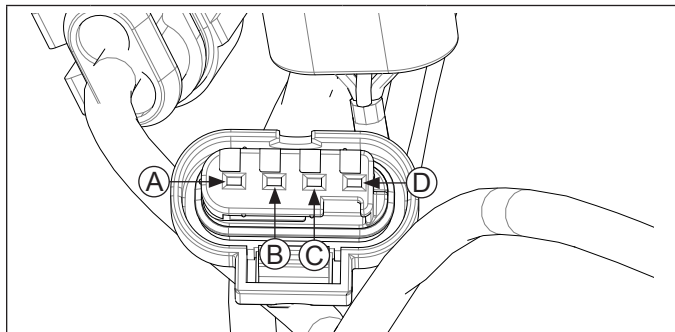
NOTE: **Do not attempt to clean sensor.** Replace as needed.

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.
6. Inspect for any exhaust system leaks upstream or downstream of oxygen sensor. Confirm oxygen sensor is secured to 50.1 N·m (37 ft. lb.).

All leaks must be repaired and an ECU reset must be performed before proceeding with sensor testing.

7. Using diagnostic tool, document any trouble codes. Determine if historic trouble codes are logically related to current fault experienced. If uncertain, clear codes and retest.

Sensor Signal Observation Engine Harness O2 Sensor Connector Plug Detail



A	Red w/Black Stripe	B	Dark Green
C	Purple	D	Black

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. With sensor connected and using Rehlko Diagnostic System (KDS) Gen 2, see Tools and Aids, start engine to observe O2 sensor activity. Run engine at sufficient speed to bring sensor and engine up to operating temperature (engine temperature of 150°F (66°C) or more displayed by Diagnostic tool).

Maintained throttle openings of less than 20% typically display closed loop operation where sensor output voltage should cycle between 0.05 to 0.95 Volts.

Maintained throttle openings of 30-40% and above typically display open loop operation where sensor should have above 0.500 Volt. Occasional spikes outside these values is normal. Lack of continuous fluctuation is not an indication of a defective sensor.

2. With key ON and engine OFF, sensor connected, using diagnostic software, O2 volts displayed should be more than 1.0 volt. This voltage is generated by ECU. If not present, there may be a power and/or ground supply fault to engine harness or ECU, a fault of engine harness itself (refer to Visual Inspection), or a fault of ECU.

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.

With key ON and sensor unplugged, using a digital voltmeter, observe voltage between Pin socket C and Pin socket D of engine wiring harness (refer to engine harness connector plug detail on page). Voltage should read approximately 5.0 volts.

3. Using a digital voltmeter, observe system sensor voltage between Pin socket A and negative (-) battery ground. Battery voltage should be seen. If battery voltage is not seen, inspect engine wiring, fuses, and/or electrical connections.

Sensor 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. With sensor at room temperature measure heater circuit resistance, Heater + (Pin A) and Heater - (Pin B), resistance should be 8.1-11.1 Ω .
4. If a damaged sensor is found, identify root cause, which may be elsewhere in application. Refer to Troubleshooting-Oxygen (O2) Sensor table.
5. 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. Torque sensor to 50.1 N·m (37 ft. lb.).

Troubleshooting-Oxygen (O2) Sensor

Condition	Possible Cause	Conclusion
Continuous low voltage output (less than 400mV) observed with throttle openings of 40% or more (lean biased condition). Fault codes P0131, P0171, or P0174 may set.	Shorted sensor or sensor circuit.	Replace sensor or replace and properly route wiring.
	Shorted lead wire.	
	Wiring shorted to ground.	
	Upstream or downstream exhaust leaks observed.	Repair all exhaust leaks and torque sensor to 50.1 N·m (37 ft. lb.).
	Air leak at sensor.	
	Restricted fuel supply.	Resolve fuel supply issues from tank to engine. Test fuel pressure. Perform repairs necessary.
	Misfire	A misfire causing incomplete combustion will result in lean (low voltage) values.
	Lean biased sensor failure.	Replace sensor.
	Silica poisoning.	Replace sensor. Identify and resolve root cause.
	Contaminated gasoline.	Purge fuel system and retest.
Continuous high voltage output (600mV or more) observed with throttle openings of 40% or less (rich biased condition). Fault codes P0172 or P0132 may set.	Wiring shorted to voltage.	Replace damaged harness.
	Overly rich condition due to unmetered fuel entering combustion chamber.	Test fuel pressure. Inspect fuel pump vent and evaporative emissions hoses for raw fuel flow. Inspect engine oil for fuel contamination; drain and refill if suspect. Perform repairs as necessary.
	Cold engine. Engine temperature below 150°F (66°C) as displayed by Rehlko® Diagnostic System (KDS) Gen 2, see Tools and Aids.	Normal operation, or engine operated in an excessively cold environment.
	Rich biased sensor failure.	Replace sensor.
	Heater circuit open or shorted.	Replace sensor.
No activity from sensor. KDS tool displays 1.015 Volts continuously. Fault codes P0031 or P0032 may set.	Engine keyed ON with sensor disconnected.	Secure and/or confirm sensor connection and clear codes.
	Historic codes.	
	Contaminated gasoline.	Purge fuel system and retest.

Fault Code		SPN	FMI
Code P0171		4237	0
Component:	Fuel System		
Function:	Fuel Delivery		
Fault:	Maximum adaptation limit exceeded		
Condition:	Fuel inlet screen/filter plugged, low pressure at high pressure fuel line, TPS malfunction, shorted connection, faulty O2 sensor, low fuel or wrong fuel type.		
Possible Causes:	Oxygen Sensor Related • 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. TPS Sensor Related • Throttle plate position incorrect during Auto-Learn. • TPS problem or malfunction. Engine Wiring Harness Related • Difference in voltage between sensed voltage and actual sensor voltage. • Problem in wiring harness. • ECU-to-harness connection problem. Systems Related • 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 bore). • Base engine problem (rings, valves). • Exhaust system leak (muffler, flange, oxygen sensor mounting boss, etc.). • Fuel in crankcase oil. NOTE: ECU reset required to clear this code. See page 34.		
Testing:	See troubleshooting starting on page 46.		

Fault Code		SPN	FMI
Code P0172		4237	1
Component:	Fuel System		
Function:	Fuel Delivery		
Fault:	Minimum adaptation limit exceeded		
Condition:	Too high pressure at high pressure fuel line, TPS malfunction, shorted connection, faulty O2 sensor or fuel pump module failure.		
Possible Causes:	Oxygen Sensor Related • Sensor connector or wiring. • Sensor contaminated or damaged. • Poor ground path. • Pin circuit wiring or connectors. ECU Black pin 10 or Black pin 17. TPS Sensor Related • Throttle plate position incorrect during Auto-Learn. • TPS problem or malfunction. Engine Wiring Harness Related • Difference in voltage between sensed voltage and actual sensor voltage. • Problem in wiring harness. • ECU-to-harness connection problem. Systems Related • 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. NOTE: ECU reset required to clear this code. See page 34.		
Testing:	See troubleshooting starting on page 46.		

EFI System-Electronic Throttle Body (ETB)

Fault Code	SPN	FMI
Code P0174	4237	31

Component:	Fuel System
Function:	Fuel Delivery
Fault:	Lean fuel condition
Condition:	Fuel inlet screen/filter plugged, low pressure at high pressure fuel line, TPS malfunction, shorted connection or faulty sensor.
Possible Causes::	TPS Auto-Learn Incorrect - Lean condition (check oxygen sensor signal with VOA and see Oxygen Sensor). Engine Wiring Harness Related - Pin circuit wiring or connectors. ECU pin Black 10, 12, 16 and 17. Low Fuel Pressure - Plugged filters. - Bad lift pump. - Vapor lock. Oxygen Sensor Related - Sensor connector or wiring problem. - Exhaust leak. - Poor ground. - Contaminated sensor. Poor system ground from ECU to engine, causing rich running while indicating lean. Fuel pump module connection. See Fuel Components.
Testing:	See troubleshooting starting on page 46.

Fault Code	SPN	FMI
Code P0201	651	31

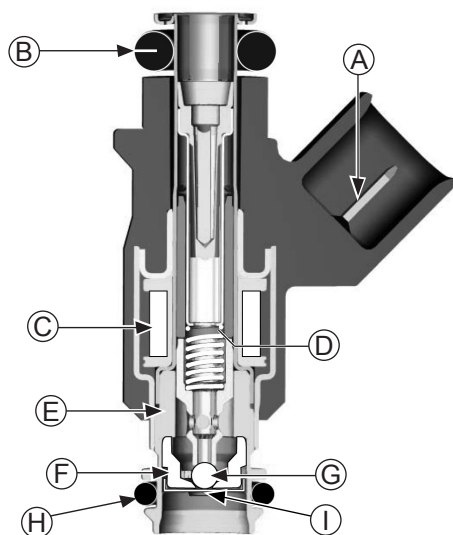
Component:	Fuel Injector
Function:	ECU controlled valve that injects fuel into cylinder
Fault:	Injector 1 Circuit Malfunction
Condition:	Injector damaged or faulty, shorted or open connection.
Possible Causes:	Injector Related - Injector coil shorted or opened. Engine Wiring Harness Related - Broken or shorted wire in harness. ECU pin Black 5. - Wiring from Ignition. ECU Related - Circuit controlling injector #1 damaged.
Testing:	See troubleshooting on page 51.

Fault Code	SPN	FMI
Code P0202	652	31

Component:	Fuel Injector
Function:	ECU controlled valve that injects fuel into cylinder
Fault:	Injector 2 Circuit Malfunction
Condition:	Injector damaged or faulty, shorted or open connection.
Possible Causes:	Injector Related - Injector coil shorted or opened. Engine Wiring Harness Related - Broken or shorted wire in harness. ECU pin Black 6. - Wiring from Ignition. ECU Related - Circuit controlling injector #2 damaged.
Testing:	See troubleshooting on page 49.

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.	



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.

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 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.
3. Using Rehlko Diagnostic System (KDS) Gen 2, see Tools and Aids, perform Adjust Injector Timing test or Injector #1 or #2 test as found in test section of tool. See instructions within help (?) area of each test.

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.
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.
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 10.5 N·m (93 in. lb.). An ECU Reset will need to be completed.

Fault Code	SPN	FMI
Code P0217	110	0
Component:	Engine Overheat Warning	
Fault:	Overheat	
Condition:	Engine operating at or above recommended temperature limit.	
Possible Causes:	Throttle opening is limited, value varies by engine model. • Ramps in and out of limit. Provides an alert to operator of a condition that may cause damage to engine. • Typically this is remedied by clearing debris blocking engine cooling air flow.	
Testing:	Perform visual inspection to ensure engine cooling system is clean and clear of debris.	

Fault Code	SPN	FMI
Code P0230	1347	5
Component:	Electric Fuel Pump	
Function:	Increases Fuel Pressure	
Fault:	Circuit Low Voltage or Open	
Condition:	Shorted or open connection.	
Possible Causes:	Fuel Pump Related • Fuel pump module open or shorted internally. Engine Wiring Harness related • Broken or shorted wire in harness. ECU pin Black 9 or Grey 17. ECU Related • ECU is damaged.	
Testing:	See possible causes and additional troubleshooting starting on page 50.	

Fault Code	SPN	FMI
Code P0232	1347	6
Component:	Electric Fuel Pump	
Function:	Increases Fuel Pressure	
Fault:	Circuit High Voltage	
Condition:	Shorted Connection	
Possible Causes:	Fuel Pump Related • Fuel pump module damaged internally Charging System Output Too High	
Testing:	See possible causes and additional troubleshooting starting on page 50.	

Electric Fuel Pump Function Test



⚠ WARNING

High Pressure Fluids can puncture skin and cause severe injury or death.

Do not work on fuel system without proper training or safety equipment.

Fluid puncture injuries are highly toxic and hazardous. If an injury occurs, seek immediate medical attention.

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 Module in following section.

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 Rehiko replacement parts can be used because fitting is specific to system and must be maintained. Visit Engines.rehiko.com for recommended Rehiko replacement parts.

	⚠ 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)

FPM is not serviceable and must be replaced if determined to be faulty. If a FPM problem is suspected, make certain pump is being activated, all electrical connections are properly secured, fuses are good. If required, testing of fuel pump may be conducted.

FPM can be tested using Rehiko® Diagnostic System (KDS) Gen 2, see Tools and Aids. Select Engine>Tests>Fuel Pump Test and follow instructions in help (?) area of test.

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.

1. Relieve fuel pressure at FPM. FPM may need to be loosened or pulled away from engine. Press release button(s) and slowly pull connector away from FPM allowing shop towel to absorb any residual fuel in high pressure fuel line. Insert pressure test jumper (from Rehiko EFI Service Kit) between high pressure fuel line and FPM.
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/power down cycles to compress air introduced into system and reach regulated pressure. System pressure of 39 psi ± 3 should be present. Turn key switch OFF and depress valve button on tester to relieve system pressure.
 - a. If pressure is too high or too low, proceed to troubleshooting.
4. If pump did not activate (step 3), confirm that safety system on equipment is not active. One potential cause of unnecessary FPM replacement may involve measuring voltage at FPM electrical connector. Using a Digital Volt Ohm Meter (DVOM) will provide a reading near battery voltage, even when ECU is not grounding FPM circuit.
 - a. Connect a DVOM across terminals in plug, turn on key switch and confirm battery voltage is present during six second prime process.
 - b. Test light confirmation: Turn key off. Disconnect DVOM. Connect 12 volt test light across terminals in plug. Key needs to remain off for a minimum of 30 seconds before proceeding. Turn key on. Confirm test light illuminates for approximately 6 seconds. After approximately 6 seconds, test light will remain off unless another prime cycle is initiated.

5. If battery voltage is not present and/or test light does not illuminate, connect red lead of DVOM to red wire of plug and black lead to a battery ground while key is still ON.
6. If battery voltage is present, turn key switch OFF and connect an ohmmeter between terminals on FPM to check for continuity. If battery voltage at plug was confirmed, and there was continuity across FPM terminals, reconnect plug to FPM, making sure you have a good connection. Turn on key switch and listen for FPM to activate.
 - a. If FPM starts, repeat steps 2 and 3 to verify correct pressure.
 - b. If FPM still does not operate, replace it.
7. If battery voltage was not present at connector inspect fuse and wiring harness

Fault Code	SPN	FMI
Code P0336	636	2

NOTE: P0336 can be caused by an incorrect sensor air gap or debris on the sensor face disrupting the magnetic signal. Visually confirm that sensor is clean and gapped correctly.

Component:	Crankshaft Position Sensor
Function:	Monitors rotation and speed (RPM) of crankshaft.
Fault:	Crankshaft Position Sensor Noisy Signal
Condition:	Loose sensor, faulty/bad battery, shorted or faulty connection, faulty sensor or faulty sensor grounding.
Possible Causes:	Crankshaft Position Sensor Related • Sensor connector or wiring. • Sensor loose. Crankshaft Position Sensor Wheel Related • Damaged teeth. • Gap section not registering. Engine Wiring Harness Related • Pin circuit wiring or connectors. ECU pin Black 4 and Black 13 may be routed near noisy signal (coils, stator, etc.). • ECU-to-harness connection problem. Ignition System Related • Non-resistor spark plug(s) used. • Faulty or disconnected ignition coil or secondary lead.
Testing:	Perform visual inspection and check for loose sensor, faulty/bad battery, shorted or faulty connection, faulty sensor or faulty sensor grounding.

EFI System-Electronic Throttle Body (ETB)

Fault Code	SPN	FMI
Code P0337	636	8

NOTE: If P0337 is present and engine operates, clear codes and retest. If Fault Code diagnosis indicates a problem within this area, proceed with testing.

Component:	Crankshaft Position Sensor
Function:	Monitors rotation and speed (RPM) of crankshaft.
Fault:	Crankshaft Position Sensor No Signal
Condition:	Loose sensor, open or shorted connection (sensor connector or battery connections) or faulty sensor.
Possible Causes:	Crankshaft Position Sensor Related • A false fault code P0337 is triggered by a voltage drop with key ON and engine off. Voltage drop may be caused by a poor/inadequate battery connection, battery charger connected or disconnected, or any event that may interrupt voltage signal to ECU like a power interruption or heavy load from equipment that results in a recordable voltage drop. • Sensor connector or wiring. • Sensor loose. Crankshaft Position Sensor Wheel Related • Damaged teeth. Engine Wiring Harness Related • Pin circuit wiring or connectors. ECU pin Black 4 or Black 13. • ECU-to-harness connection problem. If code is stored in fault history and starts normally. Clear code, no other service required.
Testing:	1. Check mounting and air gap of crankshaft position sensor. 2. Inspect wiring and connections for damage or problems. 3. Make sure engine has resistor type spark plugs. 4. Disconnect Black connector from ECU. 5. 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. 6. Disconnect crankshaft position sensor connector from wiring harness. Test resistance between terminals. A reading of 325-395 Ω should again be obtained. a. If resistance is incorrect, remove screws securing sensor to mounting bracket and replace sensor. b. 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. 7. When fault is corrected and engine starts, clear fault codes following ECU Reset procedure. Using the Rehlko diagnostic system Gen 2 (software must be registered-see details earlier in this section): 1. Confirm battery voltage is above 12.4 Volts. 2. Connect Diagnostic System to engine and observe 3. Select engine>live data>main data display 4. While cranking engine, observe RPM display. If the scan tool registers any RPM above 0 during cranking, the sensor is functioning properly.

