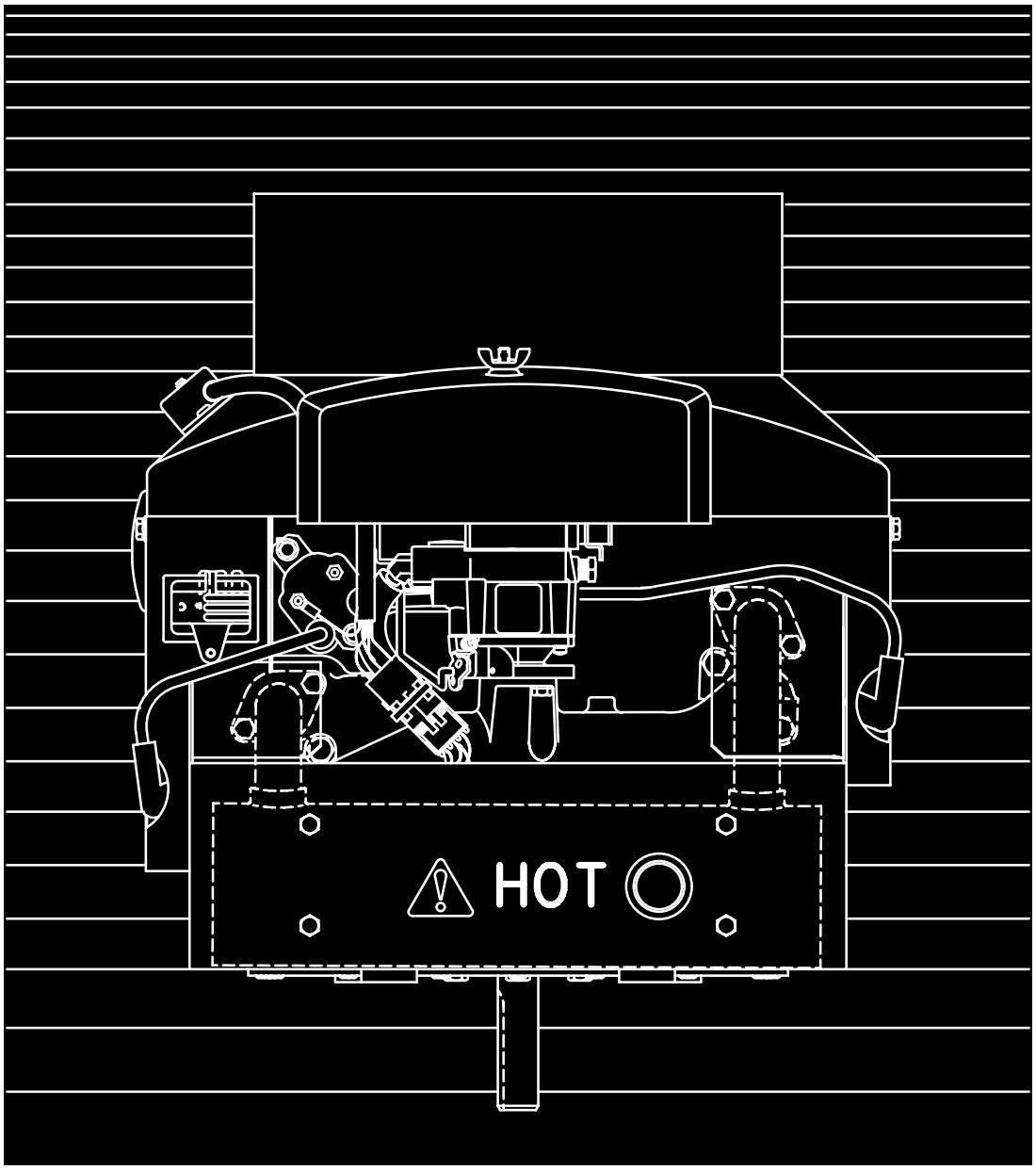
Onan

Engine

Service Manual

P216V, P218V
P220V, P248V

Performer Series



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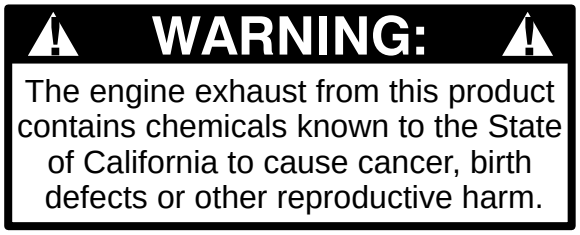

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Safety Precautions

Thoroughly read the OPERATOR'S MANUAL before operating the engine. Safe operation and top performance can be obtained only with proper operation and maintenance.

The following symbols in this Manual alert you to potential hazards to the operator, service person and equipment.

⚠ DANGER ***alerts you to an immediate hazard which will result in severe personal injury or death.***

⚠WARNING ***alerts you to a hazard or unsafe practice which can result in severe personal injury or death.***

⚠ CAUTION ***alerts you to a hazard or unsafe practice which can result in personal injury or equipment damage.***

Electricity, fuel, exhaust, moving parts and batteries present hazards which can result in severe personal injury or death.

GENERAL PRECAUTIONS

- Keep ABC fire extinguishers handy.
- Make sure all fasteners are secure and torqued properly.
- Keep the engine and its compartment clean. Excess oil and oily rags can catch fire. Dirt and gear stowed in the compartment can restrict cooling air.
- Before working on the engine, disconnect the negative (**-**) battery cable at the battery to prevent starting.
- Use caution when making adjustments while the engine is running—hot, moving or electrically live parts can cause severe personal injury or death.
- Used engine oil has been identified by some state and federal agencies as causing cancer or reproductive toxicity. Do not ingest, inhale, or contact used oil or its vapors.
- Benzene and lead in some gasolines have been identified by some state and federal agencies as causing cancer or reproductive toxicity. Do not to ingest, inhale or contact gasoline or its vapors.
- Do not work on the engine when mentally or physically fatigued or after consuming alcohol or drugs.
- Carefully follow all applicable local, state and federal codes.

⚠WARNING ***This engine is not designed or intended for use in aircraft. Such use can lead to engine failure, severe personal injury or death.***

FUEL IS FLAMMABLE AND EXPLOSIVE

- Keep flames, cigarettes, sparks, pilot lights, electrical arc-producing equipment and switches and all other sources of ignition well away from areas where fuel fumes are present and areas sharing ventilation.
- Do not fill the fuel tank while the engine is running.
- Fuel lines must be copper or steel tubing or piping, adequately secured and free of leaks.
- Use approved flexible fuel hose for connections at the engine. Do not use copper tubing as a flexible connector—vibration will cause it to work-harden and break. Use non-conductive hose if the fuel line could become a path for cranking current.
- LPG leaks into an inadequately ventilated space can lead to explosive accumulations of gas. LPG sinks when released into the air and can accumulate inside basements and other below-grade spaces. Precautions must be taken to prevent gas leaks and the accumulation of gaseous fuel in the event of a leak.
- The fuel line must have a manual shutoff valve unless the highest fuel level in the supply tank is lower than the connection at the engine.

ENGINE EXHAUST IS DEADLY!

- Learn the symptoms of carbon monoxide poisoning in this Manual.
- Inspect the exhaust system every time the engine is started and after every eight hours of operation. If the exhaust noise changes, shut down the engine immediately and have it inspected.
- The integral exhaust system must not be modified in any way.
- Do not use engine cooling air to heat a room.
- Make sure there is ample fresh air when operating the engine in a confined area.

BATTERY GAS IS EXPLOSIVE

- Wear safety glasses and do not smoke while servicing batteries.
- When disconnecting or reconnecting battery cables, always disconnect the negative (**-**) battery cable first and reconnect it last to reduce arcing.

MOVING PARTS CAN CAUSE SEVERE PERSONAL INJURY OR DEATH

- Do not wear loose clothing or jewelry near moving parts such as PTO shafts, fans, belts and pulleys.
- Keep hands away from moving parts.
- Keep guards in place over fans, belts, pulleys, etc.

1. General Information

INTRODUCTION

This manual deals with specific mechanical and electrical information needed by engine mechanics for troubleshooting, servicing, repairing, or overhauling the engine. Figure 1-1 shows a typical engine.

Use the separate Parts Manual for parts identification and for establishing their proper location on assemblies. The Parts Manual contains detailed exploded views of each assembly and the individual piece part numbers and their proper names for ordering replacement parts.

The illustrations and procedures presented in each section apply to the engines listed on the cover. The air cleaner side of the engine is the front end. Right and left sides are determined by viewing the engine from the front. The No. 1 cylinder is on the right; the No. 2 cylinder is on the left.

If a major repair or an overhaul is necessary, a competent mechanic should either do the job or supervise and check the work of the mechanic assigned to the job to ensure that all dimensions, clearances, and torque values are within the specified tolerances.

Use the table of contents for a quick reference to the separate engine system sections.

The troubleshooting guide is provided as a quick reference for locating and correcting engine troubles.

The wiring diagram shows how the electrical components are interconnected.

The disassembly section contains major overhaul procedures for step-by-step removal, disassembly, inspection, repair, and assembly of the engine components.

Use only Genuine Onan replacement parts to ensure quality and the best possible repair and overhaul results. When ordering parts, always use the complete model and spec number as well as the serial number shown on the nameplate.

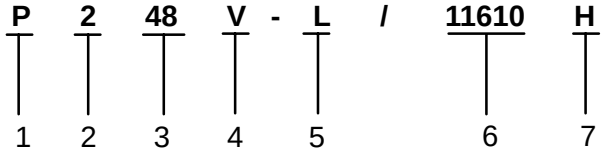
See the Operator's Manual for fuel and engine oil recommendations and the Periodic Maintenance Schedule.

⚠WARNING ***Incorrect service or replacement of parts can result in severe personal injury and/or equipment damage. Service personnel must be qualified to perform electrical and/or mechanical service.***

ENGINE MODEL REFERENCE

Identify your model by referring to the model and specification (spec letter) as shown on the unit nameplate. Always use these numbers and the engine serial number when making reference to your engine.

How to interpret MODEL and SPEC NO:



1. Factory code for general identification of basic engine series.
2. Number of cylinders.
3. BPH rating (except for Model P248V, where it indicates displacement in cubic inches).
4. Crankshaft orientation (G = horizontal, V = vertical).
5. Fuel type (I = gasoline, L = LPG, D = dual).
6. Factory code for designated optional equipment, if any.
7. Specification (spec letter) which advances with factory production modifications.

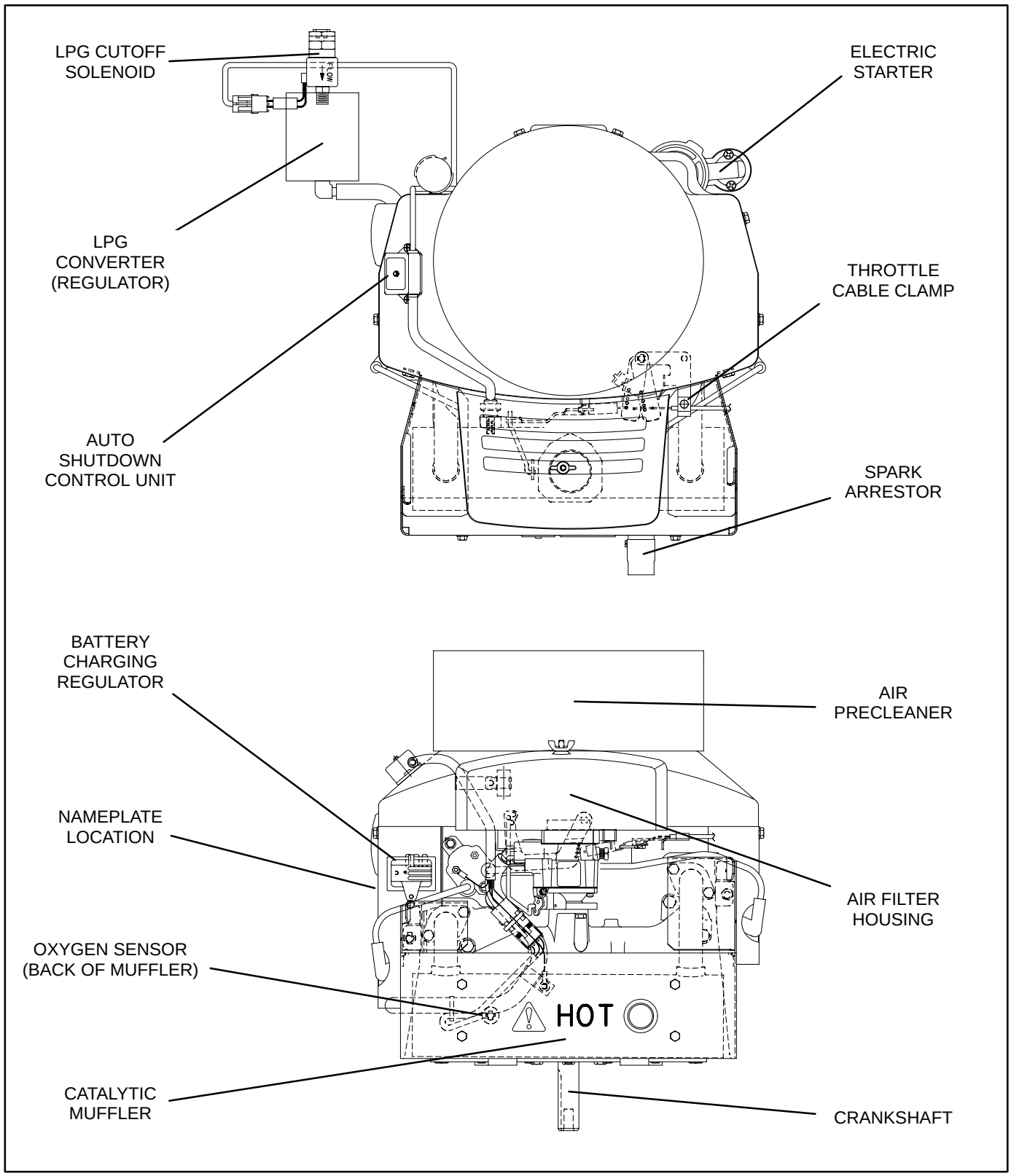


FIGURE 1-1. TYPICAL CONFIGURATION SHOWING A FLOORCARE ENGINE

2. Specifications

This Manual contains SI metric equivalents that follow immediately in parentheses after the U.S. customary units of measure.

SPECIFICATION	UNIT OF MEASURE	SERIES			
		P216V	P218V	P220V	P248V
Number of Cylinders		2	2	2	2
Bore	in. (mm)	3.250 (82.55)	3.250 (82.55)	3.250 (82.55)	3.250 (82.55)
Stroke	in. (mm)	2.625 (66.68)	2.875 (73.03)	2.875 (73.03)	2.875 (73.03)
Displacement	cu in. (cm^3)	43.3 (710)	48 (782)	48 (782)	48 (782)
Compression Ratio		6.5 to 1	7.0 to 1	7.0 to 1	7.0 to 1
Power at Rated Speed (3600 rpm)	BHP (kW)	16 (11.9)	18 (13.4)	20 (14.9)	**gasoline** 20 (14.9)
					LPG 17 (12.7)
Oil Capacity without Filter	Qts (litre)	1.7 (1.6)	1.7 (1.6)	1.7 (1.6)	1.7 (1.6)
Oil Filter Capacity	Qts (litre)	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)
Intake Valve Clearance (Cold)	in. (mm)	0.005 (0.13)	0.005 (0.13)	0.005 (0.13)	0.005 (0.13)
Exhaust Valve Clearance (Cold)	in. (mm)	0.013 (0.33)	0.013 (0.33)	0.013 (0.33)	0.013 (0.33)
Spark Plug Gap	in. (mm)	0.025 (0.64)	0.025 (0.64)	0.025 (0.64)	0.025 (0.64)
Ignition Timing	BTDC	20°	20°	20°	20°
Cylinder Compression	psi (kPa)	75 - 115 (517 - 793)	75 - 115 (517 - 793)	75 - 115 (517 - 793)	75 - 115 (517 - 793)

3. Dimensions and Clearances

All measurements given at room temperature of 70°F (21°C). All measurements are given in inches with approximate millimeter measurements. Measurements are for standard size parts.

DESCRIPTION	MINIMUM		MAXIMUM	
	Inches	Millimeters	Inches	Millimeters
CYLINDER BLOCK				
Cylinder Bore Diameter	3.2490	82.52	3.2500	82.55
Piston Clearance	0.0033	0.084	0.0053	0.135
Maximum Allowable: Taper Out-of-Round	 — —	 — —	 0.005 0.003	 0.13 0.08
Top Main Bearing Bore	2.1870	55.55	2.1880	55.58
Top Main Bearing Inside Diameter (bearing installed)	2.0015	50.84	2.0040	50.90
Top Main Bearing Clearance	0.0024	0.061	0.0042	0.107
Bottom Main Bearing Bore	2.1840	55.47	2.1850	55.50
Bottom Main Bearings Inside Diameter (bearings installed)	1.9990	50.77	2.0020	50.85
Bottom Main Bearing Clearance	0.0010	0.025	0.0048	0.122
Cam Bearing Bore	1.4995	38.08	1.5005	38.11
Cam Bearing Inside Diameter (bearing installed)	1.3757	34.94	1.3787	35.02
Cam Bearing Clearance	0.0015	0.038	0.0030	0.076
Intake Valve Seat Bore	1.4395	36.56	1.4405	36.59
Exhaust Valve Seat Bore	1.1890	30.20	1.1900	30.23
Tappet Bore Diameter	0.7500	19.05	0.7515	19.09
Tapper Clearance	0.0020	0.051	0.0040	0.102
CRANKSHAFT				
Top Main Bearing Journal Diameter	1.9992	50.78	2.0000	50.80
Bottom Main Bearing Journal Diameter	1.9972	50.73	1.9980	50.75
Connecting Rod Journal Diameter	1.6252	41.28	1.6260	41.30
End Play	0.0060	0.152	0.0120	0.305
CONNECTING ROD				
Large Bore Inside Diameter (rod bolts torqued)	1.6280	41.35	1.6285	41.36
Large Bore Clearance	0.0020	0.051	0.0033	0.084
Piston Pin Bore	0.6879	17.47	0.6882	17.48
Piston Pin Clearance	0.0002	0.005	0.0007	0.018
End Play	0.0020	0.051	0.0320	0.813

DESCRIPTION	MINIMUM		MAXIMUM	
	Inches	Millimeters	Inches	Millimeters
CAMSHAFT				
Journal Diameter	1.3740	34.90	1.3745	34.91
Lobe Height: P216V, P218V Intake P216V, P218V Exhaust P220V, P248V Intake P220V, P248V Exhaust	 — — — —	 — — — —	 1.1370 1.1570 1.1670 1.1570	 28.88 29.39 29.64 29.39
End Play	0.0110	0.279	0.0480	1.219
PISTON				
Diameter (Standard size - Measure 90° from pin bore, 1.187 in. below top of piston)	3.2445	82.41	3.2462	82.45
Ring Groove Width: Top Groove Middle Groove Bottom Groove	 0.0800 0.0800 0.1880	 2.032 2.032 4.775	 0.0810 0.0810 0.1890	 2.057 2.057 4.800
Top Groove Clearance	0.0030	0.076	0.0080	0.203
Pin Bore	0.6877	17.47	0.6882	17.48
Pin Clearance	0.00004	0.001	0.00064	0.016
PISTON PIN				
Diameter	0.6875	17.46	0.6877	17.47
PISTON RINGS				
End Gap	0.0100	0.254	0.0200	0.508
INTAKE VALVE				
Stem Diameter	0.2795	7.099	0.2800	7.112
Face Angle	44°			
INTAKE VALVE SEAT				
Outside Diameter	1.4700	37.34	1.4710	37.36
Seat Width	0.0310	0.787	0.0470	1.194
Seat Angle	45°			
EXHAUST VALVE				
Stem Diameter	0.2780	7.061	0.2785	7.074
Face Angle	44°			
EXHAUST VALVE SEAT				
Outside Diameter	1.1920	30.28	1.1930	30.30
Seat Width	0.0310	0.787	0.0470	1.194
Seat Angle	45°			

DESCRIPTION	MINIMUM		MAXIMUM	
	Inches	Millimeters	Inches	Millimeters
VALVE GUIDE				
Intake Inside Diameter	0.2810	7.137	0.2820	7.163
Intake Stem to Guide Clearance	0.0010	0.025	0.0025	0.064
Exhaust Inside Diameter	0.2805	7.125	0.2815	7.150
Exhaust Stem to Guide Clearance	0.0020	0.051	0.0035	0.089
TAPPET				
Body Diameter	0.7475	18.99	0.7480	19.00
GEAR BACKLASH				
Timing Gear	0.0010	0.025	0.0050	0.127
Oil Pump Gear	0.0010	0.025	0.0080	0.203
	APPROXIMATE			
	Inches		**Millimeters**	
VALVE SPRINGS				
Free Length	1.600		40.64	
Valve Open Length	1.055		26.80	
Valve Closed Length	1.346		34.19	
Spring Load (valve open length)	55 lb		25 kg	
Spring Load (valve closed length)	25 lb		11 kg	

4. Assembly

TORQUES

The torque values given in Table 4-1 have been determined for specific applications. Standard torque values must not be used where those listed in Table 4-1 apply. The engine assembly torques given here will assure proper tightness without danger of stripping threads. All threads must be clean and lubricated with new engine oil before torquing.

Tighten all studs, nuts, and capscrews as required to keep them from working loose. Refer to the *Parts Manual* for the location of washers and capscrews.

SPECIAL TOOLS

The following is a partial list of the special tools available from Onan. Use Onan tools whenever a repair or overhaul is required. Refer to the *Tool Catalog* for a complete listing of tools available.

- Valve Seat Driver
- Valve Guide Driver
- Oil Seal Guide and Driver
- Combination Bearing Remover (Main and Cam)
- Combination Bearing Driver (Main and Cam)
- Flywheel Puller

TABLE 4-1. ASSEMBLY TORQUES

DESCRIPTION	TORQUE SPECIFICATION (RANGE)	
	Lb-Ft	Nm
Gearcase Cover	10-12	14-16
Oil Base	27-29	36-39
Oil Base Cover (inner bolts)	19-21	25-28
Oil Base Cover (outer bolts)	9-11	12-15
Oil Cooler	20-24	27-33
Oil Pump	7-9	10-12
Hood Support Screws	7-9	10-12
Starter Mounting Bolts	19-21	25-28
Connecting Rod Bolts	12-14	16-19
Flywheel Capscrews	50-55	67-75
Valve Cover	3-4	4-5
Cylinder Head Bolts (cold): Asbestos Gasket Graphoil Gasket	 16-18 14-16	 22-24 19-22
Intake Manifold Mounting Screws	6-10	8-14
Exhaust Manifold Mounting Screws	9-11	12-15
Other 1/4-in. Cylinder Block Nuts and Bolts	7-9	10-12
Other 5/16-in. Cylinder Block Nuts and Bolts	8-10	11-14
Oxygen Sensor*	44	59

* Apply high temperature anti-seize compound (Fel-Pro Nickel Ease PN 51119 or equivalent) to the threads of the sensor. Be careful not to damage the sensor by fouling it with compound.

5. Engine Troubleshooting

TROUBLE / CAUSE	Backfiring	Bearing Wear	Black Exhaust	Blue Exhaust	Burned Valves	Con Rod Wear	Cranks Slowly	Cylinder Wear	Engine Stops	Failure to Start	Governor Hunting	High Oil Pressure	Low Oil Pressure	Mechanical Knocks	Misfiring	Overheating	Piston Wear	Poor Compression	Ring Wear	Sticking Valves
STARTING SYSTEM																				
Loose or Corroded Battery Connection						•			•											
Low or Discharged Battery						•			•											
Faulty Starter						•			•											
Faulty Start Solenoid									•											
IGNITION SYSTEM																				
Ignition Timing Wrong	•				•				•				•	•	•					
Wrong Spark Plug Gap									•				•	•						
Faulty Ignition Coil									•					•						
Faulty Spark Plug Wires									•					•						
FUEL SYSTEM*																				
Out of Fuel - Check								•	•											
Lean Fuel Mixture					•				•	•				•	•					
Rich Fuel Mixture or Choke Stuck	•		•						•				•	•						
Engine Flooded (gasoline)	•		•					•	•											
Poor Quality Fuel (gasoline)	•		•		•				•				•	•						
Dirty Carburetor	•							•	•	•				•						
Dirty Air Cleaner	•	•	•					•		•					•		•		•	
Dirty Fuel Filter (gasoline)									•	•				•						
Faulty Fuel Pump (gasoline)								•	•	•				•						
Faulty Pressure Regulator (LPG)	•							•	•					•						
INTERNAL ENGINE																				
Wrong Valve Clearance					•					•				•	•			•		
Broken Valve Spring					•					•				•	•			•		•
Valve or Valve Seal Leaking				•	•						•				•			•		
Piston Rings Worn or Broken				•						•				•				•		
Wrong Bearing Clearance		•				•	•						•	•						
COOLING SYSTEM																				
Poor Air Circulation														•	•					
Dirty or Oily Cooling Fins														•	•					
Blown Head Gasket								•	•					•			•			
LUBRICATION SYSTEM																				
Faulty Oil Gauge											•	•								
Stuck Relief Valve											•	•								
Faulty Oil Pump		•				•		•	•	•		•	•			•		•		
Faulty Low Oil Pressure Cutout Switch								•	•											
Dirty Oil or Filter		•				•		•								•		•	•	
Oil Too Light or Diluted		•		•		•		•					•	•		•		•		
Oil Level Low		•				•		•					•	•		•		•		
Oil Too Heavy							•					•								
THROTTLE AND GOVERNOR																				
Linkage Out of Adjustment										•	•									
Linkage Worn or Disconnected											•									
Governor Spring Sensitivity Too Great											•									
Linkage Binding											•									

* See 7. Fuel System if the engine has an auto shutdown system

6. Oil System

OIL AND FILTER CHANGE

Refer to *Periodic Maintenance* in the Operator's Manual for oil and filter change intervals.

