Section VII

ENGINE

CONTENTS

Section VII
ENGINE
DATA AND SPECIFICATIONS

	LC-1 and 2	LC-3 and LY-1
ENGINE		
Type	V 90°	V 90°
Number of Cylinders	8	8
Bore	3.94″	4.00″
Stroke	3.63″	3.90″
Piston Displacement	354 cu. in.	392 cu. in.
Compression Ratio	10.0 to 1	10.0 to 1
Compression Pressure at 150 rpm (plugs removed) Wide Open Throttle	150 to 200 lbs.	150 to 200 lbs.
Maximum Variation Between Cylinders (any one engine)	20 lbs.	20 lbs.
Firing Order	1-8-4-3-6-5-7-2	1-8-4-3-6-5-7-2
CYLINDER NUMBERING—From Front of Engine		
Left Bank	1-3-5-7	1-3-5-7
Right Bank	2-4-6-8	2-4-6-8
CRANKSHAFT		
Type	Fully Counter-Balanced	Fully Counter-Balanced
Bearings	Steel Backed Babbitt	Steel Backed Babbitt
Journal Diameter	2.4995 to 2.5005″	2.687 to 2.688″
Crank Pin Diameter	2.249 to 2.250″	2.374 to 2.375″
Maximum Out-of-Round Permissible	.001″	.001″
Number Main Bearings	5	5
Diameter Clearance (Desired)	.005 to .0015″	.005 to .0015″
End Play	.002″ to .007″	.002″ to .007″
*C75-1 (2 Barrel Carburetor)		
C75-2 (4 Barrel Carburetor)		
Thrust Taken by	No. 3 Main Bearing	No. 3 Main Bearing
Finish at Rear Seal Surface	Diagonal Knurling	Diagonal Knurling
Interchangeability of Bearings	Upper and Lower Nos. 1, 2, 4 Upper and Lower No. 3 Upper and Lower No. 5 Not Interchangeable	Upper and Lower Nos. 1, 2, 4 Upper and Lower No. 3 Upper and Lower No. 5 Not Interchangeable
MAIN BEARINGS (service) All Available in Standard and the Following Undersizes	.001, .002, .003, .010, .012″	.001, .002, .003, .010, .012″
CONNECTING RODS AND BEARINGS		
Type	Drop Forged "I" Beam	Drop Forged "I" Beam
Length (Center to Center)	6.625″	6.951″
Weight (less bearings) (shells)	25.2 oz.	27.6 oz.

ENGINE (Cont'd)

	LC-1 and 2	LC-3 and LY-1
Bearings	Steel-Backed Babbitt	Steel-Backed Babbitt
Diameter and Length	2.2507 to 2.2512″ x 29/32″	2.375 x 29/32″
Diametral Clearance Desired	.0005 to .0015″	.0005 to .0015″
Maximum Allowable Before Reconditioning	.0025″	.0025″
Side Clearance	.006 to .014″	.006 to .014″
Bearings for Service	Standard .001, .002, .003, .010, .012″ US	Standard .001, .002, .003, .010, .012″ US
CONNECTING ROD BUSHING		
Type	Steel-Backed Bronze	Steel-Backed Bronze
Number of Bearings	8	8
Diameter and Length	.9843 to .9846 x 1¼″	.9843 to .9846 x 1¼″
Interchangeability	All	All
Clearance	.0001 to .0004″ Selective	.0001 to .0004″ Selective
CAMSHAFT		
Drive	Chain	Chain
Bearings	Steel-Backed Babbitt	Steel-Backed Babbitt
Number	5	5
Thrust Taken By	Thrust Plate	Thrust Plate
End Play	.002 to .006″	.002 to .006″
Maximum Allowable Before Reconditioning	.010″	.010″
Diametral Clearance	.001 to .003″	.001 to .003″
Maximum Allowable Before Reconditioning	.005″	.005″
CAMSHAFT BEARING JOURNALS		
Diameter and Length		
No. 1	1.998 to 1.999 x 15/16″	1.998 to 1.999 x 15/16″
Nos. 2, 3 and 4	1.998 to 1.999 x ¾″	1.998 to 1.999 x ¾″
No. 5	1.4355 to 1.4365 x 29/32″	1.4355 to 1.4365 x 29/32″
CAMSHAFT BEARINGS		
Diameter and Length (after reaming)		
No. 1	2.000 to 2.001 x 15/16″	2.000 to 2.001 x 15/16″
Nos. 2, 3 and 4	2.000 to 2.001 x 13/16″	2.000 to 2.001 x 13/16″
No. 5	1.4375 to 1.4385 x 29/32″	1.4375 to 1.4385 x ⅞″
TIMING CHAIN		
Adjustment	None	None
Number of Links	68	68
Pitch	.375″	.375″
Width	1⅛″	1⅛″

ENGINE (Cont'd)

	LC-1 and 2	LC-3 and LY-1
TAPPETS		
Type	Hydraulic	Hydraulic
Clearance in Block	.0005 to .0015″	.0005 to .0015″
Body Diameter	.9040 to .9045″	.9040 to .9045″
Clearance Between Valve Stem Rocker Arm or Tappet	Dry Lash .060 to .210″	Dry Lash .060 to .210″
PISTONS		
Type	Horizontal Slot w/steel strut	Horizontal Slot w/steel strut
Material	Aluminum Alloy Tin Coated	Aluminum Alloy Tin Coated
Land Clearance (diametral)	.028 to .033″	.029 to .034″
Clearance at Skirt	1½″ from Bottom of Skirt .0005 to .0015″	1½″ from Bottom of Skirt .0005 to .0015″
Weight (Std. through .060″ oversize)	646 gm.	700 gm.
Piston Length (overall)	3.99 in.	4 in.
Ring Groove Depth		
No. 1	.200″	.209″
No. 2	.200″	.209″
No. 3	.194″	.201″
Pistons for Service	Std. .005, .020, .040, .060″ OS	Std. .005, .020, .040″ OS
PISTON PINS		
Type	Full Floating	Full Floating
Diameter and Length	.9841 to .9843 x 3.140 to 3.150″	.9841 to .9843 x 3.140 to 3.150″
Clearance in Piston (thumb press at 70° F.)	.0000 to .0005″	.0000 to .0005″
End Play	.004 to .026″	.004 to .026″
Clearance in Rod (selective)	.0001 to .0004″	.0001 to .0004″
Piston Pins for Service	Std., .003, .008″ OS	Std., .003, .008″ OS
Direction Offset in Piston	Toward Right Side of Engine	Toward Right Side of Engine
PISTON RINGS		
Number of Rings per Piston	3	3
Compression	2	2
Oil	1	1
Width of Rings—		
(Compression)	.0775 to .0780″	.0775 to .0780″
(Oil)	.1860 to .1865″	.1860 to .1865″
Piston Ring Gaps (all)	.010 to .020″	.013 to .025″
RING SIDE CLEARANCE		
(Compression)		
Upper	.002 to .0035″	.002 to .0035″

ENGINE (Cont'd)

	LC-1 and 2	LC-3 and LY-1
Intermediate	.002 to .0035"	.002 to .0035"
(Oil)	.001 to .0025"	.0010 to .0025"
VALVES—Intake		
Material	Silicon-Chromium Steel	Silicon-Chromium Steel
Head Diameter	1 15/16"	2"
Length (to top of valve face)	4 23/32"	5 1/32"
Stem Diameter	.372 to .373"	.372 to .373"
Stem to Guide Clearance	.001 to .003"	.001 to .003"
Maximum Allowable Before Reconditioning	.004"	.004"
Angle of Seat	45°	45°
Adjustment	None	None
Lift	.388"	.388"
VALVES—Exhaust		
Material	Nitrogen Treated Manganese Chromium—Nickel Steel	
Head Diameter	1 1/2"	1 3/4"
Length (to top of valve face)	4 3/4"	5 1/32"
Stem Diameter	.371 to .372"	.371 to .372"
Stem to Guide Clearance	.002 to .004"	.002 to .004"
Maximum Allowable Before Reconditioning	.006"	.006"
Angle of Seat	45°	45°
Adjustment	None	None
Lift	.388"	.388"
VALVE SPRINGS		
Number	16	16
Free Length	2"	2"
Load When Compressed to (valve closed)	1 11/16" 78 to 88 lbs.	1 11/16" 78 to 88 lbs.
Load When Compressed to (valve open)	1 5/16" 170 to 184 lbs.	1 5/16" 170 to 184 lbs.
Valve Springs I.D.	1.010 to 1.030"	1.010 to 1.030"
CYLINDER HEAD		
Number Used	2	2
Combustion Chamber	Polyspherical	Hemispherical
Valve Seat Runout (maximum)	.002"	.003"
Intake Valve Seat Angle	45°	45°
Seat Width (finished)	.060 to .085"	.060 to .085"
Exhaust Valve Seat Angle	45°	45°
Seat Width (finished)	.040 to .060"	.040 to .060"

ENGINE (Cont'd)

	LC-1 and 2	LC-3 and LY-1
Cylinder Head Gasket Compressed (thickness)	.027″	.028″
ENGINE LUBRICATION		
Pump Type	Rotary, Full Pressure	Rotary, Full Pressure
Capacity (qts.)	4*	5*
Pump Drive	Camshaft	Camshaft
Operating Pressure at 40 to 50 mph	40 to 65 lbs.	40 to 65 lbs.
Pressure Drop Results from Clogged Filter	15 to 20 lbs.	15 to 20 lbs.
*When Filter Element is Replaced Add 1 Qt.		

SPECIAL TOOLS

Tool Number	Tool Name
C-119	Indicator—Cylinder Bore
C-385	Compressor—Piston Ring
C-425	Vacuum Gauge
C-455	Wrench—Starting Motor Flange Nut
C-647	Tester—Clutch and Valve Spring
C-690	Scale and Gauge—Piston Fitting
C-741	Reamer—Solid Valve Guide
C-756	Cleaner—Valve Guide
C-863	Timing Light—6 and 12 Volt
C-897	Driver—Welch Plug Installer
C-3005	Wrench—Torque 100 Foot-Pounds (Sensory Type)
C-3012	Reamer—Cylinder Bore Ridge
C-3020	Tool Main Bearing Seal
C-3024	Tool—Rocker Arm and Spring Compressor
C-3025	Sleeve—Guide Wear Measuring—Intake
C-3026	Sleeve—Guide Wear Measuring—Exhaust
C-3028	Reamer Set—Valve Tappet
C-3033	Puller Set—Damper, Sprocket, Crank Gear
C-3038	Fixtures—Cylinder Head Holding (FirePower)
C-3046	Tool—Piston Ring Installer (SpitFire)
C-3049	Reamer—Piston Pin Line (.980 to 1.030)
C-3052	Remover—Distributor Shaft Bushing
C-3053	Driver and Burnisher—Distributor Drive Shaft Bushing
C-3054	Wrench—Spark Plug
C-3059	Tool—Main Bearing Upper Shell
C-3061	Gauge—Valve Stem Length (FirePower)

SPECIAL TOOLS (Cont'd)

Tool Number	Tool Name
C-3065	Gauge—Cylinder Compression
C-3066	Connector—Timing Light
C-3068	Rack—Hydraulic Tappet
C-3075	Gauge—Top Dead Center (FirePower)
C-3132	Puller and Installer—Camshaft Bearing
C-3151	Driver—Welch Plug Installing
C-3160	Pliers—Hydraulic Tappet Leakdown Checking
C-3167	Stand—Engine Repair
C-3168	Adapter—Engine Repair Stand
C-3216	Puller—Hydraulic Tappet
C-3221	Tool—Piston and Connecting Rod Assembly
C-3339	Dial Indicator Set
C-3419	Wrench—Distributor Lock Plate
C-3422	Compressor—Valve Spring (FirePower)
C-3427	Reamer—Valve Guide (.404 to .405 inch)
C-3430	Reamer—Valve Guide (.389 to .390 inch) (SpitFire)
C-3433	Reamer—Valve Guide (.379 to .380 inch) (SpitFire)
C-3436	Gauge—Valve Stem Length (SpitFire)
C-3466	Plate—Engine Lifting
C-3495	Tool—Piston Ring Installer (FirePower)
C-3501	Cylinder Bore Deglazing Hone
C-3506	Removing and Installing Tool—Chain Case Cover Oil Seal
C-3509	Tool—Camshaft Holding
C-3511	Tool—Rear Main Bearing Seal Installing
C-3574	Tool Main Bearing Seal
DD-883	Driver—Valve Guide

TIGHTENING REFERENCE

	(Foot-Pounds)
Camshaft Sprocket Bolt	35
Camshaft Sprocket Hub Thrust Plate Bolt	15
Carburetor to Manifold Stud Nut	15
Chain Case Cover Bolt	35
Connecting Rod Bearing Cap Bolt Nut	45
Cylinder Head Bolt	85
Distributor Clamp Bolt	15
Engine Front Mounting to Frame Nut	85
Engine Front Mounting to Block Nut	45
Exhaust Manifold Stud Nut	25
Exhaust Pipe Flange Bolt Nut	40
Crankshaft Bearing Cap Bolt	85

TIGHTENING REFERENCE (Cont'd)

	(Foot-Pounds)
Fan Blade Bolt	15
Flywheel Housing to Cylinder Block Bolt	50
Fuel Pump Bolt	30
Generator Adjusting Strap Bolt	15
Generator Adjusting Strap Mounting Bolt	30
Generator Bracket Bolt	50
Generator Mounting Bolt	20
Ignition Cable Cover Screw	7
Intake Manifold Bolt	30
Main Bearing Cap Bolt	85
Oil Filter Bolt	25
Oil Level Indicator Tube Bracket Bolt Nut	10
Oil Pan Bolt	15
Oil Pan Drain Plug	35
Oil Pump Cover Bolt	10
Oil Pump Mounting Bolt	35
Spark Plugs	30
Vibration Damper Hub Bolt	135
Vibration Damper Inertia Member Flange Bolt	15
Water Outlet Elbow Bolt	35
Water Pump Housing Bolt	30

	(Inch-Pounds)
Crankcase Ventilator Outlet Pipe Bolt	15
Manifold Heat Control Counterweight Bolt	50
Rocker Arm Cover Bolt Nut	30
Tappet Chamber Cover	50

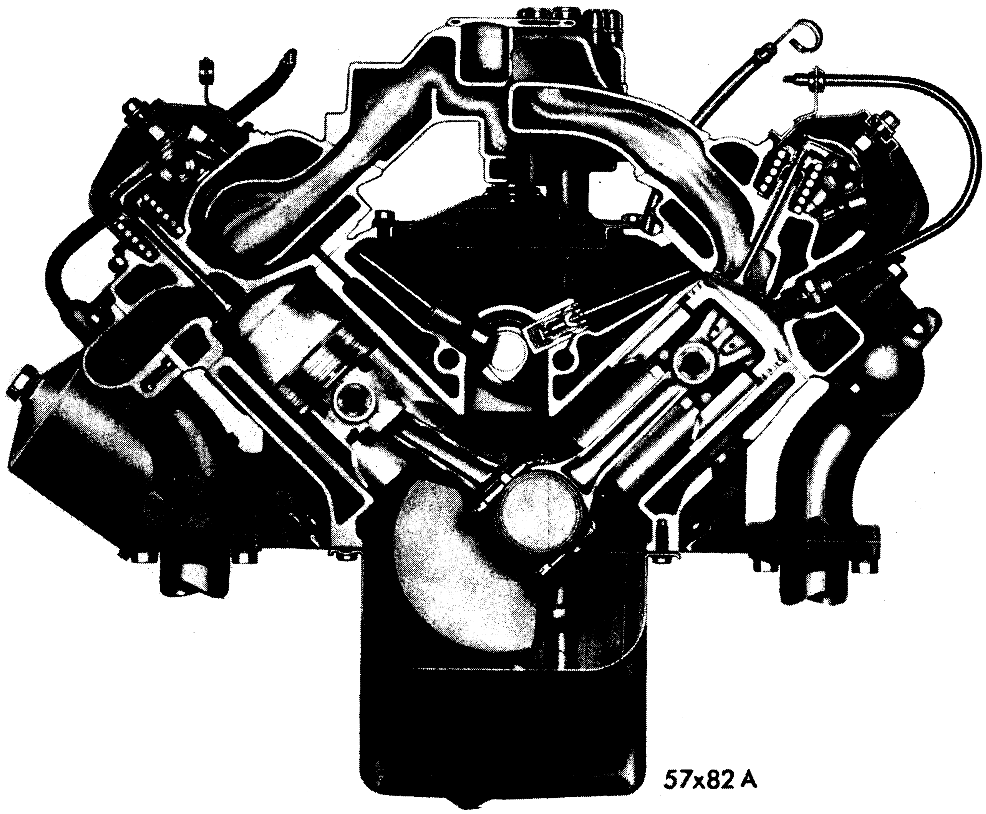

Fig. 1—SpitFire V-8 Engine (End Sectional View)

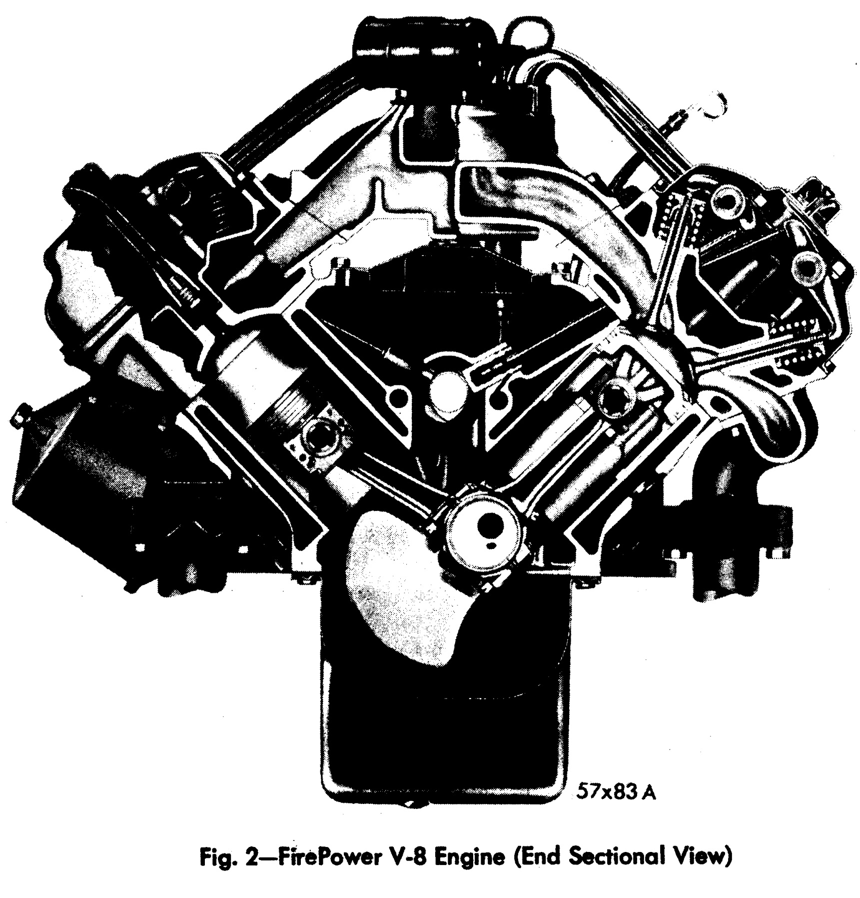

Fig. 2—FirePower V-8 Engine (End Sectional View)

Section VII
ENGINE (FIGS. 1 and 2)

1. MINOR TUNE-UP

The following procedures are provided as a guide which should be followed when performing minor engine repairs or a complete engine over-haul.