Fault Code	SPN	FMI
Code P0351	1268	31
Component:	Ignition Coil	
Function:	Transforms low battery voltage into a high-voltage pulse that generates spark needed for combustion	
Fault:	Cylinder 1 Ignition Coil Malfunction	
Condition:	Broken/shorted wire in harness (may not be visible), shorted connection or faulty sensor.	
Possible Causes:	Engine Wiring Harness Related • Connection to ignition or fuse. • Pin circuit wiring or connectors. • ECU pin Black 1. • ECU-to-harness connection problem. Ignition System Related • Incorrect spark plug(s) used. • Poor connection to spark plug.	
Testing:	See Ignition Coil Troubleshooting Chart	

Fault Code	SPN	FMI
Code P0352	1269	31
Component:	Ignition Coil	
Function:	Transforms low battery voltage into a high-voltage pulse that generates spark needed for combustion	
Fault:	Cylinder 2 Ignition Coil Malfunction	
Condition:	Broken/shorted wire in harness (may not be visible), shorted connection or faulty sensor.	
Testing:	See troubleshooting chart	
Possible Causes:	Engine Wiring Harness Related • Connection to ignition or fuse. • Pin circuit wiring or connectors. • ECU pin Black 1. • ECU-to-harness connection problem. Ignition System Related • Incorrect spark plug(s) used. • Poor connection to spark plug.	
Conclusion:	Engine Wiring Harness Related • Connection to ignition or fuse. • Pin circuit wiring or connectors. • ECU pin Grey 10. • ECU-to-harness connection problem. Ignition System Related • Incorrect spark plug(s) used. • Poor connection to spark plug.	
Testing:	See Ignition Coil Troubleshooting Chart	

Ignition Coil Troubleshooting

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 8000-18000 Ω .
 - d. If secondary resistance is not within specified range, coil is faulty and needs to be replaced.

Using the Rehlko diagnostic system Gen 2 (software must be registered-see details earlier in this section):

1. Confirm battery voltage is above 12.4 Volts.
2. Connect Diagnostic System to engine and observe
3. Select engine>tests.
4. See instructions within help (?) area of each test.

Fault Code	SPN	FMI
Code P0562	168	4

Component:	System Voltage
Fault:	System Voltage Low
Condition:	Faulty voltage regulator, bad fuse or shorted connection.
Conclusion:	Corroded Connections Bad Stator Bad Battery • Low output charging system. • Poor magnet in flywheel. • Bad or missing fuse.
Testing:	See electrical troubleshooting starting on page 62.

Fault Code	SPN	FMI
Code P0563	168	3

Component:	System Voltage
Fault:	System Voltage High
Condition:	Faulty voltage regulator or shorted connection.
Conclusion:	Faulty Rectifier-Regulator Bad Stator. Bad Battery.
Testing:	See electrical troubleshooting starting on page 62.

Fault Code	SPN	FMI
Code P2100	5419	5

Component:	Throttle Actuator Control Motor Circuit Open
Fault:	Low Current
Condition:	Throttle drive motor open circuit.
Conclusion:	Engine will only run at fixed low speed.
Testing:	See Throttle Actuator Troubleshooting

Fault Code	SPN	FMI
Code P2119	5419	7

Component:	Throttle Actuator
Fault:	Sticking/sticky/binding
Condition:	Throttle performance-binding
Conclusion:	Movement of throttle blade is restricted.
Testing:	See Throttle Actuator Troubleshooting

Throttle Actuator Troubleshooting

Using the Rehlko diagnostic system Gen 2 (software must be registered-see details earlier in this section):

1. Confirm battery voltage is above 12.4 Volts.
2. Connect Diagnostic System to engine and observe
3. Select engine>tests>Throttle Position Test.
4. See instructions within help (?) area of each test.

NOTE: ECU Reset is required if electronic throttle body is replaced. See page 34.

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

Troubleshooting Flow Chart

Following 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 after chart), and any signaled fault codes, you should be able to quickly locate any problems within system.

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.

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. If no MIL is present, see note above. Twelve volt supply to bulb will be part of vehicle wire harness. Rehlko key switch model will have MIL on engine with 12V supply to bulb. *All current fault codes will turn on MIL when engine is running.	
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 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 #4 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 #5 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 #6 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 #7 FUEL SYSTEM	
(fuel pressure)	
Low Fuel Pressure-Condition	• 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 #8 BASIC ENGINE	
(cranks but will not run)	
Condition	• Refer to basic engine troubleshooting charts within Troubleshooting.

**Diagnostic Aid #9 SPEED CONTROL-Analog
(0-5V input)**

(engine speed does not change when requested)

Condition	• Speed request voltage from OEM controller is not being received by engine. Consult OEM service information for OEM diagnostics. • Bad connection in speed input circuit (terminal G in engine connector, red w/ yellow tracer). • Bad connection in engine connectors (ETB/equipment connector). • Stuck/damaged ETB assembly.
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**Diagnostic Aid #10 SPEED CONTROL-CAN
Communications**

(engine speed does not change when requested)

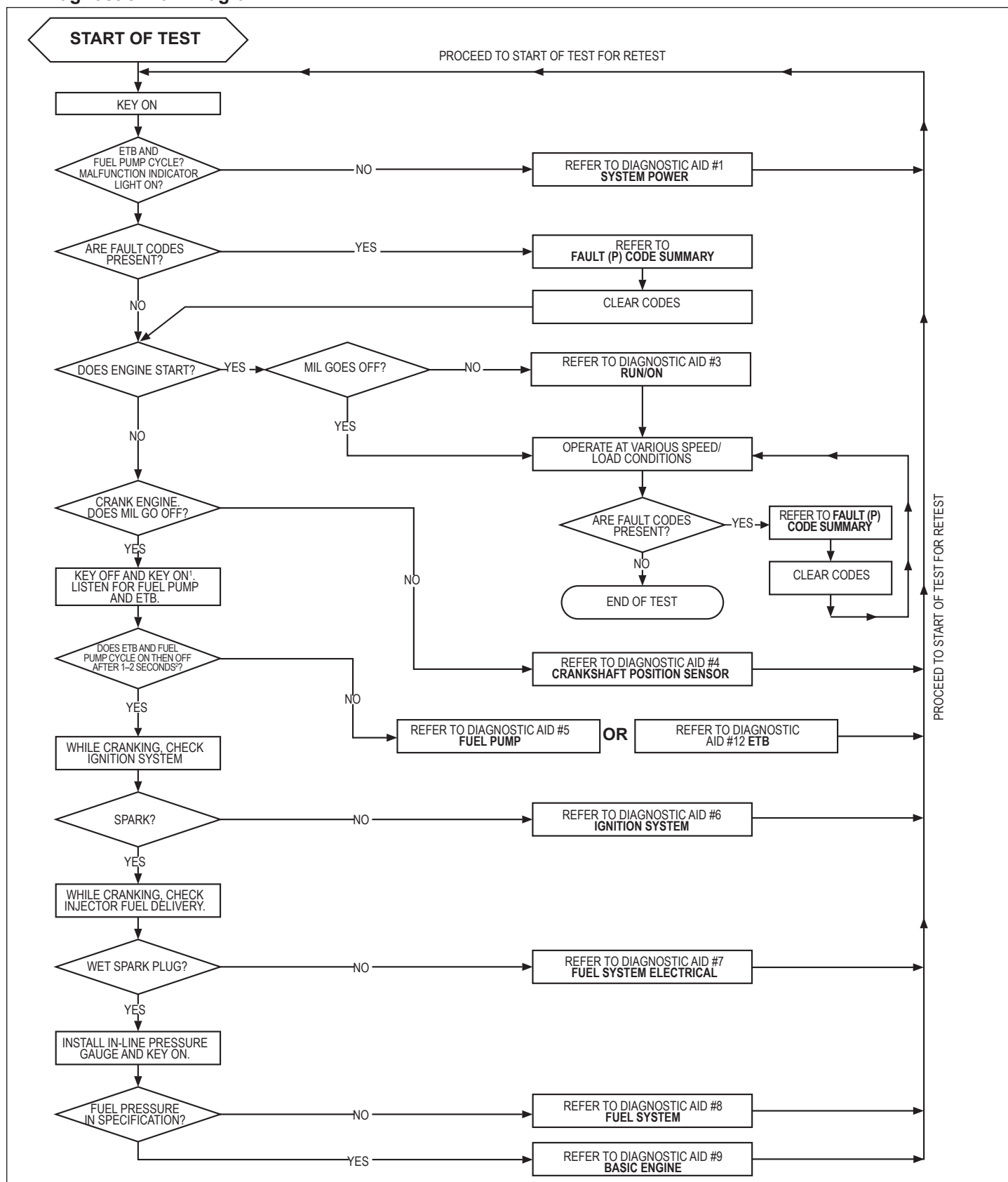
Condition	• Speed request from OEM CAN controller is not being received by engine. Consult OEM service information for OEM diagnostics. • Bad connection in engine connectors (ETB/equipment connector). • Stuck/damaged ETB assembly.
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Diagnostic Aid #11 ETB

(ETB does not cycle when key is switched from off to on)

Condition	• Blown power fuse • Bad electrical connection • Stuck throttle plate • Defective throttle
------------------	--

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

This engine utilizes an Electronic Throttle Body (ETB) in place of a traditional mechanical governor to control throttle position and regulate engine speed and torque. ETB-equipped engines use full electronic throttle control.

Electronic Throttle Body (ETB) System Overview

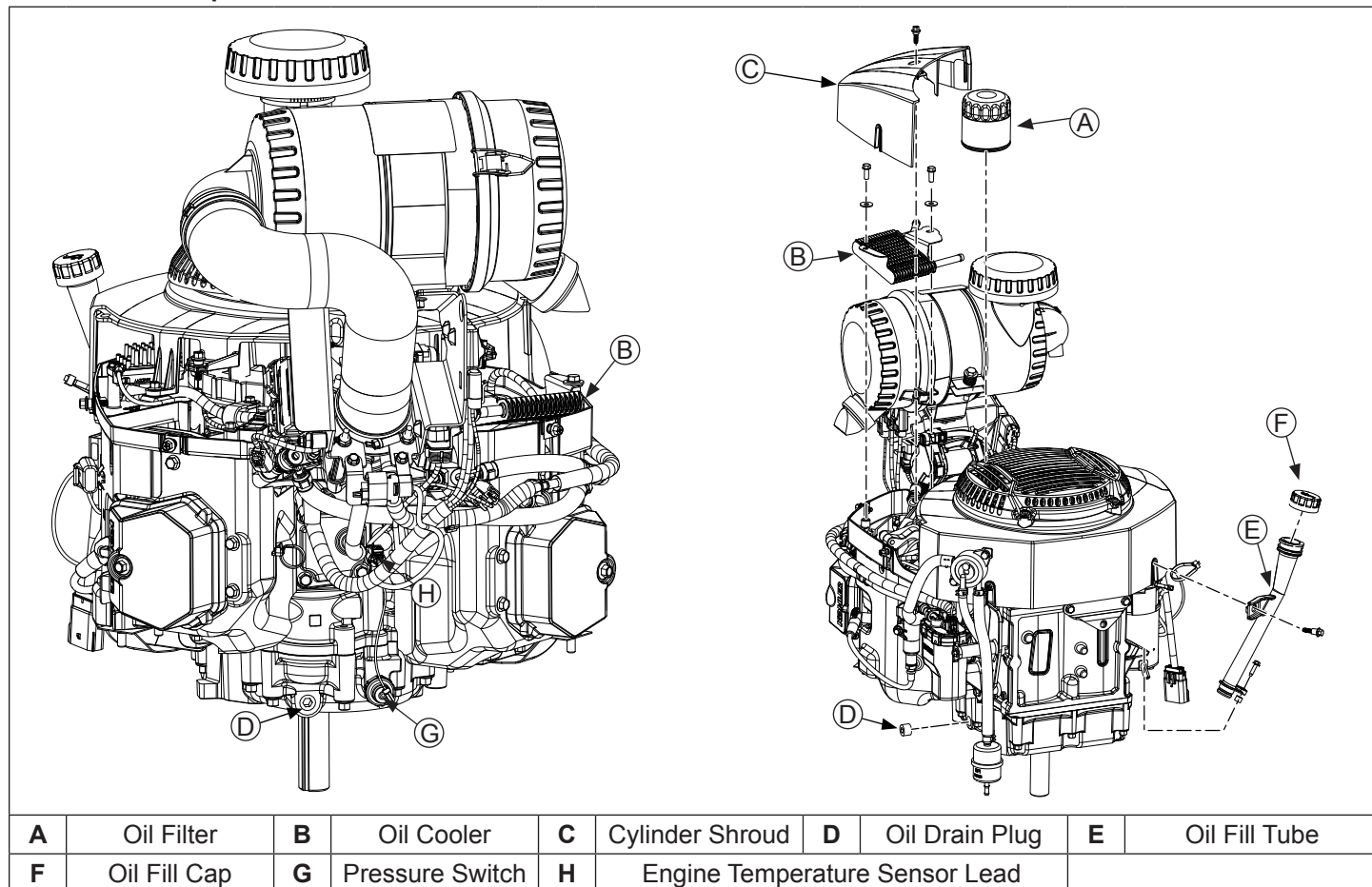
The Engine Control Unit (ECU) continuously monitors engine speed, load, temperatures, and other parameters via sensors, while receiving the primary speed request from the OEM controller.

See EFI Fuel System Electronic Throttle Body (ETB) section for all governor system troubleshooting.

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 (Engine Mounted)

NOTE: When oil cooler is remote mounted in application and supplied by OEM, refer to your equipment manual for cleaning detail.

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

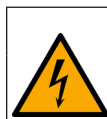
1. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to threads of switch.
2. Install switch into tapped hole in oil pan.
3. Torque switch to 10.7 N·m (95 in. lb.).

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.

BATTERY CHARGING SYSTEM



CAUTION

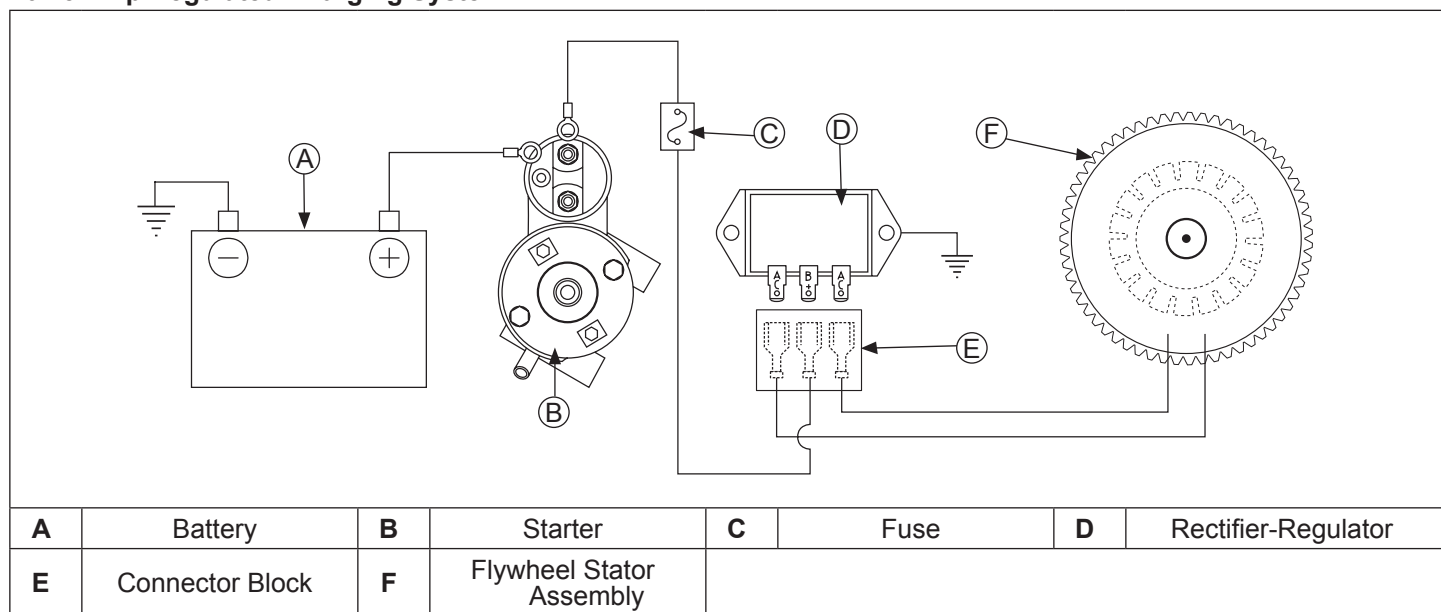
Electrical Shock can cause injury.
Do not touch wires while engine is running.

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

NOTE: These engines are equipped with a 20/25 amp regulated charging system (refer to pages 61-62) or an optional high output 40/50 amp charging system (refer to pages 63-64).

- Make sure battery polarity is correct. A negative (-) ground system is used.
- Inspect charging system fuse. If damaged, replace before continuing.
- Disconnect rectifier-regulator plug (20/25 amp) or ring terminals (optional high output) 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.

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

Rectifier-regulator is mounted on backing shroud assembly. To replace, disconnect plug, remove mounting screws, and ground lead.

Troubleshooting Guide

20/25 Amp Battery Charging System

NOTE: Always zero digital volt-ohm meter (DVOM) on each scale before testing to ensure accurate readings. Voltage test should be made with engine running at specific test condition noted. Battery should be checked for state of charge (non-operating voltage 12.5 VDC or lower, battery should be charged or replaced).

When problems occur in keeping a battery fully charged or a battery charges at a high rate, battery or charging system may be cause of fault. Before performing any testing, battery must be fully charged.

To test charging system:

1. Inspect charging system fuse. If damaged, replace before continuing.
2. Visually inspect system components and wiring. Look for damaged or loose wire connections, including battery cables.
3. Set DVOM to DC volts, place one lead of tester on rectifier-regulator body and other lead to battery negative (-) terminal. Run engine and observe volt reading on meter. If voltage is 0.5 VDC or less continue with testing. If voltage is higher than 0.5 VDC, inspect and repair wiring/connections as needed (insufficient ground).

4. Perform these output tests for charging system using DVOM set to DC volts.
 - a. With engine off and key switch in OFF position, measure voltage at battery. If less than 12.4 VDC, recharge battery and retest. If 12.5 VDC continue with tests.
 - b. Run engine at high speed no load (greater than 3000 RPM). After running 1 minute, measure voltage at battery.
 - i. If voltage increases to between 13-15 VDC, system is working correctly.
 - ii. If voltage increases to 15.5 VDC or higher, system is overcharging. Replace rectifier-regulator.
 - iii. If voltage stays at 12.5 VDC or decreases, charging system is NOT operating, proceed to step 5.
5. With engine off, unplug rectifier-regulator connector and inspect connector terminals within connector body and rectifier-regulator terminals for corrosion/arcing/damage. Repair/replace as needed. If OK, proceed to next test.
6. Set DVOM to AC volts, place test leads to each white stator wire. Run engine at 1200 RPM or greater and monitor voltage.

Condition	Conclusion
Voltage is 13 volts AC or more.	Stator is OK.
Voltage is less than 13 volts AC.	Stator is faulty. Continue with steps 7 and 8).