CRANKCASE BREATHER

The crankcase breather prevents pressure from building up in the crankcase. It also prevents oil contamination by removing moisture or gasoline vapors and other harmful blow-by materials from the crankcase. These vapors are routed to the carburetor where they are mixed with incoming air and burned in the combustion chamber. A sticky breather valve can cause oil leaks, high oil consumption, rough idle, reduced engine power, and a rapid formation of sludge and varnish within the engine.

The crankcase breather does not require servicing. Replace the breather if it's broken or cracked, or if the crankcase becomes pressurized by evidenced by oil leaks at the seals or excessive oil in the air cleaner housing.

PRESSURE LUBRICATION

All engines use an oil pump to provide a constant flow of oil to the engine parts. The oil supply collects in the oil base where it is picked up by the oil pump pick-up cup. A bypass valve is used to control oil pressure. Drain the oil before removing the oil base and always use a new gasket when replacing the oil base.

Oil Pump

The oil pump is mounted below the gear cover and is driven by the crankshaft gear. A discharge passage in the pump cover registers with a drilled passage in the crankcase. Parallel passages distribute oil to the top and bottom main bearing and the oil bypass valve.

Circumferential grooves in the main bearings supply oil to the connecting rod bearings through drilled passages from each main journal. A drilled passage connects the front main bearing oil supply to the front camshaft bearing. The rear cam bearing is splash lubricated.

Check the oil pump thoroughly for worn parts and replace the pump as an assembly if parts are worn. Other component parts (pickup cup, pickup tube, gaskets, etc.) can be replaced individually. Prime the pump by oiling it before installing.

Oil Bypass Check Ball

The oil bypass check ball is located in the oil base. To gain access to the check ball, the oil base cover must be removed. The check ball limits oil pressure to a maximum of about 25 psi (172 kPa) at normal operating temperatures (250°F oil temperature).

The check ball is non-adjustable and normally does not need maintenance. Determine if the check ball is operating correctly by inspecting it as follows. Refer to Figure 6-1.

1. Remove the internal retaining ring.
2. Remove the spring and check ball with a magnetic tool.
3. Determine the proper operation by checking the spring and check ball according to the following measurements:

   Check Ball Diameter . . 0.3125 in. (7.94 mm)

   Spring:

   Free Length . . . . . 1.0 in. (25.4 mm)

   Load . . . . . 2.6 ± 0.2 lb (11.6 ± 0.9 N) when compressed to 0.5 in. (12.7 mm)
4. Check the check ball seat and clean away any accumulation of metal particles which could cause erratic check ball action. Verify the check ball seat is not damaged.
5. Clean the spring and check ball in parts cleaning solvent and install.
6. A new internal retaining ring must be installed with the outside edges turned towards the top. Press in until the retaining ring outside edge is 0.13 ± 0.01 inch (3.3 ± 0.3 mm) from the top.

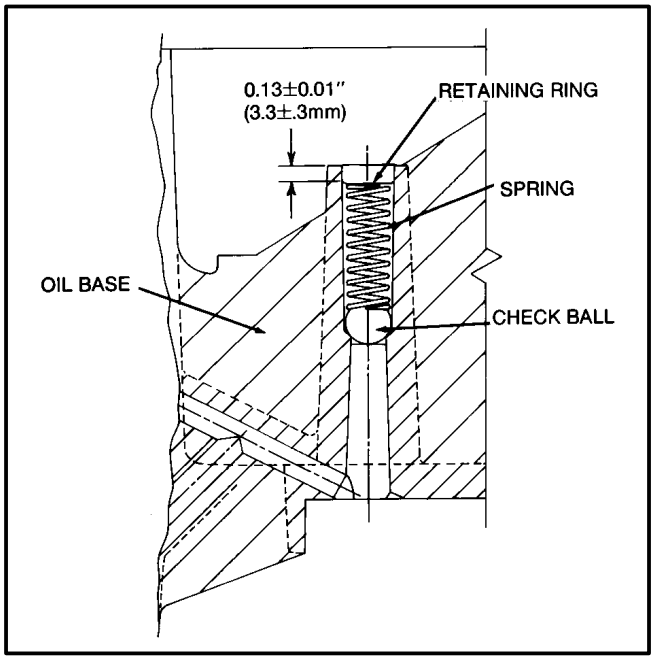


FIGURE 6-1. OIL BYPASS CHECK BALL

7. Fuel System

AIR CLEANER

See *Periodic Maintenance* in the Operator's Manual regarding air cleaner service.

GASOLINE CARBURETOR (PRIOR TO SPEC G)

All carburetors have a fixed main jet. An optional fixed main jet is available for altitude compensation above 5,000 feet.

The carburetor idle mixture was set for maximum efficiency at the factory and should normally not be disturbed. If adjustments seem necessary, first be sure the ignition system is working properly and governor sensitivity is properly adjusted.

The carburetor has a limited idle adjustment range between stops of ± 1/8 turn. The screw should only be adjusted within these limits: in to lean the mixture, out to richen.

⚠ CAUTION ***Overtightening the mixture adjustment screw will cause carburetor damage. Turn mixture adjustment screw in only until light resistance can be felt.***

If replacing the idle mixture screw, turn it in until lightly seated, then turn the screw back out 1-1/4 turns. Replace limiter cap with the plastic stop approximately centered.

Carburetor Speed Settings

1. Start the engine and allow it to warm up thoroughly (at least 10 minutes).
   Some equipment manufacturers may require higher throttle stop speed and governor low speed rpm settings. Refer to equipment manufacturer's Operator's Manual for the correct rpm settings. When rpm settings are not specified by the equipment manufacturer, use the rpm setting listed in Steps 2 and 3, below.
2. Move the engine speed control to the slow position. Adjust the low speed adjustment screw on the governor so the throttle stop screw on the carburetor controls engine speed. Adjust the throttle stop screw for 1000 rpm idle. See Figures 7-1 and 7-2.
3. Adjust the governor low speed stop for 1100 rpm idle.

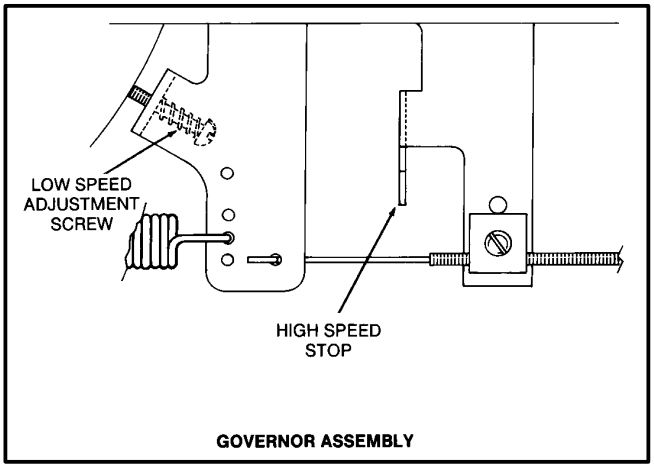


FIGURE 7-1. GOVERNOR SPEED ADJUSTMENT

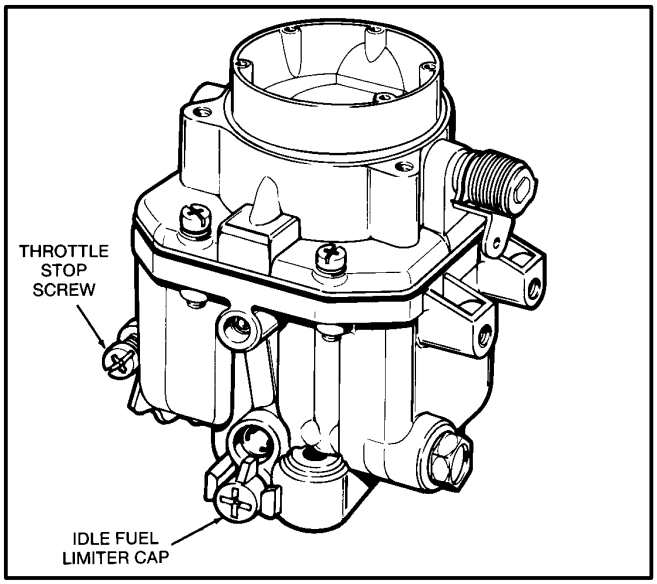


FIGURE 7-2. CARBURETOR ADJUSTMENTS

4. Move the engine speed control to the fast position. Bend the high speed stop on the governor so the engine runs at the equipment manufacturer's recommended speed.

Carburetor Overhaul (Prior To Spec G)

Carburetor problems that are not corrected by mixture adjustments are usually a result of gummed-up fuel passages or worn internal parts. The most effective solution is a carburetor overhaul.

In general, overhauling a carburetor consists of disassembly, a thorough cleaning, and replacement of worn parts. Carburetor overhaul kits are available.

General instructions for overhauling a carburetor are given below. Carefully note the position of all parts while removing to assure correct placement when reassembling. Read through all the instructions before beginning for a better understanding of the procedures involved. Carburetor components are shown in Figure 7-3.

⚠WARNING ***Ignition of fuel can result in severe personal injury or death. Do not smoke or allow any flame, spark, pilot light, or arcing switch or equipment, or other source of ignition near the work area or areas sharing ventilation.***

Removal:

1. Remove the air cleaner assembly.
2. Disconnect the throttle linkage, choke control, and fuel line from the carburetor.
3. Remove the carburetor from the intake manifold.

Disassembly:

1. Remove the main jet and idle adjustment needle.
2. Remove the attaching screws and separate the upper and lower carburetor sections.
3. Carefully note position of float assembly parts, then pull out the retaining pin and float assembly.
4. Remove the needle valve.

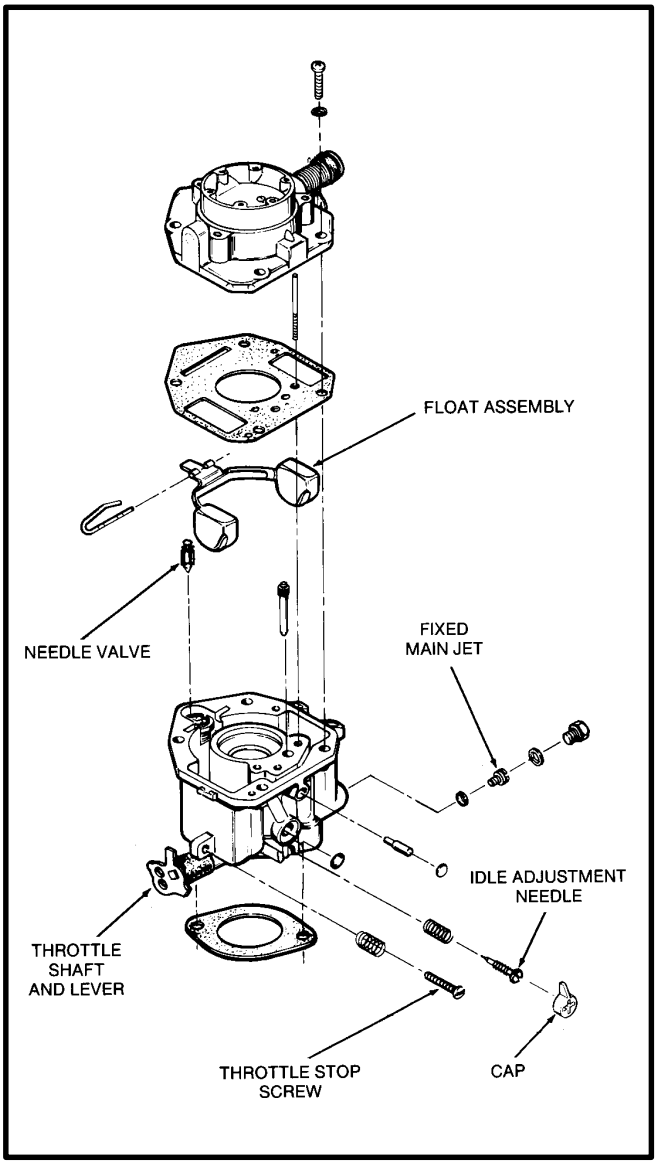


FIGURE 7-3. CARBURETOR ASSEMBLY

Cleaning and Repair:

1. Soak all metal components not replaced in carburetor cleaner. Do not soak non-metal floats or other non-metal parts. Follow the cleaner manufacturer's recommendations.
2. Clean all carbon from the carburetor bore, especially where the throttle and choke plates seat. Be careful not to plug the idle or main fuel ports.
3. Dry out all passages with low pressure air (35 psi). Avoid using wire or other objects for cleaning which could increase the size of critical passages.
4. Check the condition of the adjustment needle; replace if damaged. Replace the float if loaded with fuel or damaged.
5. Check the choke and throttle shafts for excessive play in their bore. This condition may necessitate replacement of the carburetor.
6. Replace old components with new parts.

Reassembly and Installation:

1. Install the needle valve, main jet, and float assembly. Make sure the float pivot pin is properly placed and the float moves freely without binding.
2. Turn the carburetor on its side and measure the float level (the distance from the top of the carburetor body to the top of the float). See Figure 7-4. Adjust the float level only if necessary.
3. Position the gasket on the lower carburetor section and install the upper carburetor section.
4. Install the idle adjustment screw, throttle stop screw, and fixed main jet plug.
5. Mount the carburetor on the intake manifold and install the assembly on the engine.
6. Connect the governor and throttle linkage, choke control, and fuel line. Mount the air cleaner assembly.
7. Adjust the carburetor and governor according to directions given in this section.

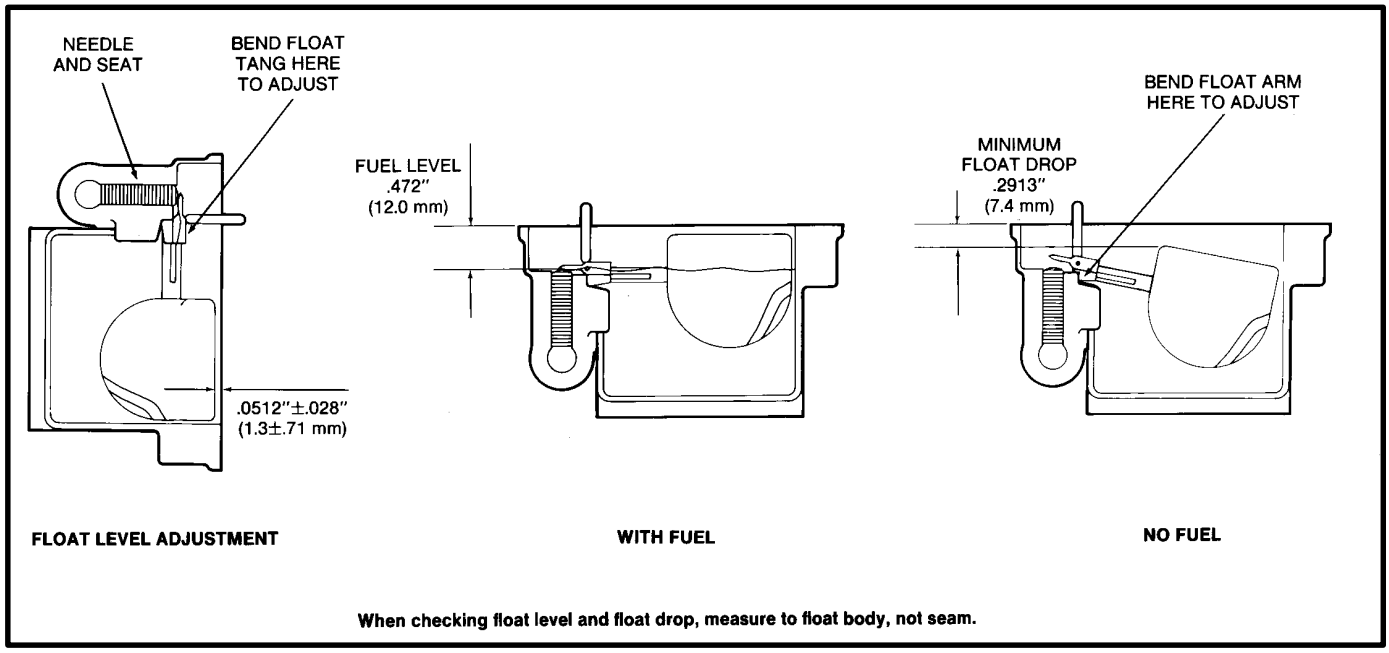


FIGURE 7-4. CARBURETOR FLOAT LEVEL ADJUSTMENTS

GASOLINE CARBURETOR (BEGINNING SPEC G)

Carburetor Replacement

Other than replacing the carburetor main fuel jet (fixed-type) with the optional high-altitude jet (Figure 7-5), fuel mixture adjustments should not be attempted. Nor should the carburetor be overhauled. Instead, a malfunctioning carburetor should be replaced. Before replacing a carburetor, however, make certain that:

- All other necessary engine and generator adjustments and repairs have been performed
- The carburetor is actually malfunctioning (see *Engine Troubleshooting*).

⚠WARNING ***Unauthorized modifications or replacement of fuel, exhaust, air intake, or speed control system components that affect emission on California certified engines are prohibited by law in the State of California.***

To remove the carburetor, remove the air cleaner, disconnect the fuel line, choke, and throttle linkages, and unbolt the carburetor from the intake manifold. When mounting the carburetor always use a new gasket. Readjust the choke and throttle cables, and engine speed as instructed in the engine or equipment Operator's Manual.

Carburetor High-Altitude Jet (Optional)

If the engine is operated at an altitude above 5,000 feet (1,524 metres), it is recommended that the carburetor main fuel jet be replaced with the optional high-altitude jet (which has a slightly smaller orifice).

⚠CAUTION ***To avoid slipping and gouging the main fuel jet, use a screwdriver with a 5/16-inch (8-mm) wide blade.***

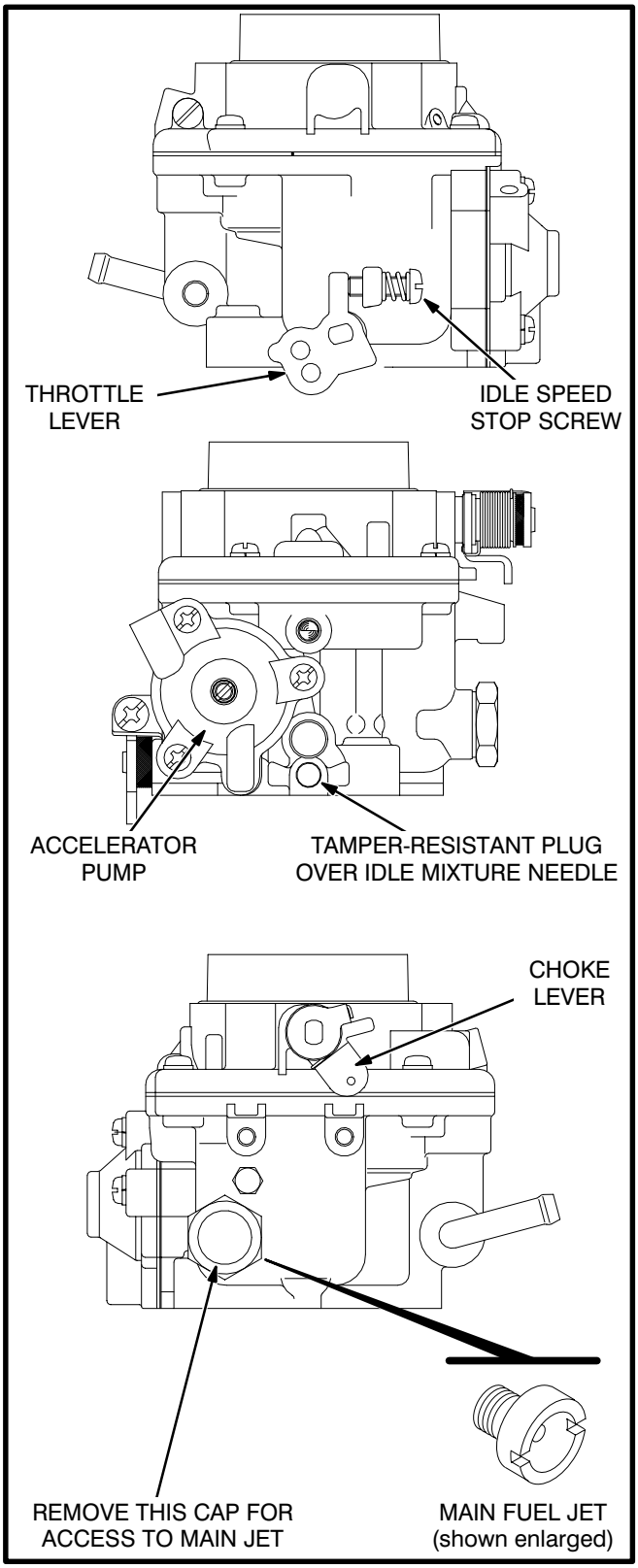


FIGURE 7-5. CARBURETOR

GASOLINE FUEL PUMP

The gasoline fuel pump is of the pulsating-diaphragm type which relies on changes in crankcase vacuum to create a pulsating movement of the pump diaphragm. As the engine pistons move outward, a vacuum is created. This vacuum is transmitted to the pump diaphragm causing it to pull back and suck fuel into the pump. As the engine pistons move inward, crankcase vacuum is reduced and the diaphragm return spring pushes the pump diaphragm forward, forcing fuel through the pump outlet.

The pump is not intended to be rebuilt and should be replaced as a complete assembly.

Fuel Pump Test Procedure

Before testing, make certain the fuel pump vacuum and fuel line connections are tight and free of leaks.

1. Operate the engine at an idle for five minutes to ensure that the carburetor is full of fuel.

   ⚠WARNING ***Ignition of fuel can result in severe personal injury or death. Thoroughly clean up any spilled fuel. Do not smoke or allow any flame, spark, pilot light, or arcing switch or equipment, or other source of ignition near the work area or areas sharing ventilation.***

2. Shut the engine off and remove the fuel inlet line from the fuel pump.
3. Connect a vacuum gauge to the fuel pump inlet using a piece of fuel hose with clamps.
4. Start the engine and allow to idle for at least five seconds. Record the vacuum gauge reading.
5. Move the throttle control to the high idle position. Wait at least five seconds and record the vacuum gauge reading.
6. Shut the engine off and remove the vacuum gauge hose from the fuel pump inlet. Connect the fuel inlet line to the fuel pump.

   ⚠WARNING ***Ignition of fuel can result in severe personal injury or death. Thoroughly clean up any spilled fuel.***

7. Remove the fuel outlet line from the fuel pump.
8. Connect a pressure gauge to the fuel pump outlet using a piece of fuel hose with clamps.
9. Start the engine and allow to idle for at least five seconds. While holding the pressure gauge level with the pump outlet, record pressure gauge reading.
10. Move the throttle control to the high idle position and allow the engine to run for at least five seconds. While holding the pressure gauge level with the pump outlet, record pressure gauge reading.
11. Shut the engine off and remove the pressure gauge hose from the fuel pump outlet. Connect the fuel outlet line to the fuel pump.

Replace the fuel pump if test readings are not within the values specified in Table 7-1.

TABLE 7-1. PULSE PUMP TEST SPECIFICATIONS

ENGINE SPEED	PUMP INLET VACUUM (Minimum)	PUMP OUTLET PRESSURE (Minimum)
Low Idle	2.6 inches of mercury	1.7 psi
High Idle	2.6 inches of mercury	1.7 psi

LPG FUEL SYSTEM

⚠WARNING ***LPG is flammable and explosive and can cause severe personal injury or death. NFPA 58, Section 1.6 requires all persons handling LPG to be trained in proper handling and operating procedures.***

Do not smoke. Keep flames, sparks, pilot lights, electrical arcs and arc-producing equipment, switches and all other sources of ignition well away from LPG equipment and areas sharing ventilation. Keep a type ABC fire extinguisher handy.

LPG "sinks" when it escapes into the air and can accumulate in explosive concentrations. Before disconnecting the LPG fuel line, close the manual fuel shutoff valve at the fuel tank. Make sure the area is well ventilated.

All fittings must be gas tight and pipe threads must be sealed with sealant that is classified for use with LPG.

The LPG carburetor, LPG converter, converter-to-carburetor hose, and solenoid fuel valve comprise the LPG fuel system components that are part of the engine assembly. Refer to Figure 7-6.

LPG Carburetor

The LPG carburetor should not require service and there are no adjustments. A new carburetor is available if replacement is necessary.

⚠WARNING ***Carbon Monoxide (CO) is deadly! The idle mixture screws on the carburetor and gas pressure regulator are factory set and sealed. DO NOT READJUST.***

Note: The user is responsible for meeting indoor carbon monoxide regulations.

