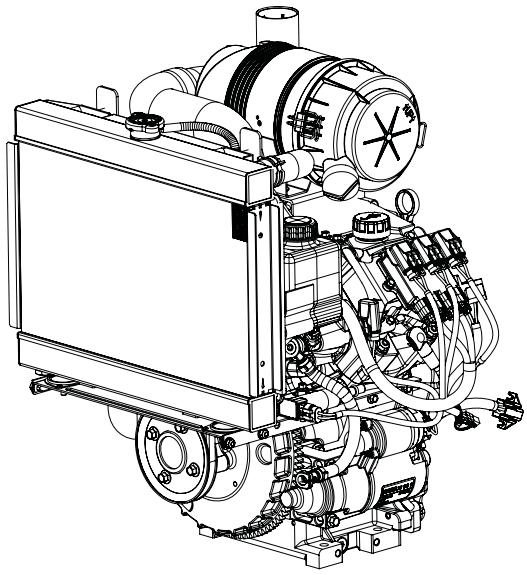
KOHLER® Aegis

ELH775

Service Manual



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

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

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

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

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.

⚠ 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.

⚠ WARNING

Hot liquid can cause severe burns.

Do not loosen radiator cap while engine is operating or warm to touch.

Liquid coolant can get extremely hot from operation. Turning radiator cap when engine is hot can allow steam and scalding liquid to blow out and burn you severely. Shut off machine. Only remove radiator cap when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.

⚠ WARNING

Explosive Fuel can cause fires and severe burns.

Fuel system ALWAYS remains under HIGH PRESSURE.

Wrap a shop towel completely around fuel connector. Press release button and slowly pull connector away 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** 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.

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

MAINTENANCE SCHEDULE

Every 200 Hours[1]

● Change oil and oil filter.	Lubrication System

Every 200 Hours

● Replace fuel filter.	

Every 250 Hours[1]

● Replace air cleaner element and check inner element.	Air Cleaner/Intake

Every 300 Hours[2]

● Change oil and oil filter (KOHLER PRO 10W-50 oil and KOHLER PRO filter).	Lubrication System

Every 500 Hours[1]

● Replace air cleaner inner element.	Air Cleaner/Intake

Every 500 Hours

● Replace spark plugs and set gap.	Electrical System

Every 1000 Hours

● Change engine coolant.	Cooling System

Every 1500 Hours[1]

● Replace unique Electronic Fuel Injection (EFI) fuel filter.

[1] Perform these procedures more frequently under severe, dusty, dirty conditions.

[2] Option only if using KOHLER® PRO oil and PRO filter.

REPAIRS/SERVICE PARTS

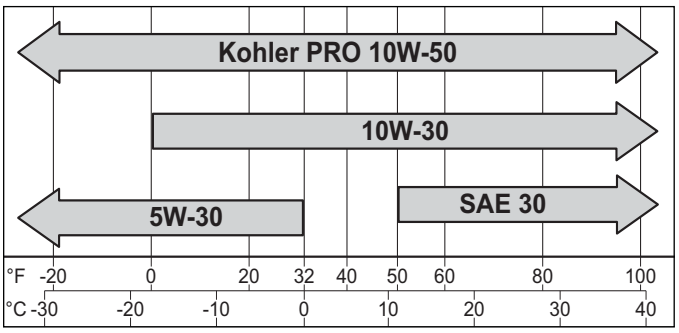
Kohler genuine service parts can be purchased from Kohler authorized dealers. Find your local Kohler Engines dealer at KohlerEngines.com or call 1-800-544-2444 (U.S.A. and Canada).

Maintenance

OIL RECOMMENDATIONS

All-season KOHLER® PRO 10W-50 Synthetic Oil is the ideal oil for KOHLER® engines. It is specifically formulated to extend the oil and oil filter change interval to 300 Hours when paired with a KOHLER PRO Extended Life Oil Filter.

300-Hour oil and oil filter change intervals are exclusive to and only authorized on KOHLER engines that utilize both the KOHLER PRO 10W-50 Synthetic Oil and KOHLER PRO Extended Life Oil Filter. Alternative engine oils and oil filters may be used with KOHLER engines but require 200-Hour oil and oil filter change intervals for proper maintenance. Oil must be API (American Petroleum Institute) service class SJ or higher. Select viscosity based on air temperature at time of operation as shown 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:

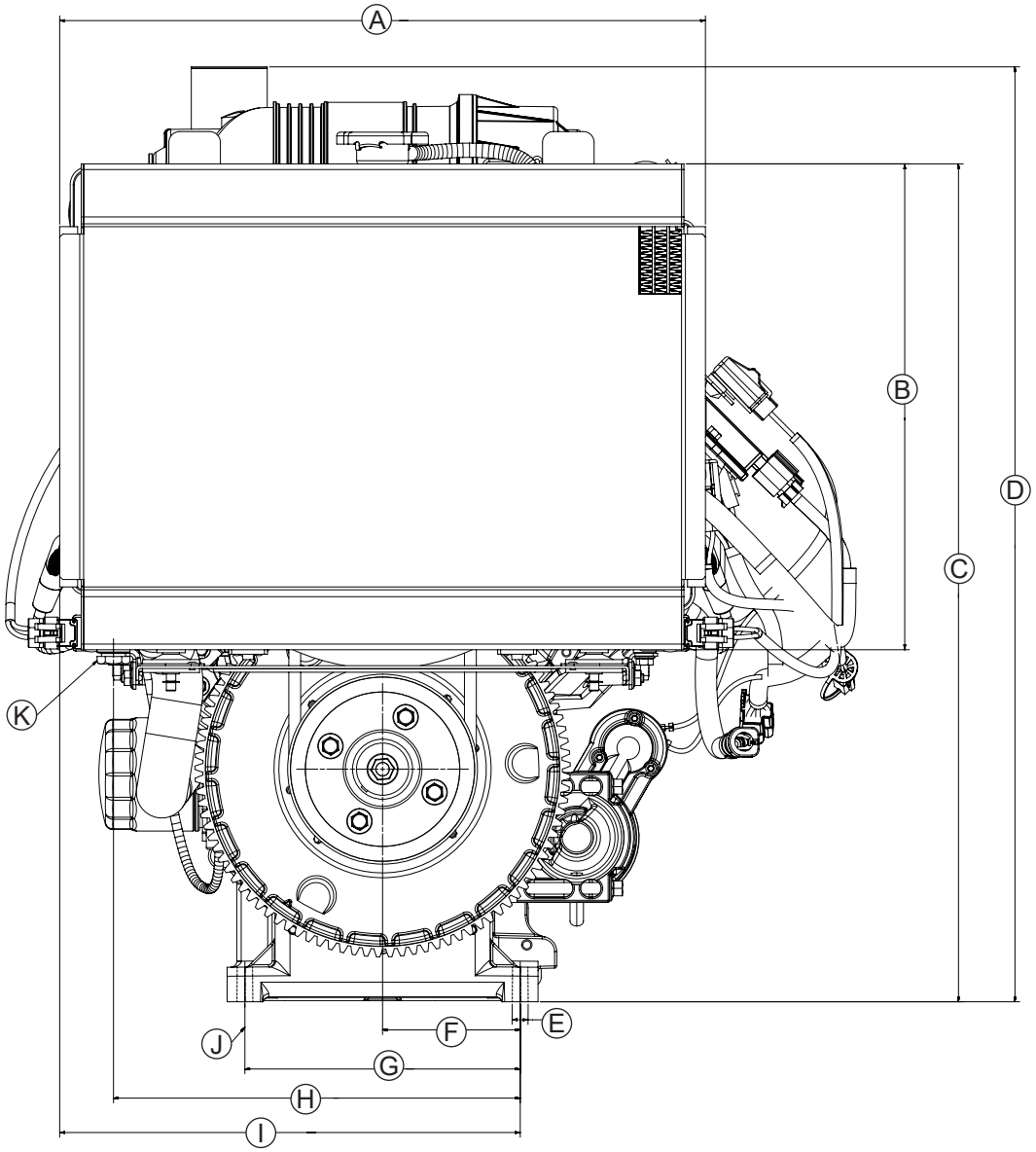
- Clean, fresh, unleaded gasoline.
- Octane rating of 87 (R+M)/2 or higher.
- Research Octane Number (RON) 90 octane minimum.
- Gasoline up to 10% ethyl alcohol, 90% unleaded is acceptable.
- Methyl Tertiary Butyl Ether (MTBE) and unleaded gasoline blend (max 15% MTBE by volume) are approved.
- Do not 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. Coolant (anti-freeze) mixture should be in good condition and tested to guard against freezing in cold temperatures. Recommended 50/50 mixture will normally provide protection down to temperatures of -34°F (-37°C). If storage temperatures will fall below this, cooling system should be drained completely. A note should then be attached to equipment and/or engine as a reminder to refill cooling system before starting.
2. Add Kohler PRO Series fuel treatment or equivalent to fuel tank. Run engine 2-3 minutes to get stabilized fuel into fuel system (failures due to untreated fuel are not warrantable).
3. Change oil while engine is still warm from operation (NOT required if using KOHLER PRO 10W-50 full-synthetic oil). 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.
4. Disconnect negative (-) battery cable.
5. Store engine in a clean, dry place.

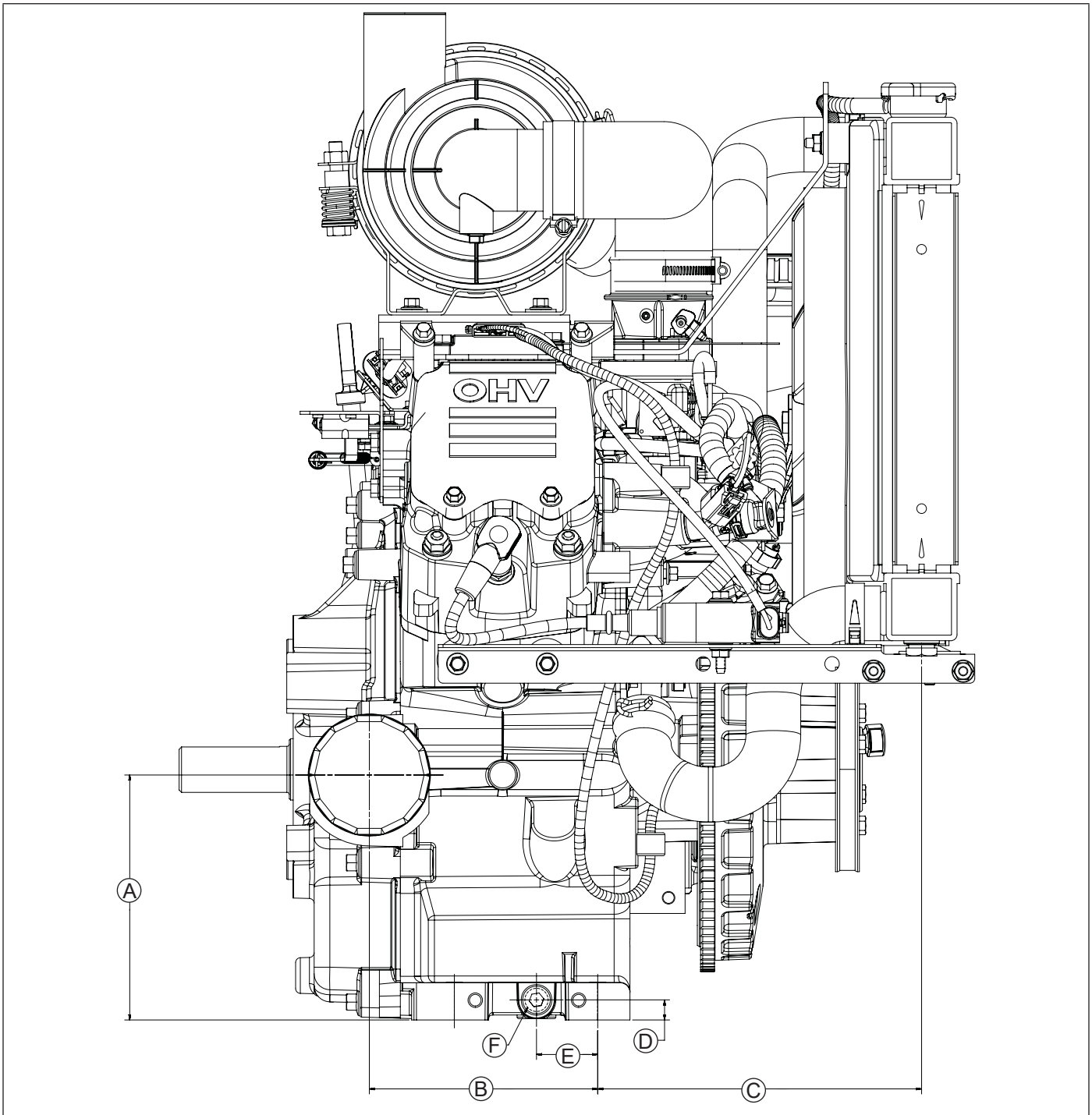
Engine Dimensions-Flywheel Side



A	432.0 mm (17.01 in.)	**B**	325.0 mm (12.80 in.)	**C**	560.45 mm (22.07 in.)	**D**	625.33 mm (24.62 in.)
E	4 X Ø 10.66 mm (0.42 in.)	**F**	92.10 mm (3.63 in.)	**G**	2 X 184.20 mm (7.25 in.)	**H**	272.10 mm (10.71 in.)
I	308.10 mm (12.13 in.)	**J**	Mounting Hole Center Line	**K**	Radiator Drain Plug		

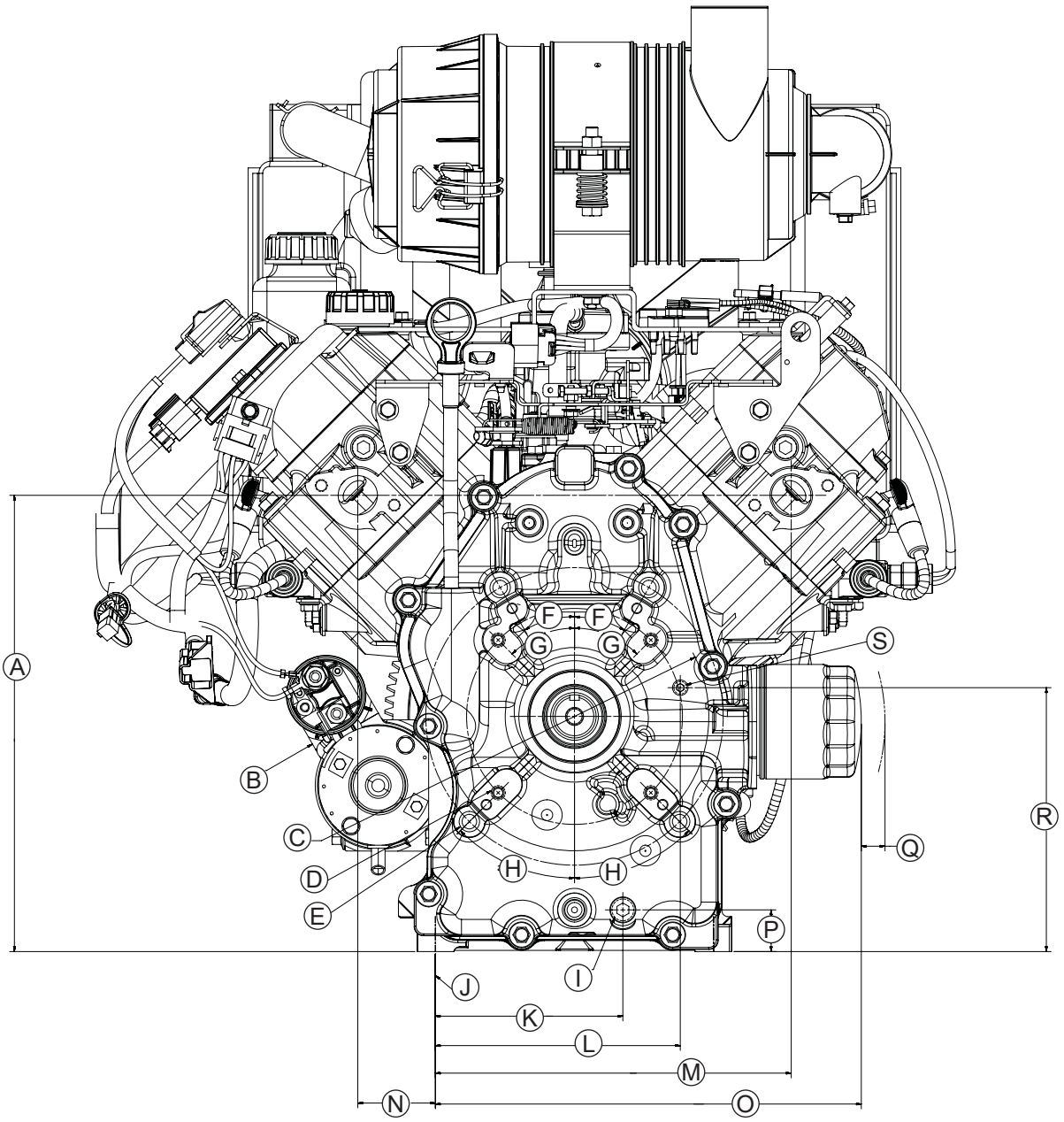
Specifications

Engine Dimensions-Oil Filter Side



A	152.08 mm (5.99 in.)	**B**	141.75 mm (5.58 in.)	**C**	201.0 mm (7.91 in.)	**D**	12.47 mm (0.49 in.)
E	38.0 mm (1.50 in.)	**F**	3/8 NPTF Plug				

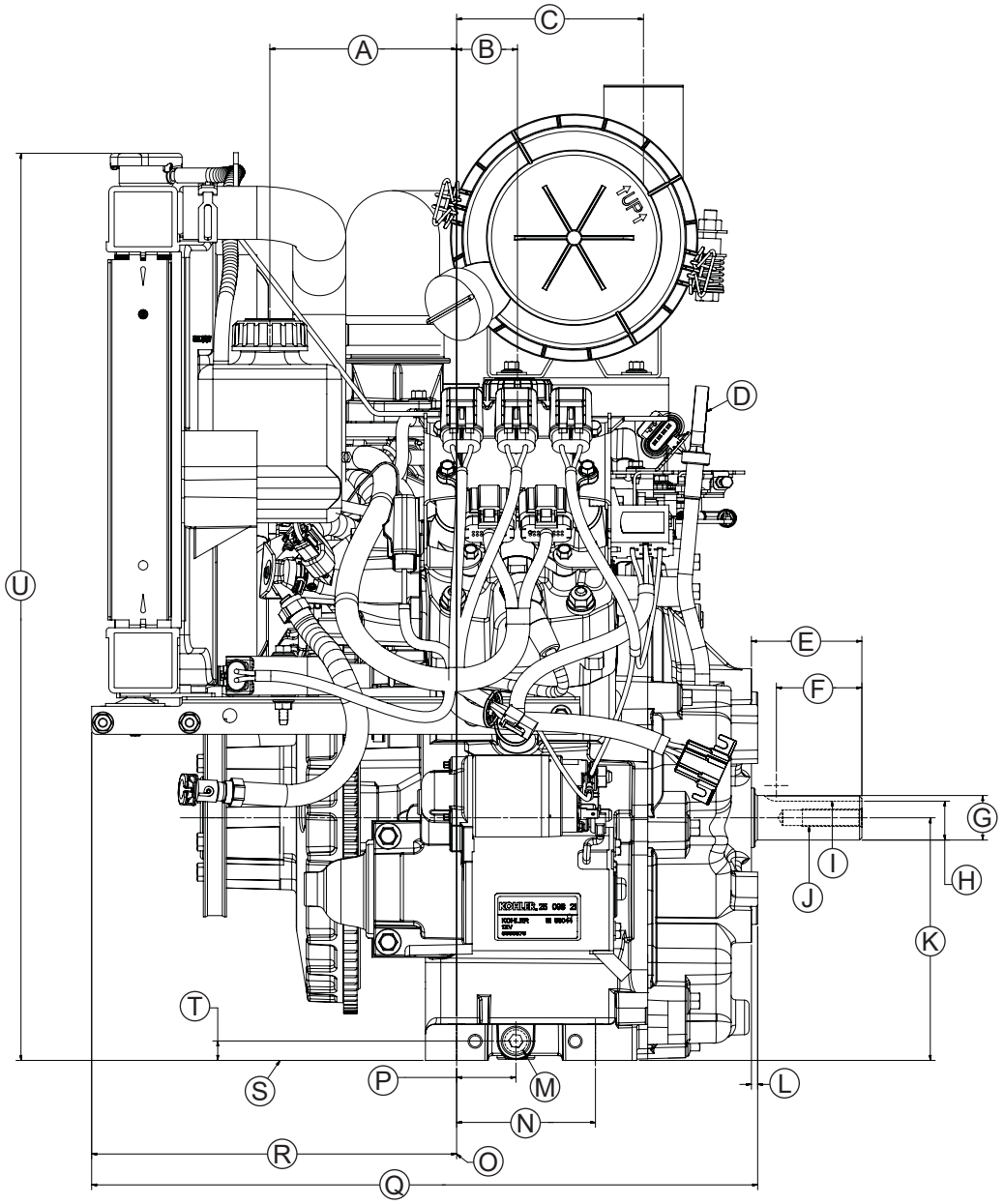
Engine Dimensions-Engine Mounting Surface (PTO End)



A	301.84 mm (11.88 in.) Exhaust Ports	**B**	Starter	**C**	Ø 177.80 mm (7.00 in.) Pilot	**D**	4 X 3/8-16 UNC-2B in. 17.0 mm (0.66 in.) Deep
E	4 X 7/16-14 UNF-2B in. 21.0 mm (0.82 in.) Deep	**F**	30°	**G**	45°	**H**	2 X 45°
I	3/8 NPTF Plug	**J**	Mounting Hole Center Line	**K**	124.10 mm (4.89 in.)	**L**	162.10 mm (6.38 in.)
M	235.54 mm (9.27 in.)	**N**	51.34 mm (2.02 in.)	**O**	281.91 mm (11.10 in.) Oil Filter	**P**	27.58 mm (1.09 in.)
Q	15.70 mm (0.62 in.) Oil Filter Removal	**R**	174.58 mm (6.87 in.)	**S**	1/8 NPTF Plug		

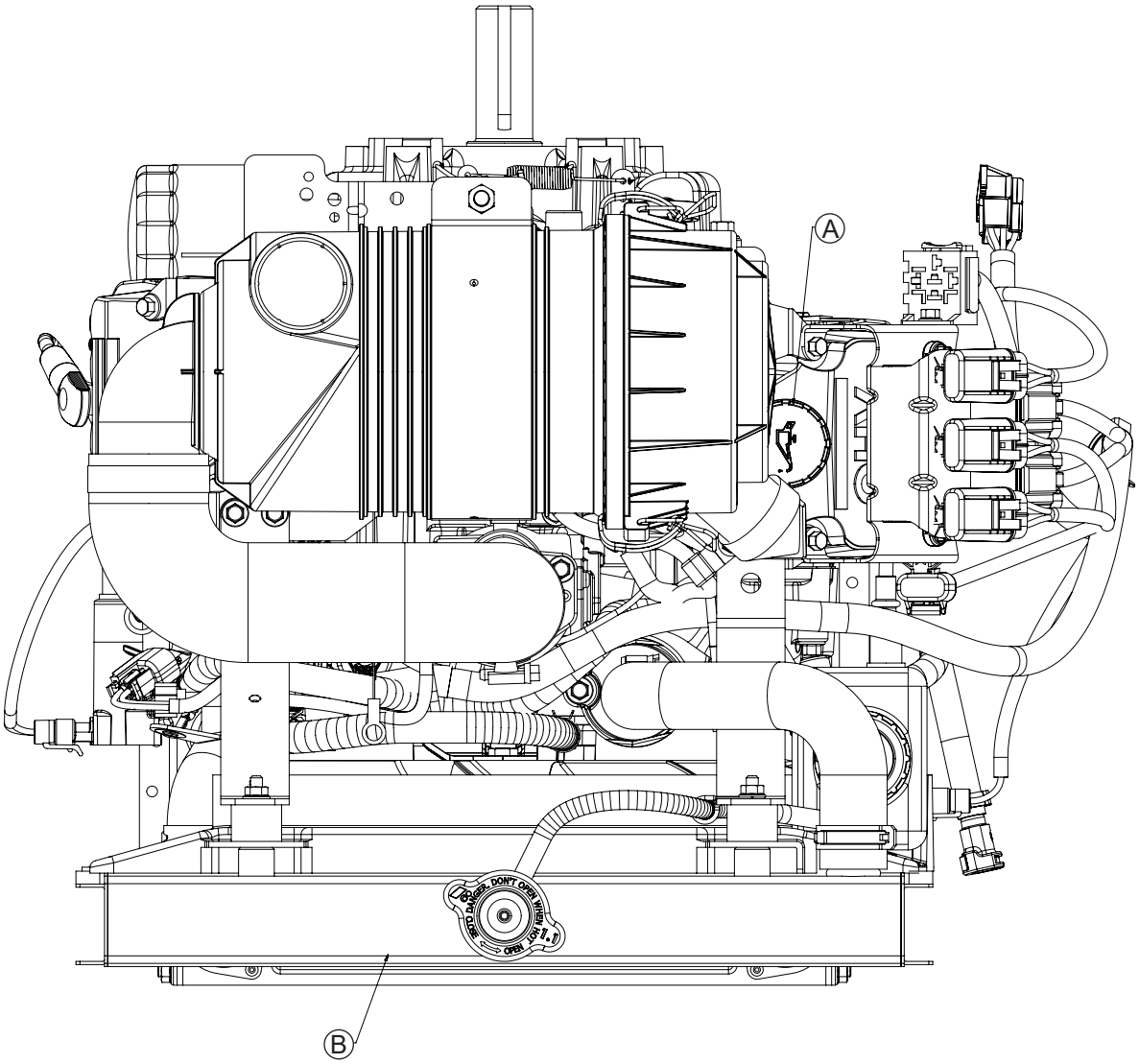
Specifications

Engine Dimensions-Starter Side



A	119.75 mm (4.72 in.) Coolant Overflow Fill	**B**	39.0 mm (1.54 in.) Oil Fill	**C**	119.78 mm (4.72 in.)	**D**	Dipstick
E	70.8 mm (2.79 in.)	**F**	54.8 mm (2.16 in.)	**G**	Ø 28.56 mm (1.13 in.) ± 0.13 mm (0.01 in.)	**H**	24.94 mm (0.98 in.) ± 0.13 mm (0.01 in.)
I	1/4 Inch Square Key	**J**	7/16-20 UNF-2B in. 38.1 mm (1.50 in.) Deep	**K**	155.58 mm (6.13 in.)	**L**	4.0 mm (0.16 in.) Pilot
M	3/8 NPTF Plug	**N**	2 X 89.0 mm (3.50 in.) Mounting Holes	**O**	Mounting Hole "A" Center Line	**P**	38.0 mm (1.50 in.) Oil Drain Plug Center Line
Q	427.0 mm (16.81 in.)	**R**	234.0 mm (9.21 in.)	**S**	Engine Mounting Surface	**T**	12.47 mm (0.49 in.)
U	581.65 mm (22.90 in.)						

Engine Dimensions-Top

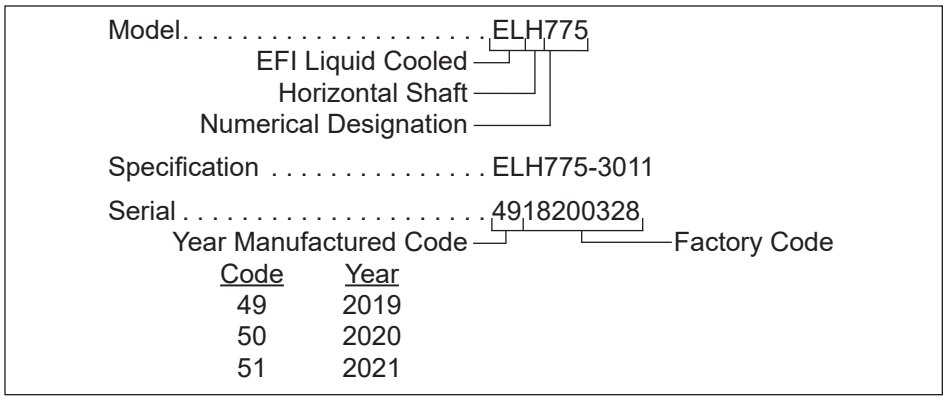


A	Oil Fill Cap	**B**	Radiator

Specifications

ENGINE IDENTIFICATION NUMBERS

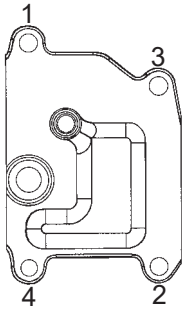
Kohler engine identification numbers (model, specification and serial) should be referenced for efficient repair, ordering correct parts, and engine replacement.



GENERAL SPECIFICATIONS[3,4]	ELH775
Bore	83 mm (3.3 in.)
Stroke	69 mm (2.7 in.)
Displacement	747 cc (45.6 cu. in.)
Oil Capacity (refill)	1.6-1.8 L (1.7-1.9 U.S. qt.)
Maximum Angle of Operation (@ full oil level)[5]	20°

TORQUE SEQUENCES **ELH775**

(Refer to Torque Specifications for torque values).

Breather Cover Fasteners	

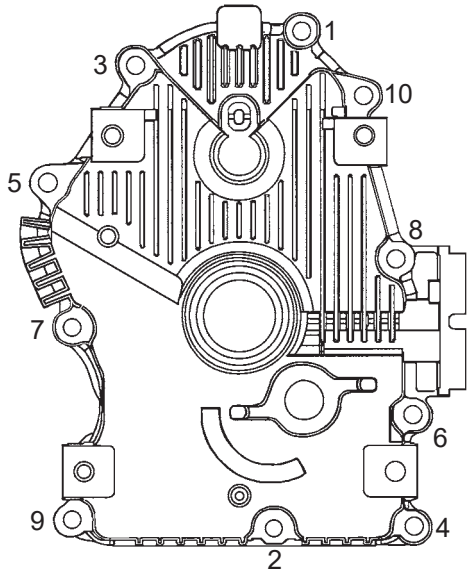
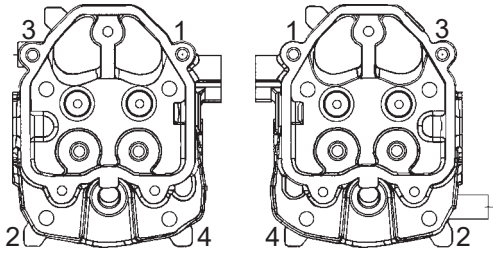
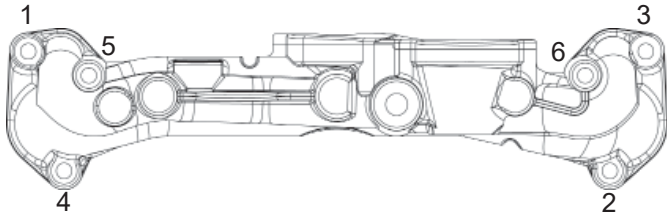
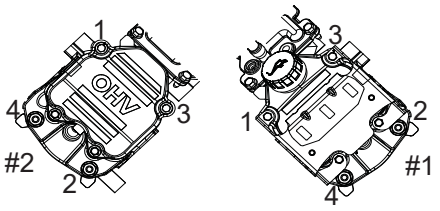
[3] Values are in Metric units. Values in parentheses are English equivalents.

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

[5] Exceeding maximum angle of operation may cause engine damage from insufficient lubrication.

TORQUE SEQUENCES	ELH775

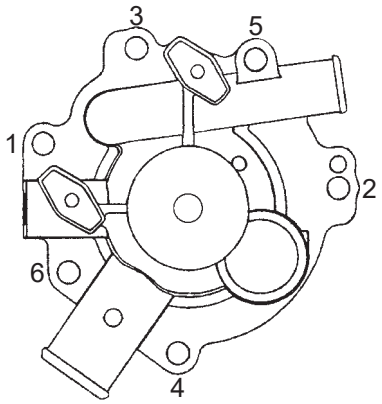
(Refer to Torque Specifications for torque values).

Closure Plate Fasteners	
Cylinder Head Bolt Fasteners	
Intake Manifold Mounting Fasteners	
Valve Cover Fasteners	

Specifications

TORQUE SEQUENCES	ELH775

(Refer to Torque Specifications for torque values).

Water Pump Fasteners	

TORQUE SPECIFICATIONS[3,6]	ELH775

Intake Manifold

Intake Manifold Fastener (torque in 2 increments) (torque sequence on page 11)	first to 7.4 N·m (66 in. lb.) finally to 9.9 N·m (88 in. lb.)
Thermostat Housing Mounting Fastener	6.2-7.3 N·m (55-65 in. lb.)
Air Cleaner Adapter Mounting Fastener	7.3 N·m (65 in. lb.)
Fuel Injector Bracket Fastener	4.0 N·m (35 in. lb.)

Closure Plate

Closure Plate Fastener (torque sequence on page 11)	24.4 N·m (216 in. lb.)

Connecting Rod

Cap Fastener (torque in increments)	13.6 N·m (120 in. lb.)

Crankcase

Breather Cover Fastener (torque sequence on page 10)	10.7 N·m (95 in. lb.) into new hole 7.3 N·m (65 in. lb.) into used hole
Breather Reed Retainer Fastener	4.0 N·m (35 in. lb.)
Oil Sentry™	4.5 N·m (40 in. lb.)
Oil Drain Plug	13.6 N·m (10 ft. lb.)

Cylinder Head

Cylinder Head Fastener (torque in 2 increments) (torque sequence on page 11)	first to 16.9 N·m (150 in. lb.) finally to 33.9 N·m (300 in. lb.)
Rocker Pivot Fastener	11.3 N·m (100 in. lb.)

