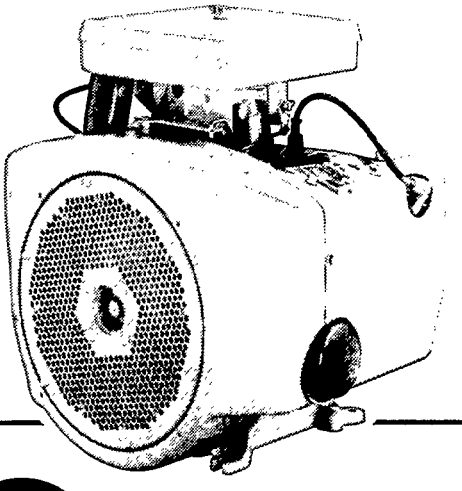
Onan

Operators and Service Manual

P216
P218
P220
Engine



Miller®

MILLER ELECTRIC MFG. CO.
APPLETON, WI USA

965-0163
10-95
Printed in U.S.A.

Emissions Supplement: 900–1021
Date: 07–2000
Insert with-
Manual Number & Date: See Table 1
Models: See Table 1

Purpose: This supplement for the Operator's Manuals specified in Table 1 clarifies how compliance with engine emissions regulations, including U. S. EPA Phase 2 and California Air Resources Board regulations for Model Year 2000 onwards, is presented on genset and engine nameplates (Figures 1 and 2). This sheet is to be bound in the genset or engine manual behind the front cover and in front of earlier Supplements, if any.

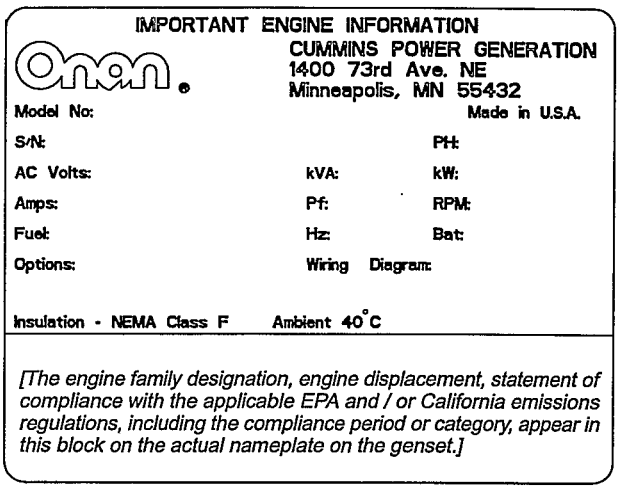
TABLE 1. MANUALS AFFECTED BY SUPPLEMENT

Manual No.	Date	Genset Models
965-0138	5/97	BGM / NHM
965-0175	7/97	BGD / NHD
965-0176	7/97	BGE / NHE
981-0153	7/97	KV
981-0158	6/99	KVC
981-0159	5/00	KY
981-0160	7/99	MKY
983-0101	5/00	HGJAA / HGJAB / HGJAC
Manual No.	**Date**	**Engine Models**
965-0163	10/95	Miller P216 / P218 / P220 / P224
965-0174	10/97	E124V Floorcare
965-0178	7/97	E125V / E140V
965-0179	7/97	E125H / E140H
965-0180	7/97	P218V / P220V
965-0182B	-	P216 / P218 / P220 / P224
965-0183	-	P248V Floorcare

Nameplate Information: See the Operator's Manual for the location of the actual nameplate on the genset or engine. Figures 1 and 2 illustrate where the information regarding compliance with U. S. EPA and California Air Resources Board regulations on the nameplate. The appropriate figure in this supplement supercedes the nameplate illustration in Figure 1 in the genset or engine manual in which the supplement is bound.

Federal Emissions Compliance Period: The Federal Emissions Compliance Period referred to on the nameplate indicates the number of operating hours for which the engine has been shown to meet Federal emissions requirements.

For engines of less than 225 cc displacement, Category C = 125 hrs, B = 250 hrs, A = 500 hrs. For engines of 225 cc and greater displacement, Category C = 250 hrs, B = 500 hrs, A = 1000 hrs.


IMPORTANT ENGINE INFORMATION

Onan®

CUMMINS POWER GENERATION
1400 73rd Ave. NE
Minneapolis, MN 55432

Model No: Made in U.S.A.

S/N: PH:

AC Volts: kVA: kW:

Amps: Pf: RPM:

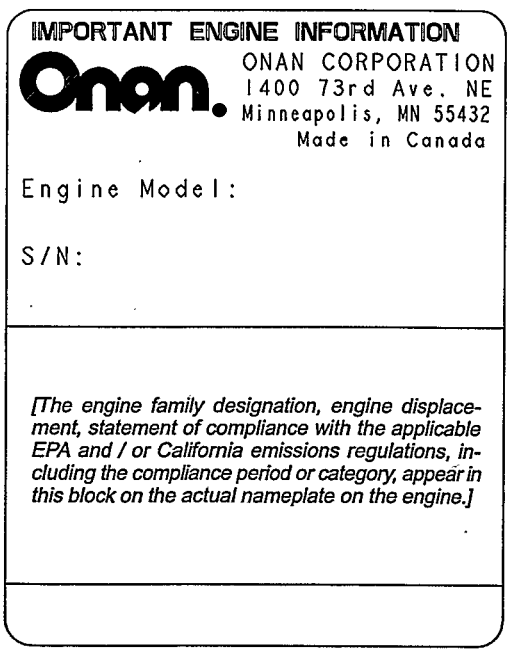
Fuel: Hz: Bat:

Options: Wiring Diagram:

Insulation - NEMA Class F Ambient 40°C

[The engine family designation, engine displacement, statement of compliance with the applicable EPA and / or California emissions regulations, including the compliance period or category, appear in this block on the actual nameplate on the genset.]

FIGURE 1. TYPICAL GENSET NAMEPLATE


IMPORTANT ENGINE INFORMATION

Onan.

ONAN CORPORATION
1400 73rd Ave. NE
Minneapolis, MN 55432
Made in Canada

Engine Model:

S/N:

[The engine family designation, engine displacement, statement of compliance with the applicable EPA and / or California emissions regulations, including the compliance period or category, appear in this block on the actual nameplate on the engine.]

FIGURE 2. TYPICAL ENGINE NAMEPLATE

Safety Precautions

It is recommended that you read your engine manual and become thoroughly acquainted with your equipment before you start the engine.

⚠DANGER ***This symbol if used warns of immediate hazards which will result in severe personal injury or death.***

⚠WARNING ***This symbol refers to a hazard or unsafe practice which can result in severe personal injury or death.***

⚠CAUTION ***This symbol refers to a hazard or unsafe practice which can result in personal injury or product or property damage.***

Fuels, electrical equipment, batteries, exhaust gases and moving parts present potential hazards that can result in serious, personal injury. Take care in following these recommended procedures. All local, state and federal codes should be consulted and complied with.

⚠WARNING ***This engine is not designed or intended for use in any type of aircraft. Use of this engine in aircraft can result in engine failure and causes serious personal injury or death.***

General

- Provide appropriate fire extinguishers and install them in convenient locations. Use an extinguisher rated ABC by NFPA.
- Make sure that all fasteners on the engine are secure and accurately torqued. Keep guards in position over fans, driving belts, etc.
- If it is necessary to make adjustments while the engine is running, use extreme caution when close to hot exhausts, moving parts, etc.

Protect Against Moving Parts

- Do not wear loose clothing in the vicinity of moving parts, such as PTO shafts, flywheels, blowers, couplings, fans, belts, etc.
- Keep your hands away from moving parts.

Batteries

- Before starting work on the engine, disconnect batteries to prevent inadvertent starting of the engine.
- DO NOT SMOKE while servicing batteries. Lead acid batteries give off a highly explosive hydrogen gas which can be ignited by flame, electrical arcing or by smoking.
- Verify battery polarity before connecting battery cables. Connect negative cable last.

Fuel System

- DO NOT fill fuel tanks while engine is running.
- DO NOT smoke or use an open flame in the vicinity of the engine or fuel tank. Internal combustion engine fuels are highly flammable.
- Fuel lines must be of steel piping, adequately secured, and free from leaks. Piping at the engine should be approved flexible line. Do not use copper piping for flexible lines as copper will work harden and become brittle enough to break.
- Be sure all fuel supplies have a positive shutoff valve.

Exhaust System

- Exhaust products of any internal combustion engine are toxic and can cause injury, or death if inhaled. All engine applications, especially those within a confined area, should be equipped with an exhaust system to discharge gases to the outside atmosphere.
- Do not use exhaust gases to heat a compartment.
- Make sure that your exhaust system is free of leaks. Ensure that exhaust manifolds are secure and are not warped by bolts unevenly torqued.

Exhaust Gas is Deadly!

Exhaust gases contain carbon monoxide, a poisonous gas that can cause unconsciousness and death. It is an odorless and colorless gas formed during combustion of hydrocarbon fuels. Symptoms of carbon monoxide poisoning are:

- Dizziness
- Headache
- Weakness and Sleepiness
- Vomiting
- Muscular Twitching
- Throbbing in Temples

If you experience any of these symptoms, get out into fresh air immediately, shut down the unit and do not use until it has been inspected.

The best protection against carbon monoxide inhalation is proper installation and regular, frequent inspections of the complete exhaust system. If you notice a change in the sound or appearance of exhaust system, shut the unit down immediately and have it inspected and repaired at once by a competent mechanic.

Cooling System

- Coolants under pressure have a higher boiling point than water. DO NOT open a radiator pressure cap when coolant temperature is above 212°F (100°C) or while engine is running.

Keep the Unit and Surrounding Area Clean

- Make sure that oily rags are not left on or near the engine.
- Remove all unnecessary grease and oil from the unit. Accumulated grease and oil can cause overheating and subsequent engine damage and present a potential fire hazard.

Supplement 965-1066
Date: 8-97
Insert with-
Title: Miller Engine Operator and Service Manual
Number (Date): 965-0163 (10-95)

NAMEPLATE ON EPA / CARB CERTIFIED ENGINES

EPA / CARB Certified engines have the following statement on the nameplate: "This engine meets EPA Ph1 and 1995-1998 California emissions regulations for ULGE engines." See Figure S-1.

MAINTENANCE, REPLACEMENT AND REPAIR OF EPA CERTIFIED ENGINES

Maintenance, replacement or repair of emission control devices and systems may be performed by any engine repair establishment or individual. However, warranty work must be completed by an authorized Onan dealer or distributor.

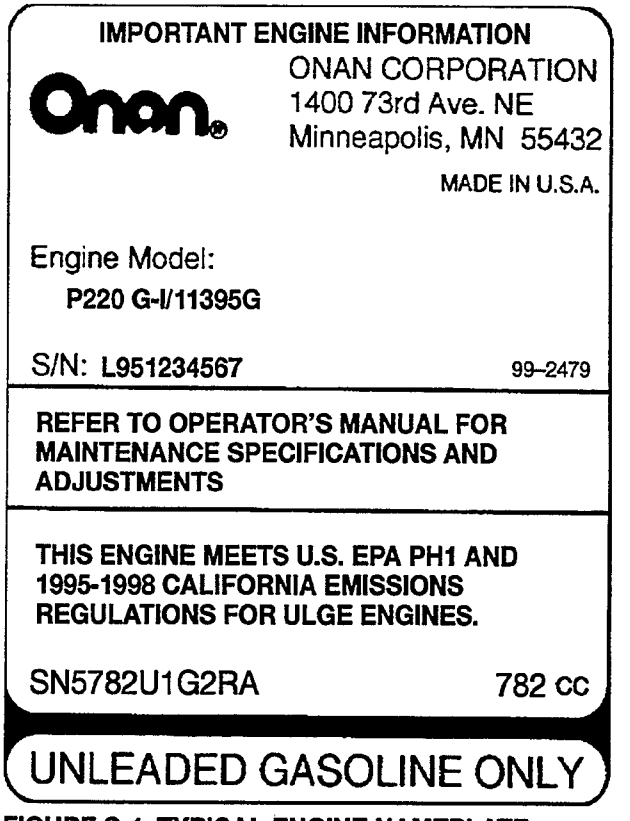


FIGURE S-1. TYPICAL ENGINE NAMEPLATE

Insert this Supplement under the front cover of the manual, on top of Supplement 965-1062

Supplement 965-1062
Date: 11-95
Insert with-
Title: Miller Engine Operator and Service Manual
Number (Date): 965-0163 (10-95)

PURPOSE

This Supplement transmits the revisions to the Operator and Service Manual necessary for covering ***Spec G*** engines. Note that the nameplate (Figure S-1) on Spec G and later engines will have the statement: "This engine meets 1995-1998 California emissions regulations for ULGE engines."

To satisfy California emissions regulations, Spec G and later engines have modified, precision-manufactured carburetors with tamper-resistant fuel mixture jets. It should therefore be noted that fuel mixture adjustments should not be attempted. Nor should the carburetor be overhauled. Instead, a malfunctioning carburetor should be replaced.

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

Modification, removal or replacement of the engine label is also prohibited.

REVISIONS TO OPERATOR AND SERVICE MANUAL 965-0163

1. **Insert this Supplement in its entirety under the front cover of the manual.**
2. On **Page 6-1** write: "See Supplement 965-1062 for fuel and engine oil recommendations."
3. On **Page 7-1** following the PERIODIC MAINTENANCE SCHEDULE write: "For Spec G and later engines, replace spark plugs after every 500 hours of operation."
4. On **Page 8-1** write: "See Supplement 965-1062 for engine oil recommendations."
5. On **Page 9-2** following the third and fourth paragraphs in the first column write: "Does not apply to Spec G and later engines. See Supplement 965-1062."
6. On **Page 9-2** following Paragraph **4. B.** under the Sub-heading **P218 Adjustments** write: "Do not attempt to adjust fuel mixture on Spec G and later engines."
7. On **Page 9-2** following Paragraph **3. B.** under the Sub-heading **P216, P220 Adjustments** write: "Do not attempt to adjust fuel mixture on Spec G and later engines."
8. On **Page 9-3** under the Heading **CARBURETOR OVERHAUL** write: "Does not apply to Spec G and later engines. See Supplement 965-1062."

MODEL IDENTIFICATION (BEGINNING SPEC G)

Whenever contacting a Miller® or Onan® dealer or distributor for information, parts or service, always provide the model number and the serial number marked on the nameplate of the engine. (The serial number is in the row marked "S/N", just below the model number.) Figure S-1 illustrates a typical engine nameplate.

FIGURE S-1. TYPICAL ENGINE NAMEPLATE

FUEL RECOMMENDATIONS

⚠WARNING ***Gasoline is highly flammable and can cause severe personal injury or death. Do not smoke if you smell gasoline or are near fuel tanks or gasoline-burning equipment or are in an area sharing ventilation with such equipment. Keep flames, sparks, pilot lights, electrical arcs and arc-producing equipment and all other sources of ignition well away. Keep an ABC fire extinguisher handy.***

Use clean, fresh unleaded gasoline having a minimum octane rating (Anti-Knock Index) of 87.

During some times of the year only mandated "oxygenated" gasolines may be available. These are acceptable for use, but not preferable. Leaded gasoline may be used but will result in the extra maintenance required for removing combustion chamber and spark plug deposits. Do not use gasoline or gasoline additives (de-icers) containing methanol because methanol can be corrosive to fuel system components.

⚠CAUTION ***Do not use gasoline or gasoline additives containing methanol because methanol can be corrosive to fuel system components.***

Avoid using highly leaded gasolines and lead additives because of the extra engine maintenance that will be required.

ENGINE OIL RECOMMENDATIONS

Use premium quality motor oil. Look for the API (American Petroleum Institute) classification and use Class SG or SH oil (also SG/CD, SG/CE, SH/CD or SH/CE). Also look for the SAE (Society of Automotive Engineers) viscosity grade. Referring to Table S-1, choose the viscosity grade appropriate for the ambient temperatures expected during the period of time until the next scheduled oil change.

Single-grade SAE 30 oil is preferable when temperatures are consistently above freezing. Multigrade oils are better when wide temperature variations are expected.

TABLE S-1. OIL VISCOSITY VS. TEMPERATURE

EXPECTED AMBIENT TEMPERATURES	SAE VISCOSITY GRADE
32° F (0° C) and higher	30
10° F to 100° F (–12° C to 38° C)	15W-40 (OnaMax)
0° F to 80° F (–18° C to 27° C)	10W-30 10W-40
–20° F to 50° F (–28° C to 10° C)	5W-30

INFORMATION FOR CALIFORNIA ENGINE USERS

These engines meet the requirements of California's Exhaust Emissions Standards for 1995 and later for Utility and Lawn and Garden Equipment Engines.

As a California user of these engines, please be aware that unauthorized modifications or replacement of fuel, exhaust, air intake, or speed control system components that affect engine emissions are prohibited. Unauthorized modification, removal or replacement of the engine label is prohibited.

You should carefully review Operator (Owner), Installation and other manuals and information you receive with your engine or equipment. If you are unsure that the installation, use, maintenance or service of your engine or equipment is authorized, you should seek assistance from an approved Onan engine dealer or an approved dealer for your equipment.

California engine users may use Table S-2 as an aid in locating information related to the California Air Resources Board requirements for emissions control.

TABLE S-2. EMISSIONS CONTROL INFORMATION

Engine Warranty Information	The California emissions control warranty statement is located in the same packet of information as this manual when the engine is shipped from the factory.
Engine Valve Lash	See *Specifications* (Page 2-1).
Engine Ignition Timing	See *Specifications* (Page 2-1). Ignition timing is not adjustable.
Engine Fuel Requirements	The engine is certified to operate on **unleaded gasoline**. See Fuel Recommendations on Page S-2 of this Supplement.
Engine Fuel Mixture Settings	The engine has a precision-manufactured carburetor which is not adjustable.
Engine Lubricating Oil Requirements	See Engine Oil Recommendations on Page S-3 of this Supplement.
Engine Adjustments	See **GOVERNOR OPERATION** on Page 9-1 and **P218 Adjustments** and **P216, P220 Adjustments** on Page 9-2, as amended by Instructions 5 and 6 on Page S-1 of this Supplement.
Engine Emission Control System	The engine emission control system consists of internal engine modifications (**EM**).

CARBURETOR (BEGINNING SPEC G)

Carburetor Replacement

Other than replacing the carburetor main fuel jet (fixed-type) with the optional high-altitude jet (Figure S-2), 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 1) that all other necessary engine and generator adjustments and repairs have been performed and 2) that the carburetor is actually malfunctioning (see *Engine Troubleshooting*).

To remove the carburetor, remove the air cleaner, disconnect the fuel line and 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 5000 feet (1524 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.***

Note: The optional high-altitude jet has not been authorized for use in California.

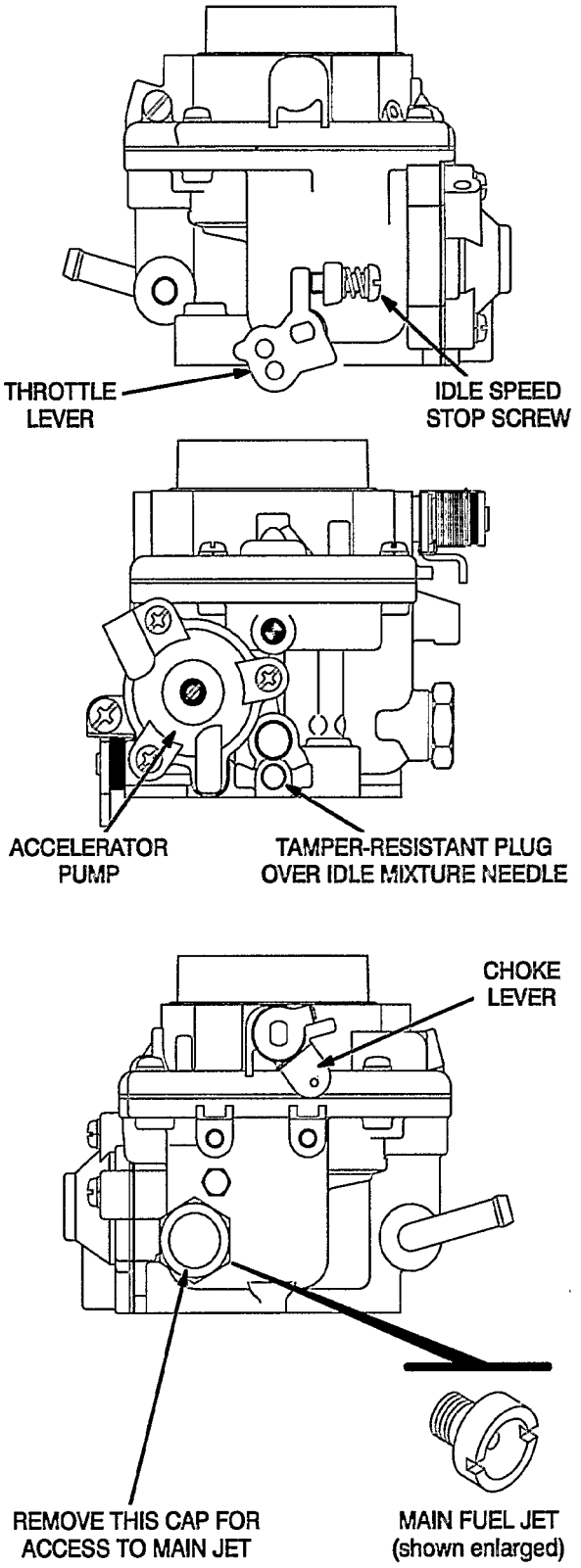


FIGURE S-2. CARBURETOR

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⚠WARNING

EXHAUST GAS IS DEADLY!