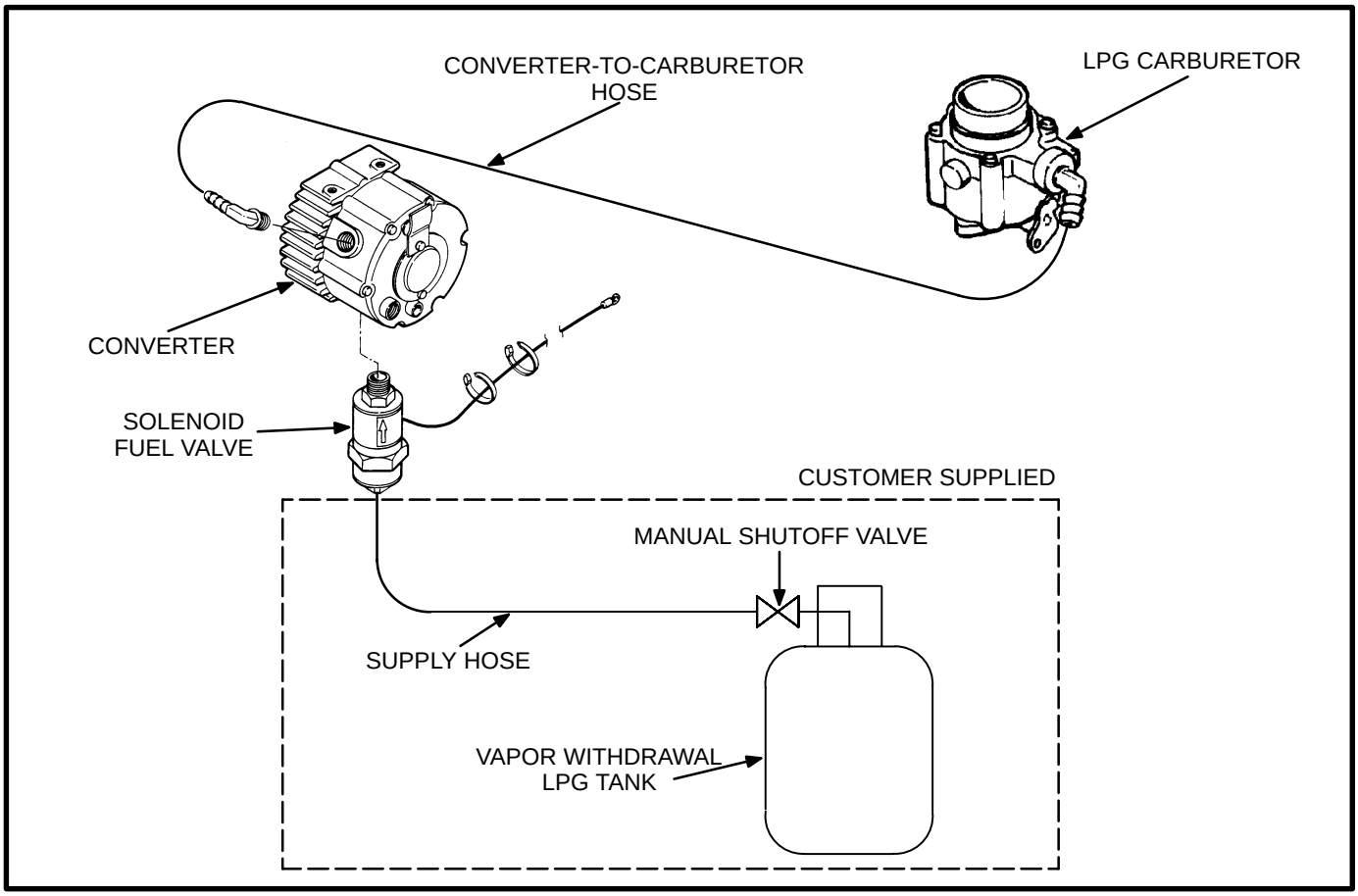


FIGURE 7-6. LPG CARBURETOR AND FUEL SYSTEM DIAGRAM

LPG Converter

The LPG converter regulates gas pressure to the carburetor. It has no replaceable parts or adjustments. The converter is supplied by Onan, but mounted at a location determined by the customer.

Converter-to-Carburetor Hose

The converter-to-carburetor hose is an integral part of the LPG fuel system. Its length is crucial to the proper operation of the engine. If a shorter hose is used, the carburetor will provide a mixture to the engine that is too rich. If a longer hose is used, the mixture will be too lean.

⚠ CAUTION ***The length of the converter-to-carburetor hose is critical for proper engine operation. Do NOT change the length of this hose.***

Solenoid Fuel Valve

Although the converter shuts off LPG when the engine stops, codes do not consider devices of this type (atmospheric-type pressure regulators) as automatic shutoff valves for the purpose of preventing the flow of LPG to the engine when the engine is not running. Therefore, a solenoid operated fuel valve is installed at the inlet of the converter to positively shut off LPG flow when the engine is not running.

The solenoid is controlled by the low oil pressure cutoff switch. This switch is closed during normal engine operation, which keeps the solenoid fuel valve open. When the engine stops, the low oil pressure cutoff switch opens, and the solenoid fuel valve closes.

The positive lead from the solenoid fuel valve is connected to the B+ terminal on the ignition coil. See Figure 9 on Page 8-7.

Operation

Referring to Figure 7-6 on Page 7-6, operation of the LPG fuel system is as follows:

1. During the starting mode, the low oil pressure switch is bypassed. Among other things, this activates the solenoid fuel valve and makes LPG available to the engine.
2. Once started, the low oil pressure switch closes and the starting mode bypass is removed. The solenoid fuel valve remains open, allowing fuel to flow to the converter.
3. The LPG converter regulates the gas pressure delivered to the carburetor.

Converter Test

Use compressed air and a pressure gauge to test the regulator as follows. Refer to Figure 7-7.

1. Connect a pressure gauge to the test port on the side of the converter.
2. Connect a source of compressed air [at least 80 psi (550 kPa)] to the inlet opening and open the air pressure valve.
3. If the primary valve is sound, the gauge will indicate approximately 1.5 psi (10.3 kPa) and the pressure will remain constant. Fluctuating pressure indicates a leaking primary valve seat.
4. Close the air pressure valve and observe the pressure gauge. The pressure should remain constant. If the pressure drops, the secondary valve seat is leaking.
5. Replace the converter if it does not pass either test.

Whenever fuel line fittings must be removed for the testing of various components and then reconnected, only qualified personnel should conduct the tests.

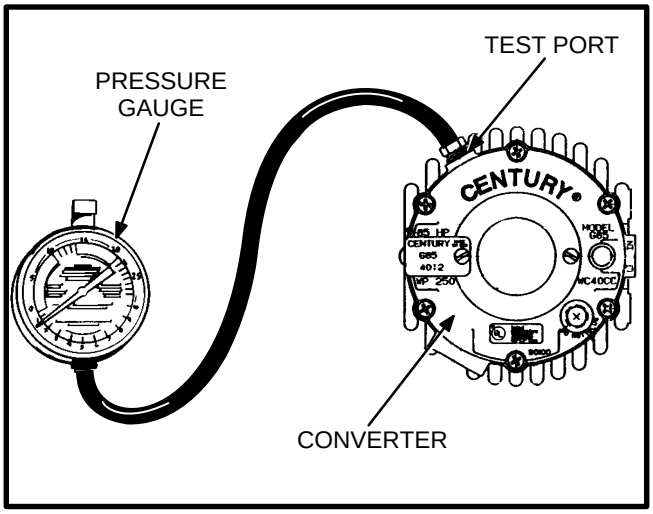


FIGURE 7-7. TESTING THE LPG CONVERTER

AUTO SHUTDOWN SYSTEM—FLOORCARE ENGINES

⚠WARNING ***If the emissions warning light comes on and the engine shuts down, emissions of deadly carbon monoxide gas could be excessive. See Troubleshooting (p. 7-9) and repair the engine as necessary.***

An LPG engine for floorcare equipment has an exhaust emissions control system consisting of a catalytic muffler, oxygen sensor, auto shutdown control unit, LPG fuel cutoff solenoid, LPG converter (regulator) and LPG carburetor (Figure 1-1). The emissions warning light on the control unit (Figure 7-8) comes on when the control unit senses that the exhaust emission levels (O_2) are out of specification. The control unit shuts down the engine approximately one minute after the light comes on.

Proper Operation and Maintenance

- Run the equipment only in well ventilated areas. Refer to *Industrial Ventilation—A Manual of Recommended Practice* published by the American Conference of Governmental Industrial Hygienists. *The user is responsible for complying with indoor carbon monoxide regulations.*
- Attach a CO monitor to the equipment.
- Keep air cleaners clean. *Do not apply oil.*
- Do not run the engine if there is an exhaust leak. A leak can cause gases to bypass the catalytic element or change the calibration of the auto shutdown system allowing excessive emissions of CO.

  ⚠WARNING ***A leaky exhaust system can result in higher levels of deadly carbon monoxide gas emissions. Do not operate the equipment if there is an exhaust leak.***

- Do not tip the engine to either side. Tipping the engine can allow oil to enter the air cleaner and cause the engine to run rich and shut down.
- Do not modify or disable any engine function or system.
- Keep to the maintenance schedule in the Operator's Manual.

Testing The Oxygen Sensor

Measure DC voltage between the Ground (white) and O_2 Out (black) leads of the oxygen sensor (Figure 7-8) while the engine is running.

- If voltage ranges between 0.3 to 0.7 VDC, the O_2 sensor does not need to be replaced.
- If voltage is consistently high, the engine is running rich.
- If there is no voltage, check all connections first and then replace the O_2 sensor, if necessary.

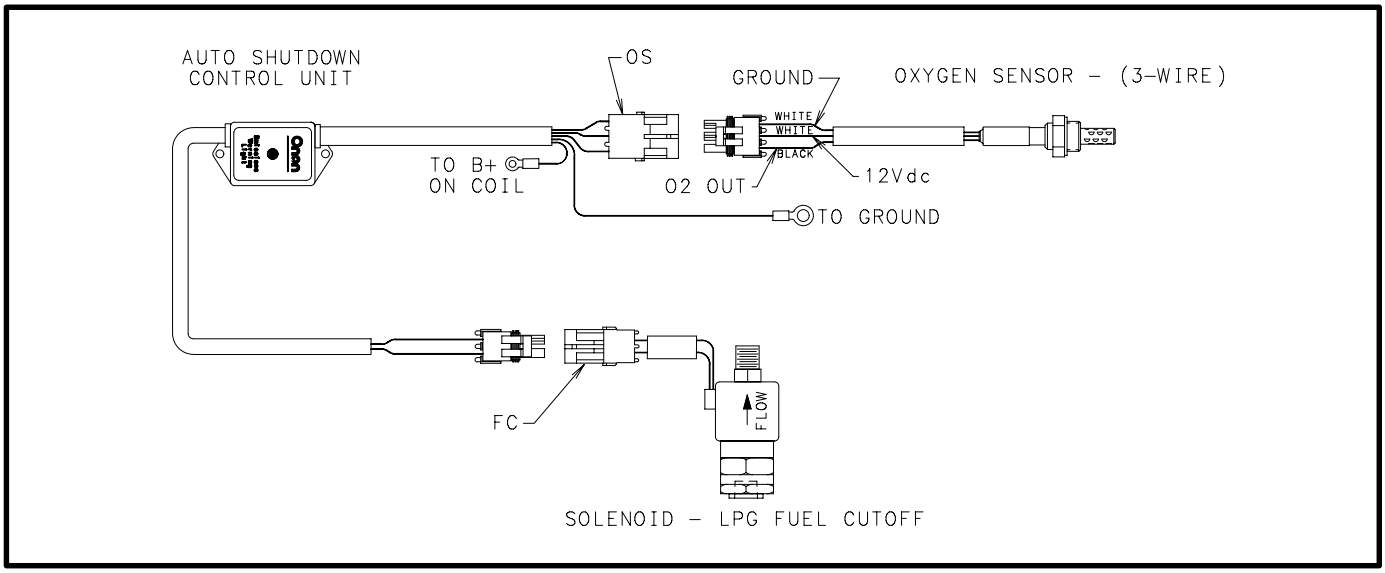


FIGURE 7-8. AUTO SHUTDOWN COMPONENTS

Troubleshooting

Table 7-2 is a guide for troubleshooting to help you quickly diagnose fuel system problems. If the engine fails to start or keeps shutting down, time can be saved by first checking the following:

1. That the manual fuel shutoff valve is open.
2. That the LPG tank is at least half full.
3. That the engine is connected to the vapor-withdrawal fitting on the LPG tank.
4. That the battery cable connections are clean and tight.
5. That the spark plug cables are connected the spark plugs and the ignition coil.
6. That the engine has the proper level of oil.
7. That the ring terminal on the black lead from the auto shutdown control unit is secured by the grounding screw on the block.
8. That the ring terminal on the red lead from the auto shutdown control unit is secured to the ignition coil B+ terminal.
9. That all wiring connectors are secure.
10. Whether maintenance is due: changing oil/oil filter, spark plugs, air filter, spark arrestor, etc.

TABLE 7-2. FUEL SYSTEM TROUBLESHOOTING

⚠ WARNING ***Some engine service procedures present hazards that can result in severe personal injury or death. Only qualified service personnel with knowledge of fuels, electricity, and machinery hazards should perform genset service. See Safety Precautions.***	
PROBLEM	**CORRECTIVE ACTION**
Engine does not crank	1. Check for an engine harness fuse and replace it if blown. 2. Check battery voltage while attempting to crank. If less than 6.5 volts, recheck battery connections and check and recharge the battery. 3. Check for proper connections between the key switch and engine and repair as necessary. See Figure 8-7, 8-8, or 8-9. 4. Check for B+ at starter solenoid terminal B. Repair the engine harness if there is no B+ at the terminal. If there is B+, service the starter as required.
Engine cranks but does not start	1. Open the manual fuel shutoff valve if closed. 2. Fill the LPG tank if not at least half full. 3. Check battery voltage while cranking. If less than 6.5 volts, recheck battery connections and check and recharge the battery. 4. Check for B+ at the ignition coil B+ terminal and repair or replace the key switch or wiring if there is no B+. 5. Check and reconnect or repair all wiring in the auto shutdown system. 6. Disconnect the fuel shutoff solenoid lead connector and measure coil resistance. Replace the fuel cutoff solenoid if coil resistance is not 10-20 ohms. 7. Bypass the auto shutdown control unit. If the engine starts, replace the auto shutdown control unit.
The light comes on and the engine shuts down in approximately one minute	1. Replace the air cleaner foam wrapper and paper element if oily. Do not oil the new foam wrapper. 2. Check for exhaust leaks. Repair and replace parts and gaskets as necessary. 3. Test the oxygen sensor and replace if necessary (p. 7-8). 4. Test and replace the LPG converter if necessary (p. 7-7). 5. Replace the carburetor (p. 7-4). 6. Repair a worn engine.

GOVERNOR SENSITIVITY

These engines are adapted for use where a wide range of speed settings is desired. Engine speed is controlled between minimum and maximum by moving the throttle level until the desired speed is reached.

Check the governor arm, spring, linkage, and throttle shaft for a binding condition or excessive wear at connecting points. A binding condition will cause the governor to act slowly and regulation to be poor. Excessive wear will cause a hunting condition and regulation to be erratic. Work the governor arm back and forth several times by hand while the engine is idling to check for above conditions.

The governor linkage should be set up as follows (see Figure 7-9):

1. The governor spring should be placed in the second hole from the end in the governor control arm. The governor spring should be placed in the third hole away from the pivot in the governor arm. Moving the spring away from the pivot will decrease sensitivity; moving the spring closer to the pivot will increase sensitivity.
2. The governor control rod should be placed in the middle hole of the governor arm.

If adjustments were made, recheck the carburetor rpm setting. Adjust if necessary.

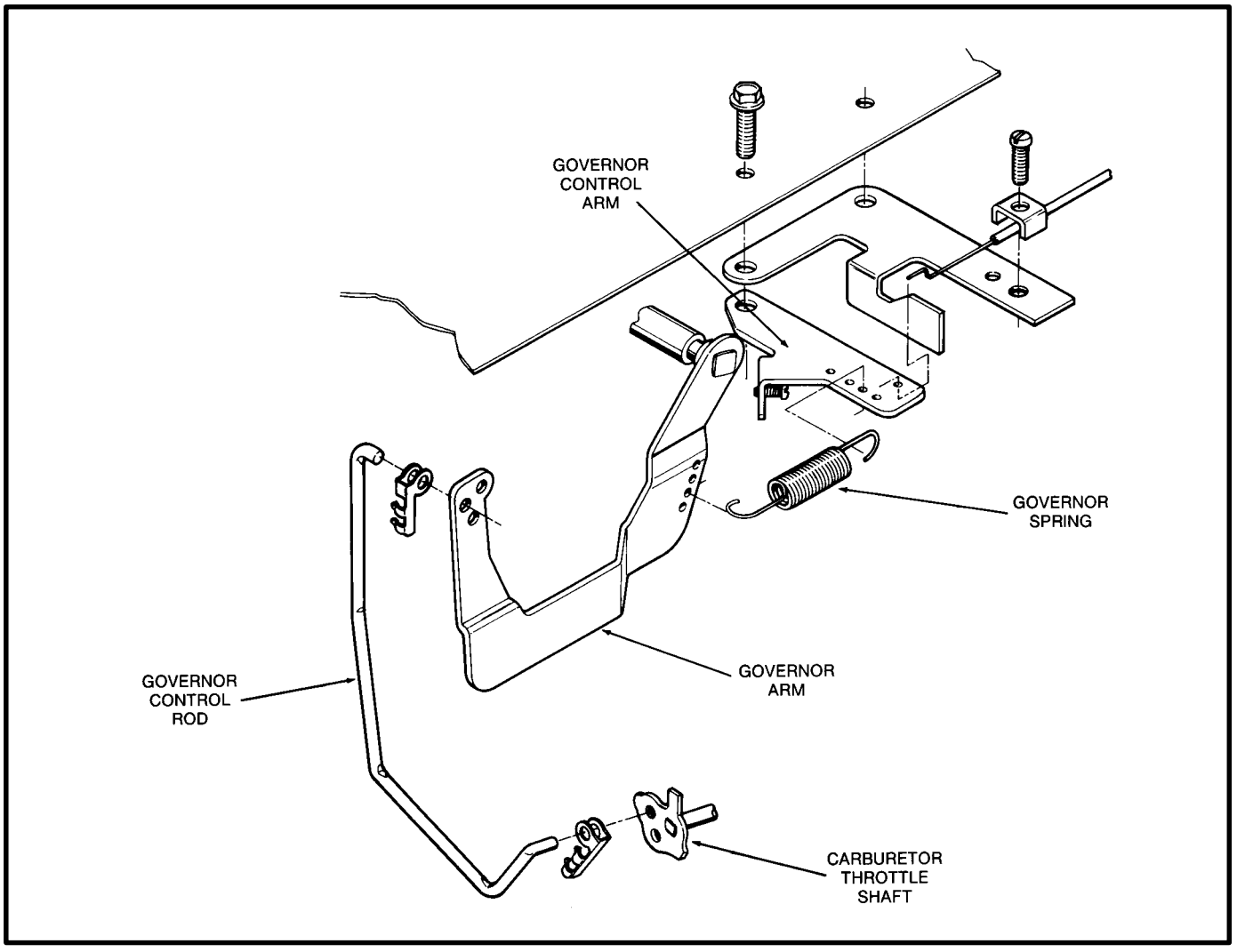


FIGURE 7-9. GOVERNOR LINKAGE

8. Electrical System

IGNITION SYSTEM

Description

This engine is equipped with an electronic battery ignition system. Both spark plugs fire simultaneously, thus the need for a distributor is eliminated. The electronic ignition module is located on the engine gear cover below the flywheel. The module receives a timing signal from magnets within the trigger ring which rotates with the engine crankshaft (see Figure 8-1).

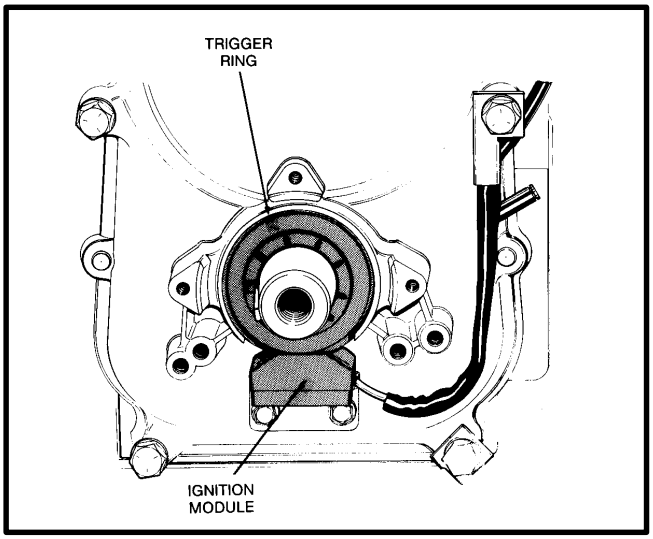


FIGURE 8-1. IGNITION MODULE AND TRIGGER RING

System Testing

If the electronic ignition is suspected of malfunctioning, proceed as follows:

1. Check all electrical connections to be sure they are clean and tight. If all connections are good and wiring is intact, go to Step 2.
2. Refer to *Ignition Coil* section on Page 8-4 to test the coil for proper resistance. If coil checks out good, go to Step 3.

   ⚠WARNING ***The electronic ignition produces voltage which can cause electrical shock. Do not touch electrical components or wire while ignition is on.***

   ⚠WARNING ***Accidental starting of the engine can result in severe personal injury or death. Remove spark plugs before proceeding.***

   ⚠WARNING ***Ignition of cylinder gases can cause severe personal injury. Ground spark tester away from spark plug holes.***
3. Pull the spark plug wires off of the spark plugs and remove the spark plugs. Connect an approved spark tester to each of the spark plug wires and ground them away from spark plug holes. Turn the key on and crank engine over for 5 seconds while watching for a spark. If a spark occurs regularly, the problem is not in the ignition system. If no spark occurs, go to Step 4.

⚠ CAUTION ***Incorrect wiring can cause electronic ignition damage. Do not attach any lead or jumper with power (such as B+) to coil negative terminal.***

4. Connect a jumper lead directly from the positive battery terminal to the positive (+) coil terminal (smaller diameter of the two threaded posts). Crank engine over while watching for a spark. If a spark occurs, the problem is in the low oil pressure cut out switch (if equipped) or related wiring, the lubricating system (low oil pressure), or in the other circuitry bringing voltage to the coil. Refer to *Engine Control Circuitry* on Page 8-8. If no spark occurs, go to Step 5.
5. Connect the positive probe of a 12-volt test light to the negative (-) coil terminal (the larger diameter of the two threaded posts) and the negative probe to a good engine ground. Turn the key to the START position to crank the engine. The test light should flash on and off. If the test light remains on or doesn't light at all, replace the ignition module.

⚠ CAUTION ***Incorrect wiring can cause electronic ignition damage. Do not attach any lead or jumper with power (such as B+) to coil negative terminal.***

6. If the trigger ring (see Figure 8-1 on Page 8-1) was removed for some reason, take care to reinstall it correctly on the crankshaft. The side of the ring with the part number on it must be readable when installed on the crankshaft before installing the flywheel (the number must face the flywheel). Do not push the ring up against the seal.
7. Install the spark plugs and wires. If the ignition module is being replaced, be sure to connect the red lead from the new ignition module to the positive (+) terminal of the coil, and the black lead from the module to the negative (-) terminal of the coil.

Ignition Timing

The ignition timing is preset at the factory and is not adjustable. For troubleshooting purposes, it is possible to make an approximate check of the ignition timing using reference marks on the blower housing and a chaff screen bolt (see Figure 8-2). This check can be performed by a continuity test.

Continuity Test. A continuity test can be performed as follows:

1. Pull the spark plug wires off of the spark plugs and remove the spark plugs.

   ⚠WARNING ***Accidental starting of the engine can result in severe personal injury or death. Remove spark plugs before proceeding.***

2. Turn the ignition on.
3. Connect a voltmeter between the negative (-) coil terminal (larger diameter of the two threaded posts) and a good engine ground.

   ⚠WARNING ***The electronic ignition produces voltage which can cause electrical shock. Do not touch electrical components or wire while ignition is on.***

4. Rotate the flywheel slowly by hand in the clockwise direction until the voltmeter reading switches from approximately 1 volt to battery voltage. At this point, one of the chaff screen bolts should lie between the two timing marks on the blower housing. To recheck the timing, the flywheel must be rotated another complete revolution in the clockwise direction. Moving the flywheel back and forth across the reference timing mark will not activate the electronic ignition control.
5. Install the spark plugs and wires.

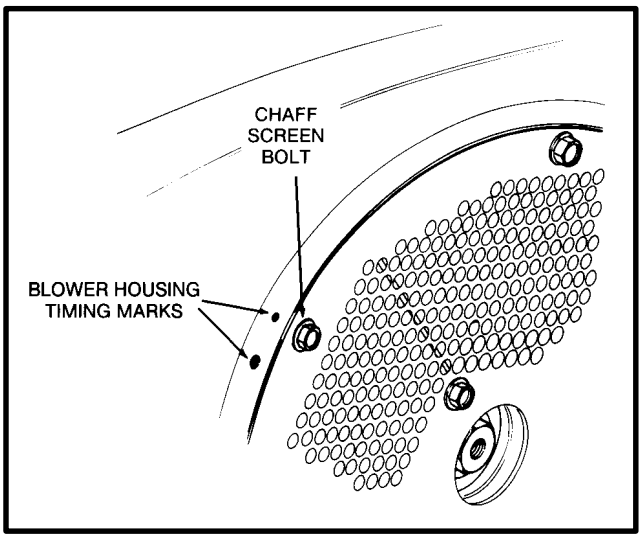


FIGURE 8-2. IGNITION TIMING MARKS

Ignition Coil

To test the primary and secondary windings within the ignition coil, first make sure the ignition power is off and the coil is at room temperature [70°F (21°C)].

1. Use a Simpson 260 VOM or equivalent.
2. Place the black lead on the negative (-) coil terminal and the red lead on the positive (+) coil terminal. Primary resistance should read between 2.90 and 3.60 ohms. See Figure 8-3.
3. Change the resistance setting on ohmmeter. Place ohmmeter leads inside of the spark plug cable holes as shown in Figure 8-3. Secondary resistance should read between 14,500 and 19,800 ohms
4. If either of the above resistances are not within specification, replace the coil.

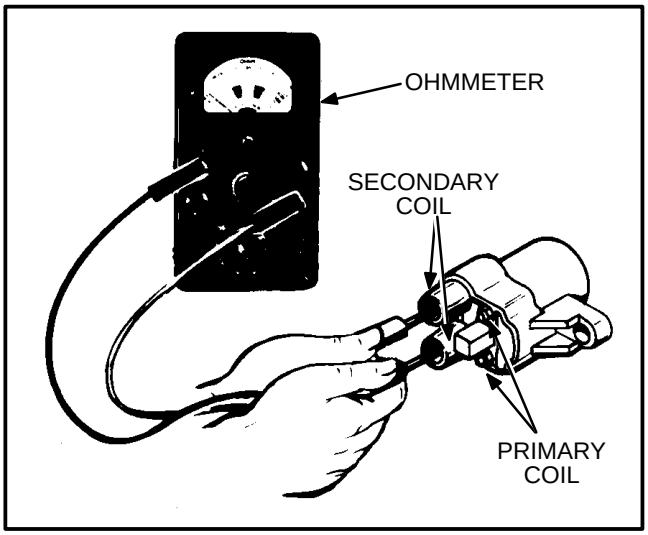


FIGURE 8-3. COIL TEST

Spark Plugs

Check or replace spark plugs as recommended in the *Periodic Maintenance Schedule* in the Operator's Manual. Replace spark plugs that show signs of fouling or electrode erosion.