Electric Starter

Starter Mounting Screw	15.3 N·m (135 in. lb.)
Starter Solenoid Positive (+) Brush Lead Retaining Nut	8.0-11.0 N·m (71-97 in. lb.)

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

[6] Lubricate threads with engine oil prior to assembly.

TORQUE SPECIFICATIONS[3,6]	ELH775
Fan/Flywheel	
Rear Fan Shaft to Mounting Bracket Nut	15.8 N·m (140 in. lb.)
Front Fan Assembly to Fan Shaft Nut	15.8 N·m (140 in. lb.)
Fan/Pulley/Hub Assembly Fastener	6.8 N·m (60 in. lb.)
Flywheel Retaining Screw	66.4 N·m (49 ft. lb.)
Lower Pulley Mounting Screw	24.3 N·m (215 in. lb.)
Governor	
Governor Lever Nut	6.8 N·m (60 in. lb.)
Ignition	
Spark Plug	27 N·m (20 ft. lb.)
Crankshaft Position Sensor to Bracket Screw	11.3 N·m (100 in. lb.)
Crankshaft Position Sensor Bracket to Crankcase Screw	9.9 N·m (88 in. lb.)
ECU to ECU Bracket Fastener	7.3 N·m (65 in. lb.)
Ignition Coil Fastener	6.2 N·m (55 in. lb.) into new hole 4.0 N·m (35 in. lb.) into used hole
Rectifier-Regulator Fastener	4.0 N·m (35 in. lb.)
Oil Pump	
Mounting Screw	7.9 N·m (70 in. lb.)
Oxygen Sensor (Muffler is OEM Supplied)	
Sensor Torque	18 N·m (159 in. lb.)
Radiator	
Lower Radiator Support Fasteners	9.9 N·m (88 in. lb.)
Upper Radiator Support Fasteners	9.9 N·m (88 in. lb.)
Upper Brackets to Top Radiator Fasteners	9.9 N·m (88 in. lb.)
Speed Control	
Speed Control Bracket Assembly Fastener	10.7 N·m (95 in. lb.) into new holes 7.3 N·m (65 in. lb.) into used holes
Stator	
Stator Mounting Screw	6.2 N·m (55 in. lb.)
Valve Cover	
Valve Cover Fastener	6.2 N·m (55 in. lb.)
Water Pump	
Mounting Screw (torque sequence on page 12)	9.9 N·m (88 in. lb.)
Pulley Mounting Screw	9.9 N·m (88 in. lb.)

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

[6] Lubricate threads with engine oil prior to assembly.

Specifications

CLEARANCE SPECIFICATIONS[3]	ELH775
Camshaft	
End Play (with shim)	0.076/0.127 mm (0.0030/0.0050 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.)
Camshaft Bearing Surface O.D. New Max. Wear Limit	 19.962/19.975 mm (0.7859/0.7864 in.) 19.959 mm (0.7858 in.)
Connecting Rod	
Connecting Rod-to-Crankpin Running Clearance New Max. Wear Limit	 0.043/0.068 mm (0.0016/0.0026 in.) 0.083 mm (0.0032 in.)
Connecting Rod-to-Crankpin Side Clearance	0.26/0.63 mm (0.0102/0.0248 in.)
Connecting Rod-to-Piston Pin Running Clearance	0.015/0.028 mm (0.0006/0.0011 in.)
Crankcase	
Governor Cross Shaft Bore I.D. New Max. Wear Limit	 8.025/8.075 mm (0.3159/0.3179 in.) 8.088 mm (0.3184 in.)
Crankshaft	
End Play (free)	0.070/0.590 mm (0.0028/0.0230 in.)
Crankshaft Sleeve Bearing I.D. (crankcase) New Max. Wear Limit	 40.974/40.987 mm (1.6131/1.6136 in.) 41.000 mm (1.6141 in.)
Crankshaft Bore (in closure plate) New Max. Wear Limit	 40.974/41.000 mm (1.6131/1.6141 in.) 41.038 mm (1.6156 in.)
Crankshaft Bore (in closure plate)-to-Crankshaft Running Clearance New	 0.039/0.087 mm (0.0015/0.0034 in.)
Main Bearing Journals O.D. - New O.D. - Max. Wear Limit Max. Taper Max. Out-of-Round	 40.913/40.935 mm (1.6107/1.6116 in.) 40.84 mm (1.608 in.) 0.022 mm (0.0009 in.) 0.025 mm (0.0010 in.)
Crankshaft to Sleeve Bearing (crankcase) Running Clearance New	 0.039/0.074 mm (0.0015/0.0029 in.)
Connecting Rod Journal O.D. - New O.D. - Max. Wear Limit Max. Taper Max. Out-of-Round	 35.955/35.973 mm (1.4156/1.4163 in.) 35.94 mm (1.415 in.) 0.018 mm (0.0007 in.) 0.025 mm (0.0010 in.)
Crankshaft T.I.R. PTO End, Crank in Engine Entire Crank, in V-Blocks	 0.15 mm (0.0059 in.) 0.10 mm (0.0039 in.)

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CLEARANCE SPECIFICATIONS[3]	ELH775
Cylinder Bore	
Cylinder Bore I.D. New Max. Wear Limit	 83.006/83.031 mm 3.2679/3.2689 in.) 83.069 mm (3.2704 in.)
Max. Out-of-Round Max. Taper	0.12 mm (0.0047 in.) 0.05 mm (0.0020 in.)
Cylinder Head	
Max. Out-of-Flatness	0.076 mm (0.003 in.)
Governor	
Governor Cross Shaft to Crankcase Running Clearance	0.025/0.126 mm (0.0009/0.0049 in.)
Governor Cross Shaft O.D. New Max. Wear Limit	 7.949/8.000 mm (0.3129/0.3149 in.) 7.936 mm (0.3124 in.)
Governor Gear Shaft O.D. New Max. Wear Limit	 5.990/6.000 mm (0.2358/0.2362 in.) 5.977 mm (0.2353 in.)
Governor Gear Shaft -to-Governor Gear Running Clearance	0.090/0.160 mm (0.0035/0.0063 in.)
Ignition	
Spark Plug Gap	0.76 mm (0.030 in.)
Piston, Piston Rings, and Piston Pin	
Piston-to-Piston Pin	0.006/0.017 mm (0.0002/0.0007 in.)
Piston Pin Bore I.D. New Max. Wear Limit	 17.006/17.012 mm (0.6695/0.6698 in.) 17.025 mm (0.6703 in.)
Piston Pin O.D. New Max. Wear Limit	 16.995/17.000 mm (0.6691/0.6693 in.) 16.994 mm (0.6691 in.)
Top Compression Ring-to-Groove Side Clearance	0.030/0.070 mm (0.001/0.0026 in.)
Middle Compression Ring-to-Groove Side Clearance	0.030/0.070 mm (0.001/0.0026 in.)
Oil Control Ring-to-Groove Side Clearance	0.060/0.190 mm (0.0022/0.0073 in.)
Top Compression Ring End Gap New Bore Used Bore (Max.)	 0.189/0.277 mm (0.0074/0.0109 in.) 0.531 mm (0.0209 in.)
Middle Compression Ring End Gap New Bore Used Bore (Max.)	 1.519/1.797 mm (0.0598/0.0708 in. 2.051 mm (0.0808 in.)
Piston Thrust Face O.D.[7] New	 82.978 mm (3.2668 in.)
Max. Wear Limit	82.833 mm (3.2611 in.)
Piston Thrust Face-to-Cylinder Bore[7] Running Clearance	0.019/0.062 mm (0.0007/0.0024 in.)

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

[7] Measure 6 mm (0.2362 in.) above bottom of piston skirt at right angles to piston pin.

Specifications

CLEARANCE SPECIFICATIONS[3]	ELH775
Valves and Valve Lifters	
Hydraulic Valve Lifter to Crankcase Running Clearance	0.0124/0.0501 mm (0.0005/0.0020 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.) 7.134 mm (0.2809 in.)
Intake Valve Stem Diameter New	 6.982/7.000 mm (0.2749/0.2756 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.)
Exhaust Valve Stem Diameter New	 6.970/6.988 mm (0.2744/0.2751 in.)
Valve Guide Reamer Size Standard 0.25 mm O.S.	 7.048 mm (0.2775 in.) 7.298 mm (0.2873 in.)
Intake Valve Lift	8.88 mm (0.3496 in.)
Exhaust Valve Lift	8.88 mm (0.3496 in.)
Nominal Valve Seat Angle	45°

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

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						
	Property Class					Noncritical Fasteners Into Aluminum
Size	 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.

SEPARATE TOOL SUPPLIERS

Kohler Tools
Contact your local Kohler source of supply.

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

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

TOOLS

Description	Source/Part No.
Alcohol Content Tester For testing alcohol content (%) in reformulated/oxygenated fuels.	Kohler 25 455 11-S
Camshaft Endplay Plate For checking camshaft endplay.	SE Tools KLR-82405
Camshaft Seal Protector (Aegis) For protecting seal during camshaft installation.	SE Tools KLR-82417
Cylinder Leakdown Tester For checking combustion retention and if cylinder, piston, rings, or valves are worn. Individual component available: Adapter 12 mm x 14 mm (Required for leakdown test on XT-6 engines)	Kohler 25 761 05-S Design Technology Inc. DTI-731-03
Dealer Tool Kit (Domestic) Complete kit of Kohler required tools. Components of 25 761 39-S Ignition System Tester Cylinder Leakdown Tester Oil Pressure Test Kit Rectifier-Regulator Tester (120 V AC/60Hz)	Kohler 25 761 39-S Kohler 25 455 01-S Kohler 25 761 05-S Kohler 25 761 06-S Kohler 25 761 20-S
Dealer Tool Kit (International) Complete kit of Kohler required tools. Components of 25 761 42-S Ignition System Tester Cylinder Leakdown Tester Oil Pressure Test Kit Rectifier-Regulator Tester (240 V AC/50Hz)	Kohler 25 761 42-S Kohler 25 455 01-S Kohler 25 761 05-S Kohler 25 761 06-S Kohler 25 761 41-S
Digital Vacuum/Pressure Tester For checking crankcase vacuum. Individual component available: Rubber Adapter Plug	Design Technology Inc. DTI-721-01 Design Technology Inc. DTI-721-10
Electronic Fuel Injection (EFI) Diagnostic Software For Laptop or Desktop PC.	Kohler 25 761 23-S
EFI Service Kit For troubleshooting and setting up an EFI engine. Components of 24 761 01-S Fuel Pressure Tester Noid Light 90° Adapter Code Plug, Red Wire Code Plug, Blue Wire Shrader Valve Adapter Hose Wire Probe Set (2 pieces regular wire with clip; 1 piece fused wire) Hose Removal Tool, Dual Size/End (also sold as individual Kohler tool)	Kohler 24 761 01-S Design Technology Inc. DTI-019 DTI-021 DTI-023 DTI-027 DTI-029 DTI-037 DTI-031 DTI-033
Flywheel Puller For properly removing flywheel from engine.	SE Tools KLR-82408

TOOLS

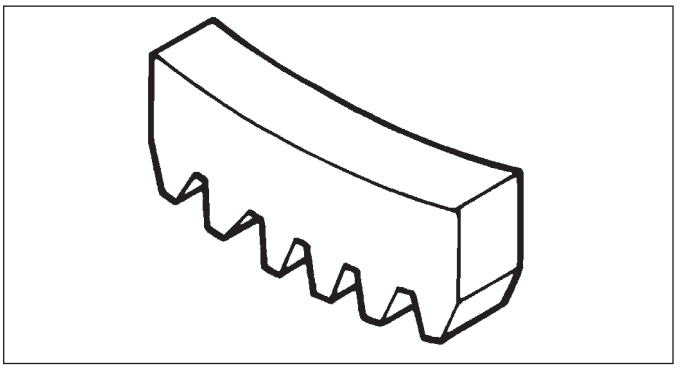
Description	Source/Part No.
Hose Removal Tool, Dual Size/End (also available in EFI Service Kit) Used to properly remove fuel hose from engine components.	Kohler 25 455 20-S
Hydraulic Valve Lifter Tool For removing and installing hydraulic lifters.	Kohler 25 761 38-S
Ignition System Tester For testing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

AIDS

Description	Source/Part No.
Camshaft Lubricant (Valspar ZZ613)	Kohler 25 357 14-S
Dielectric Grease (GE/Novaguard G661)	Kohler 25 357 11-S
Dielectric Grease	Loctite® 51360
Kohler Electric Starter Drive Lubricant (Inertia Drive)	Kohler 52 357 01-S
Kohler Electric Starter Drive Lubricant (Solenoid Shift)	Kohler 52 357 02-S
RTV Silicone Sealant Loctite® 5900® Heavy Body in 4 oz. aerosol dispenser. Only oxime-based, oil resistant RTV sealants, such as those listed, are approved for use. Permatex® the Right Stuff® 1 Minute Gasket™ or Loctite® Nos. 5900® or 5910® are recommended for best sealing characteristics.	Kohler 25 597 07-S Loctite® 5910® Loctite® Ultra Black 598™ Loctite® Ultra Blue 587™ Loctite® Ultra Copper 5920™ Permatex® the Right Stuff® 1 Minute Gasket™
Spline Drive Lubricant	Kohler 25 357 12-S

Tools and Aids

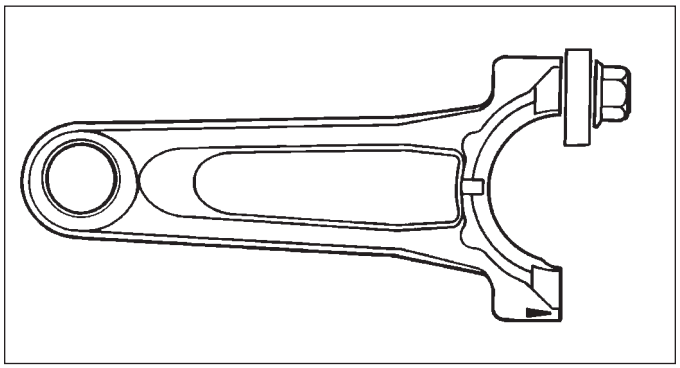
FLYWHEEL HOLDING TOOL



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. Use these to locate causing factors.

Engine Cranks But Will Not Start

- Battery connected backwards.
- Blown fuses.
- Clogged fuel line or fuel filter.
- Empty fuel tank.
- Faulty electronic control unit.
- Faulty ignition coil(s).
- Faulty spark plug(s).
- Fuel pump malfunction.
- 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.
- 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 spark plug(s).
- Flywheel key sheared.
- Fuel pump malfunction.
- 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.
- Seized internal engine components.

Engine Runs But Misses

- Fuel system issue (fuel injectors).
- Engine overheated.
- Faulty spark plug(s).
- Ignition coil(s) faulty.
- Damaged crankshaft position sensor.
- 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.
- Inadequate fuel supply.
- Low compression.
- Quality of fuel (dirt, water, stale, mixture).
- Restricted fuel tank cap vent.

Engine Overheats

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

Engine Knocks

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

Engine Loses Power

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

Engine Uses Excessive Amount of Oil

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

Oil Leaks from Oil Seals, Gaskets

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

EXTERNAL ENGINE INSPECTION

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

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

- Check for buildup of dirt and debris on crankcase, cooling fins, grass screen, and other external surfaces. Dirt or debris on these areas can cause overheating.
- Check for obvious fuel and oil leaks, and damaged components. Excessive oil leakage can indicate a clogged or inoperative breather, worn or damaged seals or gaskets, or loose fasteners.
- Check air cleaner cover and base for damage or indications of improper fit and seal.
- Check air cleaner element. Look for holes, tears, cracked or damaged sealing surfaces, or other damage that could allow unfiltered air into engine. A dirty or clogged element could indicate insufficient or improper maintenance.
- Check intake manifold 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. Complete instructions are provided in kits.

To test crankcase vacuum with manometer:

1. Insert rubber stopper into oil fill hole. Be sure pinch clamp is installed on hose and use tapered adapters to connect hose between stopper and one manometer tube. Leave other tube open to atmosphere. Check that water level in manometer is at 0 line. Make sure pinch clamp is closed.
2. Start engine and run no-load high speed.
3. Open clamp and note water level in tube.

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

   If level in engine side is less than specified (low/no vacuum), or level in engine side is lower than level in open side (pressure), check for conditions in table below.
4. Close pinch clamp before stopping engine.

To test crankcase vacuum with vacuum/pressure gauge:

1. Remove dipstick or oil fill plug/cap.
2. Install adapter into oil fill/dipstick tube opening, upside down over end of a small diameter dipstick tube, or directly into engine if a tube is not used. Insert barbed gauge fitting into hole in stopper.
3. Run engine and observe gauge reading.

   Analog tester–needle movement to left of 0 is a vacuum, and movement to right indicates a pressure.

   Digital tester–depress test button on top of tester.

   Crankcase vacuum should be a minimum of 10.2 cm (4 in.) of water. If reading is below specification, or if pressure is present, check table below for possible causes and conclusions.

Condition	Conclusion
Crankcase breather clogged or inoperative.	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

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

Some models (recoil 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.

CYLINDER LEAKDOWN TEST

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

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

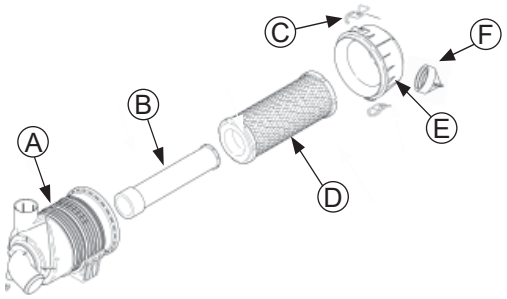
1. Run engine for 3-5 minutes to warm it up.
2. Remove spark plug(s) and air filter from engine.
3. Rotate crankshaft until piston (of cylinder being tested) is at top dead center (TDC) of compression stroke. Hold engine in this position while testing. Holding tool supplied with tester can be used if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

   If flywheel end is more accessible, use a breaker bar and socket on flywheel nut/screw to hold it in position. An assistant may be needed to hold breaker bar during testing. If engine is mounted in a piece of equipment, it may be possible to hold it by clamping or wedging a driven component. Just be certain that engine cannot rotate off of TDC in either direction.
4. Install adapter into spark plug hole, but do not attach it to tester at this time.
5. Turn regulator knob completely counterclockwise.
6. Connect an air source of at least 50 psi to tester.
7. Turn regulator knob clockwise (increase direction) until gauge needle is in yellow set area at low end of scale.
8. Connect tester quick-connect to adapter hose. While firmly holding engine at TDC, gradually open tester valve. Note gauge reading and listen for escaping air at combustion air intake, exhaust outlet, and crankcase breather.

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

AIR CLEANER

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



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

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

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

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

BREATHER TUBE

Ensure both ends of breather tube are properly connected.

AIR COOLING

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

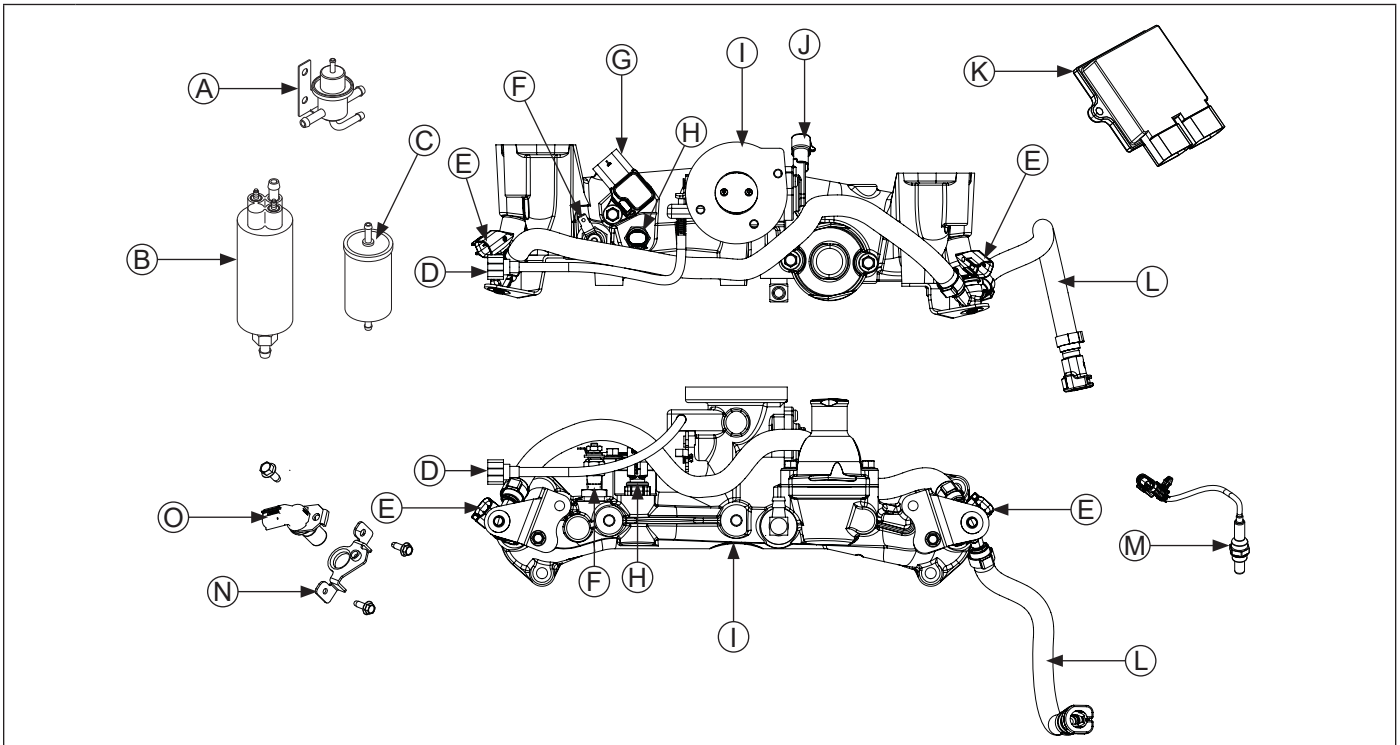
NOTE: Operating engine with a restricted air intake screen or radiator, damaged/ broken fan assembly, or missing fan shroud will cause engine damage due to over heating.

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

EFI System

	**⚠ 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.

EFI System Components



A	Fuel Pressure Regulator	**B**	Electric Fuel Pump	**C**	Fuel Filter	**D**	Idle Speed Adjustment Cable
E	Fuel Injector Connector	**F**	High Temperature Sensor (See Cooling System)	**G**	Temperature/Manifold Absolute Pressure (TMAP) Sensor	**H**	Coolant Temperature Sensor
I	Throttle Body/Intake Manifold	**J**	Throttle Position Sensor (TPS)	**K**	Electronic Control Unit (ECU)	**L**	Fuel Rail
M	Oxygen Sensor	**N**	Crankshaft Position Sensor Bracket	**O**	Crankshaft Position Sensor		

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

- Electric fuel pump.
- Fuel filter.
- Fuel rail.
- Fuel line(s).
- Fuel injectors.
- Fuel pressure regulator.
- Throttle body/intake manifold.
- Electronic control unit (ECU).
- Ignition coils.
- Coolant temperature sensor.
- Throttle position sensor (TPS).
- Crankshaft position sensor.
- Oxygen sensor.
- Temperature/Manifold Absolute Pressure (TMAP) Sensor.
- Wire harness assembly & affiliated wiring.
- 10 amp fuse (battery power).
- 10 amp fuse (ignition switch).
- 30 amp fuse (charging system).
- 10 amp fuse (fuel pump relay).
- Malfunction indicator light (MIL)-optional.

FUEL RECOMMENDATIONS

Refer to Maintenance.

FUEL LINE

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

OPERATION

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

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

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

An electric fuel pump is used to move fuel from tank through fuel line and in-line fuel filter. A fuel pressure regulator maintains a system operating pressure of 39 psi and returns any excess fuel to tank. At engine, fuel is fed through fuel rail and into injectors, which inject it 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, fuel/air mixture is drawn into combustion chamber, ignited, and burned.

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

- Engine coolant temperature is greater than 35°C (95°F).
- Oxygen sensor has warmed sufficiently to provide a signal (minimum 375°C, 709°F).
- Engine operation is at a steady state (not starting, warming up, accelerating, etc.).

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

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

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

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

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

ECU requires a minimum of 6.0 volts to operate.

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

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

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

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

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

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

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

Crankshaft position sensor 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) reacts to engine load, angle of throttle plate is directly related to load on engine.

Mounted on throttle body/intake manifold 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 pre-programmed maps to determine required fuel and ignition settings for amount of load.

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

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

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

Oxygen sensor functions after being heated to a minimum of 375°C (709°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.

Electrical relay is used to supply power to fuel pump. When key switch is turned ON and all safety switch requirements met, relay provides 12 volts to fuel pump circuit. Fuel pump circuit is continuously grounded, so pump is immediately activated and pressurizes system.

Fuel injectors mount into throttle body/intake manifold, and fuel rail 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 fuel rail 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 and relay is closed, fuel rail will pressurize, 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 fuel rail forces fuel down through inside. Director plate at tip of injector contains a series of calibrated openings which directs fuel into manifold in a cone-shaped spray pattern.

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

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

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

An electric fuel pump is used to transfer fuel in EFI system. Pump is in fuel line near tank. Pumps are rated for a minimum output of 25 liters per hour at 39 psi. Pumps have an internal 60-micron filter. In-line pump systems may also have a filter between tank and pump on pickup/low pressure side.

When key switch is turned ON and all safety switch requirements are met, ECU, through relay activates fuel pump, 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.

Fuel pressure regulator assembly maintains required operating system pressure of 39 psi ± 3. A rubber-fiber diaphragm divides regulator into two separate sections; fuel chamber and pressure regulating chamber. Pressure regulating spring presses against valve holder (part of diaphragm), pressing valve against valve seat. Combination of atmospheric pressure and regulating spring tension equals desired operating pressure. Any time fuel pressure against bottom of diaphragm exceeds desired (top) pressure, valve opens, relieving excess pressure, returning excess fuel back to tank.

Fuel rail is an assembly of hoses, injector caps and a fuel connector. Fuel rail 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.

Fuel rail assembly is serviced as a complete assembly to prevent tampering and safety hazards. Components are not individually serviceable.

This EFI engine is equipped with an engine mounted purge port on #2 upper radiator support bracket. This capped purge port can be used by OEM to vent fuel tanks or used in conjunction with a carbon canister kit for Tier III evaporative emissions compliance. Purge port connects to vent hose assembly and directs all fuel vapor into throttle body. If purge port remains unused, port must remain capped to prevent dirt from entering engine.

EFI engines have no carburetor, so throttle function (regulate incoming combustion airflow) is incorporated in intake manifold assembly. Manifold consists of a one-piece aluminum casting which also provides mounting for fuel injectors, throttle position sensor, fuel rail, air baffle, idle speed screw, and air cleaner assembly.

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

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

IMPORTANT NOTES!

- Cleanliness is essential and must be maintained at all times when servicing or working on EFI system. Dirt, even in small quantities, can cause significant problems.
- Clean any joint or fitting with parts cleaning solvent before opening to prevent dirt from entering system.
- Always depressurize fuel system through fuel connector before disconnecting or servicing any fuel system components.
- Never attempt to service any fuel system component while engine is running or ignition switch is ON.
- Do not use compressed air if system is open. Cover any parts removed and wrap any open joints with plastic if they will remain open for any length of time. New parts should be removed from their protective packaging just prior to installation.
- Avoid direct water or spray contact with system components.
- Do not disconnect or reconnect ECU wiring harness connector or any individual components with ignition on. This can send a damaging voltage spike through ECU.
- Do not allow battery cables to touch opposing terminals. When connecting battery cables attach positive (+) cable to positive (+) battery terminal first, followed by negative (–) cable to negative (–) battery terminal.
- Never start engine when cables are loose or poorly connected to battery terminals.
- Never disconnect battery while engine is running.
- Never use a quick battery charger to start engine.
- Do not charge battery with key switch ON.
- Always disconnect negative (–) battery cable before charging battery, and also unplug harness from ECU before performing any welding on equipment.

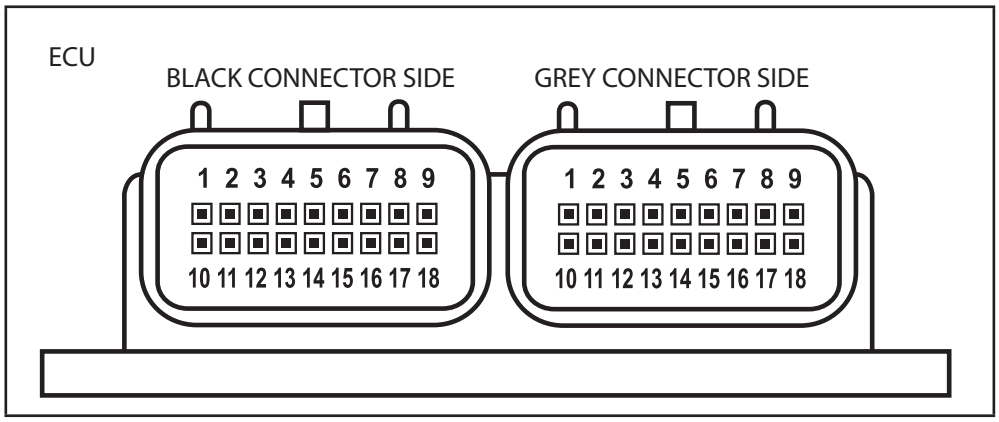
ELECTRICAL COMPONENTS

Electronic Control Unit (ECU)

Pinout of ECU

Black Connector Side	
Pin #	**Function**
1	Ignition Coil #1 Ground
2	Battery Ground
3	Diagnostic Communication Line
4	Crankshaft Position Sensor input
5	Fuel Injector Output #1 Ground
6	Fuel Injector Output #2 Ground
7	Oxygen Sensor Heater
8	Intake Air Temperature (TMAP) sensor input
9	Fuel Pump Ground/Relay Switch
10	Ground for TPS, TMAP, O2 and Coolant Temperature Sensors
11	Manifold Absolute Pressure (TMAP) sensor input
12	Throttle Position Sensor (TPS) input
13	Crankshaft Position Sensor Ground
14	Coolant Temperature Sensor input
15	Ignition Switch (Switched +12V)
16	Power for TPS and TMAP Sensors (+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	Not Used
7	Not Used
8	Not Used
9	Battery Ground
10	Ignition Coil #2 Ground
11	Not Used
12	Not Used
13	Not Used
14	Safety Switch Ground
15	Not Used
16	ECU Diagnostics
17	Fuel Pump Control (+12V)
18	Not Used



Pinout of ECU

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.

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

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

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

This system will NOT reset when battery is disconnected!

ECU Reset Procedure

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

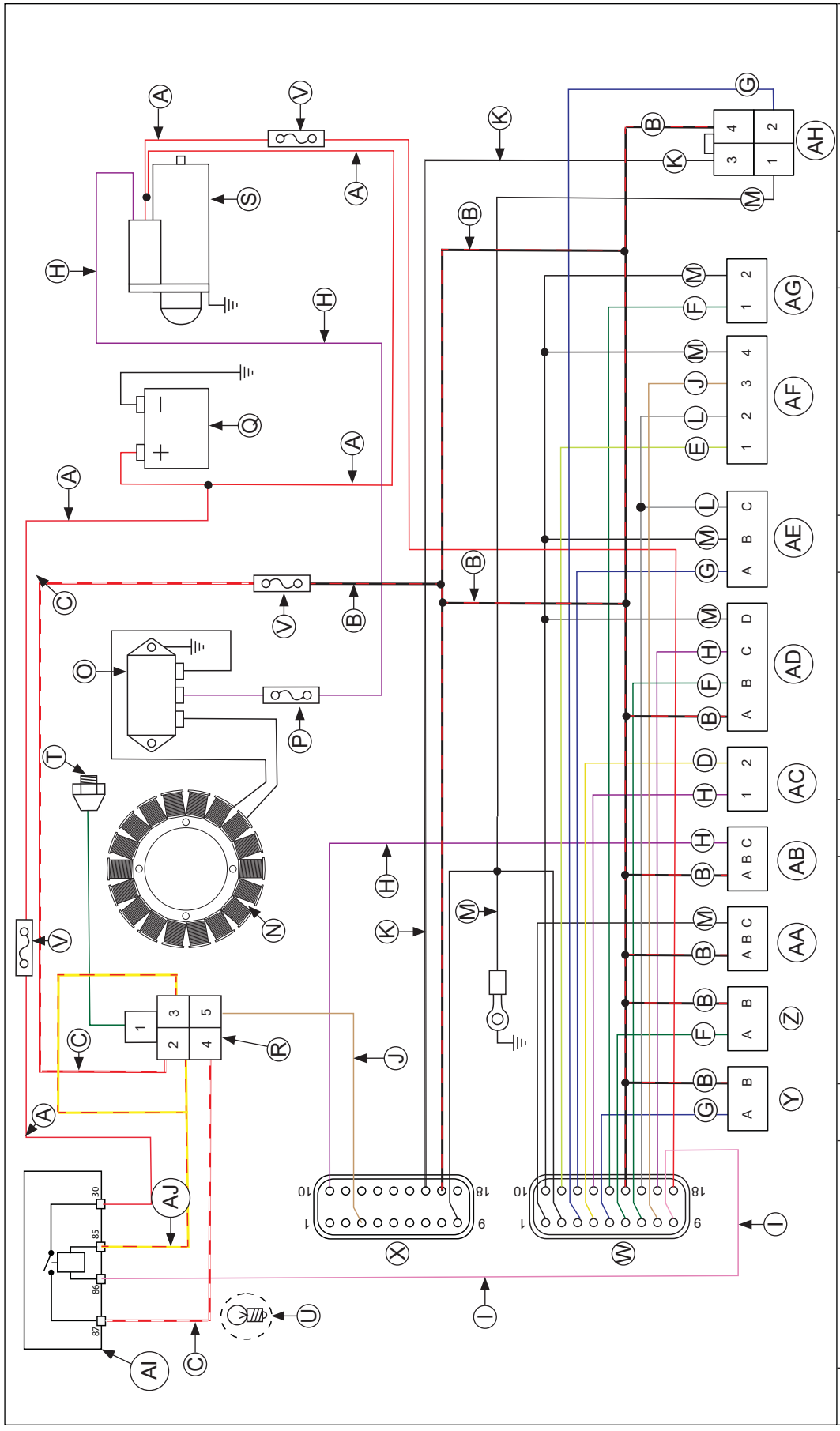
A TPS Learn Procedure **must** be performed after ECU Reset.