Exhaust gases from all fuels (including diesel, gasoline, liquid propane, natural gas) contain carbon monoxide, an odorless and colorless gas. Carbon monoxide is poisonous and can cause unconsciousness and death. Symptoms of carbon monoxide poisoning can include:

- ***Dizziness***
- ***Nausea***
- ***Headache***
- ***Weakness and Sleepiness***
- ***Throbbing in Temples***
- ***Muscular Twitching***
- ***Vomiting***
- ***Inability to Think Coherently***

IF YOU OR ANYONE ELSE EXPERIENCE ANY OF THESE SYMPTOMS, GET OUT INTO THE FRESH AIR IMMEDIATELY. If symptoms persist, seek medical attention. Shut down the unit and do not operate until it has been inspected and repaired.

Protection against carbon monoxide inhalation includes proper installation, ventilation and regular, frequent visual and audible inspections of the complete exhaust system.

⚠ WARNING: ⚠

The engine exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects or other reproductive harm.

General Information

INTRODUCTION

This manual deals with specific mechanical and electrical information needed by engine mechanics for troubleshooting, servicing, repairing, or overhauling the 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 flywheel-blower end of the engine is the front end so right and left sides are determined by viewing the engine from the front. The No. 1 cylinder is on the left, No. 2 cylinder is on the right.

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 trouble.

The wiring diagram shows how the electrical components are interconnected.

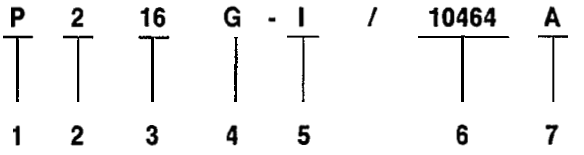
The disassembly section contains major overhaul procedures for step by step removal, disassembly, inspection, repair, and assembly of the engine components.

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.

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. BHP rating.
4. Fuel required (G = gasoline).
5. Engine duty cycle.
6. Factory code for designated optional equipment, if any.
7. Specification (spec letter) which advances with factory production modifications.

⚠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.

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 P216	SERIES P218	SERIES P220
Number of Cylinders		2	2	2
Bore	in (mm)	3.250 (82.55)	3.250 (82.55)	3.250 (82.55)
Stroke	in (mm)	2.620 (66)	2.875 (73)	2.875 (73)
Displacement	cu in (cm^3)	43.3 (710)	47.7 (782)	47.7 (782)
Compression Ratio		6.5 to 1	7.0 to 1	7.0 to 1
Rated Speed (Maximum)	RPM	3600	3600	3600
Power at Rated Speed	BHP (kW)	16 (11.9)	18 (13.4)	20 (14.9)
Oil Capacity Without Filter	Qts (litre)	1.5 (1.4)	1.5 (1.4)	1.5 (1.4)
Oil Capacity With Filter Change	Qts (litre)	1.8 (1.7)	1.8 (1.7)	1.8 (1.7)
Crankshaft Rotation (viewed from flywheel)		Clockwise	Clockwise	Clockwise
Valve Clearance (Cold)				
Intake	in (mm)	.005 (.13)	.005 (.13)	.005 (.13)
Exhaust	in (mm)	.013 (.33)	.013 (.33)	.013 (.33)
Spark Plug Gap	in (mm)	.025 (.64)	.025 (.64)	.025 (.64)
Ignition Timing	BTC	20°	20°	20°
Cylinder Compression	psi (kPa)	75 to 115 (517 to 793)	75 to 115 (517 to 793)	75 to 115 (517 to 793)

Dimensions and Clearances

All clearances given at room temperature of 70°F. (21°C). All dimensions in inches (approximate millimeter dimensions in parentheses) unless otherwise specified.

DESCRIPTION	MINIMUM		MAXIMUM	
	Inches	(mm)	Inches	(mm)
CYLINDER BLOCK				
Cylinder Bore Honed Diameter	3.2490	(82.52)	3.2500	(82.55)
Maximum Allowable				
Taper			0.005	(0.13)
Out-of-Round			0.003	(0.08)
Main Bearing Inside Diameter (Without bearing)	2.1870	(55.55)	2.1880	(55.58)
Main Bearing Inside Diameter (Installed service bearing)	2.0015	(50.84)	2.0040	(50.90)
Camshaft Bearing Bore (Installed service bearing)	1.3757	(34.94)	1.3787	(35.02)
CRANKSHAFT				
Main Bearing Journal Diameter	1.9992	(50.78)	2.0000	(50.80)
Main Bearing Clearance	0.0024	(0.061)	0.0042	(0.107)
Connecting Rod Journal Diameter	1.6252	(41.28)	1.6260	(41.30)
Crankshaft End Play	0.0060	(0.152)	0.0120	(0.305)
CONNECTING ROD				
Large Bore Diameter (Rod bolts properly torqued)	1.6280	(41.35)	1.6285	(41.36)
Connecting Rod Side Clearance	0.0020	(0.051)	0.0160	(0.406)
Piston Pin Bushing Bore (Finished bore)	0.6879	(17.47)	0.6882	(17.48)
Bearing to Crankshaft Clearance	0.0020	(0.051)	0.0033	(0.084)
CAMSHAFT				
Bearing Journal Diameter	1.3740	(34.90)	1.3745	(34.91)
Bearing Clearance	0.0015	(0.038)	0.0030	(0.076)
End Play	0.0110	(0.279)	0.0480	(1.219)
Camshaft Lift		Intake	Exhaust	
P216, P218		.275	.295	
P220		.305	.295	
PISTON				
Clearance in Cylinder				
Measure 90° to pin 1.187 inch below top of piston	0.0033	(0.084)	0.0053	(0.135)
Piston Pin Bore	0.6877	(17.47)	0.6882	(17.48)
Ring Groove Width				
Top Compression Ring	0.0800	(2.032)	0.0810	(2.057)
Middle Compression Ring	0.0800	(2.032)	0.0810	(2.057)
Bottom Oil Control Ring	0.1880	(4.775)	0.1890	(4.800)

DESCRIPTION	MINIMUM Inches	(mm)	MAXIMUM Inches	(mm)
PISTON PIN				
Clearance in Piston	0.00004	(0.001)	0.00064	(0.016)
Clearance in Connecting Rod	0.0002	(0.005)	0.0007	(0.018)
Diameter	0.6875	(17.46)	0.6877	(17.47)
PISTON RINGS				
Clearance				
Top Groove	0.0030	(0.076)	0.0080	(0.203)
Ring End Gap in Cylinder	0.0100	(0.254)	0.0200	(0.508)
INTAKE VALVE				
Stem Diameter	0.2795	(7.099)	0.2800	(7.112)
Clearance (Stem to Guide)	0.0010	(0.025)	0.0025	(0.064)
Valve Face Angle			44°	
INTAKE VALVE SEAT				
Seat Bore Diameter in Block	1.4395	(36.56)	1.4405	(36.59)
Seat Outside Diameter	1.4700	(37.34)	1.4710	(37.36)
Valve Seat Width	0.0310	(0.787)	0.0470	(1.194)
Valve Seat Angle			45°	
EXHAUST VALVE				
Stem Diameter	0.2780	(7.061)	0.2785	(7.074)
Clearance (Stem to Guide)	0.0020	(0.051)	0.0035	(0.089)
Valve Face Angle			44°	
EXHAUST VALVE SEAT				
Seat Bore Diameter in Block	1.1890	(30.20)	1.1900	(30.23)
Seat Outside Diameter	1.1920	(30.28)	1.1930	(30.30)
Valve Seat Width	0.0310	(0.787)	0.0470	(1.194)
Valve Seat Angle			45°	
VALVE GUIDE				
Intake Inside Diameter	0.2810	(7.137)	0.2820	(7.163)
Exhaust Inside Diameter	0.2805	(7.125)	0.2815	(7.150)
TAPPET				
Body Diameter	0.7475	(18.99)	0.7480	(19.00)
Bore Diameter	0.7500	(19.05)	0.7515	(19.09)
Clearance in Bore	0.0020	(0.051)	0.0040	(0.102)
VALVE SPRINGS INTAKE AND EXHAUST				
Valve Spring Free Length (Approx.)		1.600	(40.64)	
Valve Spring Length				
Valve Open		1.055	(26.80)	
Valve Closed		1.346	(34.19)	
Spring Load (Valve Open Length)		55 lb.	(25 kg)	
Spring Load (Valve Closed Length)		25 lb.	(11 kg)	
GEAR BACKLASH				
Timing Gear	0.0010	(0.025)	0.0050	(0.127)
Oil Pump Gear	0.0010	(0.025)	0.0080	(0.203)

Assembly Torques

The torque values given in Table 1 have been determined for specific applications. Standard torque values must not be used where those listed in Table 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.

TABLE 1.

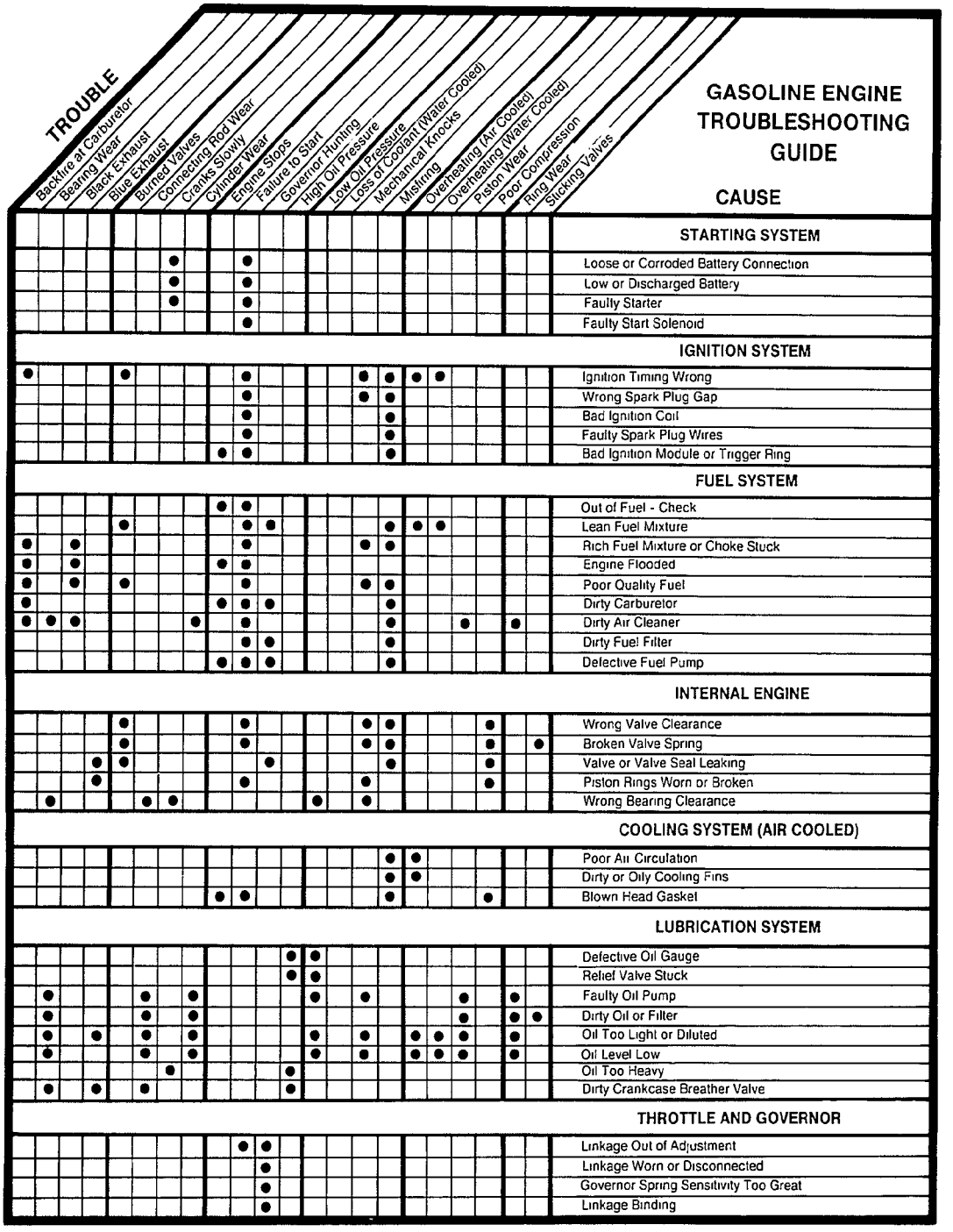
DESCRIPTION	TORQUE SPECIFICATION Ft.-Lb.	Nm	DESCRIPTION	TORQUE SPECIFICATION Ft.-Lb.	Nm
Gearcase Cover	8-10	11-14	Intake Manifold Mounting Screws	6-10	8-14
Rear Bearing Plate Screws	25-27	34-37	Exhaust Manifold Mounting Screws	9-11	12-15
Starter Mounting Bolts	19-21	25-28	Other 1/4" Cylinder Block Stud and Nuts	7-9	10-12
Connecting Rod Bolts	14	19	Other 5/16" Cylinder Block Stud and Nuts	8-10	11-14
Flywheel Capscrews	50-55	67-75	Other 3/8" Cylinder Block Stud and Nuts	18-23	24-31
Oil Base	18-23	24-31			
Oil Pump	7-9	10-12			
Valve Cover	1-2	1-3			
Cylinder Head Bolts (Cold)					
Asbestos Gasket	16-18	22-24			
Graphoil Gasket	14-16	19-22			

Special Tools

The following special tools are available from Onan. For further information see *TOOL CATALOG 900-0019.*

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

Engine Troubleshooting



M-1686

Engine Set-Up

Inspect the engine visually. Check for loose or missing parts and any damage that may have occurred in shipment.

⚠CAUTION ***Oil and fuel have been drained from the engine prior to shipping from Onan. Severe engine damage will result if engine is started without oil.***

BATTERIES

The batteries and battery cables used for starting the engine should be of sufficient size to provide prompt starting. Undersized batteries will result in poor starter operation and a very short starter service life.

⚠WARNING ***Ignition of explosive battery gases can cause severe personal injury. Do not smoke while servicing batteries.***

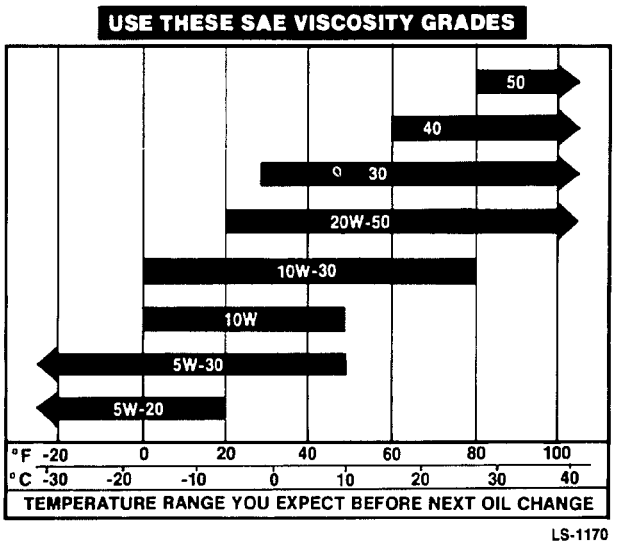
⚠CAUTION ***This engine uses a 12 volt, negative ground system. Alternator must be connected to battery at all times when engine is running. Reversing positive and negative battery will damage the engine electrical system.***

CRANKCASE OIL RECOMMENDATIONS

Fill crankcase with correct amount of oil. Refer to *Specifications* for crankcase capacity. Use oils meeting the API classification SF, SF/CC, or SF/CD. Refer to chart below to determine the proper viscosity grade of oil to use. Straight weight oils are recommended for severe duty use and at temperatures above 32°F (0°C) for minimum oil consumption.

⚠WARNING ***Crankcase pressure can blow out hot oil and cause serious burns. Do NOT check oil while the engine is operating.***

⚠CAUTION ***Do not overfill crankcase. Excess oil causes high oil consumption and oil accumulation in air cleaner housing.***



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Oil Level

Check oil level at least every 8 hours of operation. Check more frequently on a new or reconditioned engine as oil consumption is higher until the piston rings seat properly.

When adding oil between oil changes, it is preferable to use the same brand, as various brands of oil may not be compatible together. Refer to *MAINTENANCE* section for recommended oil change intervals and procedures.

FUEL RECOMMENDATIONS

⚠WARNING ***Ignition of fuel can cause serious personal injury or death by fire or explosion. Do not permit any flame, cigarette, or other igniter near the fuel system.***

Use clean, fresh, unleaded gasoline. Regular leaded gasoline may also be used but is not a preferred fuel. Do not use highly leaded premium gasoline. Use of unleaded gasoline results in less maintenance.

⚠CAUTION ***Do not use gasoline de-icers. Gasoline de-icers can cause internal damage to carburetor and fuel pump parts. Do not use fuels containing alcohol concentrations greater than ten percent. Fuel containing alcohol may cause poor engine performance and internal engine damage.***

If regular leaded gasoline is used continually, carbon and lead deposits should be removed from the cylinder heads as required because of engine power loss. Unleaded gasoline may be used safely after lead deposits have been removed.

⚠WARNING ***Spilled fuel can ignite and cause serious personal injury or death. Never fill the fuel tank when the engine is running.***

EXHAUST SYSTEM

Exhaust products of any internal combustion engine are toxic and can cause injury, or death if inhaled. All engine applications, especially those within a confined area, should be equipped with an exhaust system to discharge gases to the outside atmosphere.

⚠WARNING ***Inhalation of exhaust gases can result in serious personal injury or death. Use extreme care during installation to ensure a leak-free exhaust system.***

Operation

STARTING

Most engines are equipped with a start-stop switch and cable controlled choke and throttle.

1. Place the throttle control in the *SLOW* position and the choke into the *FULL* choke position.
2. Turn the ignition switch on and engage starter. If engine fails to start after 30 seconds determine the cause. Wait one minute before recranking. If the engine fails to start at first attempt, rust inhibitor oil used at the factory may have fouled the plugs. Remove the plugs, clean in a suitable solvent, dry thoroughly and reinstall. Heavy exhaust smoke when the engine is initially started is normal and usually caused by rust inhibitor oil.
3. When the engine starts, gradually push the choke lever in until the engine runs smoothly.
4. Black smoke from the exhaust and a rough running engine usually indicate over-choking.
5. To stop the engine, turn the ignition switch to the *OFF* position.

BREAK-IN PROCEDURE

Controlled break-in is the ideal fitting of all internal moving metal parts. Using the proper oil and applying a conscientious maintenance program during this period helps assure satisfactory service from your Onan engine.

Maintain the proper cooling and lubrication during break-in. Run the engine at half load for the first three hours with intermittent periods of full load to control engine break-in.

⚠CAUTION ***Using the wrong grade and weight of oil and high engine operating temperatures during break-in can cause engine damage.***

Check the oil level at least every five operating hours. Add oil to keep it at the proper level, but never overfill as overfilling may cause the oil to foam and enter the breather system.