BATTERY

Inspection

⚠WARNING ***Ignition of explosive battery gases can result in severe personal injury. Ventilate battery compartment and do not allow any spark, flame, pilot light, lit cigarette, or other ignition source near the battery.***

Check battery cells with a hydrometer as shown in Figure 8-4. The specific gravity reading should be between 1.260 and 1.290 at 77°F (25°C).

If one or more cells are low on water, add distilled water and recharge. Keep the battery case clean and dry. An accumulation of moisture or dirt will accelerate discharge and battery failure.

Keep the battery terminals clean and tight. Push the cable terminal down flush with or slightly below the top of the battery post as shown in Figure 8-5. After making connections, coat the terminals with a light application of petroleum jelly or grease to retard corrosion.

Poor contact at the battery cable connections is often a source of trouble. Make sure battery cables are in good condition and that contacting surfaces are clean and tightly connected. Do not reverse battery leads. Use recommended battery tools when disconnecting leads to avoid mechanical battery damage.

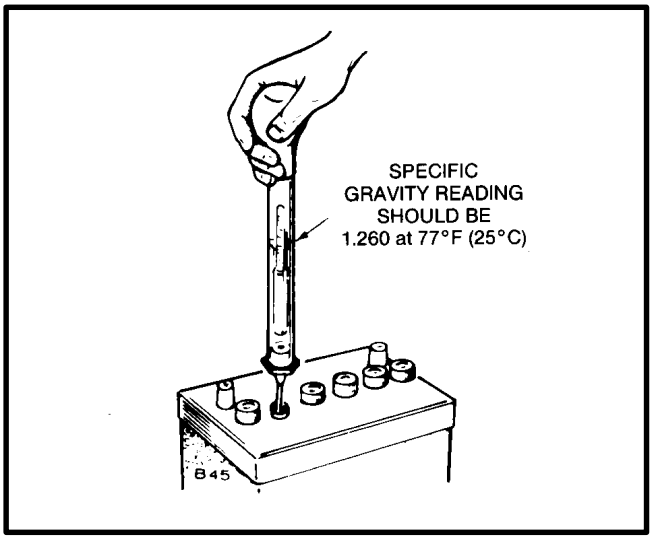


FIGURE 8-4. SPECIFIC GRAVITY TEST

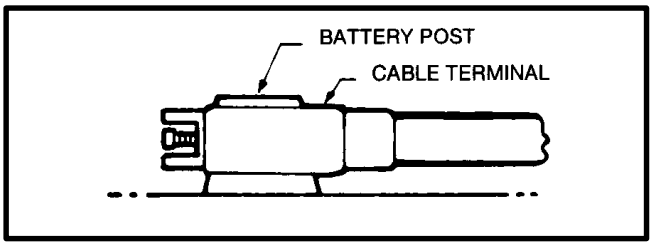


FIGURE 8-5. BATTERY CABLE CONNECTION

Jump Starting

Occasionally, it may be necessary to jump start (charge) a weak battery using a charged booster battery. If jump starting is necessary, the following procedure is recommended to prevent starter damage, battery damage, and personal injuries.

1. Disconnect engine load.
2. Use a battery of the same voltage (12V) as is used with your engine.
3. Attach one end of the positive booster cable (red) to the positive (+) terminal of the booster battery. Attach the other end on the positive cable to the positive (+) terminal of your engine battery.

   ⚠WARNING ***Electrical arcing can cause severe personal injury. Do not allow positive and negative cable ends to touch.***

4. Attach one end of the negative booster cable (black) to the negative (-) terminal of the booster battery. Attach the other end of the negative cable to a solid chassis ground on your engine.
5. Jump starting in any other manner may result in damage to the battery or the electrical system.

   ⚠WARNING ***Jump starting a battery incorrectly can cause either battery to explode, resulting in severe personal injury or death. Do not allow any spark, flame, pilot light, lit cigarette, or other ignition sources near the battery. Do not jump start a frozen battery.***

6. Turn ignition switch to START to start engine.

   ⚠CAUTION ***Overcranking the engine can cause starter damage. Do not engage starter for longer than 30 seconds. If engine does not start, allow 5 minutes for starter to cool between cranking intervals.***

FLYWHEEL ALTERNATOR

Description

This unit is equipped with a permanent magnet flywheel alternator and solid-state voltage regulator-rectifier (see Figure 8-6). As with all solid-state electrical units, precautions are necessary when servicing.

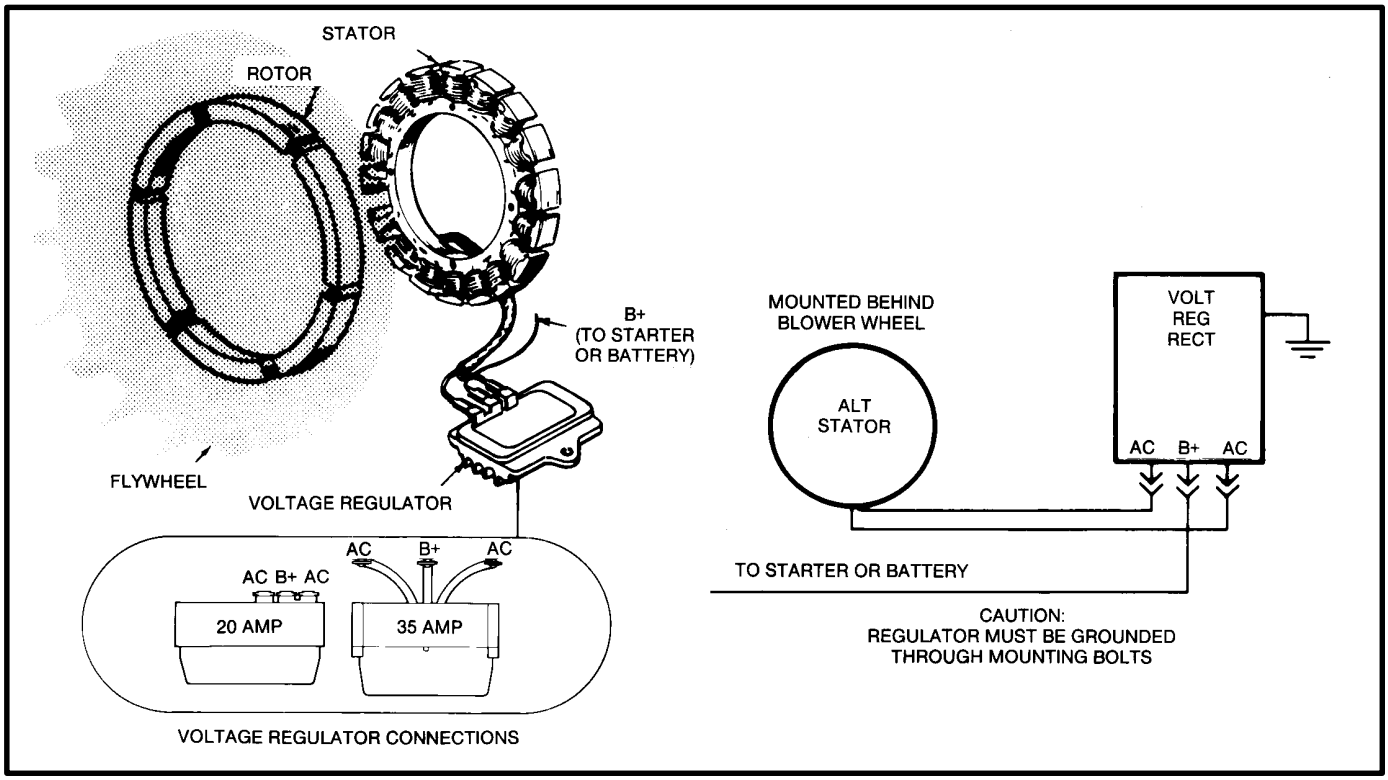


FIGURE 8-6. FLYWHEEL ALTERNATOR SYSTEM

⚠ CAUTION ***Reversing positive and negative battery connections or allowing engine to run without being connected to the alternator will result in engine electrical system damage. Do not switch battery connections or allow engine to run without being connected to the alternator.***

Weak ignition spark or a discharged battery indicates trouble in the charging system. Before testing the engine's changing system, always check the battery for serviceability.

Keep these points in mind when testing or servicing the flywheel alternator:

1. Be sure the engine is being run long enough and fast enough to recharge the battery after each start. Charging system tests require a fully charged battery. Alternator output is reduced in direct proportion to engine rpm. Also, the power required for accessories reduces the power available to recharge the battery.
2. The regulator-rectifier has built-in protection against open circuits or short circuits on the alternator output (B+) terminal. Either condition will cause the regulator-rectifier to shut off and appear as if it is not functioning. Prior to checking the regulator-rectifier, check all wiring between the regulator-rectifier B+ terminal and the battery positive (+) terminal to assure it is free of open circuits, resistances, or short circuits. Also, if the battery is extremely discharged it may have insufficient power to "turn on" the regulator-rectifier.
3. If your unit has a regulator-rectifier plug (connector), be sure it is inserted properly. The plug must bottom in the receptacle; this eliminates any resistance due to a poor connection. Keep clean and tight.
4. Make sure the alternator stator leads are not shorted together.
5. Be sure the regulator-rectifier has a good ground connector. The mating surface for mounting must be clean and the fasteners tightened properly.
6. Never reverse the battery leads

When the engine is running between 1800 to 2600 rpm, observe the panel ammeter (if not already equipped, connect a test ammeter). If no charging is evident, proceed with the *Output Test.*

Output Test

Use a volt-ohmmeter, such as the Simpson 370, when testing the charging system.

1. Check the battery voltage when the engine is not running. If not within the specifications in Table 8-1, charge the battery before proceeding to Step 2.

TABLE 8-1. TESTING 20- AND 30-AMPERE SYSTEMS

	BASIC TEST			
	BATTERY	**REGULATOR**	**STATOR AC VOLTAGE**	**STATOR RESISTANCE**
PROCEDURE	Refer to *Output Test*	Refer to *Output Test*	Refer to *Output Test*	Refer to *Output Test*
20-AMP SYSTEM	12 to 13 VDC	13.6 to 14.7 VDC	29 VAC @ 1800 rpm approximately 57 VAC @ 3600 rpm approximately	0.10 to 0.19 ohms
35-AMP SYSTEM	12 to 13 VDC	13.6 to 14.7 VDC	24VAC @ 1800 rpm approximately 47 VAC @ 3600 rpm approximately	0.06 to 0.10 ohms

2. With the engine running, check the battery terminal voltage (regulator output) using a DC voltmeter. The voltage output should be within the values specified in Table 8-1 on Page 8-7. If the voltage is greater than specified, replace the regulator-rectifier assembly. If the voltage is less than specified, proceed to Step 3.
3. Examine all wires for loose, corroded, broken connections, short circuits, etc. Check fuses. Repair, as needed, to assure complete circuits from the regulator-rectifier B+ terminal to battery positive (+) terminal and from the battery negative (-) terminal to the regulator-rectifier case. If the battery voltage remains low with the engine running, proceed to Step 4.
4. Disconnect the plug from the regulator-rectifier and test the AC voltage at the plug with the engine running. If the AC voltage reads more or less than specified in Table 8-1 on Page 8-7, proceed to Step 5. If the AC voltage is as specified but the DC voltage is low, replace the regulator-rectifier.
5. Use the Rx1 scale on the ohmmeter for detecting an open or ground in the stator (engine not running). Disconnect the plug from the regulator-rectifier. Connect one ohmmeter test lead to a stator wire, and connect the other test lead to ground. The reading should show an open (no continuity). If it doesn't, that stator must be replaced. If the reading shows no continuity, connect one ohmmeter lead to each wire coming from the stator. Refer to Table 8-1 on Page 8-7 for resistance specifications. If the resistance is not as specified, replace the stator. If the stator resistance readings are as specified and the windings are not shorted or open, low AC voltage may be due to loss of magnetism. If so, blower wheel assembly must be replaced.

ENGINE CONTROL

Gasoline Models

Gasoline versions of Performance Series engines may or may not have oil pressure switches as an option. Figure 8-7 on Page 8-9 shows a typical engine wiring diagram with an optional low oil pressure warning light or horn. Figures 8-8 and 8-9 on Pages 8-9 and 8-10, respectively, show typical engine wiring diagrams with an optional oil pressure switch that automatically shuts off the engine in a no oil pressure condition.

These typical wiring diagrams show the basic wiring necessary for operation of the engine. Your engine may differ in circuitry and features depending on how the equipment manufacturer chose to configure the final product.

LPG Model (P248V)

Although the converter shuts off LPG when the engine stops, codes do not consider devices of this type (atmospheric-type pressure regulators) as automatic shutoff valves for the purpose of preventing the flow of LPG to the engine when the engine is not running. Therefore, a solenoid operated fuel valve is installed at the inlet of the converter to positively shut off LPG flow when the engine is not running.

The solenoid is controlled by the low oil pressure cutoff switch. This switch is closed during normal engine operation, which keeps the solenoid fuel valve open. When the engine stops, the low oil pressure cutoff switch opens, and the solenoid fuel valve closes. Figure 8-9 on Page 8-10 shows the wiring for the P248V, including the solenoid fuel valve.

The positive lead from the solenoid fuel valve is connected to the B+ terminal on the ignition coil.

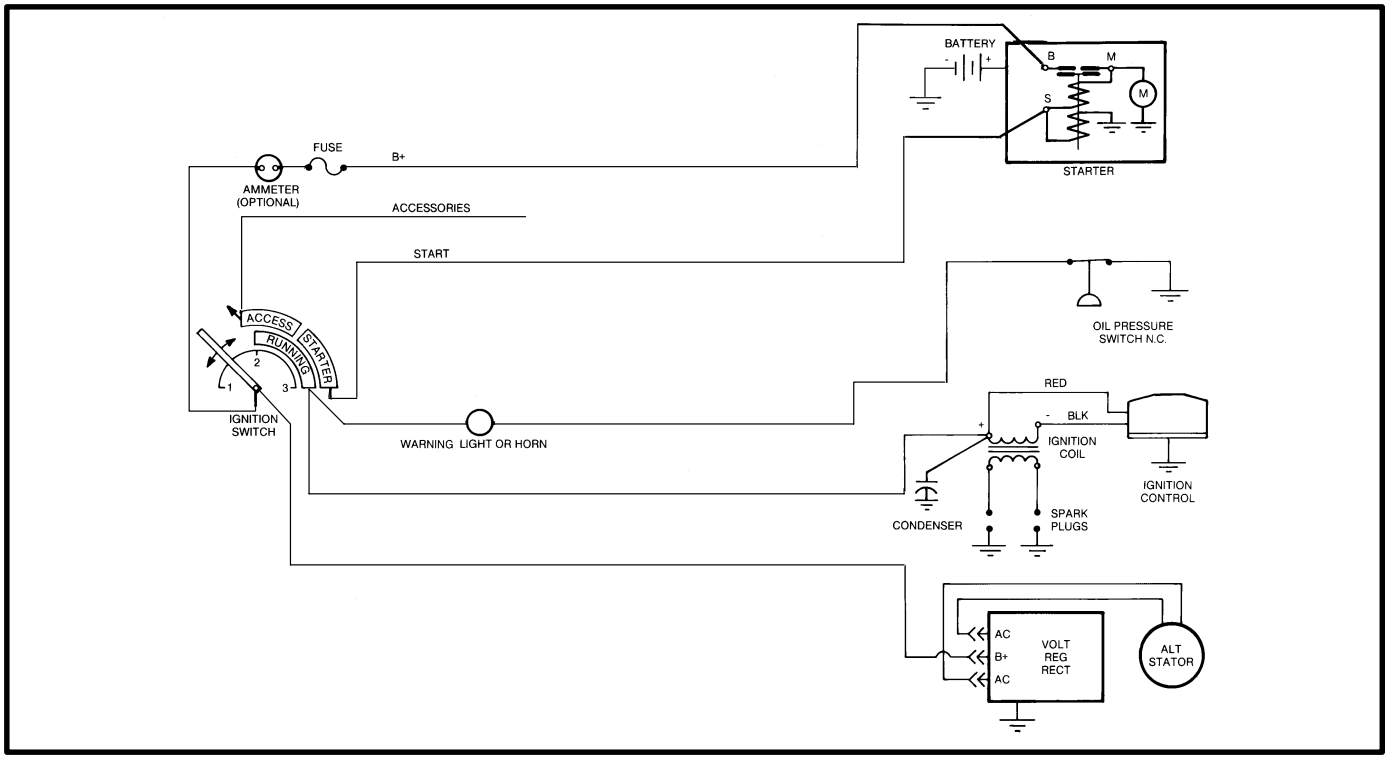


FIGURE 8-7. TYPICAL WIRING DIAGRAM WITH LOW OIL PRESSURE WARNING LIGHT/HORN

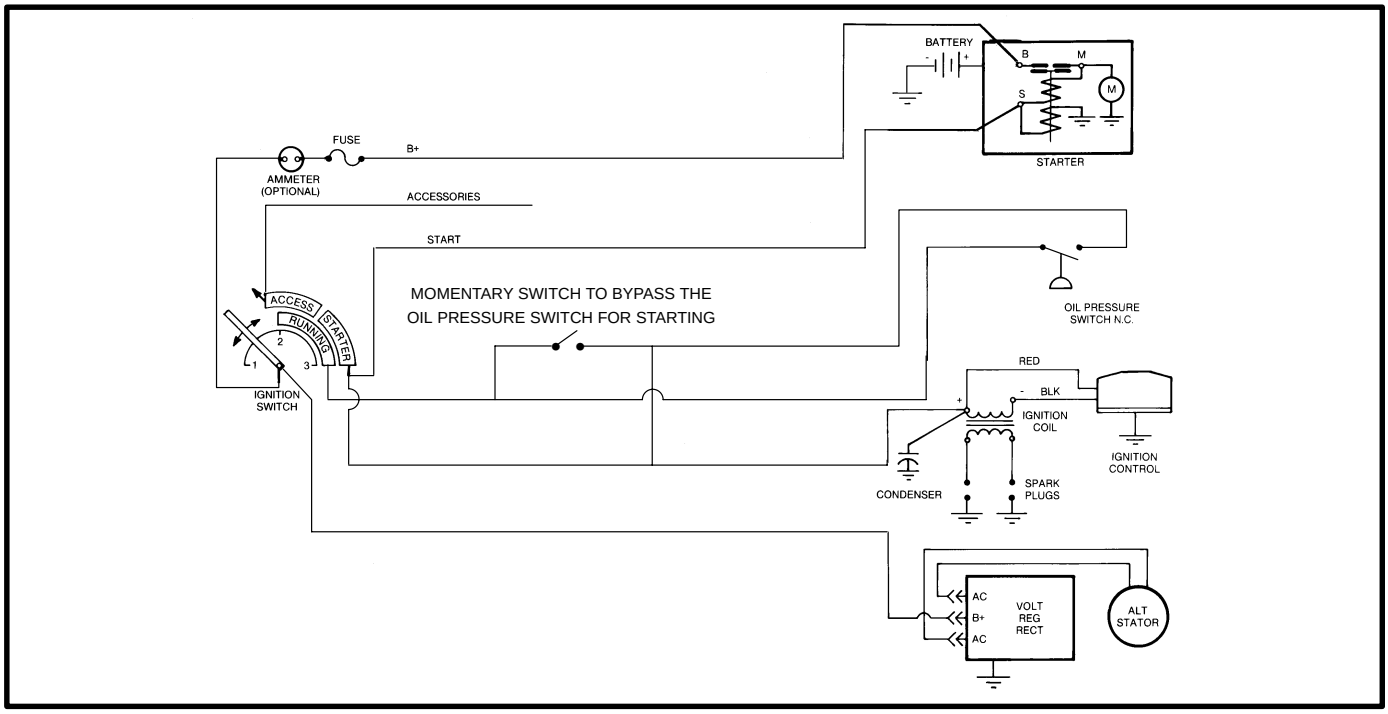


FIGURE 8-8. TYPICAL WIRING DIAGRAM WITH LOW OIL PRESSURE AUTOMATIC SHUTDOWN (MOMENTARY CONTACT VERSION)

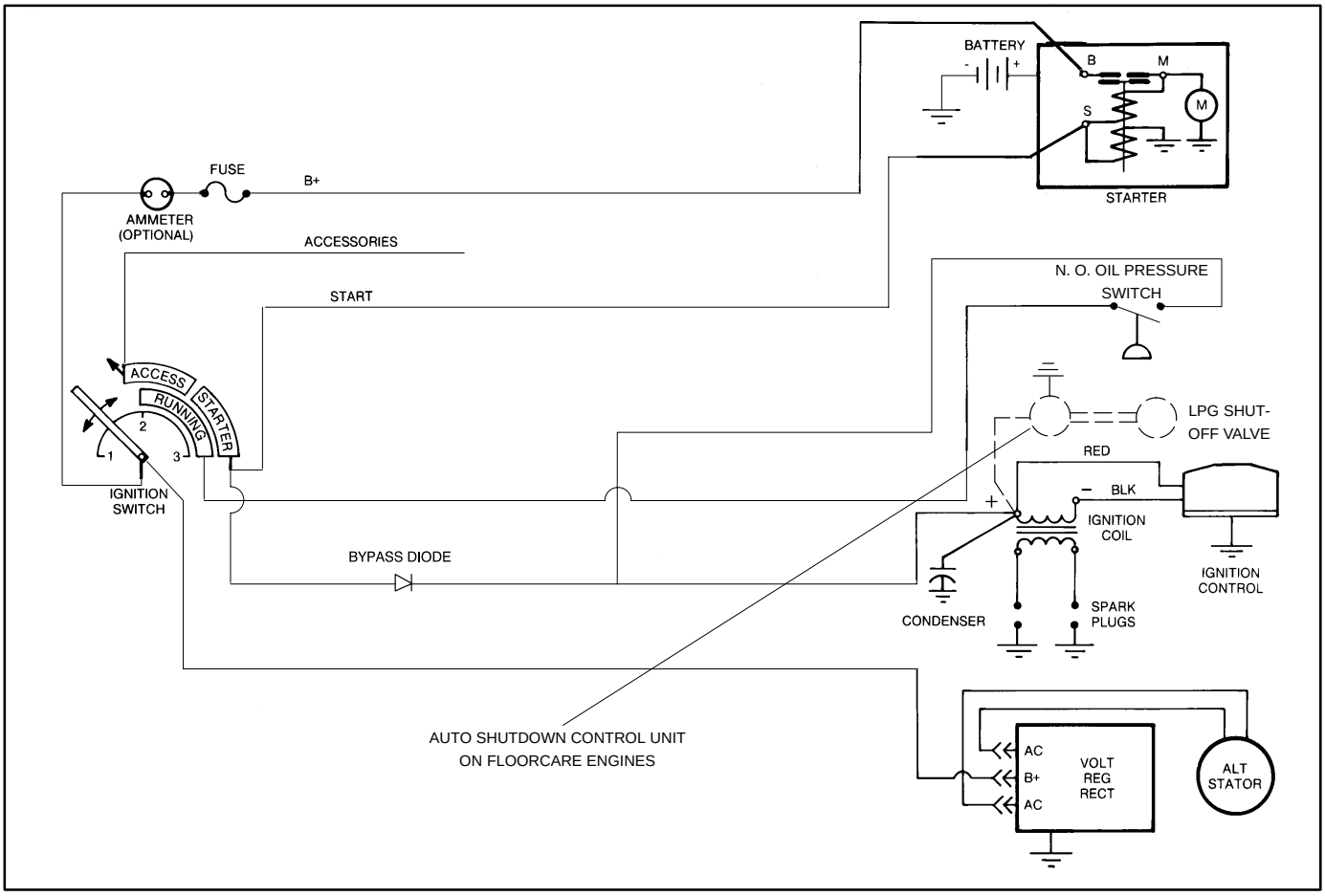


FIGURE 8-9. TYPICAL WIRING DIAGRAM WITH LOW OIL PRESSURE AUTOMATIC SHUTDOWN (DIODE VERSION)

9. Starting System

ELECTRIC STARTER

Normally, the starter requires little or no service other than possible brush replacement. However, if through accident or misuse, the starter requires service or overhaul, the following will provide the information necessary to perform this service.

Service

When starting the engine, note the starter motor action. The pinion gear should mesh quickly with the flywheel ring gear and spin the engine. Once the engine starts and the solenoid opens, the starter should disengage and stop. If the starter cranks the engine slowly, or not at all, check the start circuit components. Failure to crank is normally caused by a low battery charge, defective battery cables, corroded or poor connections, or low temperatures. If after checking these variables, the starter continues to crank slowly, the starter must be removed and repaired.