7. With engine off and stator unplugged from rectifier-regulator, check for resistance/continuity between across stator leads (white wires).

Note: Resistance testing across the stator wire leads may yield values too low to reliably measure, leading to misdiagnosis. If the stator passes output testing, it should be considered functional.

Condition	Conclusion
Resistance is 0.1/0.2 ohms.	Stator coil is OK.
Resistance is 0 ohms.	Stator is shorted; replace.
Resistance is infinity ohms/no continuity.	Stator is open; replace.

8. With engine off and stator unplugged from rectifier-regulator, check for resistance/continuity from stator leads (white wires) to ground.

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.

9. If stator tests good (steps 5-8), but system was identified in step 4 as not working, failure is likely with rectifier-regulator. Replace rectifier-regulator, retest system to confirm repairs (step 4).

FUSES

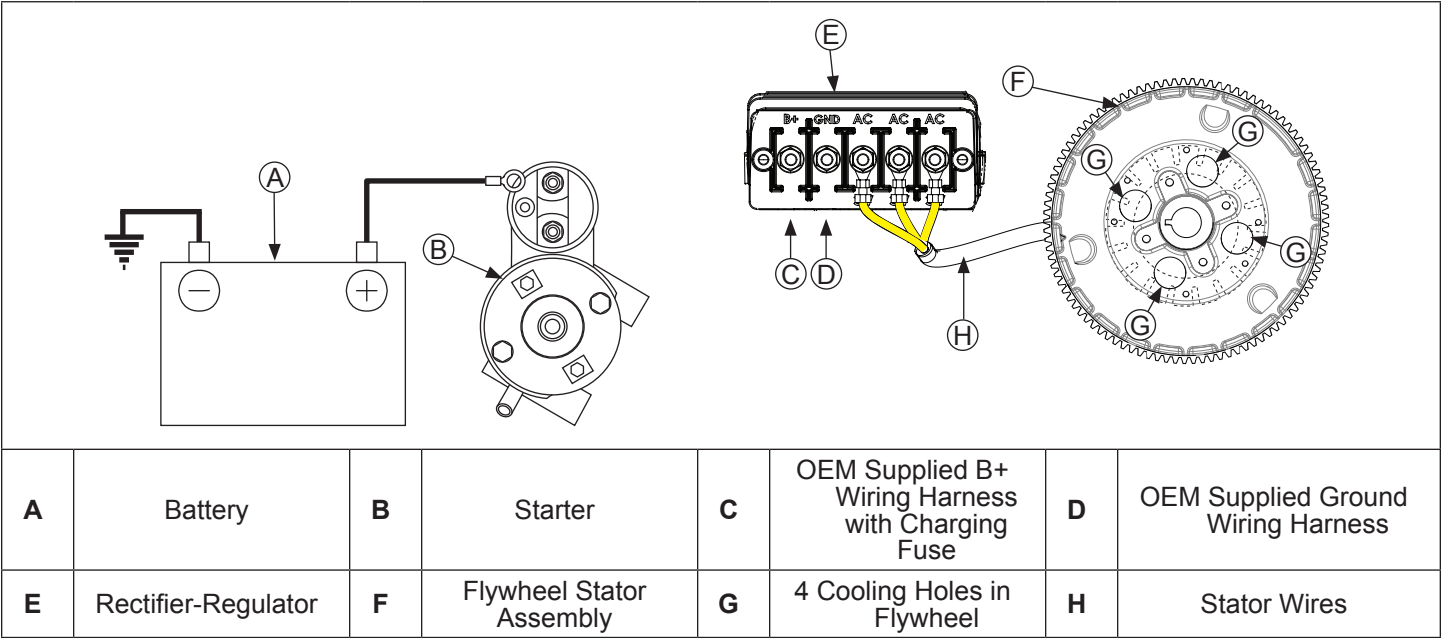
This engine has 3 blade type automotive fuses. Replacement fuses must have same rating as blown fuse. Use fuse chart below to determine correct fuse.

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. Inspect condition of fuse holder.
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.
6. If replacement fuse fails, there is a problem within circuit. Diagnostics are required. Identify which circuit is affected (see EFI System for electrical schematic) by identifying failed fuse/circuit. Perform troubleshooting procedures appropriate for circuit fuse that failed.
7. Install fuse holder into fuse cover.

40/50 Amp High Output Regulated Charging System



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

Rectifier-Regulator
NOTE: When installing rectifier-regulator, take note of terminal markings and install ring terminals accordingly. Rectifier-regulator is OEM installed in application. Refer to your equipment manual if rectifier-regulator replacement is necessary.

High Output Charging Wiring Harness (OEM Supplied)
In addition to main engine wiring harness (with 3 blade type automotive fuses), engines equipped with a high output charging system will have a separate charging wiring harness with one (1) large blade type automotive type fuse. However, 30-amp fuse in main engine wiring harness is then nonfunctional. Purple charge wire ring terminals in main engine wiring harness are completely sealed and retained using a special heat shrink cap for non use. No service is required for this circuit. Refer to equipment manual for fuse detail in OEM supplied wiring harness.

Troubleshooting Guide

40/50 Amp High Output Battery Charging System

NOTE: Always zero digital volt-ohm meter (DVOM) on each scale before testing to ensure accurate readings. Voltage test should be made with engine running at specific test condition noted. Battery should be checked for state of charge (non-operating voltage 12.5 VDC or lower, battery should be charged or replaced).

When problems occur in keeping a battery fully charged or a battery charges at a high rate, battery or charging system may be at fault. Before performing any testing, battery must be fully charged.

To test charging system:

1. Inspect charging system fuse. If damaged, replace before continuing. Refer to equipment manual for fuse detail in OEM supplied wiring harness.
2. Visually inspect system components and wiring. Look for damaged or loose wire connections, including battery cables.
3. Set DVOM to DC volts, place red (positive) lead of tester on rectifier-regulator negative (-) post and black (negative) lead to battery negative (-) terminal. Run engine and observe volt reading on meter. If voltage is 0.5 VDC or less, continue with testing. If voltage is higher than 0.5 VDC, inspect and repair wiring/connections as needed (insufficient ground).
4. Perform output tests a and b for charging system using DVOM set to DC volts OR perform test c using carbon pile test tool.
 - a. With engine off and key switch in OFF position, measure voltage at battery. If less than 12.4 VDC, recharge battery and retest. If 12.5 VDC continue with tests.
 - b. Run engine at high speed no electrical or mechanical load (greater than 3000 RPM). After running 1 minute, measure voltage at battery.

- i. If voltage increases to between 13-15 VDC, system is working correctly.
 - ii. If voltage increases to 15.5 VDC or higher, system is overcharging. Replace rectifier-regulator.
 - iii. If voltage stays at 12.5 VDC or decreases, charging system is NOT operating, proceed to step 5.
- c. If a carbon pile test tool is available, connect tool to battery posts (Red positive +/Black negative -) turn load knob counterclockwise (no load). Start and run engine at high speed (3600 RPM optimal), adjust carbon pile voltage to 12 volts and observe amperage on amp meter. Displayed amperage should be near or at maximum rated system output. (Follow tool directions for carbon pile test procedures.)

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 5-8).

5. With engine off, remove terminal block cover from rectifier-regulator and inspect ring terminals and rectifier-regulator studs for corrosion/arcing/damage. Repair/replace as needed. If OK, proceed to next test.
6. Label each yellow stator wire (1, 2, 3) on ring terminal sheathing. Remove nuts retaining stator eyelets and cover each ring terminal with electrical tape, to ensure no accidental contact can be made.

NOTE: DVOM must be able to read to 0.05 ohms.

Set DVOM to AC volts, place test lead to each yellow stator wire ring terminal (under tape). Run engine at high speed and monitor voltage. Measure between each stator lead and ground (1-ground, 2-ground, 3-ground).

Condition	Conclusion
Voltage is 17 volts AC or more.	Stator is OK.
Voltage is less than 17 volts AC.	Stator is faulty. Continue with steps 7 and 8).

7. With engine off and stator ring terminals removed from rectifier-regulator, check for resistance/continuity between across stator leads (yellow wires; 1-2, 1-3, 2-3).

Condition	Conclusion
Resistance is 0.1/0.2 ohms.	Stator coil is OK.
Resistance is 0 ohms.	Stator is shorted; replace.
Resistance is infinity ohms/no continuity.	Stator is open; replace.

8. With engine off and stator ring terminals removed from rectifier-regulator, check for resistance/continuity from stator leads (yellow wires) to ground.

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.

9. If stator tests good (steps 5-8), but system was identified in step 4 as not working, failure is likely with rectifier-regulator. Replace rectifier-regulator, retest system to confirm repairs (step 4).

FUSES (High Output Charging System)

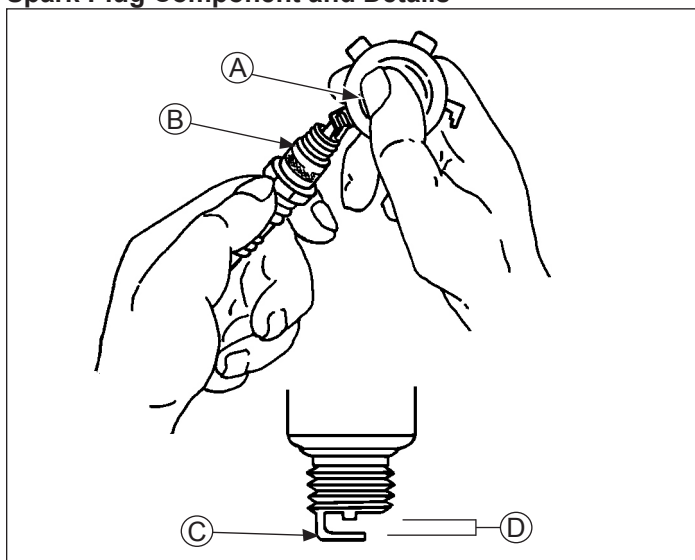
Engines equipped with a high output charging system have one (1) large blade type automotive fuse, in addition to three (3) blade type automotive fuses. However, 30-amp fuse is then nonfunctional as 30-amp charging circuit has been disabled. Purple charge wire ring terminals in main engine wiring harness are completely sealed and retained using a special heat shrink cap for non use. No service is required for this circuit.

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
High Output Charging System adds	
In separate wiring harness; when OEM supplied, refer to your equipment manual for fuse detail.	Rehiko 60-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.
6. If replacement fuse fails, there is a problem within circuit. Diagnostics are required. Identify which circuit is affected (see EFI System for electrical schematic) by identifying failed fuse/circuit. Perform troubleshooting procedures appropriate for circuit fuse that failed.
7. Install fuse holder into fuse cover.

IGNITION SYSTEM**Spark Plug****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 (0.030 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 (0.030 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 fuel mixture.

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 fuel mixture 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 fuel mixture, weak ignition, or poor compression.

Overheated



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

Troubleshooting Guide

Test Ignition System

NOTE: If engine starts or runs during testing, you may need to ground kill lead to shut it down. Because you have interrupted kill circuit, it may not stop using switch.

Isolate and verify trouble is within engine.

1. If Rehlko diagnostic software is available, review "Safety System Active" status in Data Display screen. If yes is displayed, equipment safety circuit is active (seat switch/PTO switch/Safety interlocks, etc.). This must be corrected prior to continuing testing.

If diagnostic software is not available, locate connectors where wiring harnesses from engine and equipment are joined. Separate connectors and remove white kill lead from engine connector. Rejoin connectors and position or insulate kill lead terminal so it cannot touch ground. Try to start engine to verify whether reported problem is still present.

Condition	Possible Cause	Conclusion
Problem goes away.	Electrical System	Check key switch, wires, connections, safety interlocks, etc.
Problem persists.	Ignition or Electrical System	Leave kill lead isolated until all testing is completed. Identify white kill lead of engine wiring harness connector. Establish a connection to a known good ground location. Engine should kill completely. If not or only 1 cylinder is affected, test ignition coils.

Test for Spark

NOTE: If 2 ignition system testers are available, testing can be performed simultaneously for both cylinders. However, if only 1 tester is available, 2 individual tests must be performed. Side not being tested must have spark plug lead connected or grounded. Do not crank engine or perform tests with 1 spark plug lead disconnected and not grounded, or permanent coil damage may occur.

1. With engine stopped, disconnect 1 spark plug lead. Connect spark plug lead to post terminal of spark tester and attach tester clip to a good engine ground.
2. Crank engine over, establishing a minimum of 350-450 RPM, and observe tester(s) for spark.
3. Repeat spark test on opposite cylinder if cylinders are being tested individually.

Condition	Possible Cause	Conclusion
1 cylinder is not firing or 1 cylinder has good spark and other cylinder has no or intermittent spark.	Wiring, Connections, or System Power	Using a DVOM, attach black (-) lead of meter to battery ground, remove primary plug from coil, test voltage at red wire with black tracer at coil primary connector with ignition key ON. Battery voltage should be seen. If no voltage, check all fuses. Key OFF, perform continuity test between black primary wire connector and corresponding terminal connector (ignition coil #1 or #2) on black or grey ECU connector (see EFI System Wiring Diagram). If no continuity is found, repair or replace electrical wiring harness. If continuity is found, refer to EFI System, Ignition Coil Testing or exchange ignition coils (side to side) and retest. If problem follows ignition coil, replace that coil. If problem stays with cylinder, test circuit (power and ground) for problem cylinder. Repair/replace as needed. Test ignition coils and connections. Refer to Test Ignition System (on previous page).
Tester shows spark but engine misses or won't run on that cylinder.	Spark Plug(s)	Try new spark plug(s).
	Flywheel Key	Remove flywheel, inspect key, replace key if damaged.
Neither side is firing.	Ignition Switch, EFI System, Kill Lead	Test for "Safety System Active" as described in step 1 of Test Ignition System (on previous page). Inspect red 10 amp fuses. Replace fuse if found blown. If fuse is OK, using a DVOM, attach black (-) lead of meter to battery ground, key ON, test for voltage at 2 red 10 amp fuses. Battery voltage should be seen on both sides of fuses. If voltage is found on 1 side of fuse only, inspect for blown fuse or inspect fuse holder/terminals for arcing or corrosion. If no voltage is seen at any fuse, further electrical testing inspection is required (application, key switch, ground connections, etc.). Recheck position of ignition switch and check for shorted kill lead.
Both cylinders have good spark but engine runs poorly or existing plug condition is questionable.	Spark Plug(s)	Install new spark plug(s) and retest engine performance.
	Flywheel Key	Remove flywheel, inspect key, replace key if damaged.

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.

Starter System

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.

NOTE: 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. See Electrical System section for additional battery information.

Engines in this series use solenoid shift starters.

Troubleshooting-Starting Difficulties

Condition	Possible Cause	Conclusion
Starter does not energize.	Battery	Check battery state of charge. 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 battery state of charge. 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.

Starting System Voltage Test

	⚠ WARNING		⚠ CAUTION
	Explosive Fuel can cause fires and severe burns. Do not fill the fuel tank while the engine is hot or running.		Electrical Shock can cause injury. Do not touch wires while engine is 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. Do not fill the fuel tank while the engine is hot or running, since spilled fuel could ignite if it comes in contact with hot parts or sparks from ignition. Do not start the engine near spilled fuel. Never use gasoline as a cleaning agent.	Never touch electrical wires or components while the engine is running. They can be sources of electrical shock.	

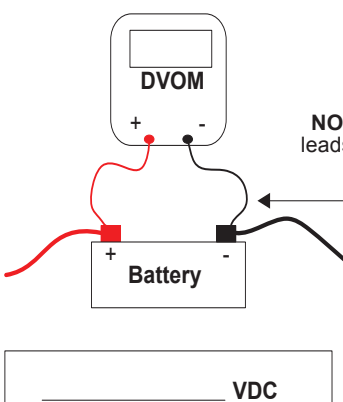
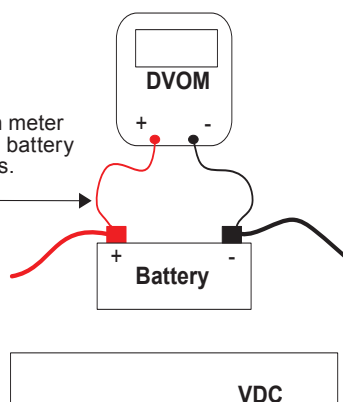
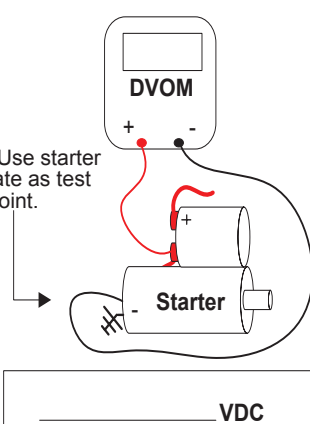
Before Starting

NOTE: Please perform the following testing as near to the conditions during failure (i.e. in the morning when cold, a hot restart, or as close to the description of failure provided by the customer).

NOTE: Voltage drop testing measures the voltage lost across portions of the starting circuit while the starter is under full load. Excessive voltage drop indicates unwanted resistance that restricts current flow and prevents the starter from receiving the voltage and amperage required for proper operation

- Disable ignition system: disconnect the spark plug lead from the spark plug, then ground the spark plug lead to the engine block using mechanical means. Refer to the correct engine service manual if necessary.
- Battery voltage should be tested and must be at 12.4 VDC or higher. Do not proceed if battery voltage is less than 12.4 VDC as battery should be charged.
- Test meter leads before use. (Set meter to Ohms and check for resistance reading of less than 0.5 Ohm.)
- If available, use clamping meter leads to assist with testing.
- Set meter to next highest voltage scale that includes 12 VDC.
- When taking readings, allow the meter to stabilize before recording. The reading should stabilize after 3 to 5 seconds. **If reading continues to drop while cranking, stop the test and perform a battery load test.**

Procedure

Test #1 Battery Voltage Test (Static)	Test #2 Voltage Drop Across Battery (Cranking)	Test #3 Voltage Drop Across Starter (Cranking)
	NOTE: Touch meter leads to actual battery terminals. 	NOTE: Use starter end plate as test point. 
Test 1 Conclusions • If battery voltage is above 12.4 VDC continue to Test 2. • If voltage is below 12.4 VDC, charge battery and retest. • If battery will not hold a charge it should be replaced before continuing the test or replacing the starter.	Test 2 Conclusions • If battery cranking voltage is above 9.0 VDC continue to Test 3. • If battery cranking voltage is below 9.0 VDC you should check the battery by using a load tester. Also check for external engine load.	Test 3 Conclusions • If the difference between test 2 and test 3 is greater than 1 VDC, a voltage drop test on the system will need to be performed to determine where the loss is occurring. Testing of the battery + and battery – circuit will need to be done independently.

