*The Series 149 Service* **Manual has** *been completely* **updated.** *Sections revised since the last manual release (No. 42 dated June,* **1987)** *are as follows:*

| SECTION | PAGES | REMARKS |
|---|---|---|
| *'Gen. Info.* | **4** | *Parts Replacement section added.* |
| *Gen. Info.* | **6** | *Model Description Chart* **revised.** |
| *Gen. Info.* | **8-9** | *Option label information added; Fig. 6 added (S.I.* **22-149-85)** |
| *Gen.* **Info.** | **10-12** | *New work safety information and CAUTIONS added.* |
| *Gen. Info.* | *12* | *Info. Added: Fabricating, Altering, Removing, Disposing of Gaskets (S.I.* **13-149-85).** |
| *Built -win Parts Book* | - | *Section removed.* |
| i. i | **1** | *Engine front lifter bracket* **CAUTION** *added.* |
| *1.1* | **1** | *New* **cylinder** *blocks with strengthened intermediate main bearing journals (S.I.* **1-149-88).** |
| *1.1* | **3** | **Block** *cleaning* **CAUTION added.** |
| *1.1* | **8** | *Fig.* **9** *revised.* |
| *1.1* | **11** | *Steps* **7** *thru 8 revised.* |
| *1.1* | *12* | **Step 21 revised:** *Install injector rack guard* **screens on** *12V,* **16V** *engines (S. I. 12-149-86).* |
| *1.2* | **1** | *Short slot* **cylinder** *head info, added (S.I. 15-149-83)* |
| *1.2* | **3** | *Integral* **head-io-block** *water seal installation info, added (S.I.* **17-149-86).** |
| *1.2* | **6** | **Cylinder** *head sealant recommendation* **added** *(S.I. 3-149-87).* |
| *1.2* | **6** | **Step 1: Do not Use** *RTV* **sealant on cylinder** *head cup plugs, valve bridge guides; use Permatex 98D, 9 8X.* |

| | | |
|---|---|---|
| 1.2 | 7-9 | *Cylinder head* installation ' *instructions revised..* |
| *1.2* | 10 | Fig. 3 added. |
| *1.2.1* | 2 | New *valve button retainer on 125 hp/cylinder engines.* |
| 1.2.1 | *2* | *Step 4 revised, Notice added: DDC does not* recommend reusing flared end fuel pipes. |
| *1.2.2* | *2* | *Exhaust valve spring testing and qualifying procedure added.* |
| *1.2.2* | *4* | *Info, added: Exhaust valve guides smaller and* no *bridge guides on 125 hp/cylinder engines.* |
| *1.2.2* | 6-10 | *Pyromet exhaust* valves on 149 *engines; Fig. 13 revised (S.I.* 7-149-86). |
| *1.2.2* | 7 | *Info, added: 125 hp/cylinder engine valve diameter.* |
| *1.2.2* | 9 | *Info added: New exhaust valve rocker arm, valve* lock, spring cap. |
| *1.2.2* | 9-10 | *Info, added: 125 hp/cylinder engine uses teflon-lip valve seal, free-floating* exhaust *valve bridge, different valve seats, caps, locks.* |
| *1.2.4* | 1 | Inspection, *Installation sections,* added. ' |
| *1.3* | 6-7 | New *crankshafts with 1/2" -14* Vibraseal-coated *pipe plugs* (S.I. 6-149-86); Fig. 10 added. |
| *1.3.2* | 1 | Fig. 2 revised. |
| *1.3.2* | 1 | *Unidirectional, fluoroelastomer-lip front and rear oil seals (S.I. 2-149-86,* 8-149-87). |
| *1.3.5* | 2 | Step & *revised.* |
| *1.3.5.1* | 2 | - *Step 6 revised.* |
| 1.3.5.1 | 1 | *Grooveless outboard support bearing (S.I.* 16-149-86). |

| | | |
|---|---|---|
| 1.3.5.2 | 4 | Steps 7, 8 *revised.* |
| 1.3.5.2 | 1 | *Grooveless outboard support bearing* (S.I. 16-149-86). |
| 1.3.6 | *1-2* | *Vibration damper safety shield i n f o , added.* |
| 1.4 | 3 | *S t e p 8 offlywheel mounting procedure revised.* |
| 1.5 | 1 | *Specially drilled and tapped flywheel housings used on high torque rise* 12V *engines ( S . I .* 6-149-85) |
| 1.6 | 6 | *New crosshead piston domes with revised piston bowl strut configurations (S. I. 1-149-89).* |
| 1.6 | 9 | *Lubrication recommendation ( S . I . 12-149-87).* |
| 1.6.1 | 1 | *S t e p 3 : DDC does not recommend reuse of piston pin bolts.* |
| 1.6.1 | 3 | *Connecting rod checking fixture supplier (Sergeant Industries) added.* |
| 1.6.3 | 3 | *Master ring gage temperature i n f o . ,* Notice added: When *measuring liner[A] take measurements with parts at* 65° to 75°F (18.3° to 23.9°C) to *insure accuracy.* |
| 1.7.1 | 3-4 | Figs. 4, 5, 6 *revised.* |
| 1.7.2 s | 2 | Fig. 1 *revised.* |
| 1.7.2 | 6 | *F i g .* 5 added |
| 1.7.2 | 7 | *Steps 17,19 (Check end play) added.* |
| 1.7.3 | 3-4 | *Gear, hub, and bearing assembly procedure revised (S. I. 15-149-85).* |
| 1.7.5 | 3 | *Steps 3, 4 revised.* |
| 1.7.7 | 5 | *Install drive gear step 1 revised.* |
| 1.0 | 7 | *Rework flywheel housing for high torque rise engine magnetic pickup ( S . I . 6-149-85).* |

| | | |
|---|---|---|
| 1.0 | 8-9 | *Block plugging chart minor revisions.* |
| 1.0 | 13 | *Wide gap ring specifications added.* |
| 1.0 | 16 | *Idler gear, cam gear locknut torques added.* |
| 1.0 | 18-19 | *Tool numbers added, revised (S.I. 7-149-87)* |
| 2.1.1 | 7 | *Injector* bodies, nuts, *filter* caps no *longer blued (S. I.* 3-149-88). |
| 2.1.1 | | Calibration *limits* change (S.I. *23-149-85).* |
| 2.1.1 | 12-13 | Blued and non-blued *injector nut, filter cap torque specifications (S.I.* 3-149-88). |
| 2.1.1 | 15 | *Notice added: DDC recommends flared end fuel pipes not be reused.* |
| 2.2 | 7 | *Steps 1, 4, 5 revised.* |
| 2.3 | 1, 3 | *Spin-on fuel strainer* and *filter* information *added (S. I.* 18-149-86). |
| 2.8.1 | 1, 2 | Hydraulic governor reservoir *information added (S. I. 2-149-83).* |
| 2.8.2 | 1, 2 | *Hydraulic governor reservoir information added (S. I.* 2-149-83). |
| 2.8.4 | 1, 2 | *Horizontal-mount governor info, added; Fig. 3 revised* (S.I. 1-149-88) |
| 2.9 | 1 | *Information added: Different colored control tube lever return springs on engines with hydraulic or electric governors and mechanical governors.* |
| 2.9 | 1 | *Injector rack guard screen notice, Fig. 3 added* (S.I. 12-149-86). |
| 2.0 | 5 | *Table 1 revised; increased* 145 *injector* output (S.I. 4-149-87). |
| 2.0 | 13 | *Notice added: DDC recommends flared end fuel pipes not be reused. Fuel jumper line maintenance section rewritten* |
| 2.0 | 20 | Blued, *non-blued injector nut, filter* |

| | | |
|---|---|---|
| | | cap *torque specifications* (S.I. 3-149-88). |
| 2.0 | 21, 22 | Tool *numbers* added, revised |
| 3 | 2 | *Piston style blower bypass* valve changepoint (S.I. 2-149-89). |
| 3.3 | 2, 5 | New *hose and clamp on turbocharged engines* (S.I. 4-149-86). |
| 3.4 | 2 | Steel oil *supply tube on rear blower end plates (S. I. 9-149-87).* |
| 3.4 | 7, 8, 13 | Blower rear end plate oil *supply tube disassembly, assembly (S. I.* 9-149-87). |
| 3.4 | 8 | *Bypass blower valve lever stop plate on* 8V *engines with flapper style* bypass valve (S.I. 8-149-86). |
| 3.4 | 14 | Step l. added. |
| 3.4 | 16 | Fig. 21 *revised.* |
| 3.4.2 | 1-6 | *New section added:* Blower *bypass valve ( S . I . 2-149-89).* |
| 3.5 | 3 | *Notice added: Do* not permit *turbocharger "drafting."* |
| 3.5 | 13 | *New hose and clamp on turbocharged engines (S. I.* 4-149-86). |
| 3.5 | 14 | *CAUTION added: Do not hold compressor* wheel while *engine is running.* |
| 3.5.2 | *1-4* | *Section rewritten:* Aramid *fiber intercooler core pads replace felt pads ( S . I . 5-149-87).* |
| 3.5.2 | 1, 2 | *Coolant strainer info: added* |
| 3.0 | 7 | Tool added (S.I. 2-149-89) . |
| 4.1.1 | *1-4* | *Section rewritten; new 70 psi (483 kPa) and 50 psi (345* kPa) oil pressure *relief* valves (S.I. 10-149-86). |
| *4 . 1 . 1* | *3* | *Oil pressure regulator, relief* CAUTION added. |

| | | |
|---|---|---|
| 4.2 | 1 | *Multi-pack lube oil filter info, added.* |
| *4.2* | 2 | *Optional finer lube oil filter available (S.I.* 11-149-87). |
| *4.2* | 3 | *Notice added: Do not hot tank multi-pack oil filter adaptors.* |
| *4.4* | 1 | *New 30-plate stainless steel* lube *oil cooler core (S. I.* 9-149-86). |
| *4.4* | 5 | *New water inlet housing and seal in tube and shell oil cooler assemblies (S.I.* 14-149-86). |
| *4.4* | 5-10 | Tube and shell oil cooler *installation procedures added.* |
| *4.4* | 10 | *Tube and shell oil cooler bypass* valve *info,* added. |
| *4. 0* | 3 | Tube *and shell oil cooler water inlet housing* rework *instructions (S.I.* 14-149-86). |
| *4. 0* | 4 | Tube and shell oil *cooler mounting* bracket *alignment tool added.* |
| *5* | 3-5 | Cooling *system requirements for direct* radiator-cooled *engines (S.I. 3-149-86).* |
| 5 | 5 | *CAUTION added; Table 1 revised.* |
| 5 | 7 | *Recommendation changed: Use DPMto contaminated clean lubrication system.* |
| 5 | 9 | *Note added to chart.* |
| 5.1 | *1-2* | *Water pump assembly procedure* revised (S.I. 11-149-85). |
| *5.2.1* | 1-3 | *Section rewritten. Info added: Thermostat operation, type, installation, preventive maintenance (S.I. 1-149-87).* |
| *5.3* | 2 | CAUTIONS added. |
| 5.3.1 | 1 | *Section rewritten.* |

| | | |
|---|---|---|
| **5.5** | **3** | **CAUTION added.** |
| **5.6** | **1-6** | ***Section rewritten: New raw water pumps with replaceable cam/liners* (S.I. 3-149-89).** |
| **5.0** | **2-4** | ***Thermostat function testing* (1-149-87).** |
| **5.0** | **5** | **Find *coolant leaks with fluorescent dy e, black light (S. I.* 5-149-86).** |
| **5.0** | **7** | **Tool *number added:* J 34034.** |
| **6.1** | **1-2** | **Section *rewritten: New two-piece exhaust manifolds with seal rings and expanders; new drain* hole *plugs (S. I. 10-149-84,1-149-87).*** |
| **6.1.1** | **1-2** | ***Section rewritten: Coolant flow path i n f o , added.*** |
| **7.1** | **1-2** | ***Section rewritten.*** |
| **7.1.1** | | ***Section removed. Obsolete.*** |
| **7.2** | **1-3** | **Section *rewritten. Battery installation,* testing *information added.*** |
| **7.3** | **1-2** | ***Minor changes.*** |
| **7.4** | **1-8** | ***Section rewritten: Crankcase pressure monitor operation, wiring, overhaul, and test* procedures (S.I. 6-149-84, *16-149-85,1-149-86).*** |
| **7.4.2** | **1-3** | ***Minor changes*** |
| **7.0** | **1-5** | ***Minor changes.*** |
| **8.1** | **1-4** | ***CAUTIONS added. Inf o, added: Use 1 , 1 , 1 trichlorethane to clean oil* cooler *core.*** |
| **9.5.5** | **1-2** | ***CAUTIONS added. I n f o added: Use 1 , 1 , 1* trichlorethane *t o* clean oil cooler core.** |
| **12.0** | **1** | ***Service tool section added* (S.I. 7-149-87).** |
| **13.1** | **1-5** | ***Section completely rewritten; air starter, hydrostarter information*** |

| | | |
|---|---|---|
| | | added. |
| 13.2 | 9 | 12V-149TI engine with TV7511 *turbos,* 240 *injectors added.* |
| 13.2 | 14 | 16V-149TI *engine with 8402* turbos, 240 *injectors* added. |
| 13.2 | 15-18 | *Cooling system requirements— Direct radiator-cooled engines (S.I. 3-149-86).* |
| 13.2.1 | 2-4 | *Info, added:* Block oil *filter bypass before initial start-up and dynamometer test of* rebuilt *engines (S. I. 6-149-87); tables 1, 2 revised.* |
| 13.3 | 1-9 | *Lubricating* oil, *fuel, filter recommendations revised.* |
| 13.3 | 10-14 | *Coolant specifications rewritten; maximum coolant change interval added.* |
| 14 | 2 | CAUTIONS added. |
| 14.2 | 1 | *Table 1 (Injector timing) revised.* |
| 15.1 | 1-11 | *Preventive maintenance interval chart revised,* section *rewritten, information added.* |
| 15.2 | 1-17 | *Minor revisions.* |

The following CAUTION on *compressed air usage has been* added to *numerous sections throughout this manual:*

> CAUTION: To *prevent* possible *injury,* wear adequate eye *protection and do not exceed 40psi (276* kPa) air *pressure.*

**The** ***following service information bulletins are now obsolete and may be removed from your f i l e s :***

| | | | |
|---|---|---|---|
| *6-149-85* | *1-149-86* | *1-149-87* | **1-149-88** |
| *8-149-85* | *2-149-86* | *2-149-87Rev.* | *2-149-1* |
| **10-149-85** | **3-149-86** | **3-149-87** | **3-149-88** |
| *1 1 - 1 4 9 - 8 5* | *4-149-86* | *4-149-87* | **4-149-88** |
| **13-149-85** | **5-149-86** | *5-149-87* | |
| **15-149-85** | **6-149-86** | **6-149-87** | **1-149-89** |
| **16-149-85** | *7-149-86* | *7-149-87* | *2-149-89* |
| *17-149-85* | *8-149-86* | *8-149-87* | *3-149-89* |
| **18-149-85** | **9-149-86** | **9-149-87** | |
| *19-149-85* | **10-149-86** | **10-149-87** | |
| **20-149-85** | **11-149-86** | *1 1 - 1 4 9 - 8 7* | |
| **21- 149-85** | **12-149-86** | **12-149-87** | |
| *22- 149-85* | *13- 149-86* | | |
| **23- 149-85** | *14- 149-86* | | |
| | **15- 149-86 Rev.** | | |
| | **16- 149-86** | | |
| | **17- 149-86** | | |
| | **18- 149-86** | | |
| | **19- 149-86** | | |
| | **20- 149-86 Rev.** | | |

# DETROIT DIESEL

## Series 149 Service Manual

DETROIT DIESEL

CORPORATION

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# FOREWORD

This manual contains instructions on the overhaul, maintenance and operation of the basic Series 149 Detroit Diesel Engines.