Starter Removal

1. Remove both battery cables from the battery, negative (-) cable first.

***WARNING** Accidental starting of the engine can result in severe personal injury or death. Disconnect the negative battery cable and spark plug wires while servicing engine, controls, or associated equipment.*

***WARNING** Arcing can ignite the explosive hydrogen gas given off by batteries, causing severe personal injury. Arcing can occur if the negative (-) battery cable is connected and a tool being used to connect or disconnect the positive (+) battery cable accidentally touches the frame or other grounded metal part of the set. To prevent arcing, always remove the negative (-) cable first, and reconnect it last.*

2. Disconnect battery cables and electrical lead wires from the starter.
3. Remove the starter motor.

Starter Disassembly

Refer to Figure 9-1 when performing the following steps:

1. Remove the “M” terminal nut and wire lead from the starter motor. Refer to Figure 9-8 on Page 9-6.

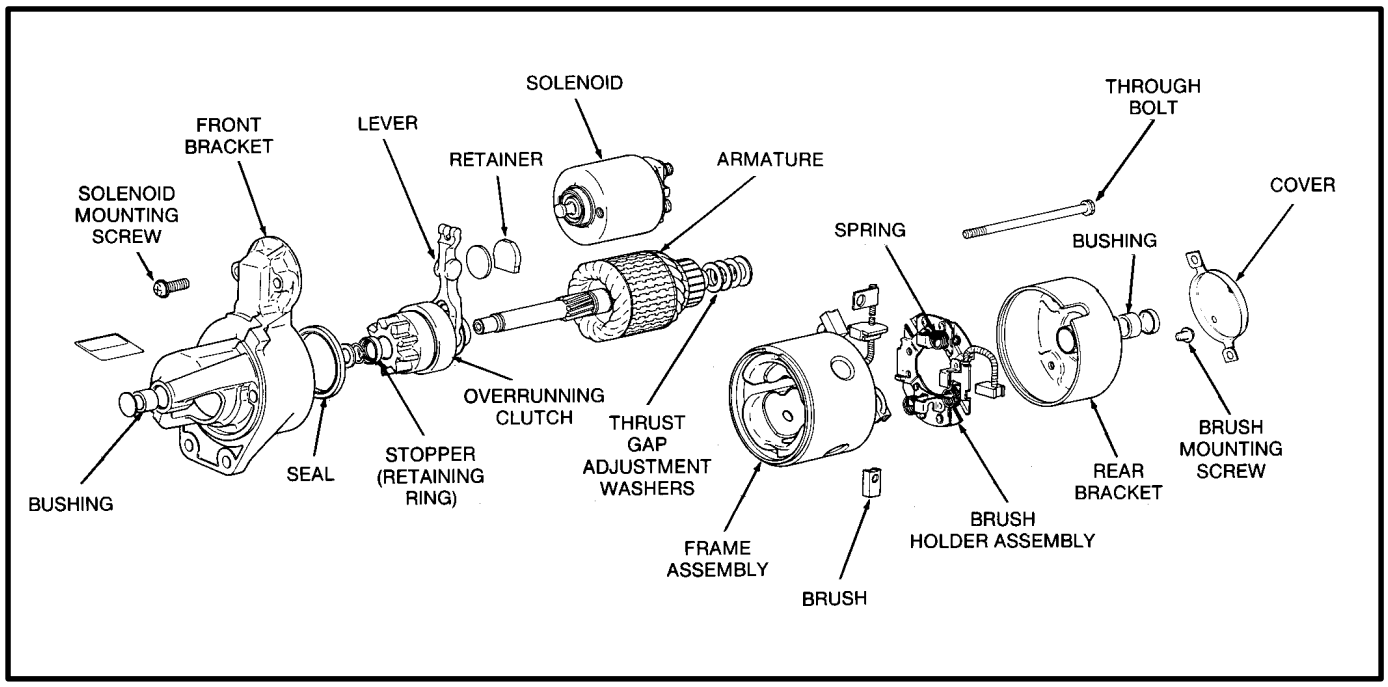


FIGURE 9-1. STARTER MOTOR

2. Remove the two solenoid mounting screws, then remove the solenoid.
3. Scribe a mark across the frame and rear bracket to aid in assembly. Remove the two through bolts.
4. Remove the rear bracket and frame assembly.
5. Carefully remove the armature and lever from the front bracket. Note direction of lever and retainer.
6. Remove the two brush mounting screws, then remove the rear bracket.
7. Remove the brush holder assembly from the frame by pulling the brushes out.
8. Push the stopper toward the pinion and remove the snap ring. See Figure 9-2.
9. Remove the stopper and overrunning clutch from the armature shaft.
10. Inspect the starter for damaged or worn parts.
11. Repair or replace all damaged or worn parts as needed.

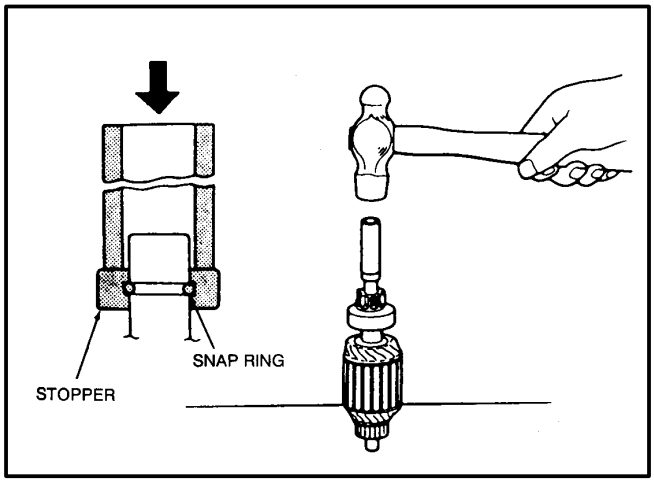


FIGURE 9-2. REMOVING OVERRUNNING CLUTCH

Starter Assembly

1. Install the seal in the nose housing.
2. Install the overrunning clutch on the armature shaft.
3. Slide the stopper on the armature shaft.
4. Position the snap ring in the groove in the armature shaft.
5. Pull the stopper all the way over the snap ring as shown in Figure 9-3.It may be necessary to tap the snap ring into the groove with a punch while maintaining tension on the stopper.
6. When the starter motor is assembled, apply grease to each of the following points (the recommended grade is Multemp PS No. 2):
    - Armature shaft spline
    - Both bushings (at both ends of armature)
    - Stopper on armature shaft
    - Pinion gear
    - Sliding portion of lever

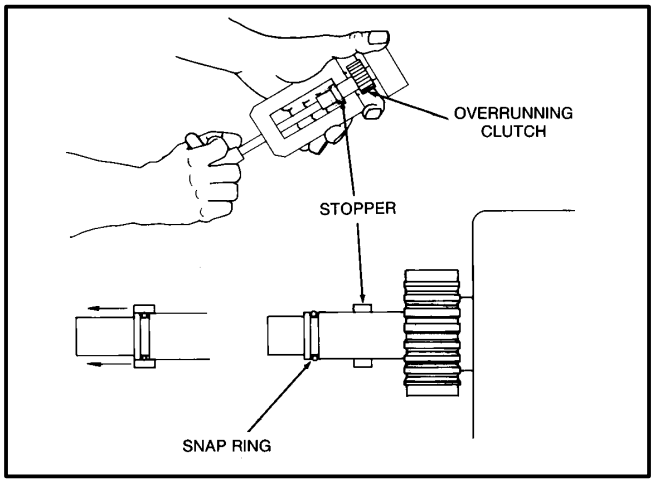


FIGURE 9-3. INSTALLING STOPPER

7. Fit the overrunning clutch into the lever and install with the armature in the front bracket.
8. Install the lever retainer and spacer. Position the frame assembly over the armature on the front bracket.
9. Install the brush holder assembly. Position the brushes in the brush holder. Make certain the positive lead wires are not grounded.
10. Install washers, as required, on the rear end of the armature shaft to obtain an armature shaft thrust gap of 0.002 to 0.020 inch (0.05 to 0.5 mm). New washers are required if the rear bracket is replaced.
11. Install the rear bracket. Secure the brush holder to the rear bracket with two machine screws. See Table 9-1 for proper torques.
12. Install and tighten the two through bolts. See Table 9-1 for proper torques.
13. Install the solenoid plunger in the lever.
14. Secure the solenoid to the front bracket with two machine screws. See Table 9-1 for proper torques.

TABLE 9-1. STARTER ASSEMBLY TORQUES

ITEM	LB-IN	Nm
Solenoid Screws	54	6.1
Brush Retaining Screws	33	3.7
Through Bolts	51	5.8

15. After assembly, adjust the pinion clearance. Pinon clearance should be 0.02 to 0.08 inch (0.5 to 2.0 mm). If not, check as follows:
    A. Connect the starter to a battery and switch as shown in Figure 9-4.
    B. Close the switch. This will shift the pinion into the cranking position.
    C. Push the pinion back by hand and measure the pinion clearance. If the clearance does not fall within the specified limits, adjust by adding or removing shims located between the solenoid and the front bracket. Adding shims decreases the clearance; removing shims increases the clearance. Shims are included with the replacement solenoid.

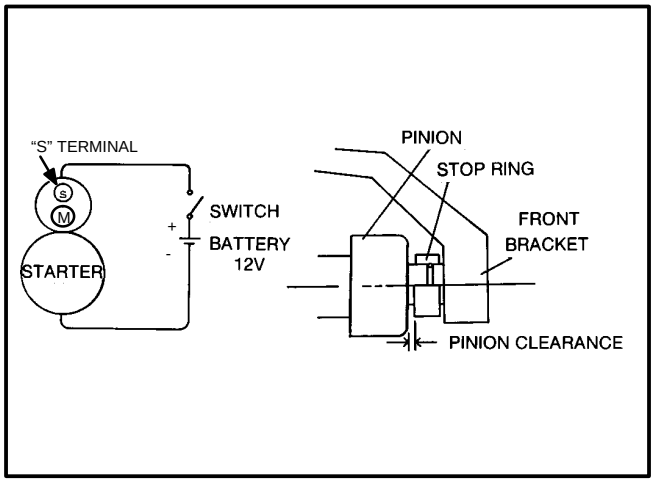


FIGURE 9-4. PINION CLEARANCE ADJUSTMENT

Inspection and Testing

Inspect the starter components for mechanical defects before testing for grounds or shorts.

Testing Armature for Grounds. Touch the armature shaft or core and the end of each commutator bar with a pair of ohmmeter leads as shown in Figure 9-5. A low ohmmeter reading indicates a grounded armature. Replace the armature.

Testing Armature for an Open Circuit. Using an ohmmeter, check for continuity between the commutator segments. If there is no continuity (high resistance), the segments are open and the armature must be replaced.

Testing Armature for a Short Circuit. Use a growler for locating shorts in the armature as shown in Figure 9-6. Place the armature in the growler and hold a thin steel blade (e.g., a hacksaw blade) parallel to the core and just above it while slowly rotating the armature in the growler. A shorted segment of the armature causes the blade to vibrate and be attracted to the core. If the armature is shorted, replace.

Commutator Inspection. If the commutator is dirty or discolored, clean with a number 00 to 000 commutator paper. Blow grit out of armature after cleaning.

If the commutator is scored, rough, or worn, turn it down on a lathe.

Field Coil. Use an ohmmeter to check for continuity between the brushes. If there is no continuity, the field coil is open and must be replaced. With the field coil mounted in the frame, check for continuity between the field coil and the frame. Replace the frame assembly if there is continuity.

Brushes. Clean around the brushes and holders, wiping off all brush dust and dirt. If brushes are worn shorter than 0.4528 inch (11.5 mm), replace. See Figure 9-7.

Check for shorts between the positive side of the brush holder and brush holder base. If there is continuity, replace the brush holder assembly. Check for free movement of the brushes. All brushes should move freely in the brush holders.

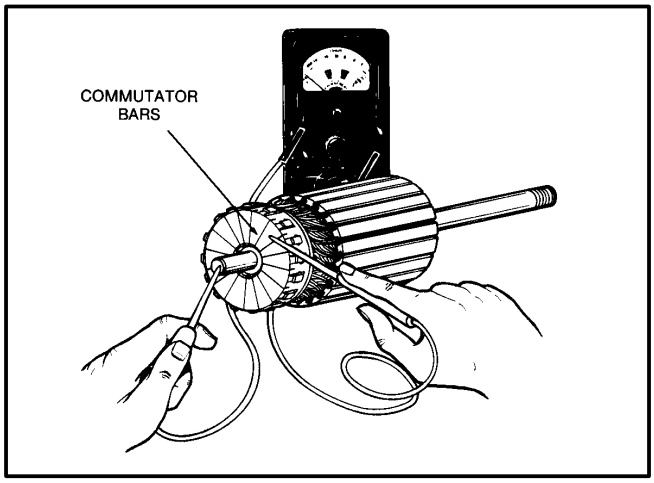


FIGURE 9-5. TESTING ARMATURE FOR GROUNDS

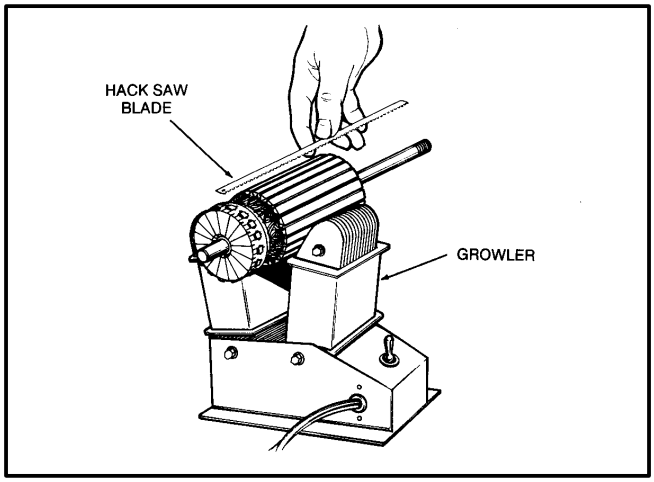


FIGURE 9-6. TESTING ARMATURE FOR SHORT CIRCUITS

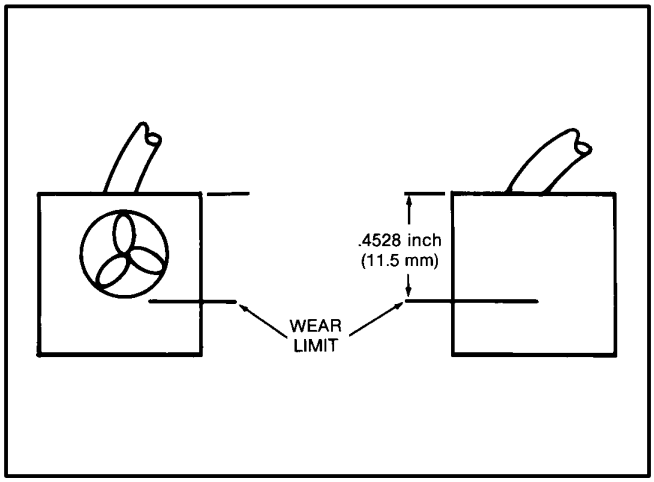


FIGURE 9-7. BRUSH WEAR LIMIT

Overrunning Clutch. Inspect the pinion and spline teeth for wear or damage.

If the pinion gear is worn or damaged, inspect flywheel ring gear as well. Rotate the pinion: it should turn freely when turned in one direction and lock when turned in the opposite direction.

⚠ CAUTION ***Cleaning the overrunning clutch in a liquid cleaning solution will result in starter damage. Do not clean the overrunning clutch in liquid cleaning solutions.***

Solenoid: Push the solenoid plunger in and release it. The plunger should return to its original position. While holding the plunger all the way in, check for continuity between terminals “M” and “B”. See Figure 9-8. If there is no continuity, replace the solenoid. After replacing the solenoid, check the pinion clearance.

Bushings. If either the front or rear bushing show signs of wear or damage, replace them. The bushing and rear bracket are replaced as an assembly. Check the armature thrust gap if the rear bracket is replaced.

1. Remove the front bushing by tapping bushing from the inside with a 7/16 inch tap. Do not remove the cap from the front bracket.
2. Thread the capscrew (the same size as the tap) into the bushing.
3. Using a slide hammer, remove the bushing from the front bracket.
4. Press the new bushing into the front bracket. Use care not to distort the inside diameter of the bushing.

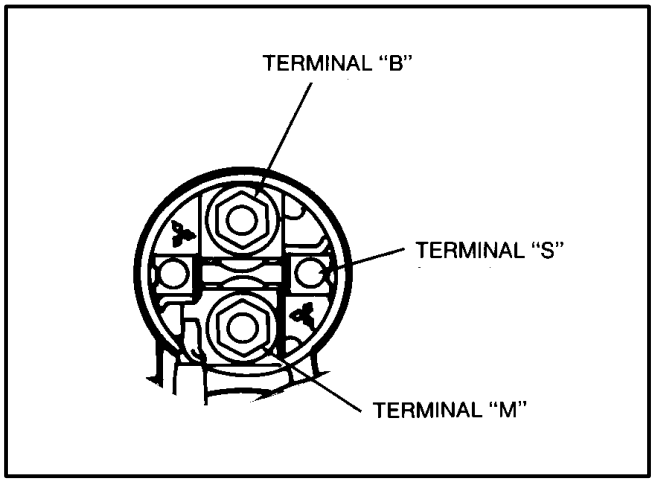


FIGURE 9-8. SOLENOID TERMINALS

Brush Replacement:

1. Cut the old positive brush from its pigtail at the brush. Be careful not to damage the field coil.
2. Clean 1/4 to 3/8 inch (6.5 to 9.5 mm) of the brush end of the pigtail with sandpaper or emery cloth. See Figure 9-9.
3. Push the prepared end of the pigtail lead into the hole in the replacement brush from the small chamfered side.
4. Solder pigtail lead to the replacement brush on the large chamfered side, using 50/50 tin/lead rosin core solder and a standard 240/325-watt soldering iron.
5. Use a file to remove any excess solder that may extend beyond the brush surface.

⚠ CAUTION ***Material protruding from the soldered side surface of the brush can cause equipment damage. Do not use excessive solder or heat and file any excess material from the brush surface.***

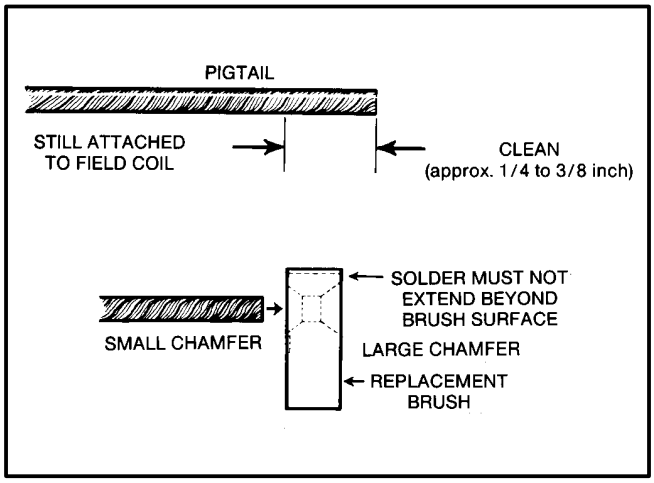


FIGURE 9-9. BRUSH REPLACEMENT

Starter Mounting

Before installing the starter motor, make sure the starter mounting surface on the engine base is clean and free of oil.

To install the starter, use the following procedure. The starter pinion gear lash does not require adjustment.

1. Install the wire lead from the starter motor to terminal “M” on the solenoid. Refer to Figure 9-8 on Page 9-6.
2. Install the starter motor and torque mounting capscrews to that specified in Table 4-1 on Page 4-1.
3. Connect the battery cables and wires to the starter solenoid as shown in Figure 9-8 on Page 9-6.
4. Connect the battery cables to the battery, negative (-) last.

⚠WARNING ***Arcing can ignite the explosive hydrogen gas given off by batteries, causing severe personal injury. Arcing can occur if the negative (-) battery cable is connected and a tool being used to connect or disconnect the positive (+) battery cable accidentally touches the frame or other grounded metal part of the set. To prevent arcing, always remove the negative (-) cable first, and reconnect it last.***

10. Engine Disassembly

DISASSEMBLY/ASSEMBLY

When complete engine disassembly is necessary, first remove all complete assemblies. Individual assemblies such as the fuel pump and the carburetor can be disassembled and repaired at another time.

Suggested Disassembly Order

1. Drain the engine oil.
2. Disconnect all exhaust and electrical lines.

   ⚠WARNING ***Arcing can ignite the explosive hydrogen gas given off by batteries, causing severe personal injury. Arcing can occur if the negative (-) battery cable is connected and a tool being used to connect or disconnect the positive (+) battery cable accidentally touches the frame or other grounded metal part of the set. To prevent arcing, always remove the negative (-) cable first, and reconnect it last.***

3. Remove the engine from its mountings and place upright in a suitable work area

   NOTE: A 2x4 wood frame 10 inches per side provides a suitable fixture to hold the engine and prevent damage to the crankshaft.

4. Remove the oil fill tube, and all housings, shrouds, blower housings, etc.
5. Remove the flywheel.
6. Remove the ignition trigger and gear cover, being careful to protect the oil seal from keyway damage.
7. Remove the crank gear using a gear puller and ring.
8. Remove all accessories such as the oil filter, starter, intake manifold, fuel lines, spark plugs, etc.
9. Remove the oil pump and cylinder heads.
10. Remove the valves, springs, lifters, etc.
11. Remove the camshaft and gear assembly.
12. Remove the oil cooler.
13. Set the engine on its back to remove the oil base, oil pickup cup, and oil pickup tube.
14. Remove the connecting rods and pistons.
15. Remove the oil base casting, crankshaft, top bearing, and lower bearing.

Keep all parts in their respective orders. Keep valve assemblies together. Return rod caps to their respective pistons. Analyze the reason(s) for parts failure.

Suggested Assembly Procedure

Engine assembly is normally the reverse of the disassembly procedure, observing proper clearances and torques. (See Section *3. Dimensions and Clearances* and Section *4. Assembly.*) Use a torque wrench to assure proper tightness. Coat the internal engine parts with oil as they are assembled. After the internal engine parts are assembled, the engine should turn over freely by hand. Use only genuine Onan parts and special tools when reassembling your engine.

1. Use the proper bearing driver to install the top main bearing after coating it with a light film of oil.
2. Insert the lower main bearings in the oil base casting.
3. Insert the crankshaft, oil base casting, and crankshaft gear.
4. Install the pistons and connecting rods.
5. Install the oil pickup tube with its spring, oil pickup cup, and oil base cover.
6. Install the oil cooler.
7. Install the camshaft and gear assembly, making sure to align the crank gear mark with the cam gear mark.
8. Install the valve assemblies, oil pump, oil cooler, and cylinder heads.
9. Install all accessories such as oil filter, starter, fuel lines, and spark plugs.
10. Check valve clearances.
11. Install all housings, shrouds, intake manifold, and oil fill tube. Always use a new oil fill tube seal when reinstalling the oil fill tube.
12. Fill the engine with new oil.

Operation

Start the engine and check the oil pressure. Run for approximately 15 minutes to bring the engine up to operating temperatures. Check for oil leaks, fuel leaks, and exhaust leaks. Adjust carburetor and governor for speed and sensitivity.

Testing Compression

The compression tester is used to determine the condition of valves, pistons, piston rings, and cylinders.

To check compression:

1. Run the engine until thoroughly warm.
2. Stop the engine and remove spark plugs

   ⚠WARNING ***Hot engine components can cause severe personal injury, if touched. Use extreme caution when working on a hot engine.***

3. Remove the air cleaner and place the throttle and choke in the wide open position.
4. Insert the compression gauge in one spark plug hole.
5. Crank the engine and note the reading.

Refer to Section *2. Specifications* for compression pressures. There can be variations due to equipment, temperature, atmospheric conditions, and altitude. These pressures are for a warm engine at cranking speed (about 300 rpm).

Tappet Adjustment

The engine is equipped with adjustable valve tappets as shown in Figure 10-1. The valve tappet clearance should be checked and adjusted as specified in the *Periodic Maintenance Schedule* located in the Operator's Manual. Adjust the valve clearance only when he engine is at ambient temperature. Proceed as follows:

1. Remove the ignition key to prevent accidental starting.
2. Remove all the parts necessary to gain access to the valve tappets.
3. Remove the spark plugs to ease the task of turning the engine over by hand.
4. Rotate the crankshaft in a clockwise direction until the right intake valve (as viewed from the carburetor end) opens and closes. Continue turning the crankshaft until the flywheel timing mark is lined up with the governor shaft on the gear cover. This should place the right piston (#1) at the top of its compression stroke. Verify that the left intake and exhaust valves are closed and there is no pressure on the valve lifters.

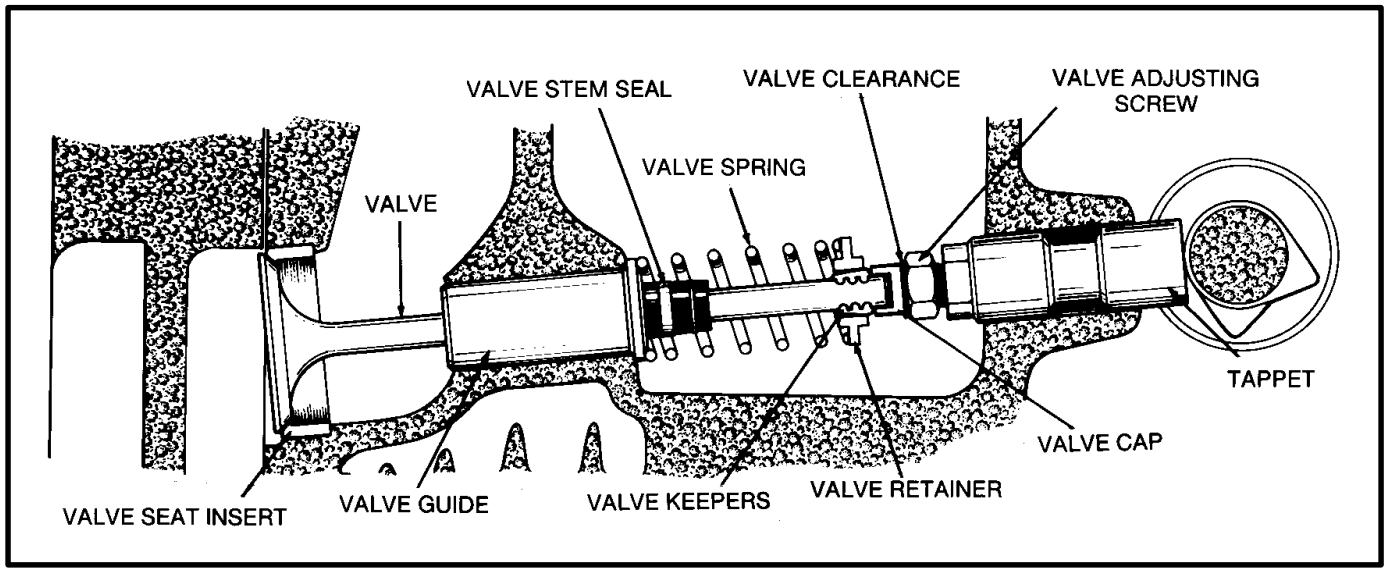


FIGURE 10-1. INTAKE VALVE ASSEMBLY

5. The correct feeler gauge for the valve adjustment (see Section *2. Specifications*) should pass freely between the valve cap and the tappet; a 0.002 inch (0.05 mm) thicker gauge should not. See Figure 10-2.
6. To correct the valve clearance, use a 7/16-inch open end wrench to turn the adjusting screw to obtain the correct clearance. The screw is self-locking and will stay where it is set. A 9/16 inch (14 mm) open end wrench is required to hold the tappet while turning the adjusting screw.
7. To adjust the valves on the left-hand cylinder, turn the engine one complete revolution and again line up the flywheel timing mark with the governor shaft of the gear cover. Then follow adjustment procedure given for the right-hand cylinder.
8. Replace all parts removed in Step 2 on Page 10-2. Tighten all screws securely. Torque valve cover bolts to specified torque.