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 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 Starter Assembly.
No continuity is indicated.	
Plunger fails to stay retracted.	

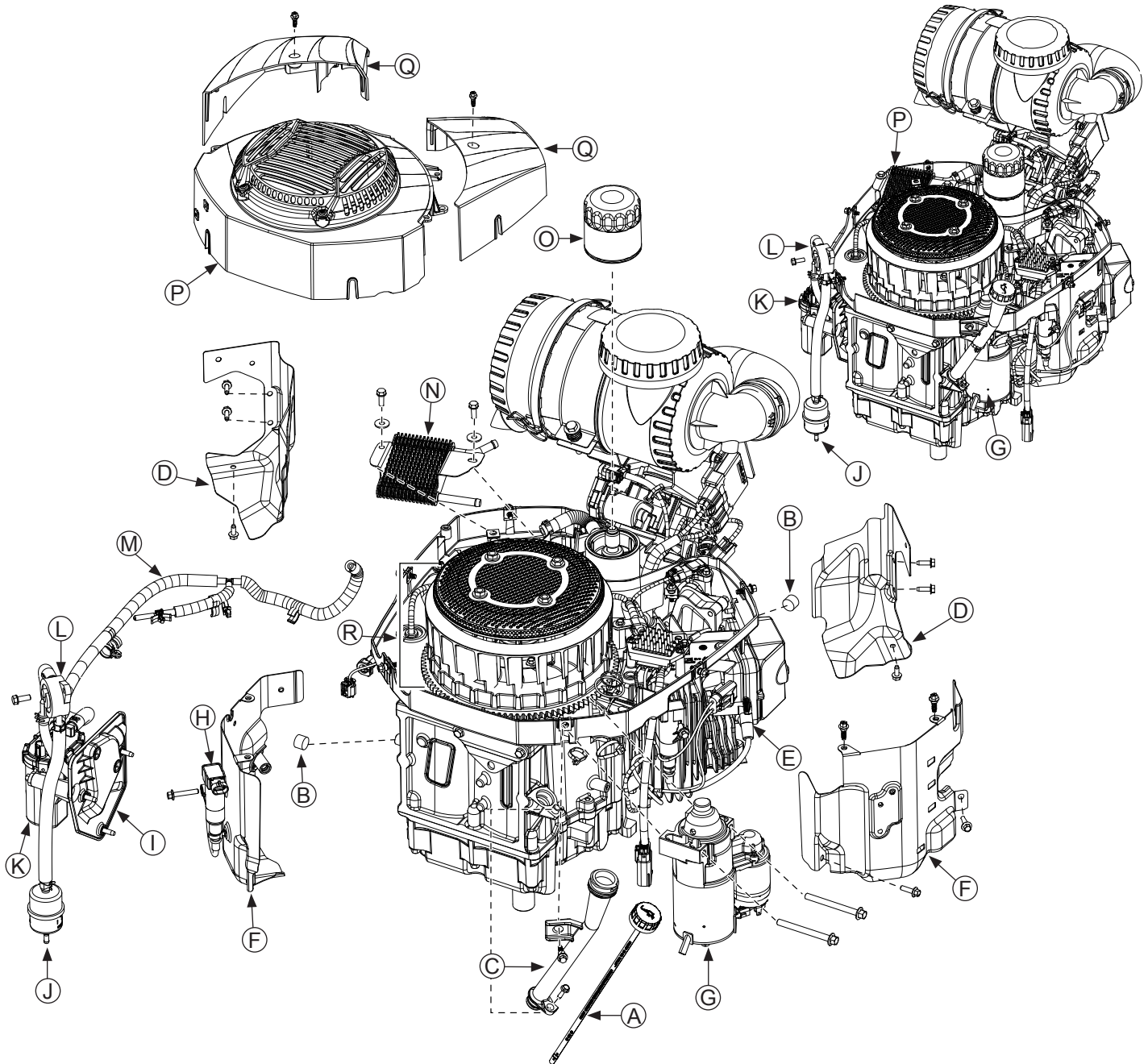


⚠ WARNING

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



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	Evap Line	N	Oil Cooler (Engine Mounted)	O	Oil Filter	P	Blower Housing with Fixed Guard
Q	Cylinder Shroud	R	Fan/Flywheel Assembly				

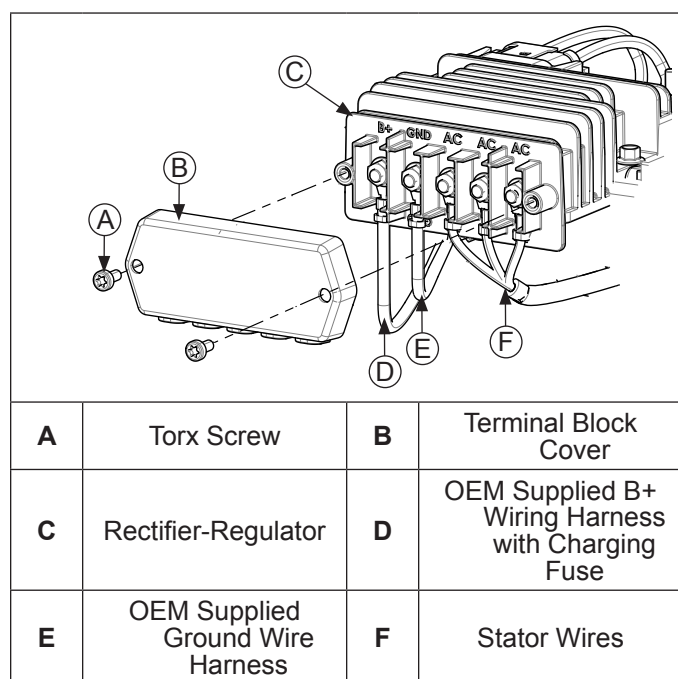
Clean all parts thoroughly as engine is disassembled. Only clean parts can be accurately inspected and gauged for wear or damage. There are many commercially available cleaners that will quickly remove grease, oil and grime from engine parts. When such a cleaner is used, follow manufacturer's instructions 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, electronic governor, or electronic throttle body (ETB) component.

Remove High Output Charging System Terminal Block Cover and Disconnect Stator Wires

NOTE: When high output charging system rectifier-regulator is supplied by Rehlko, but installed by OEM in application, you must remove terminal block cover and disconnect stator wires before removing engine from application.



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 (if equipped)

NOTE: Unless oxygen sensor is damaged or malfunctioning, disassembly from muffler is unnecessary.

1. Disconnect oxygen sensor connector from wire harness.
2. Carefully remove sensor plug from bracket (ETB ECV EFI only).
3. Remove exhaust system and attaching hardware from engine. On engines equipped with port liners, remove then now.
4. Remove oxygen sensor.

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

NOTE: Unless ignition coil is being replaced, disassembly from barrel baffle is unnecessary.

1. Remove mounting screws from #1 barrel baffle. Disconnect wiring harness from coil (#1 starter side). Let barrel baffle hang (with coil installed).
2. If equipped, carefully remove clip securing wires to #1 valley baffle. Remove screws, then valley baffle. If necessary, remove screws securing rectifier-regulator (standard ignition) for access to top barrel baffle screw.

Remove Fuel Pump Module (FPM)/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.	

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

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 FPM.
3. Wrap a shop towel completely around high pressure fuel line connector.
4. Press release button and slowly pull connector away from FPM, allowing shop towel to absorb any residual fuel in high pressure fuel line. Any spilled fuel must be wiped up immediately.
5. On ETB ECV EFI engines, remove screws and FPM from baffle. Slide clamp up on pulse line and remove line from crankcase fitting.
On ECV EFI engines, remove pulse line from crankcase fitting.
6. Remove 3 screws securing FPM baffle to crankcase.
On ETB ECV EFI engines, remove FPM baffle.
On ECV EFI engines, remove FPM, baffle, and fuel pump keeping all fuel lines connected.
Separate parts only if additional service is required.

Remove Oil Cooler (Engine Mounted)

NOTE: When oil cooler is remote mounted in application and supplied by OEM, refer to your equipment manual for disassembly detail.

NOTE: Earlier engines were built with spring clamps securing oil cooler hoses. New spring clamps are recommended any time disassembly is performed, or if clamps have been loosened (expanded) several times.

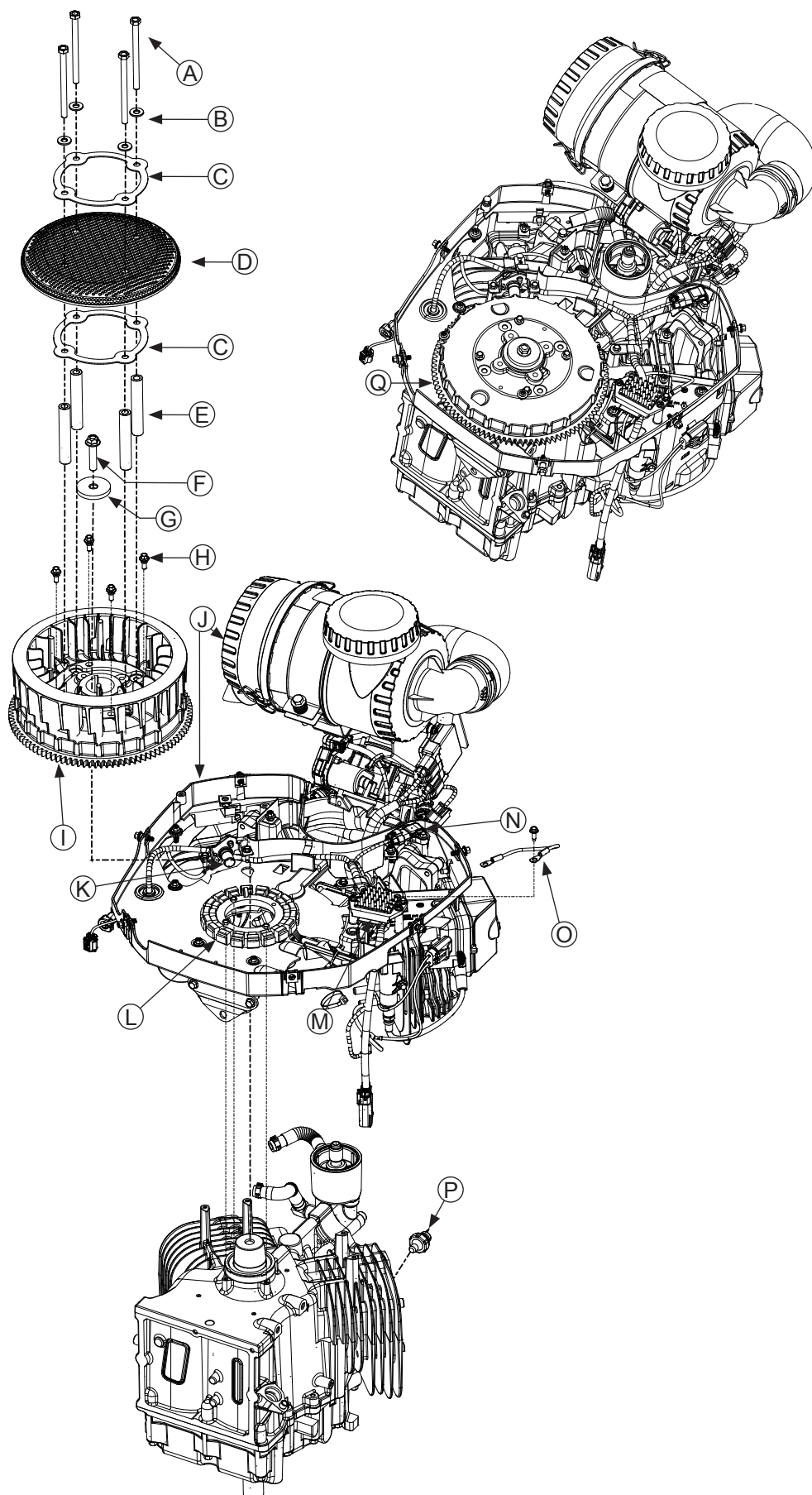
Newer engines are built with Oetiker clamps securing oil cooler hoses. Note position of each Oetiker clamp for reassembly, before carefully cutting them to remove.

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 spring clamps or carefully cut Oetiker 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 screws, 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



A	Screw
B	Washer
C	Support Ring
D	Grass Screen Guard
E	Spacer
F	Flywheel Screw
G	Flywheel Washer
H	Fan Screw
I	Fan/Flywheel Assembly
J	Backing Shroud/ Intake Manifold/ Air Cleaner
K	Crankshaft Position Sensor
L	Stator
M	Rectifier-Regulator Connector
N	MAP or TMAP Sensor Connector
O	Ground Lead
P	Oil Pressure Sensor
Q	High Output Charging System Flywheel

Remove Crankshaft Position Sensor

NOTE: Do not remove sensor from bracket unless sensor is being replaced.

1. Remove two bracket mounting screws and crankshaft position sensor from crankcase mounting posts. 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. If equipped, remove lead from engine temperature sensor (in oil pan). Remove switch from oil pan only if replacing.
4. Remove screws securing harness bracket and ground leads to #1 cylinder bosses.
5. Remove other end of ground lead from #1 cylinder boss screw. Be sure to keep washer.

Remove Grass Screen Guard and Fan

1. Loosen screws securing screen to flywheel.
2. Carefully remove the screw, washer, support rings and spacer.
3. Loosen and remove screws securing the fan to the flywheel.

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.

NOTE: High output charging system flywheel (identified by 4 large cooling holes) has very strong magnets. Magnet assembly guard on interior of this flywheel has a thin, sharp edge. Wear protective gloves when handling this flywheel.

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. ETB ECV EFI engines with high output charging system have a flywheel with very strong magnets. Wear protective gloves and use a flywheel puller to remove this flywheel.
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. Rehlko does not provide ring gear as a serviceable part. Replace flywheel if ring gear is damaged.

Remove Backing Shroud Assembly

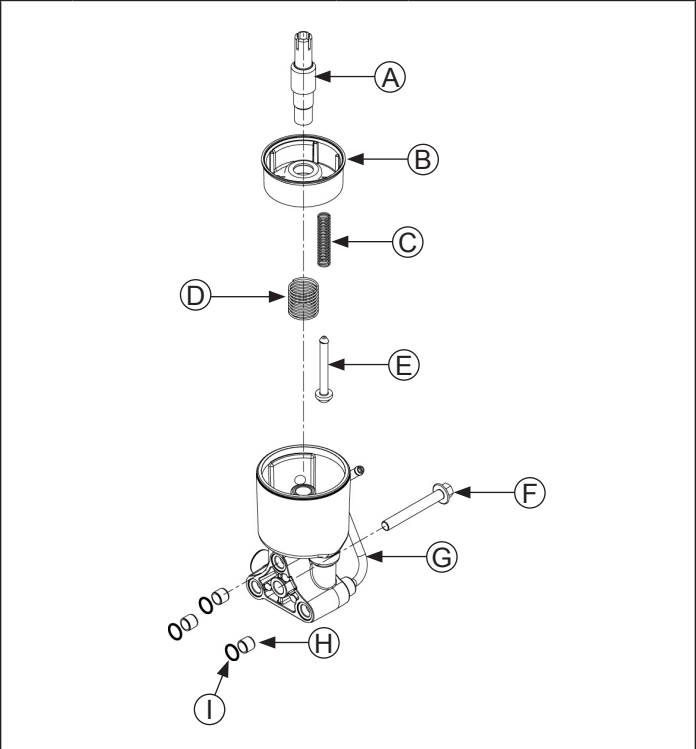
- 1. Remove screws securing stator to backing shroud. Keep leads in place and let stator lay on backing shroud.
- 2. Carefully slide lock tab on TMAP sensor outward. Press down on lock tab to release, then separate connectors.
- 3. Remove screws securing backing shroud to crankcase. Set backing shroud/harness 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 engine temperature sensor connector. Unless sensor is damaged or malfunctioning, disassembly from crankcase is unnecessary.
- 3. On ETB ECV EFI engines, slide clamp and remove breather hose from electronic throttle body (ETB). (Other end is connected to breather cover.)
On EVC EFI engines, 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, TMAP sensor, ECU, and brackets.
Separate parts only if additional service is required.