Full benefit of the long life and dependability built into these engines can be realized through proper operation and maintenance. Of equal importance is the use of proper procedures during engine overhaul.

Personnel responsible for engine operation and maintenance should study the sections of the manual pertaining to their particular duties. Similarly, before beginning a repair or overhaul job, the serviceman should read the manual carefully to familiarize himself with the parts or subassemblies of the engine with which he will be concerned.

The information, specifications and illustrations in this publication are based on the information in effect at the time of approval for printing. This publication is revised and reprinted periodically. It is recommended that users contact an authorized *Detroit Diesel Corporation Service Outlet* for information on the latest revisions. The right is reserved to make changes at any time without obligation.

# CAUTION

To reduce the chance of personal injury and/or property damage, the following instructions must be carefully observed.

Proper service and repair are important to the safety of the service technician and the safe, reliable operation of the engine. If part replacement is necessary, the part must be replaced with one of the same part number or with an equivalent part. Do not use a replacement part of lesser quality.

The service procedures recommended by Detroit Diesel Corporation and described in this service manual are effective methods of performing service and repair. Some of these procedures require the use of tools specially designed for the purpose.

Accordingly, anyone who intends to use a replacement part, service procedure or tool, which is not recommended by Detroit Diesel Corporation, must first determine that neither his safety nor the safe operation of the engine will be jeopardized by the replacement part, service procedure or tool selected.

It is important to note that this manual contains various "Cautions" and "Notices" that must be carefully observed in order to reduce the risk of personal injury during service or repair or the possibility that improper service or repair may damage the engine or render it unsafe. It is also important to understand that these "Cautions" and "Notices" are not exhaustive, because it is impossible for Detroit Diesel Corporation to warn of all the possible hazardous consequences that might result from failure to follow these instructions. See more specific cautions under "Cautions, Work Safely" in the General Information section.

# TABLE OF CONTENTS

SUBJECT



# SCOPE AND USE OF THE MANUAL

This manual covers the basic Series 149 Diesel Engines built by the Detroit Diesel Corporation. Complete instructions on operation, adjustment (tune-up), preventive maintenance and lubrication, and repair (including complete overhaul) are covered. The manual was written primarily for persons servicing and overhauling the engine and, in addition, contains all of the instructions essential to the operators and users. Basic maintenance and overhaul procedures are common to all Series 149 engines and therefore, apply to all engine models.

The manual is divided into numbered sections. The first section covers the engine (less major assemblies). The following sections cover a complete system such as the fuel system, lubrication system or air system. Each section is divided into subsections which contain complete maintenance and operating instructions for a specific subassembly on the engine. For example, Section 1, which covers the basic engine, contains subsection 1.1 pertaining to the cylinder block, subsection 1.2 covering the cylinder head, etc. The subjects and sections are listed in the Table of Contents on the preceding page. Pages are numbered consecutively, starting with a new Page 1 at the beginning of each subsection. The illustrations are also numbered consecutively, beginning with a new Fig. 1 at the start of each subsection.

Information regarding a general subject, such as the lubrication system, can best be located by using the Table of Contents. Opposite each subject in the Table of Contents is a section number which registers with a tab printed on the first page of each section throughout the manual. Information on a specific subassembly or accessory can then be found by consulting the list of contents on the first page of the section. For example, the cylinder liner is part of the basic engine. Therefore, it will be found in Section 1. Looking down the list of contents on the first page of Section 1, the cylinder liner is found to be in subsection 1.6.3. An Alphabetical Index at the back of the manual has been provided as an additional aid for locating information.

## SERVICE PARTS AVAILABILITY

Genuine Detroit Diesel service parts are available from authorized Detroit Diesel distributors and service dealers throughout the world. A complete list of all distributors and dealers is available in the Worldwide Distributor and Dealer Directory, 6SE280. This publication can be ordered from any authorized distributor.

## CLEARANCES AND TORQUE SPECIFICATIONS

Clearances of new parts and wear limits on used parts are listed in tabular form at the end of each section throughout the manual. It should be specifically noted that the “New Parts” clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled “Limits” lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still assure satisfactory performance. It should be emphasized that the figures given as “Limits” must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the paragraph entitled *Inspection* under *General Procedures* in this section.

Bolt, nut and stud torque specifications are also listed in tabular form at the end of each section.

## .PARTS REPLACEMENT

Before installing a new or used part, check it thoroughly to make sure it is the proper part for the job. The quality of the replacement part must be equivalent to the quality of the original Detroit Diesel component being replaced and must meet DDC specifications for new or reusable parts.

Parts must also be clean and not physically damaged or defective. For example, bolts and bolt hole threads must not be damaged or distorted. Gasketing must have all holes completely punched through with no residual gasket material left clinging to the top or bottom. Flatness and fit specifications in the service manual must be strictly adhered to.

**CAUTION: Failure to inspect parts thoroughly before installation, failure to install the proper parts, or failure to install parts properly can result in component or engine malfunction and/or damage and may also result in personal injury.**

# PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

## The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively (Fig. 1). In contrast, a four-cycle engine requires four piston strokes to complete an operating cycle.

A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports (Fig. 1 - scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression (Fig. 1 - compression).

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector (Fig. 1 - power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about half way down, allowing the burned gases to escape into the exhaust manifold (Fig. 1 - exhaust).

Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, in two strokes; hence, it is a “two-stroke cycle”.

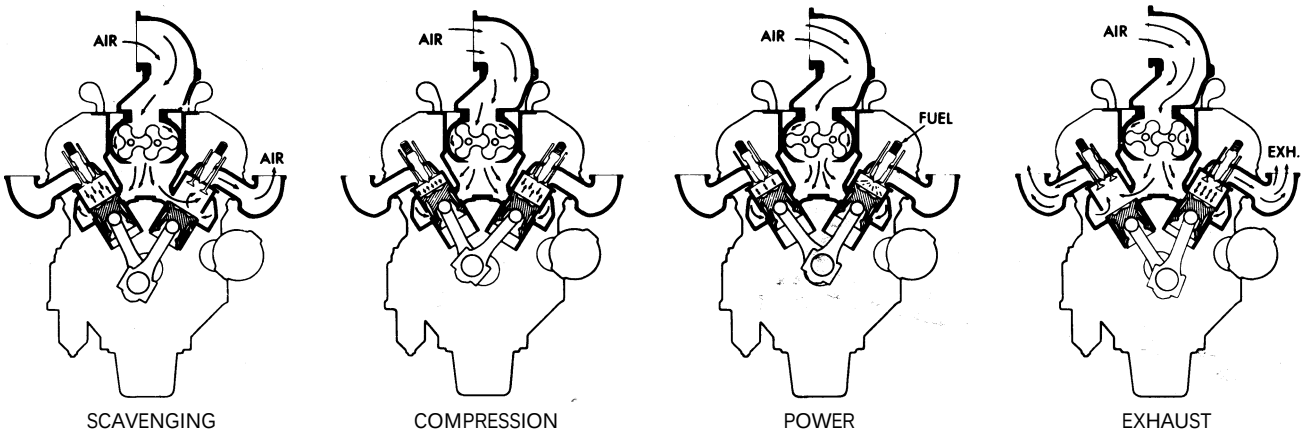



**Fig. 1 - The Two-Stroke Cycle**

# GENERAL DESCRIPTION

The Series 149 Diesel engine is a "V" type, two cycle engine. A low weight-to-horsepower ratio, full scavenging air system, individual cylinder heads, free floating pistons and unit fuel injection are all incorporated to allow trouble-free maintenance and to provide desirable operating features for many applications.

Gear trains located at both the front and rear ends of the engine provide ample locations from which accessories may be driven.

Fuel is drawn from the supply tank and through a strainer by a gear-type fuel pump; then it is forced through the filter, the fuel inlet manifold and into the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifold and connecting lines. Since fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air for scavenging and combustion is supplied by a blower(s) which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower first passes through an air cleaner or silencer and, on some models, a turbocharger.

Cooling is accomplished by circulating fresh water through the engine water jacket by a centrifugal pump mounted on the engine front cover.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings and to other moving parts.

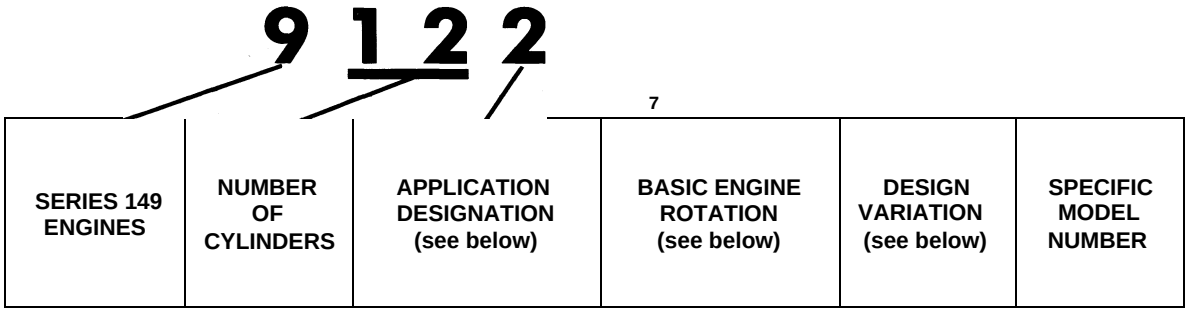
A gear-type pump draws oil from the oil pan through a screen and delivers it to the oil filter. From the filter, the oil flows to the oil cooler and then enters a longitudinal oil gallery in the cylinder block where the supply divides.

Part of the oil goes to the camshaft bearings and up through the rocker arm assemblies; the remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft.

Engine starting is provided by either a pneumatic starting system or an electric starting motor energized by a storage battery. A battery-charging alternator serves to keep the battery charged.

Dependable speed regulation of the engine is provided by either a mechanical or hydraulic governor.

Fig. 2 illustrates a complete breakdown on model designation including application, design variation and basic engine rotation.




APPLICATION DESIGNATION:

| | |
|---|---|
| 9122- 7300 | MARINE |
| 9123- 7300 | INDUSTRIAL F-F |

BASIC ENGINE ROTATION:

| | |
|---|---|
| 9122-3300 | LEFT-HAND |
| 9122-7300 | RIGHT-HAND |

DESIGN VARIATION:

| | |
|---|---|
| 9122-7000 | NON-TURBO |
| 9122-7300 | TURBO OR TURBO-INTERCOOLED |
| 9122-7400 | TURBO-AFTERCOOLED |

Rotation: L (Left) and R (Right) designates
Rotation as viewed from the front of the engine:

11921 -A

**Fig. 2 - Series 149 Engine Model Description Chart**

# GENERAL SPECIFICATIONS

| | 8V | 12V | 16V |
|---|---|---|---|
| Type | 2 Cycle | 2 Cycle | 2 Cycle |
| Number of Cylinders ..... 8 | | 12 | 16 |
| Bore (inches) | . 5.75 | 5.75 | 5.75 |
| Bore (mm) | 146 | 146 | 146 |
| Stroke (inches) | 5.75 | 5.75 | 5.75 |
| Stroke (mm) | 146 | 146 | 146 |
| Total Displacement - (cubic inches) | 1195 | 1792 | 2389 |
| Total Displacement - (liters) | 19.6 | 29.39 | 39.18 |
| Compression Ratio (standard and turbocharged engines) | | 17:1 | 17:1 |
| Compression Ratio (intercooled turbocharged engines)* | . 16:1 | 16:1 | 16:1 |

*Note: Certain high output turbocharged — intercooled engines also have 14:1 and 15:1 compression ratios.