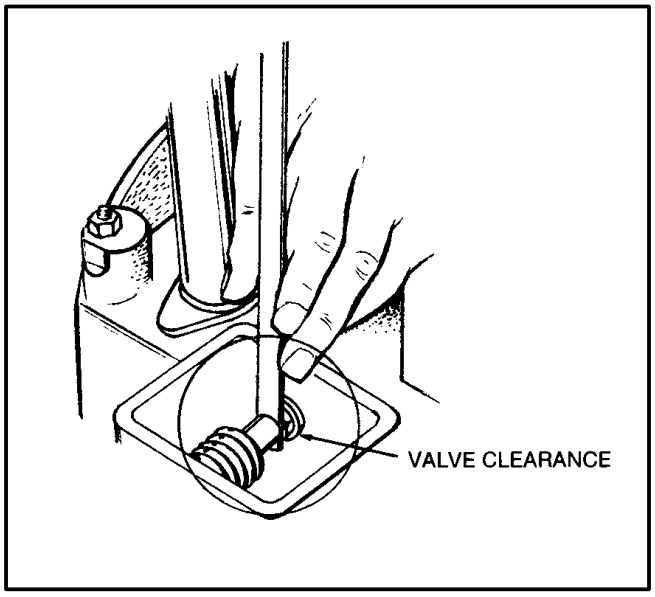


FIGURE 10-2. VALVE CLEARANCE MEASUREMENT

VALVE SYSTEM

A properly functioning valve system is essential for good engine performance. All engines utilize an L-head type valve design as shown in Figure 10-1 on Page 10-2. Access to the valve system can be obtained by removing the cylinder heads and the valve covers. A valve spring compressor must be used to remove valves from the cylinder block.

A valve stem seal is used on the intake valve guides. This seal must be replaced each time the valve is removed.

Place the valves, springs, retainers, and tappets in a rack as they are removed from the cylinder block so that they can be identified and reinstalled in their original locations. Discard old valve stem seals and replace with new ones during assembly.

Use the following procedures to inspect and service the valve system.

Inspection

Clean carbon from the valves, valve seats, valve guides, and cylinder block.

Valves. Check the valve face for evidence of burning, warpage, out-of-round, and carbon deposits.

Burning and pitting are caused by the valve failing to seat tightly. This condition is often caused by hard carbon particles on the seat. It can also be due to weak valve springs, insufficient tappet clearance, warpage, and misalignment.

Warpage occurs chiefly in the upper stem due to its exposure to intense heat. Out-of-round wear follows when the seat is pounded by a valve whose head is not in line with the stem and guide. If a valve face is burned or warped, or if the stem is worn, install a new valve.

Too much clearance in the intake guide admits air and oil into the combustion chamber, upsetting carburetion, increasing oil consumption, and making heavy carbon deposits. Carbon reduces heat dissipation. Clean metal is a good heat conductor, but carbon insulates and retains heat. This increases combustion chamber temperatures which causes warping and burning.

Unburned carbon residue gums valve stems and causes them to stick in the guide. Deposits of hard carbon with sharp points projecting become white hot and cause pre-ignition and pinging.

Refinish valves that are slightly pitted or burned on an accurate valve grinder. If valves are badly pitted or have a thin margin when refacing, replace them.

Stems and Guides. Always check valve stems and guides for wear as shown in Figure 10-3. Use a hole gauge to measure the valve guide. When clearance with the stem exceeds that specified in Section *3. Dimensions and Clearances,* replace either the valve or the guide or both, as may be necessary. Always regrind the seat to make it concentric with the newly installed guide.

Worn valve stem guides can be replaced from inside the valve chamber (a seal is provided behind the intake valve guides only). The smaller diameter of the tapered valve guides must face toward the valve head. Tappets are also replaceable from the valve chamber after first removing the valve assemblies.

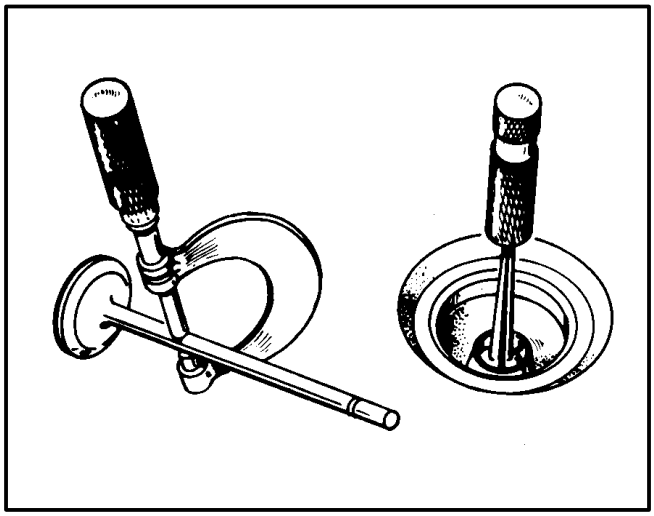


FIGURE 10-3. VALVE STEM AND VALVE GUIDE INSPECTION

Valve Guide Removal. Before removing the valve guides, use an electric drill with a wire brush to remove carbon and other foreign material from the top surface of the guides. Failure to perform this operation can result in damage to the guide bores. Drive the guides out with a hammer and valve guide drive.

⚠ CAUTION ***Driving out old valve guides can cause guide and tappet bore damage. Do not strike guide or tappet bores with driver during removal.***

Valve Guide Installation:

1. Run a small polishing rod covered with crocus cloth through the valve guide holes to clean out carbon and other foreign materials.
2. Place a new gasket on the intake valve guide, and coat the outer edge of each new guide with oil.
3. Place the guide in the cylinder block and press in until the guide protrudes 11/32 inch (8.7 mm) from the valve box side of the block. A suggested method of installation is shown in Figure 10-4.

Valve Stem Seals (intake only). Do not reuse valve stem seals. Each time the valves are removed from the cylinder block, a new seal must be used when the valve is reinstalled.

⚠ CAUTION ***Removing a valve after installing a valve stem seal can cause seal damage. Do not allow valve stem groove to come in contact with the valve stem seal after installation.***

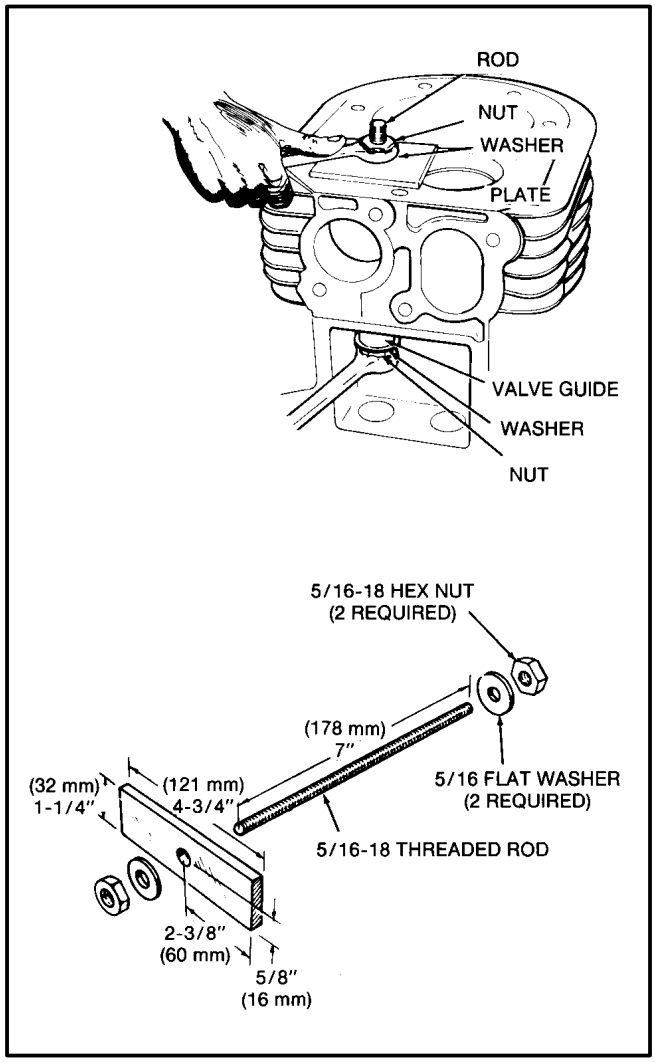


FIGURE 10-4. VALVE GUIDE INSTALLATION

Valve Spring. Check valve springs for cracks, worn ends, distortion, and tension.

1. If the spring ends are worn, check the valve spring retainer for wear.
2. Check for spring distortion by placing the spring on a flat surface next to a square. Measure the height of the spring and rotate it against the square edge to measure distortion. If distortion exceeds 0.06 inch (1.5 mm), replace the spring.
3. Check the spring tension at the installed height for both the valve open and closed position using an accurate valve spring tester.
4. Replace any valve spring that is weak, cracked, worn, or distorted.

Valve Rotators. Free rotating valves are used for intake and exhaust. While in the open position, the valves must rotate freely.

Valve Seats. Inspect the valve seat inserts. If the seats are in serviceable condition, clean the seat by using either a seat cutter or seat grinder. If the seats are loose, cracked, or severely pitted, new ones must be installed. Remove the valve seat as outlined in the *Valve Seat Removal* section, following. If the valve seat insert bores in the cylinder block are damaged or worn so that a press fit cannot be obtained when installing new, standard size valve seat inserts, the bores must be machined for an oversize seat.

Valve Seat Removal:

1. Remove carbon and combustion deposits from the valve seat.
2. Select the proper puller size as determined by the inside diameter of the valve seat. On some pullers, use a new seat as a guide to adjust puller depth as shown in Figure 10-5.
3. The puller jaws must expand into cylinder block at the point where the bottom of the valve seat insert rests on the cylinder block.
4. Position the puller on the valve seat and tighten the hex nut.
5. Clamp the cylinder block to a solid bench.
6. Attach the slide hammer to the puller.
7. Tighten the hex nut between each blow with the slide hammer.

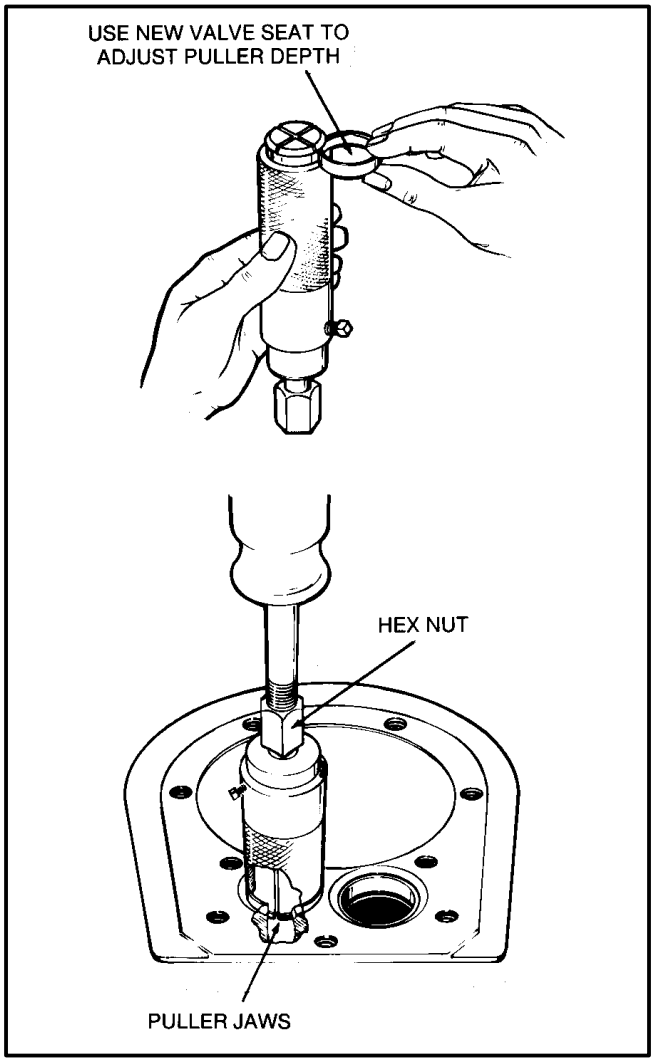


FIGURE 10-5. VALVE SEAT REMOVAL

Valve Seat Installation. After the old seat has been removed, clean out any carbon or metal burrs from the seat insert recess.

1. Soak the new valve seat in a mixture of alcohol and dry ice for 30 minutes to shrink the seat. This process causes a 0.003- to 0.005-inch (0.076- to 0.127-mm) interference fit between the valve seat bore and the valve seat.
2. Heat the valve seat bore to assist with the installation of the valve seat.
3. Use a valve seat insert driver and hammer to install the insert (see Figure 10-6).
4. Drive the valve seat insert in so the insert enters the recess evenly. Make certain that the valve seat insert rests solidly on the bottom of the recess all the way around its circumference.
5. To assure a tight valve seat fit and eliminate the danger of the seat loosening in the bore, the valve seat must be staked. Use an Onan valve seat staker **only.**
6. Insert the valve seat staker into the valve seat or guide in the cylinder block.
7. Using a lead hammer, strike the staking tool a sharp blow to wedge the new valve seat securely in place.
8. It will be necessary to refinish the valve seat inserts before installing the valves.

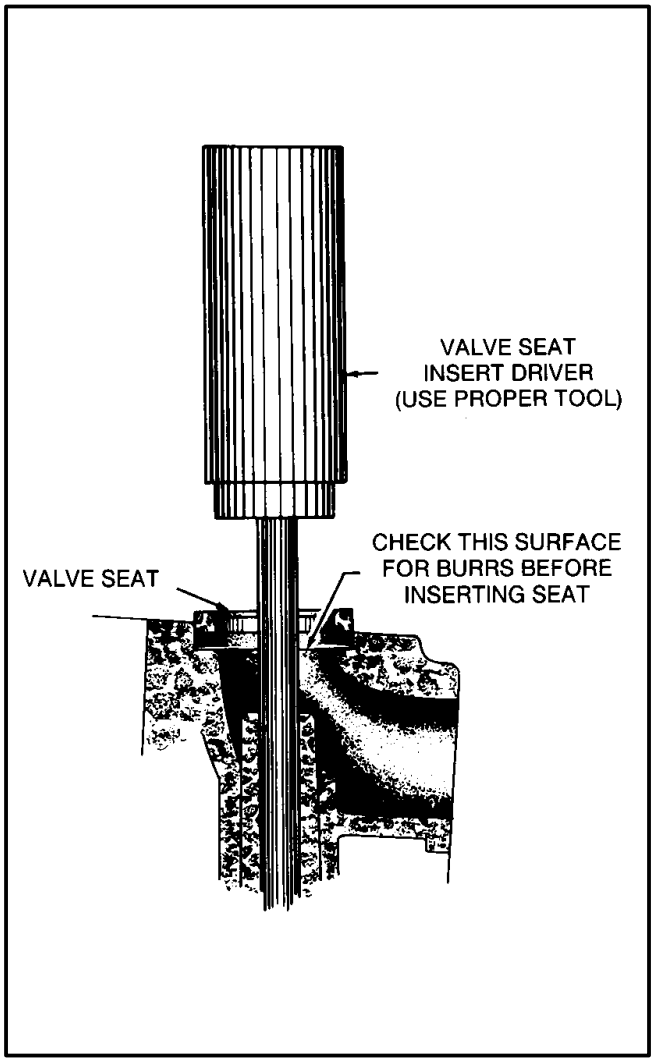


FIGURE 10-6. INSERTING NEW VALVE SEAT

TAPPETS

Very little wear takes place on the tappet diameters or in the tappet bores. If the clearance between the tappet and bore in the cylinder block exceeds specifications, replace the tappet. Oversize tappets are available.

Inspect the tappet faces which contact the camshaft lobes for roughness, scuffing, or concave wear. Replace any worn tappets. If tappets are worn, inspect the camshaft lobes for wear.

VALVE FACE AND SEAT GRINDING

Before installing new valves or previously used valves, inspect the valve seats for proper valve seating. When refacing valves and seats, remove all evidence of pitting and grooving.

Installing Previously Used Valves

If used valves are reinstalled, the valve stems should be cleaned and the valve faces ground to their specified angle.

⚠WARNING ***Always wear safety glasses with side shields when grinding to prevent severe eye damage.***

NOTE: By grinding the valve face and the seat at slightly different angles, a fine line of contact between the face and seat is obtained, eliminating the need to lap the seating surfaces. The one degree difference in angles is defined as the interference angle (see Figure 10-7). The seat angle is greater than that of the valve face. This assures contact at the maximum diameter on the valve seat seating surface.

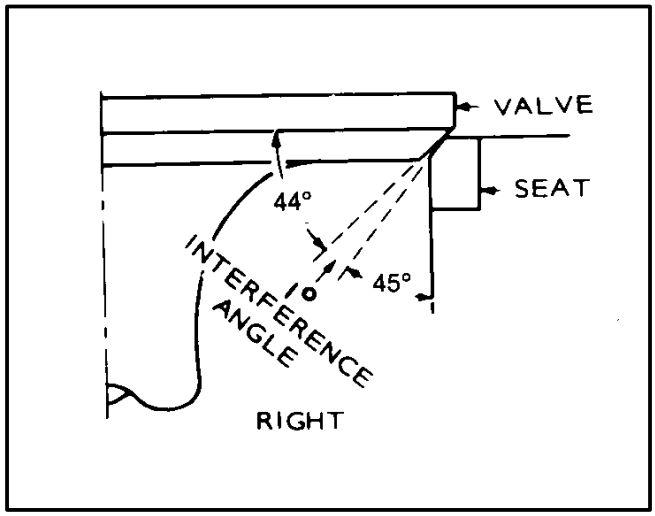


FIGURE 10-7. VALVE INTERFERENCE ANGLE

Grind the valve face to a 44° angle. Refinish the valve faces to a 44° angle on a valve refacing machine.

1. The first cut from the valve face must be a light grinding. Check if there is an unevenness of metal being removed. If only part of the valve's face has been touched, check to see if the valve is properly seated in the machine or if the valve is warped, worn, or distorted.
2. When the valve head is warped, a knife edge will be ground (see Figure 10-8) on part or all of the head due to the large amount of metal that must be removed to completely reface the valve. Heavy valve heads are required for strength and good heat dissipation. Knife edges lead to breakage, burning, and pre-ignition due to heat localizing on the edge.
3. When the cut is even around the whole valve face, keep grinding until the complete face is ground clean. Be sure the correct valve face angle is maintained.
4. Replace any valve that cannot be entirely refaced while keeping a good valve margin (see Figure 10-8) or is warped, worn, or damaged in any way. The amount of grinding necessary to true a valve indicates whether the valve head is worn or warped.
5. If the end of the valve stem is pitted or worn, true it and clean it up on the refacer wheel. A very light grind is usually enough to square the stem and remove any pits or burrs.
6. Thoroughly clean the valve guide. If the valve guide is worn, or the valve is warped, the necessary parts must be replaced.

Grinding Valve Seats

1. Refinish valve seats to a 45° angle. When new valve seats are installed, or previously used seats reground, refinishing must be done with a valve seat grinder used according to the manufacturer's directions.
2. Valve seats should be ground with a 45° stone and the width of the seat band should be 1/32 inch to 3/64 inch (0.8 mm to 1.2 mm) wide. Grind only enough to assure proper seating.

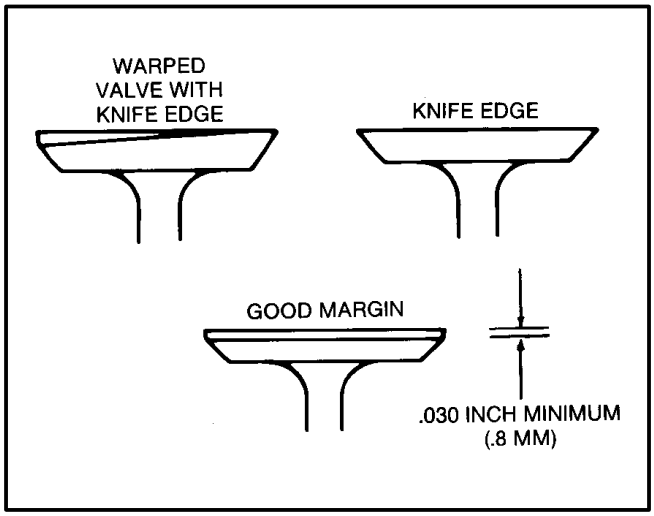


FIGURE 10-8. VALVE HEAD MARGIN

Valve Seating Check

1. Place each valve in its proper location.
2. Check each valve for a tight seat. Make several marks at regular intervals across the valve face using machinist's bluing. Observe if the marks rub off uniformly when the valve is rotated part of a turn against the seat. The valve seat should contact the valve face evenly at all points. The line of contact should be at the center of the valve face.

FLYWHEEL

Removing the flywheel is a relatively simple process, but the following procedure must be followed to avoid damage to the gear case and possible injury to the operator.

1. Turn the flywheel mounting screw outward about two turns.

   ⚠WARNING ***Incorrect flywheel removal can result in severe personal injury. Do not remove the flywheel screw completely when using the flywheel puller***

2. Install a flywheel puller on the flywheel (see Figure 10-9).
3. Turn the puller bolts inwards, alternately, until the wheel snaps loose on the shaft.

   ⚠CAUTION ***Improper flywheel removal can cause gear case damage. Do not use any tools to pry against the gear cover when removing the flywheel.***

4. Unscrew the puller from the flywheel, remove the flywheel mounting screw and washer, and pull the flywheel off the shaft. Take care not to drop the wheel. A bent or broken fin will destroy the balance.

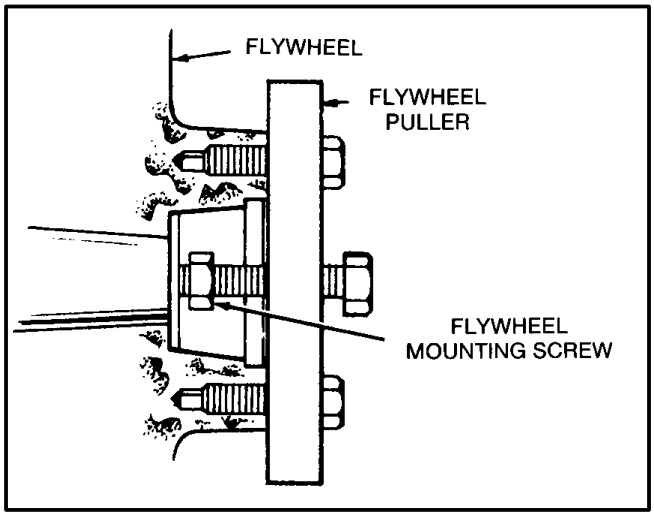


FIGURE 10-9. FLYWHEEL PULLER

GEAR COVER

Removing

After removing the mounting screws, tap the gear cover gently with a soft-faced hammer to loosen it.

Installing

1. When installing the gear cover, make sure the pin in the gear cover engages the nylon lined (smooth) hole in the governor cup.
2. Turn the governor cup so the nylon line hole is at the three o'clock position. Use a small amount of grease to assist in holding the governor cup in position.
3. The smooth side of the governor yoke must ride against the governor cup.
4. Turn the governor arm and shaft clockwise as far as possible and hold in this position until the gear cover is installed flush against the crankcase. Be careful not to damage the gear cover oil seal (see Figure 10-10).

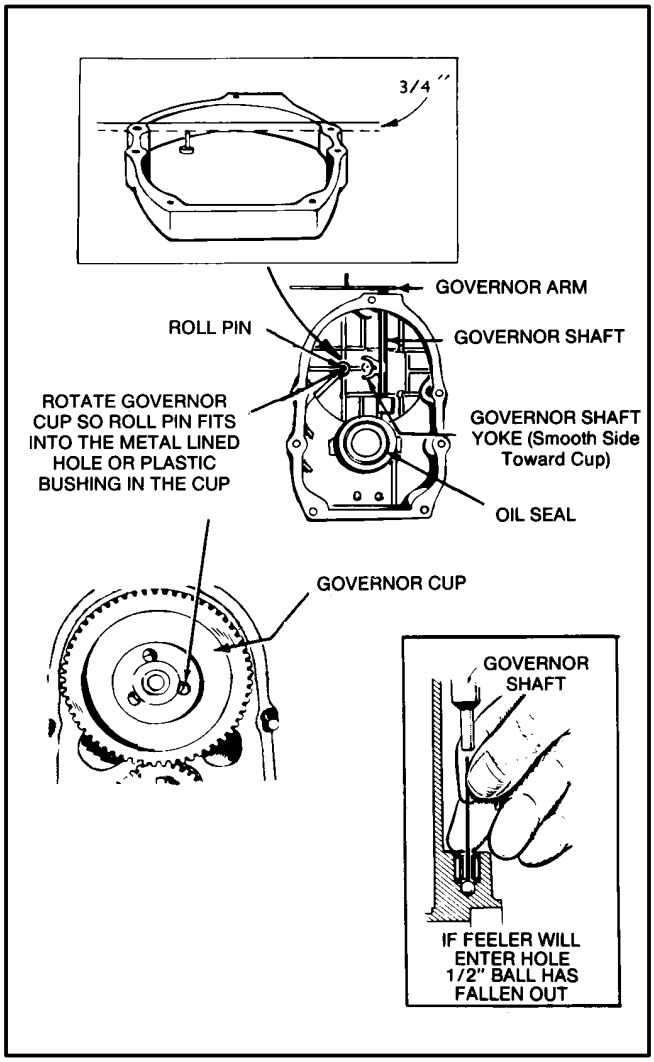


FIGURE 10-10. GEAR COVER ASSEMBLY

GOVERNOR CUP

Removing

With the gear cover removed, the governor cup can be taken off after removing the snap ring from the camshaft center pin. Catch the flyballs while sliding the cup off (see Figure 10-11).