Remove Oil Filter Housing

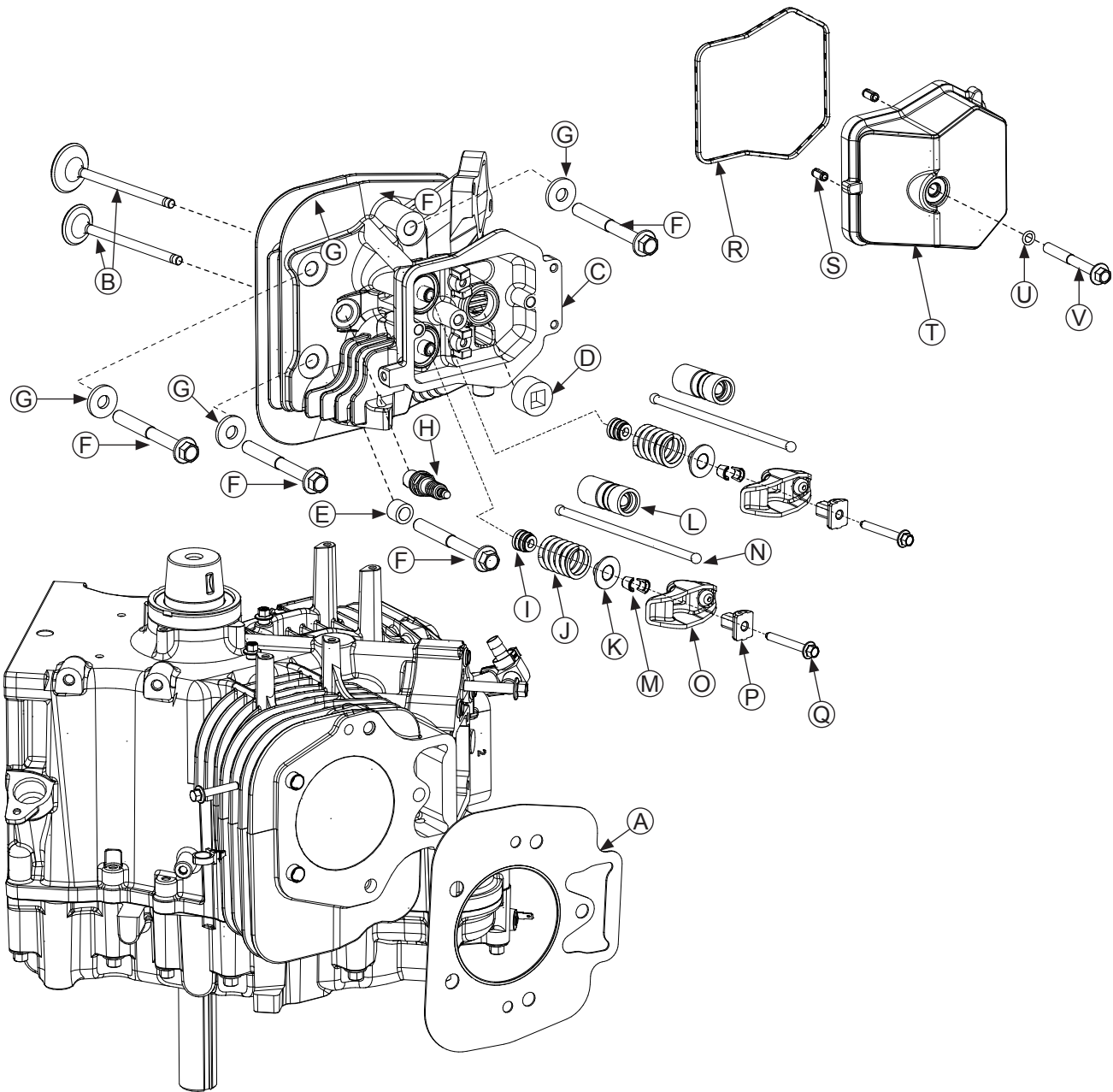
Oil Filter Housing Components



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.

Cylinder Head Components



A	Gasket	B	Valve	C	Cylinder Head	D	Pipe Plug
E	Spacer	F	Head Bolt	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 Arm Screw	R	Valve Cover Seal	S	Roll Pin	T	Valve Cover
U	O-Ring	V	Screw				

Remove Spark Plugs

Remove spark plug from each cylinder head.

Remove Valve Covers

NOTE: A new valve cover seal must be installed whenever the valve cover is removed from cylinder head.

1. Remove screw and O-ring securing each valve cover.
2. Remove valve cover and seal from each cylinder head. Remove seal from valve cover; discard seal.

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.
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 Rehlko lubricant to base of each new lifter before it is installed.

Bleeding Lifters

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.

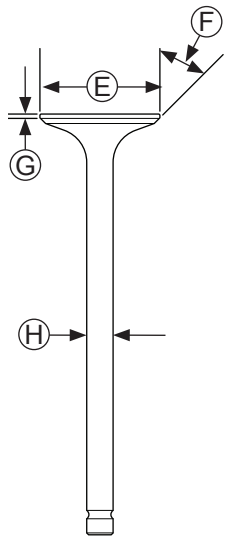
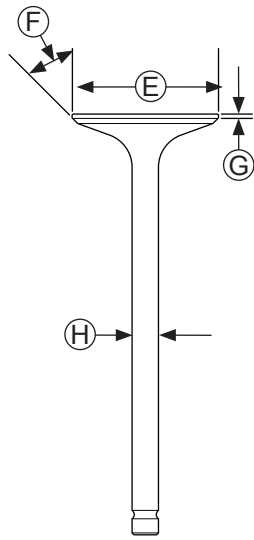
1. Lay a rag or shop towel on table of drill press. Place an 8 mm (5/16 in.) socket on towel with well end up, then place open end of lifter on socket. Ensure socket does not contact lifter ball surface.
2. Place some material, such as wood, plastic, or aluminum on top of lifter to protect lifter finish.
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.

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

Inspection and Service Valve Details

EXHAUST VALVE		INTAKE VALVE	
			
Dimension		Intake	Exhaust
A	Seat Angle	44.5°	44.5°
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 precision straight edge 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.

If guides show visible wear, replace cylinder head assembly.

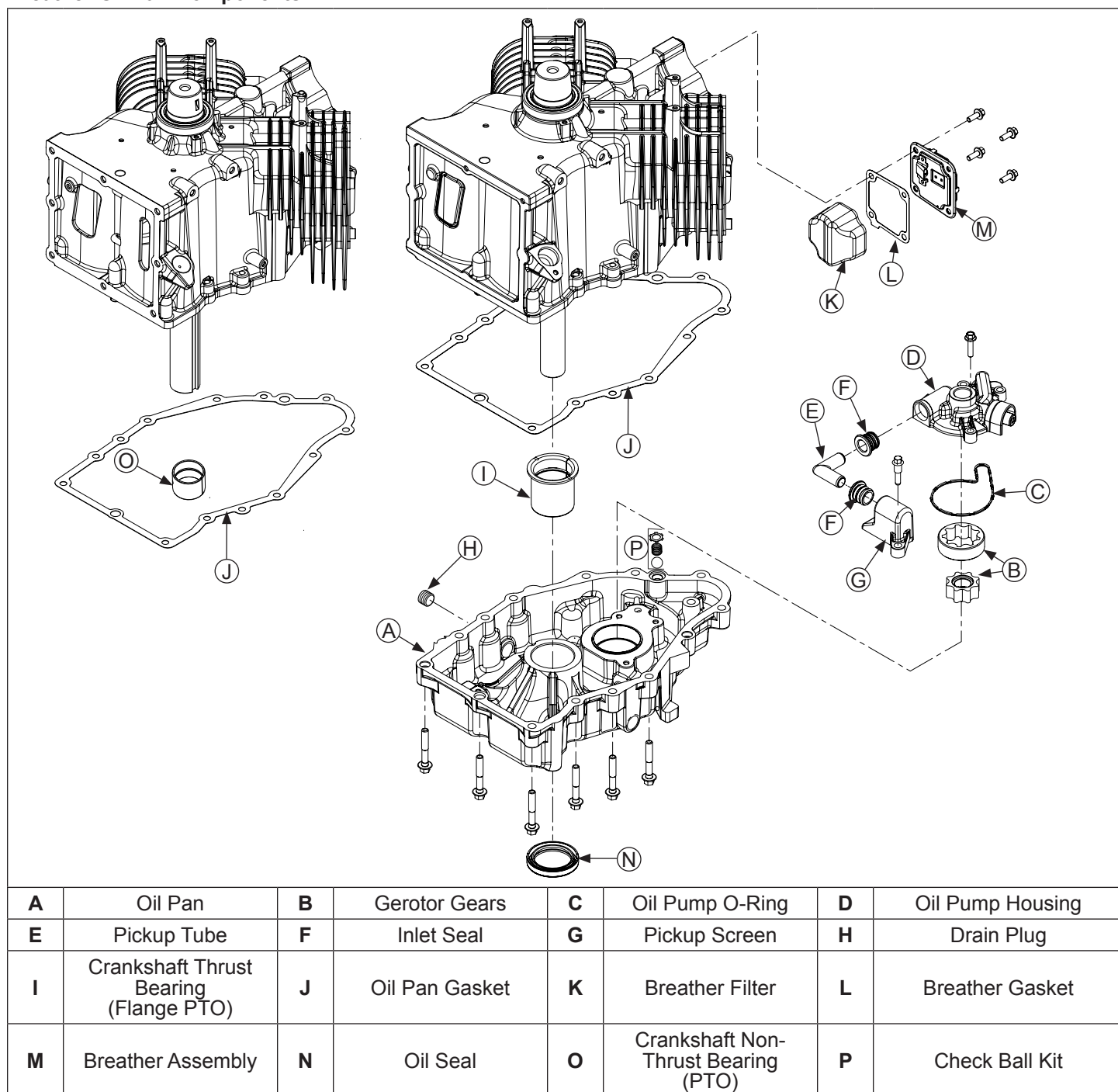
Valve Seat Inserts

Hardened steel alloy intake and exhaust valve seat inserts are press fitted into cylinder head. Inserts are not replaceable therefore reconditioning is not recommended. If valve seat is damaged, replace cylinder head assembly.

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



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

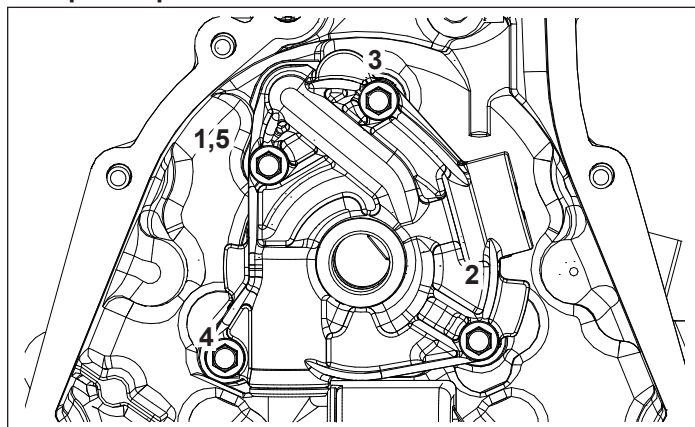
1. Remove screws securing oil pump housing including screw for pickup screen.
2. Remove oil pump housing and pickup screen from oil pan.
3. Remove oil pump gerotor gears from oil pan recess.
4. Remove oil pickup by pulling it free from oil pump body.
5. Relief valve is a one-piece style, staked to oil 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.

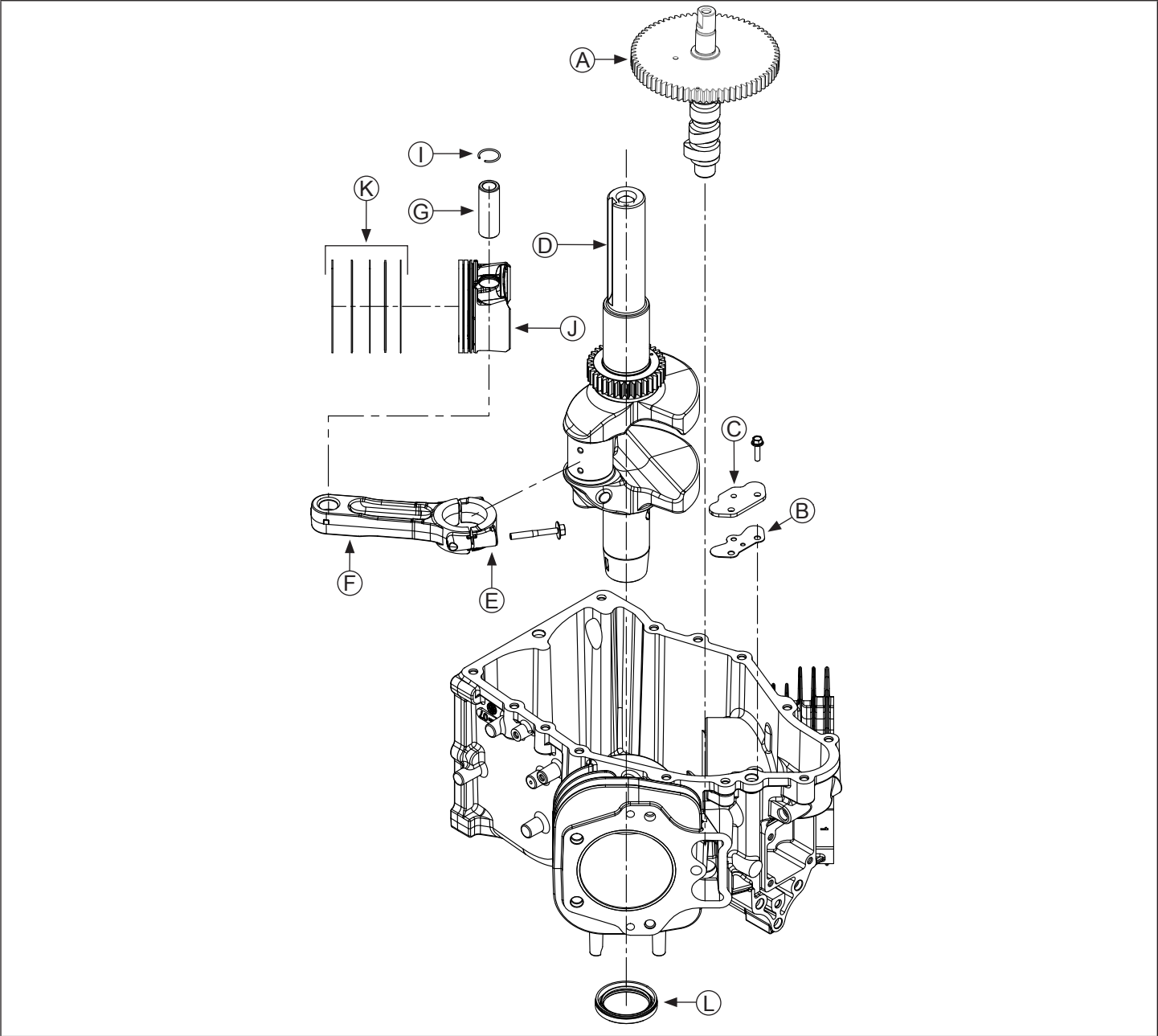
Reassembly

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 4 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. Install fastener into screw location 4 and fully torque to recommended value.
 - e. 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



A	Camshaft	B	Lifter Feed Gasket Cover	C	Lifter Feed Cover	D	Crankshaft
E	Connecting Rod End Cap	F	Connecting Rod	G	Piston Pin	H	Piston Pin Retainer
I	Piston Pin Retainer	J	Piston	K	Piston Ring Set	L	Oil Seal

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

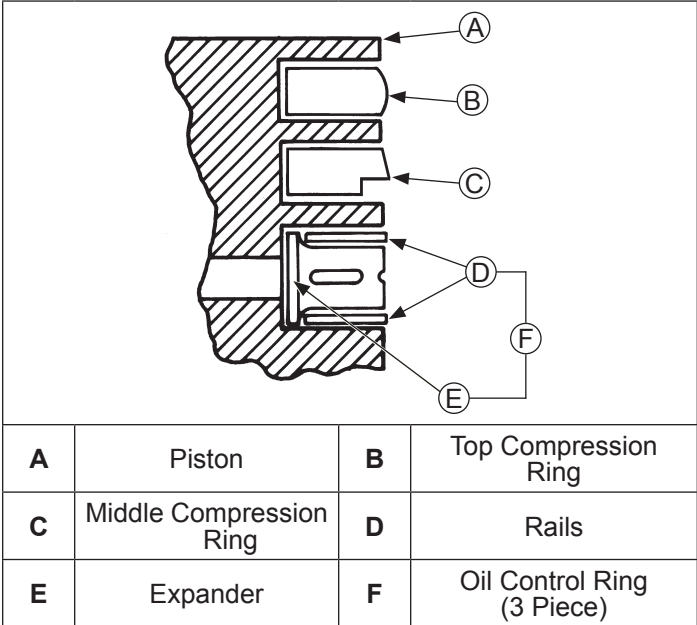
Check bearing area (big end) for excessive wear, score marks, running and side clearances. Replace rod and cap if scored or excessively worn.

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.

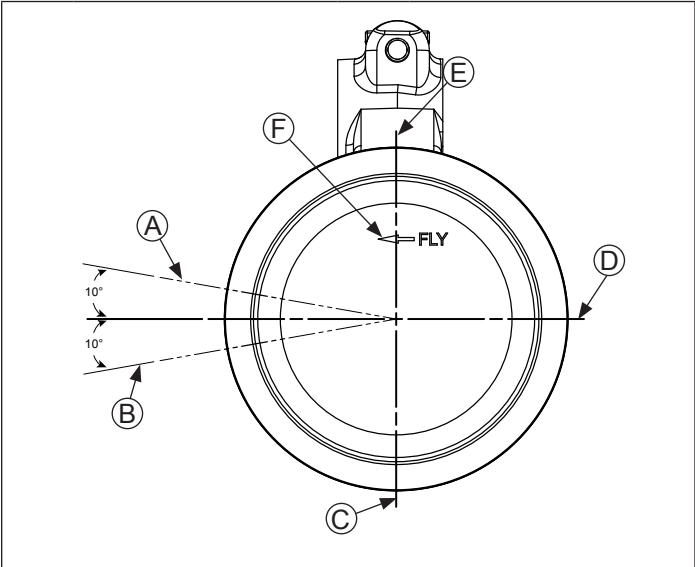
Replacement ring sets are also available separately for STD, 0.25 mm (0.010 in.), and 0.50 mm (0.020 in.) oversize pistons. Always use new piston rings when installing pistons. Never reuse old rings.

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



A	Top Oil Ring Rail Gap	B	Bottom Oil Ring Rail Gap
C	Middle Ring Gap	D	Oil Ring Expander Gap
E	Top Ring Gap	F	FLY Stamp

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:

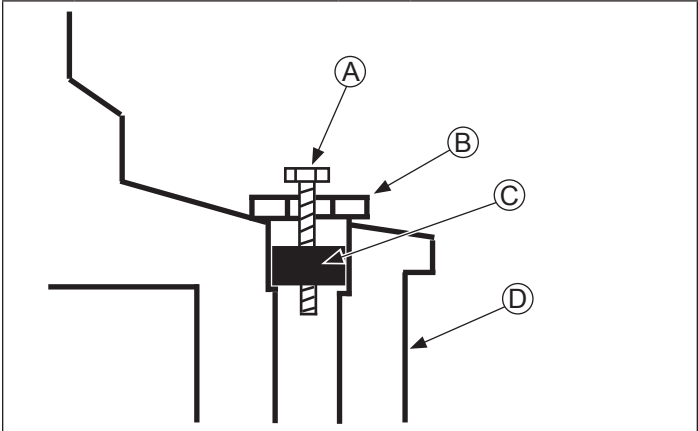
1. Oil control ring (bottom groove): Install expander and then rails. Make sure ends of expander are not overlapped.
2. Middle compression ring (center groove): Install center ring using a piston ring installation tool. Make sure identification mark is up or colored dye stripe (if contained), is to left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

Remove Crankshaft

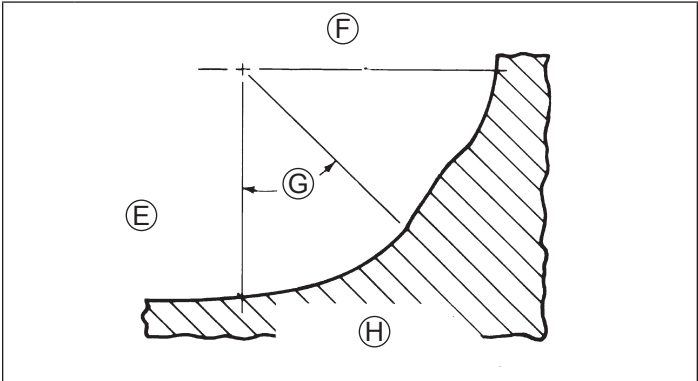
NOTE: If crankpin is reground, visually check to ensure that fillet blends smoothly with crankpin surface.