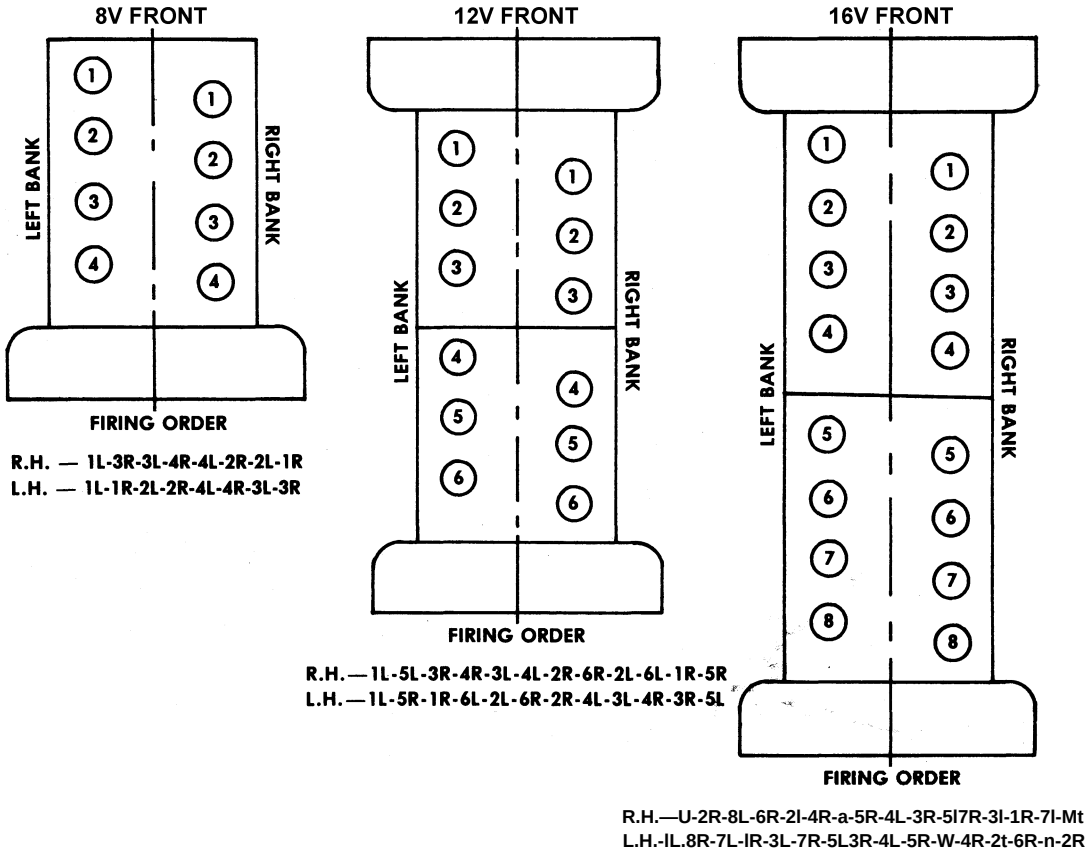



**Fig. 3 - Cylinder Designation and Firing Order**

# ENGINE MODEL. SERIAL NUMBER AND OPTION PLATE

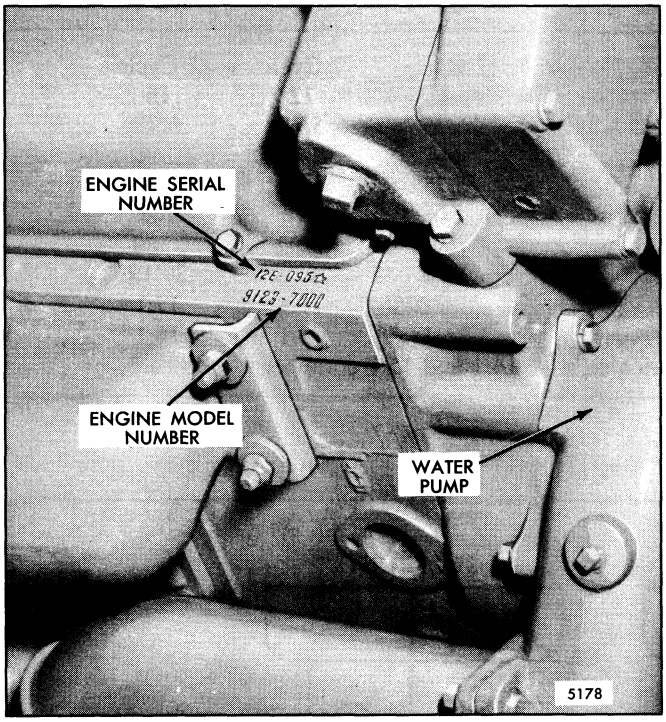



**Fig. 4 - Engine Serial and Model Number Identification**

• The unit serial number on 8V engines is stamped on the rocker cover rail at the left, rear corner of the block. The unit serial number on 12 V and 16V engines is stamped on the rocker cover rail at the right, front corner of the block (Fig. 4).

## Option Plate (Metal Labels)

A metal option plate, attached to one of the valve rocker covers (Fig. 5), was formerly used to carry the engine serial number and model number and list the optional equipment used on the engine.

## Option Plate (Paper Labels)

A paper/laminate engine option label (Fig. 6) is currently used to carry the engine serial number and model number, and list any optional equipment used on the engine. This label is attached to one of the valve rocker covers along with a disclaimer label and a bar code label which contains the engine serial number and customer specification number. • • •

• Distributors will provide their own label(s) in order to notify the customer of any distributor-made changes to Detroit Diesel manufactured engines. Distributor-typed label(s) will indicate the distributor name, address and the group/type revisions that reflect their changes to engines as originally manufactured by Detroit Diesel.

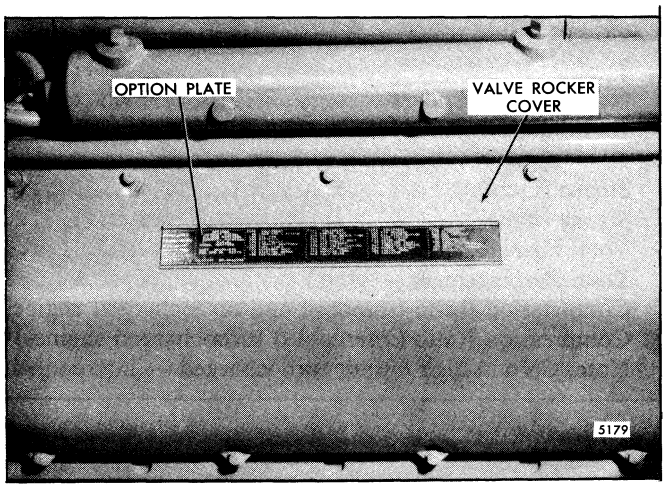



Fig. 5 – Option Plate

## Attaching Labels

Labels must be placed on rocker covers. Labels are designed to fit in the same space provided for the former stamped or current cast rocker cover option plate holder. Replacement option labels can be placed directly over existing option labels. Make certain the labels are applied to clean, dry, oil-free surfaces to assure adhesion and retention. Laminate should completely cover the label to provide a good seal.

The option plate holder on cast rocker covers is held to the cover by rivets in blind holes. Therefore, the option plate holder can be removed and the labels applied directly to the rocker covers.

**NOTICE:** Extreme heat from components such as turbocharger exhaust piping can cause the labels to darken, discolor or deteriorate over a period of time. Therefore, labels should be installed at alternate rocker cover locations.

With any- order for parts, the engine model number and serial number must be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

All groups of parts used on a unit are *standard* for the model, unless otherwise listed on the option label.

Power take-off assemblies, torque converters, marine gears, etc. may also carry name plates. The information on these name plates is also useful when ordering replacement parts for these assemblies.

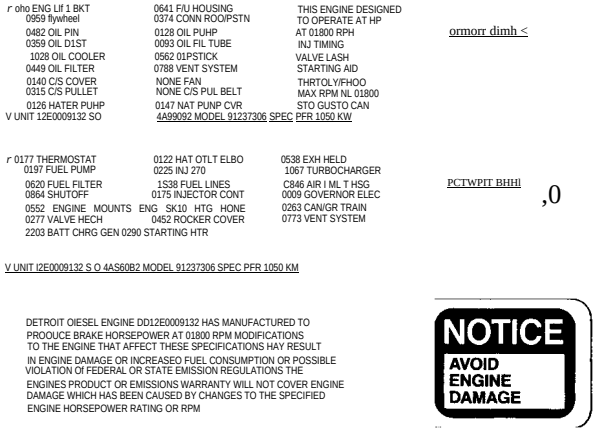



**Fig. 6 Typical Option Label**

Certain component parts used on a given engine model or in a particular engine type may be superseded or replaced at the discretion of DDC. In most cases when this occurs, only the newer part is available for service. Parts catalogs are revised periodically to reflect any changes.

# GENERAL PROCEDURES

In many cases, a Service Technician is justified in replacing parts with new material rather than attempting repair. However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Crankshafts, cylinder liners and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse, thereby saving the expense of a new part. Exchange assemblies such as injectors, fuel pumps, water pumps and blowers are also desirable service items.

Various factors such as the type of operation of the engine, hours in service and next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble-free operation.

For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

## DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, coolant, and fuel. On engines cooled by a heat exchanger, the fresh water system and raw water system must both be drained. Lubricating oil should also be drained from any transmission attached to the engine.

**CAUTION: To avoid being burned by the hot liquid, allow the engine to cool before draining the coolant.**

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be supported on a level surface; then the various subassemblies should be removed from the engine.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suitable wooden racks or blocks, or a parts dolly.

## CLEANING

Before removing any of the subassemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is outlined under *Clean Cylinder Block* in Section 1.1; any special cleaning procedures will be mentioned in the text wherever required.

### Steam Cleaning

A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

### Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provision made for heating the cleaning solution to 180-200°F (82-90°C).

Fill the tank with a commercial heavy-duty solvent which is heated to the above temperature. Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

### Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

### Drying

Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete drying of the parts without the use of compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

### Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in an engine.

## INSPECTION

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector.

The guiding factors in determining the usability of worn parts, which are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize and/or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets which include all of the parts necessary to complete a particular repair job are available.

A complete discussion of the proper methods of precision measuring and inspection are outside the scope of this manual. However, every shop should be equipped with standard gages such as dial bore gages, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other defects.

## ASSEMBLY

Following cleaning and inspection, the engine should be assembled using new parts as determined by the inspection.

Use of the proper equipment and tools make the job progress faster and produces better results. Likewise, a suitable working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment and space will be repaid many times.

Keep the working space, the equipment, tools and engine assemblies and parts clean at all times. The area where assembly operations take place should, if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should be removed as far as possible from the assembly area.

Particular attention should be paid to storing of parts and subassemblies, after removal and cleaning and prior to assembly, in such a place or manner as to keep them clean. If there is any doubt as to the cleanliness of such parts, they should be recleaned.

When assembling an engine or any part thereof, refer to the table of torque specifications at the end of each section for proper bolt, nut and stud torques.

To ensure a clean engine at time of rebuild, it is important that any plug, fitting or fastener (including studs) that intersects with a through hole and comes in contact with oil, fuel or coolant must have a sealer applied to the threads.

A number of universal sealers are commercially available. It is recommended that Loctite J 26558-97 *pipe sealer with teflon*, or equivalent, be used.

**NOTICE:** Certain plugs, fittings and fasteners available from the Parts Depot already have a sealer applied to the threads. This pre-coating will not be affected when the pipe sealer with teflon is also applied.

The sealer information above must not be confused with International Compound No. 2, which is a lubricant applied before tightening certain bolts. Use International Compound No. 2 only where specifically stated in the manual.

# CAUTIONS

## WORK SAFELY

**The service procedures recommended by Detroit Diesel Corporation and described in this service manual are effective methods of performing service and repair. Some of these procedures require the use of tools specially designed for the purpose.**

**Accordingly, anyone who intends to use a replacement part, service procedure or tool, which is not recommended by Detroit Diesel Corporation, must first determine that neither his safety nor the safe operation of the engine will be jeopardized by the replacement part, service procedure or tool selected.**

**It is important to note that this manual contains various "Cautions" and "Notices" that must be carefully observed in order to reduce the risk of personal injury during service or repair or the possibility that improper service or repair may damage the engine or render it unsafe. It is also important to understand that these "Cautions" and "Notices" are not exhaustive, because it is impossible for Detroit Diesel Corporation to warn of all the possible hazardous consequences that might result from failure to follow these instructions.**

A serviceman can be severely injured if caught in the pulleys, belts or fan of an engine that is accidentally started. To avoid such a misfortune take these precautions before starting to work on an engine:

1. Disconnect the battery from the starting system by removing one or both of the battery cables. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.
2. Make sure the mechanism provided at the governor for stopping the engine is in the stop position. This will mean the governor is in the no-fuel position. The possibility of the engine firing by accidentally turning the fan or, in the case of vehicle application, by being bumped by another vehicle is minimized.

## Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.
2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

• 3. The front engine lifter bracket is not designed to lift more than the basic engine. When lifting the engine with marine gear or generator attached or when removing a haul truck engine module, the proper hook points on the engine cradle or mounting rails *must* be used. Do not use the front lifter bracket alone under these circumstances. Failure to observe this precaution can result in personal injury and/or serious engine damage.

4. Always use caution when using power tools.

• 5. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury. Always wear adequate eye protection (safety glasses, safety face shield) when working with compressed air.

.6. To avoid possible personal injury when working with chemicals, steam and/or hot water, wear adequate protective clothing (face shield, rubber apron, gloves, boots, etc), work in a well ventilated area, and exercise caution.

• 7. Avoid the use of carbon tetrachloride, carbon disulfide, methylene, chloride, perchloroethylene and trichloroethylene as cleaning agents because of harmful vapors they release. Use 1,1,1-Trichloroethane. However, while less toxic than other chlorinated solvents, use it with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield and an apron. Follow chemical manufacturer's use and safety recommendations.

Exercise caution against chemical burns when using acids (Oxalic, phosphoric and nitric) and alkaline cleaners. Use protective gloves, goggles or face shield and an apron.

**CAUTION: Mineral spirits or mineral spirits based solvents are highly flammable. They must be stored and used in "No Smoking" areas away from heat, sparks and open flames.**

8. Use caution when welding on or near the fuel tank. Possible explosion could result if heat build-up inside the tank is sufficient.
9. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

,10. Failure to inspect parts thoroughly before installation, failure to install the proper parts, or failure to install parts properly can result in component or engine malfunction and/or damage and may also result in personal injury.

11. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals Of a battery which can result in severe arcing.

# . FABRICATING, ALTERING, REMOVING AND DISPOSING OF GASKETS

Many gasket materials contain bonded asbestos, which in itself presents no health hazard when handled properly. A health hazard may exist, however, if the asbestos in such materials is liberated and becomes airborne. This may occur if gaskets are fabricated or altered using the following improper methods: drilling, grinding, saw cutting or using practically all types of power operated machines and hand tools.

Gasket manufacturers and industrial hygienists prescribe specific methods for handling gasket material. The following guidelines are based on their recommendations. Detroit Diesel recommends that these guidelines be followed when fabricating or altering any gaskets.

1. Unless it is known otherwise, treat all gasket material as though it contains asbestos.

2. When cutting strips or blocks from sheets (blanking), hand cut with scissors, knife or paper cutter. Avoid creating dust.