TPS Learn Procedure

1. Turn idle screw clockwise one full turn prior to key/ignition ON after ECU Reset.
2. Start engine, run at low idle until engine is warm.
3. Idle speed must be above 1500 RPM. If below 1500 RPM, turn idle screw up to 1700 RPM and then shut down engine and perform ECU Reset again.
4. Restart engine, adjust idle speed down to 1500 RPM. Allow engine to dwell at 1500 RPM for about 3 seconds.
5. After this, adjust idle speed to final specified speed setting.
6. Turn key/ignition OFF and count to 10 seconds.

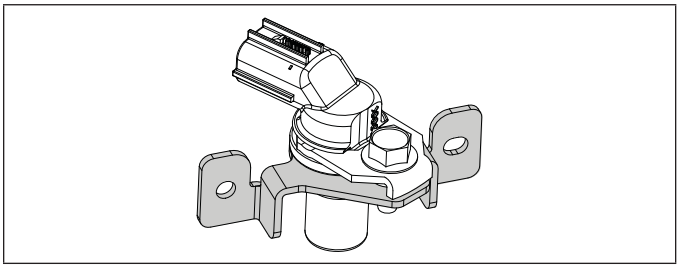
Learn procedure is complete.

Wiring Diagram



A	Red	B	Red/Black	C	Red/White	D	Yellow	E	Light Green
F	Dark Green	G	Dark Blue	H	Purple	I	Pink	J	Tan
K	White	L	Grey	M	Black	N	Stator	O	Rectifier-Regulator
P	30A Fuse	Q	Battery	R	5-Terminal Connector	S	Starter Motor	T	Oil Pressure Switch
U	MIL (Optional)	V	10A Fuse	W	Black Connector	X	Grey Connector	Y	Fuel Injector #1
Z	Fuel Injector #2	AA	Ignition Coil #1	AB	Ignition Coil #2	AC	Crankshaft Position Sensor	AD	Oxygen Sensor
AE	Throttle Position Sensor	AF	TMAP Sensor	AG	Coolant Temperature Sensor	AH	Diagnostic Connector	AI	Electrical Relay
AJ	Red/Yellow								

Crankshaft Position Sensor



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

1. Inspect wiring and connections for damage or problems.
2. Make sure engine has resistor type spark plugs.
3. Disconnect Black connector from ECU.
4. 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.
5. If resistance is incorrect remove blower housing.
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 screw securing sensor to mounting bracket and replace sensor.
   b. If resistance in step 4 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 4 again.
7. If resistance is correct from step 4, check mounting, flywheel teeth (damage, run-out, etc.) and flywheel key.
8. When fault is corrected and engine starts, clear fault codes and follow ECU Reset procedure.

Throttle Position Sensor (TPS)

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

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

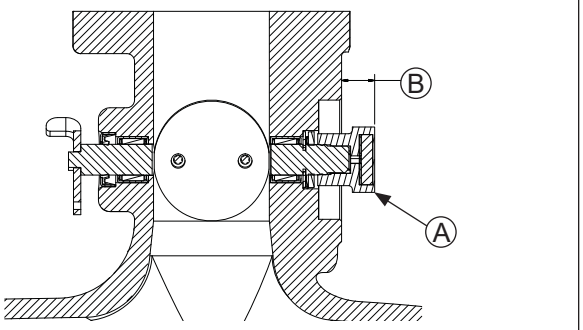
If a computer with diagnostic software is available

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

I**f only a volt meter is available**

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

Replace magnet assembly



A	Magnet Assembly	**B**	Magnet Installation Depth

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

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

Coolant Temperature Sensor

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

1. Ensure engine is cool. When radiator is cool to touch, slowly loosen radiator cap to first stop and allow any pressure to bleed off. Then loosen it fully and remove it.
2. Remove coolant temperature sensor from intake manifold and cap or block hole.
3. Wipe sensor clean and allow it to reach room temperature (25°C, 77°F).
4. Unplug Black connector from ECU.
5. With sensor still connected, check coolant temperature sensor circuit resistance between Black pin 10 and 14 terminals. Value should be 9000-11000 Ω.
6. 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 7.
7. 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.

Temperature/Manifold Absolute Pressure (TMAP) Sensor

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

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

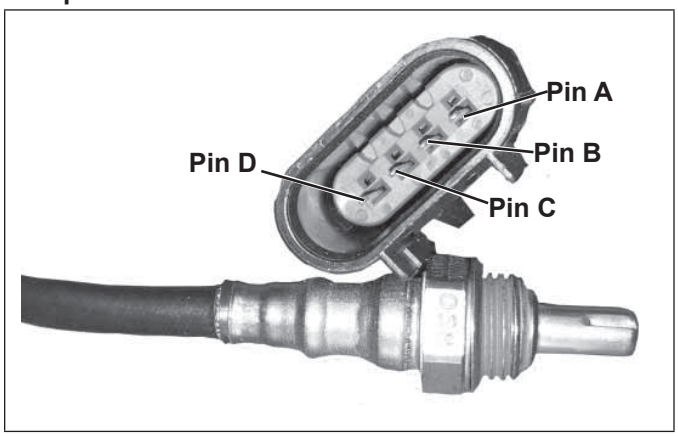
1. Remove TMAP sensor from intake manifold.
2. Allow it to reach room temperature (20°C, 68°F).
3. Unplug Black connector from ECU.
4. With sensor still connected, check temperature sensor circuit resistance between Black pin 10 and 8 pin terminals. Value should be 1850-2450 Ω.
5. Unplug sensor from wire harness and check sensor resistance separately across pin. Resistance value should again be 1850-2450 Ω.
   a. If resistance is out of specifications, check local temperature. Sensor resistance will go down as temperature is higher. Replace TMAP sensor if determined to be faulty.
   b. If it is within specifications, proceed to Step 6.
6. Check circuits (input, ground), from main harness connector to sensor plug for continuity, damage, etc. Connect one ohmmeter lead to Black pin 8 in main harness connector (as in step 4). Connect other lead to terminal #3 in sensor plug. Continuity should be indicated. Repeat test between Black pin 10 and terminal #4 in sensor plug.
7. Reinstall sensor.

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

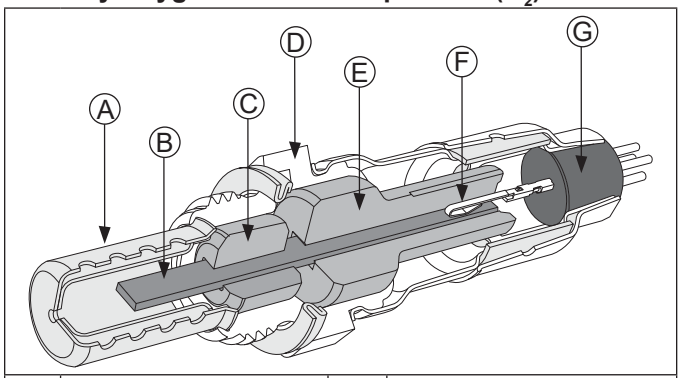
1. Make sure all connections are making proper contact and are free of dirt and debris. Slide locking tab out and pull off TMAP connector. Turn key switch to ON and check with a volt meter by contacting red lead to pin 1 and black lead to pin 2. There should be 5 volts present, indicating ECU and wiring harness are functioning.
2. Check continuity in wire harness. Ohms between Pin 3 at sensor connector and Black pin 11 connector at ECU should be near zero ohms. If no continuity is measured or very high resistance, replace wire harness.
3. Check to make sure intake manifold is not loose and TMAP sensor is not loose. Loose parts would allow a vacuum leak, making TMAP sensor report misleading information to ECU.
   a. Tighten all hardware and perform an ECU Reset and a TPS Learn Procedure to see if MIL will display a fault with sensor again. If MIL finds a fault with TMAP sensor, replace it.

Oxygen Sensor (O_2)

Components



Cutaway Oxygen Sensor Components (O_2)



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

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

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

Visual Inspection

1. Look for a damaged or disconnected sensor-to-engine harness connection.
2. Look for damage to sensor lead wire or associated engine wiring due to cutting, chaffing or melting on a hot surface.
3. Disconnect sensor connector and look for corrosion in connector.
4. Try reconnecting sensor and observe if problem has cleared.
5. Correct any problems found during visual check.

Sensor Signal Observation

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

1. Using a voltmeter or diagnostic software observe voltage before engine is started. With key ON, voltage should read about 1.0 volt. This voltage is generated by ECU. If it is not present, disconnect sensor and observe voltage at harness connector. If voltage is now present, there is a short in sensor or associated wiring and corrective action should be taken. If voltage still is not present, there is a problem with ECU or engine harness.
2. Reconnect sensor and start engine. Run engine at sufficient speed to bring sensor up to operating temperature. Maintain for 1 to 2 minutes to ensure that engine has gone closed loop. Once in closed loop, sensor voltage should cycle between about 100 to 250 mv and 700 to 900 mv. If this cycling is not observed, a determination must be made, if problem is with engine or sensor.
3. Check engine harness for battery voltage on heater circuit.

Removal Inspection

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

1. If sensor has heavy deposits on lower shield, engine, oil, or fuel may be source.
2. If heavy carbon deposits are observed, incorrect engine fuel control may be occurring.
3. If sensor is at room temperature, measure between signal leads, black wire (Pin C) and grey wire (Pin D) attached to sensor. If resistance is less than one megohm, sensor has an internal short.
4. With sensor at room temperature measure heater circuit resistance, purple wire (Pin A) and white wire (Pin B), resistance should be 8.1-11.1 Ω.
5. If a damaged sensor is found, identify root cause, which may be elsewhere in application. Refer to Troubleshooting-Oxygen Sensor (O_2) table.
6. A special "dry to touch" anti-seize compound is applied to all new oxygen sensors at factory. If recommended mounting thread sizes are used, this material provides excellent anti-seize capabilities and no additional anti-seize is needed. If sensor is removed from engine and reinstalled, anti-seize compound should be reapplied. Use an oxygen sensor safe type anti-seize compound. It should be applied according to directions on label.

Troubleshooting-Oxygen Sensor (O_2)

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

Electrical Relay

Electrical relay is used to supply power to electric fuel pump. When key switch is turned ON and all safety switch requirements met, relay provides 12 volts to fuel pump circuit. Fuel pump circuit is continuously grounded, so pump is immediately activated and pressurizes system.

Service

A malfunctioning relay can result in starting or operating difficulties. Relay and related wiring can be tested as follows:

1. Disconnect relay connector plug from relay.
2. Connect black lead of VOA meter to a chassis ground location. Connect red lead to #86 terminal in relay connector. Set meter to test resistance (Rx1). Turn key switch from OFF to ON. Meter should indicate continuity (ground circuit is completed) for 1 to 3 seconds. Turn key switch back off.
   a. Clean connection and check wiring if circuit was not completed.
3. Set meter for DC voltage. Touch red tester lead to #30 terminal in relay connector. A reading of 12 volts should be indicated at all times.
4. Connect red lead of meter to #85 terminal in relay connector. Turn key switch to ON position. Battery voltage should be present.
   a. No voltage present indicates a problem with key switch, in wiring, or at connector.
   b. If voltage is present, wiring to connector is good. Turn ignition switch OFF and proceed to Step 5 to test relay.
5. Connect an ohmmeter (Rx1 scale) between #85 and #86 terminals in relay. There should be continuity.
6. Attach ohmmeter leads to #30 and #87 terminals in relay. At first, there should be no continuity. Using a 12 volt power supply, connect positive (+) lead to #85 terminal and touch negative (–) lead to #86 terminal. When 12 volts is applied, relay should activate and continuity should exist (circuit made) between #30 and #87 terminals. Repeat test several times. If, at any time relay fails to activate circuit, replace relay.

Fuel Injectors

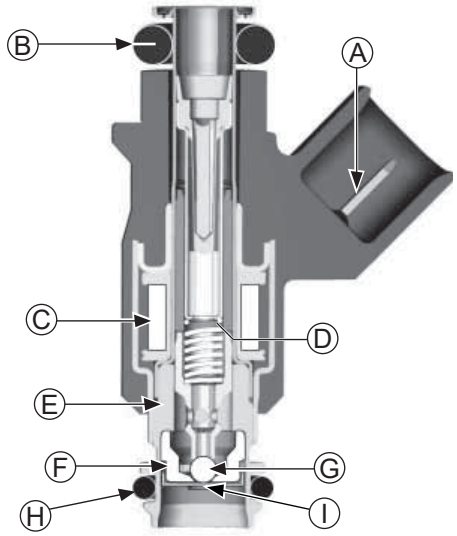
⚠ WARNING

Explosive Fuel can cause fires and severe burns.

Fuel system ALWAYS remains under HIGH PRESSURE.

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

Details



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

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

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

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

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

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

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

1. Disconnect electrical connector from both injectors. Plug a 12 volt noid light (part of EFI Service Kit) into one connector.
2. Make sure all safety switch requirements are met. Crank engine and check for flashing of noid 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 noid light 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 incorrect, replace injector.

      If injector resistance is correct, visually inspect connection between connector and injector terminals. Terminals should be free of corrosion, wear, or dirt. If a problem is found, clean/repair/replace as needed.

   b. If no noid light flashing occurs, reattach connectors to both injectors. Disconnect black connector from ECU. Use an ohmmeter (Rx1 scale) and check injector circuit resistance between black pins 5 and 15 for injector #1, and pins 6 and 15 for injector #2. Proper resistance should be 11-13 Ω for each. If circuit resistance is incorrect, check all electrical connections, connectors, and wiring harness leads for issues.

      If circuit resistance is found to be correct, injector circuit is inactive (no noid light operation) due to other problems within system. Test and inspect for proper system operating voltage and appropriate grounds. Correct or repair any problem found.

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. Refer to Disassembly for removal of injector.

1. Engine must be cool. Depressurize fuel system through fuel connector.
2. Disconnect spark plug leads from spark plugs.
3. Thoroughly clean area around manifold and injectors.
4. Remove injector bracket mounting bolts and remove injectors from manifold. Removal of tie straps securing fuel rail to manifold may be required. If removed, tie straps must be replaced.
5. Position injectors over appropriate containers and turn key switch ON to activate fuel pump and pressurize system. Do not turn switch to START position.
6. 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.
7. Depressurize fuel system through fuel connector. Disconnect electrical connector(s).
8. Pull metal retaining clip connecting fuel injector to fuel injector cap and remove injector(s).
9. Reverse appropriate procedures to install new injector(s) and reassemble engine. Use new O-rings any time an injector is removed (new replacement injectors include new O-rings). Lubricate O-rings lightly with oil. Torque injector bracket mounting screws to 4.0 N·m (35 in. lb.), and intake manifold mounting screws to 9.9 N·m (88 in. lb.).

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

Ignition Coil

If a coil is determined to be faulty, replacement is necessary. Refer to Electrical System, Ignition System Troubleshooting Guide Tests before performing coil tests below. An ohmmeter may be used to test wiring and coil windings.

NOTE: Do not ground primary coil leads 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

Main purpose of performing ignition coil resistance test is to identify if primary (low voltage) and secondary (high voltage) circuits are shorted to each other or ground. Coil resistance readings will vary based on temperature. If coil passes spark testing, and primary and secondary circuits are not shorted, resistance variations outside specified range may be normal due to temperature.

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 radiator mounting bracket 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 no more than 6400-7800 Ω.
   d. If secondary resistance is not within specified range, coil is faulty and needs to be replaced.

FUEL COMPONENTS

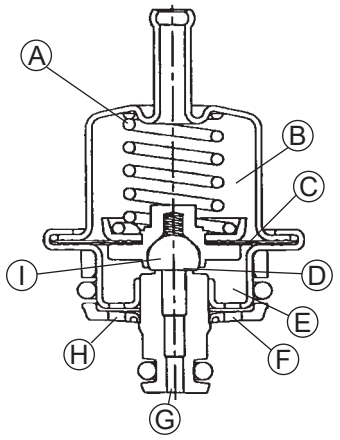
Fuel Pump

Fuel pumps are non-serviceable and must be replaced if determined to be faulty. If a fuel delivery problem is suspected, make certain pump is being activated through relay, all electrical connections are properly secured, fuses are good, and a minimum of 7.0 volts is being supplied. If during cranking, voltage drops below 7.0 volts, a reduction of fuel pressure may occur resulting in a lean starting condition. If required, testing of fuel pump and relay may be conducted.

1. Relieve pressure at fuel connector. Wrap a shop towel completely around fuel connector. Press release button and slowly pull connector away allowing shop towel to absorb any residual fuel in high pressure fuel line. Insert pressure test jumper (from Kohler EFI Service Kit) between high pressure fuel line and fuel supply.
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. If system pressure of 39 psi ± 3 is observed, relay, fuel pump, and fuel pressure regulator are working properly. Turn key switch off and depress valve button on tester to relieve system pressure.
   a. If pressure is too high, and regulator is outside tank (just down line from pump), check that return line from regulator to tank is not kinked or blocked. If return line is good, replace regulator (see Fuel Pressure Regulator).
   b. If pressure is too low, install in-line T between pump and regulator and retest pressure at that point. If it is too low there also, replace fuel pump.
4. If pump did not activate (step 3), disconnect plug from fuel pump. Connect a DC voltmeter across terminals in plug, turn on key switch and observe if a minimum of 7 volts is present. If voltage is between 7 and 14, turn key switch off and connect an ohmmeter between terminals on pump to check for continuity.
   a. If there was no continuity between pump terminals, replace fuel pump.
   b. If voltage was below 7, test wiring harness and relay as covered in Electrical Relay section.
5. If voltage at plug was good, and there was continuity across pump terminals, reconnect plug to pump, making sure you have a good connection. Turn on key switch and listen for pump to activate.
   a. If pump starts, repeat steps 2 and 3 to verify correct pressure.
   b. If pump still does not operate, replace it.

Fuel Pressure Regulator

Fuel Pressure Regulator Details



A	Pressure Regulating Spring	**B**	Pressure Regulating Chamber
C	Diaphragm	**D**	Valve Seat
E	Fuel Chamber	**F**	Outlet Port (to fuel rail)
G	Return Port (to tank)	**H**	Inlet Port
I	Valve		

Regulator is a sealed, non-serviceable assembly. If it is faulty, it must be replaced as follows:

1. Shut engine off, make sure engine is cool, and disconnect negative (–) battery cable.
2. Depressurize fuel system through fuel connector.
3. Access regulator assembly as required and clean any dirt or foreign material away from area.
4. Disconnect all fuel hoses from regulator. Remove screws securing regulator assembly.
5. Install new regulator and reconnect hoses (using new clamps).
6. Reconnect negative (–) battery cable.
7. Recheck regulated system pressure.

Fuel Rail

Fuel rail is mounted to throttle body/intake manifold. No specific servicing is required unless operating conditions indicate that it needs internal cleaning or replacement. It can be detached by removing mounting screws and injector retaining clips. Thoroughly clean area around all joints and relieve any pressure before starting any disassembly.

Purge Port and Vent Hose Assembly

No specific servicing is required for vent hose assembly or purge port unless operating conditions indicate replacement is required. All components are serviced individually. Abrasion sleeves on hoses should be reused or replaced when servicing vent hoses. Please note vent hose routing and replicate after service or component replacement to prevent pinching or abrasion of vent hoses. Only Kohler replacement parts can be used because fitting is specific to system and must be maintained. Visit KohlerEngines.com for recommended Kohler replacement parts.

Throttle Body/Intake Manifold Assembly

Throttle body/intake manifold is serviced as an assembly, with throttle shaft, TPS, throttle plates, and idle speed adjusting screw installed.

TROUBLESHOOTING GUIDE

Engine Starts Hard or Fails to Start When Cold	Fuel pump not running.
	Engine temp sensor faulty.
	Incorrect fuel pressure.
	TPS faulty.
	TPS offset incorrect.
	Old/stale fuel.
	Low system voltage.
	Speed sensor loose or faulty.
	Faulty injectors.
	Faulty coils.
	Faulty spark plugs.
Engine Starts Hard or Fails to Start When Hot	Fuel pressure low.
	Fuel pump not running.
	Engine temp sensor faulty.
	Insufficient fuel delivery.
	TPS faulty.
	TPS offset incorrect.
	Speed sensor loose or faulty.
	Faulty injectors.
	Faulty spark plugs.
Engine Misses, Hesitates, or Stalls Under Load	Fuel injector(s), fuel filter, fuel line, or fuel pick-up dirty/restricted.
	Dirty air cleaner.
	Insufficient fuel pressure or fuel delivery.
	Vacuum (intake air) leak.
	Improper governor setting, adjustment or operation.
	Speed sensor malfunction.
	TPS faulty TPS Initialization Procedure incorrect.
	Bad coil(s), spark plug(s), or wires.
Low Power	Faulty/malfunctioning ignition system.
	Dirty air filter.
	Insufficient fuel delivery.
	Improper governor adjustment.
	Plugged/restricted exhaust.
	One injector not working.
	Basic engine problem exists.
	TPS faulty.
	Throttle plates in throttle body/intake manifold not fully opening to WOT.

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.

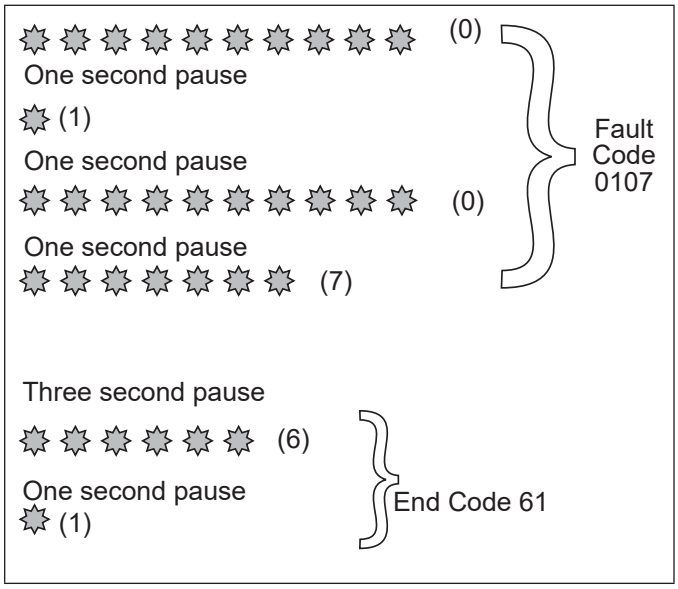
Fluid puncture injuries are highly toxic and hazardous. If an injury occurs, seek immediate medical attention.

Function of fuel system is to provide sufficient delivery of fuel at system operating pressure of 39 psi ± 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 so equipped) is fully opened.
      4. Make sure battery is supplying proper voltage.
      5. Check that fuses are good, and that all electrical and fuel line connections are good.
      6. Test fuel pump and relay operation.

Fault Codes

Example of Diagnostic Display



Diagnostic Fault Code Summary

Fault Code	Connection or Failure Description
0031	Oxygen Sensor Heater Circuit Low Voltage
0032	Oxygen Sensor Heater Circuit High Voltage
0107	Manifold Absolute Pressure (MAP or TMAP) Sensor Circuit Low Voltage or Open
0108	Manifold Absolute Pressure (MAP or TMAP) Sensor Circuit High Voltage
0112	Intake Air Temperature (IAT or TMAP) Sensor Circuit Low Voltage
0113	Intake Air Temperature (IAT or TMAP) Sensor Circuit High Voltage or Open
0117	Coolant/Oil Temperature Sensor Circuit Low Voltage
0118	Coolant/Oil Temperature Sensor Circuit High Voltage or Open
0122	Throttle Position Sensor Circuit Low Voltage or Open
0123	Throttle Position Sensor Circuit High Voltage
0131	Oxygen Sensor 1 Circuit Low Voltage, or Open
0132	Oxygen Sensor 1 Circuit High Voltage
0171	Maximum Adaptation Limit Exceeded
0172	Minimum Adaptation Limit Exceeded
0174	Lean Fuel Condition at High Load (Open Loop)
0201	Injector 1 Circuit Malfunction
0202	Injector 2 Circuit Malfunction

Fault Code	Connection or Failure Description
0230	Fuel Pump Circuit Low Voltage or Open
0232	Fuel Pump Circuit High Voltage
0336	Crankshaft Position Sensor Noisy Signal
0337	Crankshaft Position Sensor No Signal
0351	Cylinder 1 Ignition Coil Malfunction
0352	Cylinder 2 Ignition Coil Malfunction
0562	System Voltage Low
0563	System Voltage High
0650	MIL Circuit Malfunction
61	End of Code Transmission

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

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

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

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

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

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

DIAGNOSTIC CODE SUMMARY

Code 0031

Component:	Oxygen Sensor Heater
Fault:	O2S Heater Circuit Low Voltage
Condition:	System voltage too low, open connection or faulty sensor.
Conclusion:	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.

Code 0032

Component:	Oxygen Sensor Heater
Fault:	O2S Heater Circuit High Voltage
Condition:	System voltage too high, shorted connection or faulty sensor.
Conclusion:	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.

Code 0107

Component:	Manifold Absolute Pressure (TMAP)
Fault:	TMAP Circuit Low Voltage or Open
Condition:	Intake manifold leak, open connection or faulty sensor.
Conclusion:	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. Bad TPS Learn.

Code 0108

Component:	Manifold Absolute Pressure (TMAP)
Fault:	TMAP Circuit High Voltage
Condition:	Intake manifold leak, shorted connection or faulty sensor.
Conclusion:	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. Bad TPS Learn.

Code 0112

Component:	Intake Air Temperature (TMAP)
Fault:	Intake Air Temperature Sensor Circuit Low Voltage
Condition:	Shorted connection, faulty sensor or shorted wire.
Conclusion:	TMAP Sensor Related ● Sensor wiring or connection. Engine Wiring Harness Related ● Pin circuits Black 10 and Black 8 may be damaged or routed near noisy signal (coils, alternator, etc.). ● ECU-to-harness connection problem.

Code 0113

Component:	Intake Air Temperature (TMAP)
Fault:	Intake Air Temperature Sensor Circuit High Voltage or Open
Condition:	Shorted connection, faulty sensor, broken wire or connection.
Conclusion:	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.

Code 0117

Component:	Coolant/Oil Sensor
Fault:	Coolant/Oil Temperature Sensor Circuit Low Voltage
Condition:	Shorted connection, faulty sensor or shorted wire.
Conclusion:	Temperature Sensor Related ● Sensor wiring or connection. Engine Wiring Harness Related ● Pin circuits Black 10 and Black 14 maybe damaged or routed near noisy signal (coils, stator, etc.). ● ECU-to-harness connection problem.

Code 0118

Component:	Coolant/Oil Sensor
Fault:	Coolant/Oil Temperature Sensor Circuit High Voltage or Open
Condition:	Shorted connection, faulty sensor, open connection or broken wire.
Conclusion:	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.

Code 0122

Component:	Throttle Position Sensor (TPS)
Fault:	TPS Circuit Low Voltage or Open
Condition:	Open connection, broken wire or faulty sensor.
Conclusion:	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/Intake Manifold 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.

Code 0123

Component:	Throttle Position Sensor (TPS)
Fault:	TPS Circuit High Voltage
Condition:	Shorted connection or faulty sensor.
Conclusion:	TPS Sensor Related ● Sensor connector or wiring. ● Sensor output affected or disrupted by dirt, grease, oil, wear. ● Sensor loose on throttle body/intake manifold. Throttle Body/Intake Manifold 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, alternator). ● Intermittent 5 volt source from ECU (pin Black 16). ● ECU-to-harness connection problem.

Code 0131

Component:	Oxygen Sensor
Fault:	O2S 1 Circuit Low Voltage
Condition:	Open connection, broken wire or faulty sensor.
Conclusion:	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 Learn Procedure Incorrect ● Lean condition (check oxygen sensor signal with VOM and see Oxygen Sensor section). Engine wiring harness related such as a cut wire, broken or pinched.

Code 0132

Component:	Oxygen Sensor
Fault:	O2S 1 Circuit High Voltage
Condition:	Shorted connection or faulty sensor.
Conclusion:	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.

Code 0171

Component:	Fuel System
Fault:	Maximum adaptation limit exceeded
Condition:	Fuel inlet screen/filter plugged, low pressure at high pressure fuel line, TPS malfunction, shorted connection, faulty sensor, low fuel or wrong fuel type.
Conclusion:	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 Learn procedure. ● 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). ● Combustion air (air cleaner dirty/ restricted, intake leak, throttle bores). ● Base engine problem (rings, valves). ● Exhaust system leak (muffler, flange, oxygen sensor mounting boss, etc.). ● Fuel in crankcase oil.

Code 0172

Component:	Fuel System
Fault:	Minimum adaptation limit exceeded
Condition:	Too high pressure at high pressure fuel line, TPS malfunction, shorted connection, faulty sensor or fuel pump failure.
Conclusion:	Oxygen Sensor Related ● Sensor connector or wiring. ● Sensor contaminated or damaged. ● Poor ground path. ● Pin circuit wiring or connectors. ECU Black pin 10 or 17. TPS Sensor Related ● Throttle plate position incorrect during Learn procedure. ● 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). ● Combustion air (air cleaner dirty/ restricted). ● Base engine problem (rings, valves). ● Fuel in crankcase oil. ● Fuel pressure regulator malfunction.

Code 0174

Component:	Fuel System
Fault:	Lean fuel condition
Condition:	Fuel inlet screen/filter plugged, low pressure at high pressure fuel line, TPS malfunction, shorted connection or faulty sensor.
Conclusion:	TPS Learn Incorrect ● Lean condition (check oxygen sensor signal with VOM 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. ● Fuel pressure regulator malfunction. ● Fuel pump malfunction. Oxygen Sensor Related ● Sensor connector or wiring problem. ● Exhaust leak. ● Poor ground. Poor system ground from ECU to engine, causing rich running while indicating lean. Fuel pump connection. See Fuel Components.

Code 0201

Component:	Fuel Injector
Fault:	Injector 1 Circuit Malfunction
Condition:	Injector damaged or faulty, shorted or open connection.
Conclusion:	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.

Code 0202

Component:	Fuel Injector
Fault:	Injector 2 Circuit Malfunction
Condition:	Injector damaged or faulty, shorted or open connection.
Conclusion:	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.

Code 0230

Component:	Fuel Pump
Fault:	Circuit Low Voltage or Open
Condition:	Shorted or open connection.
Conclusion:	Fuel Pump Related ● Fuel pump 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.

Code 0232

Component:	Fuel Pump
Fault:	Circuit High Voltage
Condition:	Shorted connection.
Conclusion:	Fuel Pump Related ● Fuel pump damaged internally. Charging Output System Too High.

Code 0336

Component:	Crankshaft Position Sensor
Fault:	Crankshaft Position Sensor Noisy Signal
Condition:	Loose sensor, faulty/bad battery, shorted or faulty connection, faulty sensor or faulty sensor grounding.
Conclusion:	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. ● ECU-to-harness connection problem. Ignition System Related ● Non-resistor spark plug(s) used. ● Faulty or disconnected ignition coil or secondary lead.

Code 0337

Component:	Crankshaft Position Sensor
Fault:	Crankshaft Position Sensor No Signal
Condition:	Loose sensor, open or shorted connection or faulty sensor.
Conclusion:	Crankshaft Position Sensor Related ● 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 fault code is stored in history and engine starts normally. Clear code, no other service required.

Code 0351

Component:	Ignition Coil
Fault:	Cylinder 1 Ignition Coil Malfunction
Condition:	Broken wire in harness (may not be visible), shorted connection or faulty sensor.
Conclusion:	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.

Code 0352

Component:	Ignition Coil
Fault:	Cylinder 2 Ignition Coil Malfunction
Condition:	Broken wire in harness (may not be visible), shorted connection or faulty sensor.
Conclusion:	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.

Code 0562

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. ● Missing/broken magnet in flywheel. ● Bad or missing fuse.

Code 0563

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

Code 0650

Component:	MIL Circuit
Fault:	MIL Circuit Malfunction
Condition:	Failure in MIL circuit detected.
Conclusion:	Bad ECU. Bad Connection. Broken Wire.

Code 61

Component:	End of Code Transmission

Troubleshooting Flow Chart

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

Flow Chart Diagnostic Aids

Diagnostic Aid #1 SYSTEM POWER

(MIL does not illuminate when key is turned ON)

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

Conclusion

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

Diagnostic Aid #2 FAULT CODES

Refer to Diagnostic Fault Code Summary.

Diagnostic Aid #3 RUN/ON

(MIL remains ON while engine is running)*

Condition

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

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

Diagnostic Aid #4 CRANKSHAFT POSITION SENSOR

(MIL does not turn off during cranking)

Condition

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

Diagnostic Aid #5 FUEL PUMP

(fuel pump not turning on)

Condition

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

Diagnostic Aid #6 IGNITION SYSTEM

(no spark)

Condition

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

Diagnostic Aid #7 FUEL SYSTEM ELECTRICAL

(no fuel delivery)

Condition

- No fuel
- Air in high pressure fuel line
- Fuel valve shut OFF
- Fuel filter/line plugged
- Injector circuit(s), pin circuits Black 5 and Black 6
- Injector
- ECU grounds
- ECU
- Fuel pump manfunction

Diagnostic Aid #8 FUEL SYSTEM

(fuel pressure)

Low Fuel Pressure-Condition

- Low fuel
- Fuel filter plugged
- Fuel supply line plugged
- Fuel pump - internally plugged
- Pressure regulator not functioning properly.