Clean and adjust spark plugs (.035 inch gap). Adjust or replace distributor contact points (.015 to .018 inch gap). Check distributor cap for cracks and corrosion. Inspect rotor, rotor spring and plunger. Inspect distributor to spark plug wires for shorts. Inspect small lead wires for tightness, breakage, or damaged insulation. Check for excessive play in distributor vacuum advance plate bearing. Reset ignition timing. Check battery specific gravity and clean and tighten battery connections. Check starter amperage draw. Inspect fan belt, and check adjustment. Tighten carburetor flange nuts to 15 foot-pounds torque. Set carburetor idle mixture adjustment. Adjust throttle stop screw so engine idles at 450 to 500 r.p.m. Check manifold heat control valve.

2. MAJOR TUNE-UP

On cars equipped with air conditioning, power steering, power brakes, heater, etc., refer to Section covering this equipment for removal, installation and adjustment procedures.

A periodic engine tune-up will assure maximum engine performance and fuel economy. In addition, perform all steps of a "Minor Tune-Up." Tighten manifold nuts. Make a compression test. The compression should not vary more than 20 pounds between cylinders. Refer to "Engine Data and Specifications" for compression pressures. Check coil and condenser and inspect primary and secondary wires. Service the Air Cleaner — **DO NOT WASH OR OIL.** Normal operation—Replace filter element every 15,000 miles. Service more frequently under severe dusty conditions. (See Fig. 3.) Test fuel pump for pressure and vacuum, and adjust carburetor. Refer to Fuel and Exhaust System, Section VII, "Carburetor Adjustments." Check manifold heat control valve. Road test car as a final check.

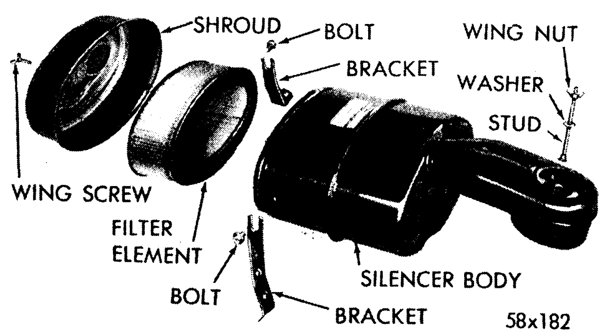

Fig. 3—Carburetor Air Cleaner (Disassembled View)

SERVICE PROCEDURES

3. REMOVAL OF ENGINE ASSEMBLY (FROM CAR)

Drain cooling system and remove battery. Remove fan shroud, (Air Conditioning Models only) radiator and hood. **Before removing hood, scribe outline of hinge brackets on hood to assure proper adjustment when installing.** Disconnect fuel lines and wire attached to engine units. Remove air cleaner and carburetor. Attach engine lifting fixture, Tool C-3466, to carburetor flange studs on intake manifold and attach a chain hoist to fixture eyebolt.

Disconnect propeller shaft, wires and linkage at transmission. Remove exhaust pipe. (Be sure exhaust system is sufficiently supported while engine is removed.) Remove rear crossmember to transmission support attaching bolts.

NOTE: Place a rollaway jack under transmission to relieve weight from crossmember. Place a wood block between head of jack and transmission to avoid damaging transmission oil pan. This jack must support weight of rear of power plant and must be able to roll with the engine as engine is being removed from chassis.

Remove crossmember rear engine support. Lower car to convenient working height and remove engine front support. With chain hoist, raise engine and, at same time work engine out of chassis. If engine is to be disassembled, place engine in engine repair stand, Tool C-3167, using transmission mounting bolts.

4. INSTALLING ENGINE (IN CAR)

Install engine lifting fixture, Tool C-3466 and attach chain hoist to fixture eyebolt. Lower engine carefully, until front and rear of engine are approximately positioned. Place a rollaway jack under transmission to support weight of rear of engine. Install engine rear support crossmember. Position engine and install nuts at front mounts. Position and install rear engine support bolts and remove jack and hoist. Remove engine lifting fixture. Install manifold, carburetor, fuel lines, wiring and linkage. Install radiator, radiator hoses, wires and radiator shroud. Install exhaust pipes, using new gaskets. Reinstall hood by checking scribe marks placed on inside of hood at removal. Connect propeller shaft at transmission. Be sure all drain cocks are closed; refill cooling system, refill engine crankcase and transmission. Refer to Lubrication, Section XIV for quantities and lubricants to use. Check entire system for leaks and correct as necessary.

NOTE: Whenever an engine has been rebuilt and a new camshaft and/or new tappets have been installed, one quart of MOPAR Oil Additive should be added to engine oil to aid break-in. The oil mixture should be left in engine for a minimum of 500 miles. It is not necessary however, to drain the mixture before normal oil change is required, nor is it necessary to use the oil additive at subsequent oil changes.

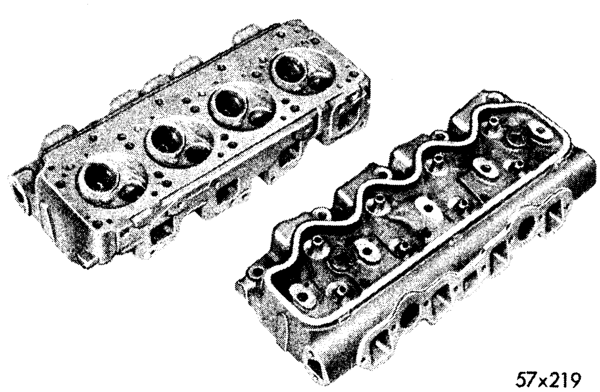

Fig. 4—Cylinder Head (SpitFire Engine)

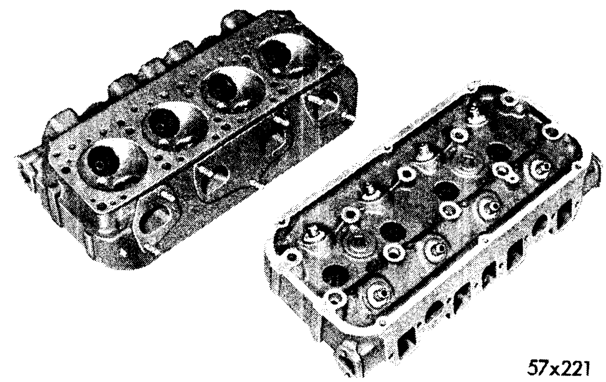

Fig. 5—Cylinder Head (FirePower Engine)

Start engine, warm up to 160 degrees F., check timing and adjust carburetor as necessary.

5. REMOVAL OF CYLINDER HEADS (Fig. 4 and 5)

Drain cooling system. Remove generator. Remove carburetor air cleaner and fuel line. Disconnect accelerator linkage. Remove vacuum control tube at carburetor and distributor. Disconnect coil wires and heater hose. Remove heat indicator sending unit wire. Remove oil level indicator (dip stick). Remove air tube between automatic choke and exhaust manifold. Remove water outlet manifold. Remove heater blower. Remove ignition cable cover and disengage insulators from spark plugs. Use a thin wall socket, or Tool C-3054 to remove spark plugs and tubes. Remove intake manifold, ignition coil and carburetor as an assembly. Remove cylinder head covers and gaskets. Disconnect exhaust pipes at manifold flanges. Remove bolts that attach rocker arm support brackets to cylinder head and block, and pull rocker assemblies and bolts directly away from heads.

CAUTION

The rocker arm assembly attaching bolts (FirePower) also hold cylinder heads to block. When these bolts are removed, cylinder heads are loose and are held by two dowel pins only.

Remove push rods and place them in their respective slots in holder Tool-C-3068. Lift off cylinder head and place into holding fixture Tool C-3038. Remove exhaust manifold and gasket, if cylinder head is to be replaced.

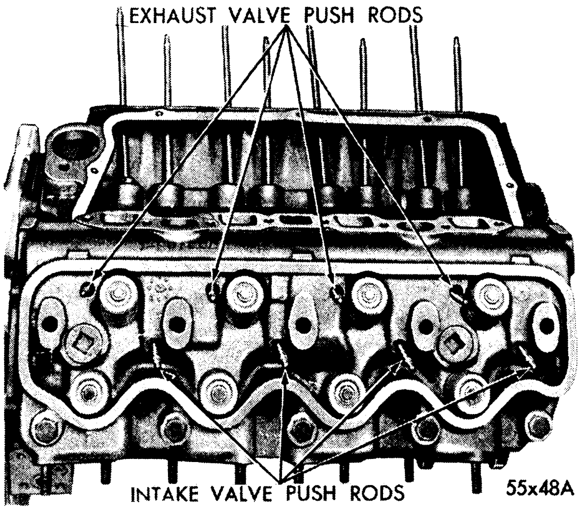

Fig. 6—Push Rods Installed (SpitFire)

NOTE: On FirePower Engine only, the right cylinder head rocker shaft brackets and the cylinder head bolts can be removed as a complete assembly. On the left cylinder head remove the stop light switch from the master brake cylinder, oil level indicator, (on Power Steering remove pump oil line) before removing the cylinder head assembly.

6. INSTALLATION OF CYLINDER HEADS

Clean gasket surfaces of cylinder block and cylinder head. Check all surfaces with a straightedge if there is any reason to suspect leakage. Install cylinder heads and new cylinder head gaskets. Coat gaskets with MOPAR Perfect Seal, Part No. 1122893 or equivalent sealer. Install push rods as shown in Figures 6 and

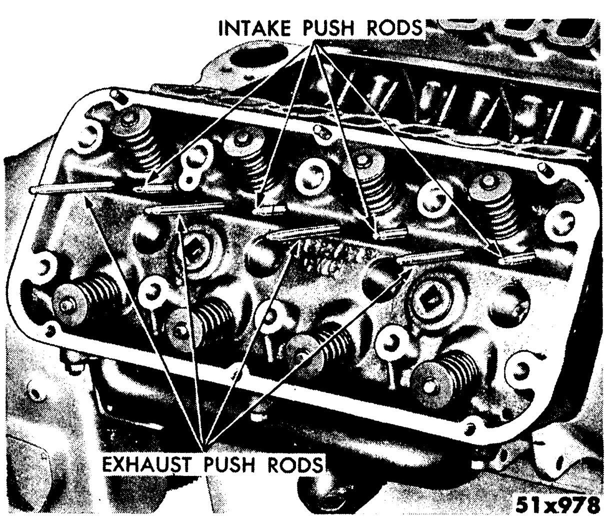

Fig. 7—Push Rods Installed (FirePower)

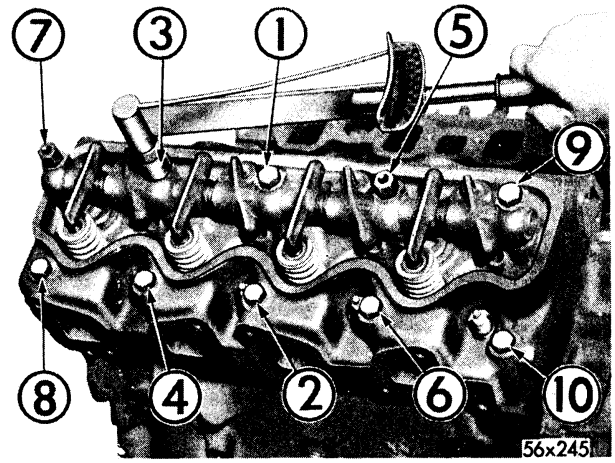

Fig. 8—Tightening Cylinder Head Bolts (SpitFire)

7. Insert cylinder head bolts into rocker arm support brackets and place rocker arm assemblies in position on head, lining up all push rods to their respective rocker arms. Starting at top center, tighten all cylinder head bolts to 60-80 foot-pounds torque, in sequence shown in Figure 8 and 9. Then repeat the procedure, tightening all head bolts to 85 foot-pounds torque. Place new valve tappet cover gaskets in position, and install tappet cover. Tighten bolts to 50 inch-pounds torque. Install crankcase breather tube on tappet cover and insert oil level indicator (dip stick) tube into position. Install new cylinder head cover gasket and install cover. Tighten nuts and bolts to 30 inch-pounds torque. On FirePower engines slide spark plug tube seals over tubes, and install in position in heads. Check spark plugs for .035 inch gap and install plugs, being careful not

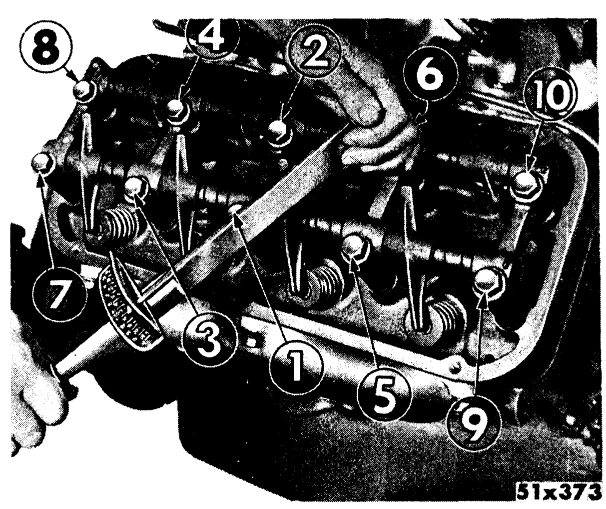

Fig. 9—Tightening Cylinder Head Bolts (FirePower)

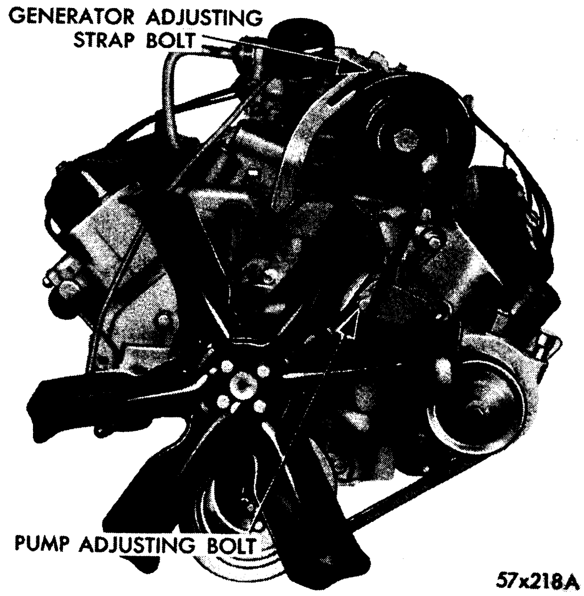

Fig. 10—Adjusting of Fan Belts

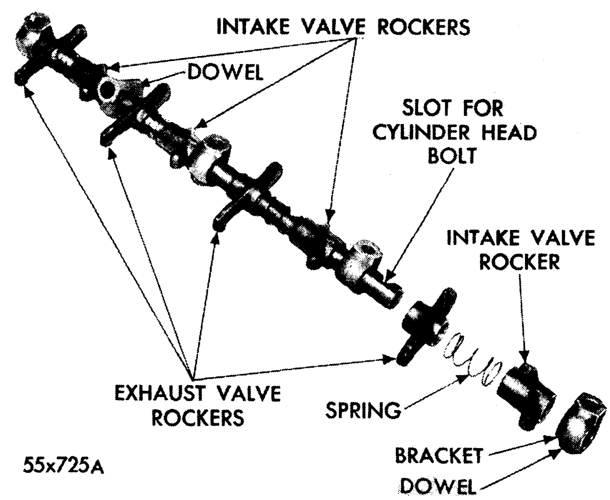

Fig. 11—Rocker Shaft Assembly (Disassembled View) (SpitFire)

to drop them on electrodes as this would cause gap setting to be altered. Tighten spark plugs to 30 foot-pounds torque with Tool C-3054. Install new intake manifold gaskets and manifold. Tighten bolts to 30 foot-pounds torque.

NOTE: When installing intake manifold, insert short bolts in holes on extreme ends of manifold.

Install distributor cap coil wire, spark plug cables and insulators. On FirePower Engines place spark plug tube seal retainers in position and install spark plug covers, after carefully arranging spark plug cables. Tighten screws securely. Install generator. Tighten generator bracket bolts to 50 foot-pounds torque and generator mounting nut to 20 foot-pounds torque.

NOTE: When adjusting fan and accessory belt drives as shown in Figure 10, refer to Section IV, Accessory Belt Drives in this Manual.

7. REMOVAL OF ROCKER ARMS AND SHAFT ASSEMBLY

Remove rocker arm cover and gasket. Remove bolts that attach rocker arm support brackets and cylinder head to cylinder block and remove rocker arms and brackets as an assembly.

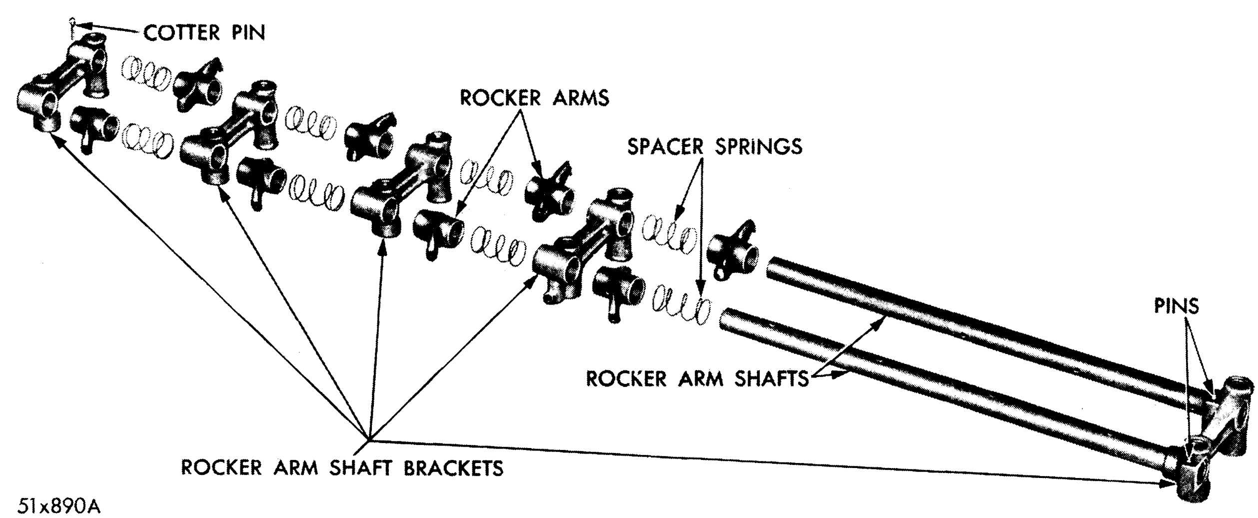

Fig. 12—Rocker Shaft Assembly (Disassembled View) (FirePower)

CAUTION

With bolts removed, the cylinder heads are held in position by two locating dowel pins only. (FirePower Engines)

If rocker arm assemblies have been disassembled for cleaning, inspection or replacement, refer to Figures 11 and 12 for proper reassembly.

NOTE: On FirePower engines rocker shafts are stamped "IN" for intake and "EX" for exhaust. The intake rocker arms are shorter than exhaust rocker arms.

8. INSTALLATION OF ROCKER ARM AND SHAFT ASSEMBLY

Install push rods as shown in Figures 6 and 7. The push rods should be properly positioned in rocker arm and tappets.

CAUTION

Be sure locating dowels on brackets are in proper alignment in head, as shown in Figure 11.

Position rocker arm assemblies. Install cylinder head bolts. Tighten bolts 60-80 foot-pounds torque in sequence shown in Figures 8 and 9. Then repeat the procedure, tightening all head bolts to 85 foot-pounds torque.