HOT WEATHER OPERATION

When operating the engine in temperatures above 100° F (38°C), pay particular attention to the following items to prevent damage:

1. Keep the engine cooling fins clean and free of obstruction.

⚠CAUTION ***Plugged or clogged cooling fins can cause overheating and engine damage.***

⚠WARNING ***Contact with rotating machinery can cause serious personal injury or death. Stay clear of rotating components and ensure that protective shields and guards are in place and secured before operating machinery.***

2. See that nothing obstructs air flow to and from the engine.
3. Ensure that you are using the proper grade and weight of oil for ambient temperatures. Check the oil level each time you fill the fuel tank.
4. Check the battery water more frequently than every 50 hours which is recommended under normal conditions. High temperatures cause faster evaporation.
5. Change crankcase oil and filter more frequently than recommended under normal conditions.

COLD WEATHER OPERATION

When the engine is being used in temperatures below 32°F (0°C), check the following items closely:

1. Use the correct grade and weight of oil for the temperature conditions. Change the oil only when the engine is warm. If an unexpected temperature drop occurs when the engine is filled with summer oil, before starting the engine, move it to a warm location until the oil will flow freely.
2. Use fresh fuel. Fill the fuel tank after each day's use to protect against moisture condensation.
3. Keep the battery in a well-charged condition.

DUST AND DIRT

1. Keep unit clean. Keep cooling system clean.
2. Service air cleaner as frequently as required.
3. Change crankcase oil and filter more often than recommended under normal conditions.

OUT-OF-SERVICE PROTECTION

Protect an engine that will be out-of-service for more than 30 days as follows:

1. Run the engine until it reaches normal operating temperature.
2. Turn off the fuel supply and run the engine until it stops.
3. Drain oil from oil base while the engine is still warm. Refill with fresh crankcase oil and attach a tag stating viscosity used.

4. Remove spark plugs. Pour 1 ounce (2 tablespoons or 28 grams) of rust inhibitor or SAE #50 oil into the cylinders. Crank the engine over a few times. Reinstall spark plugs.

5. Service air cleaner as outlined in *FUEL SYSTEM.*

6. Clean governor linkage and protect by wrapping with a clean cloth.

7. Plug exhaust outlet to prevent entrance of moisture, dirt, bugs, etc.

8. Wipe entire unit. Coat rustable parts with a light film of grease or oil.

9. Provide a suitable cover for the entire unit.

10. If battery equipped, disconnect and follow standard battery storage procedure.

RETURNING UNIT TO SERVICE

1. Remove cover and all protective wrapping. Remove plug from exhaust outlet.
2. Check tag on oil base and verify that oil viscosity is still correct for existing ambient temperatures.
3. Clean and check battery. Measure specific gravity (1.260 at 77°F [25°C]) and verify level to be at split ring. If specific gravity is low, charge until correct value is obtained. If the level is low, add distilled water and charge until specific gravity is correct.
4. Check that fuel filter and fuel lines are secure, with no leaks.
5. Check carburetor, adjust if necessary.
6. Connect battery.
7. Start engine. Exhaust smoke when the engine is started is normal and is usually caused by the rust inhibitor oil.

⚠WARNING

EXHAUST GAS IS DEADLY!

Exhaust gases from all fuels (including diesel, gasoline, liquid propane, natural gas) contain carbon monoxide, an odorless and colorless gas. Carbon monoxide is poisonous and can cause unconsciousness and death. Symptoms of carbon monoxide poisoning can include:

- ***Dizziness***
- ***Nausea***
- ***Headache***
- ***Weakness and Sleepiness***
- ***Throbbing in Temples***
- ***Muscular Twitching***
- ***Vomiting***
- ***Inability to Think Coherently***

IF YOU OR ANYONE ELSE EXPERIENCE ANY OF THESE SYMPTOMS, GET OUT INTO THE FRESH AIR IMMEDIATELY. If symptoms persist, seek medical attention. Shut down the unit and do not operate until it has been inspected and repaired.

Protection against carbon monoxide inhalation includes proper installation, ventilation and regular, frequent visual and audible inspections of the complete exhaust system.

PERIODIC MAINTENANCE SCHEDULE

Follow a regular schedule of inspection and servicing, based on operating hours. Keep an accurate logbook of maintenance, servicing, and operating time. Use the factory recommended Periodic Maintenance Schedule (based on favorable operating conditions) to serve as a guide to get long and efficient engine life. Regular service periods are recommended for normal service and operating conditions. For continuous duty, extreme temperature, etc., service more frequently. For infrequent use, light duty, etc., service periods can be lengthened accordingly. Neglecting routine maintenace can result in engine failure or permanent damage.

For any abnormalities in operation, unusual noises from the engine or accessories, loss of power, overheating, etc., contact your nearest Onan Service Center.

PERIODIC MAINTENANCE SCHEDULE

SERVICE THESE ITEMS	AFTER EACH CYCLE OF INDICATED HOURS					
	8	25	50	100	200	1000
Inspect Engine Generally	X[1]					
Check Oil Level	X					
Service Air Cleaner		X[2]				
Change Crankcase Oil (with filter)		X[3]	X[2]	X[2,8]		
Change Crankcase Oil (without filter)		X[2]				
Check Battery Electrolyte Level			X			
Clean Cooling Fins			X[2]			
Replace Oil Filter		X[3]		X[2]		
Check or Replace Spark Plugs					X	
Clean Breather Valve						X[2]
Replace Air Cleaner Element					X[2]	
Check Valve Clearance					X[4,6]	X[4,5]
Clean Carbon and Lead Deposits (Cylinder Head)						X[7]

X[1] - Check for fuel leaks. With engine running, visually and audibly check exhaust system for leaks.
X[2] - Perform more often when running under severe operating conditions.
X[3] - Initial break-in check only.
X[4] - For detailed maintenance, contact an Onan Service Center or refer to *ENGINE DISASSEMBLY.*
X[5] - For engines with extended service life package. This interval for standard engines is 200 hours.
X[6] - For standard engines without extended service life package. This interval for extended service life packages is 1000 hours.
X[7] - Clean carbon more frequently when running under continuous light load and/or on leaded fuel. Use of Onan 4C carburetor and combustion cleaner is recommended every 200 hours to help reduce carbon buildup.
X[8] - AEAD 200LE Legend Welder only.

⚠WARNING ***Inhalation of exhaust gases can result in serious personal injury or death. Do NOT use the air cleaner or exhaust elbow as a supporting step. Damage to these and connecting parts might cause an exhaust leak.***

Oil System

CRANKCASE OIL

Refer to *Periodic Maintenance Schedule* for oil change interval. If operating in extremely dusty, high ambient, or low ambient conditions, change oil more often.

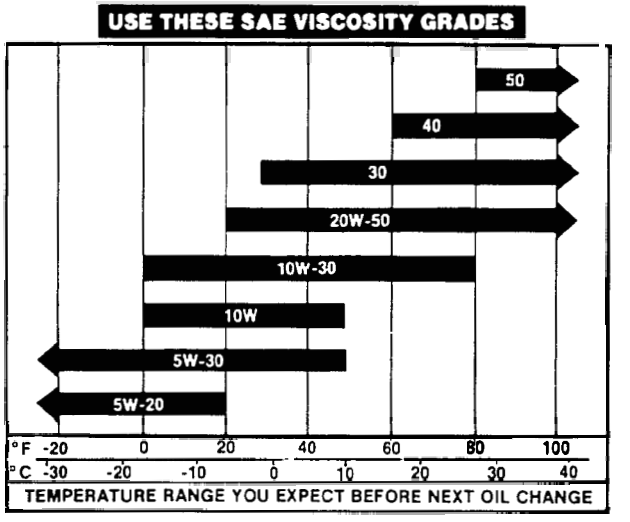
⚠WARNING ***Crankcase pressure can blow out hot oil and cause serious burns. Do NOT check oil while the engine is operating.***

⚠CAUTION ***Do not overfill crankcase. Excess oil causes higher operating temperatures and may cause foaming.***

Run engine until thoroughly warm before draining oil. Stop the engine, place a pan under the drain outlet and remove the oil drain plug. After the oil is completely drained, clean and replace the drain plug. Fill crankcase with correct amount of oil. Refer to *SPECIFICATIONS* for crankcase capacity. Use oils meeting the API classification SF, SF/CC, or SF/CD. Refer to chart to determine the proper viscosity grade of oil to use. Straight weight oils are recommended for severe duty use and at temperatures above 32°F (0°C) for minimum oil consumption.

⚠WARNING ***Hot crankcase oil can cause burns if it is spilled or splashed on skin. Keep fingers and hands clear when removing the oil drain plug and wear protective clothing.***

Oil level should be to the FULL mark of the dipstick. Start engine and run for a short time to check for oil leaks around the drain plug.



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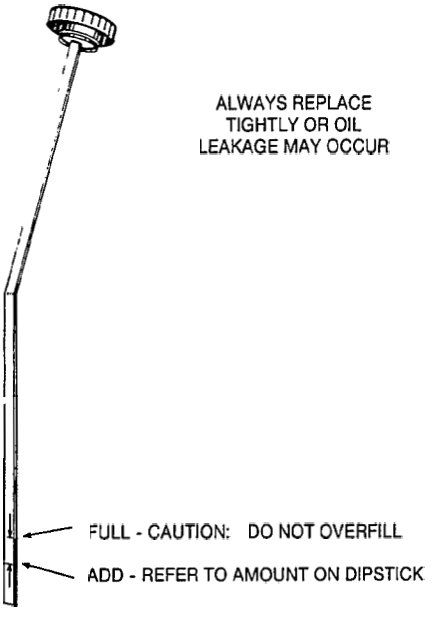

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FIGURE 1. CRANKCASE OIL FILL

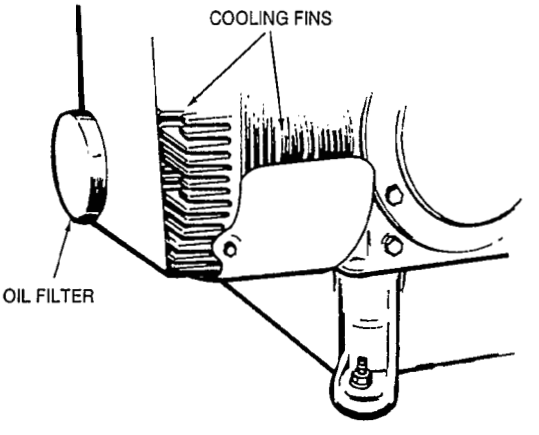

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FIGURE 2. OIL FILTER

OIL FILTER CHANGE

Refer to *Periodic Maintenance Schedule* (located in the Operator's Manual) for oil filter change interval. If operating in extremely dusty, high ambient, or low ambient conditions, change oil filter more often.

Spin off oil filter element and discard it. Thoroughly clean filter mounting surface and make sure new gasket is inserted in the element. Apply a thin film of clean oil to the gasket. Spin element down by hand until gasket just touches mounting pad and then turn down an additional 1/2-3/4 turn. Do not overtighten.

With oil in crankcase, start engine and check for leaks around filter element. Retighten only as much as necessary to eliminate leaks; do not overtighten.

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.

Crankcase Breather Service

If the crankcase becomes pressurized as evidenced by oil leaks at the seals or excessive oil in the air cleaner housing, use the following procedure to service.

⚠WARNING ***Most parts cleaning solvents are flammable and can cause severe personal injury or death if used improperly. Follow the manufacturer's recommendations when cleaning parts.***

P216, P218, P220 (Spec A and B)
Remove the breather tube from the valve cover (Figure 3). Remove capscrew, flatwashers, valve cover, pack, spring, washer, reed valve, and breather baffle. Discard gasket and clean all parts in part cleaning solvent.

⚠CAUTION ***Overtightening the valve cover can cause engine damage. Do not overtighten valve cover.***

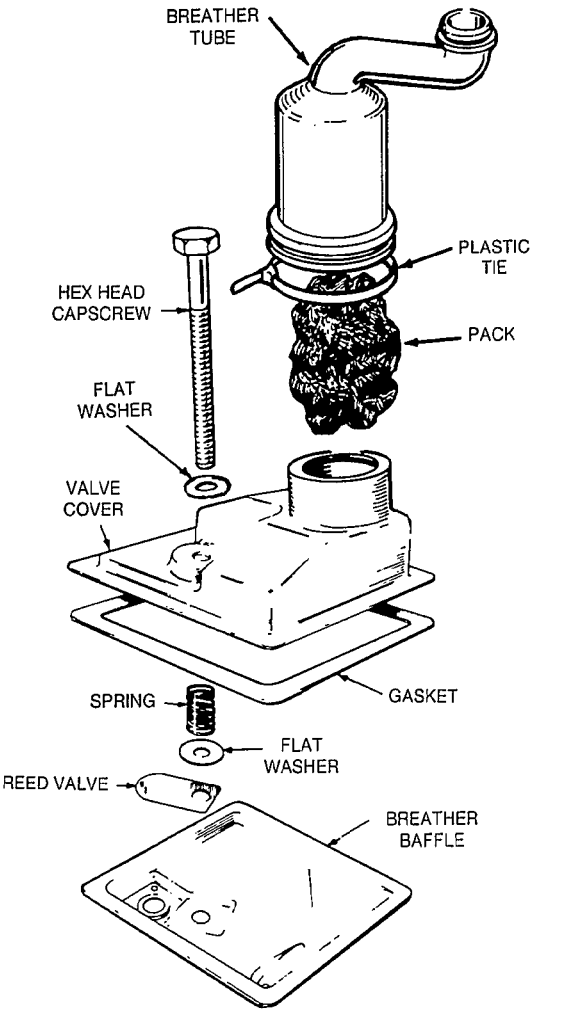


FIGURE 3. CRANKCASE BREATHER

The reed valve must be flat with no sign of a crease. Assemble using a new gasket. Refer to *ASSEMBLY TORQUES* for valve cover capscrew torque specification.

P216, P218, P220 (Beginning Spec C)
The crankcase breather does not require servicing. Replace breather if it's broken or cracked of if crankcase becomes pressurized as evidenced by oil leaks at the seals or excessive oil in the air cleaning 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 by-pass valve is used to control oil pressure. Drain oil before removing oil base and always use a new gasket when replacing the oil base.

Oil Pump

The oil pump (Figure 4) is mounted behind the gear cover and is driven by the crankshaft gear. Inlet pipe and screen assembly are attached directly to the pump body. A discharge passage in pump cover registers with a drilled passage in the crankcase. Parallel passages distribute oil to the front main bearing, rear main bearing and pressure control bypass valve.

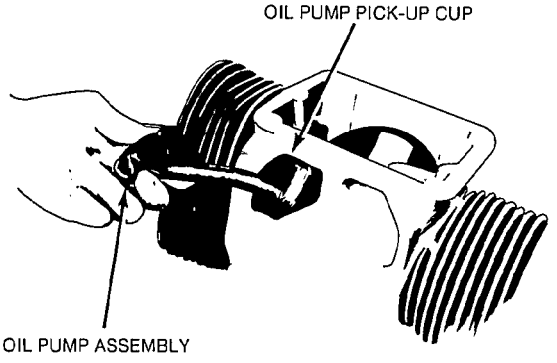


FIGURE 4. OIL PUMP ASSEMBLY

Circumferential grooves in the main bearings supply oil to 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; rear cam bearing is splash lubricated.

Normal oil pressure should be 8 psi (55 kPa) or higher at 1500 rpm, when the engine is at normal operating temperature. If pressure at 1500 rpm drops below this value, inspect oil system for faulty components.

Check oil pump thoroughly for worn parts. Oil pump to prime it before reinstalling. Except for gaskets and pick-up cup, component parts of the pump are not available individually. Install a new pump assembly if any parts are worn.

Oil By-Pass Valve

The by-pass valve (located to the right and behind gear cover) controls oil pressure by allowing excess oil to flow directly back to the crankcase. The valve limits oil pressure to a maximum of about 20 psi (138 kPa) at normal operating temperature.

The valve is non-adjustable and normally does not need maintenance. Determine if valve is operating correctly by inspecting plunger action as follows:

1. Remove the 3/8 x 24 x 7/8 cap screw located behind gear cover and under governor arm.

2. Remove spring and plunger with a magnet tool.

3. Determine proper valve operation by checking the spring and plunger according to the following measurements.

   Plunger Diameter ..... 0.3105 to 0.3125 in. (7.89 to 7.94 mm)

   Spring
   Free Length ..... 1.00 inch (25.4 mm)
   Load .....2.6 ± 0.2 lbs (11.6 ± 0.9 N) when compressed to 0.5 inch (12.7 mm)

4. Check the valve seat and clean away any accumulation of metal particles which could cause erratic valve action. Verify that the valve seat is not damaged.

5. Clean plunger and spring in parts cleaning solvent and install.

Fuel System

GOVERNOR OPERATION

These welder engines use a mechanical governor with a two-speed control. The solenoid and its linkage are supplied and installed by Miller Electric.

Check the governor arm, linkage, throttle shaft, and lever for binding condition or excessive slack and wear at connecting points. A binding condition at any point will cause the governor to act slowly and regulation will be poor. Excessive looseness may cause a hunting condition and regulation could be erratic.

The engine starts at wide open throttle. As the engine comes up to speed the governor takes over control to maintain the no load speed.

A reliable instrument for checking engine speed is required for accurate governor adjustment. Engine speed can be checked with a tachometer.

Speed settings are:

	Low	High
P218		
60 Hz	1860	3000
50 Hz	1650	3000
P216, P220	2200	3700

Governor Adjustments

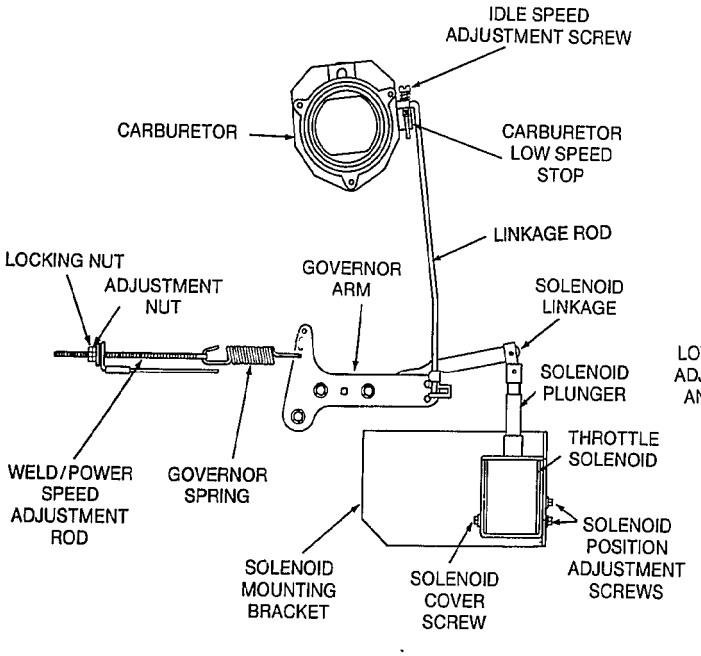
The governor linkage rod connects the governor arm (Figure 1) to the throttle shaft lever so they function properly when the engine starts and runs. The linkage rod is adjusted with the engine stopped and the throttle plate at wide open position. The engine will also crank and start in this condition.

When a load is applied, the throttle opens proportionally under governor control to provide more engine power.

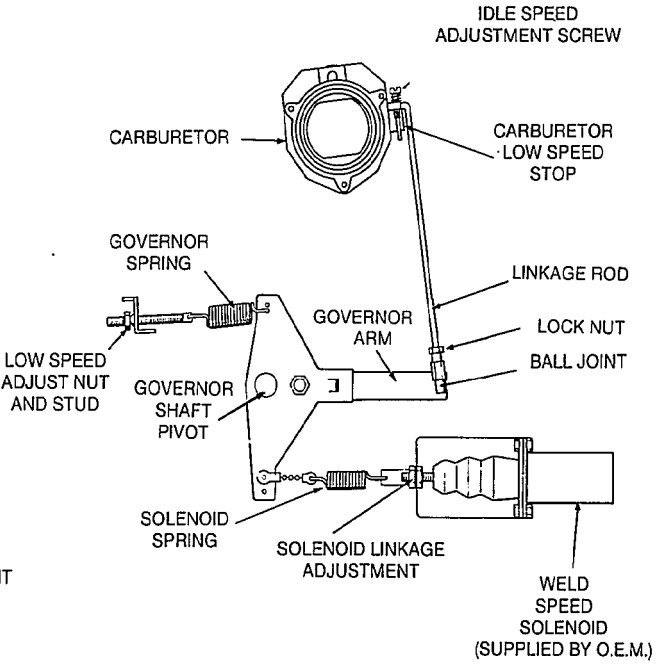
The tension of the governor spring controls engine speed. The governor spring is factory set in the hole of the governor arm nearest the pivot point or shaft. To decrease sensitivity move spring to hole farthest from pivot.