3. Form outside dimensions with a punch die or hand cut with scissors, knife or compass.

4. For internal hubs use a punch die, hand cut with scissors, knife or compass, or punch by hand with a ballpeen hammer or ball bearing.

5. When stripping gaskets from parts, do not grind or file off the material or abraid it off with a wire brush or wheel. Use a putty knife to remove the gasket after it has been wetted with water or oil.

6. After fabricating or altering a gasket, clean the area to remove any particles which may have been generated. This should be done by wiping the area with a rag wetted with water or a water-based detergent. If large areas need to be cleaned, remove gasket dust and debris using an "HEPA" (High Efficiency Particulate Arrestor) vacuum cleaner. Do not clean the area by blowing with compressed air or brushing.

Place the rags containing the waste and any scrap gasket material in an impervious container labeled with the OSHA (Occupational Health and Safety Administration) designated caution (Fig. 6) and dispose of it in a solid waste disposal facility (land fill) which will accept asbestos material. Heavy plastic garbage bags (6 mills thick), each sealed separately, or other closed and impermeable container may be used.

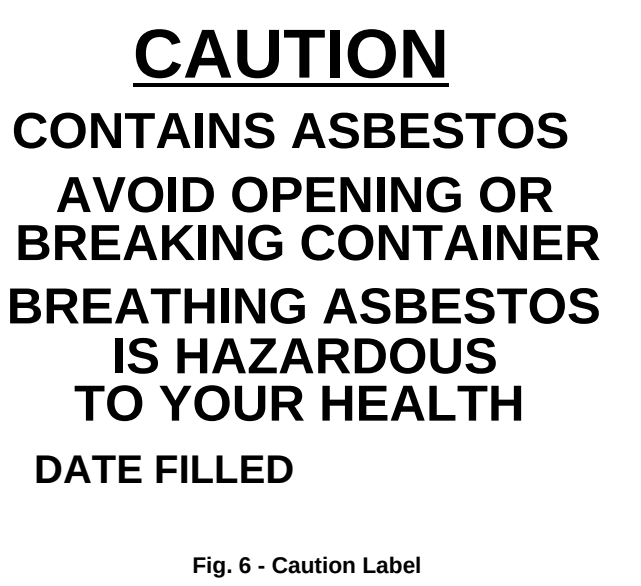
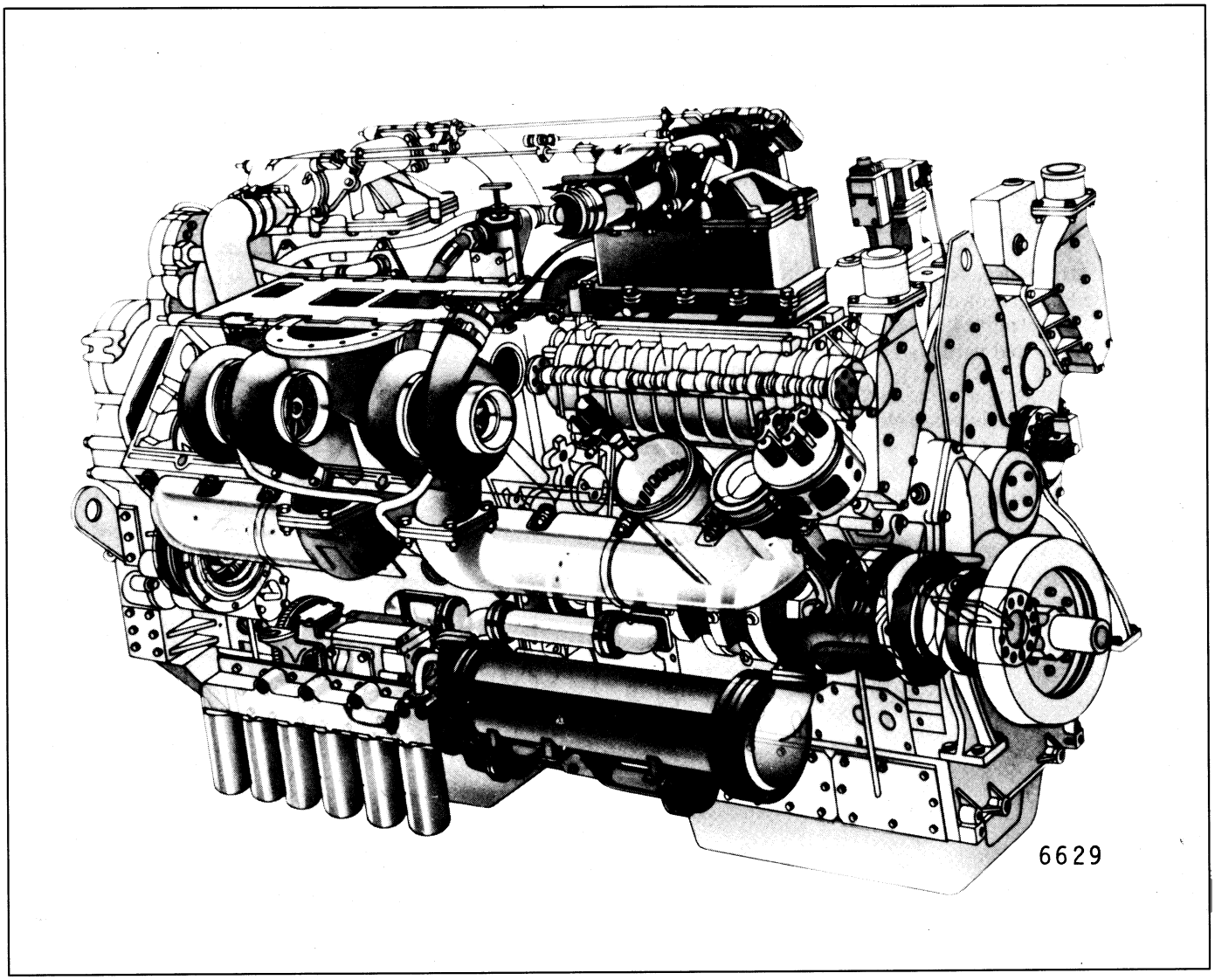
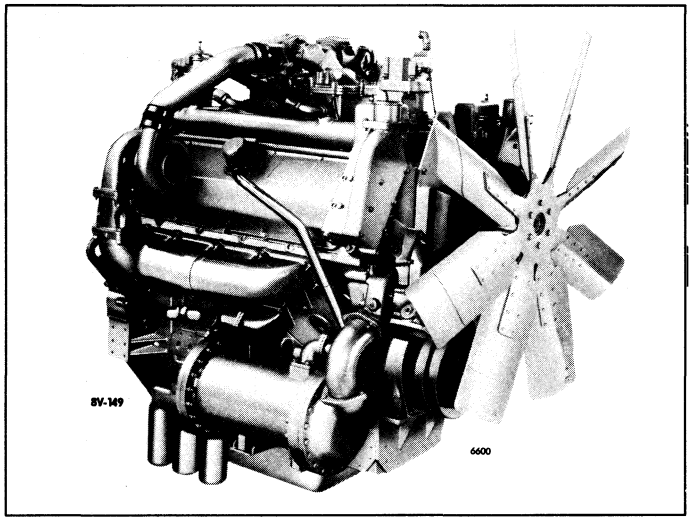



**Fig. 6 - Caution Label**

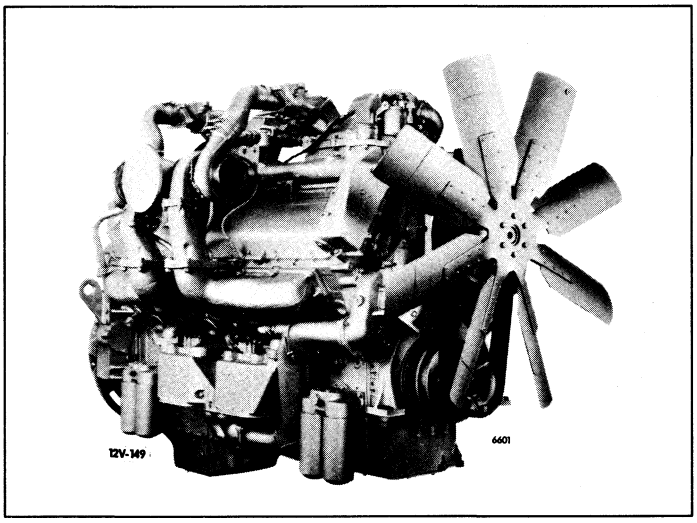



Three Quarter Cross Section View of 16V-149 Engine

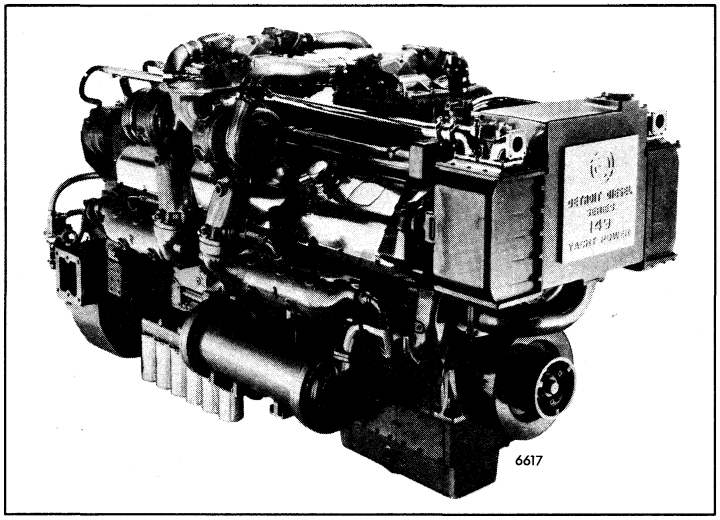
 




Turbocharged - Intercooled Engine Typical 8V-149




Turbocharged - Intercooled Engine Typical 12V-149




Turbocharged - Intercooled Engine Typical 16V-149

# SECTION 1

## ENGINE (LESS MAJOR ASSEMBLIES)

### CONTENTS

# CYLINDER BLOCK

The cylinder block serves as the main structural part of the engine (Fig. 1). The various subassemblies and parts must be removed from the cylinder block when an engine is overhauled.

New service replacement cylinder block assemblies include the crankshaft main bearing caps, bolts and washers and the camshaft bearing caps and bolts. The necessary dowel pins and plugs are also included.

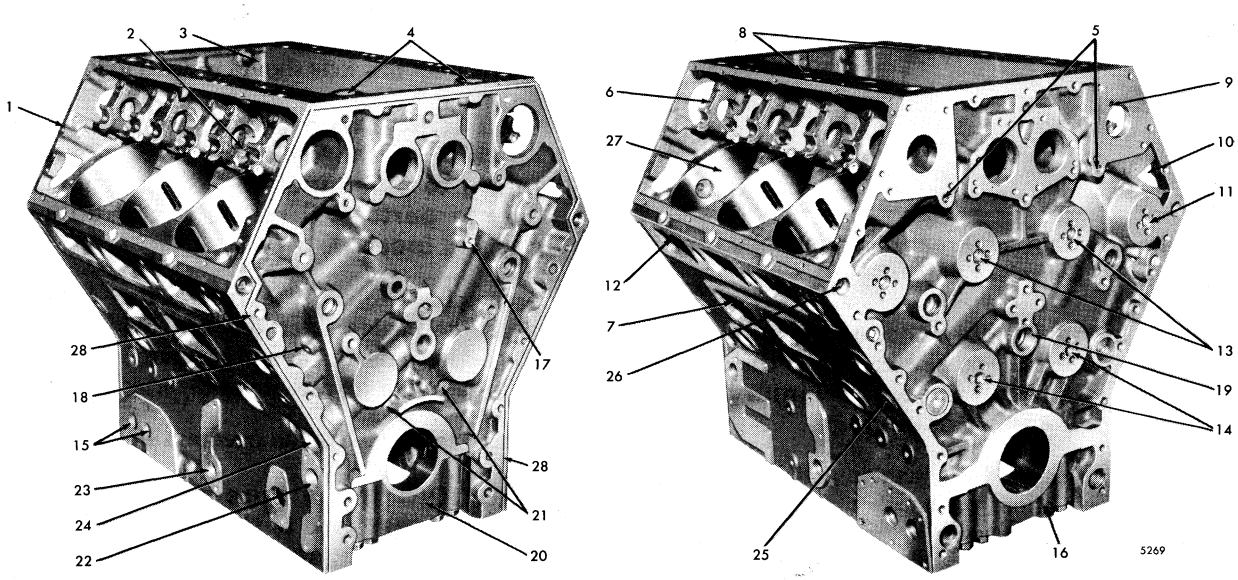
Effective with engine serial numbers 12E-5672 and 16E-5308, new cylinder block air box cover plates are being used on all engines in conjunction with the new cast breather body assembly (Section 4.8). The new cover plates are required due to the elimination of the two 1.56" diameter breather system holes. Both the former and new cover plates are serviced.

• Effective with engine serial numbers 8E02613, 12E09006, and 16E09109 new cylinder blocks with strengthened intermediate main bearing journals are used. The new blocks are similar to the former, except that intermediate main bearing journal web areas are cast thicker. The thicker journals are at the No. 2 and 3 positions on 12V-149 block halves, and at the No. 2, 3, and 4 positions on the 8V-149 block and the 16V-149 block halves. The new blocks can be distinguished from the former by the wider cast webs and broadened yokes above the strengthened journals (Fig. 2).

**NOTICE:** During an in-frame overhaul, use cylinder bore plug set J 34727 to help prevent solvent and debris from entering the crankcase while cleaning the air box.