9. REMOVAL OF VALVES AND VALVE SPRINGS

With cylinder head removed, compress valve springs with Tool C-3422 (SpitFire Engines and Tool C-3024 (FirePower Engines). Remove valve retaining locks, valve spring retainers, valve stem cup seals (intake valves only) and valve springs. **Remove burrs from valve stem lock grooves to prevent damage to valve guide when valves are removed.**

10. VALVE INSPECTION

Clean valves thoroughly, and discard burned, warped or cracked valves. Check valve stems for wear. Intake valve stems should measure .372 to .373 inch, and exhaust valve stems should measure .371 and .372 inch. If wear exceeds .002 inch, replace the valve. Remove carbon and varnish deposits from inside of valve guides with cleaner, Tool C-756.

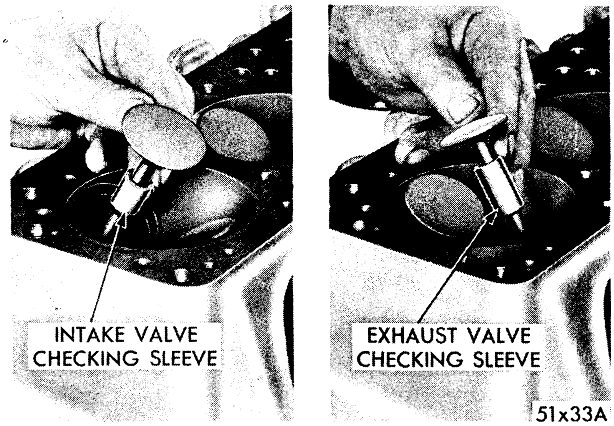

Fig. 13—Installing Sleeves to Check Guide Clearance (FirePower) (Typical of SpitFire)

NOTE: On SpitFire Engines, the valve guides are cast integrally with the cylinder head. Service valves with oversize stems are available for these engines.

Check valve stem to guide clearance as follows: Install sleeve, Tool C-3025, over intake valve stem, and sleeve Tool C-3026 on exhaust valve stem and install valves (Fig. 13). These special sleeves place valve at working height for easy checking with a dial indicator. Attach dial indicator Tool C-3339 to cylinder head and set it at right angle to edge of valve being checked (Fig. 14). Move valve to and from indicator. The total dial indicator reading should not exceed .008 inch on intake valves, or .014 inch on exhaust valves. If readings exceed the above tolerances, install new valve guides

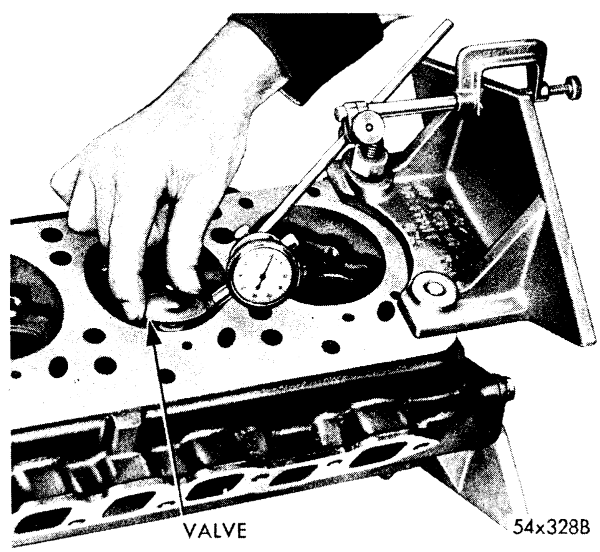

Fig. 14—Checking Valve Guide Clearance (SpitFire) (Typical of FirePower)

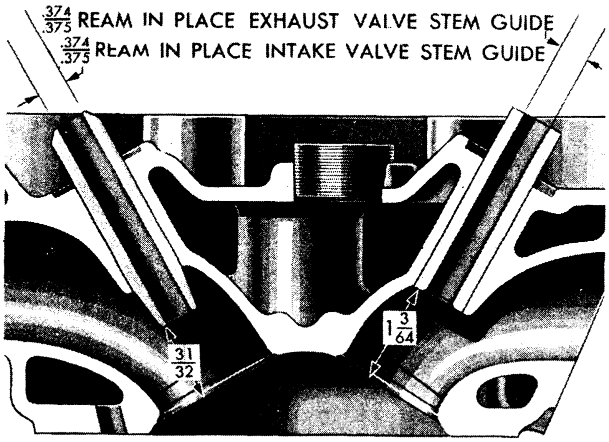

Fig. 15—Exhaust and Intake Valve Guide Installed in Head (FirePower)

(FirePower Engines), or ream guides for oversize valves (SpitFire Engines), to next oversize (if other than standard).

11. REMOVAL AND INSTALLATION OF VALVE GUIDES

On FirePower Engines drive out guides through top of cylinder heads with Tool DD-883. Install as follows: Turn cylinder head with combustion chamber facing up. Drive valve guides into position with a suitable driver to dimensions shown in Figure 15. After new valve guides have been installed, ream each guide .374 to .375 inch with Tool C-741. On SpitFire Engines valves with oversize stems are available in .005, .015, and .030 inch. Reamers to accommodate the oversize valve stems are as follows: Reamer Tool C-3433 (.379 to .380 inch), Reamer Tool C-3427 (.404 to .405 inch). Slowly turn reamer by hand and clean guide thoroughly before installing new valve.

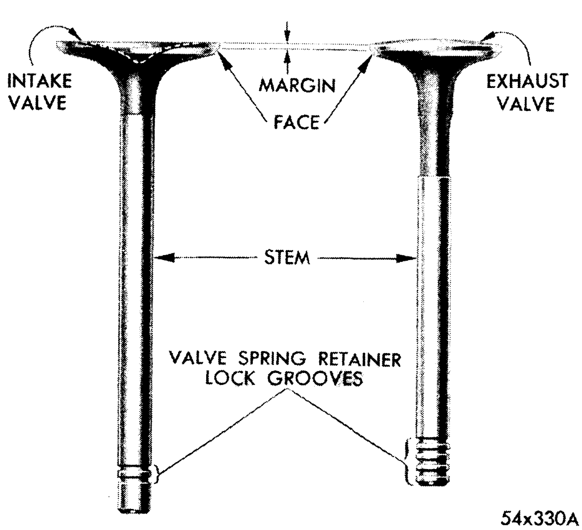

Fig. 16—Intake and Exhaust Valve Nomenclature

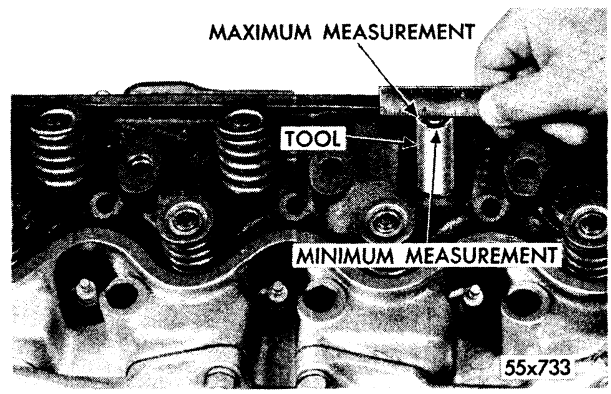

Fig. 17—Checking Valve Stem Position (SpitFire)

CAUTION

Do not attempt to ream valve guides from standard directly to .030 inch. Use step procedure of .005, .015, and .030 inch so the valve guides may be reamed true in relation to valve seat.

12. REFACING VALVES AND VALVE SEATS

The intake and exhaust valves are faced to a 45 degree angle. When refacing valve, always check remaining margin (Fig. 16). Valves with less than $\frac{3}{64}$ inch margin should be discarded. The angle of both valve and seat should be identical. When refacing valve seats with Tool MTH-80, it is important that correct size valve guide pilot be used for reseating stones. A true and complete surface must be obtained. Check concentricity of valve seat using a dial indicator; total runout should not exceed .002 inch (total indicator reading). When the seat is

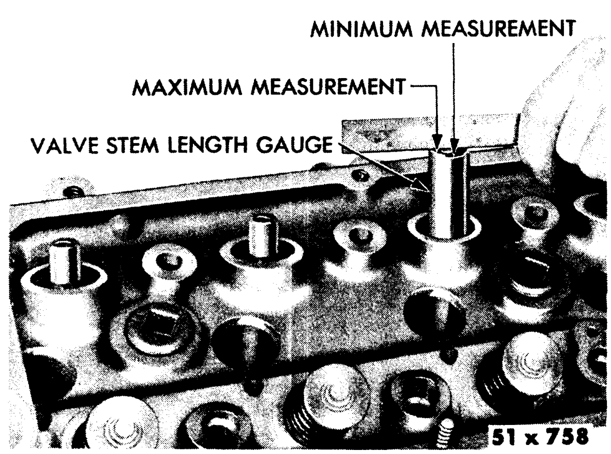

Fig. 18—Checking Valve Stem Position (FirePower)

properly positioned, width of intake seats should be 1/16 to 3/32 inch. The width of exhaust seats should be 3/64 to 1/16. When valves and seats are reground, the position of valve in head is changed, shortening operating length of hydraulic tappet. This means that plunger is operating closer to its bottomed position, and less clearance is available for thermal expansion of valve mechanism during high speed driving. Design of plunger travel includes a safety factor for normal wear and refacing of valves and seats. The dimension from valve spring seat in head to valve tip should be checked with gauge Tool C-3436 for SpitFire Engines and gauge Tool C-3061 for FirePower Engines, (Figs. 17 and 18).

The end of cylindrical gauge and bottom of slotted area represent maximum and minimum allowable extension of valve stem tip beyond spring seat. If tip exceeds maximum, grind to approach, but do not go below minimum allowable on gauge.

13. TESTING VALVE SPRINGS

Whenever valve springs are removed they should be tested with spring tester, Tool C-647. Attach torque wrench, check tension and multiply reading by 2. The valve springs should test 170 to 184 pounds when compressed to 1 5/16 inch. Discard springs that do not meet these specifications.

Check each spring for squareness with a steel square and surface plate. (Fig. 19). If spring is more than 1/16 inch out of square, install new spring.

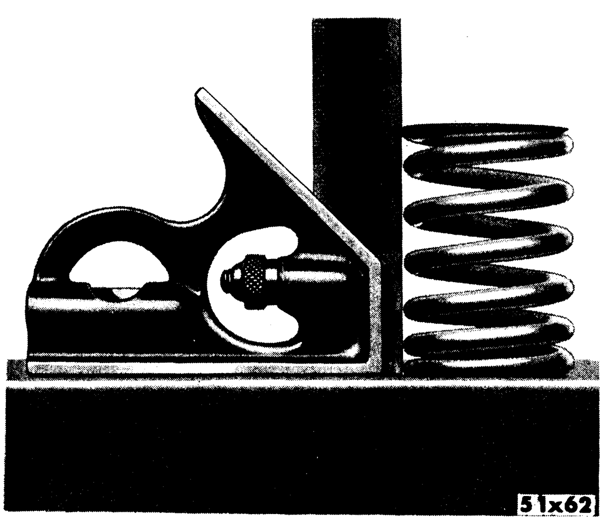

Fig. 19—Checking Valve Spring for Squareness

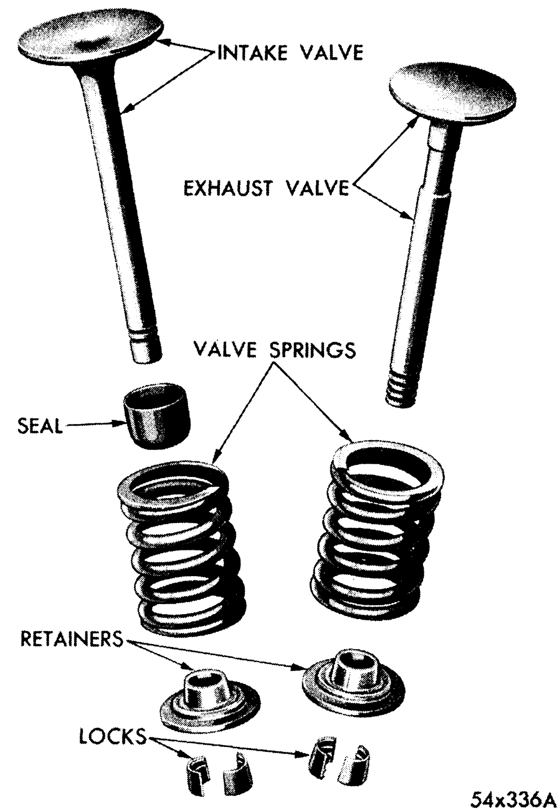

Fig. 20—Valves, Springs, Seals, Retainers and Locks (Disassembled View)

14. INSTALLING VALVES AND VALVE SPRINGS

Coat valve stems with lubricating oil and insert in position in cylinder head. Install cup seals on intake valve stems and over valve guides (Figs. 20 and 21), and install valve springs and retainers. Compress valve springs with Tool C-3422. Install locks and release tool.

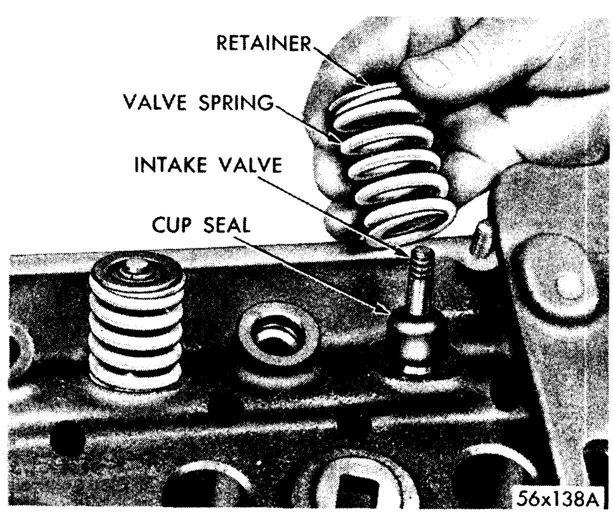

Fig. 21—Installing Intake Valves and Cup Seals

NOTE: If valves and/or seats are reground, check the installed height of springs. Make sure measurement is taken from full depth of counterbore in cylinder head to bottom surface of spring retainer. (If spacers are installed measure from top of spacer). If height is greater than 1 11/16 inches, install a 1/16 inch spacer (Part No. 1400482) in head counterbore to bring spring height back to normal 1 5/8 to 1 11/16 inch.

15. HYDRAULIC TAPPETS

a. Preliminary to Checking Hydraulic Tappets

Before disassembling any part of engine to check for tappet noise, check oil pressure at gauge and oil level in oil pan. The pressure should be between 40 to 65 pounds at 2,000 r.p.m. The oil level in pan should never be above "full" mark on dip stick, nor below "add oil" mark. Either of two conditions could be responsible for noisy tappets.

Oil Level Too High—If oil level is above "full" mark on dip stick, it is possible the connecting rods can dip into oil when engine is running and create foaming. This foam is fed to the hydraulic tappets by the oil pump, causing them to go flat and allowing valves to seat noisily.

Oil Level Too Low—Low oil level may allow pump to take in air which, when fed to tappets, causes them to lose length and allows valves to seat noisily. Any leaks on intake side of pump through which air can be drawn will create the same tappet action. When tappet noise is due to aeration, it may be intermittent or constant, and usually more than one tappet will be noisy. When oil level leaks have been corrected, the engine should run at fast idle for sufficient time to allow all of air inside of tappets to be worked out.

b. Tappet Noises

To determine source of tappet noise, run engine at idle with cylinder head covers removed. Feel each valve spring to detect the noisy tappet.

NOTE: Worn valve guides or cocked springs are sometimes mistaken for noisy tappets. If such is the case, noise may be dampened by applying side thrust on valve spring. Inspect rocker arm push rod sockets and push rod ends for wear. If noise is not appreciably reduced, it can be assumed the noise is in the tappet.

Valve tappet noise can be separated into two types, light noise and heavy noise. A light noise is usually caused by excessive leakdown around the unit plunger, or by plunger partially sticking in cylinder. A heavy noise is caused either by a tappet check valve not seating, or by foreign particles becoming wedged between plunger and tappet body, causing plunger to stick in down position. This heavy noise will be further evidenced by clearance between valve stem and rocker arm as valve closes. In either instance, the unit assembly should be removed for inspection and cleaning.

c. Removal of Tappets (with Rocker Arms in Position)

NOTE: If all of tappets are to be removed, it will be advisable to remove rocker arms and shaft. If only one or two tappets are to be removed, proceed as follows:

Install valve spring compression Tool C-3024, over rocker arm (Fig. 22) so heel of tool rests on valve stem side. Make certain valve is seated and tappet body is resting on low point of camshaft lobe. Refer to Paragraph 17, "Locating the Low Point of Camshaft Lobe in Conjunction with Valve Tappet Face." Using handle

Fig. 22—Compressing Valve Spring (FirePower) (Typical of SpitFire)

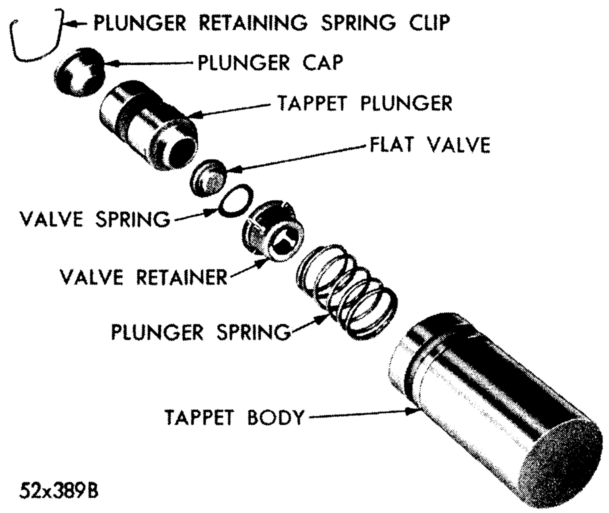

Fig. 23—Hydraulic Tappet (Disassembled View)

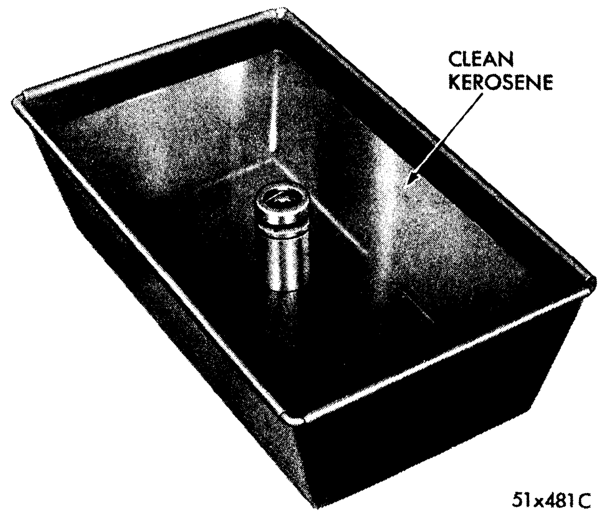

Fig. 24—Tappet Immersed in Clean Kerosene

of tool for leverage, compress valve springs sufficiently to raise rocker arm above push rod. While holding rocker arm in this position, slide rocker arm to one side along the tube.

NOTE: To avoid damage to valves, be sure that piston head is well below top of travel before compressing valve springs.

Remove intake manifold, carburetor and coil as an assembly. Remove tappet chamber cover and gasket. Lift tappet out of bore. If all tappets are to be removed, remove hydraulic tappets and place them in their respective holes in tappet and push rod holder, Tool C-3068. This will insure installation of tappets in their original locations.