Sensitivity control for the P218 is determined by the position of the solenoid spring in the governor arm hole. The throttle opening will vary depending on the load current demands of the welding operation.

For governor sensitivity and linkage adjustments refer to OEM service manual.



P216, P220 ENGINE



P218 ENGINE

FIGURE 1. GOVERNOR LINKAGE

CARBURETOR SPEED AND MIXTURE ADJUSTMENTS

The carburetor adjustments were 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 and is not the source of the problem.

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

The carburetor has a limited 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.

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

⚠CAUTION ***Forcing the mixture adjustment screw tight will damage the needle and seat. Turn in only until light tension can be felt.***

P218 Adjustments

1. Start the engine and allow it to warm up thoroughly (at least 10 minutes).
2. Place the WELD/CHARGE-POWER switch in the POWER position.
3. Rotate the FINE AMPERAGE control to 100.
4. Pull the governor arm away from the carburetor to cause the engine to idle. While holding the arm against spring tension, make the following adjustments:
   A. Rotate idle speed adjustment screw until the engine runs at 1800 rpm.
   B. Rotate the idle mixture screw in or out (±1/8 turn) to obtain maximum rpm with idle speed adjustment screw against stop.
5. Re-adjust the throttle stop screw to obtain 1700 rpm on 60 Hz models and 1500 rpm on 50 Hz models. Release governor arm.
6. Adjust low speed nut (Figure 1) on governor spring for a stable no load engine speed of 1860 rpm on 60 Hz models and 1650 rpm on 50 Hz models.
7. Place the WELD/CHARGE-POWER switch in the WELD/CHARGE position.
8. Place the AUTO IDLE switch in the OFF position.
9. Loosen the locking nut on the weld speed adjustment rod and rotate the adjustment nut until the engine runs at 3000 rpm. Tighten locking nut.

P216, P220 Adjustments

1. Start the engine and allow it to warm up thoroughly (at least 10 minutes).
2. Loosen the two throttle solenoid position adjustment screws (Figure 1).
3. Pull the governor arm away from the carburetor to cause the engine to idle. While holding the governor arm against spring tension, make the following adjustments:
   A. Rotate idle speed adjustment screw until the engine runs at 2200 rpm.
   B. Rotate the idle mixture screw in or out (±1/8 turn) to obtain maximum rpm with idle speed adjustment screw against stop.
   C. Readjust idle speed adjustment screw for 2200 rpm.
4. Place the AUTO IDLE switch in the ON position to energize the throttle solenoid.
5. Slide solenoid forward or backward until the idle speed adjustment screw just touches the carburetor low speed stop.
6. Tighten the two solenoid position adjustment screws. Check solenoid linkage for any binding, and readjust throttle solenoid if necessary. The idle speed should be 2200 rpm ±100.
7. Place the AUTO IDLE switch in the OFF position.
8. Loosen the locking nut on the weld/power speed adjustment rod, and rotate adjustment nut until the engine runs at 3700 rpm. Tighten locking nut.

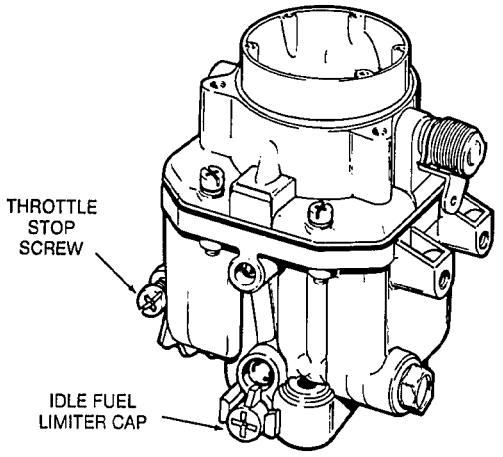


FIGURE 2. CARBURETOR ADJUSTMENTS

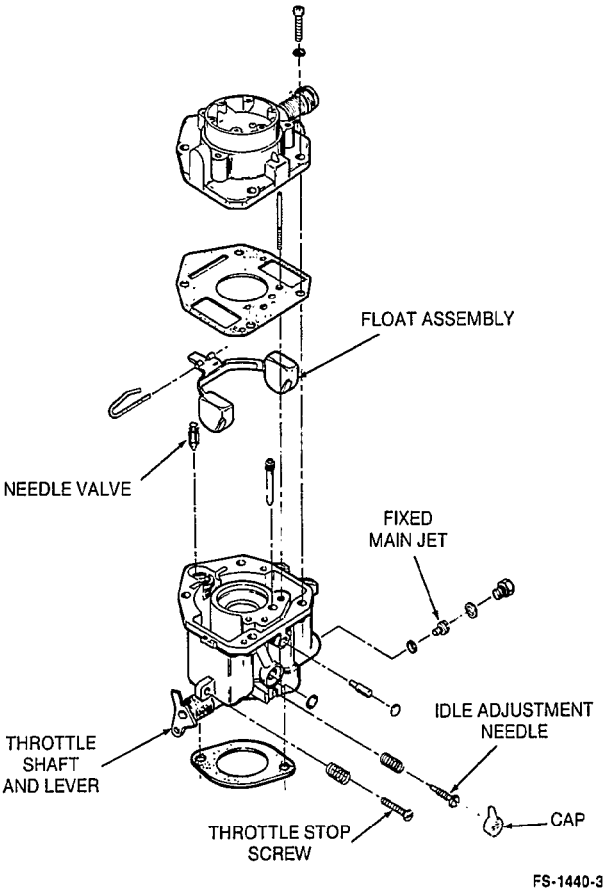


FIGURE 3. CARBURETOR ASSEMBLY

CARBURETOR OVERHAUL

Carburetion 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 3.

⚠WARNING ***Ignition of fuel can cause serious personal injury or death by fire or explosion. Do not permit any flame, cigarette, or other igniter near the fuel system.***

Removal

1. Remove air cleaner and hose.
2. Disconnect governor and throttle linkage, choke control and fuel line from carburetor.
3. Remove the four intake manifold cap screws and lift complete manifold assembly from engine.
4. Remove carburetor from intake manifold.

Disassembly

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

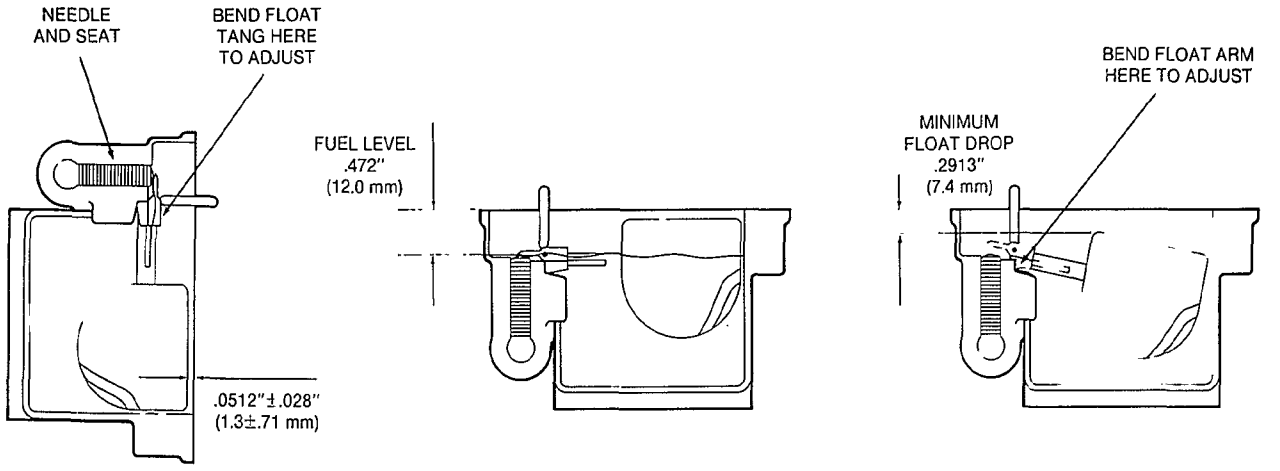


FIGURE 4. CARBURETOR FLOAT LEVEL ADJUSTMENTS

FS-1683

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 cleaning 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 may increase the size of critical passages.
4. Check the condition of the adjustment needle; replace if damaged. Replace 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 needle valve, main jet, and float assembly. Make sure float pivot pin is properly placed and float moves freely without binding.
2. Turn carburetor on its side and measure float level (Figure 4). Adjust float level only if necessary. Measure float drop (the distance from the top of carburetor body to top of float). Adjust only if necessary.
3. Position gasket on lower carburetor section and install upper carburetor section.
4. Install idle adjustment screw, throttle stop screw, and fixed main jet plug.
5. Mount carburetor on intake manifold and install assembly on engine.
6. Mount air cleaner assembly. Connect air intake hose, breather hose, fuel line, vacuum line, and throttle linkage.
7. Adjust carburetor and governor according to directions given in this section.

PULSATING-DIAPHRAGM FUEL PUMP

Pulsating-diaphragm fuel pumps, or pulse pumps, rely on changes in crankcase vacuum to create a pulsating movement of the pump diaphragm. As the engine's 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's pistons move inward, crankcase vacuum is reduced and the diaphragm return spring pushes the pump diaphragm forward, forcing fuel through the pump outlet.

Fuel Pump Test Procedure

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

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

2. Shut engine off and remove fuel inlet line from fuel pump.

⚠WARNING ***Spilled fuel can ignite and cause serious personal injury or death. Thoroughly clean-up any spilled fuel.***

3. Connect a vacuum gauge to fuel pump inlet using a piece of fuel hose with clamps.

4. Start engine and allow to idle for at least five seconds. Record vacuum gauge reading.

5. Move throttle control to high idle position. Wait at least five seconds and record vacuum gauge reading.

6. Shut engine off and remove vacuum gauge hose from fuel pump inlet. Connect fuel inlet line to fuel pump.

7. Remove fuel outlet line from fuel pump.

⚠WARNING ***Spilled fuel can ignite and cause serious personal injury or death. Thoroughly clean-up any spilled fuel.***

8. Connect a pressure gauge to fuel pump outlet using a piece of fuel hose with clamps.

9. Start engine and allow to idle for at least five seconds. While holding pressure gauge level with pump outlet record pressure gauge reading.

10. Move throttle control to high idle position and allow engine to run for at least five seconds. While holding pressure gauge level with pump outlet record pressure gauge reading.

11. Shut engine off and remove pressure gauge hose from fuel pump outlet. Connect fuel outlet line to fuel pump.

Replace the fuel pump if test readings are not within the values specified in TABLE 1.

TABLE 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

AIR CLEANER

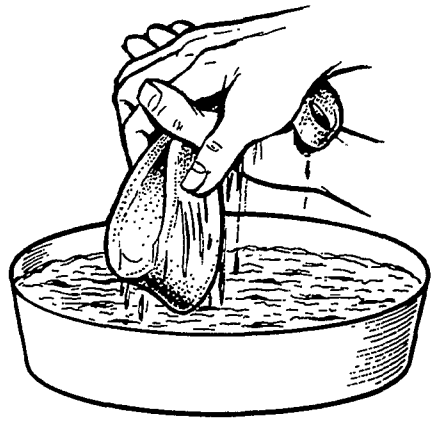
⚠CAUTION ***If air cleaner becomes too dirty, engine will not receive sufficient air to run properly. Symptoms: Loss of power, flooding, hard starting and overheating.***

Engine is equipped with a paper element. If the engine is equipped with an element wrapper, it must be removed, cleaned, and oiled every 25 hours of operation; more often under extremely dusty conditions.

1. To clean element wrapper, wash in water and detergent (Figure 5). Remove excess water by squeezing like a sponge, and allow to dry thoroughly. Distribute one tablespoon of SAE 30 engine oil evenly around the precleaner. Knead into precleaner and wring out excess oil.

2. Depending on conditions in which the engine is operating, the inner paper element should be replaced whenever it becomes excessively dirty or oily.

⚠CAUTION ***Never run engine with air cleaner removed. Dirt will enter engine and wear out rings causing excessive blow-by.***



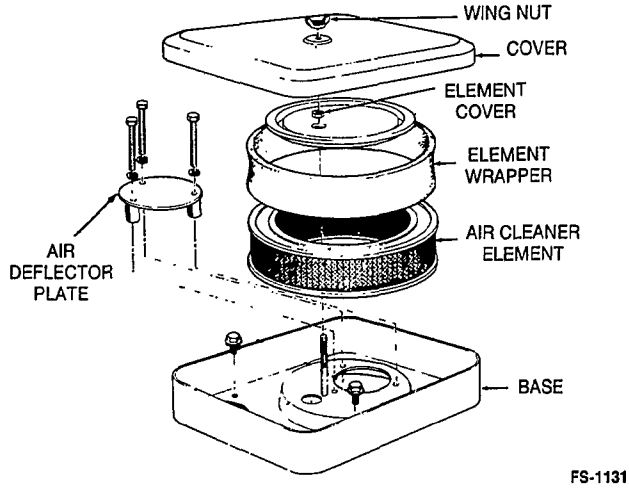


FIGURE 5. AIR CLEANER ASSEMBLY

Ignition and Battery Charging

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 behind the flywheel. The module receives a timing signal from magnets within the trigger ring which rotates with the engine crankshaft (Figure 1). If the electronic ignition is suspected of malfunctioning, proceed as follows:

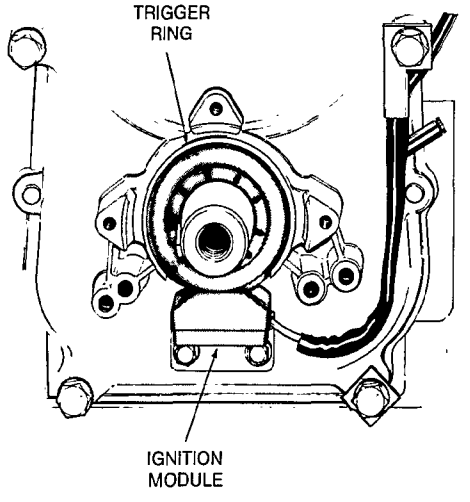


FIGURE 1. IGNITION MODULE AND TRIGGER RING

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 to test coil for proper resistance. If coil checks out good, go to step 3.

⚠WARNING ***The electronic ignition will deliver full voltage to the spark plugs even when rotated by hand. Care should be taken to avoid an electrical shock.***

⚠WARNING ***Failure to remove spark plugs before turning engine over may result in engine starting, which may cause severe personal injury.***

⚠WARNING ***Failure to ground spark tester away from spark plug hole may result in ignition of cylinder gases and may cause severe personal injury.***

3. Pull spark plug wires off spark plugs and remove spark plugs. Connect an approved spark tester to each of the spark plug wires and ground them away from spark plug hole. Turn key on and crank engine over for 5 seconds while watching for spark. If a spark occurs regularly, the problem is not in the ignition system. If no spark occurs, go to step 4.

⚠CAUTION ***Never put jumper lead to the coil negative terminal. This will cause failure of the electronic module.***

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 spark. If 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. If no spark occurs, go to step 5.

5. Connect positive side of voltmeter to negative (-) coil terminal (larger diameter of the two threaded posts) and negative side of voltmeter to engine ground. Turn key on and rotate flywheel slowly by hand while observing voltmeter. Voltage should switch between battery voltage and 1-1.5 for each revolution. If voltage does not switch properly, replace ignition module.

⚠CAUTION ***Never put B+ lead to the coil negative terminal. This will cause failure of the electronic ignition module.***

6. Install spark plugs and wires. If ignition module is being replaced, be sure to connect red lead from new ignition module to positive (+) terminal of coil, black lead from module to negative (-) terminal of 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 flywheel (Figure 2). This check can be performed by a continuity test.

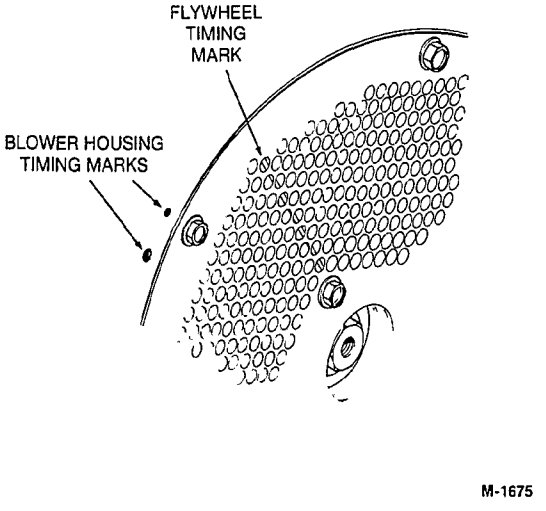


FIGURE 2. IGNITION TIMING MARKS

Continuity Test

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

⚠WARNING ***Failure to remove spark plugs before turning engine over may result in engine starting, which may cause severe personal injury.***

2. Turn 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 will deliver full voltage to the spark plugs even when rotated by hand. Care should be taken to avoid an electrical shock.***

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 screws should lie between the two reference marks on the blower housing. To recheck 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 spark plugs and wires.

IGNITION COIL

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

1. Use a Simpson 260 VOM or equivalent.

2. Place a black lead on negative (-) coil terminal and red lead to positive (+) coil terminal. Primary resistance should read between 2.90-3.60 ohms.

3. Change resistance setting on ohmmeter. Place ohmmeter leads inside of spark plug cable holes (Figure 3). Secondary resistance should read between 14,500-19,800 ohms.

4. If either of the above resistances are not within specification, replace coil.

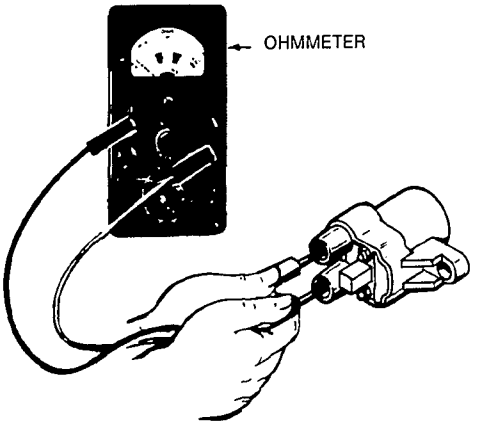


FIGURE 3. COIL TEST

SPARK PLUGS

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

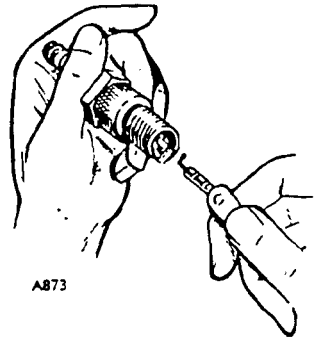


FIGURE 4. SPARK PLUG GAP

BATTERY INSPECTION

⚠WARNING ***Ignition of explosive battery gases can cause severe personal injury. Do not smoke while servicing batteries.***

Check battery cells with a hydrometer (Figure 5). 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.

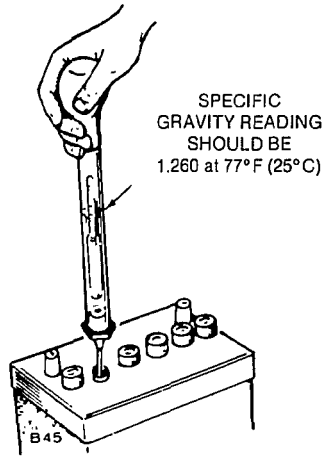


FIGURE 5. SPECIFIC GRAVITY TEST

Keep the battery terminals clean and tight. Push the cable terminal down flush with or slightly below the top of the battery post (Figure 6). 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.

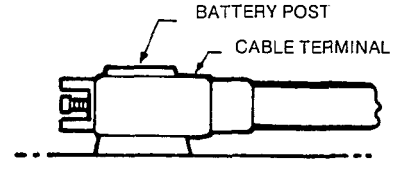


FIGURE 6. BATTERY CABLE CONNECTION

BATTERY 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 of the positive cable to the positive (+) terminal of your engine battery.

⚠WARNING ***Do not allow the positive and negative cable ends to touch each other because it will short the battery causing hazardous arcing, which can cause severe personal injury.***

4. Attach one end of the negative booster cable (black) to negative (-) terminal of booster battery. Attach other end of 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.