## Remove And Disassemble Engine

**•CAUTION: The front engine lifter bracket is not designed to lift more than the basic engine. When lifting the engine with marine gear or generator attached or when removing a haul truck engine module, the proper hook points on the engine cradle or mounting rails *must* be used. Do not use the front lifter**




1. Cylinder Block
2. Camshaft Oil Supply Holes
3. Air Box
4. Crankcase Breather Pipe Bores
5. Upper Oil Galleries
6. Camshaft Bearing Cap
7. Air Box Inspection Holes
8. Upper Water Passage Holes
9. Camshaft Gear Oil Supply
10. Oil Drain Hole
11. Accessory Drive Gear Oil Supply
12. Exhaust Ports
13. Upper Idler Gear Oil Supply
14. Lower Idler Gear Oil Supply
15. Oil Filter Supply Holes
16. Rear Main Bearing Cap
17. Cross Hole to Blower Oil Feed Hole
18. Blower Oil Drain
19. Main Oil Gallery
20. Front Main Bearing Cap
21. Crankcase Breather Holes
22. Oil Cooler Oil Return
23. Oil Cooler Oil Supply
24. Turbocharger Oil Supply
25. Air Box Drain
26. Exhaust Port Water Cooling Hole
27. Cylinder Head Bore
28. Seal Groove (rear block only)

**Fig. 1 - Cylinder Block (12V-149 Rear Block Shown)**

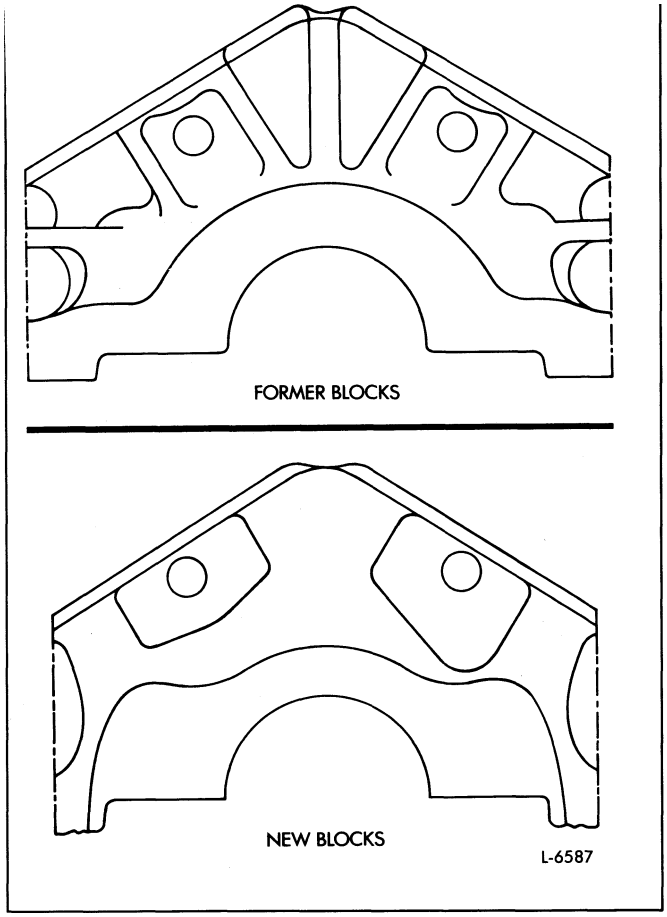



**Fig. 2 - Bearing Journal Web Areas on Former and New Cylinder Blocks**

**bracket alone under these circumstances. Failure to observe this precaution can result in personal injury and/or serious engine damage.**

Details for removing and disassembling the engine will vary from one application to another. However, the following steps will be necessary.

1. Drain the cooling system.
2. Drain the lubricating oil.
3. Disconnect the fuel lines.
4. Remove the air silencer or air cleaner and mounting bracket.
5. ' Remove the turbochargers, if used.
6. Disconnect the exhaust piping and remove the exhaust manifolds.
7. Disconnect the throttle controls.
8. Disconnect and remove the starting motor, battery-charging generator or alternator and other electrical equipment.
9. Remove the air compressor, if used.
10. Remove the radiator and fan guard, or the heat exchanger and other related cooling system parts.
11. Remove the air box drain tubes and fittings.
12. Remove the air box covers.
13. Disconnect any other lubricating oil lines, fuel lines or electrical connections.
14. Separate the engine from the transmission or other driven mechanism. For instructions on removal of the various transmissions used, see the instruction manual for the particular transmission on the unit.
15. Remove the bolts that fasten the engine to the equipment which it powers.
16. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base (Fig. 3). To prevent bending of the engine lifter brackets the lifting device should be adjusted so the lifting hooks are vertical. To ensure proper weight distribution, all engine lifter brackets should be used to lift the engine.

**CAUTION: Do not lift an engine by any opening in the cylinder block. Severe injury to personnel and destruction of engine parts will result if the engine casting breaks.**

A complete electric drive truck module must never be lifted with the engine lifter brackets. This could affect alignment between the engine and generator. A module must be lifted in the same manner it is supported in the vehicle.

17. Mount the engine on an overhaul stand.

**CAUTION: Make sure the engine is securely fastened to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks "away from the overhaul stand.**

18. Remove all of the remaining subassemblies and parts from the cylinder block.

The procedure for removing each subassembly from the cylinder block, together with disassembly, inspection, repair and reassembly of each, will be found in the various sections of this manual.

After stripping, the cylinder block must be thoroughly cleaned and inspected.

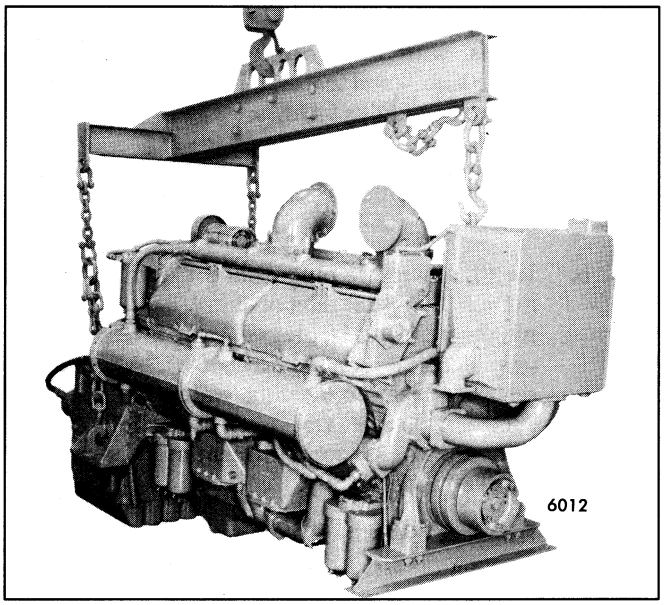



**Fig. 3 - Lifting Engine with Spreader and Sling**

## Clean Cylinder Block

Scrape all gasket material from the cylinder block. Then, remove all of the plugs (except cup plugs) from the block. Also, remove all of the core hole plugs to allow the cleaning solution to contact the inside of the water and oil passages. This will permit more efficient cleaning and eliminate the possibility of the cleaning solution attacking the aluminum water hole plug gaskets which would result in internal leaks and eventual engine damage.

After a cylinder block has been in service, water hole plugs may be difficult to remove. To facilitate removal, hold a drift against the plug and give it a few sharp blows with a one pound hammer. Exercise care when striking the drift so as not to damage the cylinder block. After the core hole plugs have been loosened, they can be easily removed and installed with tool J 23019.

Clean the cylinder block as follows:

**• CAUTION: To avoid personal injury when using steam or chemicals to clean an engine or engine component, always wear adequate face and body protection (faceplate, gloves, boots, waterproof apron, etc.)- In addition, when using chemical solutions, make sure the cleaning area is properly ventilated and follow chemical manufacturer's use and safety recommendations.**

1. Remove the grease and oil by placing the cylinder block in a hot bath of commercial heavy-duty alkaline cleaner solution.
2. Rinse the block in hot water or steam clean it to remove the alkaline solution.
3. If the water jackets are heavily scaled, proceed as follows:
   a. Place the block in a bath of inhibited phosphoric acid.
   b. Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).
   c. Lift the block, allow it to drain and reimmerse it in the same acid solution for ten (10) minutes.
   d. Repeat Step “c” until all scale is removed.
   e. Rinse the block in clear hot water to remove the acid solution.
   f. Neutralize the remaining acid that may cling to the casting by immersing the block in an alkaline bath.
   g. Wash the block in a bath of clean water or steam clean it.
4. Dry the cylinder block with compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

5. Make certain that all of the water passages, oil galleries, cylinder liner seal ring grooves and air box drain openings have been thoroughly cleaned to permit the cooling and lubricating systems to function efficiently.

The above cleaning procedure may be used on all ordinary cast iron and steel parts of the engine. Mention will be made of special cleaning precautions whenever necessary.

6. After the cylinder block has been thoroughly cleaned and dried, coat the threads of the plugs with sealant and, using new gaskets, install the core hole plugs. Tighten the plugs to 150-180 lb—ft (204-244 N#m) torque.

Lubricate the threads and washer face of the 1 3/4”-16 plugs in the end of the block with International Compound No. 2, or equivalent, and tighten the plugs to 150-200 lb—ft (204-271 N#m) torque.

Coat the threads and washer face of the 2 1/2”-16 plugs in the air box with a good grade of coolant resistant sealant and tighten the plugs to 220-250 lb—ft (298-339 N«m) torque.

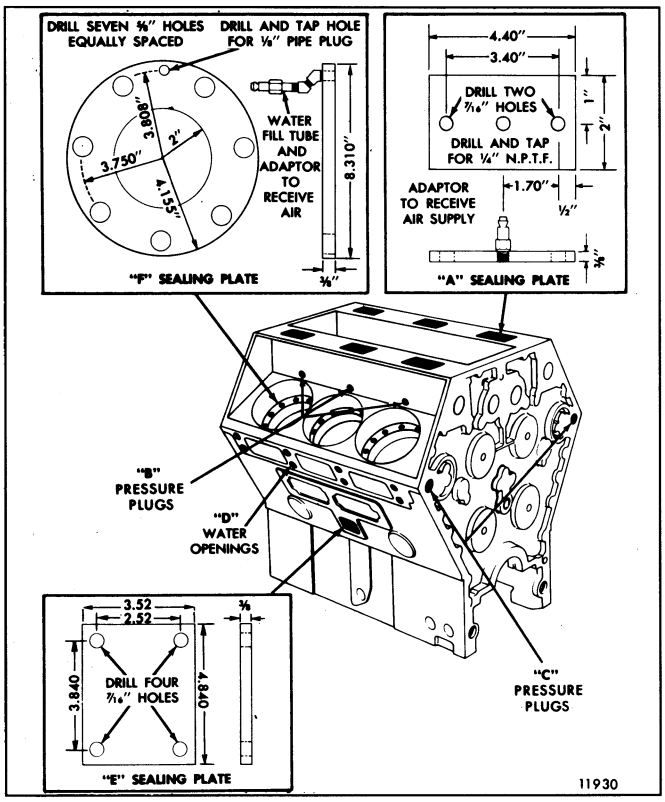



**Fig. 4 - Instructions For Sealing Block For Pressure Test**

Coat the threads of the 3/4"-14 brass plugs in the end of the block with Loctite Pipe Sealant with Teflon (J 26558-92) or equivalent. Tighten the plugs to 75-80 lb-ft (102-108 N«m) torque. The plugs must be water tight and must be flush or below the surface. If the block was equipped with 3/4"-14 steel pipe plugs, install new brass pipe plugs which are precoated with Vibra-seal thread sealant. Do not remove this coating.

## Pressure Test Cylinder Block

When a cylinder block is suspected of being cracked or when there is a noticeable loss of coolant with no obvious cause, the block should be pressure tested. There are two methods to pressure test a cylinder block. The first method (A) is to submerge the entire block in a water tank and apply air pressure inside the block, The second method (B) is to place a mixture of antifreeze and water inside the block and apply air pressure. With either method it will be necessary to seal all of the water openings in the cylinder block with appropriate plugs, seals and plates (pressure testing tool set J 24051). Fig. 4 indicates the types of plugs, seals and plates required and their relative location for sealing during the pressure test.

### METHOD A

This method is recommended when there is a water tank available large enough to submerge the block.

1. With the cylinder block completely stripped of all components, with the exception of plugging, studs, etc., refer to Fig. 4 and seal off all of the water inlet and outlet holes air tight as follows:

   a. Position a plate (A) and rubber gasket over each "A" water outlet opening along the top of the block.

   b. Install a pressure plug from tool set J 24051-B in each "B" water inlet opening (8 plugs - 8 V, 12 plugs - 12 V and 16 plugs - 16V). If desired, it is only necessary to use one set of "A" and "B" seals as their connecting water jacket is not common to the rest of the cooling system. Regardless, each compartment must be pressure checked individually.

   c. Install a pressure plug in each "C" water opening.

   d. If the exhaust manifold studs were removed, use suitable seal rings and 20 (8V), 32 (12V) or 40 (16V) l/2"-13xl$^{M}$ bolts to seal each "D" water opening.

   e. Position a plate (E) and suitable rubber gasket over each oil cooler to cylinder block "E" water opening and secure each plate using four 3/8M—16 x 1-1/4" bolts.

   f. Apply hydrogenated vegetable type shortening to 16 (8V), 24 (12V) or 32 (16V) seal rings and position two (2) in the seal ring grooves within each "F" cylinder opening.

   g. Slide another seal ring over a spare cylinder liner and position a cylinder liner in each "F" cylinder opening, using care not to dislodge the seal rings. If possible, use only the top half of cylinder liners which are cut at the port locations. With only half of the liner in the cylinder block, it will be easier to note any leak in the lower area.

   h. Place seven (7) water seal rings in each set of cylinder block to cylinder head water inlet openings.

   i; Position an "F" seal ring plate over the cylinder liner and seal rings of each cylinder and secure each plate with seven (7) 9/16"-18 x 2-1/4" bolts.

2. Make sure all of the plugs and seals are tight and apply 40 psi (276 kPa) air pressure to the cylinder block water jacket.

3. Immerse the cylinder block for twenty (20) minutes in a tank of water heated to 18O-2o0t (82-93°C). Observe the water tank for air bubbles indicating cracks or leaks.

4. After the pressure test is completed, blow out the passages with dry compressed air. Replace the cylinder block if leaks or cracks are detected in the water or oil passages.

### METHOD B

This method may be used when a large tank is unavailable or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove as many of the internal and external components as possible.

1. Attach the sealing plates and plugs as outlined in Step 1 of Method "A".

2. Loosen up the pipe plugs in the "F" seal ring plates and fill the block water jacket with a mixture of water and two (2) gallons of antifreeze. *Do not use methoxy propanol base antifreeze as it is detrimental to the water seals.*

The water passages between each set of "A" and "B" openings will have to be filled separately since these passages are separate from the rest of the cooling system.