NOTE: Do not disassemble a tappet on a dirty work bench. The plunger and tappet bodies are not interchangeable. The plunger and valve must always be fitted to the original body. It is advisable to work on one tappet at a time to avoid mixing parts. Mixed parts are not usable.

d. Disassembly (Fig. 23)

Pry out plunger retainer spring clip. Clean varnish deposits from inside of tappet body above plunger cap. Invert tappet body and remove plunger cap, plunger, flat check valve, check valve spring, check valve retainer, and plunger spring. Separate plunger, check valve retainer, and check valve spring. Place all parts in their respective place in tappet holder, Tool C-3068.

e. Cleaning and Assembly

Clean all tappet parts in a solvent that will remove all varnish and carbon. Replace tappets that are unfit for further service. Assemble tappets, as shown in Figure 24.

f. Inspection

If tappet or bore in cylinder block is scored, scuffed, or shows signs of sticking, ream bore to next oversize, using Tool C-3028. If plunger shows signs of scoring or wear and valve is pitted, or if valve seat on end of plunger indicates any condition that would prevent valve from seating, install a new tappet assembly.

g. Testing

Use a clean container. Fill the container with clean kerosene. Remove cap from plunger and completely submerge tappet in an upright position. Allow tappet to fill with kerosene. Remove tappet and replace cap. Hold tappet in an upright position and insert the lower jaw of pliers, Tool C-3160, in groove of tappet body (Fig. 25). Engage jaw of pliers with top of tappet plunger. Check leakdown by compressing pliers. If plunger collapses almost instantly as pressure is applied, disassemble tappet, clean and test again. If tappet still does not operate satisfactorily after cleaning, install a new tappet.

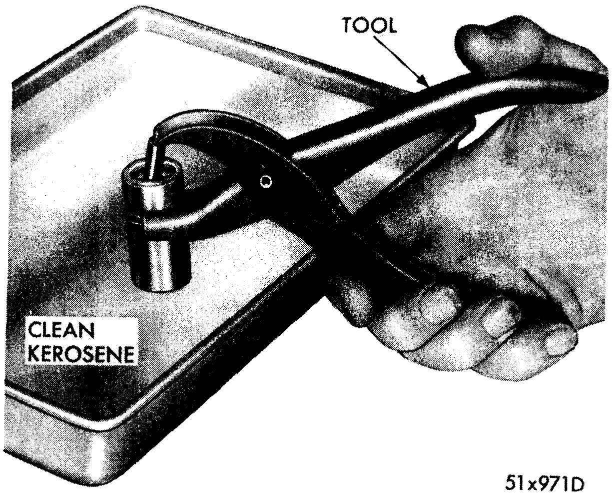

Fig. 25—Testing Hydraulic Tappet (Typical)

h. Installation

Lubricate tappets. Install tappets (Fig. 26) and push rods in their original bores. Position rocker arm so it is partially seated on valve stem. Install valve spring compressor tool and compress valve spring until rocker arm can be positioned over push rod. Remove tool and install tappet chamber cover. Install intake manifold, carburetor and coil, refill cooling system, start engine, warm up to normal operating temperature.

NOTE: To prevent damage to valve mechanism, the engine must not be run above fast idle until all of hydraulic tappets have filled with oil and become quiet.

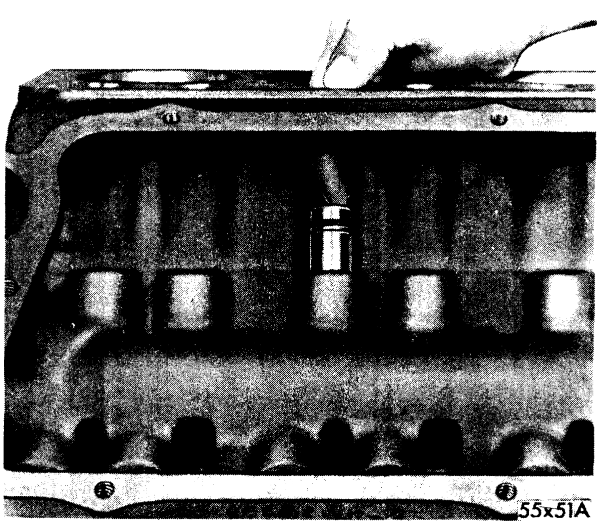

Fig. 26—Installing Tappet Assembly

16. CHECKING VALVE TIMING

Turn crankshaft until Number one intake valve is closed. Insert a .210 inch spacer between rocker arm and stem of Number one intake valve. (This can be done by prying between rocker and valve spring seat with a large screwdriver).

Install a dial indicator so that pointer contacts valve spring seat as nearly at a right angle as possible. Wait until seat stops moving. This indicates that oil has bled out of hydraulic tappet and plunger has bottomed, giving, in affect, a solid tappet. Set dial indicator on zero and turn crankshaft clockwise (normal running direction) until dial indicator shows that valve has lifted .020 inch (SpitFire) and .024 inch (FirePower). The timing on the vibration damper should now read from 5 degrees (BTDC) before top dead center to 7 degrees (ATDC) after top dead center. Before making this check, it is well to check the accuracy of the (TDC) top dead center mark on the damper by bringing Number One piston to (TDC) by means of an indicator placed in spark plug opening. After valve timing has been checked, turn crankshaft counter-clockwise until tappet is back down to valve-closed position. Remove the .210 inch spacer from between the rocker arm and valve stem.

CAUTION

Under no condition should crankshaft be turned further in clockwise direction, as spacer might cause valve spring to bottom and damage valve operating mechanism.

17. LOCATING LOW POINT OF CAMSHAFT IN CONJUNCTION WITH VALVE TAPPET FACE (CYLINDER HEAD INSTALLED)

Remove distributor cap, noting position of rotor for Number One and Number Six cylinders. Set timing mark ("DC") on vibration damper to pointer. With rotor at Number One firing position, the following tappets will be on low side of cam lobe.

2—Intake	7—Intake
2—Exhaust	8—Intake
4—Exhaust	8—Exhaust

NOTE: To remove Number One intake and exhaust tappet, rotate the crankshaft ¼ turn clockwise from above position.

With rotor at Number Six firing position, the following tappets will be on low side of cam lobe:

3—Intake	5—Intake
3—Exhaust	5—Exhaust
4—Intake	7—Exhaust

NOTE: To remove Number Six intake and exhaust tappet, rotate crankshaft ¼ turn clockwise from above position.

18. REMOVAL OF TIMING GEARS AND CHAIN

Remove radiator and water pump assembly. Remove bolt and flatwasher holding vibration damper on crankshaft. Remove two of the damper bolts, install Tool C-3033, and pull damper assembly off end of crankshaft.

Remove chain cover and gasket. Slide crankshaft oil slinger off end of crankshaft. Remove fuel pump eccentric attaching bolt, cup washer and eccentric. Remove timing chain, with crankshaft and camshaft sprockets. Remove the camshaft and crankshaft gear keys from their respective slots.

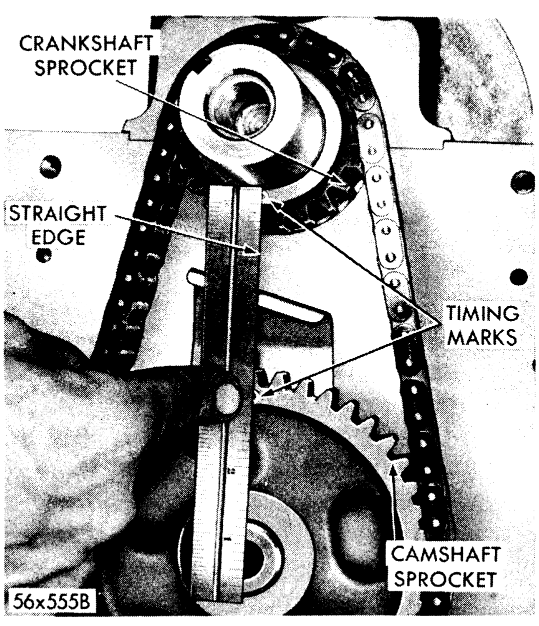

Fig. 27—Checking Alignment of Timing Marks

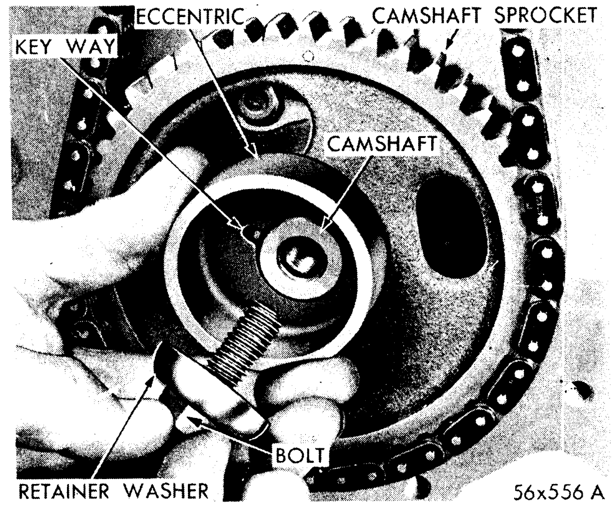

Fig. 28—Installing Fuel Pump Eccentric

19. INSTALLATION OF TIMING GEARS AND CHAIN

a. Installation

Place both camshaft sprocket and crankshaft sprocket on the bench with timing marks on exact imaginary centerline through both camshaft and crankshaft bores.

Place timing chain around both sprockets. Insert crankshaft and camshaft woodruff keys in their respective slots. Turn crankshaft and camshaft to line up with keyway locations in the sprockets.

Lift sprockets and chain (keep sprockets tight in position as described) slide both sprockets evenly over their respective shafts

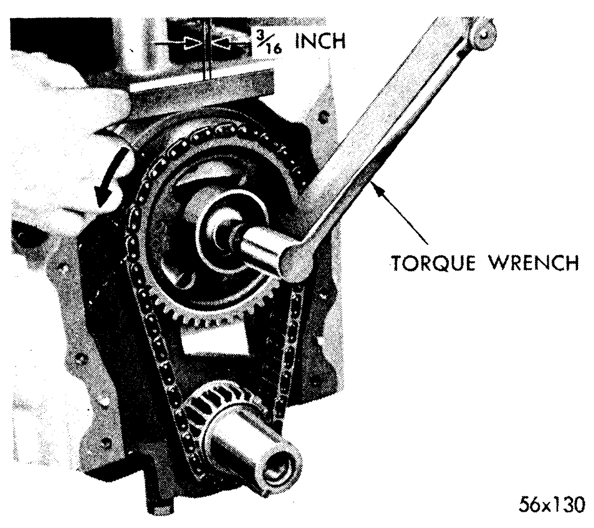

Fig. 29—Measuring Timing Chain Stretch (Typical)

(see Fig. 29), "Camshaft Installation". Use straight edge to check alignment of timing marks (Fig. 27.)

Slide fuel pump eccentric over camshaft against sprocket (Fig. 28). Be sure slot in eccentric lines up with protruding camshaft sprocket key. Install cup washer and bolt and tighten 35 foot-pounds torque.

b. Checking Timing Chain for Stretch

Place a scale next to timing chain so that any movement of chain may be measured. Place a torque wrench and socket over camshaft gear attaching bolt and apply torque in direction of crankshaft rotation to take up slack; 30 foot-pounds torque (with cylinder heads installed) and 15 foot-pounds torque (heads removed). Holding scale with dimensional reading even with edge of a chain link, apply torque in reverse direction 25 foot-pounds (with cylinder heads installed) and 15 foot-pounds (heads removed), and note the amount of chain rotation (Fig. 29). Install new timing chain, if its movement is greater than $\frac{3}{16}$ inch.

NOTE: With a torque applied to camshaft gear bolt, the crankshaft should not move. If there is any movement, however, the crankshaft should be blocked to prevent rotation.

If chain is satisfactory, slide crankshaft oil slinger over shaft and up against gear (flange away from gear.)

20. TIMING CHAIN CASE COVER OIL SEAL REPLACEMENT

a. Removing Oil Seal

Position puller screw of Tool C-3506 through

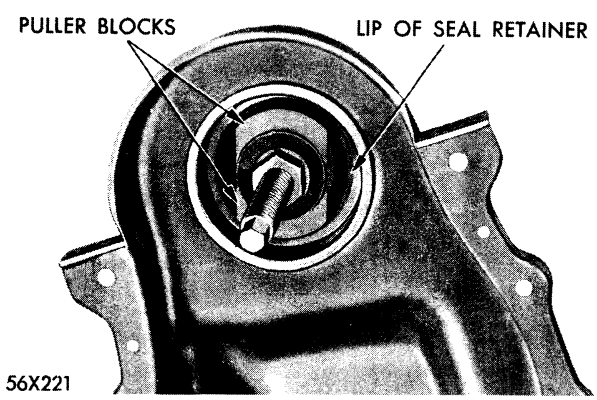

Fig. 30—Puller Blocks Expanded to Correct Pulling Position

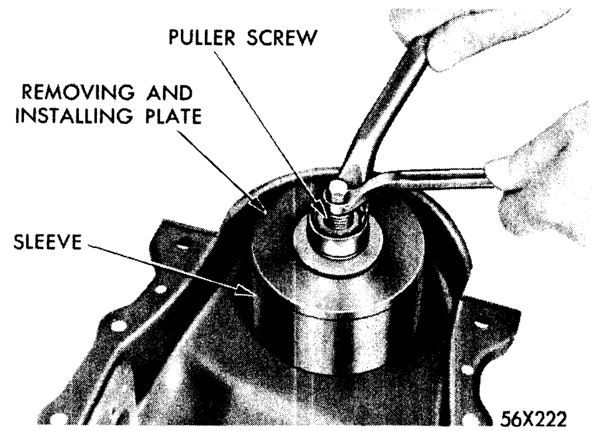

Fig. 31—Removing Oil Seal

case cover, with inside of case cover up. Position puller blocks directly opposite each other, and force angular lip between neoprene and flange of seal retainer. Place washer and nut on puller screw. Tighten nut as tight as possible by hand, forcing blocks into gap to point of distorting seal retainer lip (Fig. 30). **THIS IS IMPORTANT!** (puller is only positioned at this point.) Place sleeve over retainer and place removing and installing plate into sleeve. Place flatwasher and nut on puller screw. Hold center screw and tighten lock nut to remove seal (Fig. 31).

b. Installing Oil Seal

Insert puller screw through removing and installing plate so that the thin shoulder will be facing up.

NOTE: Always have thin shoulder up with stamped case cover, and thick shoulder up with a cast iron case cover.

Insert puller screw with plate through seal

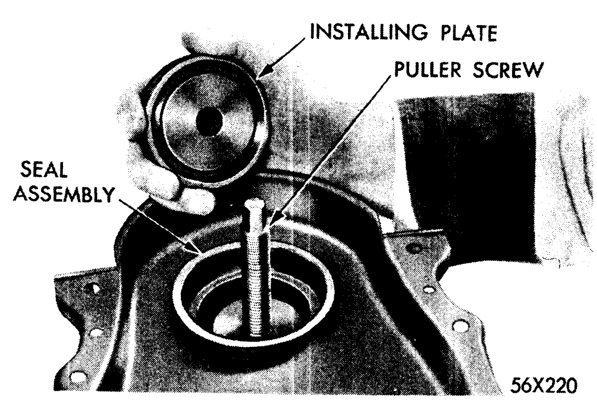

Fig. 32—Positioning Installer Plate on New Seal

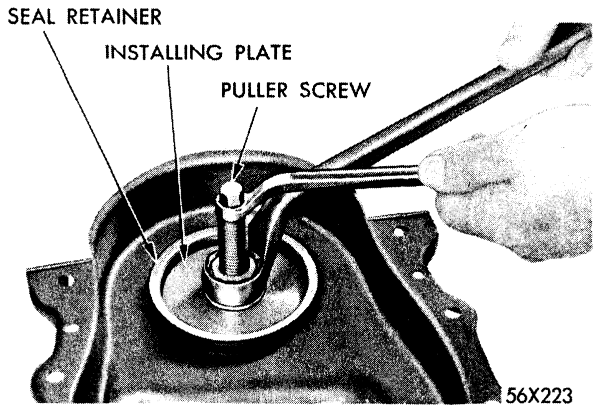

Fig. 33—Installing New Seal

opening (inside of chain case cover facing up). Place seal in cover opening, with neoprene down. Place seal installing plate into the new seal, with protective recess toward lip of seal retainer (Fig. 32). Install flatwasher and nut on puller screw, hold screw, and tighten nut (Fig. 33). Seal is properly installed when neoprene is tight against face of cover. Try to insert a .0015 feeler gauge between neoprene and cover (Fig. 34). If seal is installed properly, the feeler gauge cannot be inserted.

NOTE: It is normal to find particles of neoprene collected between the seal retainer and crankshaft oil slinger.

c. Installing Chain Case Cover

Be sure mating surfaces of chain case cover and cylinder block are clean and free from burrs. Using a new gasket, slide chain case cover over locating dowels and tighten bolts 15 foot-pounds torque.

21. INSTALLING VIBRATION DAMPER (Fig. 35)

Place damper hub key in slot in crankshaft,

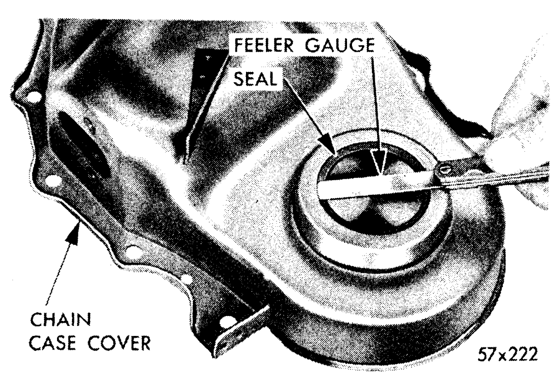

Fig. 34—Checking to Determine if Seal is Properly Seated

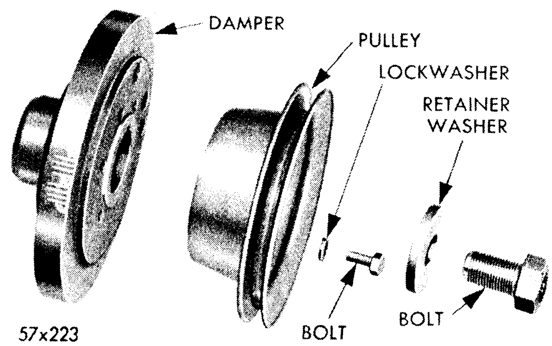

Fig. 35—Vibration Damper Assembly (Disassembled View)

and slide hub on crankshaft. Place installing tool (part of Puller set Tool C-3033) in position and press damper hub on crankshaft. Slide pul-

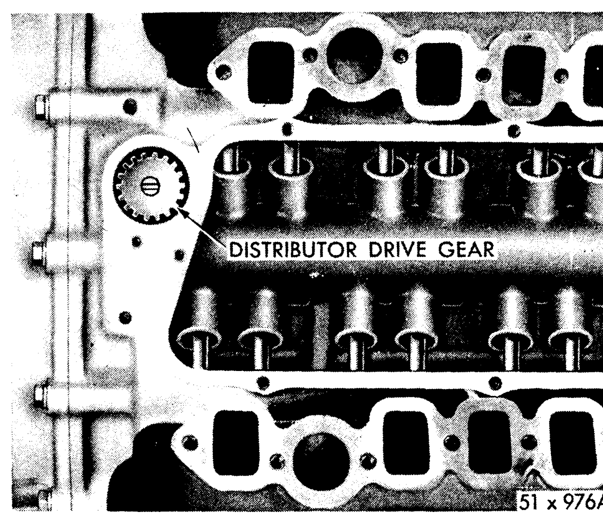

Fig. 36—Distributor Drive Gear Installation

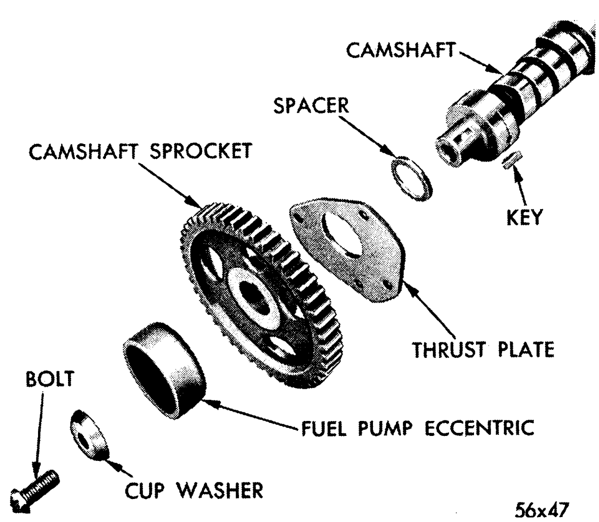

Fig. 37—Camshaft Drive Parts (Disassembled View)

ley over shaft and secure with bolts and lockwashers. Tighten bolts 15 foot-pounds torque. Install damper hub retainer washer and bolt. Tighten to 135 foot-pounds torque.