⚠CAUTION ***Do not engage starter for periods longer than 30 seconds without allowing 5 minutes for starter to cool. Starter failure may result if these guidelines are not followed.***

⚠WARNING ***Never jump start a frozen battery. To do so can cause the battery to explode. Never expose the battery to an open flame or an electrical spark because a battery creates highly explosive hydrogen gas.***

6. Turn ignition switch to ON to start engine.

FLYWHEEL ALTERNATOR

This unit is equipped with a permanent magnet flywheel alternator and solid-state voltage regulator-rectifier (Figure 7). As with all solid-state electrical units, precautions are necessary when servicing.

⚠CAUTION ***This engine uses a 12 volt, negative ground system. Alternator must be connected to battery at all times when engine is running. Do not reverse battery cables.***

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

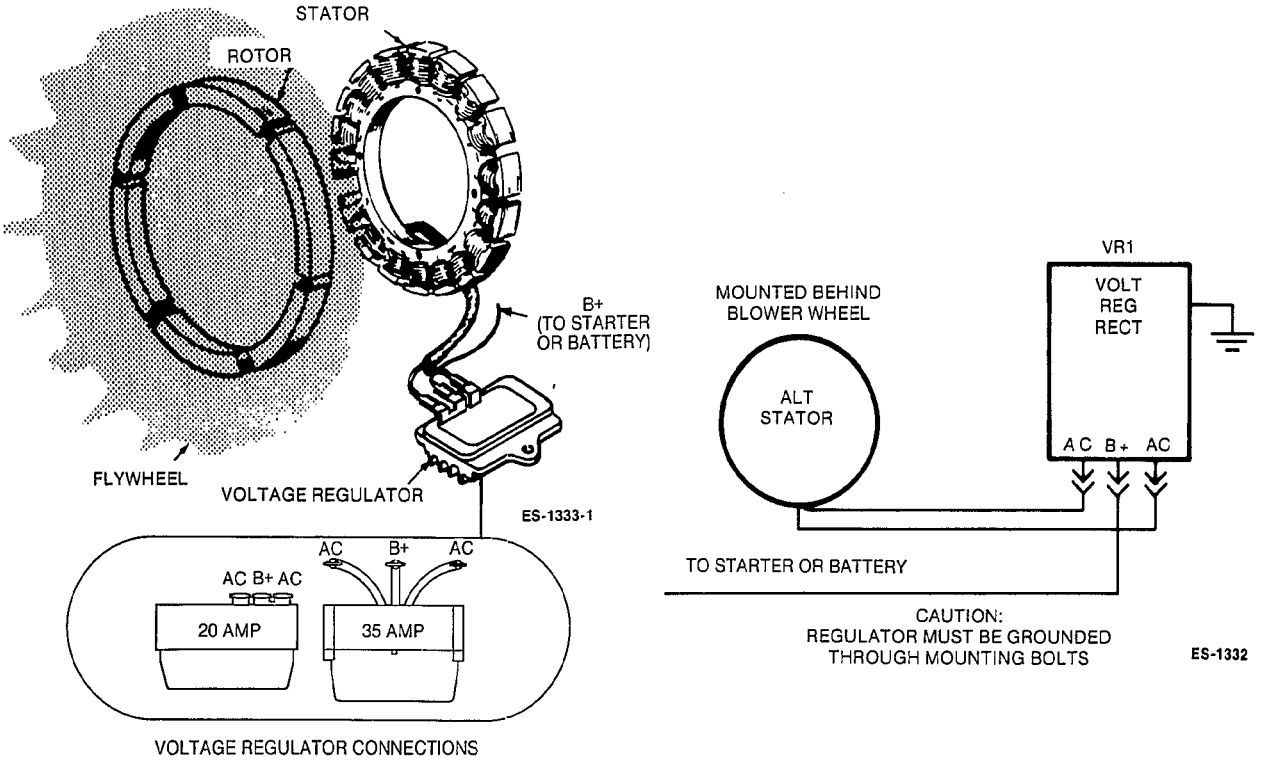


FIGURE 7. FLYWHEEL ALTERNATOR SYSTEM

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

1. Be sure engine is being run long enough and fast enough to recharge battery after each start. Charging system tests require a full charged battery. Alternator output is reduced in direct proportion to engine rpm. Also, power required for accessories reduces power available to recharge 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. Be sure regulator-rectifier plug (connector) is inserted properly. Plug must bottom in receptacle; this eliminates any resistance due to a poor connection. Keep clean and tight.

4. Make sure alternator stator leads are not shorted together.

5. Be sure regulator-rectifier has a good ground connection. Mating surface for mounting must be clean and 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 *Alternator Output Test.*

ALTERNATOR OUTPUT TEST

Use a volt-ohmmeter, such as the Simpson 270, when testing the charging system.

1. Check battery voltage with unit not running. If not within specifications (Table 1) charge battery before proceeding to step 2.

2. With the engine running, check the battery terminal voltage (regulator output) using a DC voltmeter. Voltage output should be within the values specified in Table 1. If voltage is greater than specified, replace regulator-rectifier assembly. If 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 regulator-rectifier B+ terminal to battery positive (+) terminal and from battery negative (-) terminal to regulator-rectifier case. If battery voltage remains low with engine running, proceed to step 4.

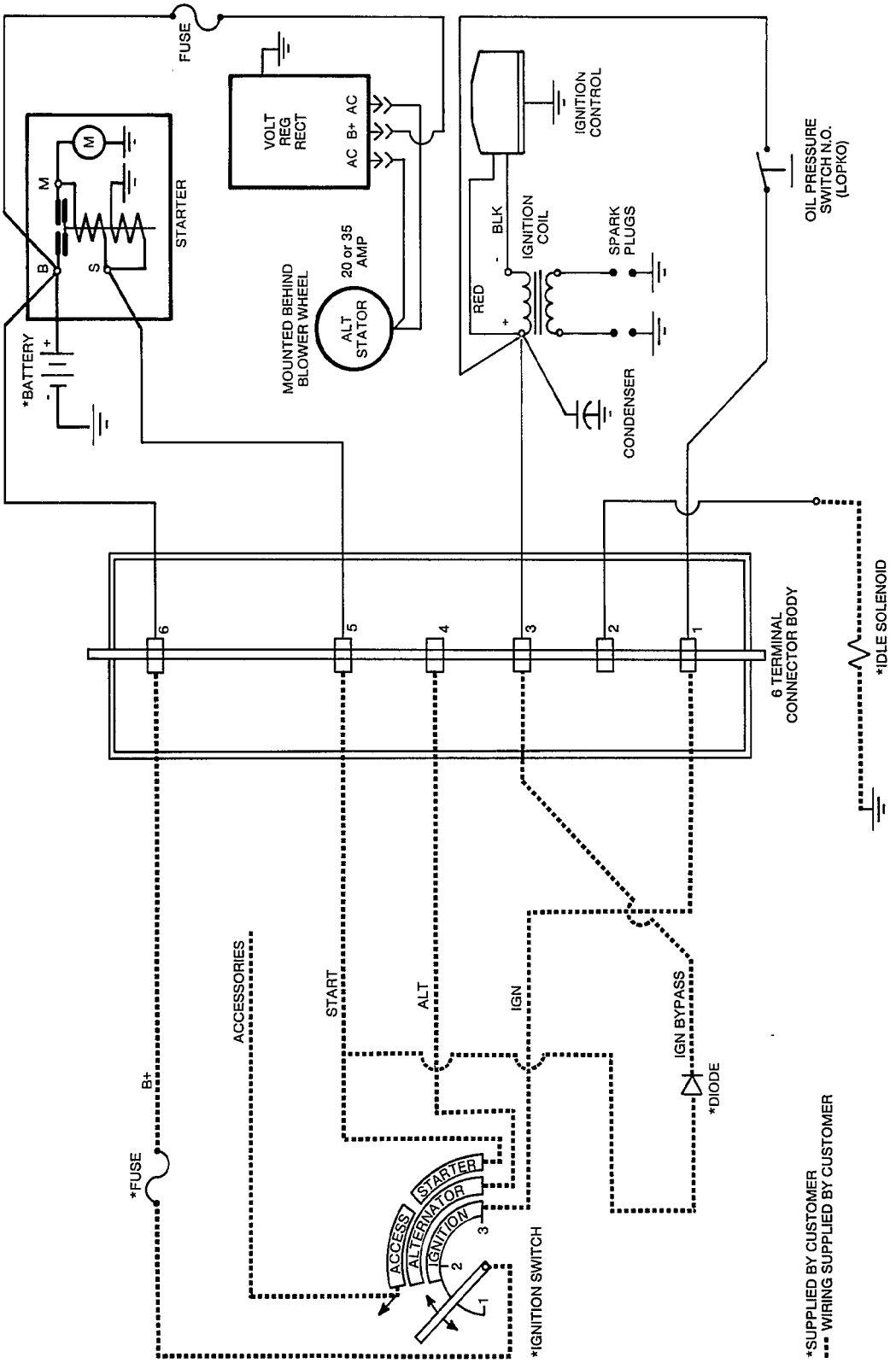
4. Disconnect plug from regulator-rectifier and test the AC voltage at the plug with engine running. If AC voltage reads more or less than specified in Table 1, proceed to step 5. If AC voltage is as specified but DC voltage is low, replace regulator-rectifier.

5. Use the Rx1 scale on the ohmmeter for detecting an open or ground in the stator (unit not running). Disconnect plug from the regulator-rectifier. Connect one ohmmeter test lead to a stator wire, connect the other test lead to ground. Reading should show an open (no continuity). If it doesn' t, stator must be replaced. If reading shows no continuity connect one ohmmeter lead to each wire coming from the stator. Refer to Table 1 for resistance specifications. If resistance is not as specified, replace stator. If stator resistance readings are as specified and windings are not shorted or open, low AC voltage may be due to loss of magnetism. If so, blower wheel assembly must be replaced.

TABLE 1. TESTING 20 AND 35 AMPERE SYSTEMS

BASIC TEST	BATTERY	REGULATOR	STATOR AC VOLTAGE	STATOR RESISTANCE
PROCEDURE	Refer to *Alternator Output Test*	Refer to *Alternator Output Test*	Refer to *Alternator Output Test*	Refer to *Alternator Output Test*
SPEC A 20 AMP	12 to 13 VDC	13.6 to 14.7 VDC	Approximately 21 VAC @ 1800 rpm Approximately 41 VAC @ 3600 rpm	0.06 to 0.10 Ohms
BEGIN SPEC B 20 AMP	12 to 13 VDC	13.6 to 14.7 VDC	Approximately 29 VAC @ 1800 rpm Approximately 57 VAC @ 3600 rpm	0.10 to 0.19 Ohms
35 AMP	12 to 13 VDC	13.6 to 14.7 VDC	Approximately 24 VAC @ 1800 rpm Approximately 47 VAC @ 3600 rpm	0.06 to 0.10 Ohms

WIRING DIAGRAM



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Starting System

ELECTRIC STARTER

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

Service

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

Starter Removal

⚠WARNING ***Accidental starting of the engine can cause severe personal injury or death. Disconnect the battery cables when repairs are made to the engine, controls, or housings.***

1. Remove both battery cables from battery. Disconnect ground cable first.
2. Disconnect battery cable and electrical lead wires from starter.
3. Remove starter.

Starter Disassembly

1. Remove "M" terminal nut and wire lead from solenoid (Figure 1).
2. Remove the two solenoid mounting screws and remove solenoid.
3. Scribe a mark across frame and rear bracket to aid in assembly. Remove the two through bolts.
4. Remove rear bracket and frame assembly.
5. Carefully remove armature and lever from front bracket. Note direction of lever and retainer.
6. Remove the two brush mounting screws, and remove the rear bracket.
7. Remove brush holder assembly from the frame by pulling the brushes out.

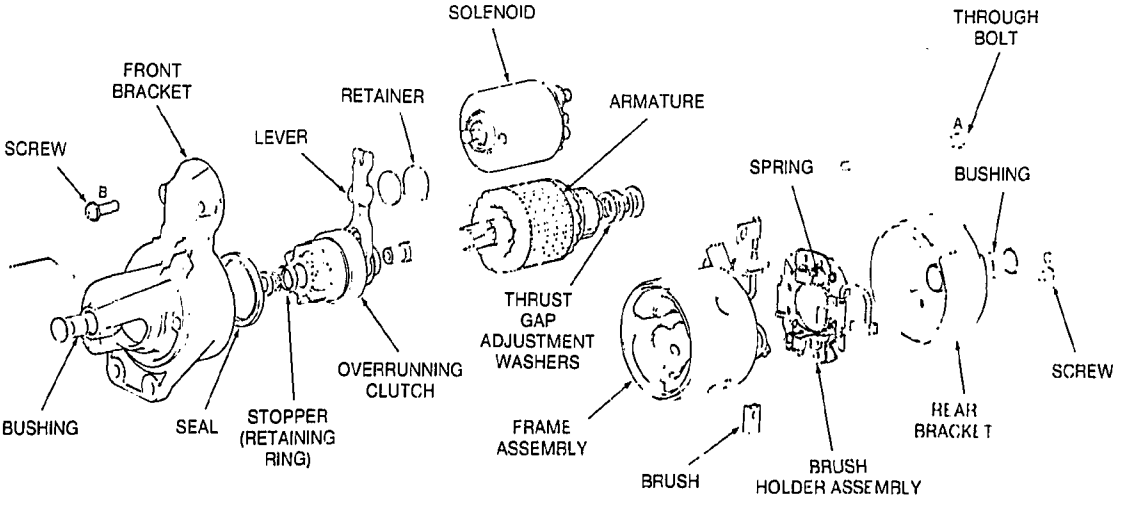

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FIGURE 1. STARTER MOTOR

8. Push stopper toward pinion and remove snap ring (Figure 2).

9. Remove stopper and overrunning clutch from armature shaft.

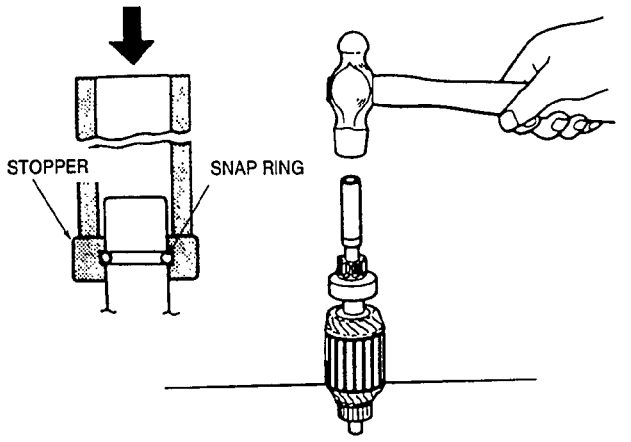

FIGURE 2. REMOVING OVERRUNING CLUTCH

10 Inspect starter for damaged or worn parts.

11. Repair or replace all damaged or worn parts as needed.

Starter Assembly

1. Install seal in nose housing. Install overrunning clutch on the armature shaft.

2. Slide stopper on the armature shaft. Position snap ring in groove in armature shaft.

3. Pull stopper all the way over snap ring (Figure 3). It may be necessary to tap snap ring into groove with a punch while maintaining tension on stopper.

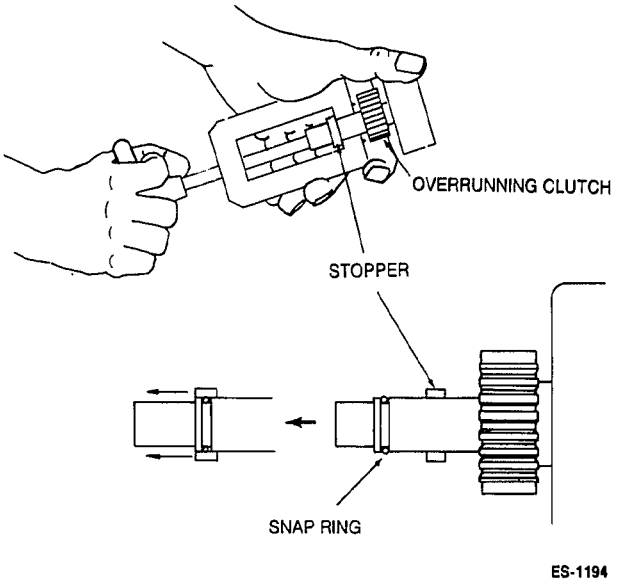

FIGURE 3. INSTALLING STOPPER

4. Lubrication: When starter motor is assembled apply grease to each of the following points (Recommended grade: Multemp PS No. 2):

   - Armature shaft spline
   - Both bushings (Both ends of armature)
   - Stopper on armature shaft
   - Pinion gear
   - Sliding portion of lever

5. Fit overrunning clutch into lever, and install with armature in the front bracket.

6. Install lever retainer and spacer. Position frame assembly over armature on the front bracket.

7. Install brush holder assembly. Position brushes in brush holder. Make certain positive lead wires are not grounded.

8. Install washers, as required, on the rear end of armature shaft to obtain an armature shaft thrust gap of 0.002 to 0.02 inch (0.05 to 0.5 mm). New washers are required if rear bracket is replaced.

Table 1. Starter Assembly Torques

Solenoid Screws	54 in.-lb.	(6.1 Nm)
Brush Retaining Screws	33 in.-lb.	(3.7 Nm)
Through Bolts	51 in.-lb.	(5.8 Nm)

9. Install rear bracket. Secure brush holder to rear bracket with two machine screws.

10. Install and tighten the two through capscrews.

11. Install solenoid plunger in lever. Secure solenoid to front bracket with two machine screws.

12. Install wire lead to the terminal "M" on solenoid.

13. After assembly, adjust pinion clearance. Pinion clearance should be 0.02 to 0.08 inch (0.5 to 2.0 mm); if not, check as follows (Figure 4):

    A. Connect starter to a battery. Close switch. This will shift pinion into cranking position.

    B. Push pinion back by hand and measure pinion clearance. If clearance does not fall within the specified limits, adjust by adding or removing shims located between solenoid and front bracket. Adding shims decreases clearance; removing shims increases clearance. Shims are included with replacement solenoid.

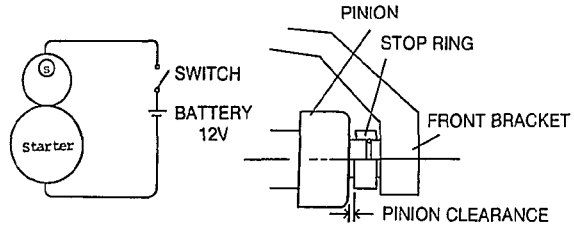

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FIGURE 4. PINION CLEARANCE ADJUSTMENT

Inspection and Testing

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

Testing Armature for Grounds: Touch armature shaft or core and the end of each commutator bar with a pair of ohmmeter leads (Figure 5). A low ohmmeter reading indicates a grounded armature. Replace grounded armature.

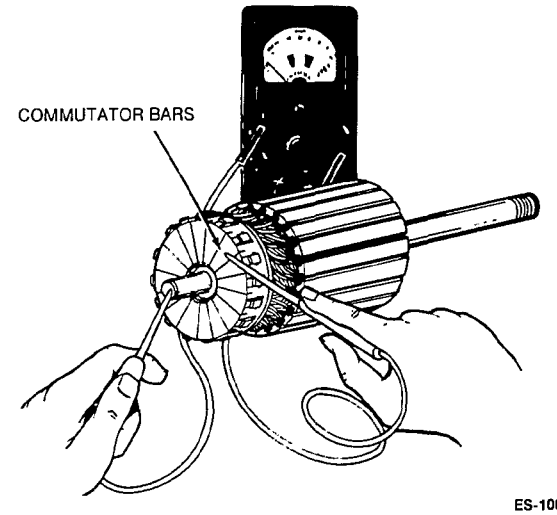

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FIGURE 5. TESTING ARMATURE FOR GROUNDS

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 armature must be replaced.

Testing Armature for a Short Circuit: Use a growler for locating shorts in the armature (Figure 6). Place armature in growler and hold a thin steel blade (e.g. hacksaw blade) parallel to the core and just above it while slowly rotating armature in growler. A shorted armature will cause the blade to vibrate and be attracted to the core. If armature is shorted, replace with a new one.