3. When the block is completely filled and the air is vented through the pipe plugs, tighten the pipe plugs securely. Apply 40 psi (276 kPa) air pressure to the cooling system. Maintain this air pressure for at least two hours to allow the water and antifreeze mixture ample time to work its way through any cracks which may exist.

4. At the end of this period, examine the cylinder bores, airbox, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture which will indicate cracks.

5. After the test is completed, remove the plates, plugs and seal rings, drain the cooling system and blow out the passages with dry compressed air.

## Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

1. Make sure the seal ring grooves in the block bores are thoroughly clean. Then, inspect the grooves and lands for evidence of pitting and erosion. Seal rings are used in the two grooves above the air inlet ports. If the grooves are eroded to the extent that sealing is affected, the block must be replaced. A .01(T oversize cylinder liner to cylinder block water seal ring is available as a service item. Refer to Section 1.0 for the cylinder block rework dimensions.

2. Measure each cylinder block bore, at the positions indicated in Fig. 5, on axis 90° apart. If the diameter does not exceed 6.5260" at position "A", 6.5050" at position "B" and 6.4040" at positions "C" and "D" and a sealing problem has not occurred at position "B", the block may be reused. Also, the taper and out-of-roundness must not exceed .0015". Dial bore gage setting master fixture J 23059-01 may be used to set bore gage J 5347-B and dial bore gage extension J 5347-2 to zero.

3. When replacing cylinder kits, always inspect the cylinder liner flange seating surface in the cylinder block for nick, dents or corrosion damage. Coolant leakage can occur if the liner flange seating area is damaged or if the seat for the water sleeve and spacer seal ring is eroded. Carefully, remove all corrosion scale deposits from the seating surface and seal seating area with a wire brush, being careful not to cause further damage by excess use of the brush. Excessive wire brushing could cause another leak path. Inspect both seating surfaces for signs of pitting, fretting, nicks, dents and/or corrosion erosion. Corrosion damage can occur if coolant inhibitor strength is not properly maintained or if there are minor leaks.

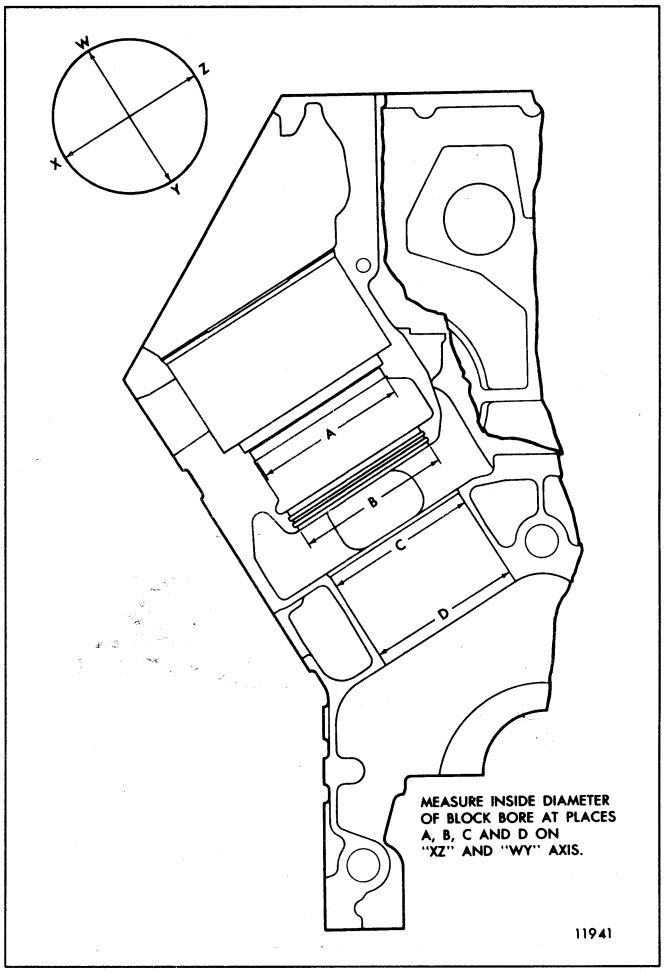



Fig. 5 – Block Bore Measurement Locations

**NOTICE:** Avoid damaging the liner flange seating surface by completely loading one cylinder kit at a time. This procedure, as outlined in Section 1.6.3, is more desirable than setting the kits into the counterbores and allowing them to rest on the seating surfaces of the cylinder block waiting for complete loading. If kits are set into the counterbores and allowed to rest on the seating surfaces of the block until the technician can lower each kit into its bore, the seating surfaces can become nicked or dented without the knowledge of the technician.

Two methods can be used to check for liner seating surface damage (a leak path):

In both methods lightly blue the underside of a new liner flange with a small, short-bristle brush. Spread the Prussian blue thinly and evenly around the full circumference of the liner flange. Do not use excessive Prussian blue.

a. Install the liner in the block. Reinstall the cylinder head with a compression gasket and lightly snug down the cylinder head bolts. The use of a liner-to-block seal or head-to-block seal is not necessary for this check, but a new or used compression gasket must be used. Remove the head and liner and inspect the block counterbore.

b. Following the bluing procedure above, install the liner in the block (a block-to-liner seal is not required for this test). Press down firmly and evenly on top of the liner, then rotate the liner approximately 15° in each direction two or three times. Remove the liner and inspect the block counterbore.

After either method is used, inspection of the liner sealing surface will reveal leak paths where the Prussian blue did not transfer from the underside of the liner flange.

If inspection of the block indicates that the cylinder liner seat or water sleeve and spacer seal ring seat requires resurfacing, the crankshaft center line-to-cylinder liner seat distance must be measured before machining. This can be done using tool PT-5075B with kit PT-5071A. The current dimension is 17.895”—17.910” (Fig. 6). Although most cylinder blocks are factory machined to the side of this specification, only the minimum amount of material should be removed during the initial resurfacing operation (Fig. 7). This allows for additional resurfacing at future overhauls. Detroit Diesel recommends that this resurfacing operation be performed only by a competent machine shop.

**NOTICE:** Overmachining can cause improper piston-to-cylinder head clearance. This can result in serious engine damage.

4. In the former *counterbored* cylinder blocks, effective with approximate engine serial numbers 12E-1490 and 16E-233, a 3/8” x 1.20” long crimped-type sleeve (Fig. 8) is installed in each cylinder block water hole supplying coolant to the cylinder head. This prevents the possibility of the water hole seal ring from becoming dislodged from the counterbore in the cylinder liner flange area of the cylinder block.

If there is evidence of a crack at the cylinder liner flange fillet through to the water hole, remove the crimped sleeve and install a non-crimped sleeve (Fig. 8).

Install a *non-crimped* water hole sleeve as follows:

a. Ream the cylinder head-to-block water holes in the cylinder block. Use a 25/64” reamer to increase the hole diameter from 3/8” to 25/64”. To facilitate reaming, grind a 3/8” diameter pilot 1/2” in length on the end of the reamer.

b. Clean the reamed holes and the counterbores thoroughly with a solvent.

c. Apply HVV “Loctite” pipe sealant to the surfaces of the newly reamed holes.

d. Install the water hole sleeves in the water holes with sleeve installer J 24233-01. The tool will install the sleeves to the proper depth so they will extend up into the counterbores sufficiently to retain the seal rings.

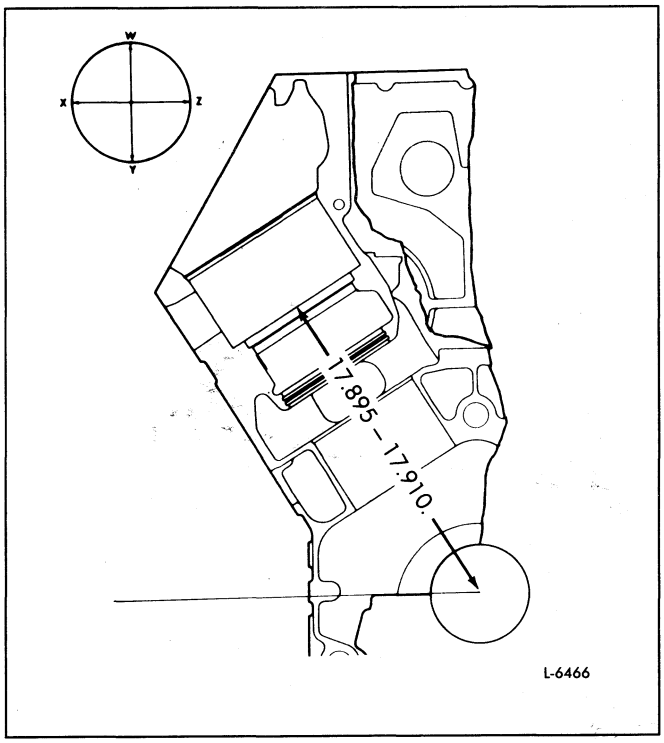



**Fig. 6 - Crankshaft Center-to-Liner Seat Dimension**

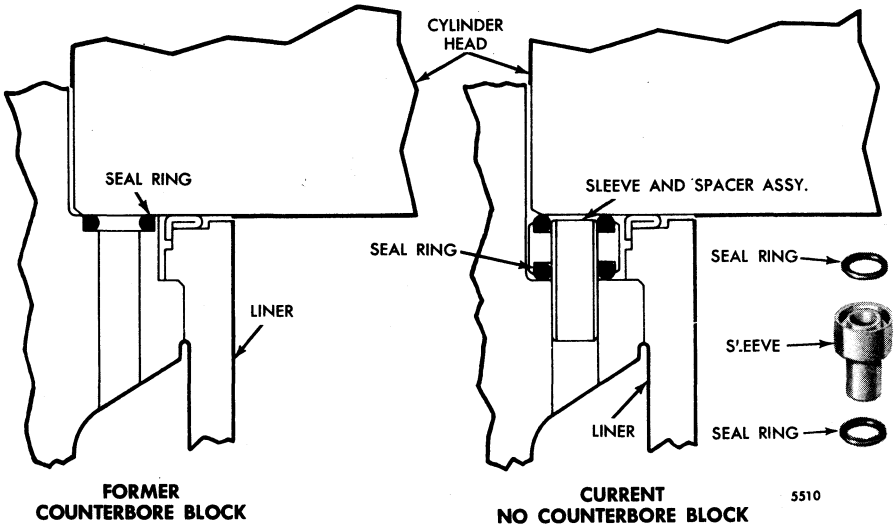



**Fig. 7 - Former and Current Cylinder Block and Seal Rings**

e. Clean the *Loctite* thoroughly from the counterbores.

f. Slip new red seal rings, which have an oval cross-section, over the sleeves and into the counterbores.

On engines built prior to the above serial numbers, a water hole sleeve must be installed the first time that the cylinder head is removed. Install a non-crimped sleeve whenever there is evidence of a crack or a leak at the cylinder liner flange fillet. Install the non-crimped sleeve when adequate facilities are available to insure the proper removal of all metal chips caused by the reaming process. Install crimped sleeves in water holes without leaks or cracks for "in-frame" overhauls.

Install *crimped* water hole sleeves as follows:

a. Clean the water holes and the seal counterbores thoroughly with a solvent.

b. Install the water hole sleeves in the water holes with sleeve installer J 24233-01. The tool will install the sleeves to the proper depth so the sleeves will extend up into the counterbore sufficiently to retain the seal rings.

In the current cylinder block, effective with engine serial numbers 12E-1703 and 16E-361, the counterbore for the cylinder liner was eliminated (Fig. 7). With the elimination of the counterbore for the cylinder liner, the small counterbores at the coolant holes were also eliminated. To conform with this change, a new coolant hole sleeve and spacer (serviced as a unitized assembly) is also used. In the current no-counterbore cylinder block, two seal rings are used at each coolant hole, one against the cylinder block and one against the cylinder head. The former counterbored cylinder block, with or without sleeves, used only one seal ring at each coolant hole.

The current sleeve is made from stainless steel and can be reused. Replace the seal rings each time the cylinder head is removed.

During extended engine operation, corrosion may build up in the water passages below the sleeves and prevent a new sleeve from seating properly. To properly clean the cylinder block water holes at engine overhaul, remove the old sleeve and use a hand or power driven 3/8" straight reamer. *Do not remove any cylinder block material.* Do not use a drill, abrasive paper or a wire brush. The reamer, with its straight flutes, will pilot in the undamaged portion of the water hole and will only remove the build up of corrosion. After cleaning the water hole, insert a new sleeve and spacer assembly without the lower seal ring. If the sleeve will hot bottom without forcing, repeat the cleaning operation.