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

Inspection and Service
Crankshaft Components and Details



A	Self-Tapping Screw	B	Flat Washer
C	Plug	D	Crankshaft



E	Fillet Must Blend Smoothly with Bearing Journal Surface
F	High Point from Fillet Intersections
G	45° Minimum
H	This Fillet Area Must Be Completely Smooth

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 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

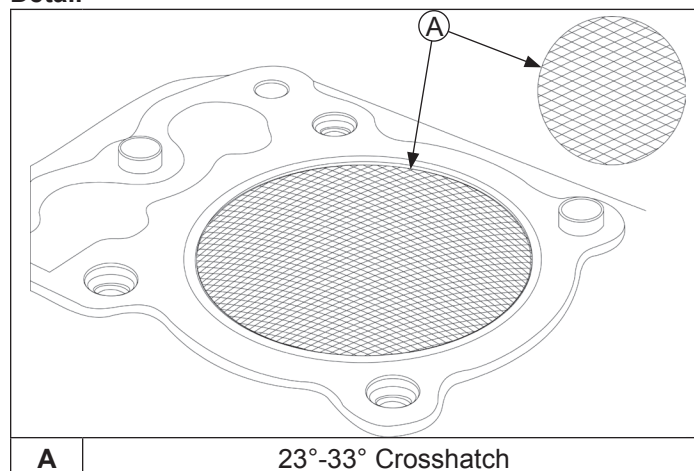
Inspection and Service

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.

Honing Detail



NOTE: Rehlko 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 Rehlko 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.

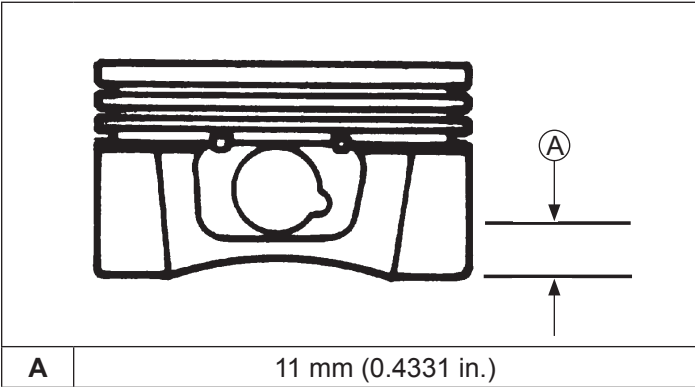
Clean Cylinder Bore After Honing

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.

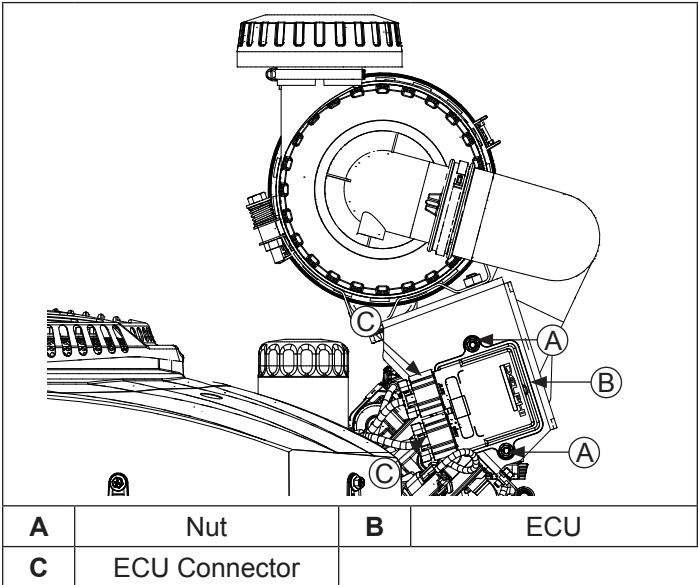
Before installing piston into cylinder bore, it is necessary that clearance be accurately checked. This step is often overlooked, and if piston thrust face-to-cylinder bore running clearance is not within 0.033/0.071 mm (0.0013/0.0028 in.), engine failure will usually result.

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).

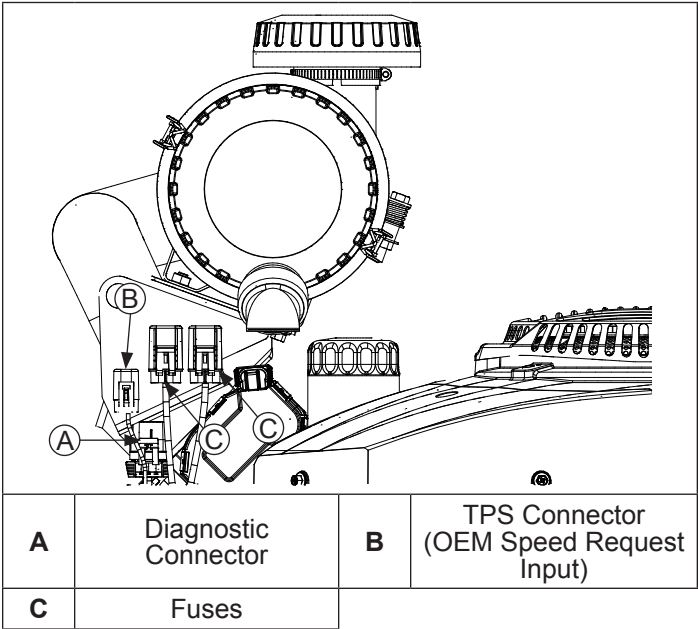
Electronic Throttle Body (ETB) and Intake Components

Remove ECU



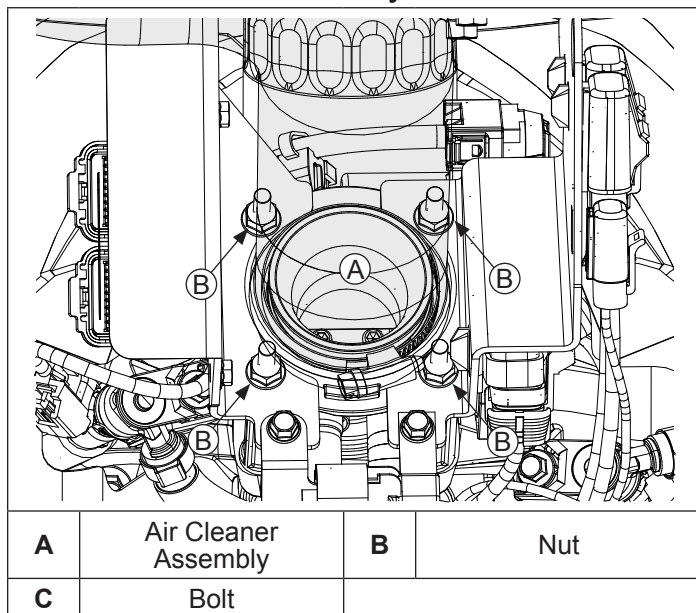
1. Remove nuts securing ECU to vibration stud isolators in bracket.
2. Disconnect Black and Gray electrical connectors from ECU.
3. Reverse procedure to reassemble. Torque nuts to 2 N·m (18 in. lb.).

Unplug Diagnostic Connector and Fuses from Holders on Bracket



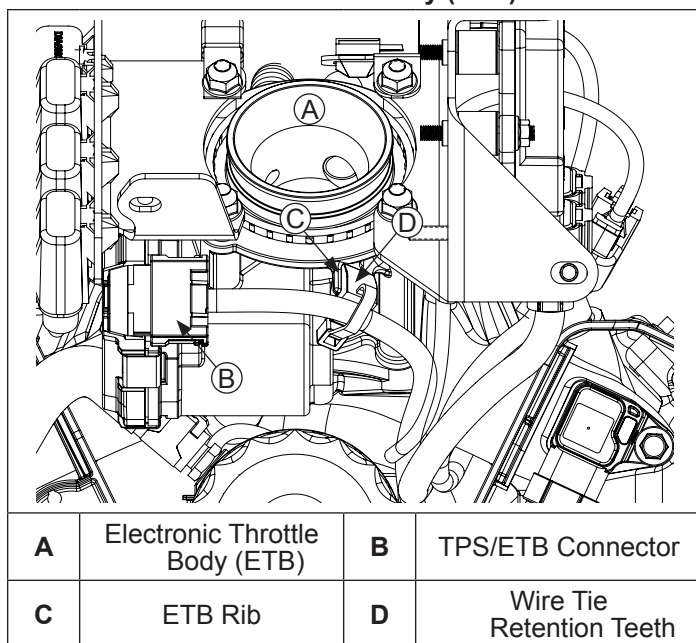
1. Unplug diagnostic connector from holder on bracket.
2. Unplug TPS Connector and 2 fuses from their holders on bracket.
3. Reverse procedure to reassemble.

Remove Air Cleaner Assembly

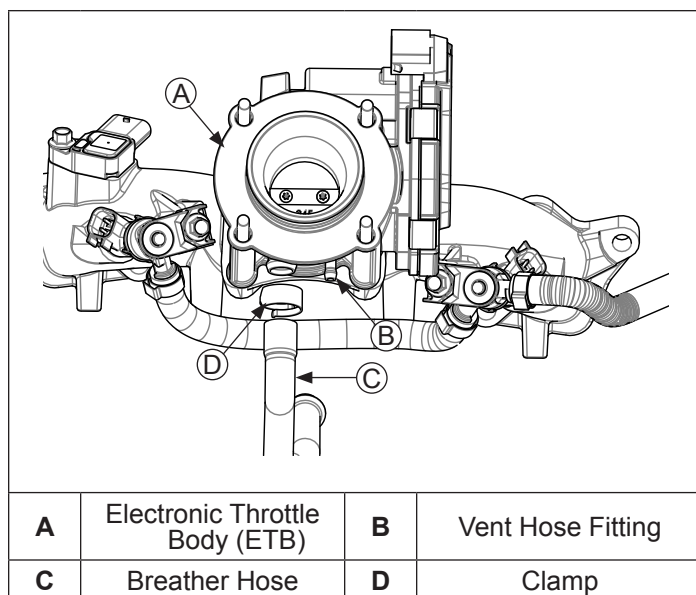


1. Remove nuts securing air cleaner assembly to electronic throttle body (ETB). Lower bolts also secure a clip and O2 sensor connector bracket.
2. Lift off air cleaner assembly with brackets and O-ring.
3. Reverse procedure to reassemble. Torque nuts to 8.3 N·m (73 in. lb.).

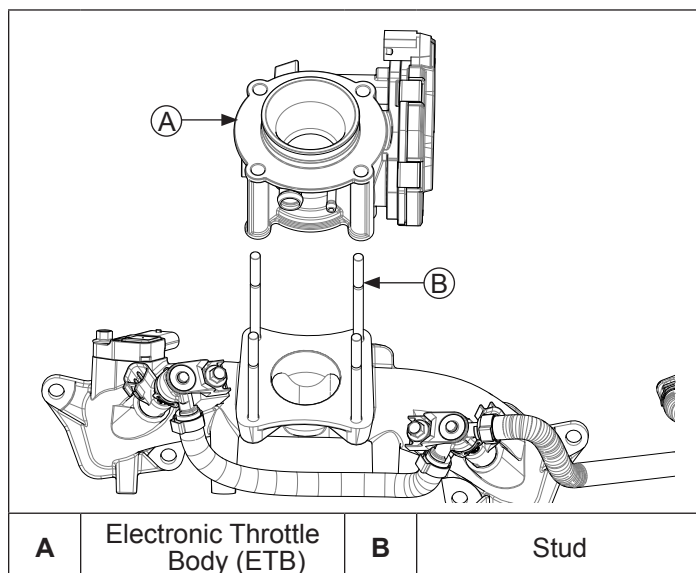
Remove Electronic Throttle Body (ETB)



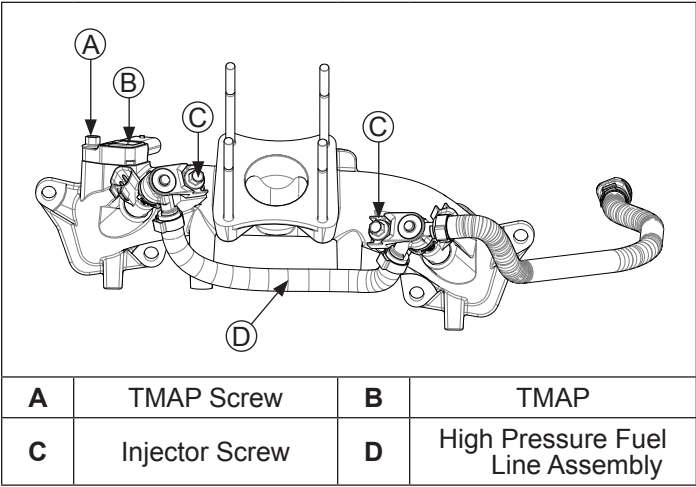
1. Disconnect TPS/ETB connector. Carefully remove retention teeth of wire tie securing TPS/ETB lead to rib on ETB.



2. Slide clamp and disconnect breather hose from ETB.
3. Disconnect vent hose from fitting on ETB.



4. Lift ETB with O-ring off studs in intake manifold.
5. Reverse procedure to reassemble.



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 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 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



WARNING

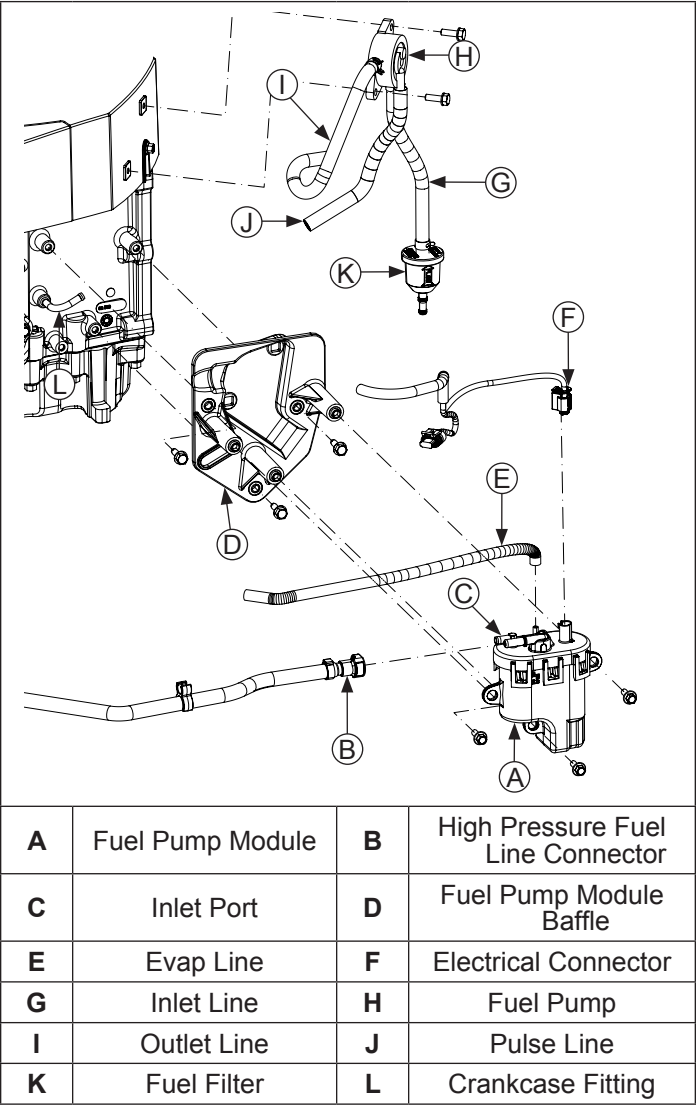
Explosive Fuel can cause fires and severe burns.

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.

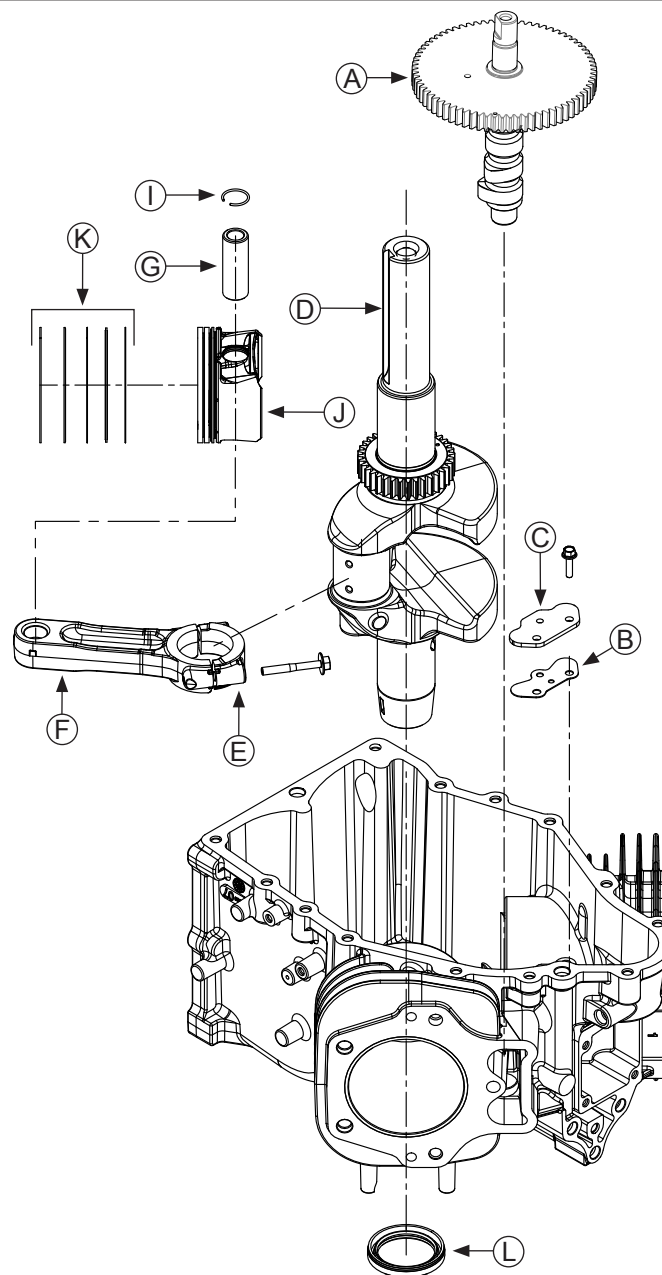
Fuel Pump Module/Fuel Pump was removed as an assembly. An exploded view of that assembly with steps to disassemble it follow.