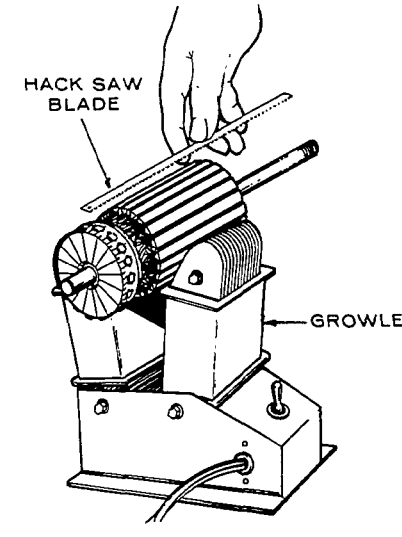

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FIGURE 6. TESTING ARMATURE FOR SHORT CIRCUITS

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

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

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

Brushes: Clean around brushes and holders, wiping off all brush dust and dirt. If brushes are worn shorter than .4528 inch (11.5 mm) replace them (Figure 7).

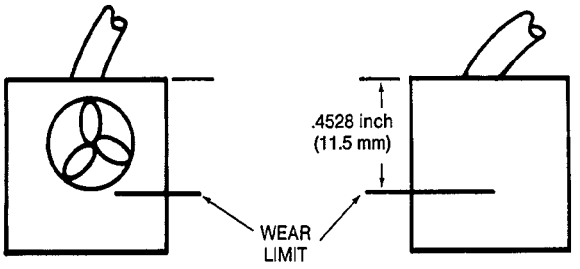


FIGURE 7. BRUSH WEAR LIMIT

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

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

If pinion gear is worn or damaged, inspect flywheel ring gear also. Rotate pinion. It should turn free when turned in one direction, and lock when turned in the opposite direction.

⚠CAUTION ***Do not clean overrunning clutch in solvent or liquid cleaning solution. Washing the clutch will cause the grease to leak out.***

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

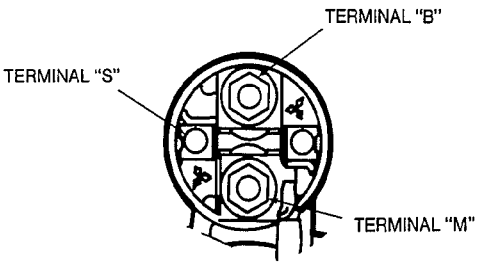


FIGURE 8. SOLENOID TERMINALS

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

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

Brush Replacement: Cut old positive brush from pigtail at the brush. Be careful not to damage field coil. Clean 1/4 to 3/8 inch (6.5 to 9.5 mm) of brush end of pigtail with sandpaper or emery cloth (Figure 9).

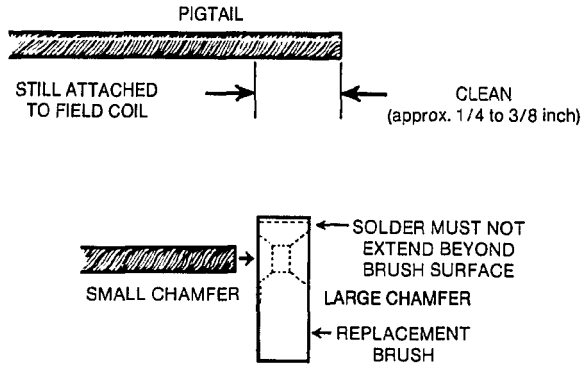


FIGURE 9. BRUSH REPLACEMENT

Push prepared end of pigtail lead into hole in replacement brush from the small chamfered side. Solder pigtail lead to replacement brush on the large chamfered side, using 50/50 tin/lead, rosin core solder and a standard 240/325 Watt soldering iron. Use a file to remove any excess solder that may extend beyond brush surface.

⚠CAUTION ***Pigtail lead must not protrude from surface on the soldered side of brush. To prevent stiffening of pigtail lead do not use excessive amount of solder and heat.***

Starter Mounting

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

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

1. Install starter motor and torque mounting capscrews to that specified in *ASSEMBLY TORQUES.*

2. Connect battery cable and wires to starter. Connect battery cables to battery. Connect ground cable last.

Engine Disassembly

DISASSEMBLY/ASSEMBLY

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

Suggested Disassembly Order

1. Drain crankcase.
2. Disconnect all exhaust lines and electrical lines.
3. Remove engine from its mountings and place on a suitable bench or work stand.
4. Remove all housings, shrouds, blower housings, etc.
5. Remove flywheel, using a puller.
6. Remove ignition trigger and gear cover, being careful to protect oil seal from keyway damage.
7. Remove crank gear, using a gear puller and ring.
8. Remove all accessories such as oil filter, starter, intake manifold, fuel lines, spark plugs, etc.
9. Remove oil base, oil pump and cylinder heads.
10. Remove valves, springs, lifters, etc.
11. Remove camshaft and gear assembly.
12. Remove connecting rods and pistons.
13. Remove rear bearing plate, crankshaft, and front bearing.

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

Suggested Assembly Procedure

Engine assembly is normally the reverse of the disassembly procedure, observing proper clearances and torques. 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 by hand freely. Use only genuine Onan parts and special tools when reassembling your engine.

1. Use proper bearing driver to install front main bearing after coating it with a light film of oil.
2. Insert rear main bearing in rear bearing plate.
3. Insert crankshaft, rear bearing plate, and crankshaft gear.
4. Install pistons and connecting rods.
5. Install camshaft and gear assembly; align crank gear mark with cam gear mark.
6. Install valve assemblies, oil pump, oil base, and cylinder heads.
7. Install all accessories such as oil filter, starter, fuel lines and spark plugs.
8. Install gear cover with oil seal, trigger ring, and flywheel.
9. Check valve clearance.
10. Install all housings and air cleaner.
11. Fill crankcase with oil.

Operation

Start engine and check oil pressure. Run for approximately 15 minutes to bring engine to operating temperature. 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 engine and remove spark plugs.
3. Remove air cleaner and place 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 *SPECIFICATIONS* for compression pressures. There may 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. The valve tappet clearance should be checked and adjusted, if necessary, at least every 1000 operating hours or when poor engine performance is noticed. Adjust the valve clearance only when engine is at ambient temperature. Proceed as follows:

1. Remove ignition key to prevent accidental starting.
2. Remove all parts necessary to gain access to valve tappets.
3. Remove spark plugs to ease the task of turning the engine over by hand.
4. Place a socket wrench on the flywheel capscrew and rotate the crankshaft in a clockwise direction until the left intake valve (viewed from flywheel end) opens and closes. Continue turning the crankshaft until the TC mark on the flywheel is lined up with the TC mark on the gear cover. This should place the left 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.
5. The correct feeler gauge for the valve adjustment (see *SPECIFICATIONS)* should pass freely between valve cap and tappet; a 0.002 inch (0.05 mm) thicker gauge should not (Figure 1).
6. To correct 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 valves on the right hand cylinder, turn engine one complete revolution and again line up mark on the flywheel and the TC mark on the gear cover. Then follow adjustment procedure given for left hand cylinder.
8. Replace all parts removed in Step 2. Tighten all screws securely. Torque manifold bolts to specified torque.

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 1. Access to the valve system can be obtained by removing the cylinder heads and the valve covers on top of the engine. 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 valves, springs, retainers, and tappets in a rack as they are removed from cylinder block so they can be identified and reinstalled in their original locations. Discard old valve stem seals and replace with new ones during assembly.

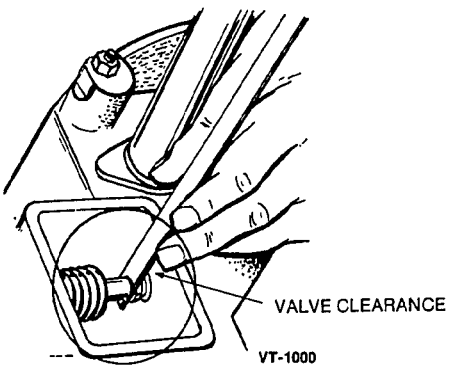
Use the following procedures to inspect and service the valve system.

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 may also be due to weak valve springs, insufficient tappet clearance, warpage, and misalignment.



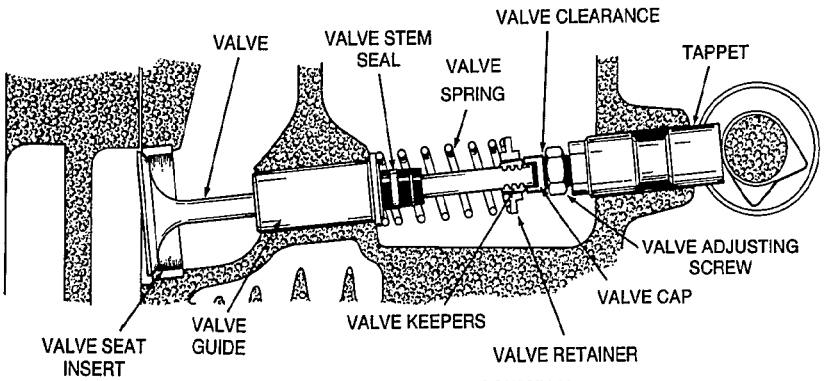


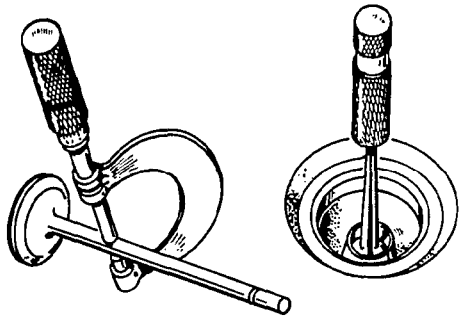
FIGURE 1. VALVE ASSEMBLY VT-1034

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.



VT-1020

FIGURE 2. VALVE STEM AND VALVE GUIDE INSPECTION

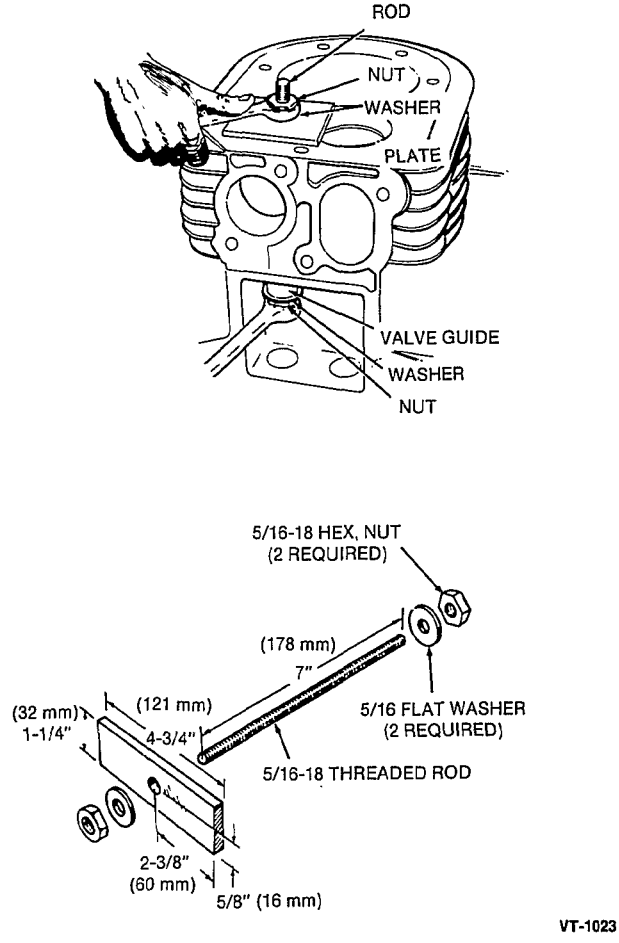
Stems And Guides: Always check valve stems and guides for wear (Figure 2). Use a hole gauge to measure the valve guide. When clearance with stem exceeds that specified in *DIMENSIONS AND CLEARANCES* replace either valve or guide or both, as may be necessary. Always regrind seat to make concentric with 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.

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

⚠CAUTION ***Driving out old guides can damage the guide or tappet bores. Be careful not to strike guide bores with driver or allow guide to strike tappet bores during removal.***

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



VT-1023

FIGURE 3. VALVE GUIDE INSTALLATION

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

⚠CAUTION ***Do not remove valve after seal is installed. Valve can be withdrawn only as far as the groove in valve stem. Do not allow valve stem seal to come in contact with groove or seal damage will result.***

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

Valve Seats: Inspect valve seat inserts. If seats are loose, cracked or severely pitted, new ones must be installed. Remove valve seat inserts using a valve seat removal tool. If valve seat insert bores in 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.

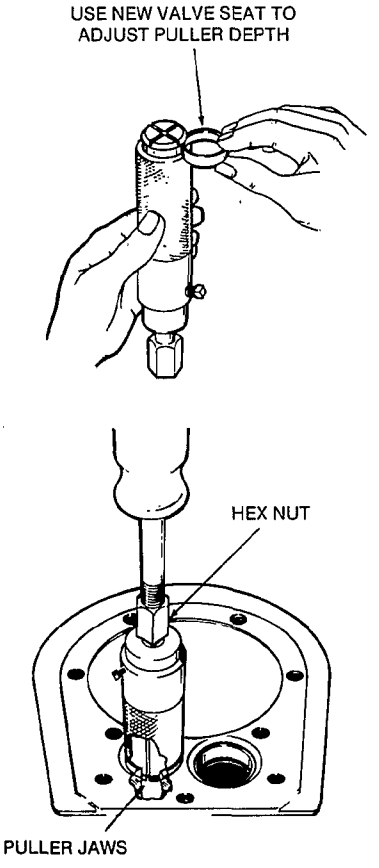


FIGURE 4. VALVE SEAT REMOVAL

Valve Seat Removal: Remove carbon and combustion deposits from valve seat. Select proper puller size determined by inside diameter of valve seat. On some pullers use a new seat as a guide to adjust puller depth (Figure 4). Puller jaws must expand into cylinder block at the point where bottom of valve seat insert rests on cylinder block. Position puller on valve seat and tighten hex nut. Clamp cylinder block to a solid bench. Attach slide hammer to puller. Tighten hex nut between each blow with the slide hammer.

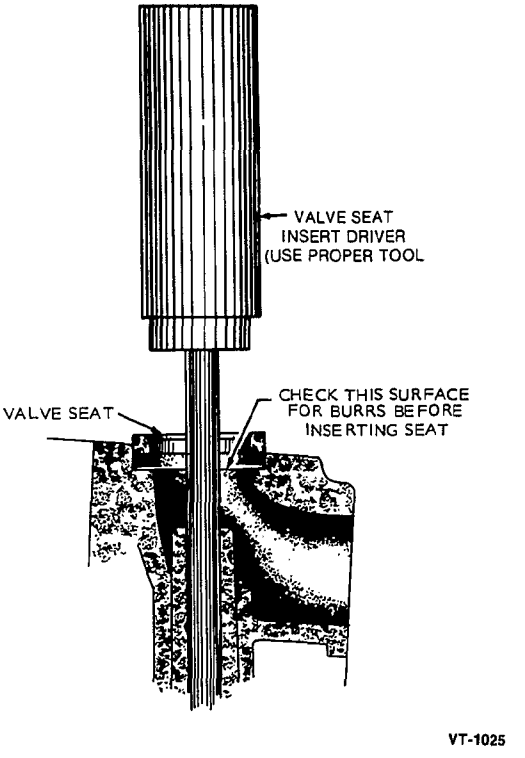


FIGURE 5. INSERTING NEW VALVE SEAT

Valve Seat Installation: After the old seat has been removed, clean out any carbon or metal burrs from the seat insert recess. Use a valve seat insert driver and hammer to install the insert (Figure 5). 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.

To assure a tight valve seat fit and eliminate the danger of seat loosening in the bore, valve seat must be staked.

Insert valve seat staker into valve seat or guide in cylinder block. Using a lead hammer, strike the staking tool a sharp blow to wedge new valve securely in place. It will be necessary to refinish valve seat inserts before installing valves.

TAPPETS

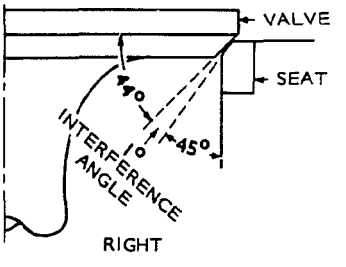
Very little wear takes place on tappet diameters or in tappet bores. If the clearance between tappet and bore in cylinder block exceeds specifications, replace the tappet.

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

VALVE FACE AND SEAT GRINDING

Before installing new valves or previously used valves, inspect valve seats for proper valve seating. If used valves are reinstalled, the valve stems should be cleaned and valve faces ground to their specified angles of 44°. Refinish valve seats to a 45° angle. When refacing valves and seats, remove all evidence of pitting and grooving. If end of 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 stem and remove any pits or burrs. The valve guide should be thoroughly cleaned. If valve guide is worn, or valve is warped, the necessary parts must be replaced.

By grinding the valve face and seat at slightly different angles, a fine line of contact on 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 (Figure 6). The seat angle is greater than that of the valve face. This assures contact at the maximum diameter on valve seat seating surface.

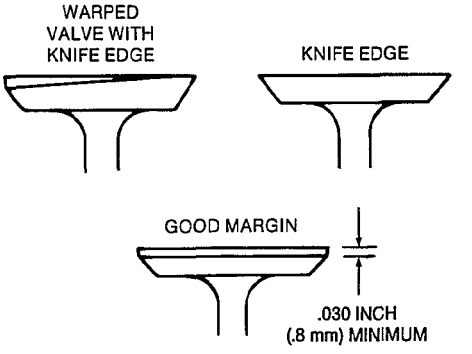


VT-1021

FIGURE 6. VALVE INTERFERENCE ANGLE

Refinish valve faces to a 44° angle on a valve refacing machine. The first cut from valve face must be a light grinding. Check if there is an unevenness of metal being removed. If only part of valve's face has been touched, check to see if valve is properly seated in machine or if valve is warped, worn, or distorted. When cut is even around the whole valve face, keep grinding until complete face is ground clean. Be sure the correct valve face angle is maintained. When valve head is warped, a knife edge will be ground (Figure 7) on part or all of the head due to the large amount of metal that must be removed to completely reface 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.

Replace any valve that cannot be entirely refaced while keeping a good valve margin (Figure 7) or is warped, worn, or damaged in any way. The amount of grinding necessary to true a valve indicates whether valve head is worn or warped.



M-1184

FIGURE 7. VALVE HEAD MARGIN

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.

Valve seats should be ground with a 45 degree stone and the width of the seat band should be 1/32 inch to 3/64 inch (0.79 to 1.2 mm) wide. Grind only enough to assure proper seating.

Place each valve in its proper location. 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 ***Do not remove the screw completely since it acts as a restrainer when the flywheel snaps loose. If the flywheel is not held by the screw, the spring action in the wheel will cause it to fly off with great force which can cause injury to the operator.***

2. Install a puller bar on the flywheel (Figure 8).

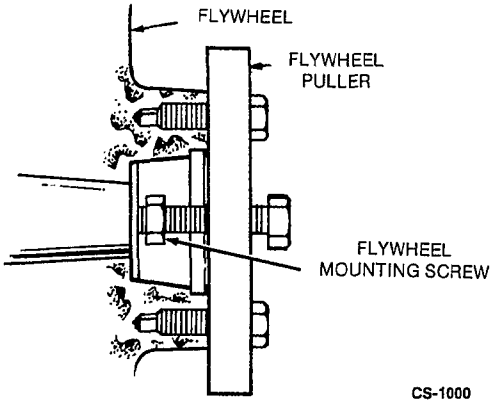


FIGURE 8. BLOWER WHEEL PULLEY

3. Turn the puller bar bolts in, alternately, until the wheel snaps loose on the shaft.

⚠CAUTION ***Do not use a screwdriver or similar tool or pry behind the flywheel against the gear case. The gear case cover is die-cast material and will break if undue pressure is applied in this manner.***

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. Always use a steel key for mounting the flywheel.

GEAR COVER

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

When installing the gear cover, make sure the pin in the gear cover engages the nylon lined (smooth) hole in the governor cup. Turn the governor cup so that the nylon lined hole is at the three o'clock position. Use a small amount of grease to assist in holding governor cup in position. The smooth side of the governor yoke must ride against the governor cup. 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 (Figure 9).