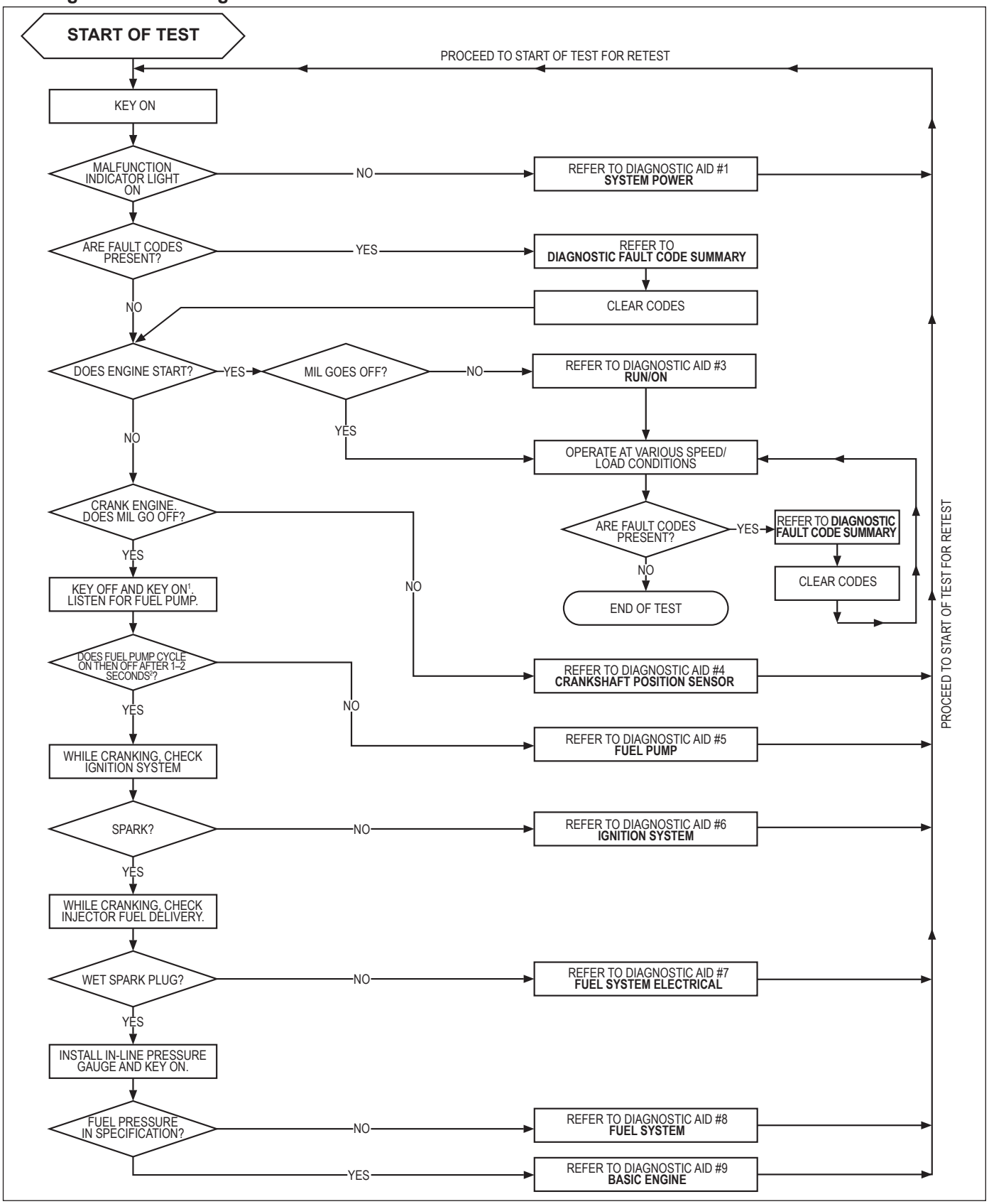
Diagnostic Aid #9 BASIC ENGINE

(cranks but will not run)

Condition

- Refer to basic engine troubleshooting charts within Troubleshooting.

EFI Diagnostic Flow Diagram

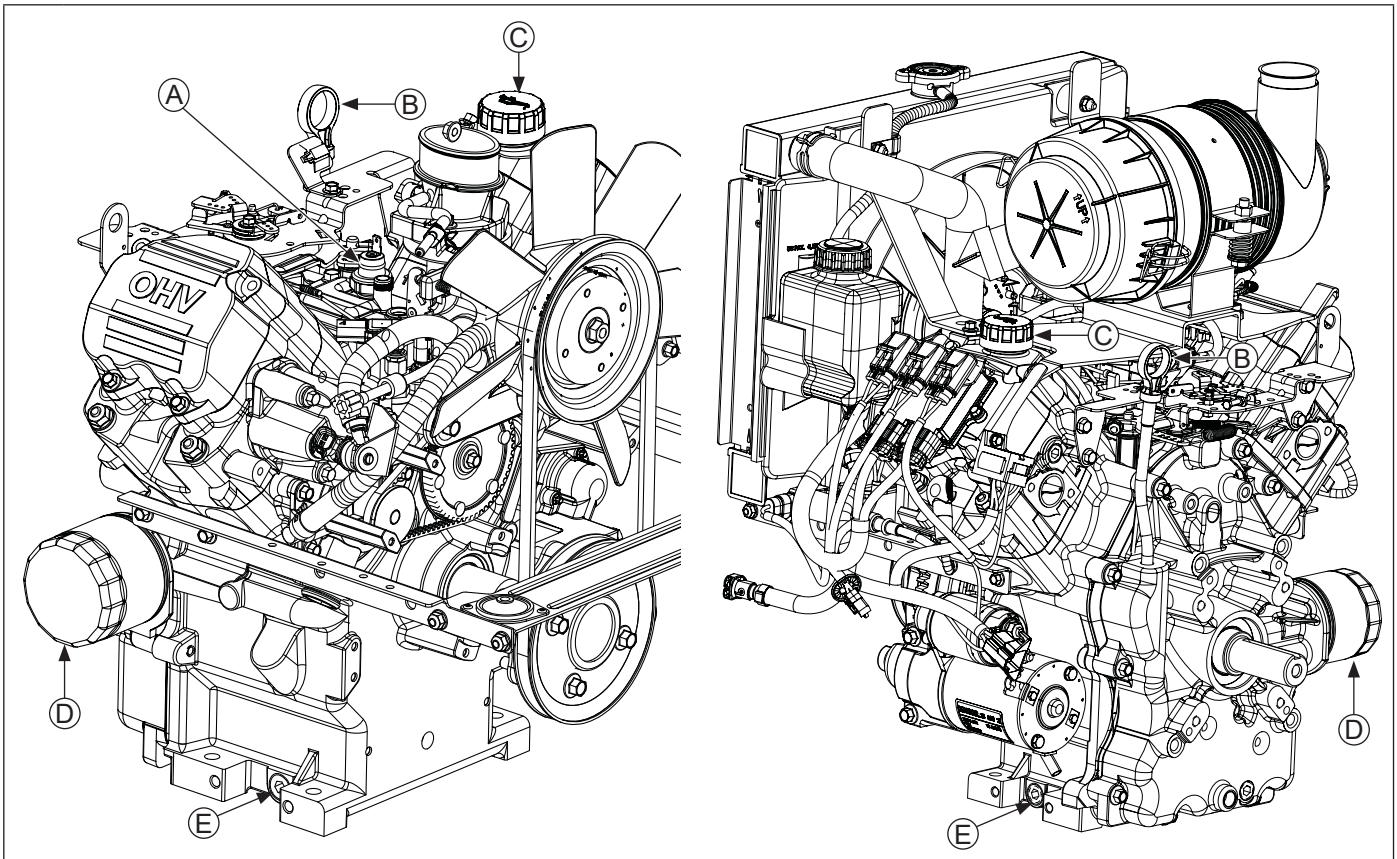


1. After turning key to OFF, wait 10 seconds before turning to ON to allow ECU to go to sleep.
2. Fuel pump can be heard or a vibration can be felt to establish pump cycle. Fuel pump will run for one 4-6 second cycle when ECU wakes up after being asleep.

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

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

Lubrication Components



A	Oil Sentry™	**B**	Dipstick	**C**	Oil Fill Cap	**D**	Oil Filter	**E**	Oil Drain Plug

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 and level. Clean oil fill/dipstick areas of any debris.

1. Remove dipstick; wipe oil off.
2. Reinsert dipstick into tube; press completely down.
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, drain plug/oil drain valve. Remove drain plug and oil fill cap/ dipstick. Allow oil to drain completely.
2. Clean area around oil filter. Place a container under filter to catch any oil and remove filter. Wipe off mounting surface. Reinstall drain plug. Torque to 13.6 N·m (10 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 SENTRY™

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 breather cover.

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 breather cover.
3. Torque switch to 4.5 N·m (40 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 2-5 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 2-5 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.

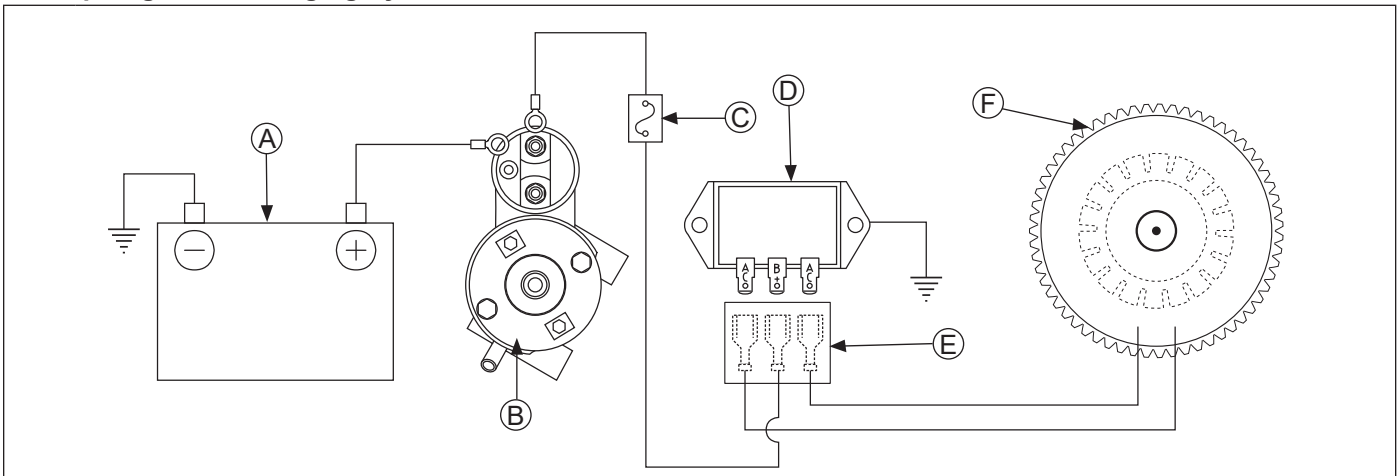
Do not touch wires while engine is running.

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

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

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

25 Amp Regulated Charging System



A	Battery	**B**	Starter	**C**	Fuse	**D**	Rectifier-Regulator
E	Connector Block	**F**	Flywheel Stator Assembly				

Stator

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

Rectifier-Regulator

Rectifier-regulator is mounted on air cleaner bracket. To replace, disconnect plug(s), remove mounting screws, and ground wire.

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)	300 cca minimum
0°F to 32°F (-18°C to 0°C)	300 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.

Fuses

This engine has 4 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 Red Wires	10-amp Fuse
1 Red Wire w/Black Stripe 1 Red Wire w/White Stripe	10-amp Fuse
2 Purple Wires	30-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 holder. 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 Wiring Diagram) by identifying failed fuse/circuit. Perform troubleshooting procedures appropriate for circuit fuse that failed.

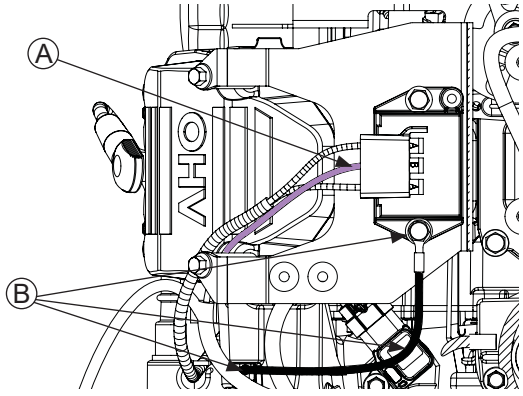
Troubleshooting Guide

25 Amp Battery Charging System

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

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

Test Charging System for No Charge to Battery



A	Purple B+ Charge Wire	**B**	Rectifier-Regulator Ground Wire with 2 Eyelets

1. With engine off, test and record battery voltage. Voltage should be above 12 volts to proceed. With voltmeter attached to battery, start engine. Set engine speed to high RPM position, battery voltage should increase (for example: 12.6 volts engine off; 13.4 volts engine running). Actual voltage increase will differ depending on state of charge in battery.
2. If no voltage increase is seen at battery, turn engine off and move voltmeter red lead to purple B+ lead on rectifier-regulator and black ground meter lead to ground eyelets. Recorded battery voltage from step 1 should be seen. If battery voltage is not seen, a blown fuse or bad connection may be at fault.

   Inspect (green 30 amp) charging system fuse for blown fuse and/or corroded fuse terminals. Inspect rectifier-regulator ground wire and eyelets for a proper connection and ensure mounting screws are secure.
3. If recorded battery voltage is seen, but no increase while running engine, proceed to step 2 of Test Charging System Output, for component diagnostic testing.
4. If a slight voltage increase is seen, but system output may be in question, proceed to step 1 of Test Charging System Output.

Test Charging System Output

1. Perform test a or b.
   a. Insert an ammeter in purple B+ lead at rectifier-regulator connector. With engine running at 3600 RPM and B+ (at terminal on rectifier-regulator) to ground using a DC voltmeter. If voltage is 13.8 volts or more, place a minimum load of 5 amps (turn on lights if 60 watts or more, or place a 2.5 ohm, 100 watt resistor across battery terminals) on battery to reduce voltage. Observe ammeter.
   b. If a carbon pile test tool is available, temporarily set carbon pile load near or at charging system maximum output and observe output voltage. (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 2 and 3).

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

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

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

Condition	Conclusion
Resistance is 0.1/0.2 ohms.	Stator is OK.
Resistance is 0 ohms.	Stator is shorted; replace.
Resistance is infinity ohms.	Stator is open; replace.

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

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

Test Charging System for Battery Continuously Charging at High Rate

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

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

To Test 25 amp Rectifier-Regulators

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

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

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

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

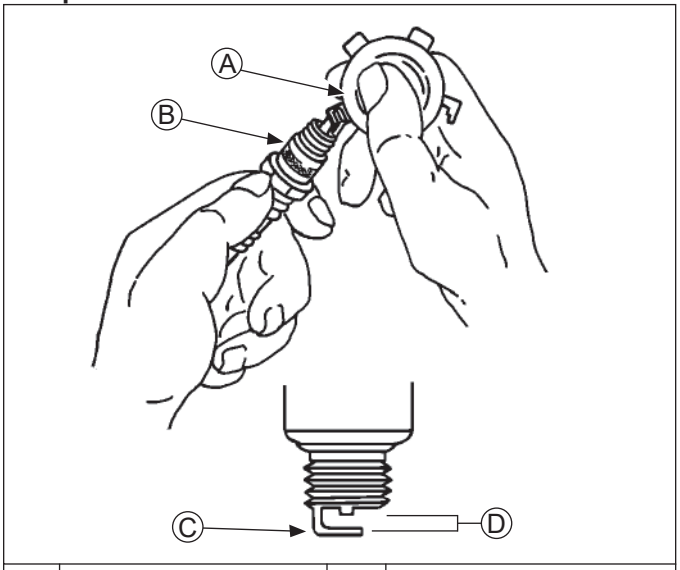
1. Connect tester ground lead (with spring clamp) to body of rectifier-regulator.
2. Connect red lead from tester to middle terminal labeled B+.
3. Connect black leads from tester to both outer AC terminals on rectifier-regulator.
4. Plug tester into proper AC outlet/power supply for tester being used.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

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

IGNITION SYSTEM

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.

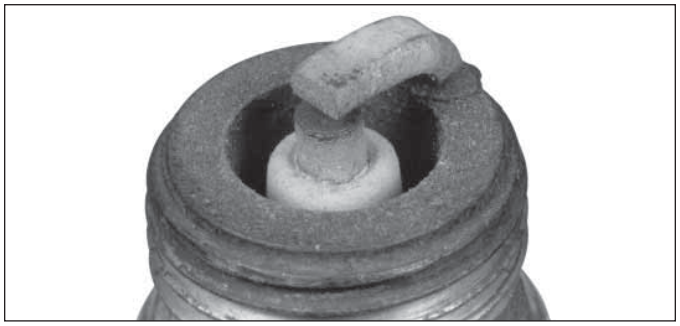
1. Check gap using wire feeler gauge. Adjust gap to 0.76 mm (0.030 in.).
2. Install plug into cylinder head.
3. Torque plug to 27 N·m (20 ft. lb.).

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.

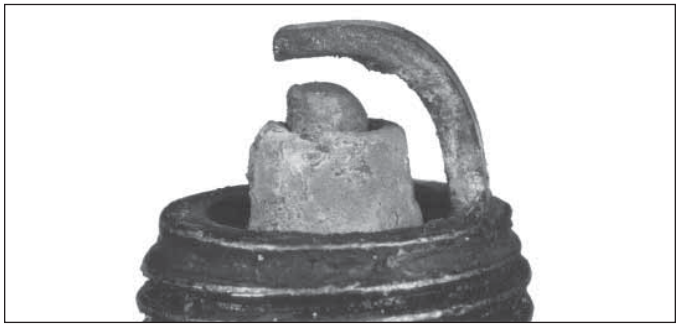
Normal and fouled plugs are shown in following photos:

Normal



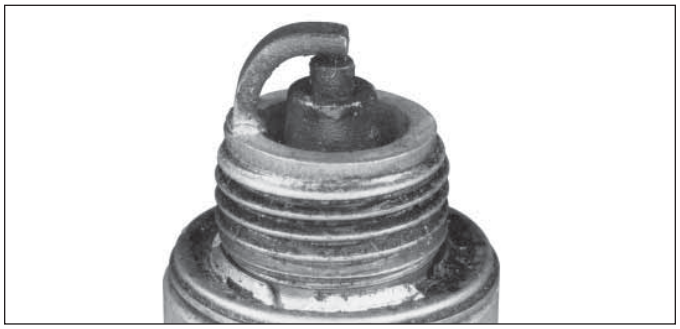
Plug taken from an engine operating under normal conditions will have light tan or gray colored deposits. If center electrode is not worn, plug can be set to proper gap and reused.

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 or a fuel mixture problem. 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 Kohler 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 550-600 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 3 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.

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 engine develops sufficient speed to disengage starter but does not keep running (a false start), engine rotation must be allowed to come to a complete stop before attempting to restart engine. 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.

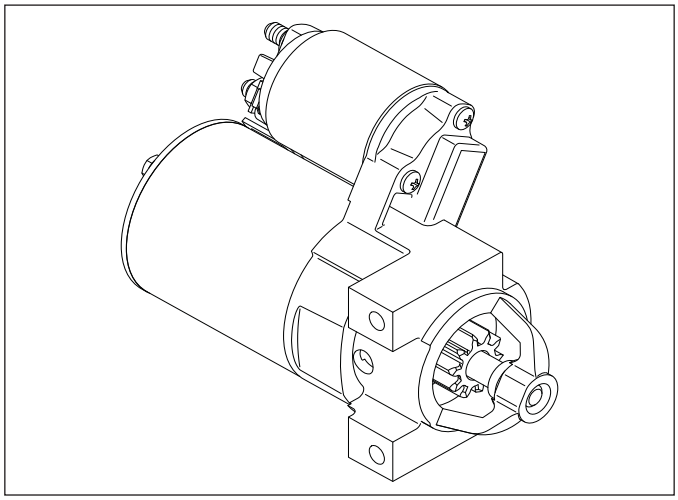
NOTE: Battery must be tested and confirmed acceptable prior to troubleshooting starter system. Follow battery or OEM battery testing procedures.

Engines in this series use solenoid shift starters.

Troubleshooting-Starting Difficulties

Condition	Possible Cause	Conclusion
Starter does not energize.	Battery	Check specific gravity of battery and 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. Consult with OEM electrical system service procedures for OEM related component diagnostics. Perform solenoid test procedure.
Starter energizes but turns slowly.	Battery	Check specific gravity of battery and battery state of charge. If low, recharge or replace battery as necessary.
	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.

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.

Inspection

Drive Pinion

Check and inspect following areas:

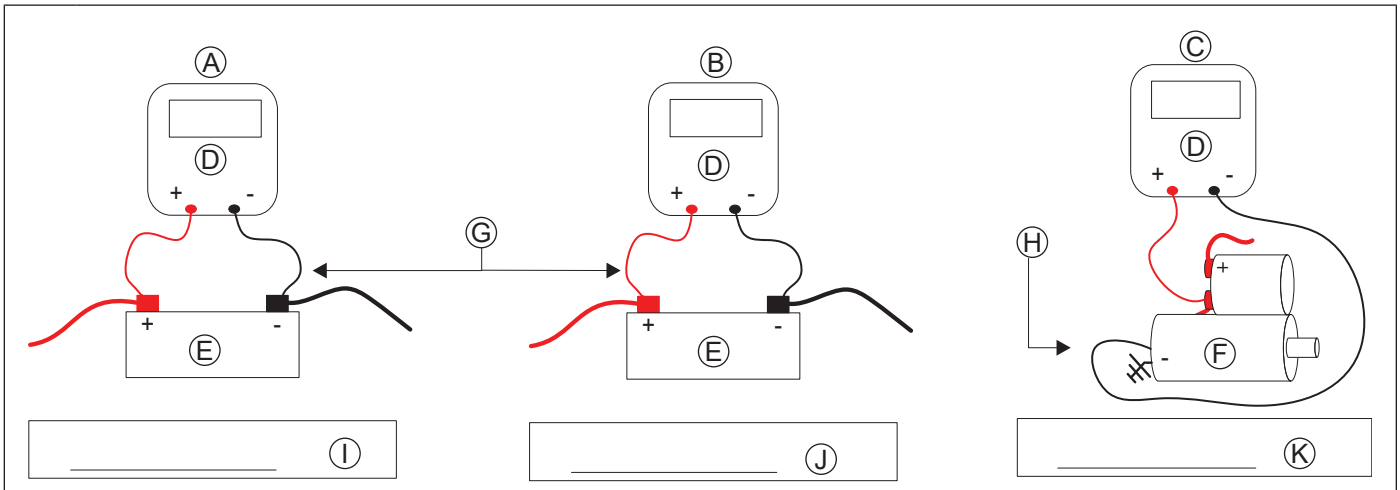
- Pinion teeth for abnormal wear or damage.
- Surface between pinion and clutch mechanism for nicks or irregularities which could cause seal damage.
- Check drive clutch by holding clutch housing and rotating pinion. Pinion should rotate in only 1 direction.

Solenoid Tests

NOTE: Please perform following testing as near to conditions during failure.

Before Starting

- Disable ignition system: with key off, unplug EFI Electronic Control Unit (ECU) or remove both 10 amp (red) engine mounted fuses.
- 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 meter to stabilize before recording. Reading should stabilize after 3 to 5 seconds. If reading continues to drop while cranking, stop test and perform a battery load test.



A	Test #1 Battery Voltage Test (Static)	**B**	Test #2 Voltage Drop Across Battery (Cranking)	**C**	Test #3 Voltage Drop Across Starter (Cranking)	**D**	DVOM
E	Battery	**F**	Starter	**G**	Touch meter leads to actual battery terminals.	**H**	Use starter end plate as test point.
I	Test #1 Results	**J**	Test #2 Results	**K**	Test #3 Results		

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 test or replacing 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 battery by using a load tester. Also check for external engine load.

Test 3 Conclusions

- If difference between test 2 and test 3 is greater than 1 VDC check all positive and negative electrical connections for corrosion and/or loose fasteners in starter circuit.

	**⚠ WARNING** Hot liquid can cause severe burns. Do not loosen radiator cap while engine is operating or warm to touch.	Liquid coolant can get extremely hot from operation. Turning radiator cap when engine is hot can allow steam and scalding liquid to blow out and burn you severely. Shut off machine. Only remove radiator cap when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.

When it is necessary to open cooling system at radiator cap, shut off engine and remove filler cap only when cool enough to touch with bare hands. Slowly loosen cap to first stop to relieve pressure before removing completely.

This section covers operation and servicing of liquid cooling system.

Cooling System Components

Cooling system consists of these following components:

- Radiator with removable screen
- Hoses
- Coolant Pump and Belt
- Thermostat
- Intake Manifold with Thermostat Housing
- Radiator Cap
- Cooling Fan, Belt, and Drive Pulleys
- Overflow Reservoir
- Crankcase and Heads with Integral Cooling Passages

Operation

Engine coolant is pumped through cooling system by a pump, belt-driven off camshaft. Coolant coming out of pump is divided, and moves simultaneously through separate circuits within each head and corresponding sides of crankcase. As coolant moves through these passages, it absorbs heat from engine parts. After traveling through engine, coolant from two separate circuits merges and moves through intake manifold to lower side of thermostat. During warm-up, thermostat is closed, preventing circulation through radiator. Coolant circulates through engine only and is returned to pump via bypass hose. When engine heat brings coolant up to a temperature of 79.4°C (175°F), thermostat will begin to open, allowing coolant to circulate through upper hose to radiator. Thermostat is completely open at 90.5°C (195°F) allowing full coolant flow through radiator, where it is cooled. After getting cooled in radiator, coolant is drawn into pump through lower radiator hose and circulation starts all over again. A cooling fan, driven off flywheel by a belt, draws ambient air through radiator, to maintain cooling process.

Coolant will provide protection from -37°C (-34°F) to 108°C (226°F). For protection and use outside indicated temperature limits, follow antifreeze manufacturer's instructions on container, but do not exceed 70% antifreeze.

DO NOT use antifreeze with stop-leak additive(s), or put any other additives in cooling system.

Cooling System Maintenance and Service

Maintenance

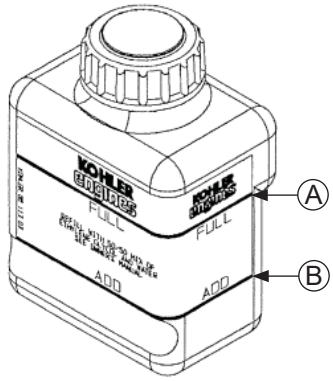
Maintaining correct coolant level, cleaning any debris accumulation from radiator surfaces, and insuring all parts are in proper operating condition, is critical to ensuring long life, proper system performance and preventing overheating. To ensure proper air circulation, make sure radiator, cooling fan, drive belt, pulleys, cooling fins, and external surfaces of engine are kept clean and in good condition at all times. Check coolant level and clean away any debris accumulation daily or before each use. Simultaneously inspect hoses and all system connections for signs of leakage. Make sure cooling fan is not cracked or missing any blades. Check that fan belt and two drive pulleys, are in good condition and proper belt tension is present.

Service

Lift screen vertically to remove for cleaning/servicing. Clean screen and cooling fins of radiator with a soft brush or blow out using clean compressed air. To avoid damage to screen and cooling fins, do not use a high pressure washer to clean.

Checking Coolant Level

Overflow Reservoir Details



A	Full	B	Add

NOTE: Do not operate engine without coolant in system. Do not remove radiator cap when hot. Engine coolant is hot and under pressure and can cause severe burns. To prevent engine overheating and damage, do not exceed more than 70% antifreeze in cooling system.

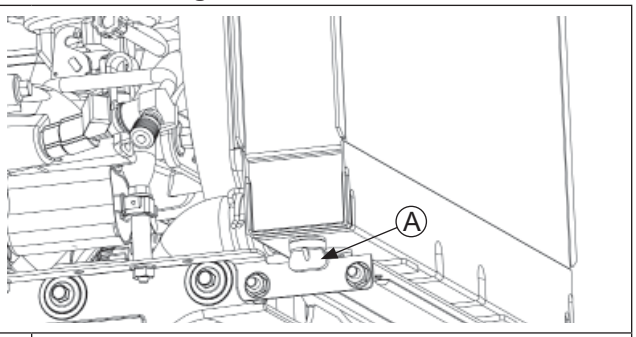
Coolant level should be checked at overflow reservoir, located behind radiator on fan shroud.

1. Check coolant level within overflow reservoir. Coolant level should be between FULL and ADD marks on reservoir. Do not operate engine with coolant level below ADD mark.

Add coolant to overflow reservoir as required, which is a 50/50 mixture of ethylene glycol and water (distilled or deionized water is recommended).

Drain Cooling System

Radiator Drain Plug Details



A	Radiator Drain Plug

1. Ensure engine is cool. When radiator is cool to touch, slowly loosen radiator cap to first stop and allow any pressure to bleed off. Then loosen it fully and remove it.

   Loosen/remove radiator drain plug and allow coolant to drain.
2. Remove overflow hose from reservoir. Unhook inboard retainer and slide reservoir out of supports. Pour out contents and wash or clean as required. Dispose of all old coolant in accordance with local ordinances.
3. Reinstall reservoir cap. Do not kink/pinch hose.
4. Flush cooling system.

Flushing Cooling System

NOTE: To prevent engine damage, do not pour water into a hot engine. Do not operate engine without coolant.

With system properly drained:

1. Fill cooling system with clean water and a cooling system cleaner recommended for aluminum engines. Follow directions on container.
2. Reinstall and tighten radiator cap.
3. Start and run engine for five minutes, or until it reaches operating temperature. Stop engine and allow it to cool.
4. Drain cooling system.
5. Fill cooling system.

Filling Cooling System

NOTE: To prevent engine damage, do not use antifreeze mixture greater than 70% ethylene glycol in cooling system. Do not use antifreeze with stop-leak additive(s) or mix/add other additives to cooling system. Use only ethylene glycol antifreeze.

Cooling system capacity is approximately 2 liters (2.18 qt.).

1. Check condition of cooling system hoses, clamps, and associated components. Replace as required.
2. Fill with 2.0 L (2.1 U.S. qt.) equal parts of ethylene glycol (anti-freeze) and water only. Distilled or deionized water is recommended, especially in areas where water contains a high mineral content. Propylene glycol based anti-freeze is not recommended.
3. Fill radiator with coolant mixture. Allow coolant to drain into lower areas. Fill overflow reservoir to a level between FULL and ADD marks. Reinstall radiator and reservoir caps.
4. Start and run engine for five minutes. Stop engine and allow to cool.
5. Recheck coolant level in reservoir. Coolant level should be between FULL and ADD marks. Add coolant to reservoir if required.

Inspection

Cooling Fan Assembly, Belt, and Drive Pulleys

Cooling fan assembly, used to draw air through radiator, is attached to a hub and pulley assembly with sealed ball bearings. This assembly is belt driven off flywheel, via a lower split pulley, and requires very little service or maintenance. DO NOT operate engine without fan and properly functioning cooling system or engine damage will occur.

1. Inspect fan for any cracks, damaged/missing fan blades, and secure mounting.
2. Bearings in hub of pulley should rotate smoothly, without roughness, binding, or play/wobble.
3. V-groove of each pulley (upper and lower) should not be bent, nicked, or damaged. Pulley mounting areas and lower pulley shims should be free of any cracks or elongation.
4. Drive belt is designed and constructed for this system. Do not use a substitute belt. Check overall condition and replace belt if cracked, damaged, or proper tension cannot be established by repositioning of lower pulley shims. Use only Kohler Part No. 66 203 02-S belt if replacement is necessary.

   See a Kohler authorized dealer for any necessary service.

Checking Fan Belt and Tension

Fan belt and belt tension should be checked daily or before each use. Fan belt should not be cracked, damaged, or exhibit excessive wear. Proper tension is 12.7 mm (3/8 - 1/2 in.) belt deflection per side under 10 lbs. applied tension.

If belt is cracked, damaged, or is worn that relocation of pulley shims cannot establish proper belt tension, belt should be replaced. Use only Kohler Part No. 66 203 02-S belt. DO NOT use a substitute belt.

For a new belt, assemble lower pulley with all three shims between pulley halves. For a used/original belt being reinstalled, assemble with two or one shim(s) between pulley halves and remaining shim(s) on outside (front) of outer pulley half. Check belt tension as described above.

When proper tension is obtained, individually remove each capscrew of lower pulley, apply Loctite® 242® to threads, and reinstall. Torque each capscrew in a criss-cross sequence to 24.3 N·m (215 in. lb.).

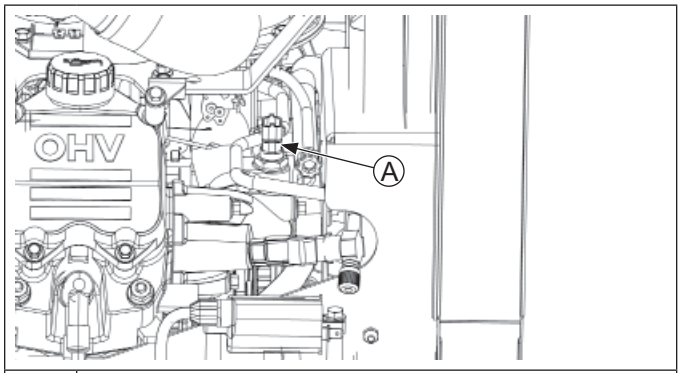
Hoses and Tubes

Hoses and tubes are used to connect components within cooling system. To guard against coolant loss and hose failure, hoses, tubes and their connections should be checked regularly for leaks or damage. Loss of coolant can result in serious engine damage. Over time, engine vibration can affect hose/joint connections, and hoses themselves can be affected by heat and coolant. Swelling, hardening, and/or deterioration can occur depending on operating environment. Deterioration usually takes place more rapidly from inside, making outside inspections incomplete and not always dependable. Regular outside inspection and careful inside inspection whenever connections are opened, can minimize a possible in-service problem.