Fuel Pump Module/Pump Assembly Components



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.

Crankcase Components



A	Camshaft	B	Lifter Feed Gasket Cover	C	Lifter Feed Cover	D	Crankshaft
E	Connecting Rod End Cap	F	Connecting Rod	G	Piston Pin	H	Piston Pin Retainer
I	Piston Pin Retainer	J	Piston	K	Piston Ring Set	L	Oil Seal

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

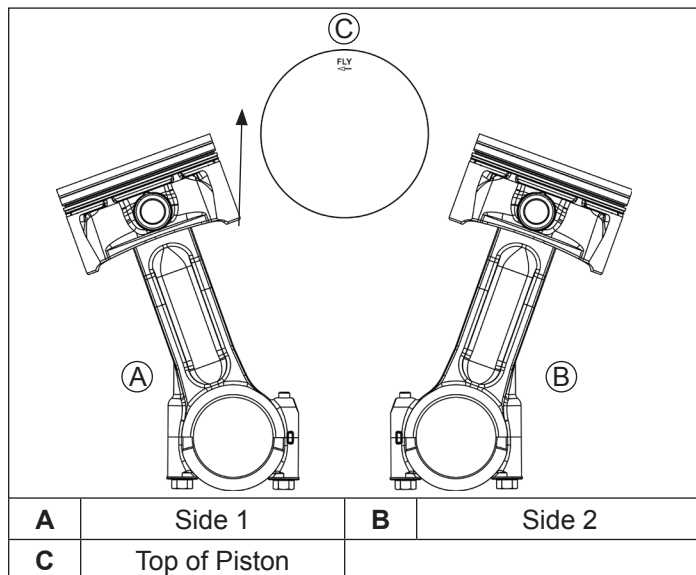
1. Install lifter feed chamber gasket, followed by lifter feed cover over lifter feed chamber.
2. Install screws. Make sure all parts are properly aligned. Torque screws to 6.6 N·m (58 in. lb.).

Install 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.).
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.)

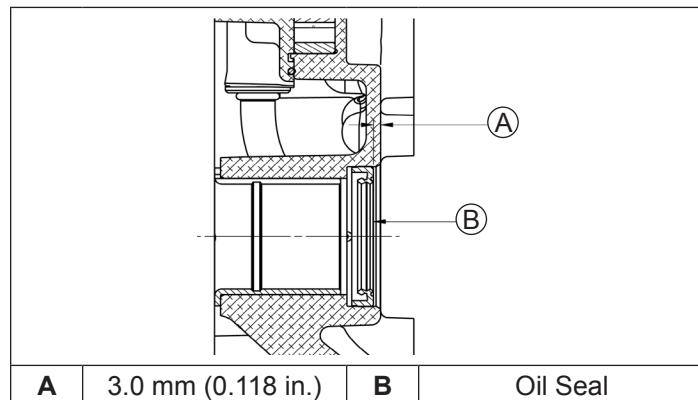
4. Reinstall end play checking tool and recheck end play.

Install Oil Pan Seal and Crankshaft Bearing (PTO)

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

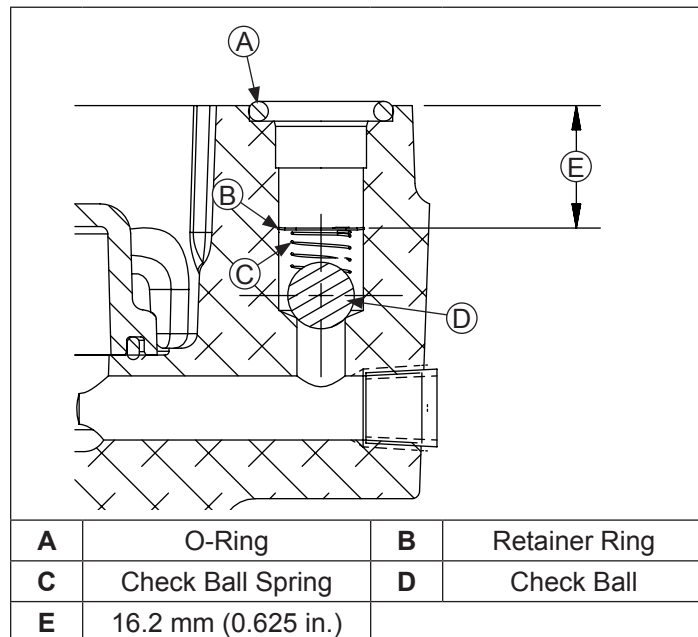
1. Make sure oil pan bore for bearing is clean, dry and free of nicks or burrs.
2. Press crankshaft bearing (PTO) in place with notch oriented in 12 o'clock position using an arbor press and driver. Make sure bearing is fully seated against flange.
3. Apply a light coat of clean engine oil to inner surface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

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.

Install Check Ball Kit



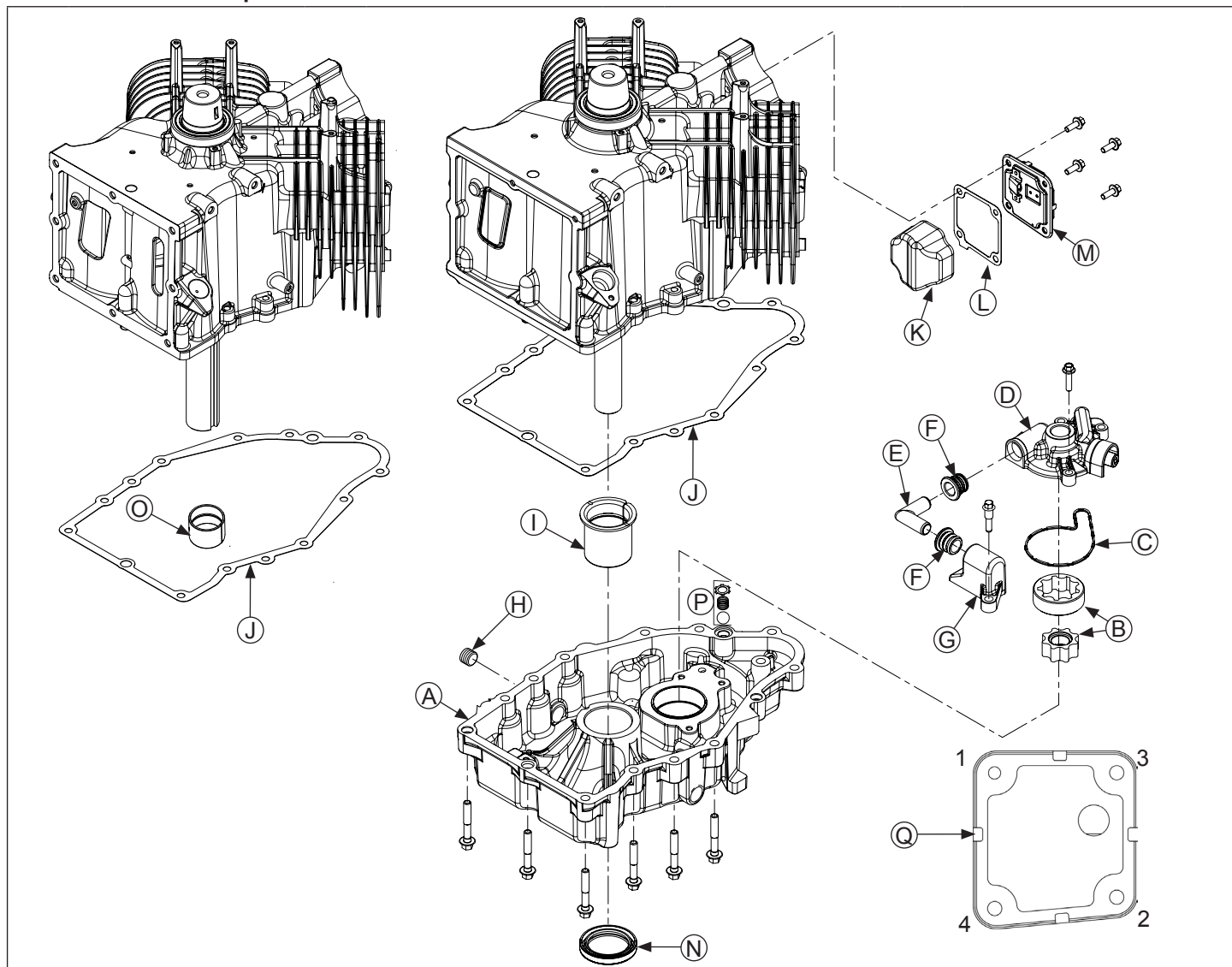
If retainer, spring, and check ball were removed from oil feed passage of oil pan, be sure to reinstall in correct assembly orientation.

Check ball first, then spring, with spring retainer last installed to proper depth below machined surface of oil pan.

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.

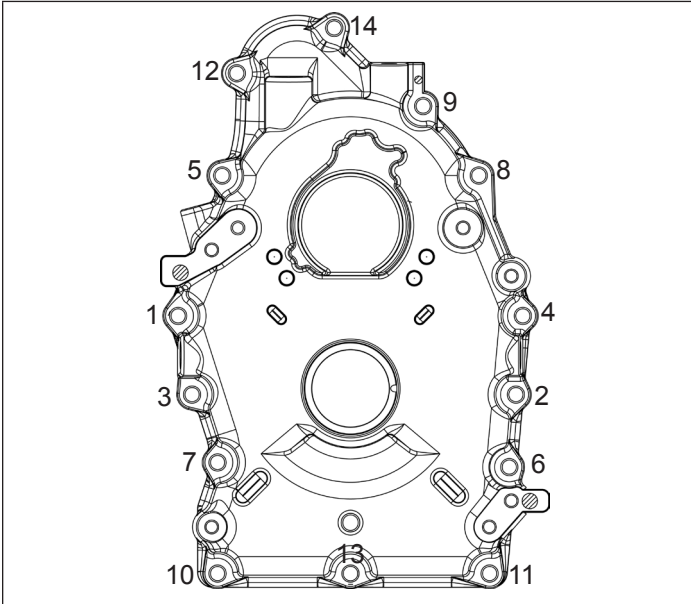
Breather/Oil Pan Components



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	Check Ball Kit
Q	Breather Fastener Torque Sequence						

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.

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

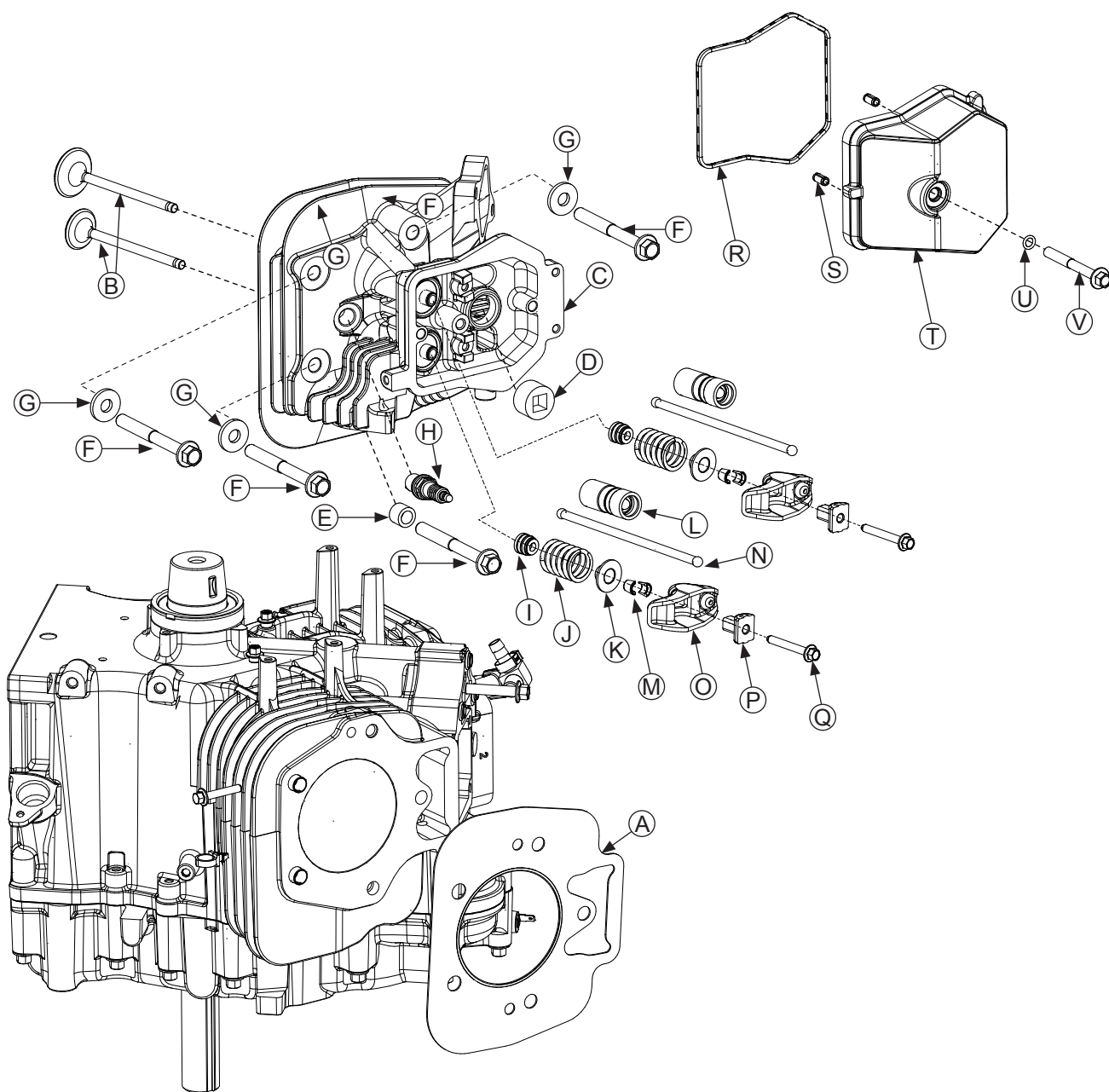
These engines use valve stem seals on intake and exhaust valves. Always use new seals whenever valves are removed from cylinder head. Seals should also be replaced if worn or damaged. Never reuse an old seal.

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).

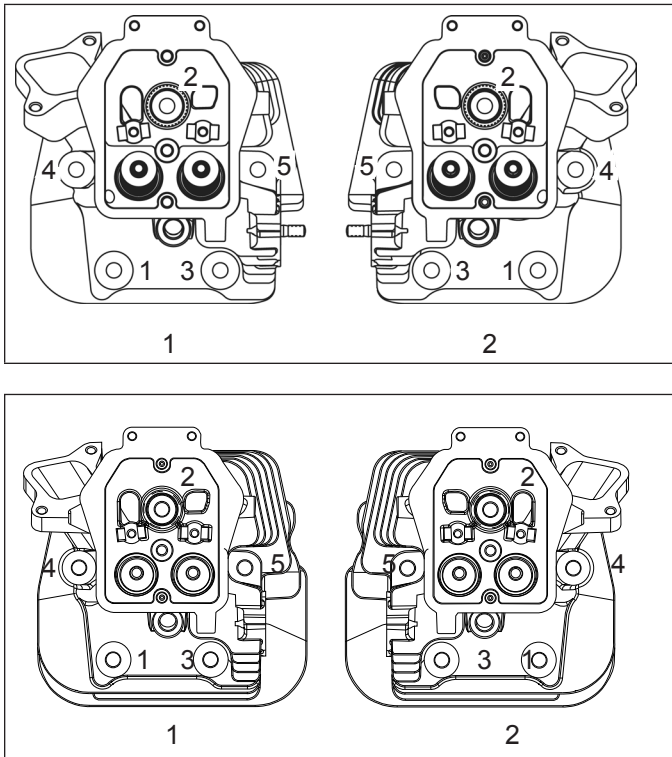
Cylinder Head Components



A	Gasket	B	Valve	C	Cylinder Head	D	Pipe Plug
E	Spacer	F	Head Bolt	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 Arm Screw	R	Valve Cover Seal	S	Roll Pin	T	Valve Cover
U	O-Ring	V	Screw				

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

NOTE: A new valve cover seal must be installed anytime the valve cover is removed from engine.

1. Make sure sealing surfaces are clean and free of any nicks or burrs.
2. Install and properly seat a new seal into each valve cover.
3. Apply clean engine oil under screw head and on threads of each valve cover screw, O-ring, and new valve cover seal.
4. Install valve covers on same side as they were originally installed and tighten screws.
5. Check position of valve cover and seal.