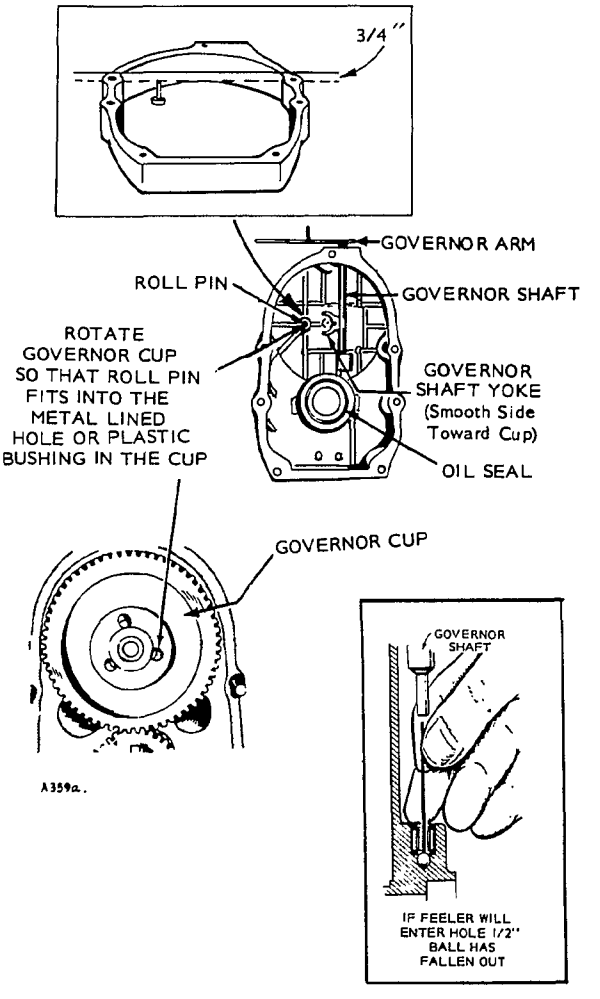


FIGURE 9. GEAR COVER ASSEMBLY

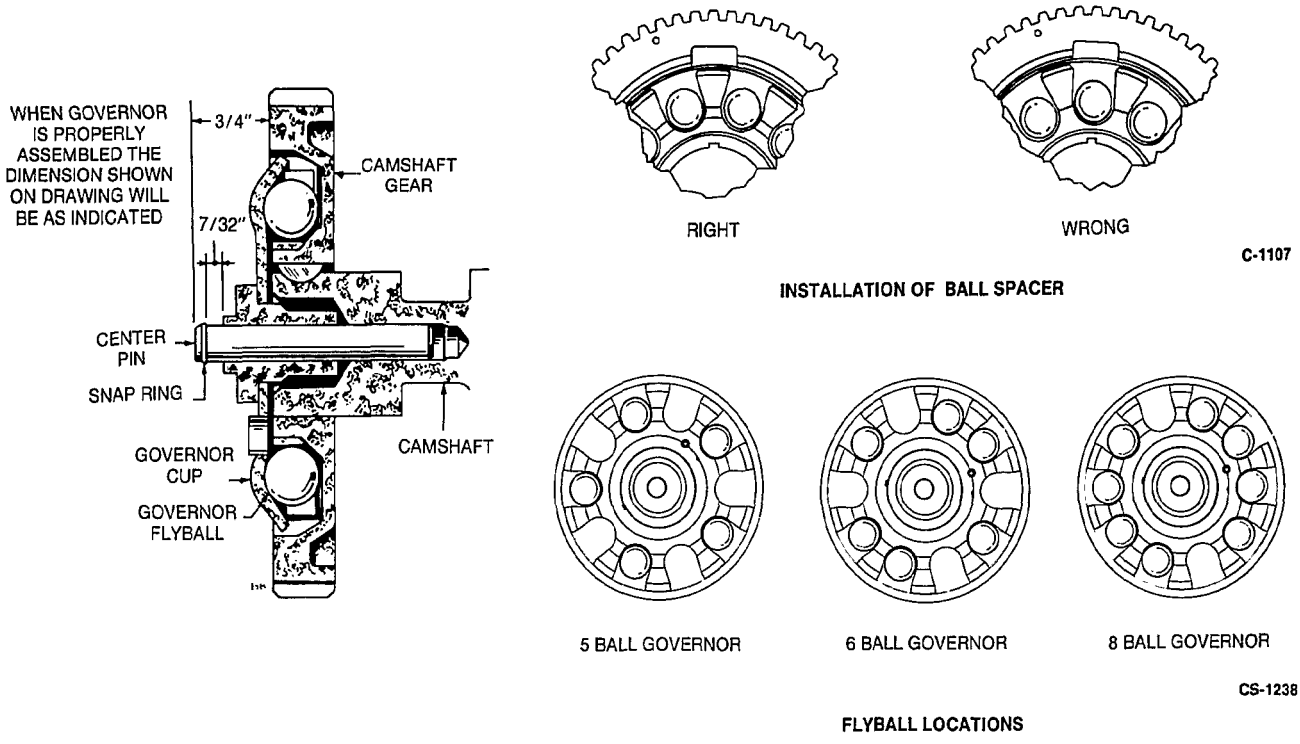


FIGURE 10. GOVERNOR CUP DETAILS

GOVERNOR CUP

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 (Figure 10).

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 gear hub, and 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.

If replacing the ball spacer, be sure to position it so an arm is lined up with the space on the camshaft gear (if your camshaft gear does not have a space in it, disregard this paragraph). If the ball spacer arm is not lined up with the space in the camshaft gear, a flyball can slip into the space and cause engine racing and governing problems (Figure 10).

When installing the governor cup, tilt the engine so the gear is up, put the flyballs in place (Figure 10), and install the cup and snap ring on the center pin.

The camshaft center pin extends out 3/4 inch (19 mm) from the end of the camshaft. This distance provides an in-and-out travel distance of 7/32 inch (5.6 mm) for the governor cup, as illustrated. Hold the cup against the flyballs when measuring. 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" (5.6 mm), (the engine will race, especially at no load) remove the center pin and press in a new pin.

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.

To remove the crankshaft gear, first remove the snap ring and retainer washer, then attach the gear pulling ring using two No. 10-32 screws (Figure 11). Tighten the screws alternately until both are tight. Attach a gear puller to the puller ring and proceed to remove the gear.

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. When installing the camshaft gear and shaft assembly, be sure that the thrust washer is properly in place behind the camshaft gear. Then install the crankshaft retaining washer and lock ring.

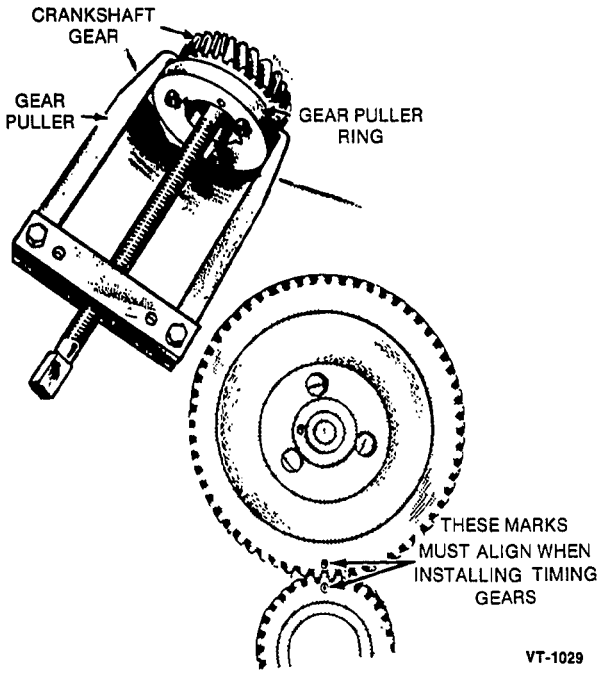


FIGURE 11. TIMING GEAR REMOVAL AND INSTALLATION

PISTONS AND CONNECTING RODS

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

1. Drain oil.
2. Remove the cylinder head and oil base pan from the engine.
3. Remove the ridge from the top of each cylinder with a ridge reamer before attempting piston removal (Figure 12).

⚠CAUTION ***Forcing the piston from the cylinder before reaming may cause damage to the piston lands and break rings.***

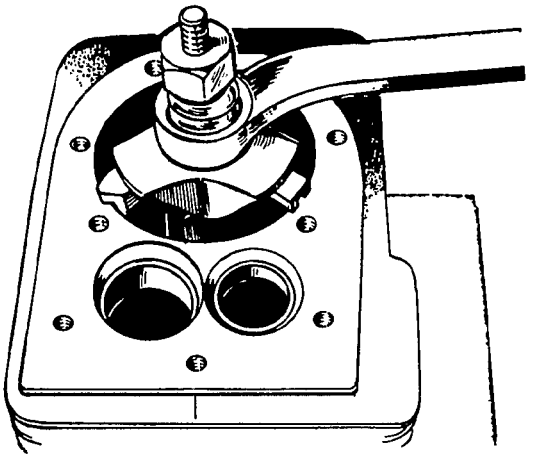


FIGURE 12. REMOVING RIDGE FROM CYLINDER

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. Avoid scratching the crankpin and cylinder wall when removing the piston and rod.

5. Mark each piston and rod assembly so 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 (Figure 13). Remove the piston pin retainer and push the piston pin out.

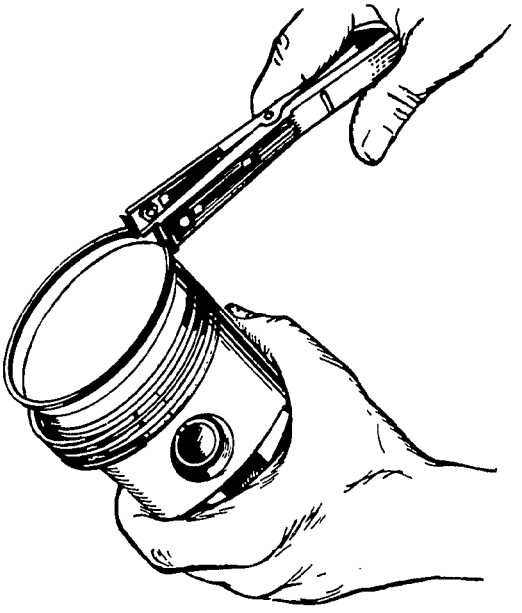


FIGURE 13. REMOVING PISTON RINGS

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 (Figure 14). Care must be taken not to remove metal from the groove sides.

⚠CAUTION ***Do not use a caustic cleaning solvent or wire brush for cleaning pistons. These materials will cause piston damage.***

When cleaning the connecting rods in solvent, be sure to include the rod bore. Blow out all passages with compressed air.

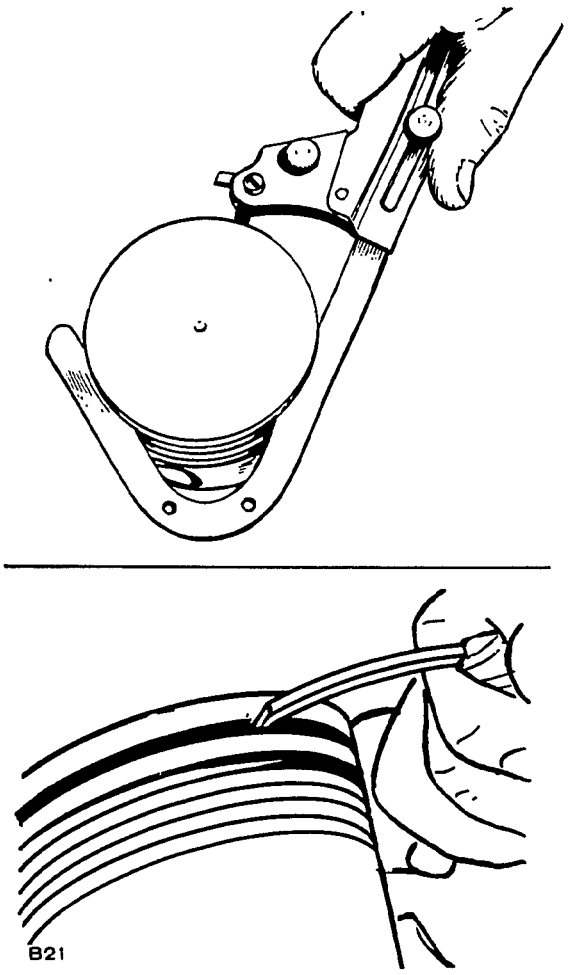


FIGURE 14. PISTON GROOVE CLEANING

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 (Figure 15). Replace the piston when the side clearance of the top compression ring reaches that specified in *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.

Connecting Rod Inspection:

1. Replace connecting rod bolts and nuts with damaged threads. Replace connecting rods with deep nicks, signs of fractures, scored bores or bores out of round more than 0.002 inch.

2. Use a new piston pin to check connecting rod for wear. A push fit clearance is required and varies from engine to engine. If a new piston pin falls through a dry rod pin bore as a result of its own weight, replace the rod.

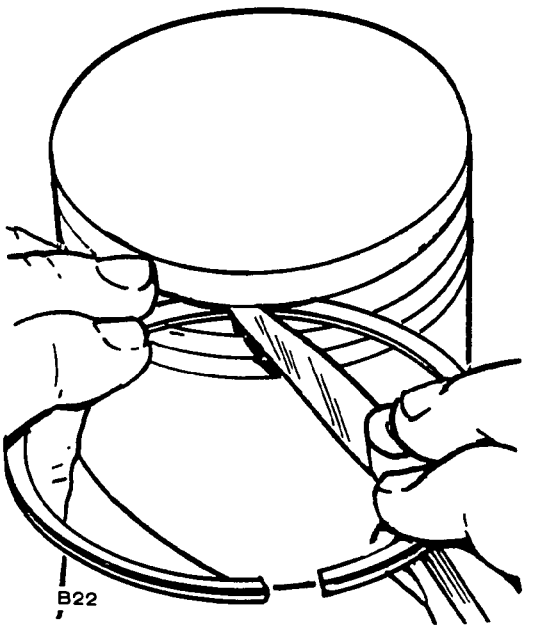


FIGURE 15. CHECKING RING SIDE CLEARANCE

Fitting Pistons:

1. Proper piston tolerances must be maintained for satisfactory operation.

2. Refer to *DIMENSIONS AND CLEARANCES* to determine where to measure piston to be sure the total clearance follows specifications.

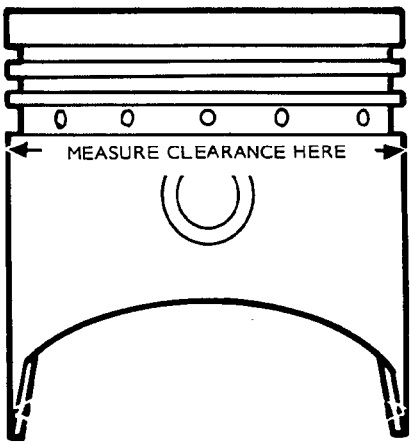


FIGURE 16. MEASURING PISTON CLEARANCE

Fitting Piston Rings:

1. Install the piston ring in the cylinder bore. Invert the piston and push the ring to the end of ring travel, about halfway into the bore, which trues the ring end gap. Check the gap with a feeler gauge (Figure 17).
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).

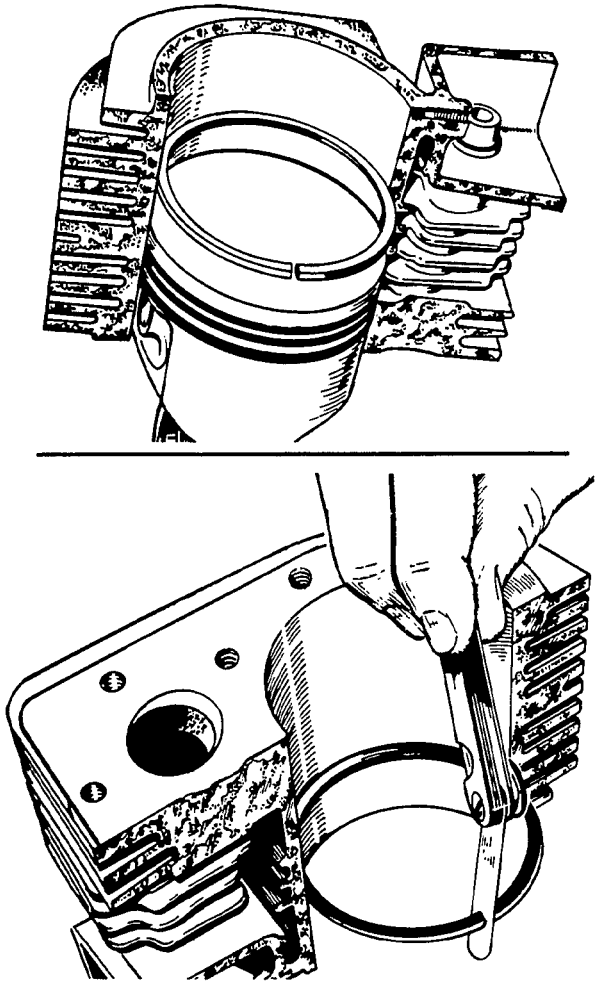


FIGURE 17. POSITIONING OF PISTON RING AND MEASURING OF END GAP

CYLINDER BLOCK

The cylinder block is the main support for all other basic engine parts. 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 block for cracks and wear. If block is still serviceable, prepare it for cleaning as follows:

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

Inspection

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

1. Make a thorough check for cracks. Minute cracks may 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 damaged 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, scored, or worn, 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 bore for wear or out of roundness as follows:

1. Check cylinder bore for taper, out of round, and wear with a cylinder bore gauge, telescope 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.
2. Record measurements taken at top and bottom of piston travel as follows (Figure 18).

A. Measure and record as "A" the cylinder bore diameter (parallel to crankshaft) near the top of cylinder bore where greatest amount of wear occurs.

B. Also measure and record as "B" cylinder bore diameter (parallel to crankshaft) at the bottom of piston travel.

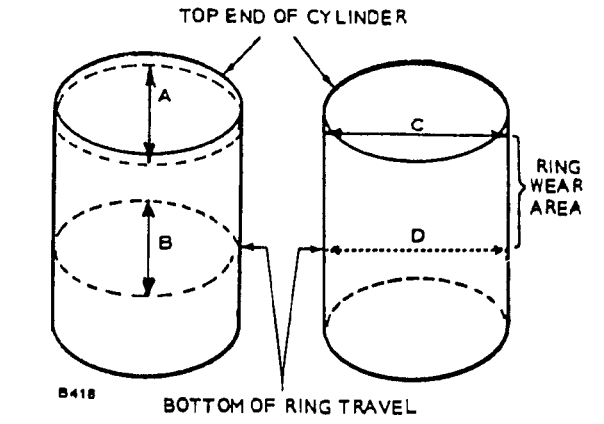
C. Measure and record as "C" cylinder bore diameter (perpendicular to crankshaft) near the top of cylinder bore where greatest amount of wear occurs.

D. Also measure and record as "D" cylinder bore diameter (perpendicular to crankshaft) at the bottom of 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 *DIMENSIONS AND CLEARANCES* rebore and hone cylinder to the next oversize.

F. Reading "A" compared to reading "C" and reading "B" compared to reading "D" indicate whether or not cylinder is out of round. If out of round exceeds that specified in *DIMENSIONS AND CLEARANCES* the cylinders must be rebored and honed to the next oversize. A reboring machine is used when going to oversize pistons.



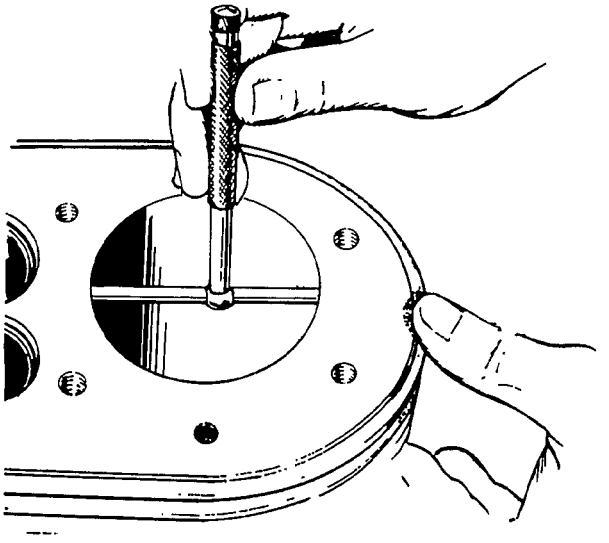


FIGURE 18. METHODS OF MEASURING THE DIAMETER OF A CYLINDER BORE

Reboring the Cylinder

Rebore and hone engine whenever cylinder bore is worn, damaged, out of round, or if 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 ***If boring bar is operated incorrectly, it will produce a rough cylinder surface that may not clean up even when honed. Boring should be done only by qualified service personnel who are careful in their work.***

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

When reboring cylinders, take the following precautions:

1. Make sure cutting tool is properly ground before using it.

2. Be sure top of engine block is smooth and deposit free.

3. Clean base of boring bar before bar is set up. Deposits under boring bar will cause it to tilt and the cylinder will be distorted after boring.