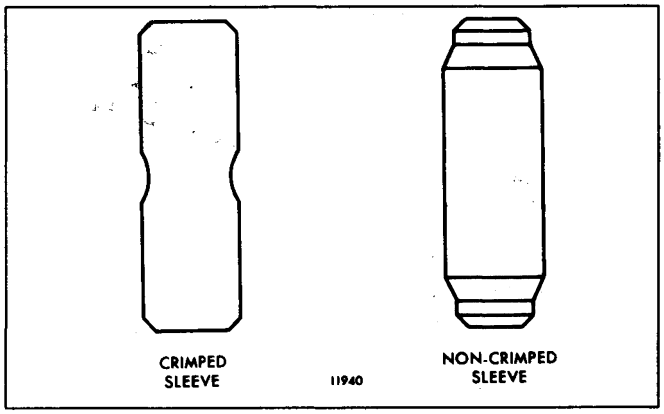
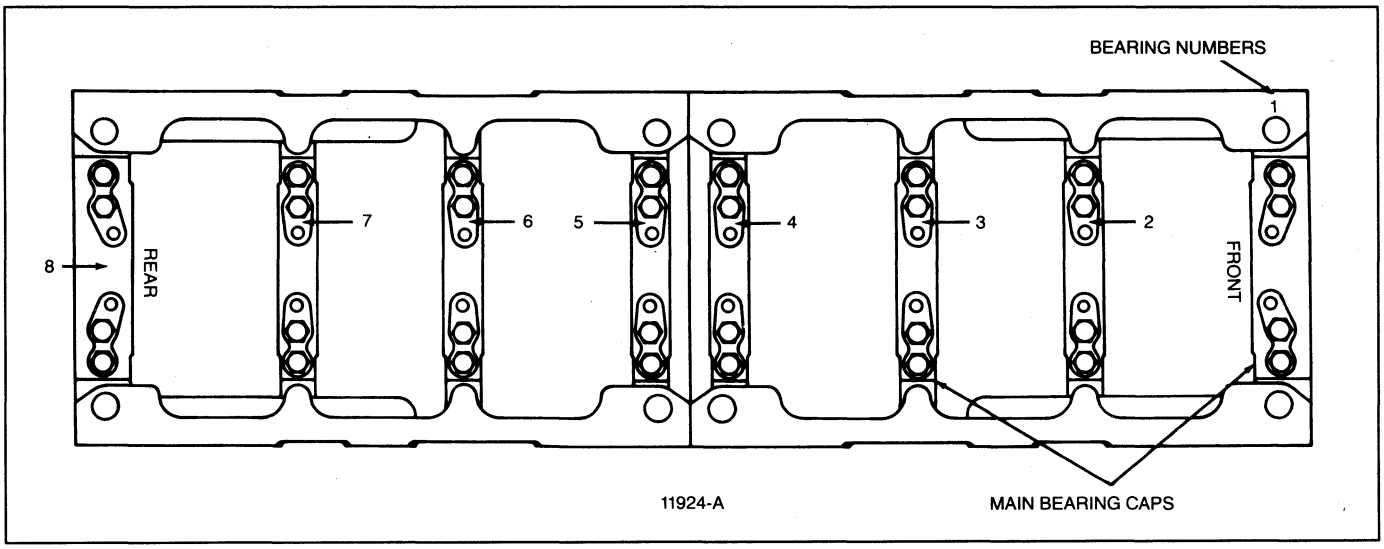



**Fig. 8 - Water Hole Sleeves (Counterbored Cylinder Block)**




**• Fig. 9 - Typical Cylinder Block Markings**

Only the current *no-counterbore* front and rear cylinder blocks are serviced. When replacing a former *counterbored* front or rear cylinder block with the current *no-counterbore block,* an additional seven (7) coolant hole seal rings per cylinder (14 per cylinder total) and seven (7) sleeve and spacer assemblies per cylinder are required.

The current *no-counterbore* block halves can be mixed with the former *counterbored* block halves in an engine.

5. Check the main bearing bores as follows:

   a. Check the bore diameters with the main bearing caps in their original positions. Bearing caps are numbered to correspond with their respective positions in the cylinder block. *It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment The number of front main bearing cap is also stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture.* The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 9). Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Then, install and tighten the bolts to the specified torque (Section 1.0). The specified standard bore diameter is 5.1870" to 5.1880". If the bores do not fall within these limits, refer to *Shop Notes* in Section 1.0. Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

   b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a *finished* replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. *If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap.* Use the unfinished bearing caps for the *front and intermediate bearing* positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the *rear bearing* position.

   c. Main bearing bores are line-bored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured In place and the bolts tightened to the specified torque (Section 1.0). Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

   d. If the main bearing bores are not in alignment when a replacement bearing cap is used, the block must be line-bored. *Install the bearing caps in their original positions and tighten the bolts to the specified torque (Section 1.0).* After boring, all bores must be within the specified limits of 5.1870" to 5.1880". However, if it is necessary to line bore the cylinder block oversize, refer to *Shop Notes* in Section 1.0.

6. Refer to the *Cylinder Block Plugging Charts* in Shop Notes - Section 1.0 and install necessary nut and dowels.

7. Air box top cover plates on all 16V-149TI engines built between engine serial numbers 16E-5376 and 16E-6261 should be visually inspected during shceduled maintenance. If the top cover plate is cracked, it must be replaced and the "T" shaped inspection hole cover and gasket installed in place of the square cover. If the top cover plate is not damaged, the square inspection hole cover should still be removed and replaced with the "T" shaped cover and gasket. Make sure that dirt, debris or moisture do not enter the engine during air box top cover plate inspection and installation.

8. Cup plugs are used to seal the breather holes in the cylinder block on current turbocharged engines using rocker cover breathers. To install cup plugs in early engines, refer to *Shop Notes* in Section 1.0.

9. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .6800". The dowels used to retain the crankshaft thrust washers on the rear main bearing cap must extend .110" to .120" from the surface of the bearing cap.

10. Check the cylinder block machined surfaces and threaded holes. Check all of the mating surfaces or mounting pads for flatness, nicks and burrs. Clean-up damaged threads in the tapped holes with a tap or install helical threaded inserts, if necessary.

11. After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time, spray or dip it in a rust preventive compound. Castings free of grease or oil will rust when exposed to the atmosphere.

## Assemble And Install Engine

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

Before a reconditioned or new service replacement cylinder block is used, thoroughly clean it to remove the rust preventive and blow out the oil galleries with compressed air.

1. If a new service replacement block is used, stamp the engine serial number and model number on the new block. Also, stamp the position numbers on the main bearing caps and the position of the No. 1 bearing on the oil pan mounting flange of the block.

2. Install all of the required cylinder block plugs and drain cocks. Use a good grade of non-hardening sealant on the threads of the plugs and drain cocks. Install the plugs flush with or below the surface of the block.

3. Clean and inspect all engine parts and subassemblies and, using new parts as required, install them on the cylinder required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and subassemblies are outlined in the following sections of this manual.

4. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.

5. Complete the engine build-up by installing all remaining accessories, fuel lines, electrical connections, controls etc.

6. Operate the engine on a dynamometer, following the *run-in* procedure as outlined in Section 13.2.1.

7. Reinstall the engine in the equipment which it powers.

# CYLINDER BLOCK DISASSEMBLY AND ASSEMBLY PROCEDURE (12V OR 16V ENGINES)

## Disassemble Cylinder Block

1. Attach suitable lifting brackets to the end of the front cylinder block (Fig. 10).

**• CAUTION: NEVER use eyebolts or any other commonly purchased hardware to lift the cylinder block. Due to the weight of the blocks, it is important that the lifting brackets are constructed (Fig. 10) and that all weld joints are magnafluxed prior to and periodically after initial use.**

2. Attach a chain hoist to the brackets. Lift the cylinder blocks into a *vertical* position and rest the end of the rear cylinder block on a clean flat surface.

3. Refer to Fig. 11 and remove the fifteen (15) bolts securing the two (2) cylinder blocks together.

4. Remove four (4) 5/16"-18 x 5/8" bolts and lockwashers from the two (2) center upper cylinder block drain screens, located in the cylinder head area between both blocks. Remove both drain screens.

5. Lift the front cylinder block off of the rear cylinder block and remove the seal strip and seal rings from the rear block.

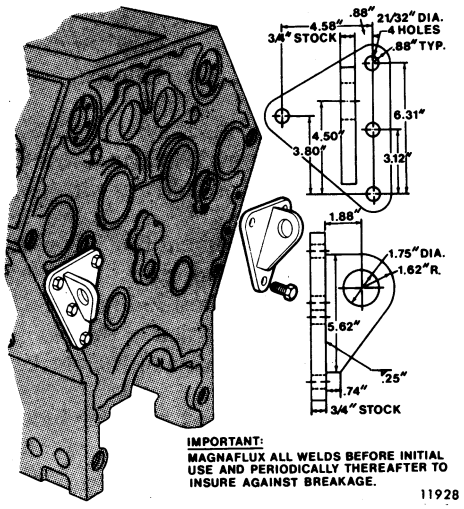



**Fig. 10 - Details of Cylinder Block Lifting Plates**

## Inspection

Clean the cylinder blocks as outlined under *Clean Cylinder Block* in this section.

Examine the entire contact surface of each cylinder block. Remove any burrs with a suitable file or stone.

Check and clean the attaching bolt holes in each cylinder block with compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine and clean the cylinder block attaching bolts. Replace any of the bolts that are damaged or rusted.

Refer to the *Cylinder Block Plugging Chart* in Shop Notes - Section 1.0 and install the necessary plugs and dowels.

## Assemble Cylinder Block

1. Place the rear cylinder block on a clean flat surface with the inter-block seal groove in the front end of the block facing up.

2. Check and clean the seal grooves and the entire top surface of the cylinder block.

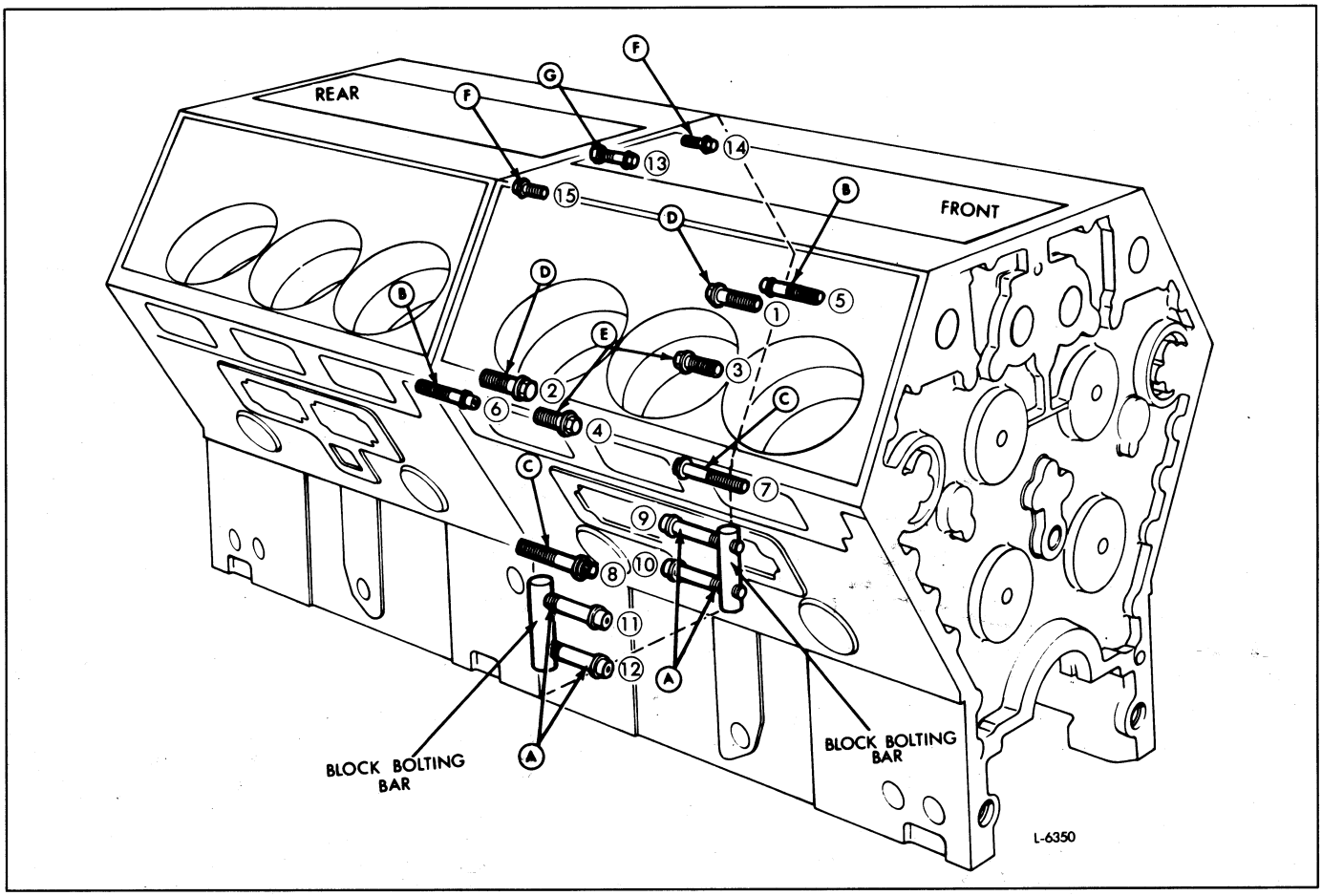



Fig. 11 – Location, Size and Tightening Sequence of Cylinder Block Attaching Bolts

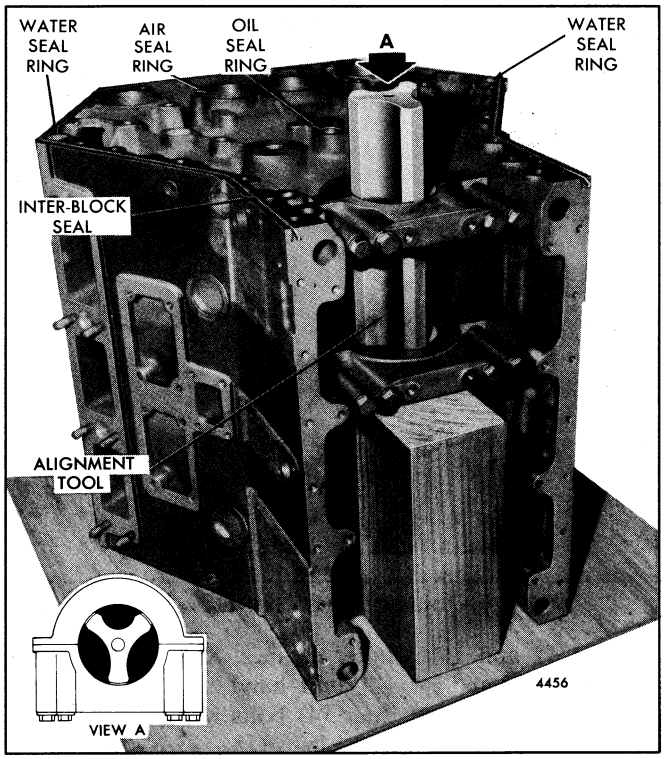



**Fig. 12 - Positioning Crankshaft Bore Alignment Tool**

3. Support the cylinder block bore aligning tool J 22486 (Fig. 12) and secure it to the block with two main bearing caps. Tighten the main bearing cap bolts to 280-290 lb—ft (379-393 N*m) torque. Place the cylinder block alignment tool in the main bearing bore with the three contact points of the tool located as shown in Fig. 12.

• 4. Apply a thin coat of Permatex High Tack Adhesive in the first 9” of the seal groove at the bottom of the block. Then, place a new inter-block seal in the groove in the block. Apply a thin coat of grease on the exposed flat surface of the inter-block seal. The inter-block seal must lay flat in the groove and must not be twisted.