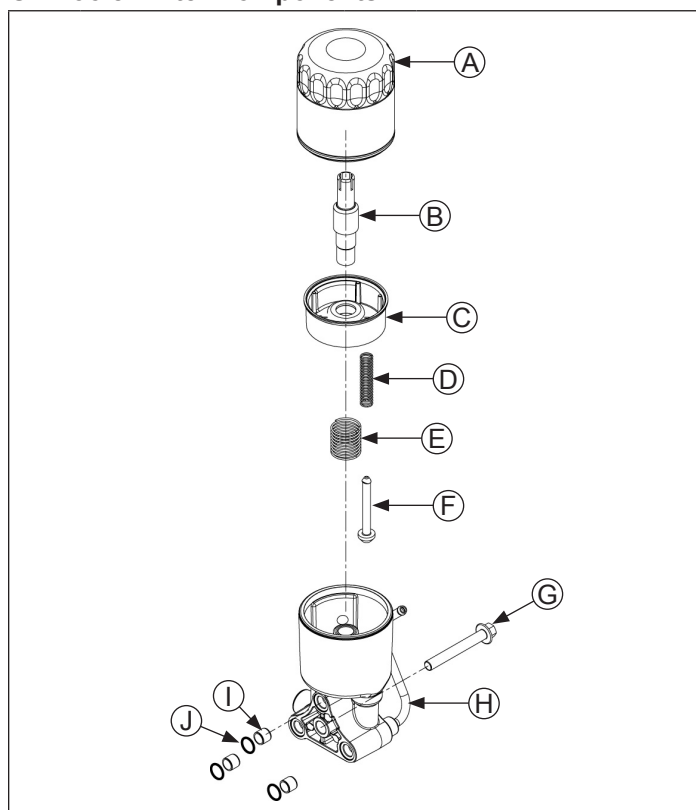
Into New Head: Torque screw to 26 N·m (230 in. lb.) to ensure seal seats in valve cover groove. Back off screw to zero and then torque screw again to 18.1 N·m (160 in. lb.).

Into Used Head: Torque screw to 16.4 N·m (145 in. lb.) to ensure seal seats in valve cover groove. Back off screw to zero and then torque screw again to 16.4 N·m (145 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.).

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

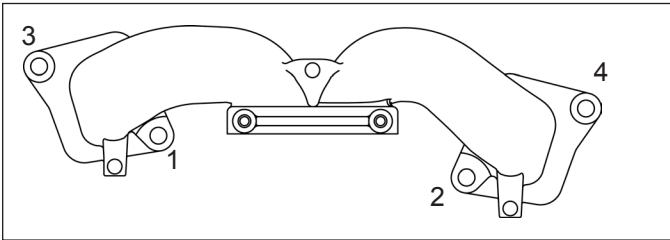
1. Install small spring onto rubber valve, and insert small end through corresponding hole in cup until properly seated.
2. Install larger spring into filter housing.
3. Insert oil filter cup, aligning cutout with corresponding section in housing.
4. Install nipple in housing and torque to 17.8 N·m (158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

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 as 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 (Standard Ignition) 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.).

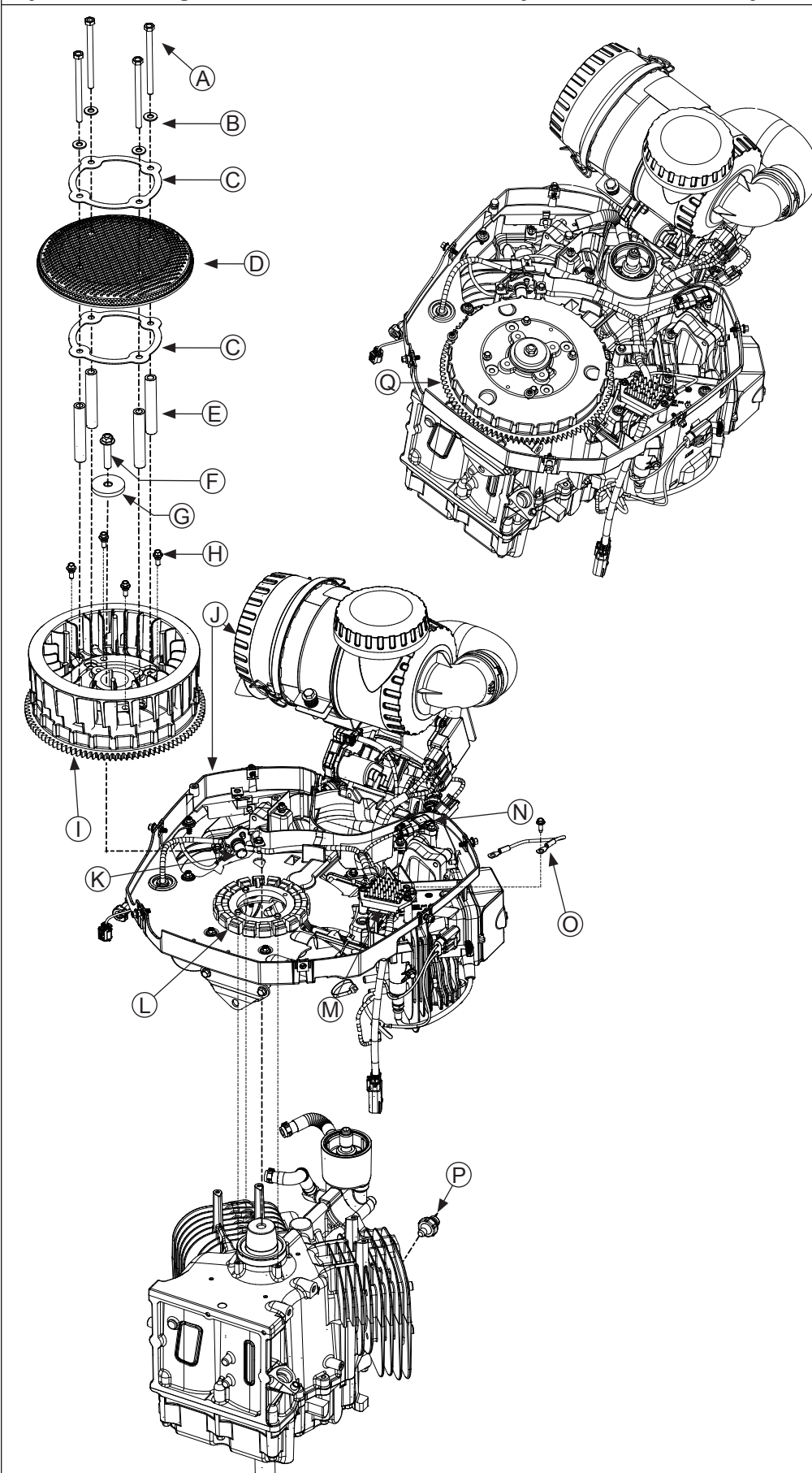
Install Oil Sentry™ (if equipped)

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 wire lead (green) to Oil Sentry™ terminal.

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. Install oil temp sensor connector.
3. Install MAP or TMAP sensor connector.

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



A	Screw
B	Washer
C	Support Ring
D	Grass Screen Guard
E	Spacer
F	Flywheel Screw
G	Flywheel Washer
H	Fan Screw
I	Fan/Flywheel Assembly
J	Backing Shroud/ Intake Manifold/ Air Cleaner
K	Crankshaft Position Sensor
L	Stator
M	Rectifier-Regulator Connector
N	MAP or TMAP Sensor Connector
O	Ground Lead
P	Oil Pressure Sensor
Q	High Output Charging System Flywheel

Install Oil Cooler (Engine Mounted)

NOTE: When oil cooler is remote mounted in application and supplied by OEM, refer to your equipment manual for reassembly detail.

NOTE: Earlier engines were built with spring clamps securing oil cooler hoses. New spring clamps are recommended any time disassembly is performed, or if clamps have been loosened (expanded) several times.

Newer engines are built with Oetiker clamps securing oil cooler hoses. Refer to position of each Oetiker clamp as noted in disassembly, before installing and crimping.

1. Connect hoses between oil filter adapter and oil cooler. Secure with new clamps. When Oetiker clamps are used, only use an Oetiker clamp pliers to crimp them.
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 (Standard Ignition)

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 over stressed 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.

NOTE: High output charging system flywheel (identified by 4 large cooling holes) has very strong magnets. Magnet assembly guard on interior of this flywheel has a thin, sharp edge. Wear protective gloves when handling this flywheel.

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. ETB ECV EFI engines with high output charging system have a flywheel with very strong magnets. Wear protective gloves and use a flywheel puller to help line up flywheel and crankshaft before magnets pull flywheel into place.
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

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

1. Install fan onto flywheel using screws.
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.

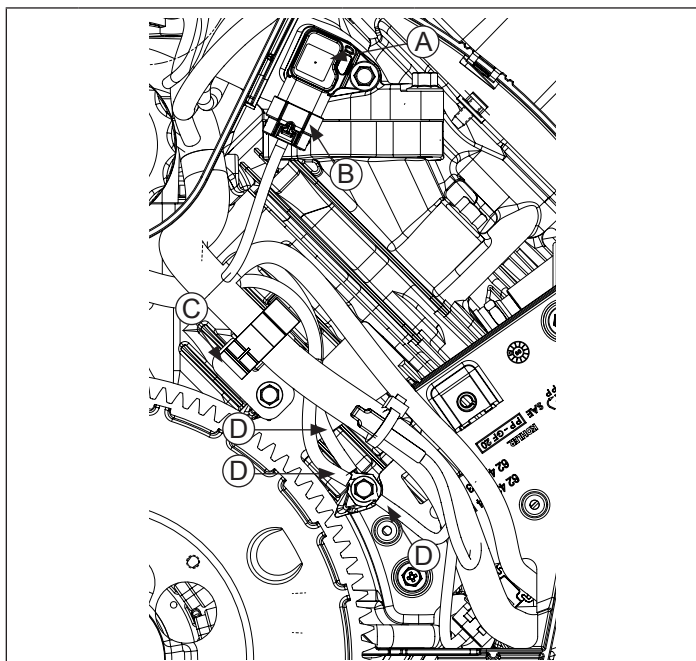
NOTE: On engines with earlier design bracket, an air gap must be set when installing. Later design brackets require no adjustment.

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. Push electrical connector on crankshaft position sensor making sure a good connection is made.

Install Ground Leads and Wiring Harness Clamp Mounting Bracket (High Output Ignition)



A	TMAP Sensor	B	TMAP Connector
C	Wiring Harness Clamp Bracket	D	Ground Lead

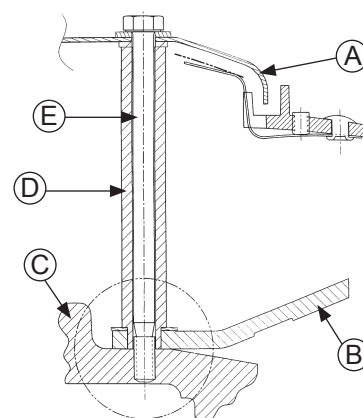
1. Install TMAP sensor connector.
2. Install screws securing wiring harness clamp bracket and ground leads to #1 side cylinder bosses. Torque bracket screws to 9.7 N·m (86 in. lb.).

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.

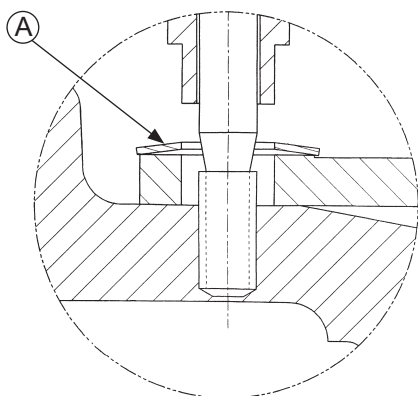


A	Metal Debris Screen	B	Fan
C	Flywheel	D	Spacer
E	Hex Bolt		

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.

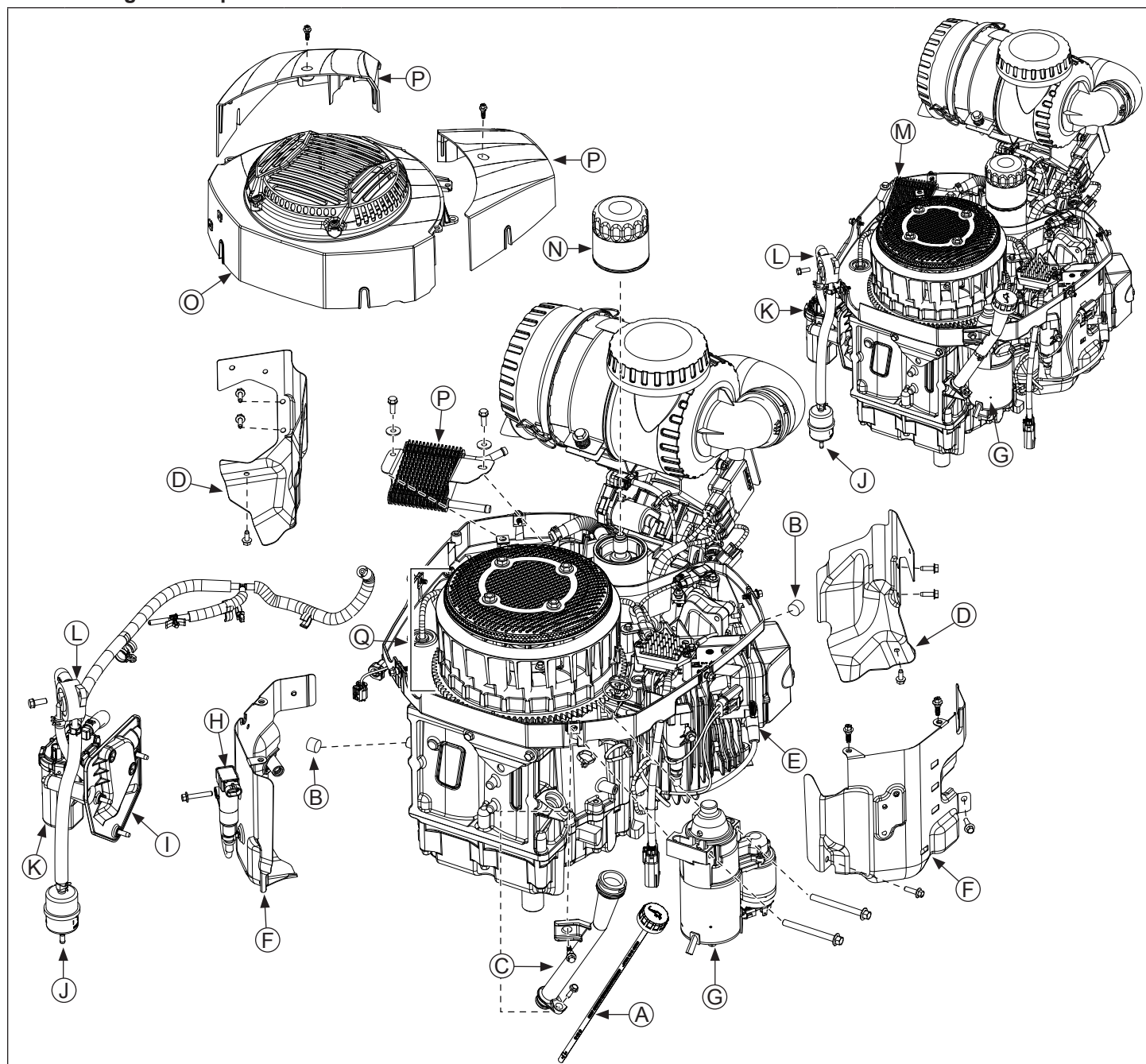
Install Metal Debris Screen

Spring Washer Details



A	Spring Washer
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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	Oil Cooler (Engine Mounted)	N	Oil Filter	O	Blower Housing with Fixed Guard	P	Cylinder Shroud
Q	Fan/Flywheel Assembly						

Install Valley and Cylinder Barrel Baffles

1. Install #1 side valley baffle and secure with screws. If equipped, reinstall clip securing harness to baffle. Install #2 side valley baffle and secure with 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. On engines equipped with high output charging system and ETB, install ignition coil connector first, then install 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 (Engine Mounted)

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. On ETB ECV EFI engines, position clamp to secure.
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. If not already done, 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

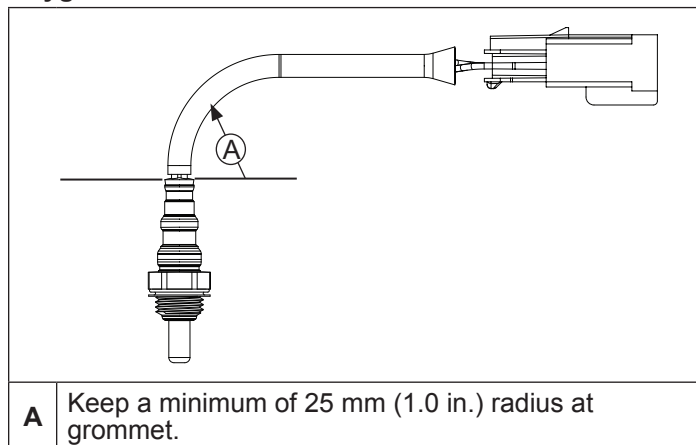
Install fuel pump to blower housing and secure with screws. Torque screws to 2.8 N·m (25 in. lb.).

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.

Install Muffler

Oxygen Sensor Wire Detail



NOTE: Always route harness away from hot exhaust and away from moving parts.

1. Install new exhaust gaskets onto exhaust studs.
2. Install port liners (if equipped) into exhaust ports. (Exhaust components will press them to final depth.) 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 oxygen sensor, torque to 50.1 N·m (37 ft. lb.) and connect to wire harness.
On ETB ECV EFI engines, carefully install plug into bracket to secure.
5. 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: Any service to ECU, TPS/Electronic Throttle Body (ETB), or fuel pump module replacement should include ECU Reset. Refer to Electronic Fuel Injection (EFI) System Electronic Throttle Body (ETB) section.
- 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.

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

ETB ECV EFI

This engine is equipped with an electronic throttle body (ETB) and cannot be tested on a test stand or bench. Install engine in application.

Connect Stator Wires and Install High Output Charging System Terminal Block Cover

NOTE: When high output charging system rectifier-regulator is supplied by Rehlko, but installed by OEM in application, you must connect stator wires and install terminal block cover after installing engine in application. Refer to equipment manual for details on securing regulator in application and connecting OEM supplied B+ and ground wiring harnesses.

A	Torx Screw	B	Terminal Block Cover
C	Rectifier-Regulator	D	OEM Supplied B+ Wiring Harness with Charging Fuse
E	OEM Supplied Ground Wire Harness	F	Stator Wires

1. Torque nuts to 4.0 N·m (35 in. lb.).
2. Install terminal block cover and secure with Torx screws. Torque screws to 2.8 N·m (25 in. lb.).

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 guage. 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.