22. CAMSHAFT REMOVAL

With intake manifold, tappet cover, push rods, tappets and timing gears removed, remove distributor. Lift out distributor drive gear and stub shaft, (Fig. 36). Remove camshaft thrust plate attaching bolts and oil trough, (Fig. 37). Withdraw camshaft and spacer, **being careful not to damage the cam bearings with the cam lobes.**

23. REMOVAL AND INSTALLATION OF DISTRIBUTOR DRIVE SHAFT BUSHING (Camshaft Removed)

a. Removal

Insert Tool C-3052 into old bushing and thread down until a tight fit is obtained, (Fig. 38). Hold puller screw and tighten puller nut until bushing is removed.

b. Installation

Slide new bushing over burnishing end of Tool C-3053 and insert tool and bushing into bore. Drive bushing and tool into position, using a soft hammer. As the burnisher is pulled through bushing by tightening puller nut, the bushing is wedged tight in block and burnished to correct size. **DO NOT REAM THIS BUSHING.**

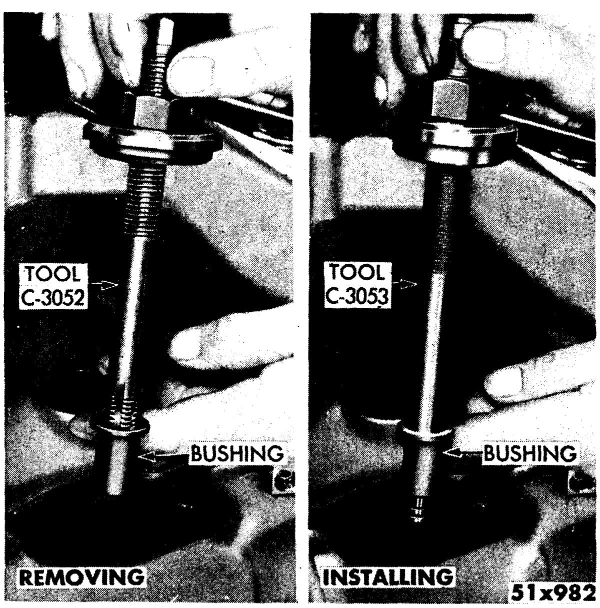

Fig. 38—Removing and Installing the Distributor Drive Shaft Bushing

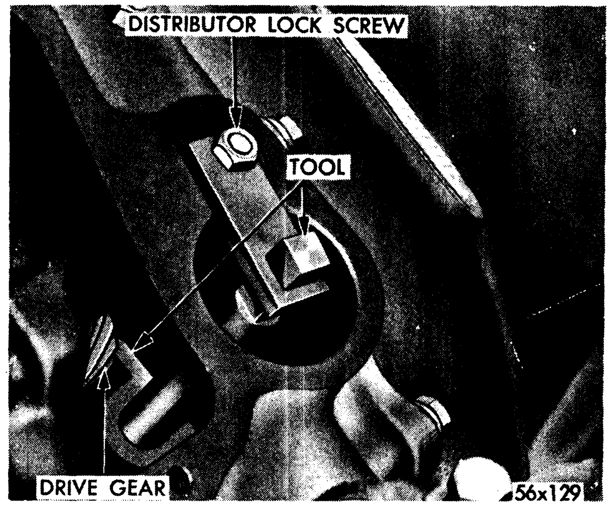

Fig. 39—Camshaft Holding Tool C-3509

24. CAMSHAFT INSTALLATION

Install Tool C-3509 in place of distributor drive gear and stub shaft (Fig. 39). Hold tool in position with distributor lock plate screw. This tool will restrict the camshaft from being pushed in too far and prevent knocking out the Welch plug, and **should remain installed until camshaft and crankshaft sprockets and timing chain have been installed.** Lubricate camshaft lobes and camshaft bearing journals and install camshaft **being careful not to damage cam bearings with the cam lobes.** Install thrust plate spacer (chamfered side toward camshaft fillet). Install thrust plate and oil trough; tighten screws 15 foot-pounds torque.

Check difference in thickness between spacer and thrust plate. The spacer should be thicker than thrust plate to extent that camshaft must have an end play of .002 to .006 inch.

NOTE: Whenever an engine has been rebuilt and a new camshaft and or new tappets have been installed, one quart of MOPAR Oil Additive should be added to the engine oil to aid break in. The oil mixture should be left in the engine for a minimum of 500 miles. However, it is not necessary to drain the mixture before normal oil change is required, nor is it necessary to use the oil additive at subsequent oil changes.

25. DISTRIBUTOR (BASIC) TIMING

Before installing the distributor drive shaft and gear, time engine as follows: Rotate crankshaft until Number One cylinder is at top dead center on Firing Stroke (check with Tool C-3075). When in this position, the pointer on chain case cover should be over ("DC") on vibration damper. Position oil pump shaft so that it lines up with slot in drive gear. Coat shaft of drive gear with engine oil. Install so that, after gear spirals into place, it will index with oil pump shaft, and slot in top of drive gear will be parallel with centerline of crankshaft (Fig. 36).

26. INSTALLATION OF DISTRIBUTOR

Hold distributor over mounting pad on cylinder block with vacuum chamber pointing toward right hand cylinder bank. Turn rotor until it points forward and to approximate location of Number One tower in distributor cap. Turn rotor counter-clockwise until breaker contacts are just separating. Place distributor oil seal ring in position. Lower distributor and engage shaft in slot of distributor drive shaft gear while holding rotor in position.

27. REMOVAL AND INSTALLATION OF CAMSHAFT BEARINGS (Engine Removed from Car)

a. Removal

With engine completely disassembled, drive out rear cam bearing Welch plug. Install proper size adapters and horse shoe washers (part of Tool C-3132) at back of each bearing shell to be removed and drive out bearing shells.

b. Installation

Install new camshaft bearings with Tool C-3132 by sliding new camshaft bearing shell over proper size adapter. Position bearing in tool (Fig. 40). Install horse shoe lock and by reversing removal procedure, carefully drive bearing shell into place. Install remaining shells in like manner. The oil holes in camshaft bearings and cylinder block must be in exact alignment to insure proper lubrication. (Fig. 40). Camshaft bearing index can be checked after installation by inserting a pencil flashlight in bearing shell. The complete circumference of camshaft bearing hole should be visible by looking through main bearing drilled oil passage. Another oil hole in cam bearings should be visible by looking down the left bank oil hole above and between No. 1 and 3 cylinders to

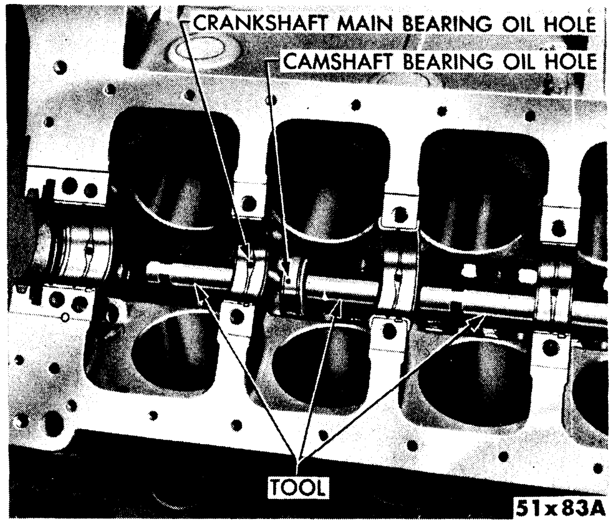

Fig. 40—Installing Camshaft Bearing Shells Using Tool C-3034

No. 2 cam bearing, and on the right bank above and between No. 6 and 8 cylinders to No. 4 cam bearing. If camshaft bearing shell oil holes are not in exact alignment, remove and reinstall. Use Tool C-897 to install a new Welch plug at rear of camshaft. Be sure this plug does not leak.

28. CYLINDER BLOCK

Clean cylinder block thoroughly, check all core hole plugs for evidence of leaking. If new core hole plugs are installed; coat edges of plug and core hole with a suitable sealer and drive plugs in place with driver, Tool C-897. Examine block for minute cracks or fractures. Remove top ridge of cylinder bores with a reliable ridge reamer before removing pistons from cylinder block. **Be sure to keep tops of pistons covered during this operation.**

NOTE: Pistons and connecting rods must be removed from the top of cylinder block. When removing piston and connecting rod assemblies from engine, rotate crankshaft so each connecting rod is centered in cylinder bore.

Remove connecting rod cap and bearing shells. Install Tool C-3221 on one connecting rod bolt and protector over the other bolts and push each piston and rod assembly out of cylinder bore. After removal, install bearing cap to mating rod.

a. Checking Cylinder Bores

The cylinder bores should be checked for out-of-round and taper with Tool CM-119. If cylinder bores show more than .005 inch out-of-round or a taper of more than .010 inch, the cylinder block should be rebored and new pistons and rings fitted.

b. Honing Cylinder Bores

To remove light scoring, scuffing, or scratches from cylinder walls, use honing Tool C-823. **The crankshaft, bearings and internal parts should be protected during honing and boring operations.** Usually one or two "passes" with a hone will clean up a bore and still maintain required limits. If cylinder bores are found to be satisfactory in respect to taper and out-of-round and new rings are to be installed, use cylinder surfacing hone Tool C-3501 with 280 grit stones for deglazing bores. This will facilitate in the break-in of new rings.

CAUTION

Be sure all abrasives are removed from engine parts after honing. It is recommended that a solution of soap and water be used with a brush and then thoroughly dried. If this is impossible use SAE No. 10 oil and CLEAN rags. When the bore can be wiped with a clean white rag and be withdrawn clean, the bore is clean.

c. Cylinder Walls

Cylinder walls which are badly scored, scuffed, scratched, or worn beyond specified limits should be rebored. Whatever type of boring equipment is used, boring operation should be closely co-ordinated with the fitting of pistons and rings, in order that specifications may be maintained.

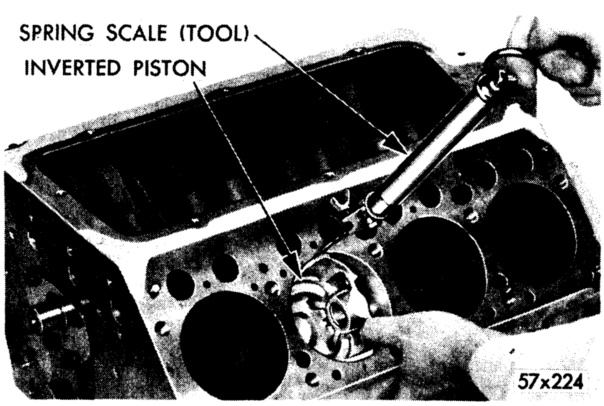

Fig. 41—Fitting Piston to Cylinder Bore (FirePower) (Typical of SpitFire)

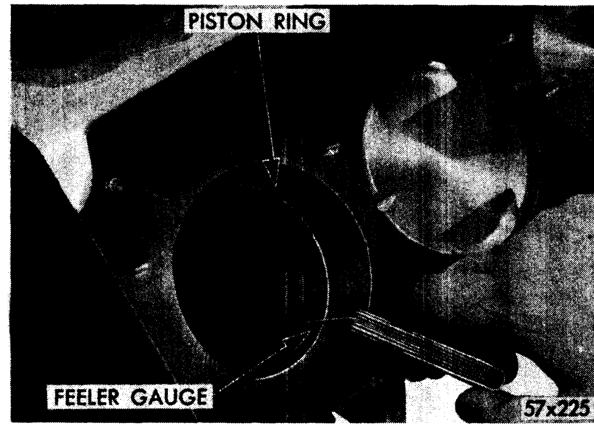

Fig. 42—Checking Ring Gap in Cylinder Bore (FirePower) (Typical of SpitFire)

d. Fitting Pistons

The piston and cylinder wall must be clean and dry. Coat the bore very lightly with SAE 10 W Engine Oil. The recommended clearance between the thrust face of piston and cylinder wall is .005 to .0015 inch. Check clearance with a .002 inch feeler stock ½ inch wide on spring scale Tool C-690, by inserting piston in bore, upside down, with feeler stock between thrust face of piston and cylinder wall. Hold piston and draw the feeler stock straight out with spring scale (Fig. 41). The amount of pull required to withdraw the feeler stock should be 8 to 12 pounds.

NOTE: Piston fitting should be done at normal room temperature, 70° F.

All service pistons include piston pins and retaining rings and are available in standard

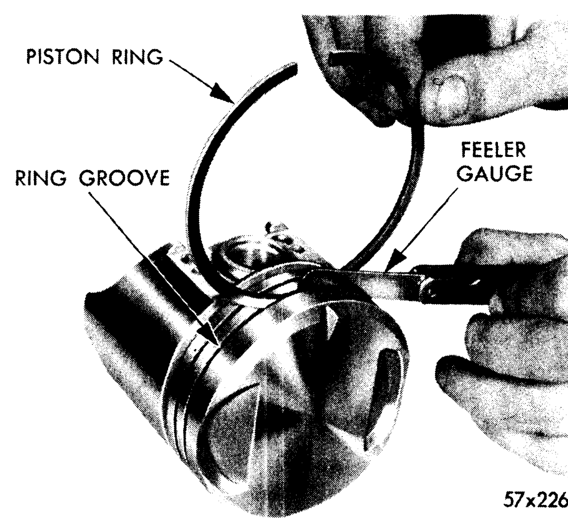

Fig. 43—Checking Piston Ring Side Clearance

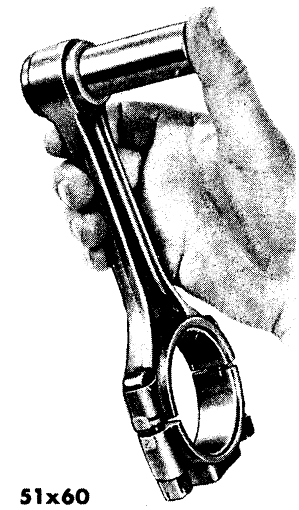

Fig. 44—Fitting Piston Pins in Connecting Rod

and the following oversizes, .005, .020, .040 and .060 inch, (C-75 only).

e. Fitting Rings

Measure piston ring gap about two (2) inches from bottom of cylinder bore in which it is to be fitted. (An inverted piston can be used to push the rings down to position.) This will insure positioning rings exactly square with cylinder wall before measuring. Insert feeler stock in gap (Fig. 42). The ring gap should be between .010 to .020 inch. This measurement is the same for all rings. Measure clearance between piston ring and ring groove (Fig. 43). The clearance should be .0015 to .0030 inch for top compression ring, .001 to .0025 inch for intermediate ring, and .001 to .003 for oil control ring. Starting with oil ring expander, place expander ring in lower ring groove and install oil control ring. Install compression rings, in top and middle grooves. Use ring installer, Tool C-3418.

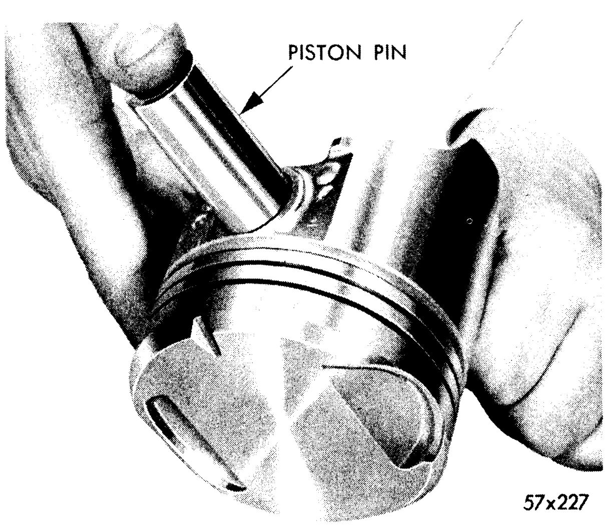

Fig. 45—Fitting Piston Pin in Piston (Typical)

NOTE: Be sure the mark "Top" on each compression ring is to the top of piston when ring is installed.

f. Fitting Pins

The piston pin should be a tight thumb press fit in connecting rod (Fig. 44) and in piston (Fig. 45) at normal room temperature, 70°F. If proper fit cannot be obtained with standard pins, ream piston and connecting rod, and install oversize piston pin. Piston pins are supplied in standard and the following oversizes: .003 and .008 inch. Assemble pistons to rods on right cylinder bank (2, 4, 6, and 8), with the indent on piston head opposite to the larger chamfer on the large end of connecting rod. Assemble pistons to rods on left cylinder bank (1, 3, 5, and 7) with the indent on the piston head on the same side as the larger chamfer on large end of connecting rod.

29. CONNECTING RODS

IMPORTANT

A Maltese Cross stamped on the engine numbering pad (Fig. 46) indicates that engine is equipped with a crankshaft which has one or more connecting rods and main bearing journals finished .001 inch undersize. The position

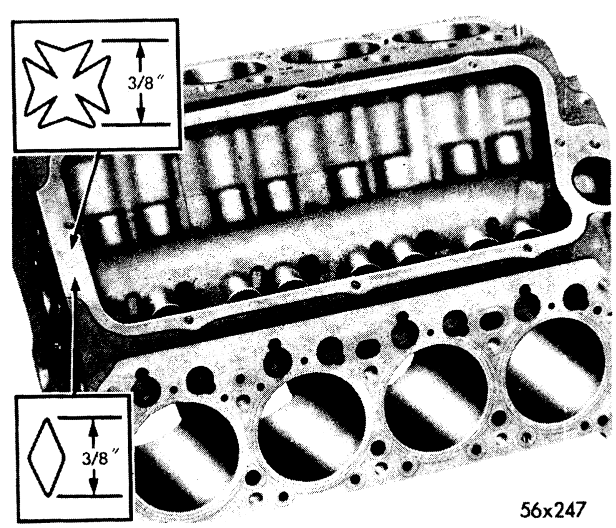

Fig. 46—External Identification (Parts other than standard size)

of the undersize journal or journals will be stamped on machined surface of Number 3 counter-weight (Fig. 47). Connecting rod journals will be identified by letter "R" and main bearing journals by the letter "M". Thus, "M-1" indicates that Number 1 main bearing journal is .001 undersize. Also, a diamond-shaped marking stamped on engine numbering pad indicates that All tappet bodies are .008 inch oversize. (See Fig. 46).

30. INSTALLING CONNECTING ROD BEARINGS

NOTE: Fit all rods of one bank until completed. Do not alternate from one bank to another, because when rods are assembled to pistons correctly, they are not interchangeable from one bank to another.

Each bearing cap has a small "V" groove across the parting face. When installing the lower bearing shell, make certain that "V" groove in shell is in line with "V" groove in cap. This allows lubrication of the cylinder wall. The bearing shells should always be installed so that small formed tang fits into machined grooves of rods. The side play should be from .006 to .014 inch (two rods).