Installing

Replace with a new part:

- any flyball which is grooved or has a flat spot
- the ball spacer, if its arms are worn or otherwise damaged
- the gear/spacer assembly, if loose on the gear hub
- the governor cup, if the race surface is grooved or rough. The governor cup must be a free-spinning fit on the camshaft center pin, but without any excessive play

When installing the governor cup, tilt the engine so the gear is up.

1. Put the flyballs in place (see Figure 10-12).
2. install the cup and snap ring on the center pin (see Figure 10-11).
3. The camshaft center pin extends out 3/4 inch (19 mm) from the end of the camshaft. This distanced provides an in-and-out travel distance of 7/32 inch (5.6 mm) for the governor cup, as illustrated in Figure 10-11. Hold the cup against the flyballs when measuring.
4. The camshaft center pin cannot be pulled outward or removed without damage. If the center pin extends out too far, the cup will not hold the flyballs properly. If the distance is less than 7/32 inch (5.6 mm), the engine will race, especially at no load. Remove the center pin and press in a new pin.

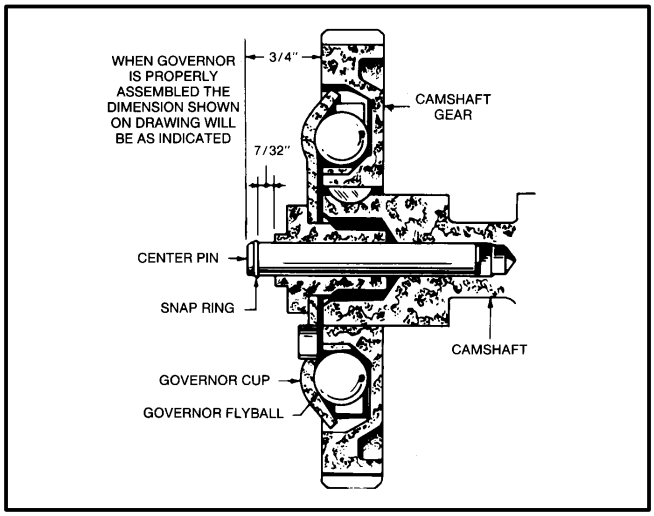


FIGURE 10-11. GOVERNOR CUP DETAILS

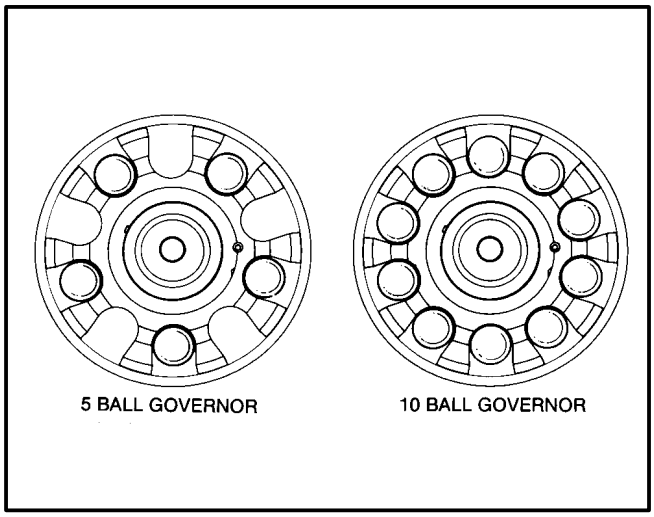


FIGURE 10-12. FLYBALL LOCATIONS

TIMING GEARS

If replacement of either the crankshaft gear or the camshaft gear becomes necessary, always install both gears new.

The camshaft and gear must be replaced as an assembly. Before removing the camshaft and gear assembly, remove the cylinder head and valve assemblies.

Refer to Figure 10-13 when performing the following steps to remove the crankshaft gear:

1. Remove the snap ring and retainer washer.
2. Attach the gear pulling ring using two No. 10-32 screws.
3. Tighten the screws alternately until both are tight.
4. Attach a gear puller to the puller ring and proceed to remove the gear.
5. When installing the camshaft gear and shaft assembly, be sure the thrust washer is properly in place behind the camshaft gear.
6. Install the crankshaft gear on the crankshaft.

   NOTE: Each timing gear is stamped with "O" near the edge. The gear teeth must mesh so that these marks exactly coincide when the gears are installed in the engine (see Figure 10-13).

7. Install the crankshaft retaining washer and lock ring.

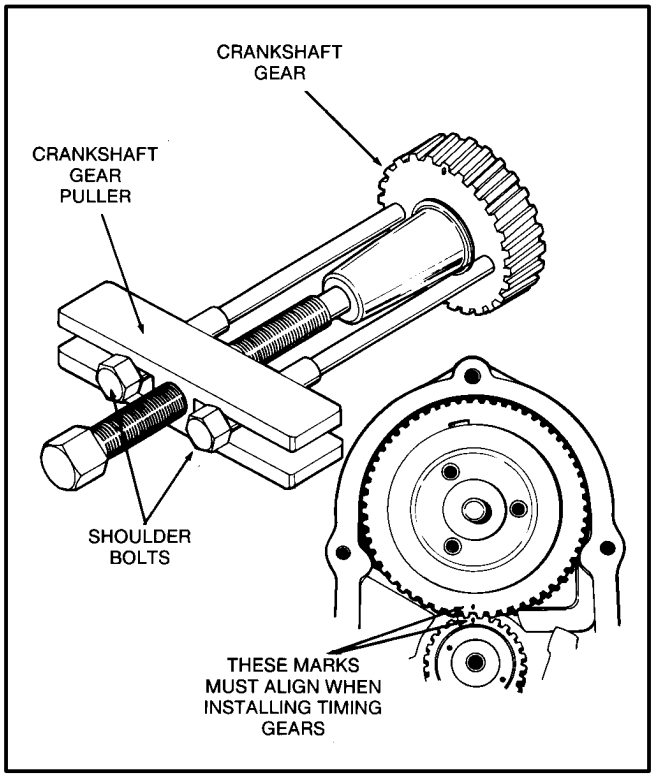


FIGURE 10-13. TIMING GEAR REMOVAL AND INSTALLATION

PISTONS AND CONNECTING RODS

Observe the following procedure when removing pistons and connecting rods from the engine.

1. Drain the oil.
2. Remove the cylinder head and oil cooler from the engine.
3. Remove the ridge from the top of each cylinder with a ridge reamer before attempting piston removal (see Figure 10-14).

   ⚠ CAUTION ***Improper piston removal can cause piston damage. Use ridge reamer to remove the cylinder ridge before removing the piston.***

4. Turn the crankshaft until the piston is at the bottom of its stroke and remove the connecting rod nuts. Lift the rod bearing cap from the rod and push the rod and piston assembly out through the top of the cylinder using a hammer handle. Do not scratch the crankpin and cylinder wall when removing the piston and rod.
5. Mark each piston and rod assembly so that they can be returned to their respective cylinders after overhaul. Keep connecting rod bearing caps with their respective rods.
6. Remove the piston rings from the piston with a piston ring spreader (see Figure 10-15). Remove the piston pin retaining and push the piston pin out.

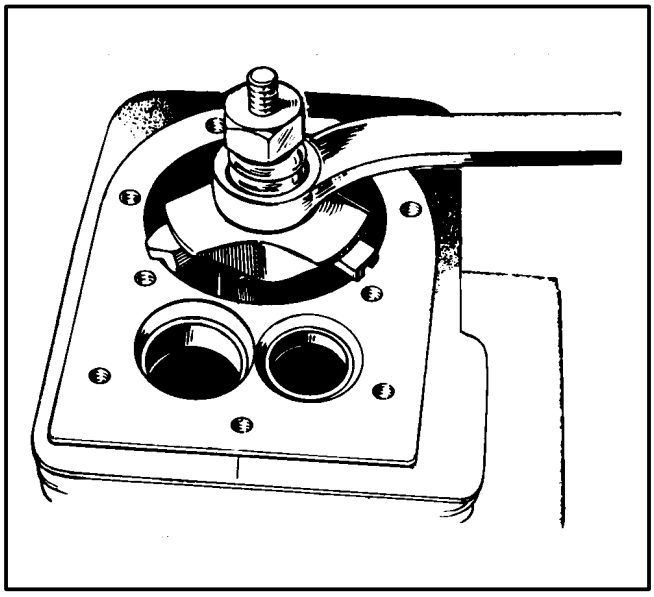


FIGURE 10-14. REMOVING RIDGE FROM CYLINDER

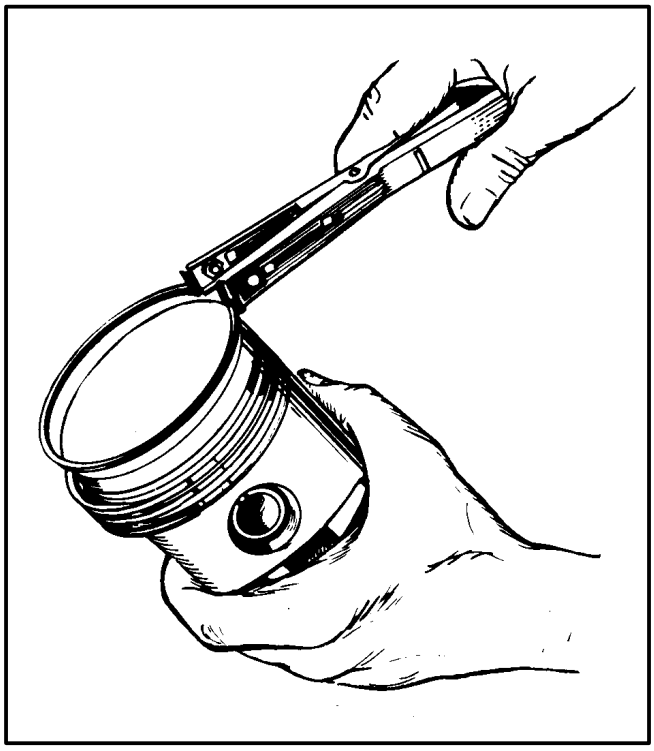


FIGURE 10-15. REMOVING PISTON RINGS

7. Remove dirt and deposits from the piston surfaces with an approved cleaning solvent. Clean the piston ring grooves with a groove cleaner or the end of a piston ring filed to a sharp point (see Figure 10-16). Care must be taken not to remove metal from the groove sides.

   ⚠ CAUTION ***Improper piston cleaning can cause piston damage. Do not use a caustic cleaning solvent or wire brush for cleaning pistons.***

8. Clean the connecting rods in solvent. Blow out all passages with compressed air.

Inspection

Follow the procedures given below when inspecting pistons and connecting rods.

Piston Inspection:

1. Inspect the pistons for fractures at the ring lands, skirts, and pin bosses. Check for wear at the ring lands using a new ring and feeler gauge as shown in Figure 10-17. Replace the piston when the side clearance of the top compression ring reaches that specified in Section *3. Dimensions and Clearances.*
2. Replace pistons showing signs of scuffing, scoring, worn ring lands, fractures, or damage from preignition. Excessive piston wear near the edge of the top ring land indicates preignition.

Measuring Pistons. Refer to Section *3. Dimensions and Clearances* to determine where to measure piston to be sure the total clearance follows specifications.

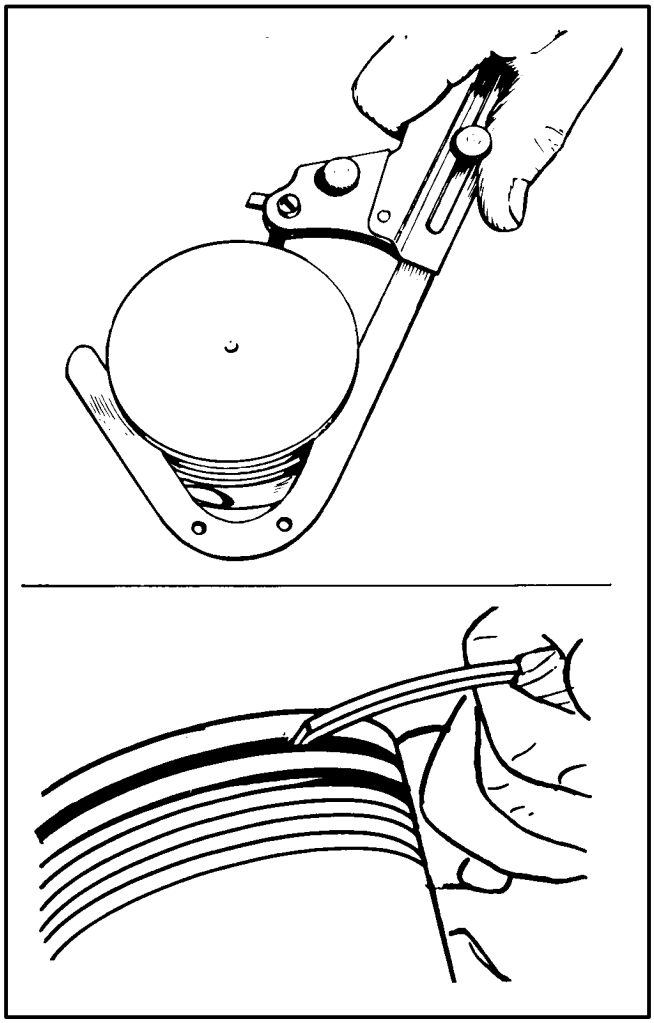


FIGURE 10-16. PISTON GROOVE CLEANING

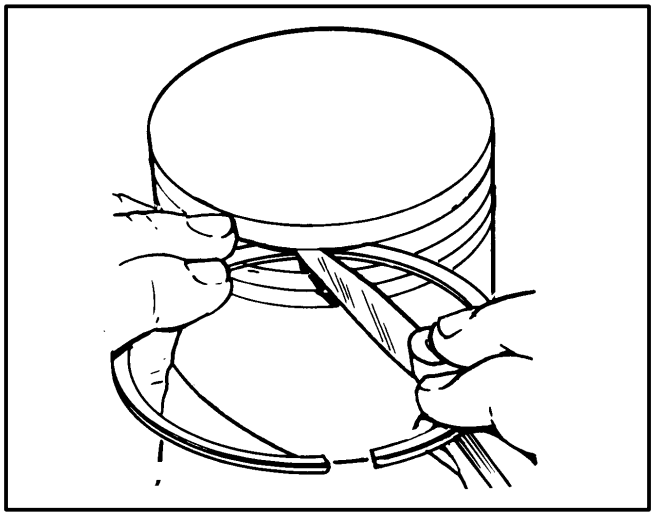


FIGURE 10-17. CHECKING RING SIDE CLEARANCE

Measuring Piston Rings:

1. Install the piston ring in the cylinder bore. Invert the piston and push the ring to the end of the ring travel, about halfway into the bore, which trues the ring end gap. Check the gap with a feeler gauge as shown in Figure 10-18.
2. The practice of filing ring ends to increase the end gap is not recommended. If the ring end gap does not meet specifications, check for the correct set of rings and the correct bore size. A cylinder bore that is 0.001 inch (0.03 mm) under size will reduce the end gap 0.003 inch (0.08 mm).

Connecting Rod Inspection. Replace connecting rod bolts and nuts that have damaged threads. Replace connecting rods that have deep nicks, signs of fractures, scored bores, or bores with dimensions which exceed that specified in Section *3. Dimensions and Clearances.*

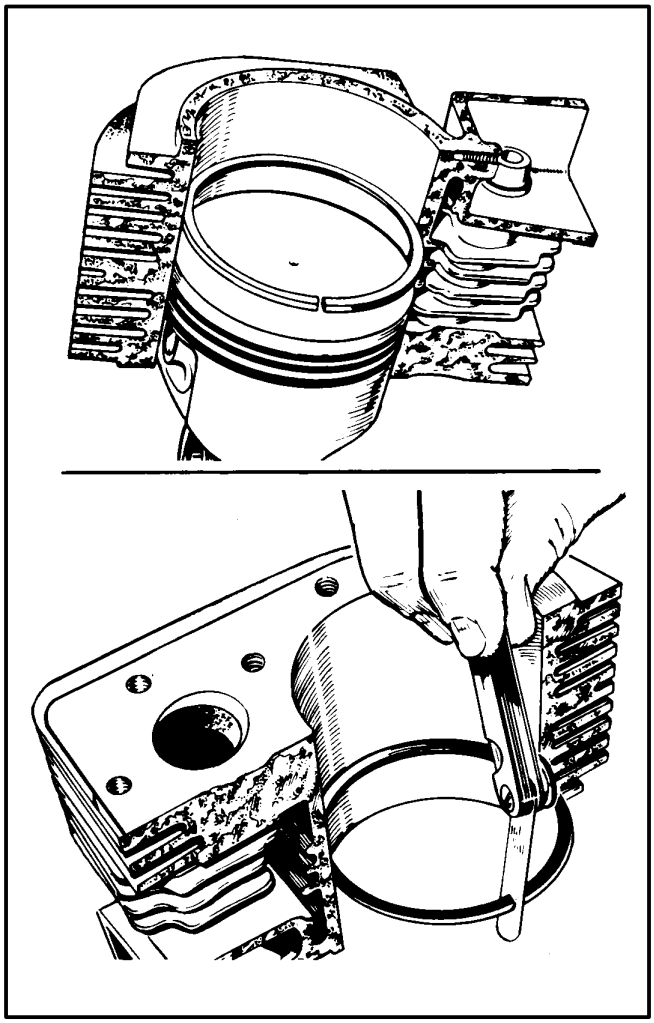


FIGURE 10-18. POSITIONING OF PISTON RING AND MEASURING OF END GAP

CYLINDER BLOCK

The cylinder block is the main support for all other basic engine parts. The crankshaft and camshaft are supported by the block, assuring alignment of the crankshaft and cylinder bores.

Cleaning

After removing pistons, crankshaft, cylinder heads, etc., inspect the block for cracks and wear. If the block is still serviceable, prepare it for cleaning, as follows:

1. Scrape all the old gasket material from the block. Remove the oil by-pass to allow cleaning solution to contact the inside of oil passages.
2. Remove grease and scale from the cylinder block by agitating in a bath of commercial cleaning solution or hot, soapy washing solution.
3. Rinse the block in clean hot water to remove the cleaning solution.

Inspection

When rebuilding the engine, thoroughly inspect the block for any condition that would make it unfit for further use. This inspection must be made after all the parts have been removed and the block has been thoroughly cleaned and dried.

1. Make a thorough check for cracks. Minute cracks can be detected by coating the suspected area with a mixture of 25 percent kerosene and 75 percent light motor oil. Wipe the part dry and immediately apply a coating of zinc oxide (white lead) dissolved in wood alcohol. If cracks are present, the white coating will become discolored at the defective area. Always replace a cracked cylinder block.
2. Inspect all machined surfaces and threaded holes. Carefully remove any nicks or burrs from machined surfaces. Clean out tapped holes and clean up any damage threads.
3. Check top of block for flatness with a straight edge and a feeler gauge.

Cylinder Bore Inspection. Inspect cylinder bores for scuffing, scratches, wear, and scoring. If cylinder bores are scuffed, scratched, worn, or scored, they must be rebored and honed for the next oversize piston.

When the appearance of cylinder bores is good and there are no scuff marks, check cylinder bores for wear or out-of-roundness as follows:

1. Check cylinder bore for taper, out-of-round, and wear with a cylinder bore gauge, telescopic gauge, or inside micrometer. These measurements should be taken at four places: top and bottom of piston ring travel; parallel and perpendicular to axis of crankshaft (see Figure 10-19).
2. Record measurements taken at top and bottom of piston travel, as follows:
   A. Measure and record as “A” the cylinder bore diameter (parallel to the crankshaft) near the top of the cylinder bore.
   B. Measure and record as “B” the cylinder bore diameter (parallel to the crankshaft) at the bottom of the piston travel.

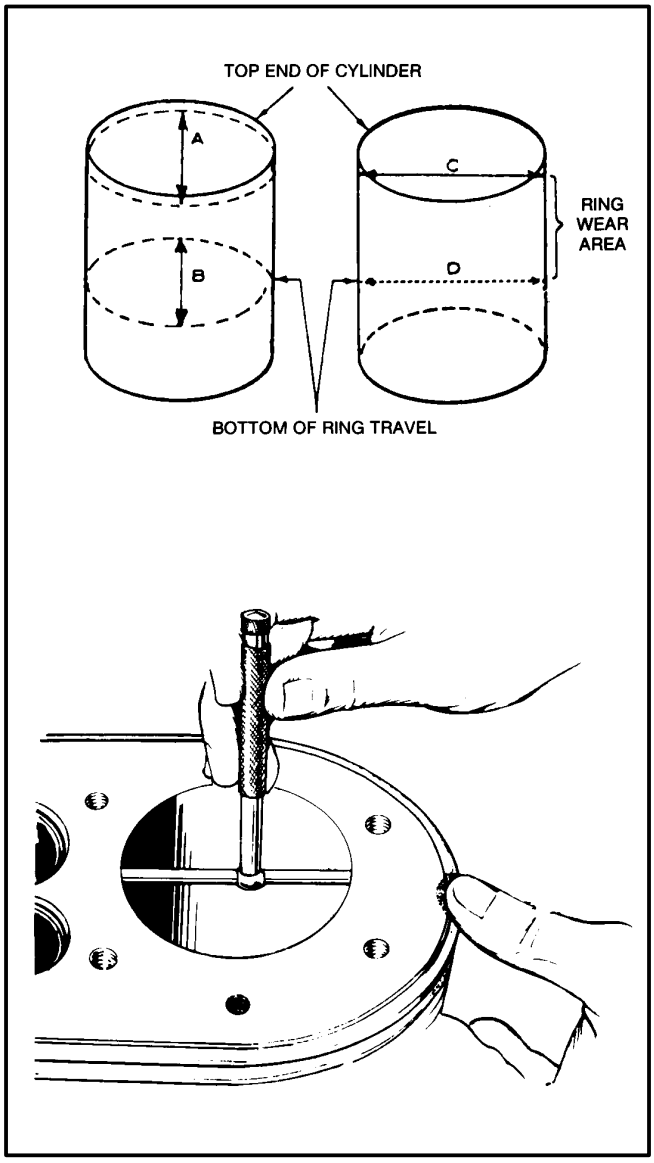


FIGURE 10-19. METHODS OF MEASURING THE DIAMETER OF A CYLINDER BORE

C. Measure and record as “C” the cylinder bore diameter (perpendicular to the crankshaft) near the top of the cylinder bore.

D. Measure and record as “D” the cylinder bore diameter (perpendicular to the crankshaft) at the bottom of the piston travel.

E. Reading “A” subtracted from reading “B”, and reading “C” subtracted from reading “D” indicates cylinder taper.

   If cylinder taper exceeds that specified in Section *3. Dimensions and Clearances,* the cylinders must be rebored and honed to the next standard oversize diameter.

F. Reading “A” compared to reading “C”, and reading “B” compared to reading “D” indicates whether or not the cylinder is out-of-round.

   If out-of-round exceeds that specified in Section *3. Dimensions and Clearances,* the cylinders must be rebored and honed to the next standard oversize diameter.

Reboring the Cylinder

Rebore and hone the engine whenever the cylinder bore is worn, damaged, out-of-round, or if the cylinder taper exceeds specifications. A worn cylinder bore should be resized to the smallest standard oversize diameter at which it will clean up. The final finish and bore diameters should then be obtained by honing. Final bore diameter should equal the standard diameter added to the oversize.

⚠ CAUTION ***Improper boring will result in engine damage. Boring must be done by qualified mechanics.***

⚠WARNING ***Always wear safety glasses with side shields when boring to prevent severe eye damage.***

After boring to the correct oversize cylinder bore dimension, piston and ring clearance should be appropriate. These is no need to adjust or “fit” pistons and rings.

When reboring the cylinders, take the following precautions:

1. Make sure the cutting tool is properly ground before using it.
2. Be sure the top of engine block is smooth and deposit free.
3. Clean the base of the boring bar before the bar is set up. Deposits under the boring bar will cause it to tilt and the cylinder will be distorted after boring.
4. Make the initial rough cut, followed by a finish cut. Then hone cylinder bore to the specified oversize.

Honing Cylinders (Using Precision Hones)

Refer to hone manufacturer’s recommended grit size to produce specified surface finish of 20 to 40 RMS. Too rough of a finish will wear out the rings and too smooth of a finish can retard piston ring seating.

⚠WARNING ***Always wear safety glasses with side shields when honing to prevent severe eye damage.***

1. Position the block solidly for either vertical or horizontal honing. Use either a drill press or heavy-duty drill which operates at approximately 250 to 450 rpm.
2. Follow the hone manufacturer’s instructions for the use of oil or lubricant on the stones. Do not use lubricants with a dry hone.
3. Insert the hone in the bore and adjust the stones to fit snugly to the narrowest section. When adjusted correctly, the hone should not shake or chatter in the cylinder bore, but will drag freely up and down when hone is not running.
4. Connect the drill to the hone and start the drill. Feel out the bore for high spots, which cause an increased drag on the stones. Move the hone up and down in the bore with short overlapping strokes about 40 times per minute. Usually, the bottom of the cylinder must be worked out first because it is smaller. As cylinder takes a uniform diameter, move the hone up and down all the way through the cylinder bore.
5. Check the diameter of the cylinder regularly during honing. A dial bore gauge is the easiest method, but a telescoping gauge can be used.

Check size at six places in the bore: measure twice at the top, middle, and bottom at 90° angles.

6. The crosshatch formed by the stones should form an included angle of 23°. This can be achieved by moving the rotating hone (250 to 450 rpm) up and down in the cylinder bore about 40 times per minute.
7. Clean the cylinder bores thoroughly with soap, water, and clean rags. A clean, white rag should not become soiled on the cylinder wall after cleaning is complete. Do not use a solvent or gasoline since they wash oil from the walls but leave the metal particles.
8. Dry the crankcase and coat it with oil.

Deglazing Cylinder Bores

Deglaze the cylinder bores if there are no scuff marks and no wear or out-of-round beyond specifications before installing new rings. Deglazing gives a fine finish, but does not enlarge the cylinder diameter, so the original pistons with new rings may still be used.