Use new clamps whenever a hose is replaced or a joint connection is opened. When making hose connections, a light coating of rubber lubricant will make assembly easier.

Thermostat Testing and Servicing

Temperature Sensor Details



A	Temperature Sensor

Thermostat is mounted in intake manifold, beneath thermostat housing. It controls rapid warm-up and operating temperature of engine. If a problem is encountered which is thought to be fault of thermostat, it can be checked to determine its operating condition. Before removing and testing thermostat, make sure all other possible causes such as debris accumulation/ obstruction, leaks, belt or fan failure, coolant level, and damaged components are eliminated as possible causes.

To Test

Remove thermostat from system. Hang or suspend thermostat by its frame in a container of water, so thermostat does not touch bottom of container. Heat water and measure temperature (an oven thermometer can be used). Spring-loaded valve of thermostat should begin to open at 79.4°C (175°F), and can be completely open at 90°C (195°F). If valve opens at a temperature more than 10 degrees below specified opening or fails to open at a temperature 10 to 15 degrees above specified opening, thermostat should be replaced. If valve in thermostat can be moved or pushed off its seat with a slight effort when thermostat is cold, unit may be considered defective and should be replaced. Thermostat should be replaced if operation is found to be questionable or faulty.

Installation

1. Thoroughly clean sealing surfaces of intake manifold and thermostat housing with an aerosol gasket remover. Make sure sealing surfaces are clean and free of nicks or damage. Make sure notch in intake manifold is clean.
2. Install a new thermostat into intake manifold, so larger spring end is down into well of intake manifold. Position a new thermostat gasket on intake manifold.
3. Install thermostat housing onto intake manifold.
4. Install and torque screws to 9.9 N·m (88 in. lb.).
5. Reconnect radiator hose and secure with hose clamp, if separated previously.

High Temperature Sensor

A high temperature sensor may be mounted in intake manifold and is used to activate a warning light, audible alarm, or kill engine (depending on application), if safe operating temperature is exceeded. Sensor is a normally open switch which completes a circuit, when coolant temperature reaches rated temperature limit of switch. For these engines temperature sensor limit is 123.8°C (255°F).

If warning device activates, or engine kills, indicating an excessive operating temperature, check following:

1. Make sure fan belt is in good condition and properly tensioned.
2. Make sure cooling fan is properly secured, not broken, damaged, or missing blades.
3. Make sure all air intake and cooling surfaces are clean and free of debris accumulation.
4. After engine has sufficiently cooled, check coolant level in system to make sure it is not low, or improperly mixed.
5. Check cooling system for leaks.

6. Check thermostat, and pressure test radiator cap.
7. Make sure water pump and drive belt are operational.
8. Check and inspect wiring from sensor for shorting or damage.

If none of those are found to be cause do following:

1. Drain coolant from system, so level is lower than installed position of temperature sensor.
2. Remove and replace temperature sensor. Use pipe sealant with Teflon® on threads.

Cooling System Leakage Test

A pressure test of cooling system can be performed as a relatively simple means of determining whether cooling system may contain a leak. A pump/pressure type cooling system tester with appropriate 45 mm adapter may be used to check cooling system and radiator cap.

Test Instructions

1. With engine cool, carefully remove radiator cap (see Pressure Radiator Cap). Make sure all parts of cap and adapter are clean. Install cap on corresponding adapter and make sure it is completely seated. Install adapter onto tester and lock in place.
2. Pressurize tester to 15 psi.
3. Observe indicated pressure. It should hold steady and not decrease or leak down.

   If leakage is detected, cap should be replaced. If tester pressure is increased to 16 psi, or above, cap should then bleed off this excess pressure.
4. Install and lock system adapter and tester onto neck of cooling system. Pressurize tester to 14-15 psi.
5. Observe system pressure on gauge.

Gauge Needle Holds Steady
If gauge needle holds steady, there should be no serious leaks in system. It is however, recommended that all connections be checked for overall condition anyway, using a flashlight.

Gauge Needle Drops Slowly
If gauge needle drops slowly it indicates presence of a small leak or seepage. Check all components and connections for signs of leakage. Check condition of radiator hoses. If they swell excessively while testing system, they may be weak and should be replaced.

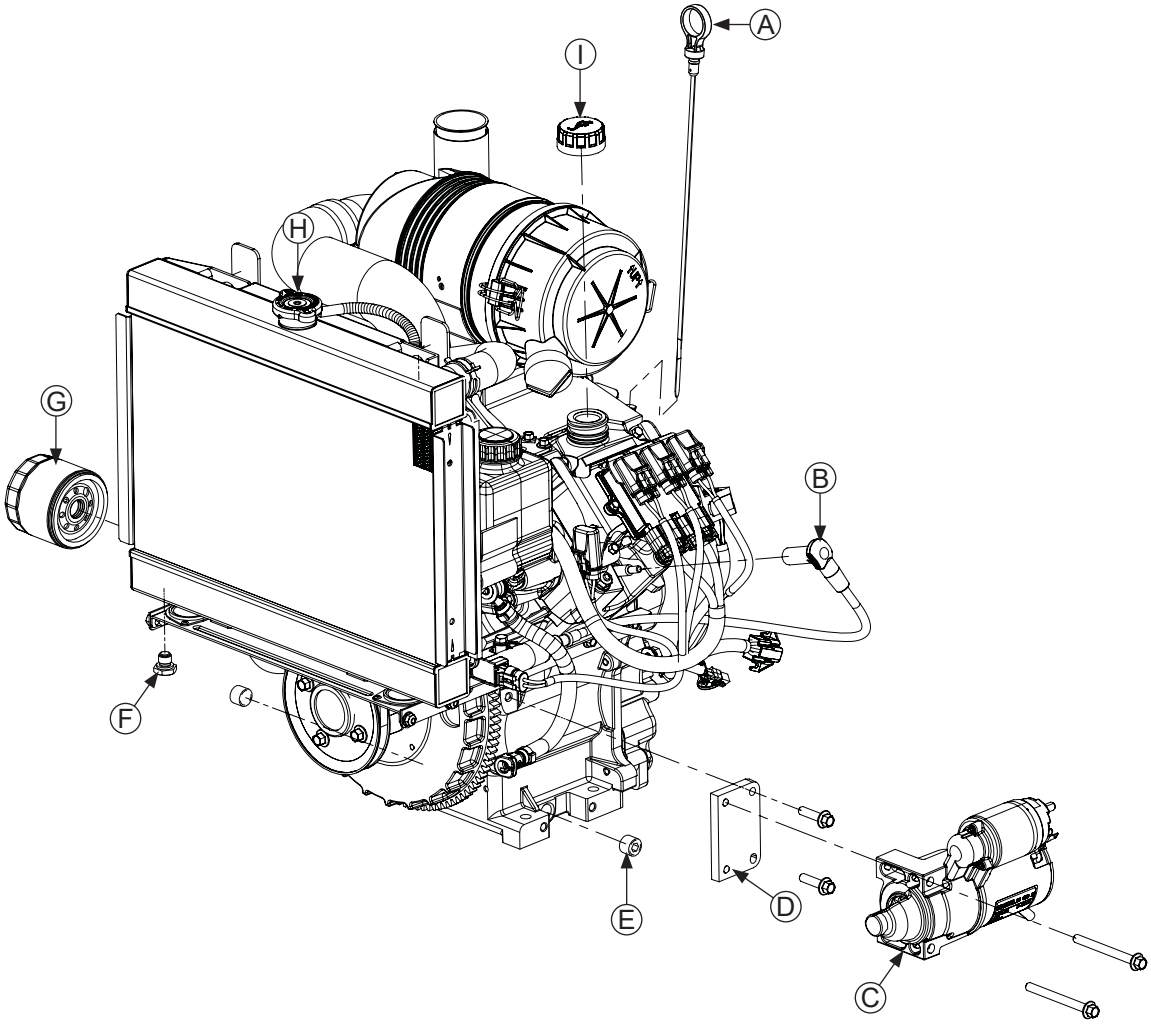
Gauge Needle Drops Quickly
A steady drop or loss of pressure indicates serious leakage is occurring within system, which must be located and corrected before engine is returned to service.

If a pressure loss is noted:

1. With pressure on system, apply a soap/water solution and check all joint connections, hoses, and cooling system components for external leakage. Repair or replace as required.
2. Remove dipstick and check appearance of oil in crankcase. Another method would be to remove an oil drain plug and drain a small amount of oil for inspection. A milky or an opaque color, similar to chocolate milk, indicates presence of engine coolant in oil. Check for a blown head gasket (step 3 below) or a possible crack or internal leakage from water jacket.
3. Remove spark plugs. Apply 14-15 lbs. of pressure and listen/inspect for internal coolant leakage into cylinder/combustion chambers. This can denote a head gasket failure/leak. If required, further test by performing a Cylinder Leakdown Test as described in Troubleshooting.

	⚠ 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**	Spark Plug Lead	**C**	Electric Starter	**D**	Starter Plate
E	Oil Drain Plug	**F**	Radiator Drain Plug	**G**	Oil Filter	**H**	Radiator Cap
I	Oil Fill Cap						

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 component.

Disconnect Spark Plug Leads

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

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

Disconnect Oxygen Sensor

NOTE: Unless oxygen sensor is damaged or malfunctioning, disassembly from muffler (OEM supplied) is unnecessary.

Disconnect oxygen sensor connector from wire harness.

Remove Starter and Starter Plate

NOTE: Unless starter plate is damaged, disassembly from crankcase is unnecessary.

1. Disconnect leads attached to starter solenoid terminals.
2. Remove screws securing starter to starter plate.
3. Remove screws attaching starter plate to crankcase. Note orientation of flat side and longer hole.

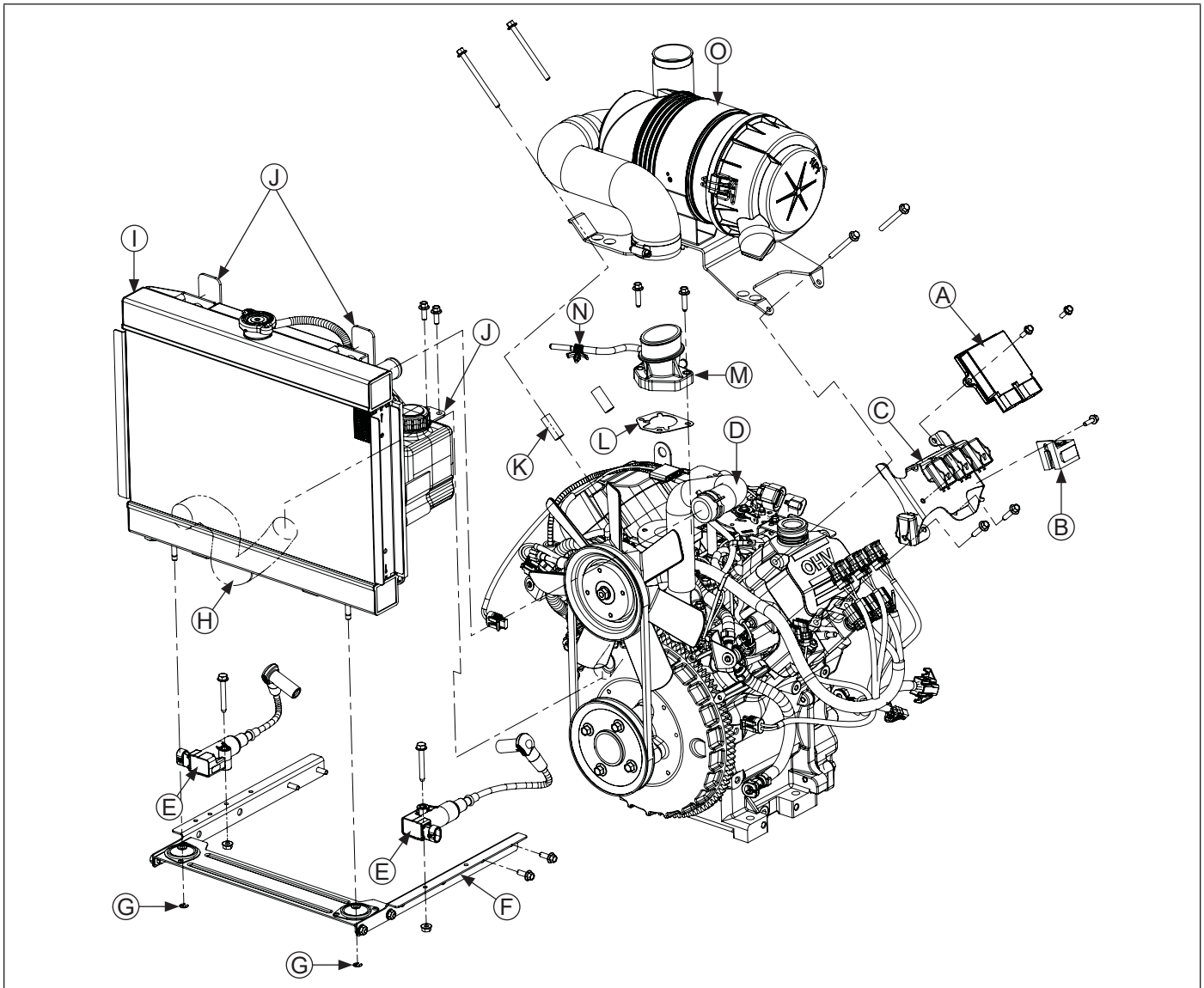
Drain Coolant from Cooling System

1. Loosen radiator cap, then loosen radiator drain plug and allow system to drain. Use a suitable container to catch coolant.
2. Allow any remaining coolant to drain out. Dispose of coolant properly, according to local regulations.

Drain Oil from Crankcase and Remove Oil Filter

1. Remove oil fill cap and dipstick, and one or both drain plugs. Allow sufficient time for oil to drain out.
2. Remove and discard oil filter.
3. Reinstall oil fill cap.

Remove Ignition Coils/Radiator Assembly/Mounting Brackets/Air Cleaner Assembly Components



A	ECU	**B**	Relay	**C**	ECU, Fuse, & Connector Mounting Bracket	**D**	Upper Radiator Hose
E	Ignition Coil	**F**	Mounting Bracket	**G**	E-clip Retainer	**H**	Lower Radiator Hose
I	Radiator Assembly	**J**	Upper Radiator Support	**K**	Spacer	**L**	Air Cleaner Adapter Gasket
M	Air Cleaner Adapter	**N**	Evap Line Clip	**O**	Air Cleaner Assembly		

Disconnect ECU and Remove Ignition Coils

1. Disconnect wire harness from ECU.
2. Disconnect wire lead from ignition coils. Remove screws and nuts securing ignition coils.

Remove Radiator Assembly, Mounting Brackets and Attached Components

NOTE: Do not allow cooling fins of radiator to contact fan blades.

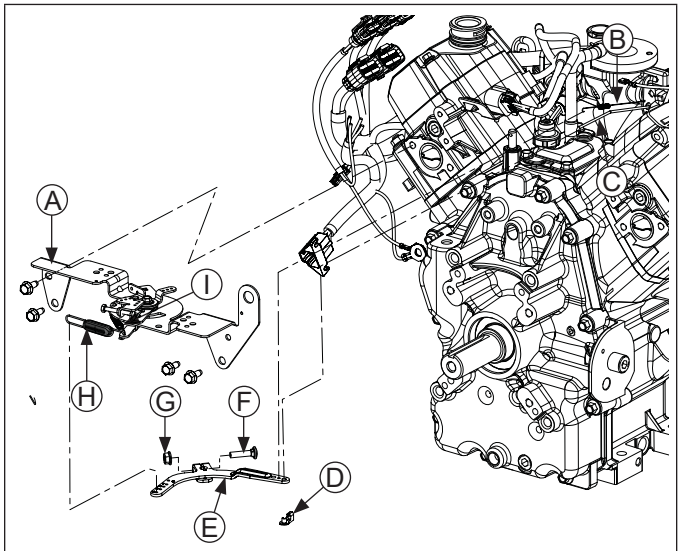
1. Disconnect upper radiator hose from radiator, and lower radiator hose from inlet of water pump.
2. Remove evap line clip from #2 side upper radiator support.
3. Remove screws securing two upper radiator supports to air cleaner mounting bracket.
4. Remove E-clip retainer from each radiator post.
5. Carefully tilt (pull) radiator forward slightly to clear fan and lift complete assembly out of lower mounting bracket.
6. Remove four screws securing #1 and #2 side mounting brackets to crankcase. Pull complete mount assembly forward to remove.
7. Further disassembly for component servicing may be performed as required.

Remove Air Cleaner Assembly

1. Remove screws securing air cleaner adapter and gasket to intake manifold.
2. Disconnect breather hose from air cleaner adapter.
3. Disconnect connector plug from rectifier-regulator. Remove screw securing rectifier-regulator ground wire. Rectifier-regulator can remain secured to air cleaner bracket.
4. Remove ECU from ECU bracket.
5. Unplug relay; remove screw and relay bracket from ECU bracket. Plug relay back into bracket.
6. Remove screws securing #1 side valve cover, ECU bracket, and air cleaner bracket.
7. Remove #2 side screws and spacers from air cleaner bracket and valve cover.
8. Lift air cleaner/mounting bracket assembly off engine.

Remove Throttle and Governor Controls

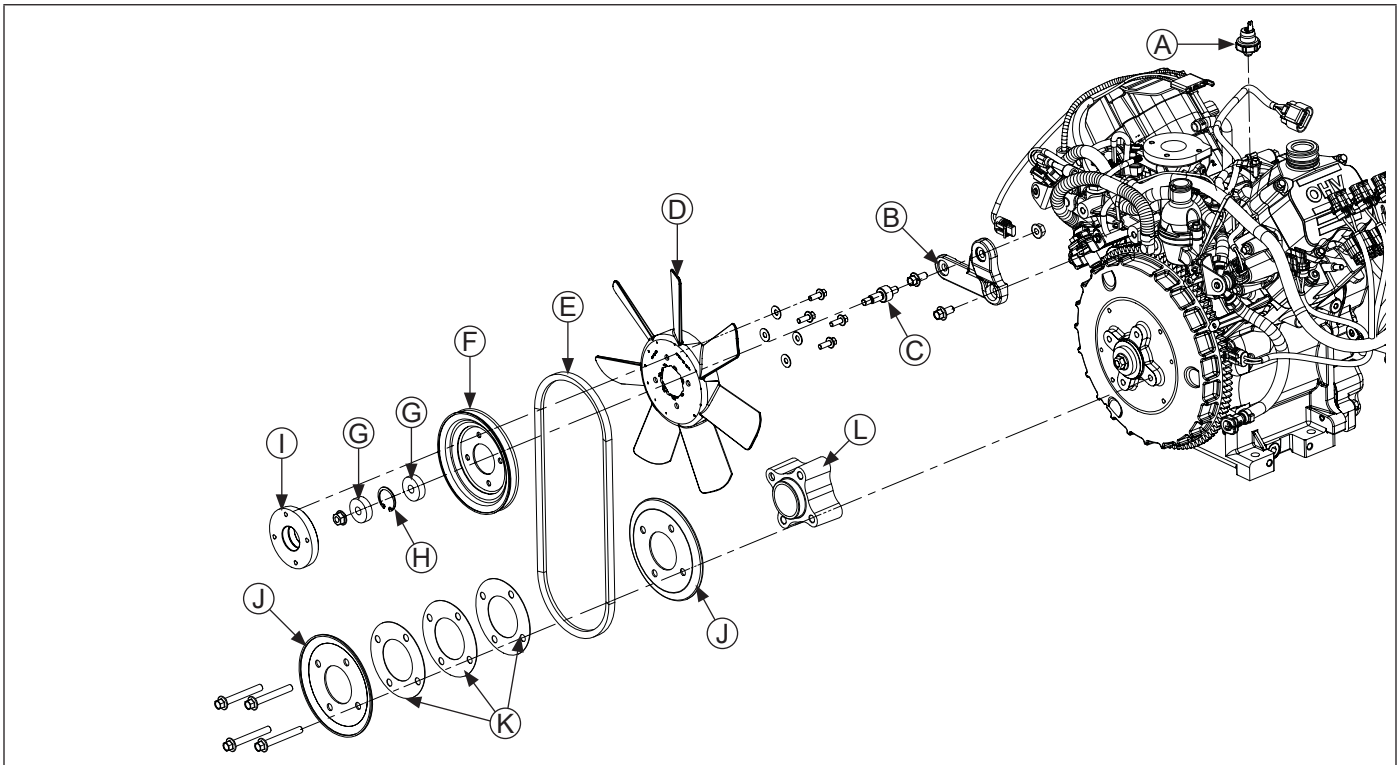
Details



A	Control Bracket	**B**	Linkage Spring
C	Throttle Linkage	**D**	Linkage Retaining Bushing
E	Governor Lever	**F**	Governor Lever Screw
G	Governor Lever Nut	**H**	Governor Spring
I	Throttle Limiter Spring		

1. Unhook linkage retaining bushing, throttle linkage, and linkage spring from governor lever.
2. Remove screws securing main control bracket to cylinder heads.
3. Mark hole location and disconnect governor spring from governor lever.
4. Loosen nut of governor lever mounting screw. Lift governor lever off governor shaft.

Fan Components



A	Oil Sentry™	**B**	Fan Mounting Bracket	**C**	Fan Shaft	**D**	Fan
E	Fan Belt	**F**	Fan Pulley	**G**	Ball Bearing	**H**	Retainer Ring
I	Bearing Carrier	**J**	Pulley Half	**K**	Spacer Shims	**L**	Pulley Adapter

Remove Oil Sentry™

NOTE: Unless Oil Sentry™ switch is damaged or malfunctioning, disassembly from breather cover is unnecessary.

Disconnect wire lead from Oil Sentry™ switch, and remove switch from breather cover.

Remove Lower Drive Pulley and Fan Belt

1. Remove four screws attaching lower drive pulley assembly to pulley adapter and flywheel.
2. Remove pulley halves with spacer shims from adapter, and take fan belt off upper pulley/fan assembly. Note number of shims between pulley halves, and on front side of pulley, especially if same belt will be reinstalled.

Remove Fan Assembly, Mounting Bracket, and Fan Shaft

NOTE: Further disassembly of fan/hub and pulley assembly is not necessary unless a problem exists. If disassembly is performed, note assembly order and position of parts.

1. Remove front nut and washer securing fan assembly to fan shaft. Remove fan and pulley assembly from upper mounting bracket.
2. Remove screws and take off mounting bracket with fan shaft attached.
3. Fan shaft may be removed from mounting bracket, by removing rear nut, if individual servicing of either part is required.

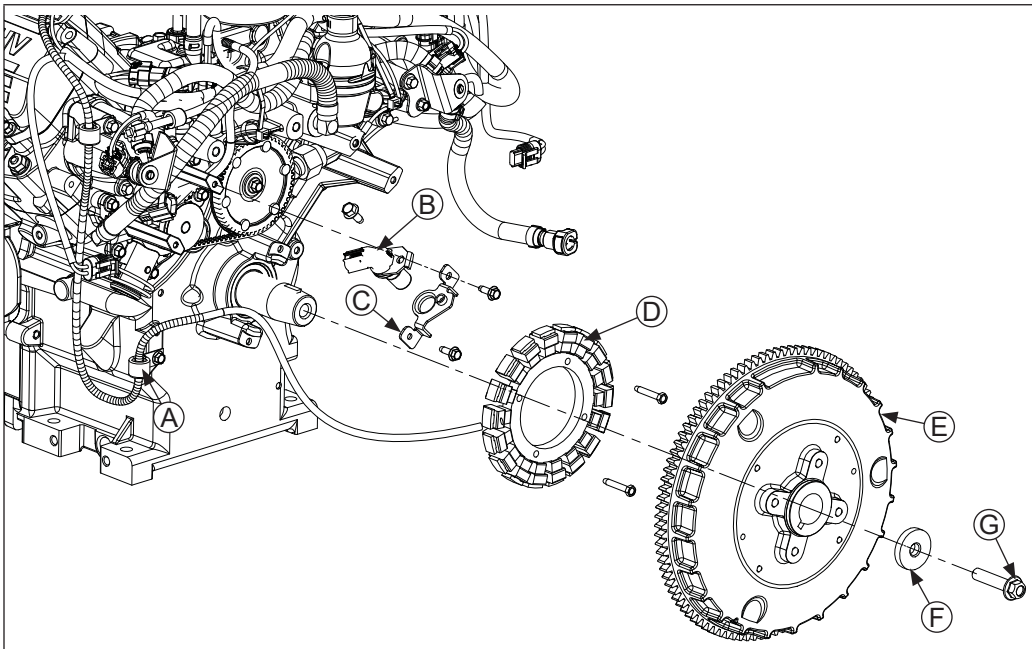
Inspection and Service

Cooling fan assembly consists of a fan attached to a v-pulley and bearing carrier (hub), rotating on a dual ball-bearing fan shaft (arbor). Assembly is mounted with a bracket to intake manifold and driven via a split pulley off flywheel.

Inspect components carefully for signs of wear or damage.

1. Inspect fan to make sure blades are in good condition and free of any cracks, nicks, or damage. Area around fan mounting holes must also be free of any cracks or damage.
2. Fan and hub assembly, when mounted to center arbor shaft, must rotate smoothly without noticeable bearing play, wobble, or binding.
3. Check v-belt for excessive wear, cracking or damage. If proper belt tension cannot be obtained, or condition of belt is suspect; replace it with Kohler Part No. 66 203 02-S. Do not use a substitute belt.

Flywheel/Stator Components



A	Wire Clip	**B**	Crankshaft Position Sensor	**C**	Crankshaft Position Sensor Bracket	**D**	Stator
E	Flywheel	**F**	Washer	**G**	Flywheel Screw		

Remove Crankshaft Position Sensor

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

1. Disconnect electrical connector from crankshaft position sensor.
2. Remove screws securing crankshaft position sensor bracket to crankcase posts.

Remove Flywheel

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

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

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

Inspection

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

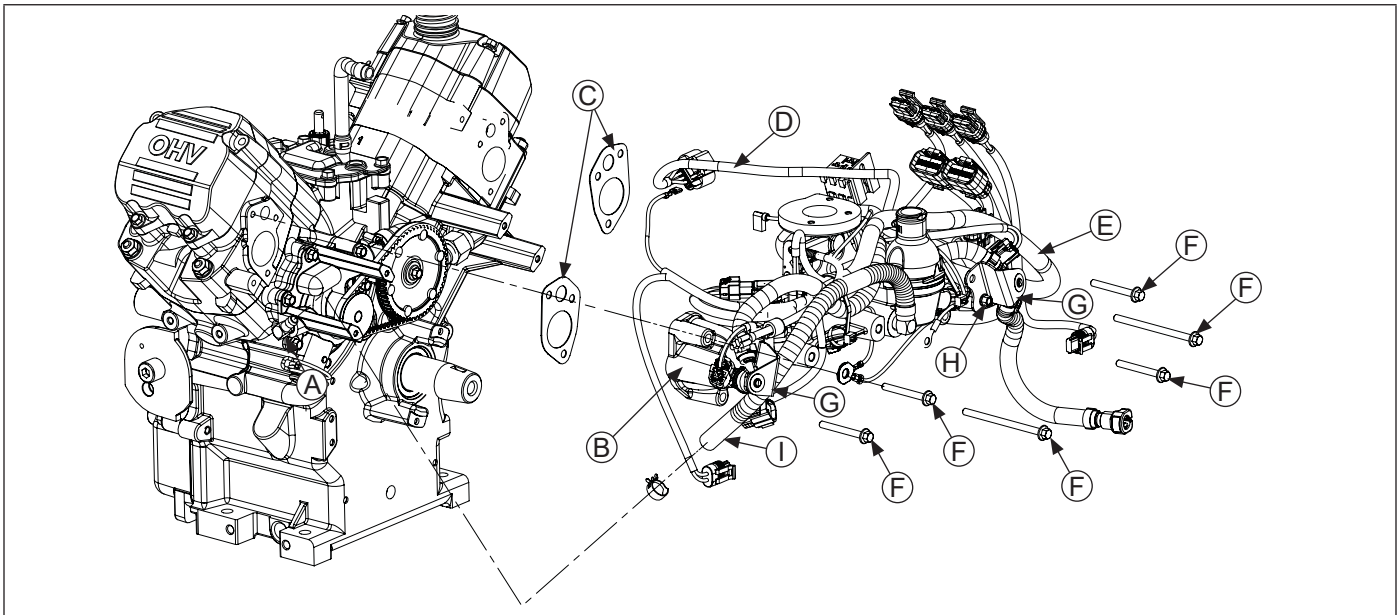
Inspect ring gear for cracks or damage. Kohler does not provide ring gears as a serviceable part. Replace flywheel if ring gear is damaged.

Check charging system magnets to be sure they are not loose or cracked.

Remove Stator Assembly

1. Remove wire clip securing stator lead to crankcase.
2. Remove mounting screws, and pull stator, with plug-in connector attached, from engine.
3. Remove purple B+ lead from center of rectifier-regulator connector.

Intake Manifold Assembly Components

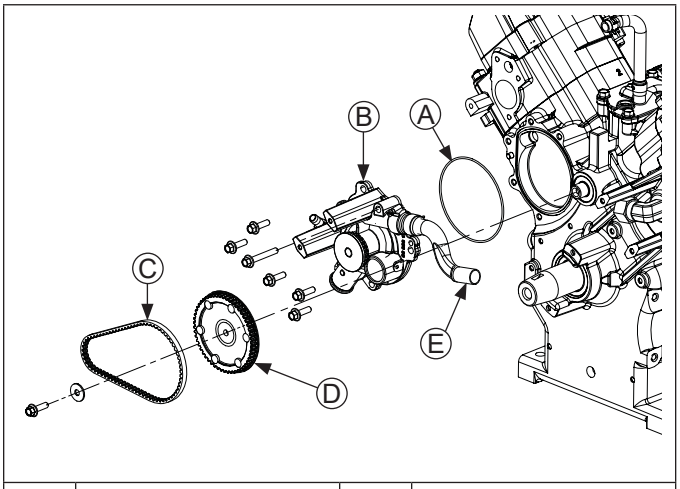


A	Fitting	**B**	Intake Manifold Assembly	**C**	Intake Manifold Gasket	**D**	Wiring Harness
E	Fuel Rail	**F**	Intake Manifold Screw	**G**	Fuel Injector Bracket	**H**	Fuel Injector Bracket Screw
I	By-Pass Hose						

Remove Intake Manifold, Thermostat Housing, By-Pass Hose and Wiring Harness

1. Disconnect by-pass hose from fitting on water pump.
2. Remove screw securing ground wire to #2 side crankcase boss.
3. Remove six mounting screws and carefully separate intake manifold from cylinder heads, with by-pass hose and wiring harness attached.
4. Remove intake manifold gaskets.
5. Further disassembly of intake manifold components may be performed as necessary. If thermostat is to be removed, loosen and remove screws securing thermostat housing to intake manifold. Separate housing and remove thermostat, discard old gasket. Unless fuel injectors are damaged or malfunctioning, disassembly from intake manifold is unnecessary. If replacement is required, note position of injector, then remove screw securing injector bracket, pull metal retaining clip connecting fuel injector to fuel injector cap and remove injector. There may be some fuel left in line. Any spilled fuel must be cleaned up immediately. O-rings and retaining clips should be replaced any time fuel injector is separated from its normal mounting position.

Water Pump Components



A	O-ring	**B**	Water Pump
C	Water Pump Belt	**D**	Camshaft Pulley
E	Transfer Tube		

Remove Camshaft Pulley and Water Pump Belt

1. Remove screw and flat washer, securing cogged drive pulley to camshaft.
2. Carefully lift pulley off camshaft and remove belt from water pump pulley.
3. Remove camshaft key from keyway.

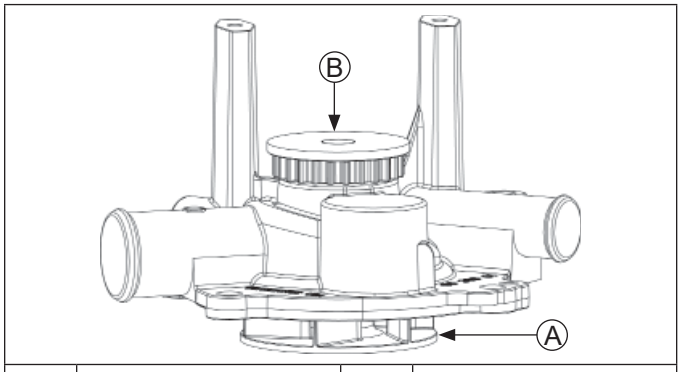
Remove Water Pump and Transfer Tube

1. Loosen and unscrew hex cap section securing transfer tube to 90° fitting in crankcase. Support fitting with a wrench, when loosening hex cap section.
2. Remove screws securing water pump to crankcase.
3. Lift water pump up, and carefully work ferruled end of transfer tube out of fitting. Remove water pump with transfer tube and hose section attached. Remove and discard O-ring from within channel of pump housing.
4. Inspect and, if necessary, separate transfer tube and hose section from water pump. Remove hose clamps, noting their size differences and position of tangs.

   IMPORTANT: 90° fitting in crankcase, which transfer tube is connected to, is sealed and installed at factory in a specific position. Do not loosen, remove, or alter mounted position of this fitting at any time. Contact factory service department for specific instructions if fitting is damaged, or its mounting is affected in any way.