Limits of taper or out-of-round on any crankshaft journals should be held to .001 inch. Bearings are available in .001, .002, .003, .010 and .012 undersize.

NOTE: Install bearings in pairs. Do not use a new bearing half with an old bearing half. Do not file rods or bearings caps.

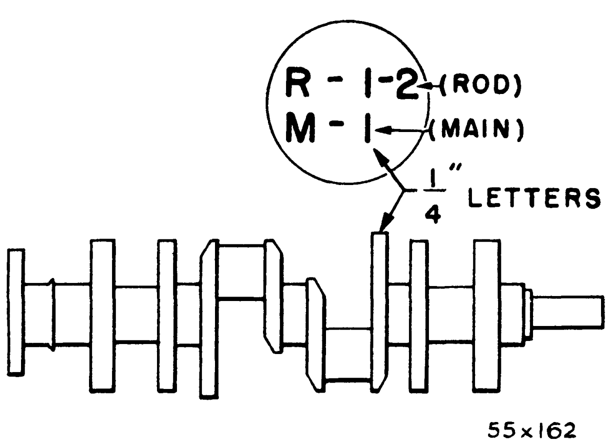

Fig. 47—Internal Identification (Parts other than standard size)

31. CHECKING CONNECTING ROD BEARING CLEARANCE (PLASTIGAGE METHOD)

The measurement of connecting rod bearing clearance can be done with the use of Plastigage with the engine in the chassis. After removing the connecting rod cap, wipe off oil from the journal and inserts. Place the Plastigage on bearing, parallel with crankshaft. Reinstall cap and tighten attaching nuts alternately to specified torque.

Remove cap and measure the width of the compressed material with the graduated scale to determine bearing clearance. Allowable clearance is from .0005 to .0015 inches. If taper of compressed material is evident, measure with the graduated scale. If difference exceeds .001 inch, journal should be checked with micrometers.

32. INSTALLING PISTON AND CONNECTING ROD ASSEMBLY IN CYLINDER BLOCK

Before installing pistons, rods, and rod assemblies in bore, be sure that compression ring gaps are diametrically opposite one another and not in line with oil ring gap. The oil ring expander gap should be toward the outside "V" of engine. The oil ring gap should be turned toward the inside of the "V" of engine. Immerse piston head and rings in clean engine oil, slide ring compressor, Tool C-385, over piston, and tighten with special wrench (part of Tool C-385). Be sure position of rings does not change during this operation. Screw connecting rod bolt protector (part of Tool C-3221) on one rod bolt, and insert rod and piston into cylinder bore. Attach puller part of Tool C-3221 on the other bolt, and guide the rod over crankshaft journal. Tap piston down in cylinder bore, using handle of a hammer. At the same time, guide connecting rod into position on crankshaft journal. The **notch or groove** on top of piston **must** be pointing toward front of engine and the larger chamfer of connecting rod bore must be installed toward crankshaft journal fillet. Install rod caps, tighten nuts to 45 foot-pounds torque.

33. CRANKSHAFT

The crankshaft journals should be checked for excessive wear, taper and scoring. Journal grinding should not exceed .012 inch under the standard journal diameter. **DO NOT** grind thrust faces of No. 3 main bearing. **DO NOT** nick crankpin or main bearing fillets. After regrinding remove rough edges from crankshaft oil holes and clean out all oil passages.

34. CRANKSHAFT BEARINGS

The halves of Number 1, 2 and 4 bearings are interchangeable (the bearing caps are not interchangeable) and should be marked at removal to insure correct reassembly. Number 3 bearing, which controls the crankshaft end thrust, is not interchangeable with the others. The upper and lower halves, however, of Number 3 bearing are interchangeable. Number 5 bearing halves are not interchangeable. Bearing shells are available in standard and the following undersizes: .001, .002, .003, .010 and .012 inch. Never install an undersize bearing shell that will reduce the clearance below specifications.

35. REMOVAL AND INSTALLATION OF MAIN BEARINGS

a. Removal

Remove oil pan and mark bearing caps before removal. Remove bearing caps one at a time. Remove upper half of bearing by inserting Tool C-3059 (Fig. 48) in oil hole of crankshaft. Slowly rotate crankshaft clockwise, forcing out upper half of bearing shell.

b. Checking Main Bearing Clearance

PLASTIGAGE METHOD. Use same technique as described in Paragraph 31.

CAUTION

If bearings are measured with the engine in the chassis, the crankshaft must be supported in order to take up clearance between the upper bearing insert and crankshaft journal. This can be done by snugging bearing caps of adjacent bearings with .005 to .015 inch cardboard between lower bearing shell and journal. Be sure to remove cardboard. Use extreme caution when this is done to avoid unnecessary strain on the crankshaft or bearings or false reading may be obtained. Do not rotate crankshaft while plastigage is installed.

It is permissible to use a .001 inch undersize bearing with a standard bearing or a .002 inch

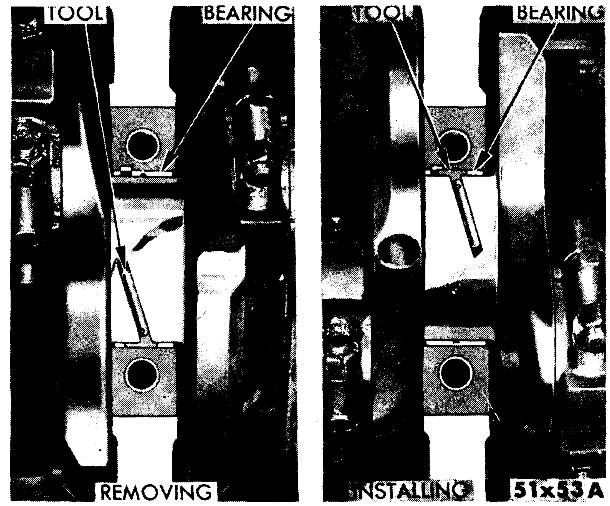

Fig. 48—Removing and Installing Main Bearing Upper Shell

bearing. Always use the smaller diameter bearing half as the upper housing half. Never use a new bearing with used bearing and never use an upper bearing half more than .001 inch smaller than the lower bearing half.

c. Installation

NOTE: When installing a new upper bearing shell, slightly chamfer the sharp edge from plain side.

Start bearing in place, and insert Tool C-3059 in oil hole of crankshaft (Fig. 48). Slowly rotate the crankshaft counter-clockwise, sliding bearing into position.

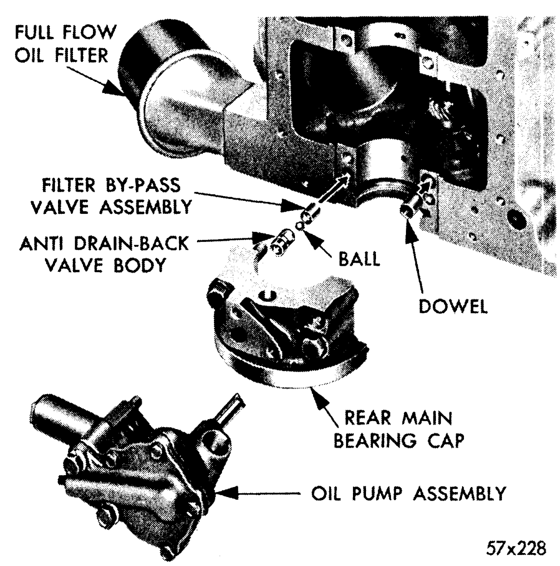

Fig. 49—Installing By-Pass Valve — Rear Main Bearing Cap

After all bearings have been fitted, tighten Number 3 (center) main bearing first, and work alternately to both ends. Tighten all caps to 85 foot-pounds torque.

NOTE: Before installing rear main bearing cap, position hollow dowel in cylinder block bore. See Fig. 49.

Crankshaft end play should be .002 to .007 inch.

36. REMOVAL AND INSTALLATION OF OIL PAN

a. Removal

Drain oil and remove dip stick. Disconnect crossover and "Y" pipe at exhaust manifolds and at clamp to exhaust extension so that crossover and "Y" pipe may be moved out of way. Remove the converter dust shield. **Be sure the rest of exhaust system is sufficiently supported.**

Loosen distributor cap to prevent interference with the heater housing with engine raised. Remove starter. Remove nuts from front engine mounts and hoist engine ¾ inch. Rotate the crankshaft until the front counterweight is up (this is done when the timing mark is 180° from the timing pointer). Disconnect steering linkage at idler arm support bracket, and allow linkage to settle away from bottom of pan. Remove bolts that hold pan to cylinder block and remove pan.

b. Installation

Clean pan thoroughly and install new seals and gaskets. **End seals should be bottomed in their grooves and retained by crimping.** Ends of seals should extend approximately 1/32 inch higher than the attaching face of oil pan to insure proper sealing. Tighten bolts evenly to 15 foot-pounds torque. Install exhaust pipes and connect steering linkage. Refill crankcase. See "Lubrication", Section XV.

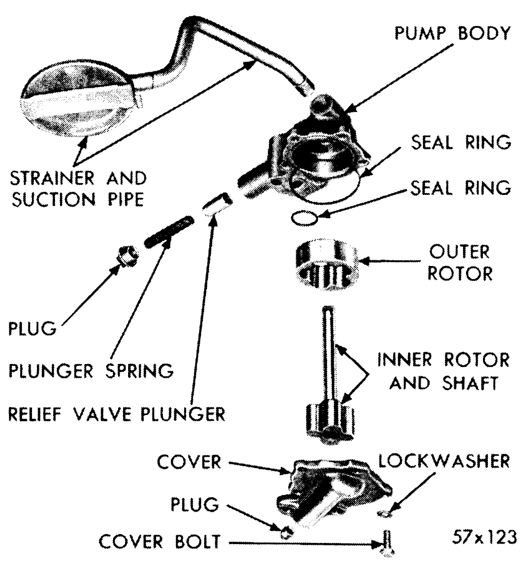

Fig. 50—Oil Pump (Disassembled View)

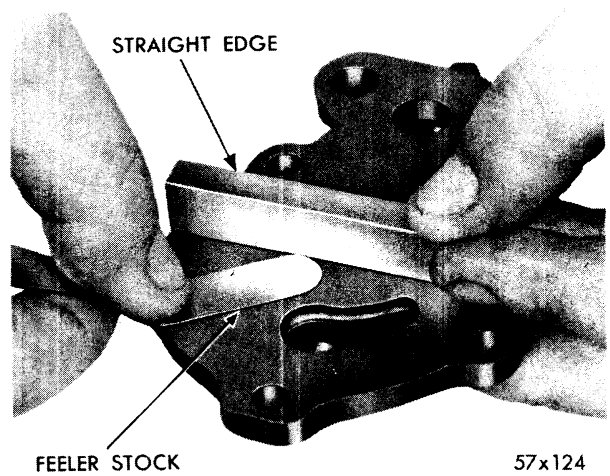

Fig. 51—Checking Oil Pump Cover

37. OIL PUMP

a. Removal

Remove oil pan, oil pump attaching bolts and remove pump by pulling straight down.

b. Disassembly (Fig. 50)

Remove oil pump cover and oil seal ring. Remove pump rotor and shaft, and lift out pump rotor body. Remove oil pressure relief valve plug, and lift out spring and plunger.

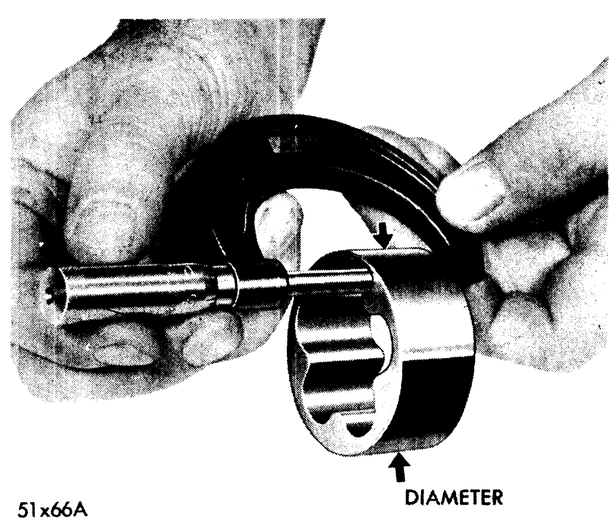

Fig. 52—Measuring Thickness of Outer Rotor

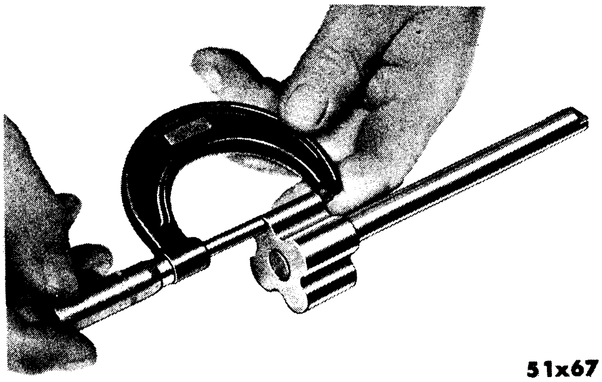

Fig. 53—Measuring Thickness of Pump Rotor

c. Inspection and Repair

Wash all parts thoroughly. The mating face of oil pump cover should be smooth. Replace cover if it is scratched or grooved.

Lay a straightedge across cover surface (Fig. 51). If a .0015 inch feeler gauge can be inserted between cover and straightedge, the cover should be replaced. If outer rotor measures less than .998 inch (Fig. 52) and diameter less than 2.244 inches, replace outer rotor. If pump rotor measures less than .998 inch (Fig. 53) a new pump rotor should be installed. Slide outer rotor and rotor into pump body and place a straightedge across face (between bolt holes), as shown in Figure 54. If a feeler gauge of more than .004 inch can be inserted between rotors and straightedge, replace pump body. Remove pump rotor and shaft, leaving outer rotor in pump cavity. Press rotor body to one side with fingers and measure clearance between outer rotor and pump body, (Fig. 55). If measurement is more than .012 inch, replace oil pump body. If clearance between pump rotor and outer rotor (Fig. 56) is more than .010 inch, replace pump rotor and outer rotor. Check

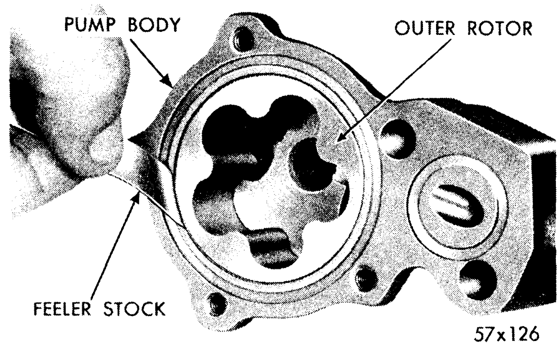

Fig. 55—Measuring Clearance between Outer Rotor and Oil Pump Body

oil pump relief valve plunger for scoring and for free operation in its bore. If plunger is scored, replace plunger. The spring should conform to Specifications on chart. If, for any reason, the spring has to be replaced, the same color spring should be used. An exception is where oil pressure is either above or below specifications. When assembling oil pump, be sure to use a new oil seal ring between cover and body. Tighten cover bolts to 10 foot-pounds torque. Prime the oil pump.

RELIEF VALVE SPRING CHART

Color	Free Height	Under Load Height	Tension Pounds
Gray (Lt.) . . .	3 $\frac{1}{32}$ inch	2$\frac{1}{16}$ inch	16.1 to 17.1
Red (Std.) . . .	2$\frac{27}{32}$ inch	2$\frac{1}{16}$ inch	19.5 to 20.5
Brown (Hvy.)	2$\frac{31}{32}$ inch	2$\frac{1}{16}$ inch	22.0 to 23.9

d. Installation

Make sure rear main bearing cap hollow dowel is in position in cylinder block, as shown in

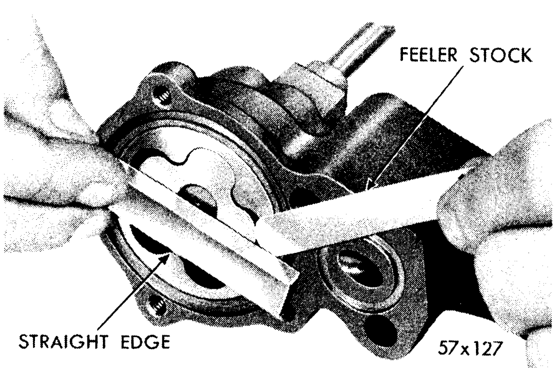

Fig. 54—Measuring Clearance over Oil Pump Rotor

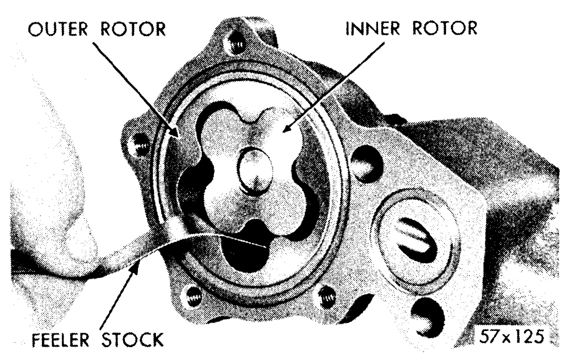

Fig. 56—Measuring Clearance Between Pump Rotors

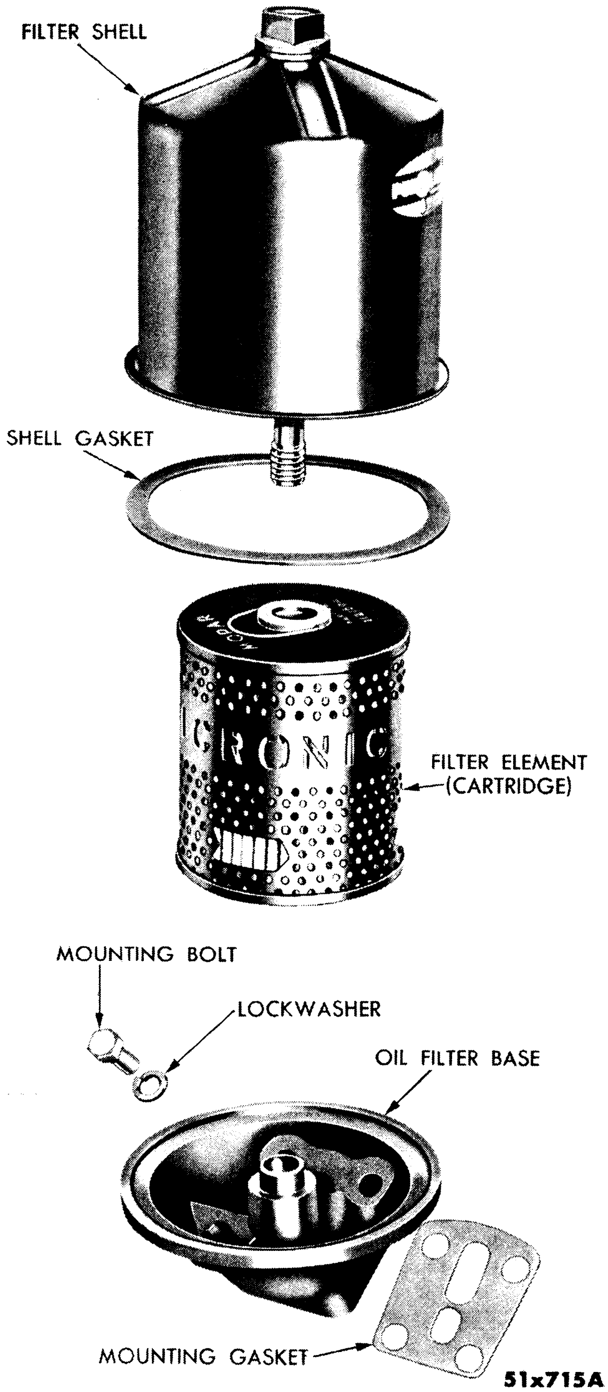

Fig. 57—Full Flow Type Oil Filter (Disassembled View)

Figure 49. Align tank on oil pump shaft with slot on distributor lower drive shaft. Install oil pump to rear main bearing cap. Tighten mounting bolts to 33 foot-pounds torque.