4. Make an 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.

1. Position 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 hone manufacturer's instructions for the use of oil or lubricant on stones. Do not use lubricants with a dry hone.

3. Insert hone in bore and adjust stones to fit snugly to the narrowest section. When adjusted correctly, the hone should not shake or chatter in cylinder bore, but will drag freely up and down when hone is not running.

4. Connect drill to hone and start drill. Feel out bore for high spots, which cause an increased drag on stones. Move hone up and down in bore with short overlapping strokes about 40 times per minute. Usually bottom of cylinder must be worked out first because it is smaller. As cylinder takes a uniform diameter, move hone up and down all the way through cylinder bore.

5. Check 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 bore; measure twice at top, middle and bottom at 90-degree angles.

6. Crosshatch formed by the stones should form an included angle of 23 degrees. This can be achieved by moving the rotating hone (250 to 450 rpm) up and down in cylinder bore about 40 times per minute.

7. Clean cylinder bores thoroughly with soap, water and clean rags. A clean white rag should not become soiled on 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 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 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 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 deglazing tool up and down in cylinder (10 to 12 complete strokes) rapidly enough to obtain a crosshatch pattern (Figure 19).

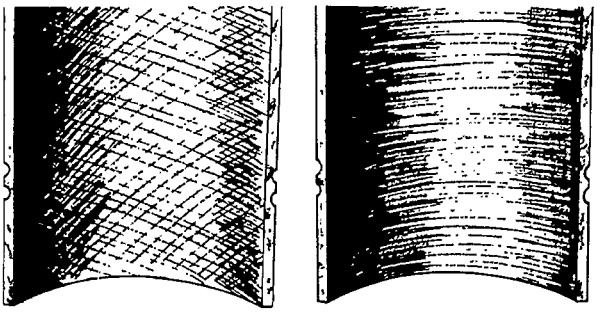


FIGURE 19. CROSS HATCHING

⚠CAUTION ***Never use gasoline or commercial cleaners to clean cylinder bores after deglazing or honing. These solvents will not remove abrasives from the walls. Abrasives not removed from engine will rapidly wear rings, cylinder walls, and bearing surfaces of all lubricated parts.***

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

CRANKSHAFT

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

Measure 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. Metallizing of bearing journals is not recommended.

If regrinding of 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 are available in sizes of 0.010, 0.020, and 0.030 inch. Undersize connecting rods are available in sizes of 0.010, 0.020, 0.030 and 0.040 inch.

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

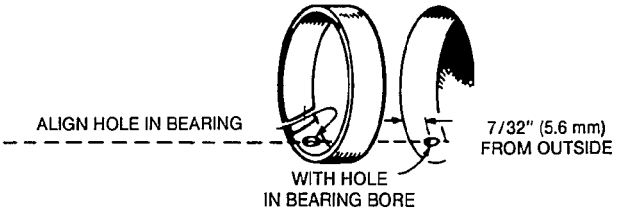
With camshaft and crankshaft removed, use a micrometer to measure diameter of bearing journals. Use a dial bore gauge or a telescopic gauge and micrometer to measure inside diameter of bearings. Refer to *DIMENSION AND CLEARANCES* section to determine if clearances are within specifications.

Any bearing that is scored, chipped, pitted or worn beyond the specified limits must be replaced.

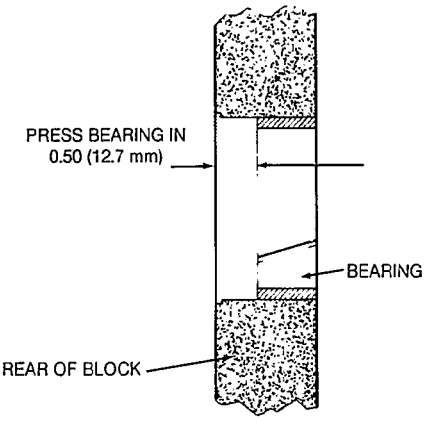
Removal of the camshaft bearings requires complete disassembly of the engine. Use a press or a suitable driver to remove bearings. Support casting to avoid distortion and to avoid damaging the bearing bore during removal and installation.

Replacement camshaft bearings are precision type which do not require line reaming or line boring after installation. Clean outside of the bearing and bearing bore in the block. Before installing cam bearings use Locktite Bearing Mount on outside diameter of bearing. Use a combination bearing driver to install bearings.

Place the bearing on the crankcase over the bearing bore with the lubricating hole (front only) in the proper position. Be sure to start the bearing straignt. Press in the front bearing flush with the outside end of the



FRONT CAMSHAFT BEARING



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REAR CAMSHAFT BEARING

FIGURE 20. CAMSHAFT BEARINGS

bearing bore. Front cam bearing oil hole must line up with oiling hole in cylinder block (Figure 20). Press in the rear camshaft bearing to the dimensions shown (Figure 20). Lubricate bearing surfaces with oil after installing.

New crankshaft main 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 casting to avoid distortion and to avoid damaging the bearing bore during removal and installation.

Before installing main bearings, expand bearing bore by placing the casting in an oven heated to 200°F (94°C). If practical, cool the precision bearing to shrink it.

Before installing the front main bearing, use the towelette included with the bearing kit to clean the outside of the bearing and bearing bore in the block.

⚠CAUTION ***Breathing vapor from towelette and prolonged contact with skin can be harmful. Be sure area is well ventilated.***

After allowing three to four minutes for drying, apply the Locktite from the small tube to the mating surfaces of the bearing and the bearing bore. Align the oil holes in the bearing with the oil holes in the bearing bore (Figure 22). The oil passage should be at least half open. Install the bearing flush with the block, using the combination driver. Wipe off excess Locktite around the bearing. Allow at least one hour for hardening at room temperature.

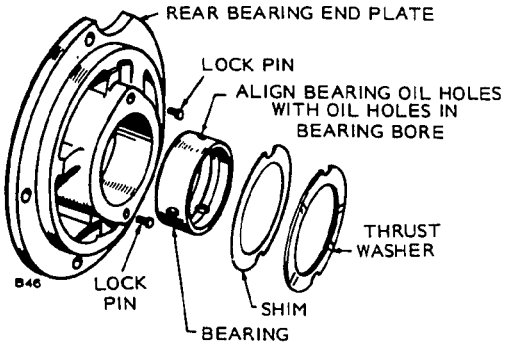


FIGURE 21. BEARINGS FOR REAR BEARING PLATE

In the rear bearing plate, install the bearing flush to 1/64 inch (0.40 mm) below the end of the bore. Be sure to align the oil holes in the bearing with the oil holes in the bearing bore (Figure 21). The oil passage must be at least half open. Lubricate bearing after installation.

If head of lock pin is damaged, use side cutters or Easy Out tool to remove and install new pin. Oil grooves in thrust washers must face the crankshaft, and washers must be flat (not bent). The two notches on each washer must fit over the two lock pins to prevent riding on the crankshaft (Figure 21).

Lubricate the front main bearing lightly with oil and insert the crankshaft. With the rear bearing plate gasket in place and the rear plate bearing lubricated, slide the thrust washer (grooves toward crankshaft) and plate over the end of the crankshaft. A light film of oil on the thrust washer may hold it in place while installing bearing plate over crankshaft. Line up notches of thrust washer with lock pins before tightening end plate or lock pins will be damaged.

Engines shipped from the factory have separate thrust washers and main bearings for both front and rear of engine. Front bearing replacement part is a one piece bearing (with attached thrust washer) as shown in Figure 22. Do not add an additional thrust washer to this front bearing.

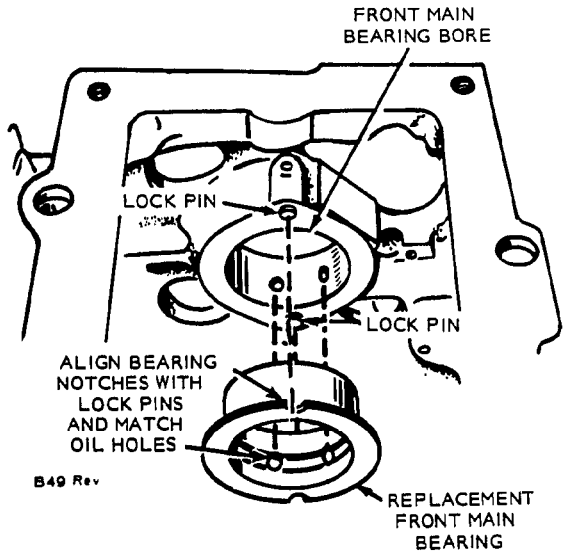


FIGURE 22. FRONT BEARING INSTALLATION

CRANKSHAFT ENDPLAY

After the rear bearing end plate has been tightened, using the torque recommended in *ASSEMBLY TORQUES AND SPECIAL TOOLS,* check the crankshaft endplay (Figure 23). If there is too much endplay (see *DIMENSIONS AND CLEARANCES* for minimum and maximum endplay), remove the rear bearing end plate and add a shim (Figure 21) between the thrust washer and plate. Reinstall the end plate, making sure the thrust washer and shim notches line up with the lock pins. Torque and recheck endplay of the crankshaft.

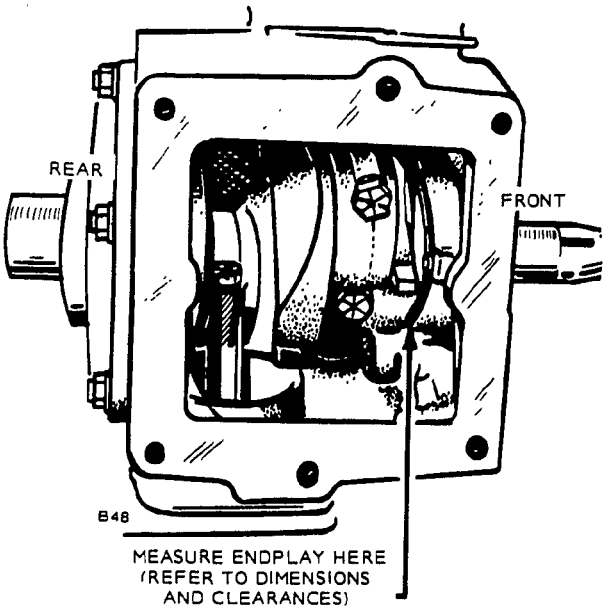


FIGURE 23. CRANKSHAFT ENDPLAY

CHECKING CONNECTING ROD BEARING CLEARANCE WITH PLASTIGAUGE

1. Make certain that all parts are marked or identified so that they are reinstalled in their original positions. Using a clean dry cloth, thoroughly clean all oil from crankshaft journal and 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 (Figure 24).

3. Rotate the crankshaft about 30 degrees from bottom dead center and reinstall the bearing cap; tighten rod bolts to the torque specified in *ASSEMBLY TORQUES AND SPECIAL TOOLS.* Do not turn the crankshaft.

4. Remove bearing cap. The flattened Plastigauge will be found adhering to either the bearing cap or crankshaft.

5. Compare flattened Plastigauge with the graduations on Plastigauge envelope to determine clearance.

   The number within the matching graduation on the envelope indicates, total clearance in millimetres or thousandths of an inch.

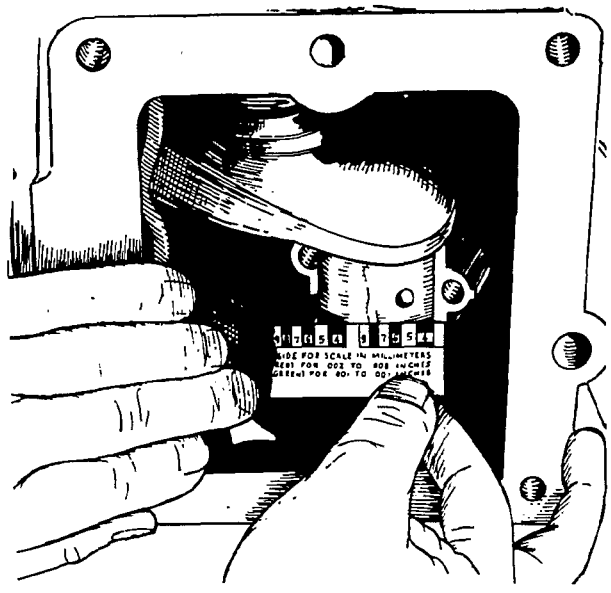


FIGURE 24. MEASURING BEARING CLEARANCE

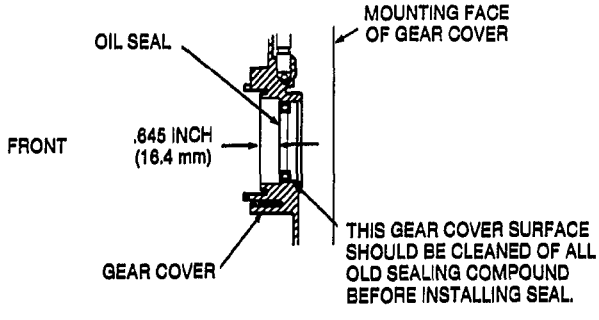
OIL SEALS

The bearing plate must be removed to replace the oil seal (Figure 25). Drive the oil seal out from the inside.

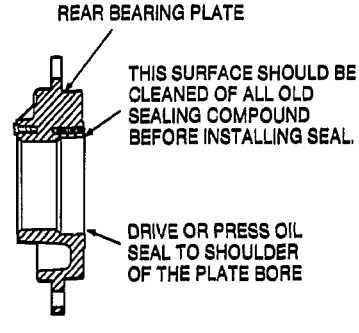
Before installing seals, fill the space between lips with a multi-purpose grease. This will improve sealing.

When installing the gear cover oil seal, tap the seal inward until it is .645 inch (16.4 mm) from the front of the gear cover.

When installing the bearing plate oil seal, tap the seal into the bearing plate bore to bottom against the shoulder in the plate bore. Use a seal expander or place a piece of heavy paper around the end of the crankshaft, when replacing the bearing plate to avoid damaging the seal. Remove the paper as soon as the plate is in place.



GEAR COVER OIL SEAL



REAR BEARING PLATE OIL SEAL

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FIGURE 25. GEAR COVER AND REAR BEARING PLATE OIL SEALS

PISTON ASSEMBLY

1. Lubricate all parts with engine oil.

2. Position piston on its respective rod and install the pin.

3. Install the rings on the pistons starting with the oil control ring (Figure 26). 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 degrees from the gap of that ring.

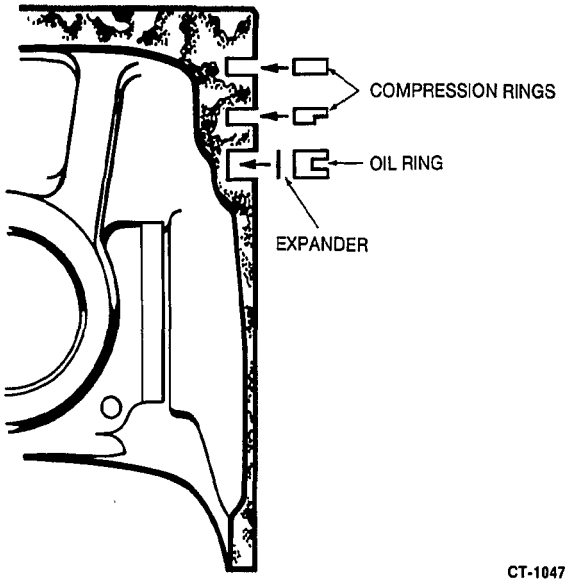


FIGURE 26. PISTON RINGS

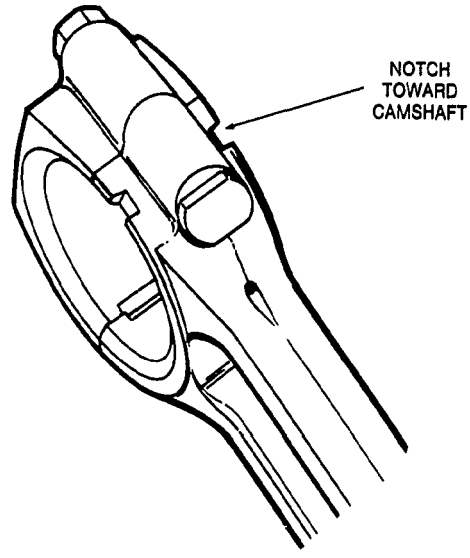
INSTALLATION OF PISTON IN CYLINDER

1. Turn the crankshaft to position the number one rod bearing journal at the bottom of its stroke.

2. Lubricate the number one piston assembly and inside of the cylinder. Compress the rings with a ring compressor (Figure 27).

3. Position the piston and rod assembly in the cylinder block. Notched side of connecting rod must face camshaft; rod bolts must be off-set toward outside of block.

4. Tap the piston down into the bore with the handle end of a hammer until the connecting rod is seated on the journal (Figure 27). Install the bearing cap on the rod. Install one fastener and tighten to 5 ft-lbs (7 Nm). Repeat this for the other fastener. Tighten both fasteners down to 14 ft-lbs (19 Nm).



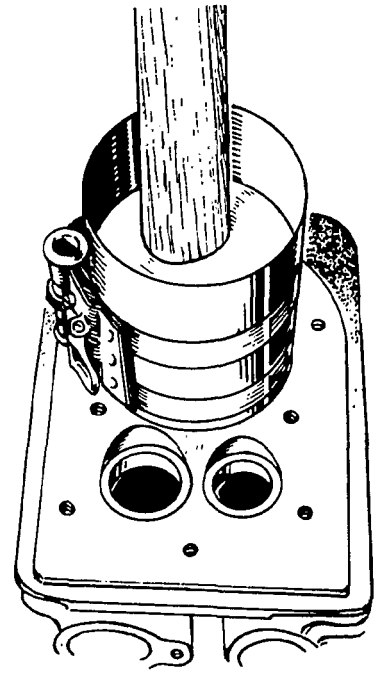


FIGURE 27. INSTALLING PISTON AND CONNECTING ROD

5. Install the remaining piston and rod in the same manner. Crank the engine over by hand to see that all bearings are free.

6. Install the oil base with a new gasket.

7. Install the cylinder heads. See *Cylinder Head* section for torques and torquing procedure.

8. Replace oil and break in engine.

CYLINDER HEADS

Remove the cylinder heads for carbon cleaning and gasket change at intervals specified in the *Periodic Maintenance Schedule.*

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

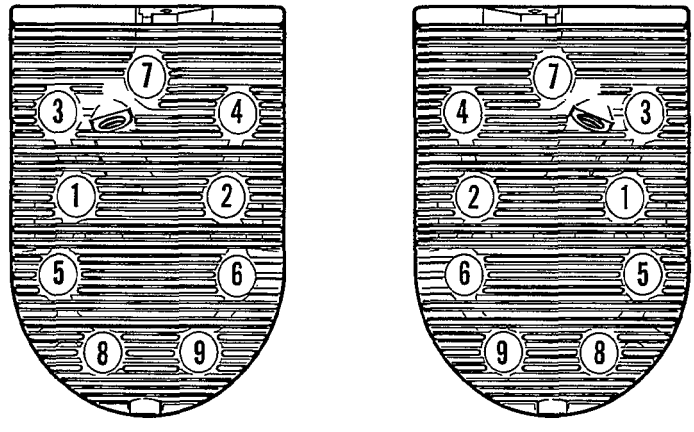
   ⚠CAUTION ***Do not torque or remove heads when they are hot. Warpage may occur. The gasket surface must be below 100° F (37° C) before removal. At temperatures above 100° F (37° C), the gasket will become gummy and difficult to remove from the surface of the block and cylinder head.***

2. After removing heads, clean out all carbon deposits. Be careful not to damage the outer sealing edges where 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.

4. 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 gasekt may tear.

5. Follow the head torque sequence shown in Figure 28. Tighten all bolts to 5 ft-lbs (7 Nm), then 10 ft-lbs (14 Nm), then to the torque specified in *ASSEMBLY TORQUES.* Recheck all head bolts for correct torques.



NO. 1 CYLINDER NO. 2 CYLINDER

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FIGURE 28. CYLINDER HEAD TORQUE SEQUENCE