Inspection and Service

Water Pump Details



A	Impeller	**B**	Drive Pulley

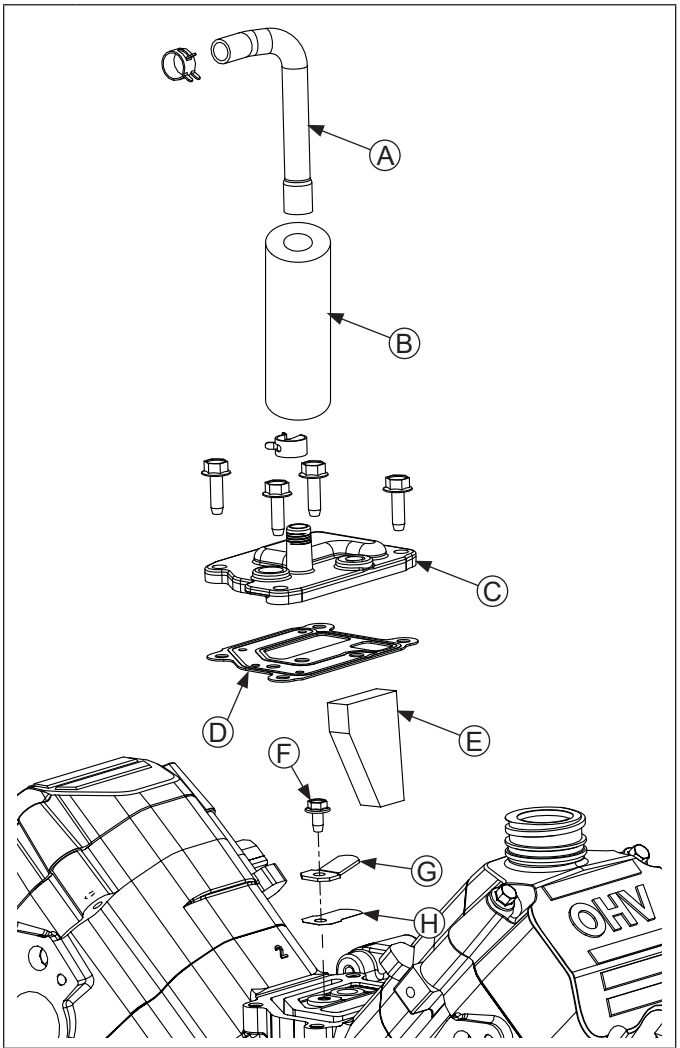
Water/coolant pump consists of a sealed impeller assembly, which includes outer cover and a cogged drive pulley. When pump is mounted to crankcase, impeller fits into a cast recess, and cover seals against an O-ring outside perimeter of recess.

Impeller assembly is not serviceable, but it should be inspected for wear or damage.

1. Inspect impeller to make sure blades are in good condition and free of any cracks, nicks, or damage.
2. Impeller shaft should rotate smoothly, without binding or wobbling, and there should be no sign that coolant has leaked past shaft to outer surface of cover.
3. Check that drive pulley is not cracked or damaged in any way.

If your inspection causes you to doubt its reliability, water pump assembly should be replaced. Always use a new O-ring whenever water pump is removed. Do not reuse old O-ring or try to use RTV in its place.

Breather Components



A	Breather Hose	**B**	Breather Hose Insulator
C	Breather Cover	**D**	Breather Cover Gasket
E	Breather Filter	**F**	Breather Reed Screw
G	Reed Retainer	**H**	Breather Reed

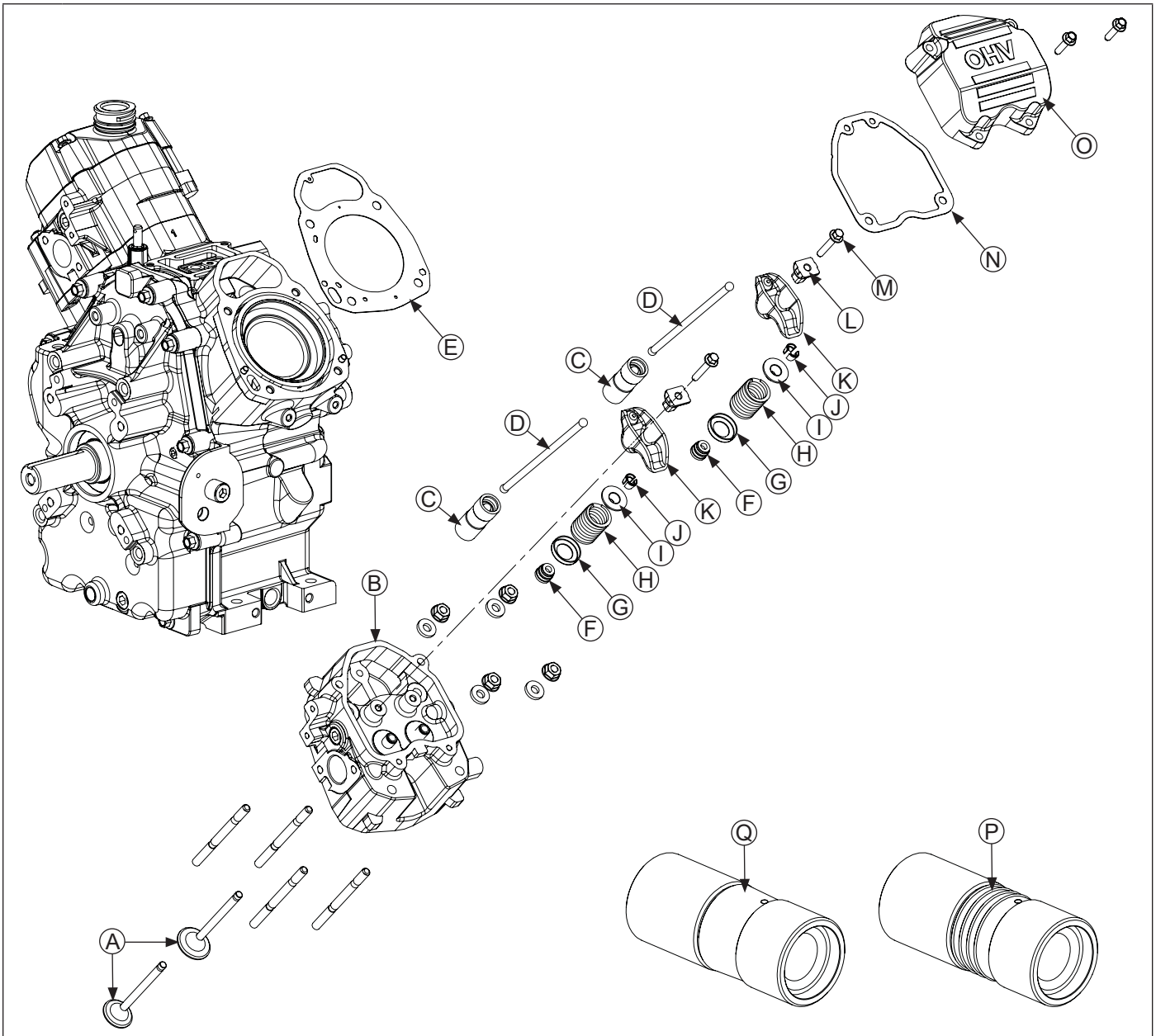
Remove Breather Cover

NOTE: Unless breather hose or breather hose insulator are damaged, disassembly from breather cover is unnecessary.

1. Remove screws securing breather cover to crankcase.
2. Carefully pry under protruding edge of breather cover to separate and remove cover from gasket.

   Do not pry on sealing surfaces as it could cause damage resulting in leaks.
3. Remove breather gasket and fiber filter from breather chamber.
4. Remove screw, breather reed retainer and breather reed from breather chamber.

Cylinder Head Components



A	Valve	**B**	Head	**C**	Hydraulic Lifter	**D**	Push Rods
E	Head Gasket	**F**	Valve Stem Seal	**G**	Valve Spring Cap	**H**	Valve Spring
I	Valve Spring Retainers	**J**	Valve Spring Keepers	**K**	Rocker Arms	**L**	Rocker Arm Pivot
M	Rocker Arm Screw	**N**	Valve Cover Gasket	**O**	Valve Cover	**P**	Hydraulic Lifter Style A (Ribbed)
Q	Hydraulic Lifter Style B (Smooth)						

Remove Valve Covers

1. Remove two lower screws from #2 valve cover mounting locations.
2. Remove valve covers and valve cover gaskets. Note on which side oil fill is located, for correct reassembly.

Remove Spark Plugs

Remove spark plugs from cylinder heads using a spark plug socket.

Remove Cylinder Heads and Hydraulic Lifters

NOTE: It is not necessary to remove cylinder studs from crankcase unless replacement is intended. If studs are removed for any reason, discard old stud(s), do not reuse/reinstall. Use new studs and refer to assembly sequence for proper installation.

1. Rotate crankshaft of engine until valves of one cylinder are closed. Loosen rocker arm screws until rocker arms can be pivoted to free push rods.
2. Remove push rods and mark their location as either intake or exhaust, and cylinder 1 or 2. Push rods should always be reinstalled in their original position.
3. Repeat for opposite cylinder.
4. Remove nuts and washers from cylinder head studs. Carefully remove cylinder heads and head gaskets.
5. Remove hydraulic lifters using a hydraulic lifter removing tool (do not use a magnet). Mark them similar to push rods (intake or exhaust and cylinder 1 or 2). Hydraulic lifters should always be reinstalled in their original location.

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

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

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

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

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

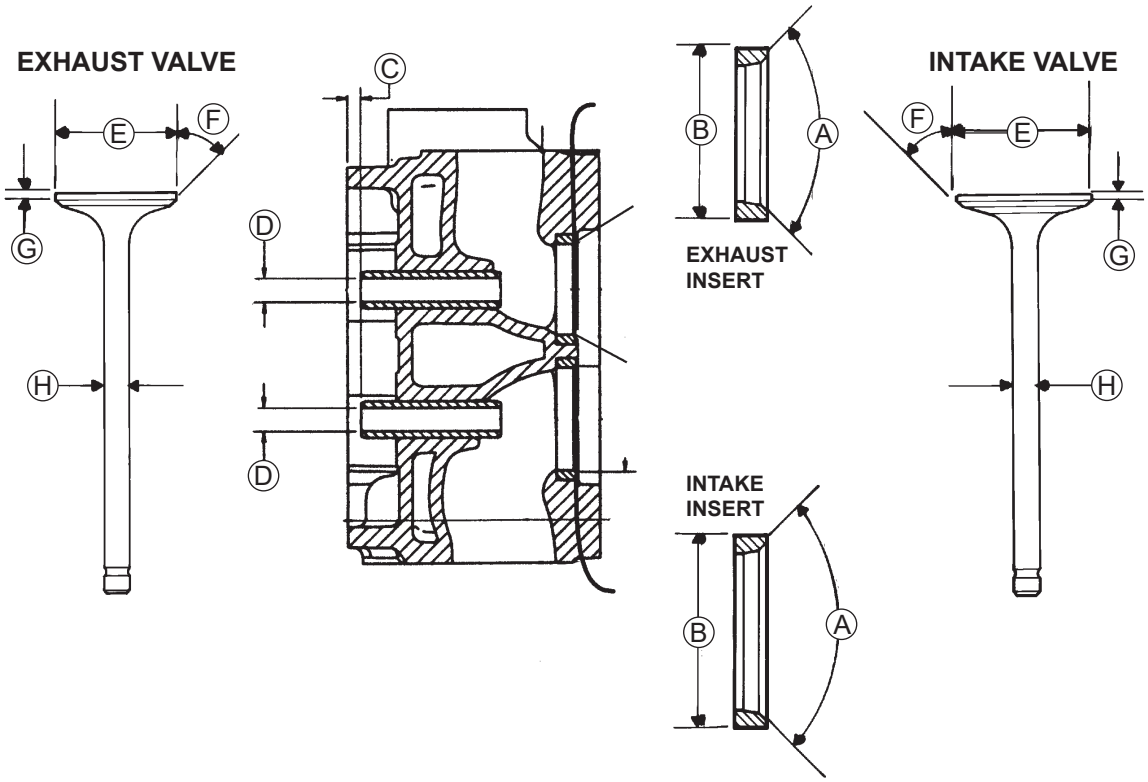
Disassemble Cylinder Heads

NOTE: These engines use a valve stem seal on intake and exhaust valves. Always use new seals when valves are removed from cylinder head. Replace seals if they are deteriorated or damaged in any way. Never reuse an old seal.

1. Remove screws, rocker arms and pivots from cylinder head(s).
2. Compress valve springs using a valve spring compressor and remove valve spring keepers. Remove compressor.
3. With keepers taken out following items can be removed.
   - valve spring retainers
   - valve springs
   - valve spring caps
   - intake and exhaust valves
   - valve stem seals
4. Repeat above procedure for other cylinder head. Do not interchange parts from one cylinder head with parts from other cylinder head.

Inspection and Service

Valve Details



	Dimension	Intake	Exhaust
A	Seat Angle	89°	89°
B	Insert O.D.	36.987/37.013 mm (1.4562/1.4572 in.)	32.987/33.013 mm (1.2987/1.2997 in.)
C	Guide Depth	4 mm (0.1575 in.)	6.5 mm (0.2559 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	33.37/33.63 mm (1.3138/1.3240 in.)	29.37/29.63 mm (1.1563/1.1665 in.)
F	Valve Face Angle	45°	45°
G	Valve Margin (Min.)	1.5 mm (0.0591 in.)	1.5 mm (0.0591 in.)
H	Valve Stem Diameter	6.982/7.000 mm (0.2749/0.2756 in.)	6.970/6.988 mm (0.2744/0.2751 in.)

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

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

Hard starting or loss of power accompanied by high fuel consumption may be symptoms of faulty valves. Although these symptoms could also be attributed to worn rings, remove and check valves first. After removal, clean valve heads, faces, and stems with a power wire brush.

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

Valve Guides
If a valve guide is worn beyond specifications, it will not guide valve in a straight line. This may result in burnt valve faces or seats, loss of compression, and excessive oil consumption.

To check valve guide-to-valve stem clearance, thoroughly clean valve guide and, using a split-ball gauge, measure inside diameter of guide. Then, using an outside micrometer, measure diameter of valve stem at several points on stem where it moves in valve guide. Use largest stem diameter to calculate clearance by subtracting stem diameter from guide diameter. If intake clearance exceeds 0.038/0.076 mm (0.0015/0.0030 in.) or exhaust clearance exceeds 0.050/0.088 mm (0.0020/0.0035 in.), determine whether valve stem or guide is responsible for excessive clearance.

Maximum (I.D.) wear on intake valve guide is 7.134 mm (0.2809 in.) while 7.159 mm (0.2819 in.) is maximum allowed on exhaust guide. Guides are not removable but can be reamed 0.25 mm (0.010 in.) oversize. Valves with 0.25 mm oversize stems must then be used.

If guides are within limits but valve stems are worn beyond limits, install new valves.

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

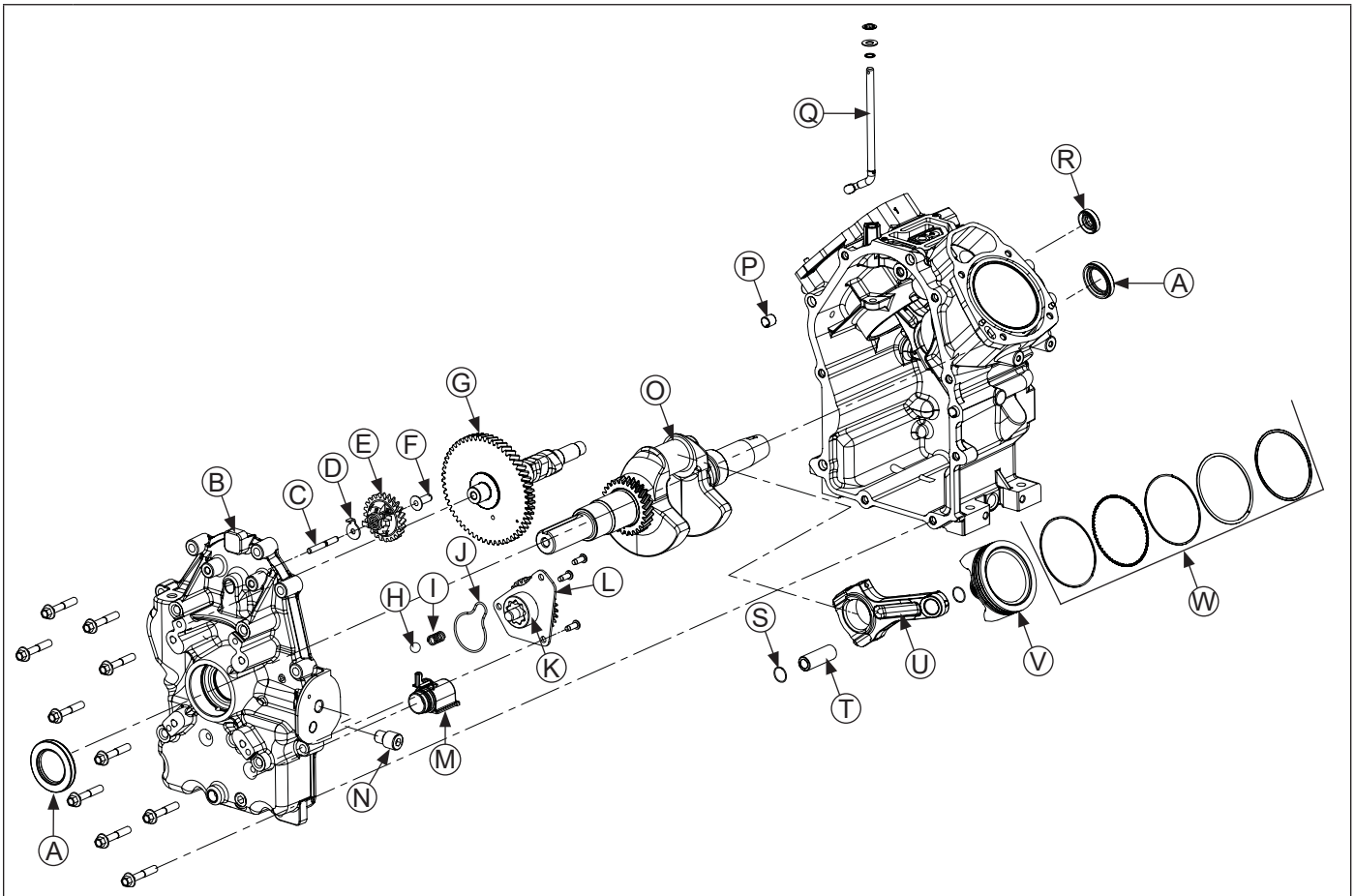
Recondition valve seat inserts following instructions provided with valve seat cutter being used. Final cut should be made with an 89° cutter as specified for valve seat angle. Cutting proper 45° valve face angle as specified, and proper valve seat angle (44.5°, half of full 89° angle), will achieve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

Lapping Valves
NOTE: Exhaust valves that are black in color cannot be ground and do not require lapping.

Reground or new valves must be lapped in, to provide proper fit. Use a hand valve grinder with a suction cup for final lapping. Lightly coat valve face with a fine grade of grinding compound, then rotate valve on its seat with grinder. Continue grinding until a smooth surface is obtained on seat and on valve face. Thoroughly clean cylinder head in soap and hot water to remove all traces of grinding compound. After drying cylinder head, apply a light coating of SAE 10 oil to prevent rusting.

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

Crankcase Components



A	Oil Seal	**B**	Closure Plate	**C**	Governor Gear Shaft	**D**	Locking Tab Thrust Washer
E	Governor Gear	**F**	Regulating Pin	**G**	Camshaft	**H**	Ball
I	Spring	**J**	Oil Pump Cover O-ring	**K**	Outer Gerotor Gear	**L**	Oil Pump Assembly
M	Oil Pick-Up	**N**	Nipple	**O**	Crankshaft	**P**	Dowel Pin
Q	Governor Cross Shaft	**R**	Camshaft Seal	**S**	Piston Pin Retainer	**T**	Piston Pin
U	Connecting Rod	**V**	Piston	**W**	Piston Ring Set		

Remove Closure Plate

1. Remove screws securing closure plate to crankcase. If a thick washer is installed under screw head in #10 location, and/or one silver (ground) screw is used, (normally No. 4 or 6 position), note these special assembly details for proper reassembly later.
2. Locate three splitting tabs, which are cast into perimeter of closure plate. Insert drive end of a 1/2" breaker bar between top splitting tab and crankcase. Hold handle horizontal and pull it toward you to break RTV seal. If necessary, pry at bottom splitting tabs also. Do not pry on sealing surfaces, as this could cause leaks. Carefully pull closure plate from crankcase.

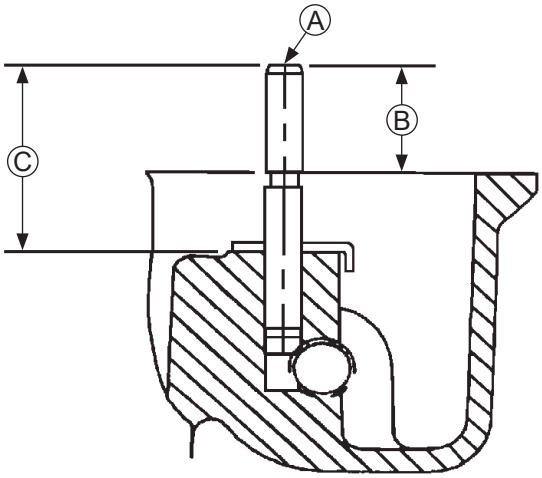
Inspection

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

Inspect main bearing surface for wear or damage. Replace closure plate assembly if required.

Governor Gear Assembly

Governor Shaft Press Depth Details



A	Gear Shaft
B	19.40 mm (0.7638 in.)
C	34.0 mm (1.3386 in.) 33.5 mm (1.3189 in.)

Governor gear assembly is located inside closure plate. If service is required, refer to these procedures.

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

Disassembly
NOTE: Governor gear is held onto shaft by small molded tabs in gear. When gear is removed from shaft, these tabs are destroyed and gear must be replaced. Therefore, remove gear only if absolutely necessary.

Governor gear must be replaced once it is removed from closure plate.

1. Remove regulating pin and governor gear assembly.
2. Remove locking tab thrust washer located under governor gear assembly.
3. Carefully inspect governor gear shaft and replace it only if it is damaged. After removing damaged shaft, press or lightly tap replacement shaft into closure plate to depth shown.

Reassembly
1. Install locking tab thrust washer on governor gear shaft with tab down.
2. Position regulating pin within governor gear/flyweight assembly and slide both onto governor shaft.

Oil Pump Assembly

Oil pump is mounted inside closure plate. If service is required, continue with Disassembly, Inspection, and Reassembly.

Disassembly
1. Remove screws.
2. Lift oil pump assembly from closure plate. Remove outer gerotor gear from closure plate.
3. Ensure ball and spring remain installed in pressure relief hole of closure plate. If ball and spring fall out of pressure relief hole, see reassembly for correct installation.
4. Remove oil pump cover O-ring from groove in closure plate.

Inspection
Inspect oil pump housing, gear, and rotors for nicks, burrs, wear, or any visible damage. Inspect oil pump cover O-ring for cuts, nicks, or any visible damage. If any parts are worn or damaged, replace oil pump assembly and/or O-ring. Check oil pickup screen for damage or restriction, replace if necessary.

Reassembly
1. Lubricate outer gerotor gear with oil. Install outer gerotor gear through shaft of oil pump, around inner gerotor gear. Matching molding dots on inner and outer gerotor gears is not necessary and will not affect oil pump efficiency.
2. Reinstall ball, then spring into pressure relief hole in closure plate.
3. Reinstall O-ring into groove in closure plate; make sure it is fully seated in groove.
4. Install oil pump inserting center shaft into corresponding recess in closure plate. Apply consistent downward pressure to oil pump cover, compressing oil pressure relief spring and start screws. Secure oil pump by torquing screws (in no specific sequence) to 7.9 N·m (70 in. lb.).
5. After torquing, rotate gear and check for freedom of movement. Make sure there is no binding. If binding occurs, loosen screws, reposition pump, retorque screws and recheck movement.

Remove Camshaft

Remove camshaft and shims.

Remove Connecting Rods with Pistons and Rings

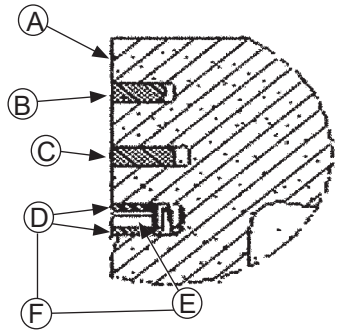
NOTE: If a carbon ridge is present at top of either cylinder bore, use a ridge reamer tool to remove it before attempting to remove piston.

NOTE: Cylinders are numbered on crankcase. Use numbers to mark each end cap and connecting rod/piston assembly for reassembly later. 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 procedure for other connecting rod and piston assembly.

Inspection

Piston and Rings Components and Details



A	Piston	**B**	Top Compression Ring
C	Middle Compression Ring	**D**	Rails
E	Expander	**F**	Oil Control Ring (3 Piece)

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 two 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.

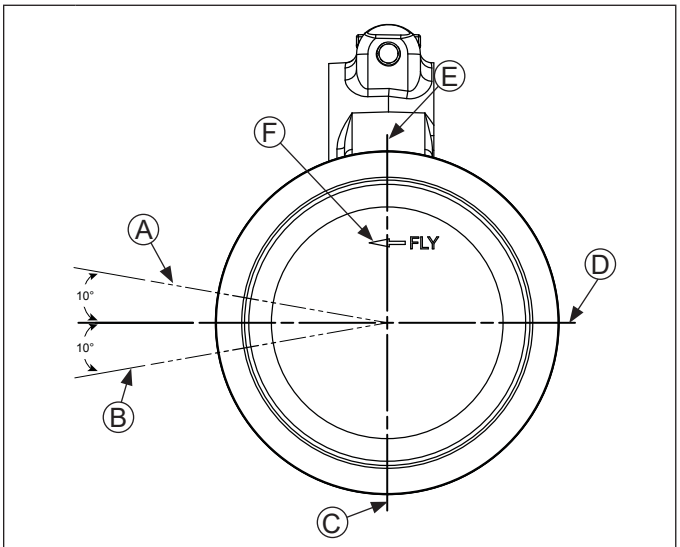
Replacement ring sets are also available separately for STD, 0.25 mm (0.010 in.), and 0.50 mm (0.020 in.) oversize pistons. Always use new piston rings when installing pistons. Never use old rings.

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 compression ring end gap clearance is 0.189/0.277 mm (0.0074/0.0109 in.) for a new bore, or 0.531 mm (0.0209 in.) for a used bore. Middle compression ring end cap is 1.519/1.797 mm (0.0598/0.0708 in.) for a new bore, or 2.051 mm (0.0808 in.) for a used bore.
5. After installing new compression (top and middle) rings on piston, make sure top compression ring-to-groove side clearance and is 0.030/0.070 mm (0.0010/0.0026 in.) and middle compression ring-to-groove side clearance 0.030/0.070 mm (0.0010/0.0026 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	Intermediate 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 dye colored stripe (if contained) is to left of end gap.
3. Top compression ring (top groove): Install top ring using a piston ring expender. Make sure identification mark is up or dye colored stripe (if contained), left of end gap.

Connecting Rods

Offset, stepped-cap connecting rods are used in all 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.

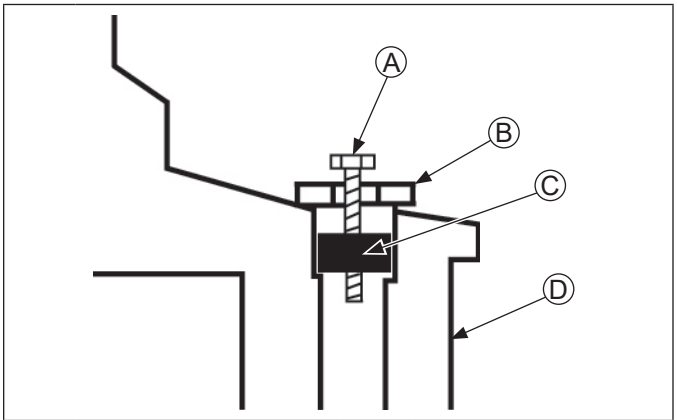
Service replacement connecting rods are available in STD crankpin size and 0.25 mm (0.010 in.) undersize. Always refer to appropriate parts information to ensure correct replacements are used.

Remove Crankshaft

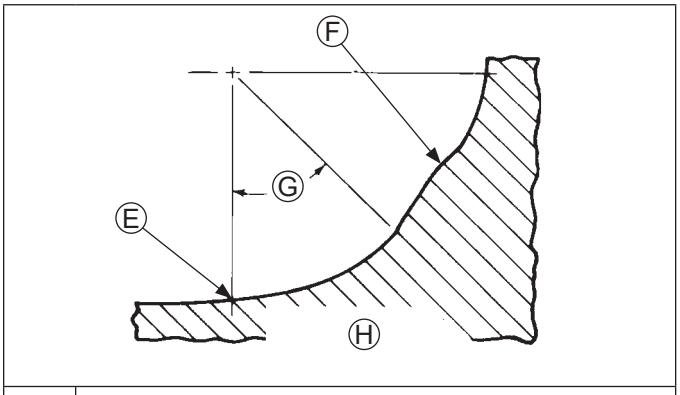
Carefully pull crankshaft from crankcase.

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. Measure running clearance between crankshaft journals and their respective bearing bores. Use an inside micrometer or telescoping gauge to measure inside diameter of both bearing bores in vertical and horizontal planes. Use an outside micrometer to measure outside diameter of crankshaft main bearing journals. Subtract journal diameters from their respective bore diameters to get running clearances. Check results against values in Specifications. If running clearances are within specification, and there is no evidence of scoring, grooving, etc., no further reconditioning is necessary. If bearing surfaces are worn or damaged, crankcase and/or closure plate will need to be replaced.

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.

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

Remove Crankshaft Plug

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

Install New Crankshaft Plug

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

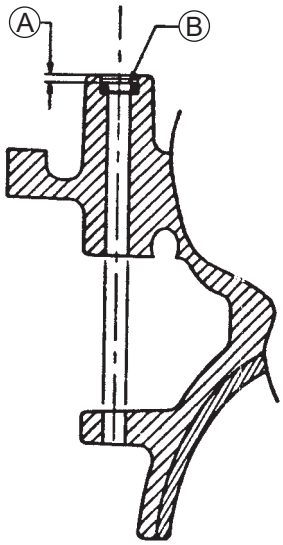
Remove Governor Cross Shaft

NOTE: Always use a new retaining ring when reassembling. Do not reuse old retaining ring.

1. Remove retaining ring and nylon washer from governor cross shaft.
2. Remove cross shaft and small washer out through inside of crankcase.

Governor Cross Shaft Oil Seal

Cross Shaft Oil Seal Details



A	2.0 mm (0.0787 in.)
B	Governor Cross Shaft Seal

Remove governor cross shaft oil seal from crankcase and replace it with a new one if seal is damaged and/or leaks. Install new seal to depth shown using a seal installer.

Remove Flywheel End Oil Seals

Remove flywheel end crankshaft and camshaft oil seals from crankcase.

Crankcase

These engines contain a cast-iron cylinder liner that may be reconditioned as follows:

Inspection and Service

NOTE: If bore is beyond wear limit, a new miniblock or short block will be required.

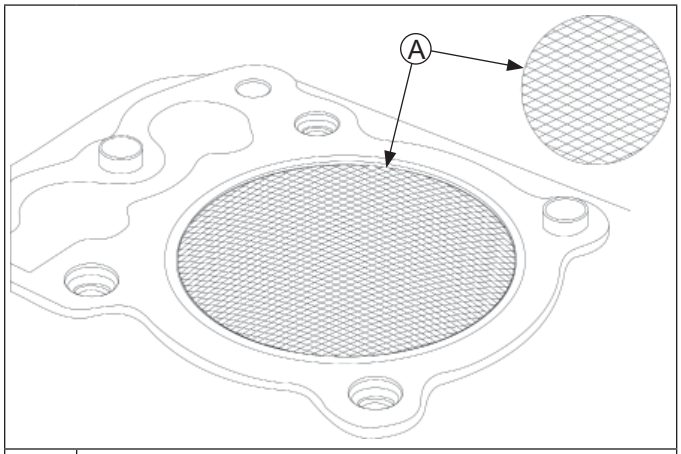
Check all gasket surfaces to make sure they are free of gasket fragments. Gasket surfaces must also be free of deep scratches or nicks.

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 a cooling system problem 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 0.08 mm (0.003 in.), 0.25 mm (0.010 in.), or 0.50 mm (0.020 in.). Resizing to one of 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



A	23°-33° Crosshatch

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 that 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 with burnishing stones. Continue with burnishing stones until within 0.013 mm (0.0005 in.) of desired size and then use finish stones (220-280 grit) and polish to 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, 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.

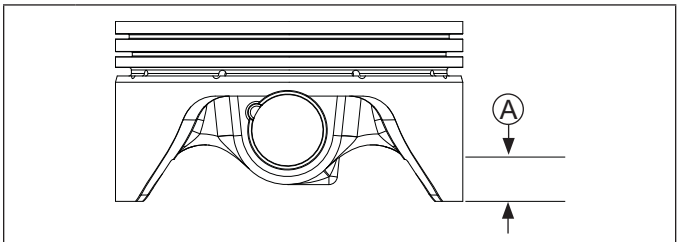
Clean Cylinder Bore After Honing

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



A	6 mm (0.2362 in.)