After oil pump has been installed, check alignment of strainer. The bottom of strainer must be on a horizontal plane with machined surface of cylinder block. The foot on the strainer should touch bottom of oil pan.

38. REMOVAL AND INSTALLATION OF OIL FILTER

Remove the shell retaining center bolt and lift off outer shell and gasket. (Fig. 57). Remove filter element. Remove filter base attaching bolts and filter base if necessary.

Use new gaskets, reinstall filter base and new filter element. Install outer shell and tighten center bolt securely.

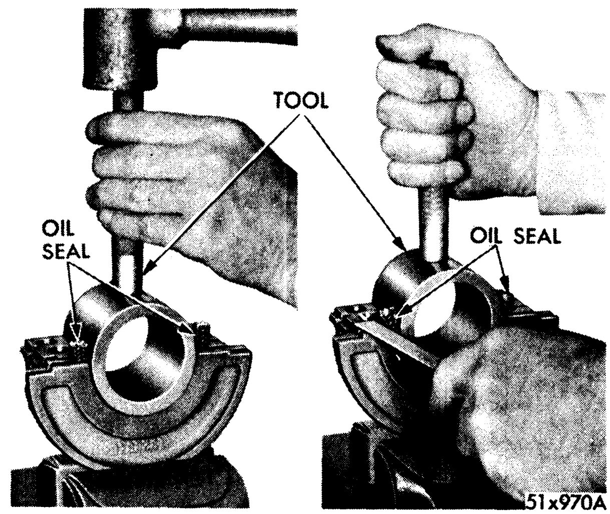

Fig. 58—Installing Rear Main Bearing Oil Seal

NOTE: FirePower Engine—Remove air cleaner. Loosen oil filter. Raise car. Remove filter from below car.

39. REPLACEMENT OF REAR MAIN BEARING OIL SEAL (Crankshaft removed)

Remove old oil seals from cylinder block and bearing cap. Install a new rear main bearing oil seal in block so that both ends protrude. Tap seal down into position using Tool C-3574 on the FirePower Engines and Tool C-3020 on the SpitFire Engines until tool is seated in bearing bore. Hold tool in this position, and cut off portion of seal that extends above block on both sides.

Install a new seal in bearing cap (bearing shell removed) so that the ends protrude. (Fig. 58.) Tap seal down into position with Tool C-3511 (left-hand view), until tool is seated. Trim off portion of seal that protrudes above cap (right-hand view). Install two cap side seals in grooves in cap. Care should be used when installing these seals as they are **NOT** inter-

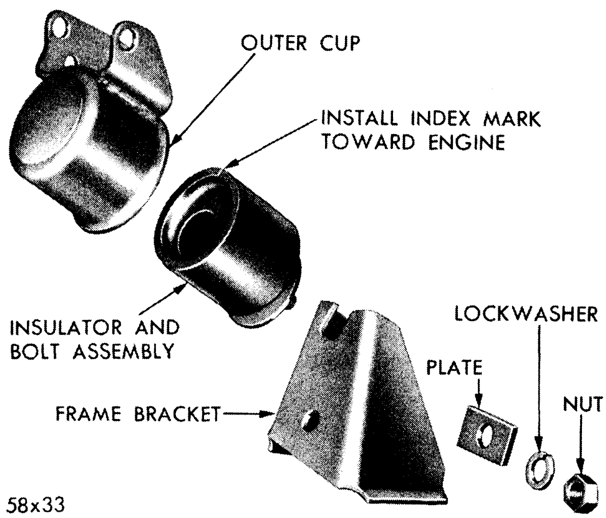

Fig. 59—Front Engine Mounting (Disassembled View)

changeable from left to right or from (Spitfire) to (Firepower) engines. The seal with the longer body should be installed on the oil filter side of the block. Seals incorrectly installed will cause an oil leak.

40. REMOVAL OF FRONT ENGINE MOUNTINGS (Fig. 59)

Remove nut, washer and lockwasher from underside of frame bracket. Place jack under engine toward front of bottom portion of **oil pan.** Remove nuts, bolts from each mount.

SERVICE DIAGNOSIS

41. ENGINE WILL NOT START

Possible Causes:

a. Weak battery.

b. Overheated engine.

c. Low compression.

d. Corroded or loose battery terminal connections.

e. Weak coil.

f. Broken or loose ignition wires.

g. Dirty or corroded distributor contact points.

h. Defective ignition switch.

i. Moisture on ignition wires, caps, or plugs.

j. Cracked distributor cap.

k. Fouled spark plugs

l. Stuck valves.

m. Improper spark plug gap.

n. Improper timing (ignition).

o. Damaged distributor rotor.

p. Dirt or water in gas line or carburetor.

q. Ice in carburetor or fuel line.

r. Carburetor flooded.

s. Fuel level in carburetor bowl not correct.

t. Insufficient supply of fuel.

u. Defective fuel pump.

v. Vapor lock.

w. Sticking choke.

x. Defective starting motor or solenoid.

y. Defective neutral switch.

42. ENGINE STALLS

Possible Causes:

a. Idling speed too low.

b. Needle valve and seat in carburetor stuck.

c. Idle mixture too lean or too rich.

d. Carburetor flooding.

e. Dirt or water in gas line or carburetor.

f. Frozen gas line.

g. Incorrect carburetor float level.

h. Leak in intake manifold, distributor vacuum line or carburetor mounting gaskets.

i. Worn accelerator pump. (Stall occurs on acceleration.)

j. Improper choke adjustment.

k. Choke sticking.

l. Carburetor icing (cold, wet weather).

m. Excessive pressures (air conditioning).

n. Loose ignition wires.

p. Weak battery.

q. Loose ignition switch connection.

r. Spark plugs dirty, damp, or gaps incorrectly set.

s. Distributor advance not operating.

t. Defective coil or condenser.

u. Distributor points dirty, burned, or incorrectly spaced.

v. Exhaust system restricted.

w. Trailing edge of rotor worn.

x. Leaks in ignition wiring.

y. Incorrect valve tappet clearance. (C-300)

z. Burned valves.

aa. Low compression.

bb. Engine overheating.

cc. Use of winter fuels in hot weather.

43. ENGINE HAS NO POWER

Possible Causes:

a. Torque converter stator assembled in reverse.

b. Incorrect ignition timing.

c. Weak coil or condenser.

d. Stiff accelerator linkage.

e. Trailing edge of rotor worn.

f. Defective mechanical or vacuum advance (distributor).

g. Hydraulic tappet pump up (high speed).

h. Excessive play in distributor shaft.

i. Weak spring in contact points.

j. Distributor cam worn.

k. Spark plugs dirty or gap incorrectly set.

l. Insufficient point dwell.

m. Fouled spark plugs.

n. Low grade fuel.

o. Weak valve springs.

p. Carburetor in poor condition.

q. Valves sticking when hot.

r. Dirt or water in gas line or carburetor.

s. Ice in gas line or carburetor.

t. Improper carburetor float level.

u. Worn camshaft lobes.

v. Defective fuel pump.

w. Pistons or pins fit tight.

x. Valve timing incorrect.

y. Too rich or lean fuel mixture.

z. Incorrect valve tappet clearance (C-300).

aa. Blown cylinder head gasket.

bb. Low compression.

cc. Flow control valve not operating (Power Steering).

dd. Burned, warped, or pitted valves.

ee. Spark plug breakdown under load.

ff. Plugged, restricted, or damaged muffler or tail pipe.

gg. Brakes dragging.

hh. Tight wheel bearings.

ii. Clutch slipping. (If so equipped.)

jj. Engine overheating.

kk. Detonation.

ll. Stuck transmission regulator valve.

mm. Improper ignition or battery ground.

44. ENGINE "LOPES" OR MISSES (AT IDLE)

Possible Causes:

a. Air leak between intake manifold and heads due to retaining bolts bottoming or damaged gasket.

b. Incorrect carburetor idle adjustment.

c. Dirt or water in gas line or carburetor.

d. Dirty jets or plugged passages in carburetor.

e. Incorrect valve tappet clearance. (C-300).

f. Burned, warped, or pitted valves.

g. Incorrect ignition timing.

h. Leaks in ignition wiring.

i. Blown head gasket.

j. Air leak at carburetor mounting gasket.

k. Worn lobes on the camshaft.

l. Moisture on ignition wires, cap, or plugs.

m. Worn timing chain.

n. Defective spark advance mechanism.

o. Sticking valves.

p. Excessive play in distributor shaft.

q. Distributor cam worn.

r. Inoperative choke.

s. Spark plugs damp, dirty, or the gaps set too close.

t. Overheated engine.

u. Weak battery.

v. Uneven compression.

w. Low grade of fuel. (Winter fuel used in summer.)

x. Flooding carburetor.

y. Carburetor icing (cold, damp weather).

45. ENGINE MISSES WHILE IDLING

Possible Causes:

a. Spark plugs dirty, damp, or gap incorrectly set.

b. Broken or loose ignition wires.

c. Burned or pitted contact points, or points set with insufficient gap.

d. Coil or condenser defective.

e. Weak battery.

f. Distributor cap cracked.

g. Trailing edge of rotor worn.

h. Moisture on ignition wires, cap, or plugs.

i. Excessive play in distributor shaft.

j. Distributor shaft cam worn.

k. Burned, warped, or pitted valves.

l. Incorrect valve tappet clearance. (C-300.)

m. Incorrect carburetor idle adjustment.

n. Improper carburetor float level.

o. Low compression.

46. ENGINE MISSES AT HIGH SPEED

Possible Causes:

a. Dirt or water in gas line or carburetor.

b. Dirty jets in carburetor, especially the economizer jet.

c. Weak coil or condenser.

d. Incorrect ignition timing.

e. Distributor points dirty or incorrectly spaced.

f. Trailing edge of rotor worn.

g. Loose ignition wiring.

h. Excessive play in distributor shaft.

i. Spark plugs fouled, damp, or dirty, or the gaps set too wide.

j. Insufficient point dwell.

k. Insufficient spring tension on points.

l. Normal hydraulic tappet pump up.

m. Worn camshaft lobes.

n. Weak valve springs.

o. Abnormal resistance in spark plugs.

p. Distributor cam lobe worn.

q. Engine overheating.

r. Low grade fuel.

s. Badly worn diaphragm in fuel pump.

t. Detonation or pre-ignition.

u. Frozen heat control valve.

47. EXTERNAL OIL LEAKAGE

Possible Causes:

a. Outside oil lines.

b. Timing chain case cover oil seal.

c. Rear main bearing oil seal.

d. Oil pan gaskets.

e. Oil pan drain plug.

f. Oil filter gasket.

g. Clogged rear camshaft bearing drain hole.

h. Tappet cover gaskets.

i. Fuel pump gasket.

j. Timing chain cover gasket.

48. OIL PUMPING PAST PISTON RINGS

Possible Causes:

a. Oil level too high. (a) Dip stick not entering oil pan far enough. (b) Dip stick incorrectly marked.

b Loose main or connecting rod bearings.

NOTE: Excessive bearing clearance will cause the cylinder walls to be flooded with oil.

c. Too light oil for the type of service and conditions.

d. Excessively hot operating temperatures.

e. Piston ring gaps not staggered or incorrect size rings used.

f. Incorrect set of piston rings or rings out-of-round.

g. Cylinder head improperly torqued, causing a distortion of the cylinder bores for which the piston rings cannot compensate.

h. Rings fitted too tight in piston.

i. Oil rings carboned up or return grooves in piston clogged.

j. Insufficient piston ring tension.

NOTE: Common condition after engine has overheated.

k. Compression rings installed upside-down.

l. Excessive oil pressure or broken piston rings.

m. Burned piston.

NOTE: This condition can be brought about by excessive detonation and pre-ignition.

n. Scored cylinder walls or piston rings.

o. Excessively worn rings or cylinder walls.

NOTE: This condition can be traced to one or more of the following:

(1) Normal wear.

(2) Failure to keep air cleaners, carburetor, and crankcase filler cap installed and serviced.

(3) Failure to service the oil filter.

(4) Careless filling of the oil pan by allowing dirt or foreign material to fall in.

(5) Failure to clean cylinder walls properly after reboring or honing.

(6) Failure to prevent grindings and stone dust from getting on cylinder walls or improper cleaning of valve ports after grinding seats.

(7) Use of rings with heavier wall tension than necessary.

(8) Excessive speeding of a cold engine. In addition to the foregoing, many engines are overhauled for excessive use of oil or smoking without any degree of success because the actual cause may be due to any one or more of the following.

(9) Excessive clearance between valve guide and valve stem.

(10) Diaphragm of fuel pump porous.

(11) External oil leaks.

(12) Internal oil leak into cooling system.

49. OIL PUMPING AT VALVE GUIDES

Possible Causes:

a. Worn valve stems or guides.

b. Intake valve stem guide in inverted position. (FirePower engine.)

c. Intake valve seals damaged or missing.

50. HIGH OIL CONSUMPTION DUE TO LUBRICATING OIL

Possible Causes:

a. Oil level too high.

b. Contaminated oil.

c. Poor grade of oil.

d. Thin, diluted oil.

e. Oil pressure too high.

f. Sludge in engine.

51. HIGH OIL CONSUMPTION—MISCELLANEOUS

Possible Causes:

a. Overheated engine.

b. Sustained high speeds.

c. Misadjusted breather cap, causing excessive crankcase ventilation.

Certain mechanical conditions can affect engine oil pressure readings. In order to aid in determining the cause, the following conditions and possible causes are listed.

52. NO OIL PRESSURE WHEN ENGINE IS FIRST STARTED

Possible Causes:

a. Oil from the oil galleries and oil filter has drained back into the oil pan when the engine was shut off.

b. Frozen or partially clogged oil gauge line.

53. NO OIL PRESSURE AT IDLE

Possible Causes:

a. Oil gauge not registering properly, due to higher than normal pressure required to start gauge registering.

b. Excessive oil pump rotor end clearance.

c. Stuck oil pump relief valve.

d. Loose main and connecting rod bearings.

e. Loose camshaft bearings.

f. Plugs in ends of rocker shafts. Loose or missing.

g. Internal oil passage leakage.

h. Oil pump body cover seal ring blown out or missing.

i. Oil pump body cover seal ring replaced with common gasket.

54. NO OIL PRESSURE ON FAST STARTS OR RAPID ACCELERATION

Possible Causes:

a. Low oil level in oil pan.

b. Oil pump suction tube not aligned, or bent, causing the oil strainer to extend above the oil surface in the pan.

c. The foot on the oil strainer should touch the bottom of the oil pan.

d. Oil pump rotor pin sheared.

e. Expansion plug missing in oil pump cover.

f. Oil filter and oil filter by-pass plugged.

g. Air leak in oil pump suction tube.

h. Oil pump strainer plugged.

i. Oil pump relief valve stuck open.

j. Internal oil passage leak.

55. BROKEN VALVES

Possible Causes:

a. Weak valve springs.

b. Worn valve guides.

c. Excessive tappet clearance. (C-300)

d. Cocked springs or retainers.

e. Out-of-round valve seats.

f. Defective valve forgings.

g. Excessive engine speeds.

h. Detonation or pre-ignition.

56. BURNED OR STICKING VALVES

Possible Causes:

a. Close tappet clearance. (C-300).

b. Weak valve springs.

c. Gum formations on stem or guide.

d. Eccentric valve face.

e. Deposits on valve seats.

f. Incorrect valve seat width.

g. Improper valve guide clearance.

h. Warped valves.

i. Improper block cooling.

j. Exhaust back pressure.

k. Improper spark timing.

l. Out-of-round valve seat.

57. NOISY VALVES

Possible Causes:

a. Incorrect tappet clearance. (C-300).

b. Worn tappets or adjusting screws (C-300).

c. Wear in cam lobes.

d. Worn valve guides.

e. Excessive run-out of valve seat or valve face.

NOTE: When replacing valve guides, be sure the counterbore in guide is up for exhaust and down for intake.

58. BROKEN VALVE SPRINGS

Possible Causes:

a. Valve flutter at high speed.

b. Improper crankcase ventilation.

c. Worn timing chain.

d. Cold engine operation due to defective thermostat.

e. Rust, due to improper storage.

f. Coolant leaking into crankcase.

59. VALVE DEPOSITS

Possible Causes:

a. Quality of fuel.

b. Quality of lubricating oil.

c. Valve stem wear.

d. Improper cooling of block.

e. Sludged engine.

f. Worn valve guides.

g. Improper lubrication of valve stem.

h. Excessive engine idling.

i. Rich carburetor setting.

When diagnosing the cause of valve failure, it must be remembered that a valve can only transfer its heat through the valve seats and guides, to the cooling system. There is only one basic cause for valve failure and that is the inability of a valve to dissipate its heat into the cooling system as rapidly as necessary.

The following information is presented as an aid in diagnosing valve failure and also to help in preventing a recurrence.

60. CONDITIONS WHICH CAN CAUSE BOTH INTAKE AND EXHAUST VALVE FAILURE

a. Deposits on the upper part of the valve stems which prevents full seating of the valves.

b. Sludge deposits on the end of the valves and springs cause the valves to stick. These deposits are caused by poor maintenance of the engine oil or filter, low engine operating temperatures due to an inoperative thermostat, or short intermittent engine operation. The latter condition does not allow the engine to reach operating temperature to evaporate the condensation in the crankcase. Extremely slow driving of the vehicle does not induce sufficient crankcase ventilation to remove condensation.

c. Insufficient tappet clearance or operating clearance between tappet plunger and bottom of tappet body (hydraulic tappets).

On hydraulic tappets, this condition is usually caused by excessive valve face and seat regrinding which allows the valve stems to extend too far out of the guides.

Sufficient clearance is very important and will insure complete closing of the valves when the engine is hot.

d. Valves or seats that are not ground concentric with the valve guide. This can be due to worn refacing equipment. Valve-to-seat contact should be checked with a film of Prussian blue.

e. Improper valve seat width. Recondition valve faces and seats as directed in Paragraph 12.

f. Valve and valve seat not refaced to a 45 degree angle, due to worn or inaccurate equipment.

g. Excessively refaced valves. The distance between the top edge of the valve face and the top of the valve must not be less than $\frac{3}{64}$ inch. **Discard any valve that does not meet specifications.**

h. Incorrect valve timing.

i. Excessive valve guide wear. Worn guides will not provide proper cooling and permit oil to be sucked into the intake ports causing a carbon formation which could lead to valve sticking.

j. Restrictions in the cooling passages around the valve seats caused by excessive scale and rust deposits. This is the result of not using a rust inhibitor in the cooling system.

k. Engine overheating to such a degree that there is insufficient coolant remaining in the engine to dissipate the valve heat.

61. CONDITIONS WHICH CAN CAUSE INTAKE VALVE FAILURE

a. Sticking valves. This condition can be brought about by heavy carbon and/or a varnish deposit on the valve stems and heads. Gum forms as a result of the exposure of gasoline to air for an extended period. In some cases where gum and varnish have deposited on the valve stem, valve sticking has occurred while the engine was hot and operating under power. A good idle might be obtained while such an engine was relatively cool.

Cars which have been improperly prepared for extended storage or have been using fuel from bulk storage that is used very little—such as on a farm or ranch during the winter months —are susceptible to this type of valve sticking.