The reason for deglazing a cylinder is to provide cavities to hold oil during piston ring break-in.

1. Wipe the cylinder bores with a clean cloth which has been dipped in clean, light engine oil.
2. Use a brush-type deglazing tool with coated bristle tips to produce a crosshatch pattern in the cylinder bore.
3. Use a slow speed drill to drive the deglazing tool. Move the deglazing tool up and down in the cylinder (10 to 12 complete strokes) rapidly enough to obtain a crosshatch pattern as shown in Figure 10-20.

   ⚠ CAUTION ***Improper cylinder cleaning will result in engine damage. Do not use gasoline, solvents, or commercial cleaners to clean cylinder bores.***

4. Clean cylinder bore thoroughly with soap, water, and clean rags. Continue cleaning until a clean, white rag shows no discoloring when wiped through the cylinder bore.

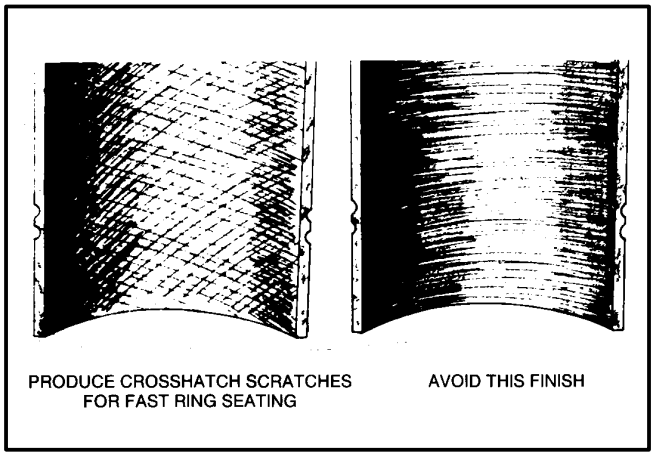


FIGURE 10-20. CROSSHATCHING

CRANKSHAFT

Clean the crankshaft thoroughly and inspect the journals for scoring, chipping, cracking, or signs of overheating. If the crankshaft has overheated, is scored, or excessively worn, reconditioning or replacement is required. Examine bearing journals for cracks if overheating has occurred.

Measure the crankshaft main bearing and connecting rod journals at several places on their diameter to check for roundness and taper.

The only recommended method of reconditioning the crankshaft is regrinding, as required to accommodate undersize bearings. Metalizing of bearing journals is not recommended.

If regrinding of the crankshaft journals is necessary, the work should be done by a reputable machine shop that has suitable equipment to handle precision work of this type. Undersize main bearings and connecting rods are available.

Whenever making major repairs on the engine, always inspect the drilled passages of the crankshaft. Clean them to remove any foreign material and to assure proper lubrication of the connecting rods.

BEARINGS

With the camshaft and crankshaft removed, measure all bearing journal diameters. Measure the inside diameter of the bearings. Refer to Section *3. Dimensions and Clearances* to determine if the measurements are within specifications.

Visually inspect the bearings and journals. Replace any bearing that is scored, chipped, pitted, or worn beyond specifications.

Camshaft Bearings

Replacement camshaft bearings are precision type which do not require line reaming or line boring after installation. Use a press or a suitable driver to remove bearings. Support the casting to avoid distortion and to avoid damaging the bearing bore during removal and installation.

Clean the outside of the bearing and bearing bore in the block. Before installing the bearings, use Loctite Bearing Mount on the outside diameter of the bearing. Use a combination bearing driver to install the bearings.

Place the top camshaft bearing on the crankcase over the bearing bore with the lubricating hole lined up with the hole in the block as shown in Figure 10-21. Be sure to start the bearing straight. Press in the top bearing flush with the outside end of the bearing bore. The lubricating hole in the bearing must be aligned with the hole in the block after installation.

Press in the bottom camshaft bearing to the dimension shown in Figure 10-21. Lubricate the bearing surfaces with oil after installation.

Crankshaft Bearings

New crankshaft main bearings are precision type which do no require line reaming or line boring after installation. Use a press or suitable driver to remove the bearings. Support casting to avoid distortion and to avoid damaging the bearing bore during removal and installation.

Inspect the top and bottom main bearing lock pins for damage. Replace if necessary.

Before installing the main bearings, expand the bearing bores by placing the casting in an oven heated to 200°F (94°C). Cool the precision bearings to shrink them, if possible.

⚠WARNING ***Hot bearings can cause severe burns. Handle with tongs or high temperature insulated mitts.***

The replacement top main bearing has the thrust washer attached to the bearing. Do not add an additional thrust washer.

Before installing the top main bearing, use the towelette included with the bearing kit to clean the outside of the bearing and bearing bore in the block. Allow three to four minutes to dry. Apply Locktite from the small tube to the mating surfaces of the bearing and the bearing bore. Align the lock pin and oil holes in the bearing with the lock pins and oil holes in the bearing bore (see Figure 10-22). Use a combination driver and install the bearing flush with the block. The oil holes must be at least half open after installation. Wipe off excess Locktite around the bearing. Allow at least one hour at room temperature for hardening.

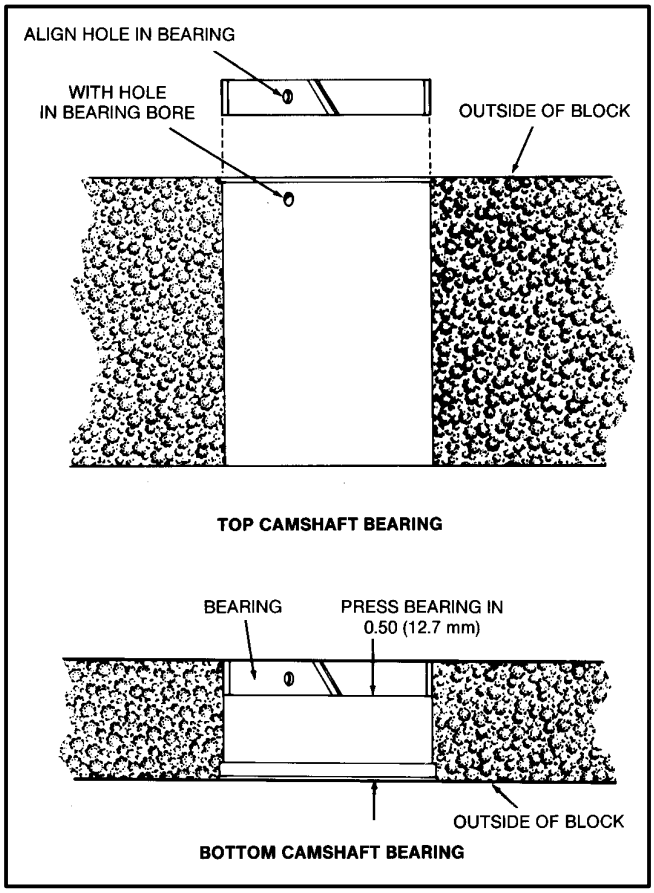


FIGURE 10-21. CAMSHAFT BEARINGS

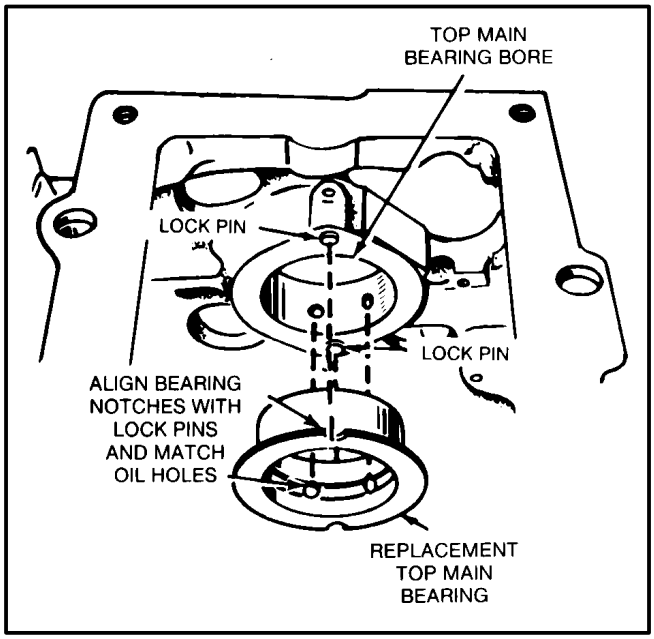


FIGURE 10-22. TOP MAIN BEARING INSTALLATION

⚠WARNING ***Breathing vapor from towelette and prolonged contact with skin can be harmful. Use only in well ventilated area and avoid prolonged contact with skin.***

The bottom main bearing consists of two bearings. Use a combination driver and lubricate the outside of the bearings with SAE 30 oil before installing them to the dimension shown in Figure 10-23. Oil holes in the bearings must line up with those drilled in the engine block so that a 1/8-inch diameter pin can be inserted into the hole. Lubricate main bearings lightly with oil after installation.

Place the thrust washer on the oil base so that the notches fit over the lock pins and the grooves are facing away from the oil base (see Figure 10-24). Place a new oil base gasket on the oil base. Insert crankshaft into the top main bearing. Install the oil base on the engine block. Be sure the thrust washer has not moved off the lock pins before tightening the oil base, or the lock pins will be damaged.

CRANKSHAFT ENDPLAY

Tighten the oil base to the torque recommended in Section *4. Assembly.* Check the crankshaft endplay (see Figure 10-25) and compare it with that specified in Section *3. Dimensions and Clearances.* If the endplay exceeds the specified limits, remove the oil base and add shim(s) between the thrust washer and the oil base. Install the oil base, making sure the thrust washer and shim(s) notches line up with the lock pins. Torque the oil base and check the endplay.

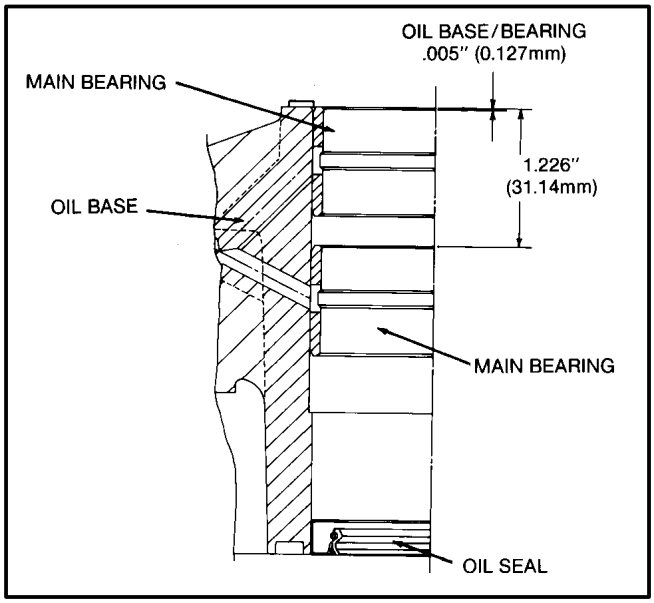


FIGURE 10-23. BOTTOM MAIN BEARING INSTALLATION

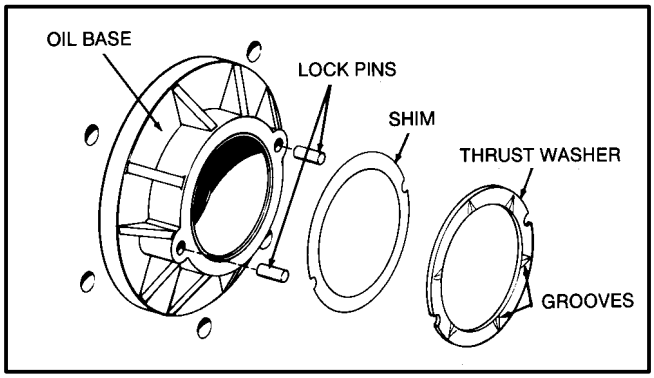


FIGURE 10-24. OIL BASE THRUST WASHER AND SHIM

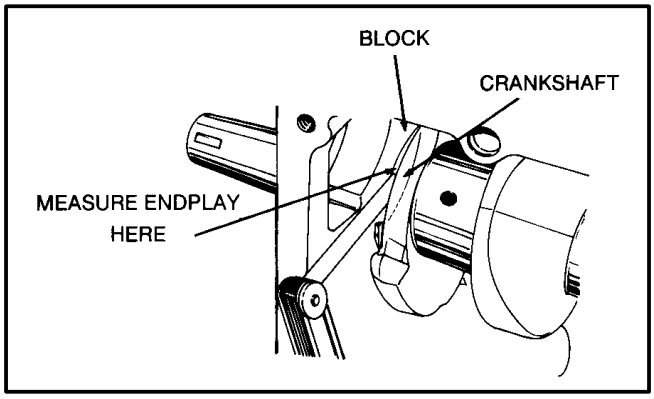


FIGURE 10-25. CRANKSHAFT ENDPLAY

CHECK CONNECTING ROD BEARING CLEARANCE WITH PLASTIGAUGE

1. Make certain that all parts are marked or identified so they are installed in their original positions. Using a clean, dry cloth, thoroughly clean all oil from the crankshaft journal and the connecting rod.
2. Place a piece of correct size Plastigauge in the bearing cap the full width of the journal surface and about 1/4 inch (6.35 mm) off center as shown in Figure 10-26.
3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the rod bolts to the torque specified in Section *4. Assembly.* Do not turn the crankshaft.
4. Remove the bearing cap. The flattened Plastigauge will be found adhering to either the bearing cap or the crankshaft.
5. Compare the flattened Plastigauge with the graduations on the Plastigauge envelope to determine the clearance.

   The number with the matching graduation on the envelope indicates total clearance in millimeters or thousandths of an inch.

OIL SEALS

The gear cover and oil base have to be removed to replace the oil seals. Drive the oil seals out from the inside, being careful not to damage the oil base and gear cover surfaces.

Before installing oil seals, fill the space between the lips with a multi-purpose grease.

Clean old sealing compound off of the gear cover oil seal mounting surface before installing the new oil seal. Install the gear cover oil seal to the dimension shown in Figure 10-27.

Use a seal expander when installing the oil base oil seal to prevent damage to the oil seal. Install the oil seal flush with the outside of the oil base (see Figure 10-23 on Page 10-23).

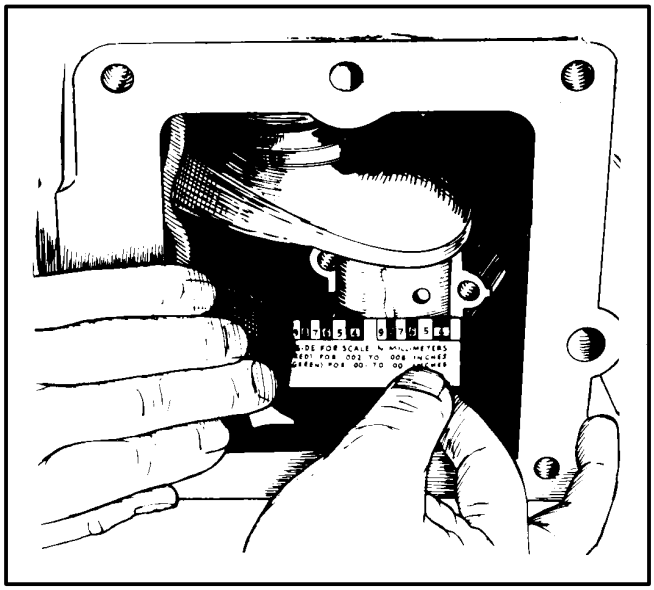


FIGURE 10-26. BOTTOM MAIN BEARING INSTALLATION MEASURING BEARING CLEARANCE

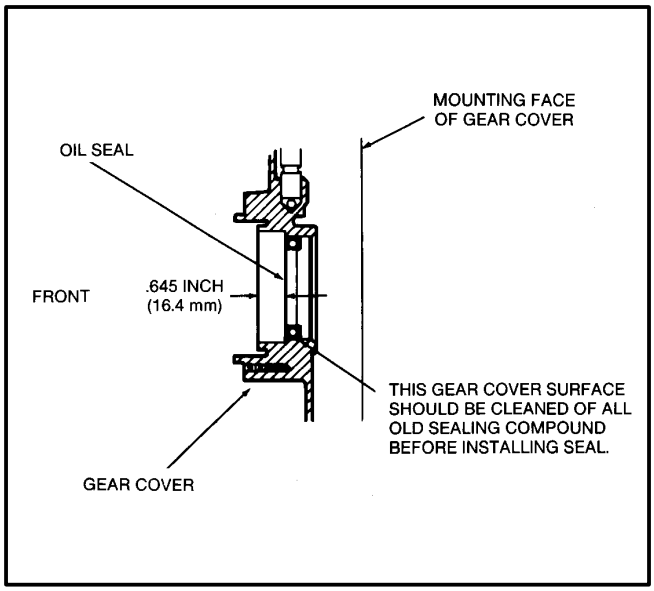


FIGURE 10-27. GEAR COVER OIL SEAL

PISTON ASSEMBLY

1. Lubricate all parts with engine oil.
2. Position the piston on its respective rod and install the pin.
3. Install the rings on the pistons starting with the oil control ring (see Figure 10-28). Use a piston ring spreader to prevent twisting or excessive expansion of the ring. Compression rings have a dot or the word “top” on one side of the ring to indicate which side faces the top of the piston. Unmarked piston rings can be installed either way. The oil control ring has an expander. Install the expander first and then close until the expander ends butt. The joint should be 180° from the gap of that ring.

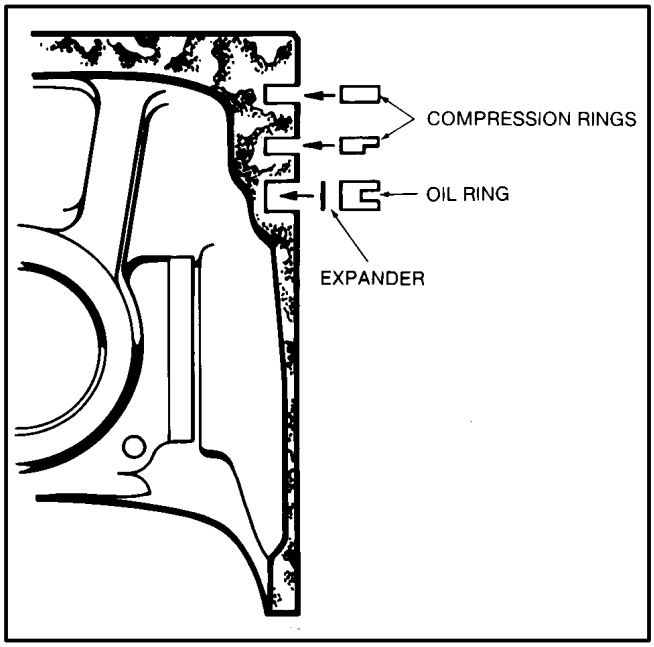


FIGURE 10-28. PISTON RINGS

INSTALLATION OF PISTON IN CYLINDER

1. Turn the crankshaft in order to position the number one road bearing journal at the bottom of its stroke.
2. Lubricate the number one piston assembly and the inside surface of the cylinder. Compress the rings with a ring compressor (see Figure 10-29).
3. Position the piston and rod assembly in the cylinder block. The oil squirt hole of the connecting rod must face the camshaft.
4. Tap the piston down into the bore with the handle end of a hammer until the connecting rod is seated on the journal (see Figure 10-29). Install the bearing cap on the rod.
5. Install one fastener and tighten to 5 lb-ft (7 Nm). Repeat this for the other fastener. Tighten both fasteners down to the torque specified in Section *4. Assembly.*
6. Install the remaining piston and rod in the same manner. Crank the engine over by hand to see that all bearings are free.
7. Install the oil cooler with a new gasket.
8. Install the cylinder heads. See the following section *Cylinder Heads* for torques and torquing procedures.
9. Replace oil and break-in the engine.

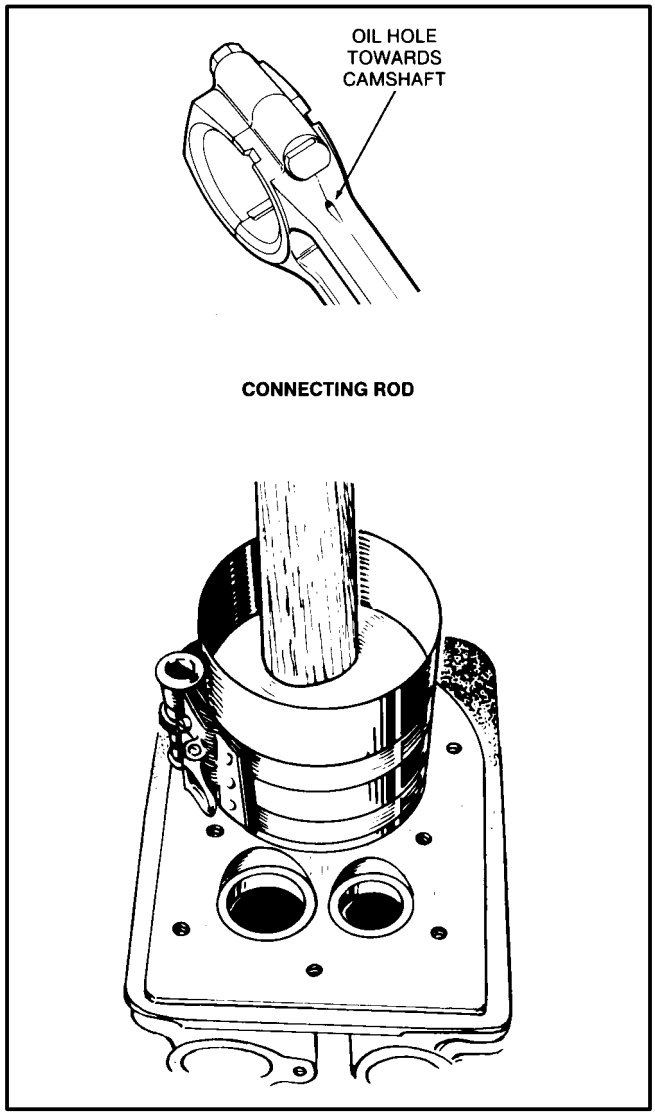


FIGURE 10-29. INSTALLING PISTON AND CONNECTING ROD

CYLINDER HEADS

Remove the cylinder heads for carbon cleaning and gasket change at intervals specified in the *Periodic Maintenance Schedule* located in the Operator's Manual.

1. Use a 1/2-inch (13-mm) socket wrench to remove the cylinder head bolts or nuts. Lift off heads.

   ⚠ CAUTION ***Torquing or removing cylinder heads when hot [above 100° F (37° C)] will result in head damage. Allow heads to cool to below 100° F (37° C)] before torquing or removing.***

2. After removing the heads, clean out all carbon deposits. Be careful not to damage the outer sealing edges where the gaskets fit. The heads are made of aluminum and can be damaged by careless handling.

3. Use new head gaskets and clean both the heads and the cylinder block thoroughly where the head gaskets rest.

Cylinder Head Installation

1. Place a head gasket on the cylinder block and align the holes in the gasket with the holes in the cylinder block. While holding the gasket against the cylinder head, carefully install the cylinder head on the engine. Do not attempt to slide the head bolts through the gasket without the cylinder block behind it or the gasket could tear.

2. Follow the head torque sequence shown in Figure 10-30. Tighten all bolts to 5 lb-ft (7 Nm), then to 10 lb-ft (14 Nm), then to the torque specified in Section *4. Assembly.* Recheck all head bolts for correct torque.

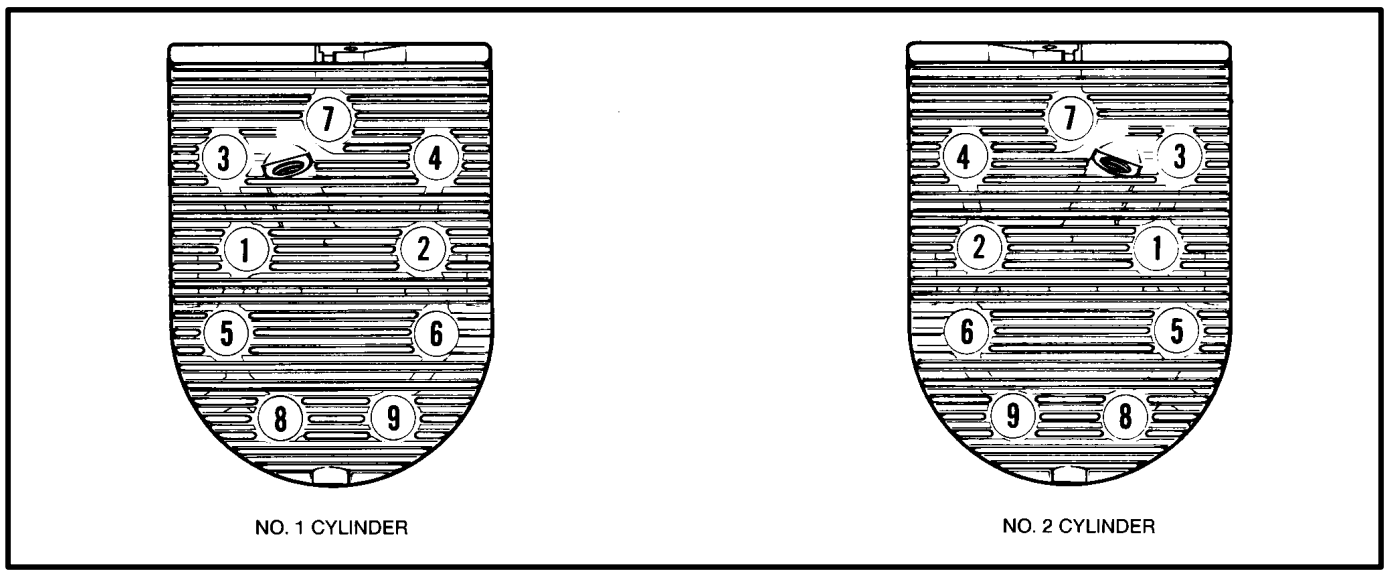


FIGURE 10-30. CYLINDER HEAD TORQUE SEQUENCE

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