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

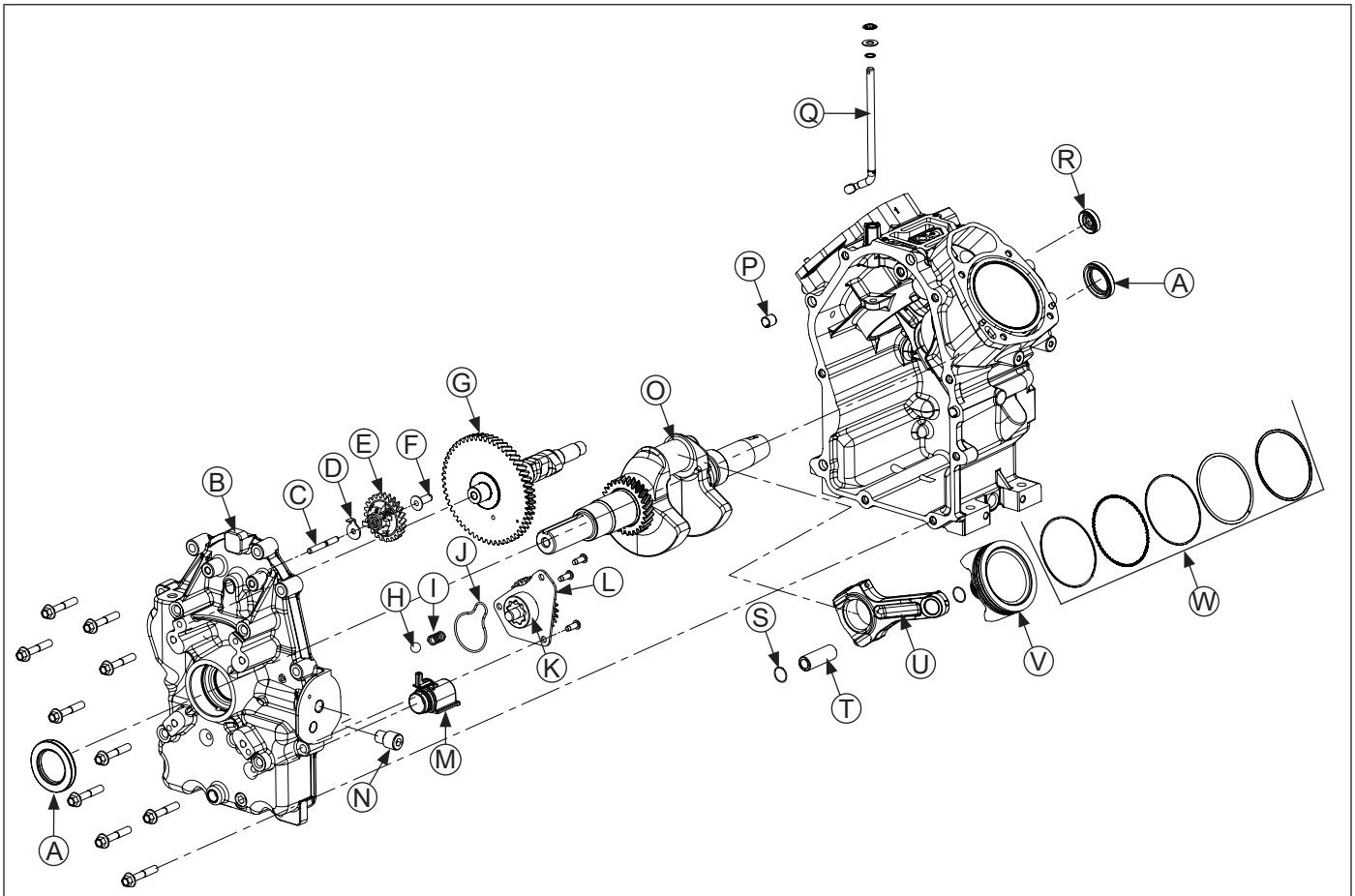
Before installing piston into cylinder bore, it is necessary that clearance be accurately checked. This step is often overlooked, and if clearances are not within specifications, engine failure will usually result.

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

1. Use a micrometer and measure diameter of piston 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).

Reassembly

Crankcase Components



A	Oil Seal	**B**	Closure Plate	**C**	Governor Gear Shaft	**D**	Locking Tab Thrust Washer
E	Governor Gear	**F**	Regulating Pin	**G**	Camshaft	**H**	Ball
I	Spring	**J**	Oil Pump Cover O-ring	**K**	Outer Gerotor Gear	**L**	Oil Pump Assembly
M	Oil Pick-Up	**N**	Nipple	**O**	Crankshaft	**P**	Dowel Pin
Q	Governor Cross Shaft	**R**	Camshaft Seal	**S**	Piston Pin Retainer	**T**	Piston Pin
U	Connecting Rod	**V**	Piston	**W**	Piston Ring Set		

NOTE: Make sure engine is assembled using all specified torque values, tightening sequences and clearances. Failure to observe specifications could cause severe engine wear or damage. Always use new gaskets. Apply a small amount of oil to 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 closure plate, crankcase, cylinder heads, and valve covers to be certain that all old sealing material has been removed. Use gasket remover, lacquer thinner, or paint remover to remove any remaining traces. Clean surfaces with isopropyl alcohol, acetone, lacquer thinner, or electrical contact cleaner.

Install Flywheel End Oil Seal and Camshaft Oil Seal

1. Check to make sure that there are no nicks or burrs in crankshaft and camshaft seal bores of crankcase.
2. Apply a light coat of engine oil to outside diameter of flywheel end oil seal.
3. Install oil seal into crankcase using a seal driver. Make sure oil seal is installed straight and true in bore, until tool bottoms against crankcase.
4. Apply a light coat of engine oil to outside diameter of camshaft oil seal.
5. Install camshaft oil seal to a depth of 1.0-1.5 mm (0.039-0.059 in.) below top of seal bore. Do not bottom seal in bore or oil passage may be obstructed.

Install Governor Cross Shaft

1. Lubricate governor cross shaft bearing surfaces in crankcase with engine oil. Apply a small amount of grease to lips of oil seal.
2. Slide small lower washer onto governor cross shaft and install cross shaft from inside of crankcase.
3. Install nylon washer onto governor cross shaft, then start push-on retaining ring. Hold governor shaft up in position, then place a 0.25 mm (0.010 in.) feeler gauge on top of nylon washer, and push retaining ring down shaft to secure. Remove feeler gauge, which will have established proper end play.
4. Pivot governor cross shaft so bottom end faces cylinder 1 side.

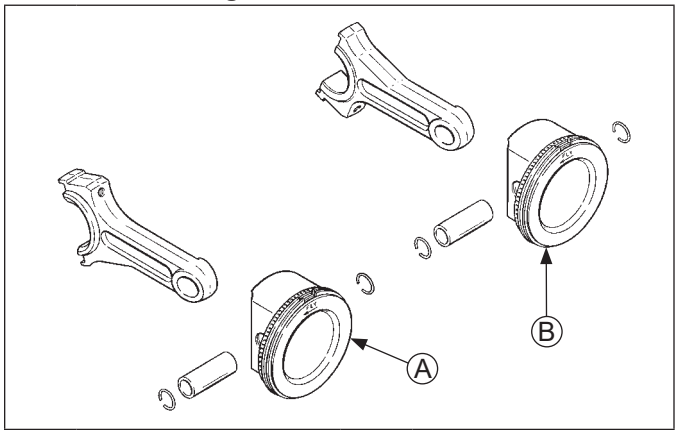
Install Crankshaft

NOTE: Apply cellophane tape over crankshaft keyway to prevent cutting oil seal during installation.

1. Lightly lubricate lips of crankshaft seal with grease.
2. Carefully slide flywheel end of crankshaft into crankcase through oil seal.

Install Connecting Rods with Pistons and Rings

Piston/Connecting Rod Details



A	Cylinder 1	**B**	Cylinder 2

NOTE: Cylinders are numbered on crankcase. Make sure to install piston, connecting rod and end cap into its appropriate cylinder bore, as previously marked at time of 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.

NOTE: Make sure to 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.

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 cylinder 1 piston 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. Guide lower end of connecting rod and rotate crankshaft to join two. Install rod cap to connecting rod using screws and torque in increments to 13.6 N·m (120 in. lb.).
6. Repeat above procedure for other connecting rod and piston assembly.

Install Camshaft

1. Inspect edges of camshaft keyway, make sure they are not nicked or burred. Use a seal protector (11/16") to prevent damaging seal lips, or dislodging inner spring when camshaft is installed. Cellophane tape over keyway is also recommended.
2. Lubricate camshaft bearing surfaces of crankcase and camshaft with engine oil. Apply a small amount of grease to lips of oil seal.
3. Rotate crankshaft and position timing mark of crankshaft gear at 12 o'clock position.
4. Turn governor cross shaft clockwise until lower end of shaft contacts crankcase (cylinder 1 side). Make sure cross shaft remains in this position while installing camshaft.
5. Slide camshaft into bearing surface of crankcase, positioning timing mark of camshaft gear at 6 o'clock position. Make sure that camshaft gear and crankshaft gear mesh, and timing marks are aligned.

Checking/Setting Camshaft End Play

1. Install shim removed during disassembly onto camshaft.
2. Position end play tool on camshaft.
3. Apply pressure on end play checking tool (pushing camshaft toward crankshaft). Use a feeler gauge to measure end play between shim and end play tool. Camshaft end play should be 0.076/0.127 mm (0.003/0.005 in.).
4. If camshaft end play is not within specified range, remove original shim and reinstall end play tool. Use a feeler gauge to determine clearance between camshaft and tool. Subtract 0.100 mm (0.004 in) from measured clearance to obtain required shim thickness. Refer to table below and install shim that matches calculated thickness. Repeat steps 1-3 to verify that correct end play exists.

Camshaft Shims

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.)

Oil Pump Assembly

Oil pump is mounted to inside of closure plate. If service was required, and oil pump was removed, refer to assembly procedures under Oil Pump Assembly in Reassembly.

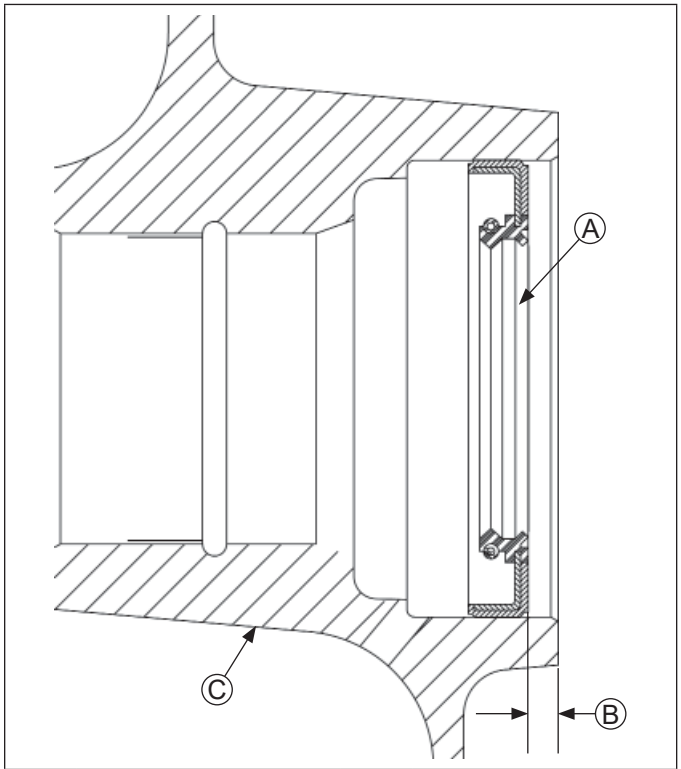
Governor Assembly

Governor assembly is located inside closure plate. If service was required, and governor was removed, refer to assembly procedures under Governor Assembly in Reassembly.

Remove closure plate. If end play requires adjustment, remove original shim and install appropriate size replacement.

Install Closure Plate Oil Seal

Oil Seal Details

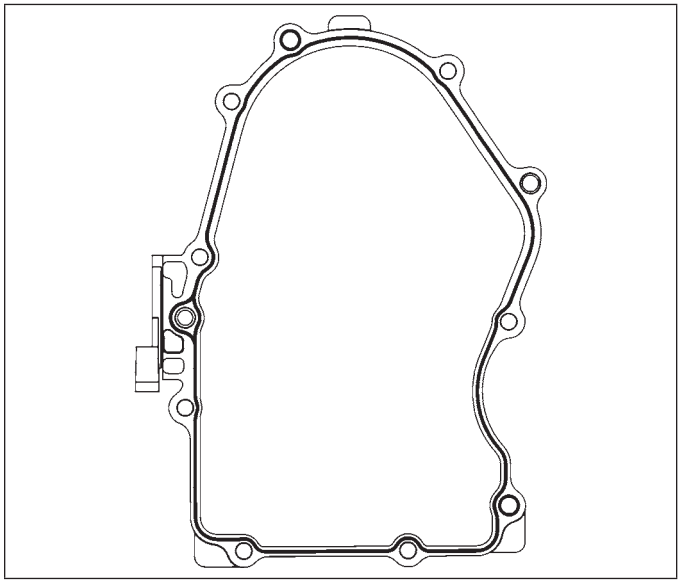


A	Oil Seal	**B**	10.5 mm (0.413 in.)
C	Closure Plate		

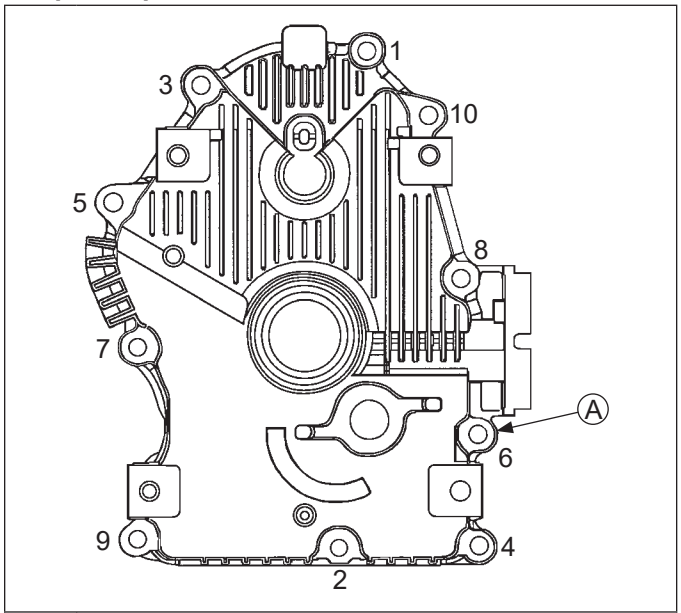
1. Check to make sure that there are no nicks or burrs in crankshaft bore of closure plate.
2. Apply a light coat of engine oil to outside diameter of oil seal.
3. Drive oil seal into closure plate using a seal driver. Make sure oil seal is installed straight and true in bore to depth shown.

Install Closure Plate Assembly

Closure Plate Sealant Pattern



Torque Sequence



A	Plated Screw Location

RTV silicone sealant is used as a gasket between closure plate and crankcase. Always use fresh sealant. Using outdated sealant can result in leakage.

1. Be sure sealing surfaces have been cleaned and prepared.
2. Check to make sure that there are no nicks or burrs on sealing surfaces of closure plate or crankcase.
3. Apply a 1/16" bead of sealant to sealing surface of closure plate.
4. Make sure end of governor cross shaft is lying against bottom of cylinder 1 inside of crankcase.
5. If alignment pins were removed previously, install them in their respective locations in crankcase.
6. Install closure plate on crankcase. Carefully seat camshaft and crankshaft into their mating bearings. Rotate crankshaft to help engage oil pump and governor gear meshes.
7. Install screws securing closure plate to crankcase. If a thick flat washer was used on one of screws, install it in number 10 location. Install silver plated (ground) screw in its original location (normally number 4 or 6 location). Torque fasteners, in torque sequence shown to 24.4 N·m (216 in. lb.).

Install Cylinder Studs

Details

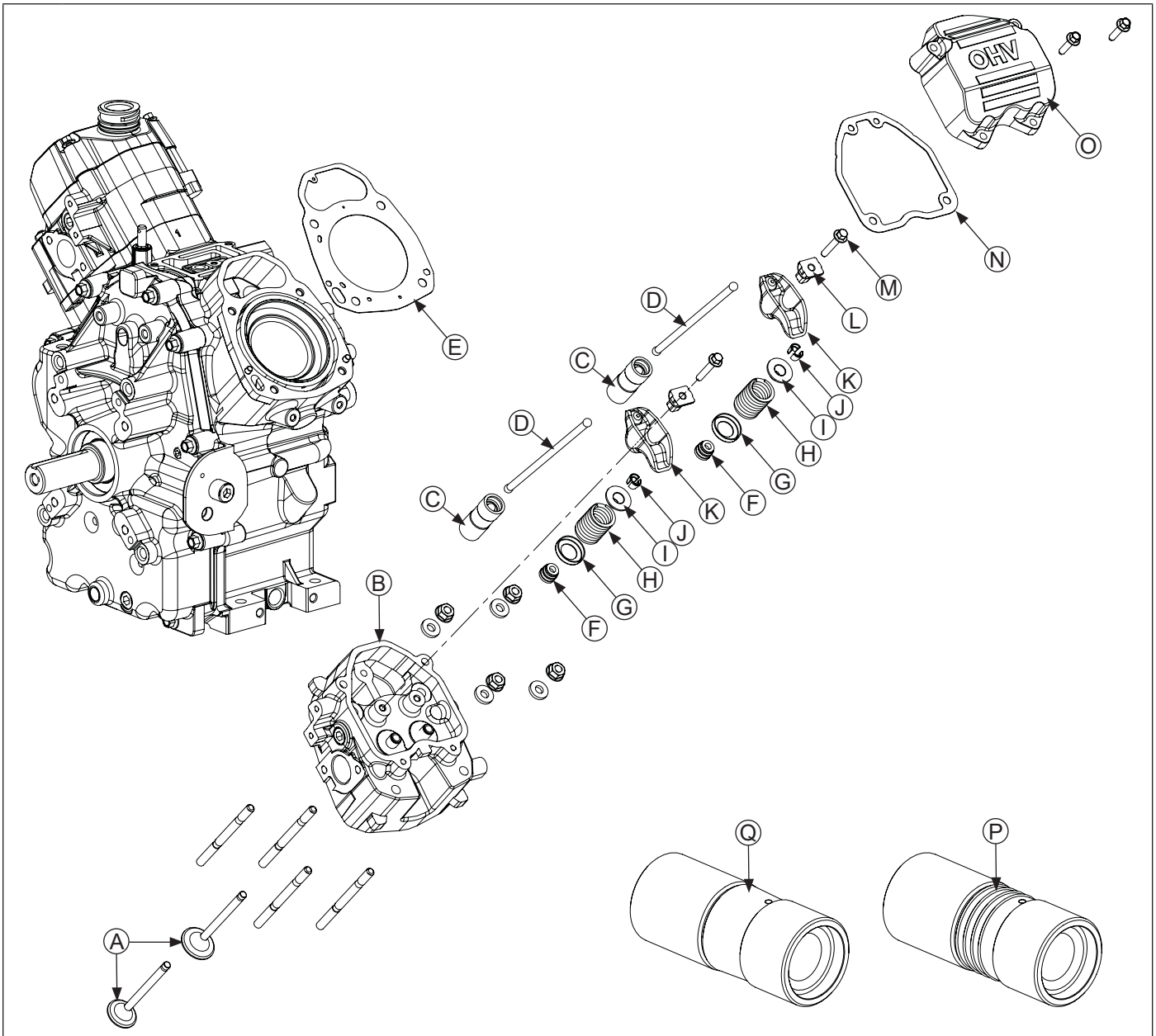
A	Stud End with Loctite® Dri-Loc®

NOTE: Do not reinstall or attempt to reuse any cylinder studs that have been removed. Discard any removed stud(s) and replace with new.

If any of cylinder studs were removed, install new stud(s) as follows:

1. Identify longer threaded end of new stud containing Loctite® Dri-Loc®.
2. Tighten nuts together on shorter threaded section, with identification mark on end.
3. Thread end of stud with Loctite® into crankcase, until an exposed stud height of 75 mm (2 61/64 in.) is obtained. End with dash mark must be out. When threading in studs, use a steady tightening motion, without interruption, until proper height is obtained. Frictional heat from engaging threads may otherwise cause locking compound to set up prematurely. Remove two nuts.
4. Repeat steps 1-3 for each of studs.

Cylinder Head Components



A	Valve	**B**	Head	**C**	Hydraulic Lifter	**D**	Push Rods
E	Head Gasket	**F**	Valve Stem Seal	**G**	Valve Spring Cap	**H**	Valve Spring
I	Valve Spring Retainers	**J**	Valve Spring Keepers	**K**	Rocker Arms	**L**	Rocker Arm Pivot
M	Rocker Arm Screw	**N**	Valve Cover Gasket	**O**	Valve Cover	**P**	Hydraulic Lifter Style A (Ribbed)
Q	Hydraulic Lifter Style B (Smooth)						

Install Hydraulic Lifters

NOTE: Hydraulic lifters should always be installed in same position as before disassembly.

1. Refer to Disassembly/Inspection and Service for lifter preparation (bleed down) procedures.
2. Apply camshaft lubricant (see Tools and Aids) to bottom surface of each lifter. Lubricate hydraulic lifters and lifter bores in crankcase with engine oil.
3. Install lifters into their respective lifter bores according to location and cylinder number marked during disassembly. 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.

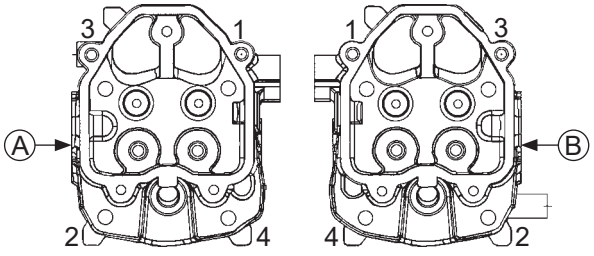
Assemble Cylinder Heads

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

- Valve stem seals
- Intake and exhaust valves
- Valve spring caps
- Valve springs
- Valve spring retainers
- Valve spring keepers

Install Cylinder Heads

Cylinder Head Torque Sequence



A	Cylinder Head 1	**B**	Cylinder Head 2

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. Rotate crankshaft to position piston in cylinder 1 to top dead center (TDC) on compression stroke.
3. Install a new cylinder head gasket.
4. Install cylinder 1 head onto number 1 side mounting studs.
5. Install a plain washer onto each stud and secure with a nut.
6. Torque nuts in two steps, first to 16.9 N·m (150 in. lb.) and then to 33.9 N·m (300 in. lb.), using torque sequence shown.
7. Repeat installation procedure for cylinder 2 side head.

Install Push Rods and Rocker Arms

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

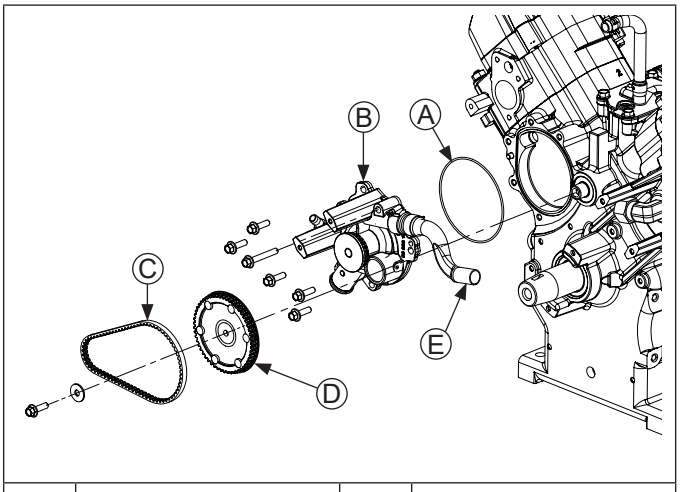
1. Note mark or tag identifying push rod as either intake or exhaust for cylinder 1. Lightly apply engine oil or grease to ends of push rods and install. Make sure that each push rod ball seats in its respective hydraulic lifter socket.
2. Apply grease to contacting surfaces of rocker arms and rocker arm pivots. Install rocker arms and rocker arm pivots on cylinder head.
3. Install new rocker arm screws with Dri-Loc® thread locking compound on threads. Torque screws to 11.3 N·m (100 in. lb.). When tightening, use a steady motion, without interruption, until proper torque is achieved. Frictional heat from engaging threads may otherwise cause locking compound to set prematurely. If new screws are not available, apply Loctite® 242® to bottom 4 or 5 threads. Then install and torque screws to 11.3 N·m (100 in. lb.).
4. Use a spanner wrench or rocker arm lifting tool (see Tools and Aids) to lift rocker arms and position push rods underneath.
5. Rotate crankshaft so piston in cylinder 2 is at top dead center on compression stroke, and repeat steps for remaining cylinder. Do not interchange parts from one cylinder head with parts from other cylinder head.
6. Rotate crankshaft to check for free operation of valve train. Check clearance between valve spring coils at full lift. Minimum allowable clearance is 0.25 mm (0.010 in).

Install Valve Covers

1. Make sure sealing surfaces of cylinder heads and valve covers are clean and free of all old gasket material.
2. Install new valve cover gaskets onto valve covers.
3. Install valve covers with gaskets in their original locations.
4. Install lower mounting screws in #2 cover, and finger tighten only. Upper screws will be installed with air cleaner bracket.

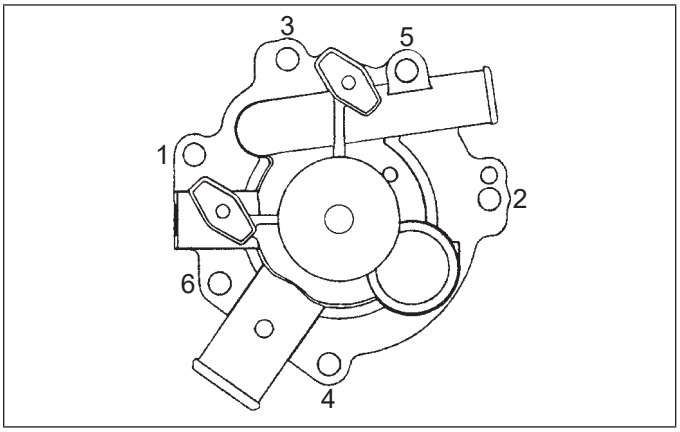
Install Water Pump, Drive Belt, and Transfer Tube Assembly

Water Pump Components



A	O-ring	**B**	Water Pump
C	Water Pump Belt	**D**	Camshaft Pulley
E	Transfer Tube		

Water Pump Torque Sequence



NOTE: A mark or dot of paint applied to top, of pulley, indicating keyway location, will make installation easier.

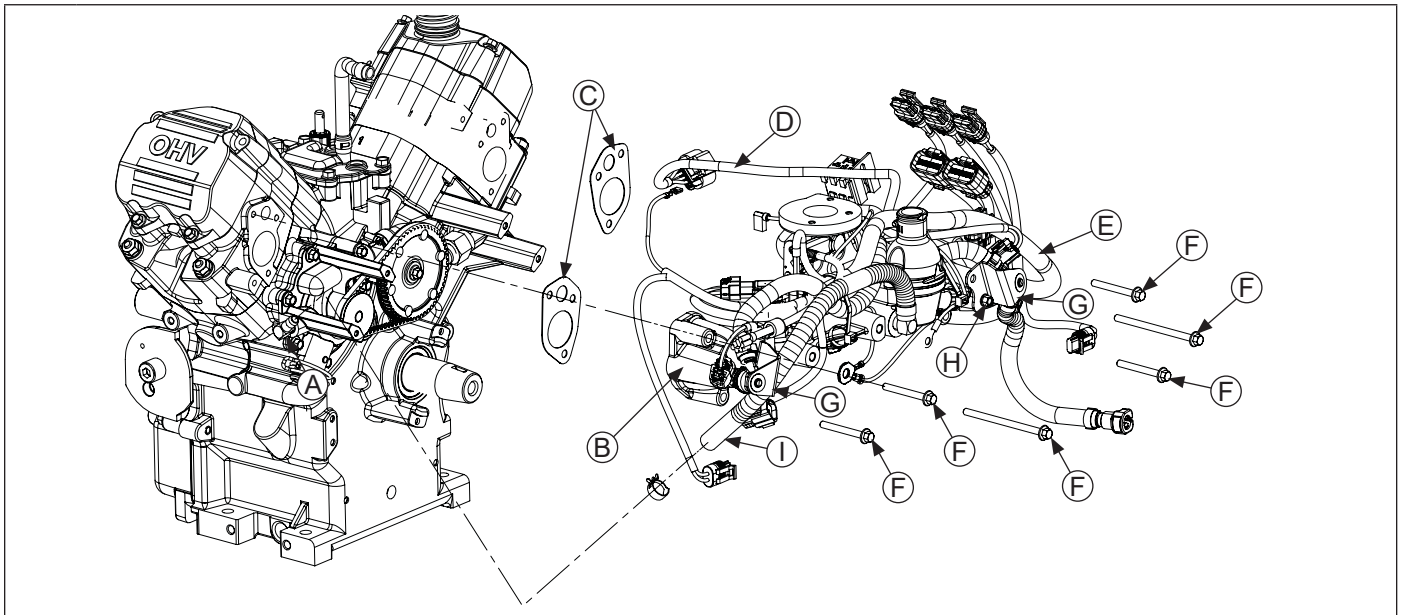
NOTE: When installation is complete, tangs of two hose clamps should face outward, away from flywheel and slightly down.

1. Remove seal protector and/or protective tape (if used) from over keyway and make sure end of camshaft is clean and free of any nicks or damage. Install and fully seat key, squarely into keyway. Be careful not to contact camshaft seal. Test fit cam pulley onto shaft and key; it must slide on without force or restriction. Remove pulley.
2. If water pump by-pass hose fitting was removed previously, apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) on threads and tighten it into pump. Orient fitting so outlet points in 11 o'clock position.
3. Check sealing surfaces of water pump and crankcase. They must be clean and free of any nicks or damage.
4. Apply a small amount of grease in several locations to hold new water pump O-ring in place. Install a new O-ring in groove of crankcase. Do not use RTV sealant in place of O-ring, or attempt to reinstall a used O-ring.
5. Apply rubber lubricant to inner surfaces of short hose section. Assemble hose to outlet of water pump and secure with larger diameter clamp. Orient clamp so tangs extend out in 3 to 4 o'clock position.
6. Slide smaller diameter clamp onto extruded end of formed metal tube and insert this end of tube into hose section. Position tube so its formed offset leads down and away from outlet, perpendicular to pump. Install clamp onto hose and position tangs of clamp parallel to those of first clamp.
7. Holding pump assembly elevated, assemble transfer tube to 90° fitting in crankcase as follows:
   a. For new/first time tube installation:
      1. Place a new ferrule/compression ring in 90° fitting of crankcase and loosely install hex cap onto threads of fitting.
      2. Insert plain end of transfer tube through hex and compression ring.
   b. For reinstallation of an existing tube:
      1. Insert end of transfer tube, with compression ring, into 90° fitting of crankcase.
      2. Start hex cap onto threaded section of fitting.

90° fitting in crankcase is installed and sealed at factory, in a specific position. Special tools and procedures are involved. Do not loosen, remove, or alter mounting position of this fitting at any time.

8. Carefully push water pump down from raised position, thereby rotating tube 90° within end connections. Guide pump into position over O-ring; aligning two mounting pins and five screw hole locations. Start screws, with longer screw nearest pump outlet. Torque screws to 9.9 N·m (88 in. lb.) in sequence shown.
9. Push down on formed tube and hold in this position to prevent it from pivoting upward when tightening hex cap. Torque hex cap to 22.6 N·m (200 in. lb.), to secure joint connection. Support fitting with a wrench while torquing, if possible, to prevent applying unnecessary pressure on fitting and joint. Check that formed tube and hose section have not been pulled up.
10. Install drive belt onto cogged pulley of water pump, then around cam pulley. Slide cam pulley, with belt attached, down onto keyway end of camshaft. Be careful not to push key out of keyway and/or into seal when installing pulley.
11. Check or use a feeler gauge to see that there is at least 3.17 mm (0.125 in.) clearance between underside of pulley, and hose, tube, and clamps. Remove pulley and reposition tube or clamps if required. Install flat washer and screw, to secure pulley in place. Torque screw to 9.9 N·m (88 in. lb.).

Intake Manifold Assembly Components



A	Fitting	**B**	Intake Manifold Assembly	**C**	Intake Manifold Gasket	**D**	Wiring Harness
E	Fuel Rail	**F**	Intake Manifold Screw	**G**	Fuel Injector Bracket	**H**	Fuel Injector Bracket Screw
I	By-Pass Hose						

Install Fuel Injectors

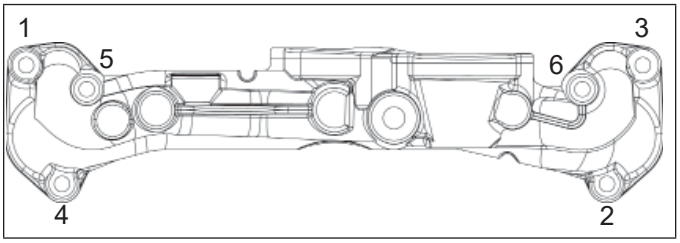
NOTE: Ensure all parts are clean, undamaged and free of debris and make sure electrical connectors have seal in place.

NOTE: O-rings and retaining clips should be replaced any time fuel injector is separated from its normal mounting position.

1. Lightly lubricate fuel injector O-rings with clean engine oil.
2. Push retaining clip onto fuel injector, aligning clip.
3. Press fuel injector into fuel injector cap until retaining clip snaps into place.
4. Press fuel injector into bore in intake manifold and rotate to original position, as noted in Disassembly/ Inspection and Service.
5. Install fuel injector bracket screw into intake manifold and torque to 4.0 N·m (35 in. lb.).
6. Push electrical connector on fuel injector making sure a good connection is made. Ensure injector connector is in proper position based on identification steps made in Disassembly.
7. Repeat steps 1 through 6 for other fuel injector.