Heavy carbon deposits can result from short trip operation.

Rust. This condition results from prolonged storage without proper preparation.

b. Valve dishing and valve face grooving are usually the result of overheating. Overheating can be aggravated by, or attributed to, pre-ignition or detonation.

62. CONDITIONS WHICH CAN CAUSE EXHAUST VALVE FAILURE

a. Back-pressure due to restrictions in the exhaust system which prevent rapid expulsion of the hot gases.

b. Excessively lean fuel-air mixtures.

c. Carburetion (improper size jets.)

d. Air leaking into the intake manifold.

e. Air leak at carburetor mounting or throttle body gaskets.

f. Air leaks in vacuum line for booster brakes or other vacuum-operated accessories.

g. Improper ignition timing.

h. Detonation or pre-ignition.

i. Overloading engine by pulling heavy house trailers, luggage trailers, or boat trailers.

k. Low grade fuel.

l. Heat control valve stuck in the closed position.

As a matter of interest, broken or cracked exhaust valve seats, as well as cylinder heads with cracks radiating out from an exhaust valve port, can be traced to prolonged operation with burned or leaking exhaust valves.

63. PISTON RING NOISE

Possible Causes:

a. Broken ring.

b. Top ring striking cylinder ridge.

c. Broken ring lands.

d. Excessive side clearance in groove.

64. PISTON NOISE

Possible Causes:

a. Piston pin fits too tight or too loose.

b. Excessive piston-to-bore clearance.

c. Carbon accumulation in head.

d. Collapsed piston skirt.

e. Insufficient clearance at top ring land.

f. Broken piston skirt, or ring land.

g. Misaligned connecting rods.

65. CONNECTING ROD NOISE

Possible Causes:

a. Low oil pressure.

b. Insufficient oil supply.

c. Thin or diluted oil.

d. Misaligned rods.

e. Excessive bearing clearance.

f. Eccentric or out-of-round crank pin journal.

66. MAIN BEARING NOISE

Possible Causes:

a. Low oil pressure.

b. Insufficient oil supply.

c. Thin or diluted oil.

d. Loose vibration damper or torque converter.

e. Excessive bearing clearance.

f. Excessive end play.

g. Eccentric or out-of-round journals.

h. Sprung crankshaft.

i. Excessive belt tension.

67. BROKEN PISTON RINGS

Possible Causes:

a. Wrong type or size.

b. Detonation.

c. Undersize pistons.

d. Pre-ignition.

e. Ring striking top ridge.

f. Worn ring grooves.

g. Rings assembled improperly.

h. Broken ring lands.

i. Insufficient gap clearance.

j. Excessive side clearance in groove.

k. Uneven cylinder walls (particularly due to a previous ring breakage in same cylinder).

68. BROKEN PISTONS

Possible Causes:

a. Undersize pistons.

b. Eccentric or tapered cylinders.

c. Misaligned connecting rod.

d. Engine overheating.

e. Water or fuel leakage into combustion chamber.

f. Detonation or pre-ignition.

69. DETONATION

Detonation, pre-ignition, and after-running are abnormal types of combustion. Normal combustion starts at the spark plug and the flame expands to the extremes of the combustion chamber. During the short period of combustion, a high pressure is produced which pushes down on the piston to develop engine power.

Detonation occurs after the spark plug fires, when some of the fuel-air mixture in the combustion chamber is ignited by spontaneous combustion before the flame reaches it. The mixture is burned much more rapidly than during normal combustion. Thus, detonation produces excessive temperatures and pressures. Detonation is most easily recognized by a pinging sound during acceleration or continuous wide open throttle operation, such as climbing a steep hill.

A detonation complaint is usually concerned with the noise that is produced. Although a mild case of detonation will not damage an engine, excessive detonation may result in engine failure caused by the excessive temperatures and pressures. Detonation can cause broken piston rings, broken and burned piston ring lands, blown cylinder head gaskets, and short bearing life.

Detonation is caused primarily by the following:

a. Advanced spark timing.

b. Combustion chamber deposits.

c. Low octane fuels.

d. Excessively high coolant or air temperatures.

When correcting a detonation complaint the first thing to check is the spark timing as directed in Paragraph 73. If detonation persists at the proper timing, the distributor should be removed and checked to see if it conforms to spark advance specifications. The spark advance mechanism should be repaired if necessary. Further investigation depends on the type of operation. If the vehicle is used primarily for light duty, the detonation probably results from excessive combustion chamber deposits. These should be removed.

70. PRE-IGNITION

Pre-ignition is the burning of the air-fuel mixture before the spark plug fires. The mixture is ignited by a hot spot in the combustion chamber. Since this is equivalent to advancing the spark, it results in higher temperatures and pressures in the combustion chamber than those produced during normal combustion.

Sometimes, pre-ignition produces a pinging sound which is louder than detonation. If pre-ignition occurs early on the compression stroke, it is not audible. If it occurs before the intake valve closes, the engine will backfire through the air cleaner.

In many cases, it is difficult to distinguish between audible pre-ignition and detonation; in fact, they may occur simultaneously. Audible pre-ignition may be isolated from detonation by accelerating the vehicle at wide open throttle (not above 2000 rpm) until the loud pinging is heard and then turning off the ignition. If the engine continues to fire, it is pre-ignition; if it ceases to fire, the engine is detonating. Remove the foot from accelerator pedal before turning on the ignition again.

Often, inaudible pre-ignition is difficult to distinguish during operation, but it can be recognized by the failures it can produce, as noted below. If the engine back-fires through the air cleaner during wide open throttle operation, a colder set of plugs should be installed. If the back-firing ceases, it was probably caused by pre-ignition. If the engine continues to back-fire, it is caused by other factors, such as faulty ignition, incorrect carburetor mixture, incorrect valve timing, or a worn camshaft.

Inaudible pre-ignition cannot be recognized until a piston or valve failure occurs. It is generally caused by a hot spark plug, or advanced ignition timing. Check spark plug type and set ignition timing as described below. **ALWAYS USE SPECIFIED SPARK PLUGS.**

71. HOT STARTING NOISE

A form of aúdible pre-ignition sometimes occurs when a hot engine is started. Usually, the noise is limited to two or three sharp raps which are heard just as the engine begins to fire. This condition does not cause damage to the engine and is common with high compression engines. It cannot be eliminated by retarding ignition timing or changing spark plugs. Slow cranking speed may accompany the hot starting noise.

72. AFTER-RUNNING

After-running is a compression ignition of the engine at very slow speeds after the ignition has been turned off.

This condition is a source of irritation to the owner but it does not cause engine failure. After-running is primarily caused by one or more of the following factors:

a. Fast idle speed.

b. High coolant temperatures.

c. Combustion chamber deposits.

After-running is generally caused by fast idle speed or cutting the ignition before the engine throttles down to idle. The idle speed should be properly adjusted and the owner questioned as to whether he has the habit of pumping the accelerator pedal before turning off the ignition. If this does not correct the complaint, the vehicle should be checked for overheating.

If the vehicle has been used primarily for light duty operation, some highway operation will remove combustion chamber deposits which may eliminate the complaint.

This complaint cannot be corrected with cold spark plugs.

73. IGNITION TIMING

Due to normal variations between engines in their fuel requirements, high altitude operation (which results in a richer fuel mixture that reduces the octane requirements of the engine), and the variations in octane ratings of the fuels being marketed, the established ignition timing setting of 6 degrees BTDC for the V-8 engines should be considered a basic or starting point when tuning an engine. As a result of the conditions mentioned, a variation of plus or minus 6 degrees from the starting setting is permissible.

CAUTION

The advancing of timing in excess of 6 degrees of the basic setting is not recommended, as in-

audible pre-ignition could be encountered under some operating conditions at high speeds.

When tuning an engine to obtain maximum performance, economy, and smooth operation, and to take advantage of variations in octane requirements, it is desirable to make the final ignition timing during actual road test. Should the final timing be made during the road test, it is suggested the following procedures be followed:

a. Set the ignition timing at 6 degrees BTDC.

b. Drive the vehicle until normal operating temperature has been reached.

c. While in high gear, decelerate the car to 20 mph or just before the transmission downshifts; then, with a wide open throttle, accelerate to about 40 mph. Without downshifting to second gear.

d. During this wide open throttle operation, if a slight unobjectionable pinging or detonation is heard that disappears as the car approaches 40 mph, the timing can be considered to be the best setting; however, if the pinging or detonation is objectionable, the timing should be retarded 1 degree at a time until the proper setting has been reached.

74. TAPPET STARTING NOISE

This is a condition where the tappets are noisy upon starting and remain so for approximately 5 or 10 minutes, or until the engine has reached normal operating temperature.

Possible Causes:

a. Engine oil drain-back.

If the anti-drain back valve leaks, the oil drains out of the oil galleries and drilled passages into the oil pan. This occurs when the engine is not operating. Upon starting, it is necessary that the oil pump refill the system and, at the same time, force the air that entered the system out of the engine through the tappets. Until the oil system has been refilled and all the air bled out, noisy tappets may be experienced.

b. Filter change.

This may cause the same condition as above, and for the same reasons. Air trapped in the lubricating system may require a minimum of 20 to 30 minutes to bleed out. When changing an oil filter element, there is always a possibility that air may be trapped in the cover of the filter and not work out through the tappets until some time later, after the tappets have originally quieted.

c. Tappet varnish.

The problem of tappet varnish will not necessarily hinder the tappets since they are designed to allow the varnish to build up in areas that do not affect their operation. There is, however, a condition in which a varnish-coated tappet can possibly cause trouble; this is when a valve has been replaced. A new valve can effectively change the length of the valve mechanism and thereby allow the tappet plunger to operate in a new position in the body which may have a varnish build-up and result in the plunger sticking.

d. Anti-freeze.

Starting noise can also be caused by a gummy deposit, which results from leakage of anti-freeze or glycol into the engine oil. When cold, this deposit will be hard, but when hot, it becomes soft and gummy. This is another reason excessive tappet noise can be experienced when starting and gradually disappear as the gummy substance softens and allows the plungers to assume their normal operating positions. If this deposit is permitted to remain, it can eventually cause scuffing of the hydraulic tappet plunger.

e. Normal tappet leakdown.

This condition occurs on all engines and is due to the normal leakdown of the tappets that remain under valve spring pressure when the engine is shut off. The expulsion of air and the duration for quieting these particular tappets is dependent on the clearance to which the tappet plunger body has been fitted. The closer the fit, the longer the noise will persist.

75. ALL TAPPETS NOISY

In cases where all 16 tappets are noisy, it is generally safe to assume that the noise is not the fault of the tappets, but of the oil supply, which is inadequate, **or into which air has been induced. No advantage can be gained by installing 16 new tappets unless they are found to be stuck due to an anti-freeze leak. In this case it is imperative that the leak be corrected to prevent reoccurrence.**

Possible Causes:

a. Drain plug out of oil pan.

The loss of the drain plug from the oil pan will result in the loss of oil and oil pump pressure.

b. Plug out of the oil pump cover.

A plug out of the oil pump cover will permit the majority of oil from the pump to escape back into the oil pan. This usually shows up as fluctuation or low oil pressure on the gauge.

c. Oil strainer improperly located in pan.

When this occurs, tappet noise may occur shortly after a turn, stop, or fast acceleration. This condition may also be detected by close observation of the oil pressure gauge.

d. Low oil level.

Low oil level permits the oil strainer to become uncovered while accelerating, stopping, or turning. Air will be pumped into the lubrication system when this happens.

e. Plugged oil screen.

A plugged oil screen is generally due to inadequate oil and/or filter change periods for the type of operation.

f. Oil pump relief valve stuck.

When this condition occurs, it usually permits pressure to be normal at higher speeds while falling below normal at low engine speeds or at idle. **Normal oil pressure for a warm engine at idle is considered to be 12 psi or more at 500 rpm.**

g. A major oil pressure drop is generally caused by excessive bearing clearance, etc., which permits excessive leakage of hot engine oil and reduces the pressure of oil delivered to the tappets below the minimum required for quiet and proper operation of the tappet.

h. Oil foaming.

This is a condition where a large quantity of air bubbles are trapped in the oil, producing a condition of foaming or sudsing (aeration). Since air unlike oil, is compressible, tappet noise or loss of valve lift will result when the aerated oil enters the tappet.

i. Excessive oil supply.

When the oil level is too high in the oil pan, the crankshaft and connecting rods dip into the oil and churn it, causing an aerated condition.

j. Low oil supply.

This condition permits the reuse of a small quantity of oil which does not have sufficient time to cool and rid itself of the normal air induced into the oil.

k. Air entering the oil pump.

This condition can be caused by an improperly located oil screen, a leak in the suction tube, loose oil pump cover, etc. In all cases, air will be drawn into the oil pump and induced into the oil.

l. Plug out of oil pump cover.

A plug that is loose or missing out of the oil pump cover will cause excessive by-passing and aeration of the oil.

m. Prolonged use of engine oil.

Where operating conditions are such that the majority of driving is slow or short and intermittent, not permitting the engine to warm up to operating temperature, it is possible for normal condensation to build up in the crankcase to a point where it will cause the oil to foam.

n. Water from the cooling system leaking into the engine oil.

Water from the cooling system leaking into engine oil will cause excessive oil foaming.

o. Glycol in the engine oil.

When glycol leaks into the engine lubrication system it has a tendency to form a gummy substance which deposits on the engine parts. This substance will normally affect the operation of the hydraulic tappets, first by causing sticking, and then gradually causing the tappets to scuff and become increasingly noisy until they reach a point where the plungers will stick completely. **This is the only condition which may require the replacement of all 16 tappets. However, unless the leak is corrected, it will repeat itself.**

76. ONE OR MORE TAPPETS NOISY

Possible Causes:

a. Excessive dry lash.

The term of dry lash refers to the clearance between the valve stem and rocker arm when the tappet is on the heel of the cam lobe and the plunger is bottomed in the tappet body. The normal clearance is .060 to .210 inch, and any lash exceeding .210 inch could cause a tappet to be noisy. **A condition of excessive dry lash usually indicates wear.**

To determine if proper dry lash is the problem, insert a 1/8 inch (.125) feeler between the rocker arm and the valve stem; then, start the engine. If the noise has disappeared it is quite possible it was caused by a worn rocker arm or push rod.

b. Broken valve spring.

c. Sticking rocker arm.

This could be the result of any condition that prevents free movement of the rocker arm on the rocker shaft.

d. Worn rocker arm.

This condition is usually due to lack of hardness of the rocker arm or push rod end, and can be detected by the dry lash test as described above.

e. Face of rocker arm not true.

When this condition is present, it will be noted that the rocker arm is making contact on the edge of the valve stem. This can cause a valve cocking condition and result in the valve stem to ride heavy or bind in the guide.

f. Push rods worn, bent, or interfering (in head).

A worn push rod can be identified by a worn spot on one end. This can be caused by insufficient lubrication. Check holes in arm and rocker shaft.

When installing a new rocker arm, be sure the lubricating oil holes are open.

Worn, bent, or interfering push rods can be detected by the dry lash test, as described above.

A bent push rod is generally caused by mishandling and can result in the cylinder head or increased dry lash.

The push rod interference in the cylinder head can be caused by inadequate clearance in the push rod passages through the cylinder heads. If this condition is found, it is only necessary to relieve the ends of the hole at the top and bottom.

g. Tight tappet.

While rare, this condition occurs where the tappet or the tappet bore is of incorrect size, bell-mouthed, or out-of-round, causing the tappet to stick in its bore. A condition of this nature is indicated by heavy wear or scuff marks on portions of the side of the tappet body. Unless the tappet bores in the cylinder block are cleaned up, the same condition will occur with a replacement tappet. **To check bore, slide a new tappet in and out. If the tappet sticks, ream bore to next oversize and install new oversize tappet.**

h. Stuck hydraulic tappet plungers.

This condition is where a tappet plunger is stuck in the tappet body and is unable to compensate for changes in the valve train clearance. **Extended engine operation at high speed with this condition existing, could cause valve breakage.** Three basic causes for this condition are: **Dirt or metal chips; glycol in the lubricating oil; and, the mismatching of parts in assembly after cleaning.**

Varnish build-up around the top of the tappet above the operating range of the plunger is a normal condition, therefore, it should not be confused with a stuck tappet in which the plunger will normally be found stuck below the operating range.

i. Valve stem varnish.

Occasionally, this condition may occur where a heavy deposit of varnish has adhered to the valve stem and restricts the movement of the valve in the guide.

j. Faulty tappets.

This is caused by conditions that may be inherent in the individual tappets, such as bent valve washers, omitted valve washers, tight plunger caps, improperly fitted retainer, bad flat valve or valve seat, a plugged or missing oil hole in the tappet body or plunger, or a loose plunger to body fit that causes a fast leakdown under spring pressure. (The latter usually shows up at idle when the oil is hot.)

Since the hydraulic tappet is not reparable, only those determined to be faulty should be

replaced. The replacement of any tappets other than the individual ones causing the condition, would serve no purpose.

k. Worn valve guide.

Tappet noise can also be caused by a guide that is worn .015 inch or more, or by a valve that is bent to a point where it will actually hang up in the guide. Valves can be bent in the field when attempting to compress a valve spring on an engine with the piston up or near TDC, or by failing to use the proper head holding fixtures, Tool C-3209, when the heads have been removed for repairs.

l. Tappet oil feed hole plugged or restricted.

In many cases where a tappet has been removed for being noisy, it has been found that the oil feed hole in the tappet or the cylinder block was restricted or plugged. This condition is due to varnish, sludge, dirt, or other foreign materials. **Again this condition can be attributed to infrequent filter element or oil change.** Before installing any tappet, it is a good policy to run a drill rod or drill into the feed hole to make sure it is open. **Be sure no burr is left in the tappet bore after opening with rod.**

m. Worn tappet or camshaft lobe.

There have been instances where scoring starts between the cam lobe and the face of the tappet, in the same manner as any other bearing surface. When this condition occurs, it can result in damage not only to the face of the tappet, but to the camshaft lobe as well. It will produce tappet noise and a lack of engine performance.

This condition can be determined by measuring the lift of the valve. The lift can be measured by bottoming the tappet in the same way as checking for valve timing, by inserting a shim of sufficient size to take up the dry lash. The lift of the valve can then be measured with a dial indicator and compared with other valves shimmed in the same manner. The normal valve lift should be approximately .360 inch. Since wear of up to .030 inch is permissible, the mileage of the engine, as well as the comparison check with other cylinders, should be taken into consideration before a decision is reached to replace the camshaft. When tappets and/or camshaft replacement is necessary due to excessive wear, a very thorough cleaning of the lubricating system should be performed, or else the particles of worn metal that have deposited out of the oil will cause a reocurrence of the same trouble.

77. INTERMITTENT TAPPET NOISE

Possible Causes:

a. Aerated or foaming oil.

This is a condition where a large quantity of air bubbles are trapped in the oil, producing a condition of foaming or sudsing (aeration). Since air, unlike oil, is compressible, tappet noise or loss of valve lift will result when the aerated oil enters the tappet.

b. Defective tappets.

Although these defects cannot be corrected in the field, and therefore require replacement of the individual tappet, the following is presented to point out possible defects:

c. Extremely wide seat on the lapped seat of the tappet plunger.

d. Insufficient check valve travel to compensate for various speeds.

e. Out-of-round tappet plunger.

78. TAPPET CLEANING

When cleaning tappets (if needed) at the time of engine overhaul or valve grind, it should be done in accordance with the procedure described in this section. Extreme precautions must be taken to be sure that all work be done in clean surroundings and using clean materials. If the cleanliness precautions are not observed, it is more than likely the effort will be wasted and noisy or stuck tappets can be expected.