Install Intake Manifold Assembly

Torque Sequence



1. Check that gasket surfaces of intake manifold and cylinder heads are clean and free of any nicks or damage.
2. Install new intake manifold gaskets onto port surfaces of cylinder heads.
3. Set intake manifold assembly down into position onto gaskets and cylinder heads. Route wires as noted in Disassembly. Install and finger tighten screws in their appropriate locations. Make sure clamp for wiring harness is positioned on long screw on #2 side. Torque six intake manifold mounting screws in two steps: first to 7.4 N·m (66 in. lb.), finally to 9.9 N·m (88 in. lb.) in sequence shown.
4. Install and tighten temperature warning switch, if removed previously from threaded port of intake manifold. Use pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) on threads. Torque to 22.6 N·m (200 in. lb.).

5. Connect wire leads to temperature warning switch, audible alarm, and/or Oil Sentry™ switch as equipped.

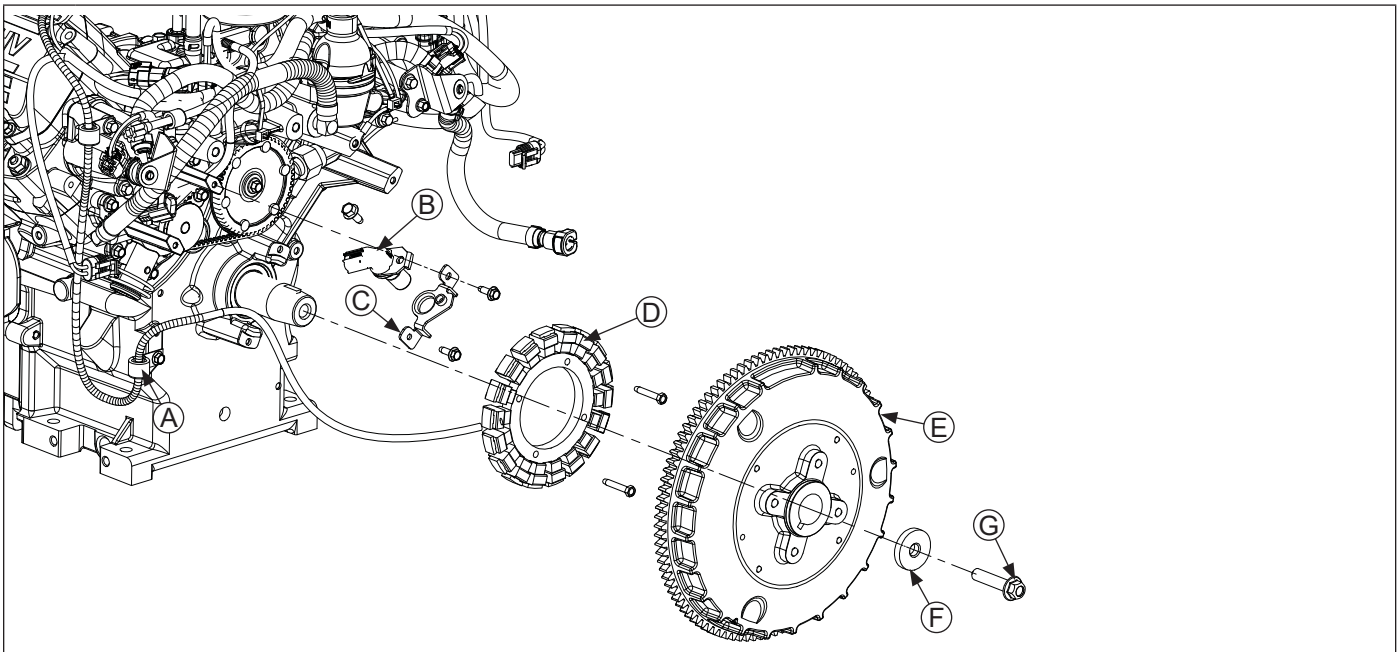
If thermostat and thermostat housing were removed from intake manifold, reassemble them at this time.

6. Make sure sealing surfaces of housing and manifold are clean and free of nicks or damage.
7. Install thermostat into recess in intake manifold, so larger spring end is down. Place a new thermostat housing gasket onto manifold surface, aligning screw holes. Make sure that one of notches in gasket is aligned with by-pass slot in manifold and thermostat housing. Do not use a substitute gasket.
8. Position thermostat housing on gasket and intake manifold. Notch in manifold, gasket and thermostat housing must all be aligned. Install and torque screws to 9.9 N·m (88 in. lb.).
9. Apply rubber lubricant to inside end of upper radiator hose, and install hose to thermostat housing, if separated for servicing. Secure with clamp. Make sure tangs of clamp point toward cylinder 1, away from fan.

Install Coolant By-pass Hose (If separated from intake manifold through individual component servicing)

1. If connector fitting for by-pass hose was removed from manifold, reinstall it at this time. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) onto threads and tighten, so fitting faces/points toward 2 side, long intake manifold screw.
2. Attach coolant by-pass hose to fittings in water pump and intake manifold. Secure with clamps.
3. Connect wire leads to temperature warning switch, audible alarm, and/or Oil Sentry™ switch, as equipped.

Flywheel/Stator Components



A	Wire Clip	**B**	Crankshaft Position Sensor	**C**	Crankshaft Position Sensor Bracket	**D**	Stator
E	Flywheel	**F**	Washer	**G**	Flywheel Screw		

Install Stator Assembly

1. Place a small amount of pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) into holes for stator mounting screws. Position stator assembly onto mounting post so leads are directed out toward cylinder 2, in 9 o'clock position. Align mounting holes and install screws. Torque each screw to 6.2 N·m (55 in. lb.).
2. Secure stator wire to crankcase with wire clip.

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 lubricants. Presence of lubricants can cause flywheel to be overstressed and damaged when screw is torqued to specifications.

NOTE: Always use a flywheel strap wrench or holding tool to hold flywheel when tightening flywheel fastener. Do not use any type of bar or wedge to hold flywheel, as component damage and personal injury could result.

NOTE: Make sure flywheel key is installed properly in keyway. Flywheel can become cracked or damaged if key is improperly installed.

1. Install woodruff key into keyway of crankshaft. Make sure that key is properly seated and parallel with shaft.
2. Thread starter mounting bolts into hub of flywheel, or use flywheel puller to serve as a handle and set flywheel in place.
3. Install screw and washer.
4. Use a flywheel holding tool to hold flywheel and torque screw to 66.4 N·m (49 ft. lb.).
5. Using a light, visually check that sufficient clearance exists between cooling system components and flywheel.
   - If clearance is insufficient or contact is noted, remove flywheel and adjust as required. Reinstall flywheel and recheck for adequate clearance.

Install Crankshaft Position Sensor

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

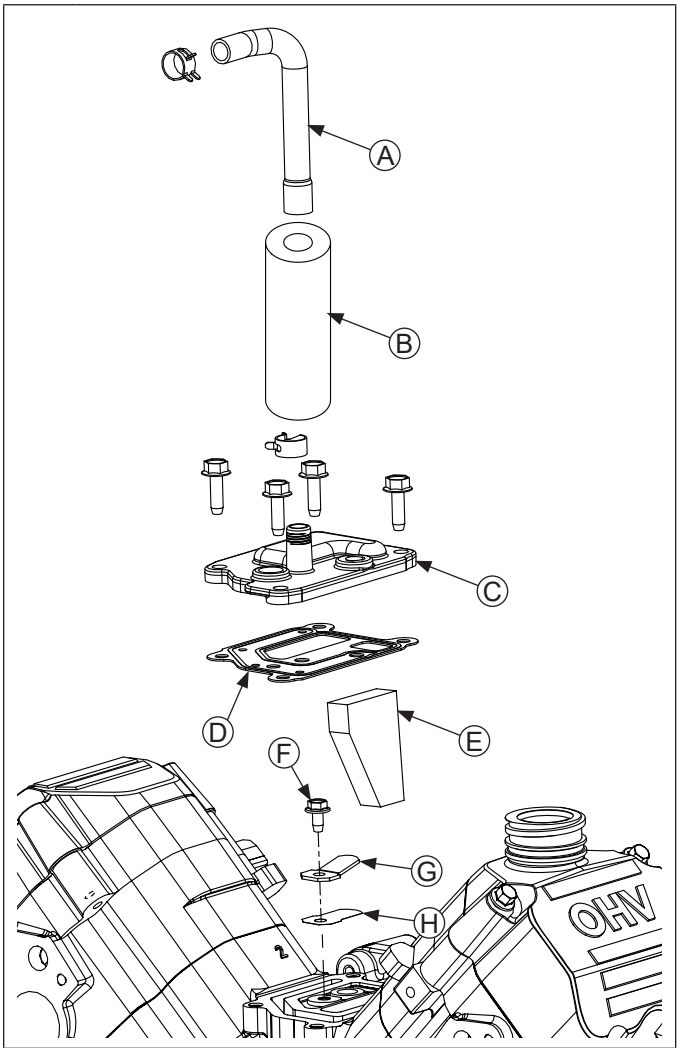
1. If removed, install crankshaft position sensor to bracket and torque screw to 11.3 N·m (100 in. lb.).
2. Connect plug to sensor.
3. Install crankshaft position sensor and bracket assembly to crankcase posts. Torque bracket screws to 9.9 N·m (88 in. lb.).

Install Spark Plugs

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

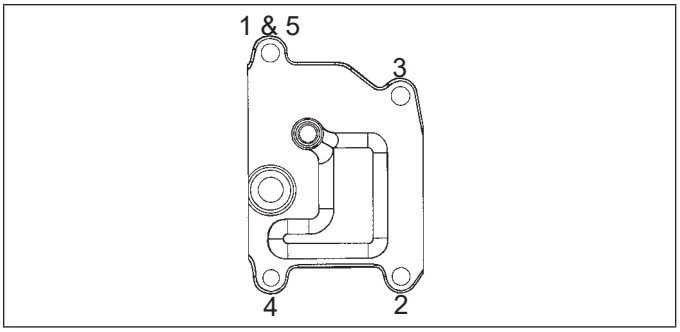
Reassembly

Install Breather Components



A	Breather Hose	**B**	Breather Hose Insulator
C	Breather Cover	**D**	Breather Cover Gasket
E	Breather Filter	**F**	Breather Reed Screw
G	Reed Retainer	**H**	Breather Reed

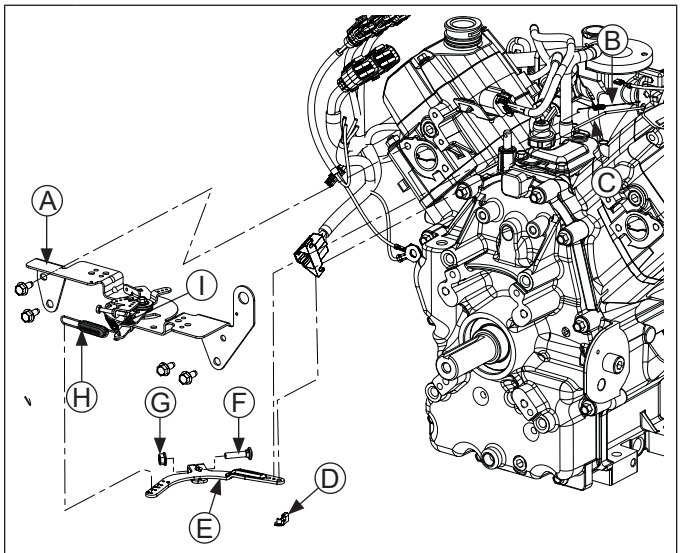
Breather Cover Fastener Torque Sequence



1. Make sure sealing surfaces of crankcase and breather cover are clean and free of all old gasket material. Clean with an aerosol type gasket remover or cleaning solvent. DO NOT scrape surfaces as this can result in leakage.
2. Check to make sure there are no nicks or burrs on sealing surfaces.
3. Install breather reed and breather reed retainer onto crankcase and secure with screw. Hold assembly in line when tightening. Torque screw to 4.0 N·m (35 in. lb.).
4. Install breather filter into cavity in crankcase.
5. Carefully install breather cover gasket and breather cover onto crankcase.
6. Install and torque four breather cover screws to 10.7 N·m (55 in. lb.) into new holes, or 7.3 N·m (65 in. lb.) into used holes, in sequence shown.
7. Install Oil Sentry™ switch into tapped breather port if removed earlier. Apply pipe sealant with Teflon® (Loctite® PST® 592™ Thread Sealant or equivalent) to threads. Torque to 4.5 N·m (40 in. lb.).

Install External Governor Controls and Main Control Bracket

Details

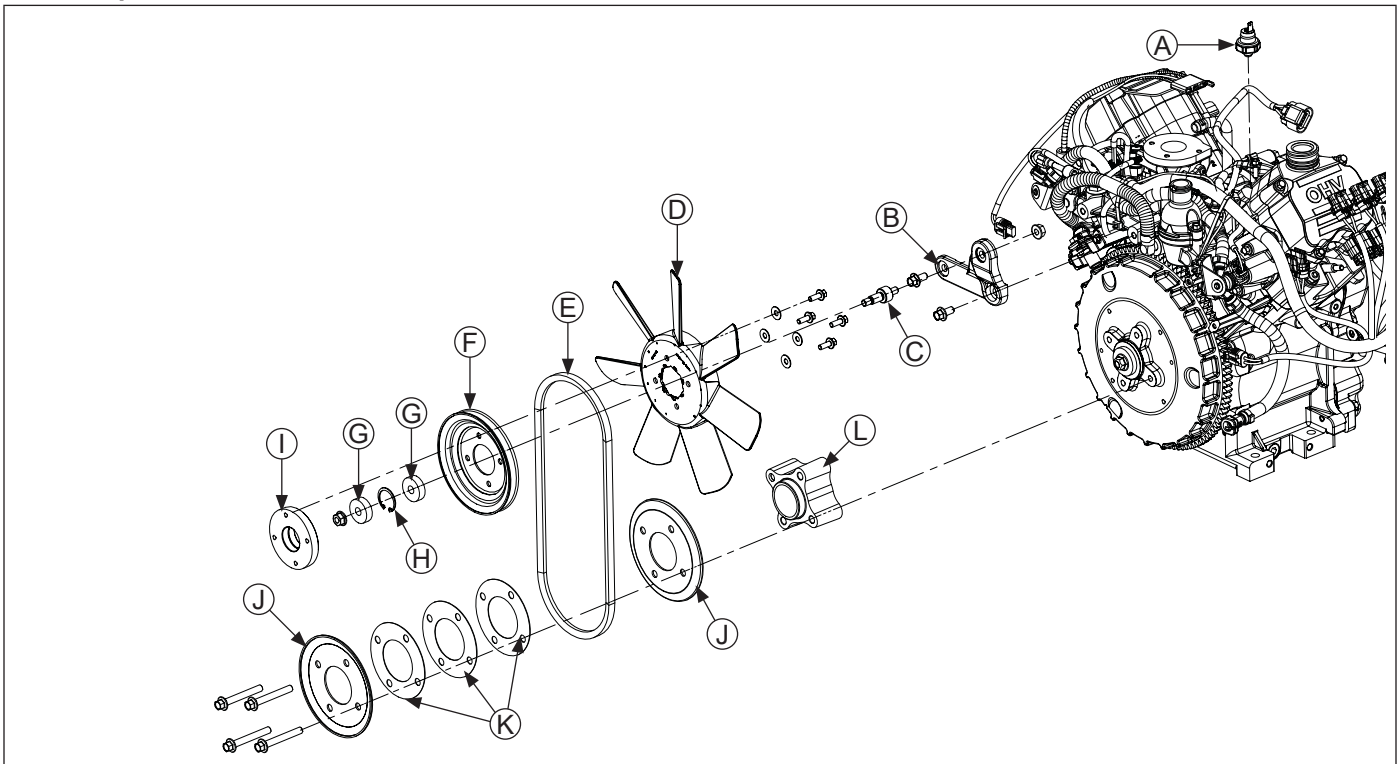


A	Control Bracket	**B**	Linkage Spring
C	Throttle Linkage	**D**	Linkage Retaining Bushing
E	Governor Lever	**F**	Governor Lever Screw
G	Governor Lever Nut	**H**	Governor Spring
I	Throttle Limiter Spring		

1. Install governor lever onto governor cross shaft. If separated, connect throttle link to governor lever with plastic bushing. Hook dampening spring into small (middle) hole.
2. Move governor lever TOWARDS intake manifold as far as it will go (wide open throttle) and hold in this position.

3. Insert a nail into hole in cross shaft and rotate shaft COUNTERCLOCKWISE as far as it will turn. Then torque nut to 6.8 N·m (60 in. lb.).
4. Mount main control bracket to cylinder heads with four screws. Torque screws to 10.7 N·m (95 in. lb.) into new holes, or 7.3 N·m (65 in. lb.) into used holes.
5. Connect dampening spring to throttle lever. Connect governor spring from throttle control bracket to appropriate governor lever hole.

Fan Components



A	Oil Sentry™	**B**	Fan Mounting Bracket	**C**	Fan Shaft	**D**	Fan
E	Fan Belt	**F**	Fan Pulley	**G**	Ball Bearing	**H**	Retainer Ring
I	Bearing Carrier	**J**	Pulley Half	**K**	Spacer Shims	**L**	Pulley Adapter

Install Lower Crankshaft Pulley, Pulley Adapter, and Cooling Fan Assembly

NOTE: Do not assemble lower pulley with belt between pulley halves, as pinching of belt or damage to pulley can occur.

1. Make sure shoulder of flywheel hub and adjacent face surface are clean and free of any nicks or damage.
2. Install crankshaft pulley adapter onto flywheel hub, so offset for pulley is out, and holes are aligned. Make sure adapter rests squarely on face of flywheel.
3. Assemble front and rear pulley halves placing shims as indicated.
   a. For a new belt: Assemble with 2 or 3 shims between pulley halves, and remaining shim (if any) on outside (front) of outer pulley half.
   b. For a used belt: Assemble with 2 shims between pulley halves and remaining shim(s) on outside (front) of outer pulley half.

   Install and snug pulley assembly. Final belt tension and pulley assembly will be made after fan/upper pulley assembly is installed.
4. Install upper fan mounting bracket to intake manifold with screws.

   Torque:

   M6 Screws to 7.3 N·m (65 in. lb.)

   M8 Screws to 24.4 N·m (216 in. lb.)
5. If disassembled, reassemble fan and pulley assembly as shown.

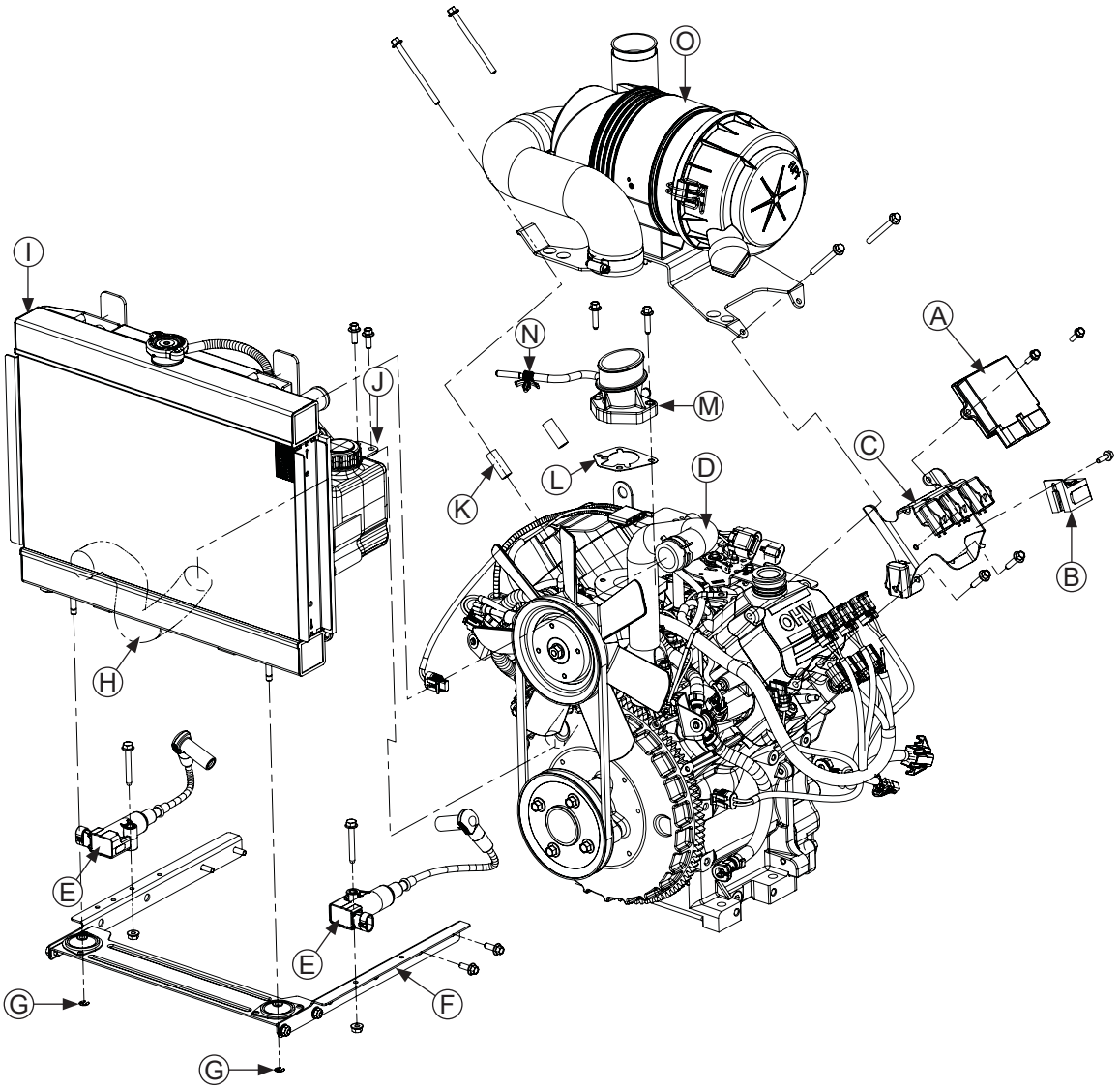
   Make sure one flat washer is placed between bearings in hub. Other washer is located under front nut. Torque fan/pulley/hub mounting screws to 6.8 N·m (60 in. lb.).
6. If fan shaft was removed from upper mounting bracket, apply Loctite® 242® to rear threads. Install and torque rear nut to 15.8 N·m (140 in. lb.). Install fan and pulley assembly onto fan shaft and upper mounting bracket.

7. Apply Loctite® 242® to front threads of fan shaft. Install flat washer and nut to secure. Torque nut to 15.8 N·m (140 in. lb.).
8. Carefully work belt into place on pulleys. Check belt tension. There should be no more than 9.53-12.7 mm (3/8"-1/2") belt deflection per side with 10 lbs. of applied tension.

   If belt tension is low, remove belt and relocate a shim from between pulley halves to outside (front). Reinstall belt and recheck tension. Repeat procedure until correct tension is reached. If shims have all been moved to outside, and belt is still too loose, replace belt.

   When proper tension is obtained, individually remove each capscrew, apply Loctite® 242® to threads of lower pulley and reinstall. Torque four bolts in a criss-cross sequence to 24.3 N·m (215 in. lb.).
9. Mount RH and LH lower radiator supports with cross support bracket attached, to crankcase, using screws. Snug screws only at this time.

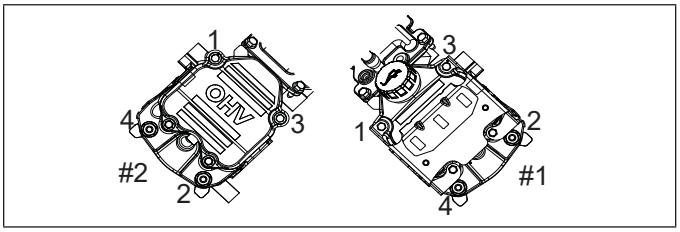
Install Ignition Coils/Radiator Assembly/Mounting Brackets/Air Cleaner Assembly Components



A	ECU	**B**	Relay	**C**	ECU, Fuse, & Connector Mounting Bracket	**D**	Upper Radiator Hose
E	Ignition Coil	**F**	Mounting Bracket	**G**	E-clip Retainer	**H**	Lower Radiator Hose
I	Radiator Assembly	**J**	Upper Radiator Support	**K**	Spacer	**L**	Air Cleaner Adapter Gasket
M	Air Cleaner Adapter	**N**	Evap Line Clip	**O**	Air Cleaner Assembly		

Reassembly

Install Air Cleaner Assembly



1. Install a new air cleaner adapter gasket onto intake manifold. Make sure that holes align.
2. Set air cleaner/mounting bracket assembly, with hose and elbow attached, in position on engine. Align all mounting holes. Start and finger tighten #2 side top screws with spacers.
3. Connect breather hose to air cleaner adapter.
4. Torque air cleaner adapter mounting screws to 7.3 N·m (65 in. lb.).
5. Install ECU bracket on #1 valve cover. Torque screws in sequence shown to 6.2 N·m (55 in. lb.).
6. Install ECU to mounting bracket. Torque screws to 7.3 N·m (65 in. lb.).
7. Install ground wire on rectifier-regulator mounting screw. Install purple wire if it was removed from connector. Attach connector plug to rectifier-regulator.
8. Connect wires for audible alarm, if used.

Install Radiator Assembly

1. Reassemble components of radiator assembly, including upper and lower radiator hoses. Rubber lubricant may be applied to inner surfaces of hoses to make installation easier. Secure with hose clamps.
2. Tighten radiator drain plug.
3. Carefully set radiator assembly into place, guiding lower radiator hose inside RH support bracket. Make sure that cooling fins do not come in contact with fan blades as radiator is installed.
4. Position upper radiator support brackets on top of air cleaner mounting bracket. Install and finger tighten four mounting screws.
5. Connect upper and lower radiator hoses to inlets of radiator and water pump. Secure with hose clamps.
6. Check for adequate clearance between fan and shroud. Adjust lower radiator supports as required, then torque four mounting screws to 9.9 N·m (88 in. lb.).
7. Hold radiator assembly in position; then torque screws securing two upper radiator supports to 9.9 N·m (88 in. lb.).
8. If upper brackets to top radiator mounts were loosened, torque to 9.9 N·m (88 in. lb.).
9. Reinstall retainer clips to secure radiator to support brackets.

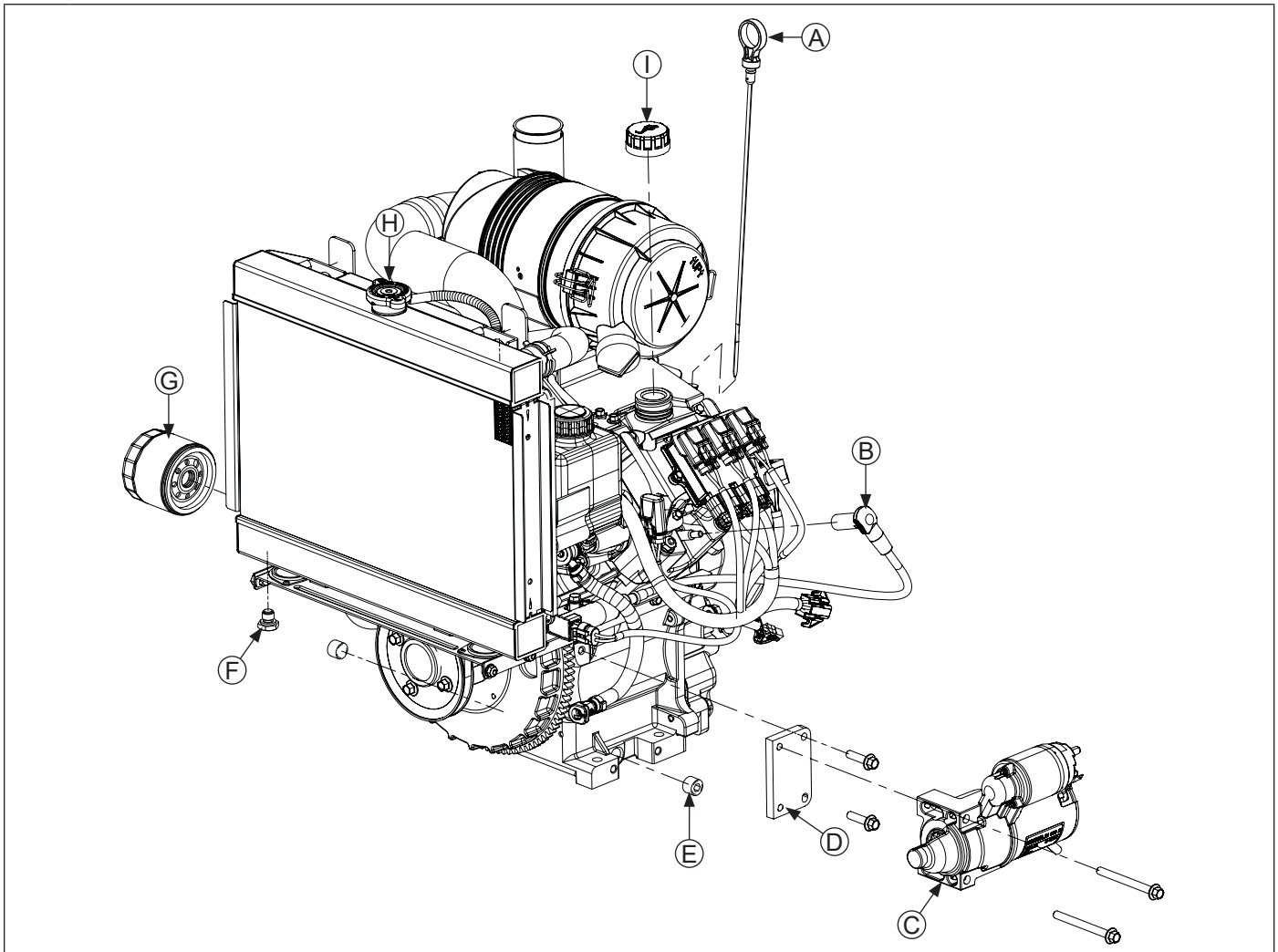
Install Ignition Coils

1. Install ignition coil to radiator mounting bracket. Torque screw to 6.2 N·m (55 in. lb.) into new hole or 4.0 N·m (35 in. lb.) into used hole.
2. Repeat step 1 for other ignition coil.
3. Connect leads to ignition coils.

Install Fuses, Relay/Bracket

1. Connect ECU plugs and place fuses in holders.
2. Install relay bracket on ECU bracket. Install relay in bracket.

External Engine Components



A	Dipstick	**B**	Spark Plug Lead	**C**	Electric Starter	**D**	Starter Plate
E	Oil Drain Plug	**F**	Radiator Drain Plug	**G**	Oil Filter	**H**	Radiator Cap
I	Oil Fill Cap						

Install Starter Plate and Starter Assembly

1. Install starter plate to crankcase. Install mounting screws and torque screws to 15.3 N·m (135 in. lb.).
2. Mount starter to adapter plate using screws.
3. Make sure starter is square to flywheel, and torque screws to 15.3 N·m (135 in. lb.).
4. Attach leads to appropriate starter solenoid terminals.

Connect Oxygen Sensor

1. If oxygen sensor was removed from muffler (OEM supplied), reinstall it and torque to 18 N·m (159 in. lb.).
2. Connect oxygen sensor to wire harness.

Install Oil Filter and Fill Crankcase with Oil

NOTE: Make sure both oil drain plugs are installed and torqued to specifications to prevent oil leakage.

1. Install oil drain plug(s). Torque plug(s) to 13.6 N·m (10 ft. lb.). If oil drain valve is used, make sure valve body is closed and cap is on.
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 oil 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.

Install Coolant

1. Use equal parts of ethylene glycol (antifreeze) and water only. Distilled or deionized water is recommended, especially in areas where water contains a high mineral content. Propylene glycol based antifreeze is not recommended.
2. Fill cooling system, through radiator, with coolant mix. Allow coolant to drain into lower areas. Fill overflow reservoir midway between FULL and ADD marks, then install radiator and reservoir caps.

Reconnect Spark Plug Leads and Battery

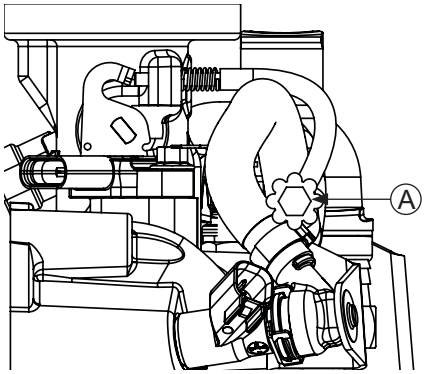
Connect leads to spark plugs. Reconnect positive (+) battery lead first, and negative (-) lead last when connecting battery.

Preparing Engine for Operation

It is recommended engine be appropriately secured and operated on a test stand or bench, prior to installation in application.

1. Make sure all hardware is tightened, and hose clamps are properly secured.
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.
4. Turn on fuel supply.

Testing Engine and Setting Speed



A	Idle Speed Adjustment Cable

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

1. Set up engine on a test stand. Install an oil pressure gauge. Start engine and check to be certain that 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. Check all cooling system components and joint connections for leaks.
3. Using idle speed adjustment cable (on throttle body/ intake manifold), set idle speed 100 RPM below specified idle speed setting.
4. Make sure maximum engine speed does not exceed 3750 RPM (no load). Adjust throttle and high speed stop as necessary. Refer to Fuel System.
5. Place throttle control into idle or slow position and check low idle speed (RPM). Refer to Fuel System if adjustment is required.
6. Stop engine.
7. Recheck oil and coolant levels. Oil level should be at F mark on dipstick, and coolant level in reservoir should be midway between ADD and FULL marks. Add additional amounts as required.