#5. Apply a thin coat of spray adhesive around the edge of the oil gallery opening and place a new seal ring in position (Fig. 13).

• 6. Apply a thin coat of spray adhesive around the edge of the exhaust port coolant holes (Fig. 13) and place a new water seal ring in position in both holes.

• 7. Apply a thin coat of spray adhesive around the edge of the blower drive coupling hole (Fig. 12) and place a new air seal ring in position. Engines built prior to 12E-1040 and 16E-057 did not use the air seal ring. On these engines, apply a thin coat of sealant around the blower drive coupling hole.

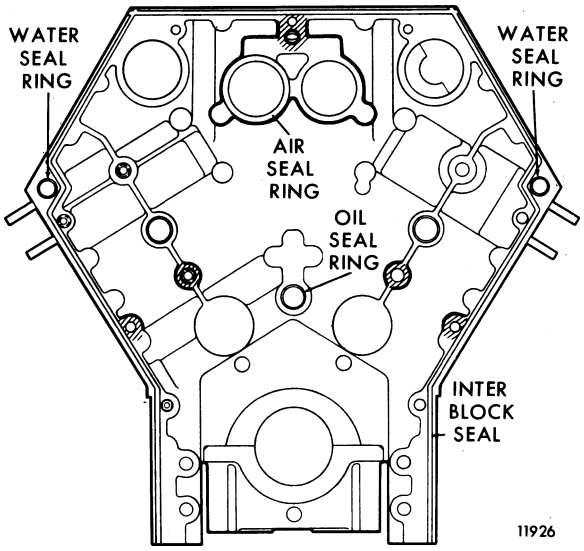



**Fig. 13 - Locations For Sealant Application**

• 8. Apply a thin coat of Loctite No. 515 Gasket Eliminator to the cylinder block as indicated by the shaded areas (Fig. 13). Clean any excess gasket eliminator from the cylinder block.

9. Attach the lifting brackets to the rear end of the front cylinder block (Fig. 10).

10. Attach a chain hoist to the brackets and lift the cylinder block approximately four feet off of the floor. Check and clean the entire lower end of the cylinder block. Carefully, position the front cylinder block over the rear cylinder block with the aligning tool against the crankshaft bore of the front block and the diamond-shaped dowel pin, pressed in the rear block, engaged with the dowel pin hole of the front block.

11. Place the rear main bearing cap of the front cylinder block in position over the alignment tool and against the cylinder block. Install the four main bearing cap bolts and tighten them to approximately 280-290 lb—ft (379-393 N«n) torque.

12. Move the sled gage J 22273-01 across the bottom faces (oil pan rails) of the cylinder blocks at the joint between the two blocks. The mismatch, if any, between the bottom faces of the two blocks must not exceed .003” on either side.

13. Fubricate the threads and the contact face of the cylinder block attaching bolts (except “G”-l/2”-20 x 2” bolt) with International Compound No. 2 or equivalent.

14. Position the two block bolting bars (Fig. 11) into the cylinder block and install the four (4) attaching bolts (A) and washers. Be sure to install cup plugs in the bolting bar holes.

| Bolt | Size | Torque | |
|---|---|---|---|
| | | lb-ft | Nm |
| A | 3/4"-10 Socket Head | .270-290 | 366-393 |
| B | 1/2"-13 Socket Head | 75-85 | 102-115 |
| C | 5/8"-l 1, 12-Point | 160-175 | 217-238 |
| D | 3/4"-10 x 3" Hex Head | 270-290 | 366-393 |
| E | 3/4"-1 0 x 2-1/2" Hex Head | 270-290 | 366-393 |
| F | 1 /2"-13, 12-Point | 75-85 | 102-115 |
| G | I/2"-20 Hex Head | 85-95 | 115-129 |

**Block Attaching Bolt Torques**

15. Install the bolts and washers (B) through (F). A flat washer was used with the former socket head "B" f* bolts. Use torque wrench adaptor J 24533 when tightening "C" bolts. Refer to Section 1.3 for the IRr formular.

16. Install bolt, washer and nut (G) with the washer located on the bolt head side.

17. First snug all the bolts in sequence (Fig. 11). Then, tighten the bolts in the same sequence to the torque given in the Chart.

**NOTICE:** When tightening bolt (G), turn the bolt instead of the nut. Turning the nut will result in damage to the cylinder block.

18. Cut off the excess lengths of the block seal strip flush with the bottom face of the block.

19. Remove the cylinder block alignment tool.

20. Lift the cylinder block assembly with a chain hoist and place it in a horizontal position on a clean flat surface.

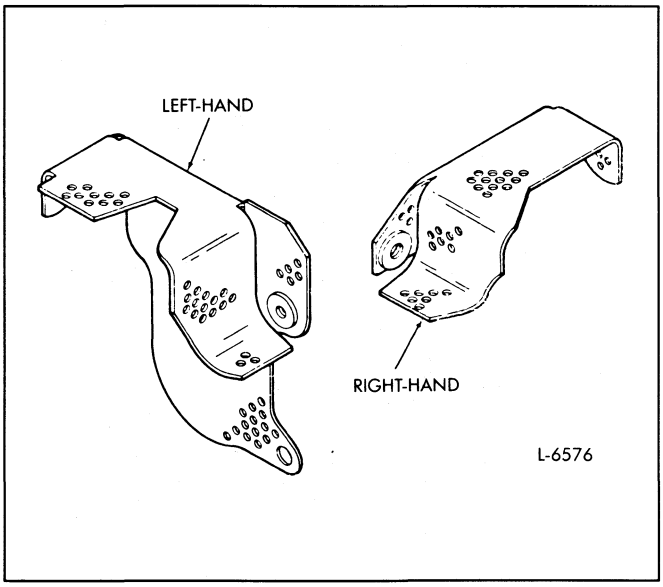



Fig. 14 – Injector Rack Guard Screens

• 21. On 12 and 16 cylinder engines, install the two (2) left-hand and two (2) right-hand injector rack guard screens (Fig. 14), four (4) bolts and lock washers. Tighten bolts to 13 - 17 lb—ft (18 - 23 N#m) torque.

**NOTICE:** Injector rack guard screens (Fig. 14) are used in place of cylinder block drain screens on all current 12V-149 and 16V-149 engines. Guard screens protect the injector control tube linkage passing through the front and rear block halves by preventing debris from wedging between the block and the injector control tube lever, jamming the racks. If racks are jammed at *full-fuel*, an overspeed condition and serious engine damage may result. *Guard screens must be replaced if removed.*

# AIR BOX DRAINS

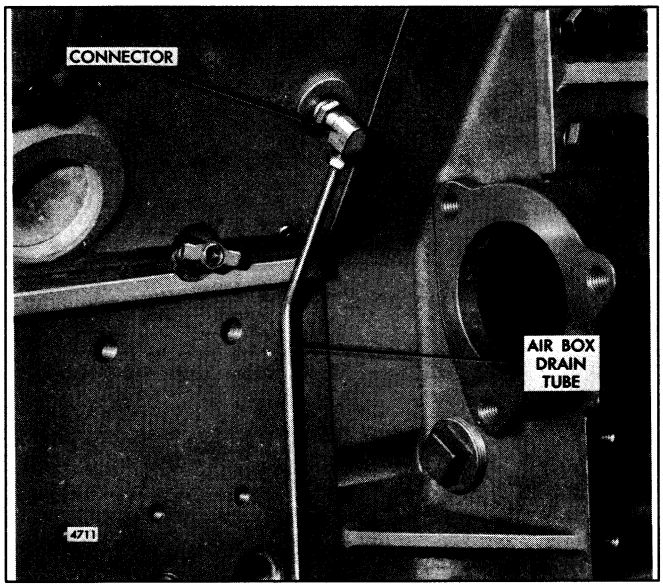



**Fig. 1 - Typical Air Box Drain Tube**

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condenses and settles on the bottom of the air box. This condensation is removed by air box drain tubes (Fig. 1) mounted on the sides of the cylinder block. One air box drain tube is installed in each corner of the cylinder block on 12 and 16V-149 engines. On 8V-149 engines, two rear drain tubes are used.

The air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

## Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Section 15.1).

# CYLINDER HEAD

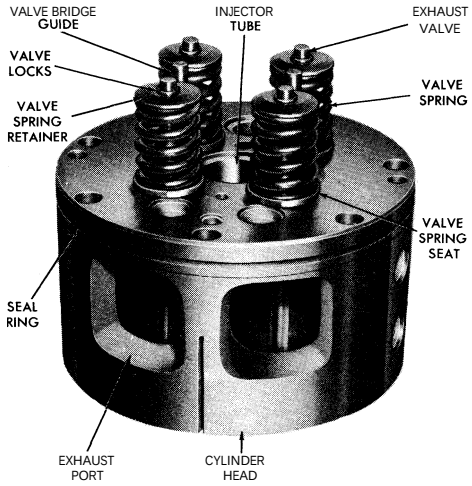



**Fig. 1 - Cylinder Head Assembly**

The 149 engines utilize an individual cylinder head (pot head) for each cylinder. Each cylinder head is recessed into the cylinder block and secured with seven special bolts and lock washers.

The cylinder head is a one-piece casting which houses the exhaust valves and the fuel injector (Fig. 1).

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the valves under varying conditions of temperature and materially prolong the life of the cylinder head.

To ensure efficient cooling, the fuel injector is installed in a thin-walled tube which passes through the water jacket in the cylinder head. The lower end of the injector tube is pressed into the cylinder head and flared over; the upper end is flanged and sealed with a neoprene seal. The sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

The exhaust passages from the exhaust valves of each cylinder head lead through two openings in the cylinder head, out through a single port in the cylinder block and then to the exhaust manifold. The exhaust passages are completely surrounded by engine coolant.

• To relieve thermal stresses, the current cylinder head incorporates a machined slot in the strut area between the exhaust ports. The former cylinder head had a 2.35” long slot. The current head has a 1” long slot.

A laminated metal gasket is used to seal compression between the cylinder head and the cylinder liner. Water passages between the cylinder head and cylinder block are sealed with a fluoroelastomer seal ring. The former Red silicone seal ring and the new Black fluoroelastomer seal ring are different in material, color and design. The new seal ring is larger in diameter to provide a larger sealing area. The former and new seal rings are interchangeable in an engine, however, only the black fluoroelastomer seal ring will be serviced.

Engines used in standby service, generator sets, fire pumps or other units in storage which were originally built (before 12E-5329 and 16E$^{A}$-4813) or subsequently overhauled using red silicone cylinder head-to-block seals should have these seals replaced with the black fluoroelastomer seals as a preventive maintenance measure to prevent the possibility of an internal coolant leak.

## Cylinder Head Maintenance

The engine operating temperature should be maintained between 160-185°F (71-85°C) and the cooling system should be inspected daily and kept full at all times. When necessary, add water *slowly* to a hot engine to avoid rapid cooling which can result in distortion and cracking of the cylinder head (and cylinder block).

Abnormal operating conditions or neglect of certain maintenance items may cause cracks to develop in the cylinder head. If this type of failure occurs, a careful inspection should be made to determine the cause and to avoid a recurrence of the failure.

Unsuitable water in the cooling system may result in lime and scale formation which prevent proper cooling. At time of cylinder head overhaul, the cylinder head should be inspected around the exhaust valve water jackets. This can be done by removing an injector tube. Where inspection discloses such deposits, use a reliable noncorrosive scale remover to remove the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine. Refer to Section 13.3 for engine coolant recommendations.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and also result in loss of engine coolant. The tubes must be tight to be properly seated. Refer to Section 2.1.4.

## Remove Cylinder Head

Certain service operations on the engine require removal of the cylinder head:

1. Remove and install piston.
2. Remove and install cylinder liner.
3. Remove and install exhaust valves.
4. Remove and install exhaust valve guides.
5. Recondition exhaust valves and valve seat inserts.
6. Replace fuel injector tube.
7. Install new cylinder head gaskets and seals.

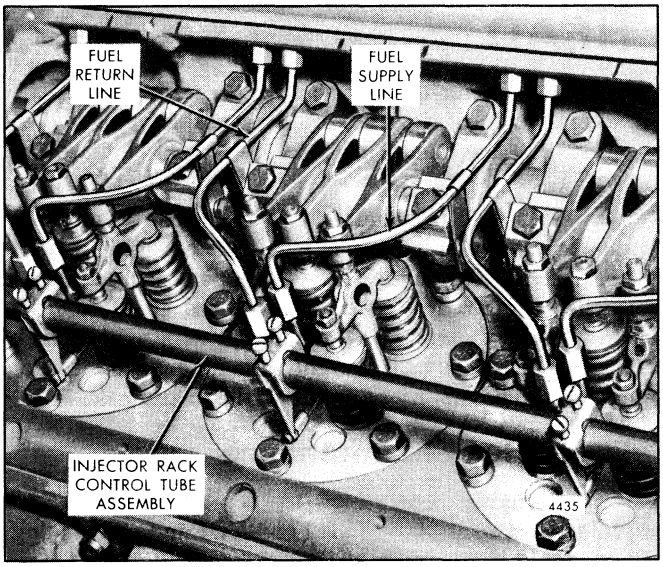



**Fig. 2 - Location of the Injector Rack Control Tube Assembly**

Due to various optional and accessory equipment used on the different engine models, only the general steps for removal of the cylinder head are covered. If the engine is equipped with special accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct reinstallation. Then, remove the cylinder head as follows:

1. Drain the cooling system.
2. Clean and remove the valve rocker cover.
3. Remove the clevis pin securing the fuel rod to the injector rack control tube (Fig. 2).
4. Remove the four bolts and lock washers securing the injector rack control tube assembly to the cylinder block and remove the control tube assembly.
5. Disconnect the fuel pipe support clips and remove the fuel supply and return pipes as follows:
   a. Disconnect the fuel pipe at the injector.
   b. Move the nut back on the pipe and slide a 3/8" I.D. hose over the open end of the pipe, being careful to avoid fuel spillage.

**NOTICE:** It will be necessary to loosen the fuel pipe nut at the fuel manifold a few turns to permit the fuel pipe to swing away from the injector.

   c. Drain the fuel into a container. This will prevent the fuel in the manifold from draining onto the cylinder head. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

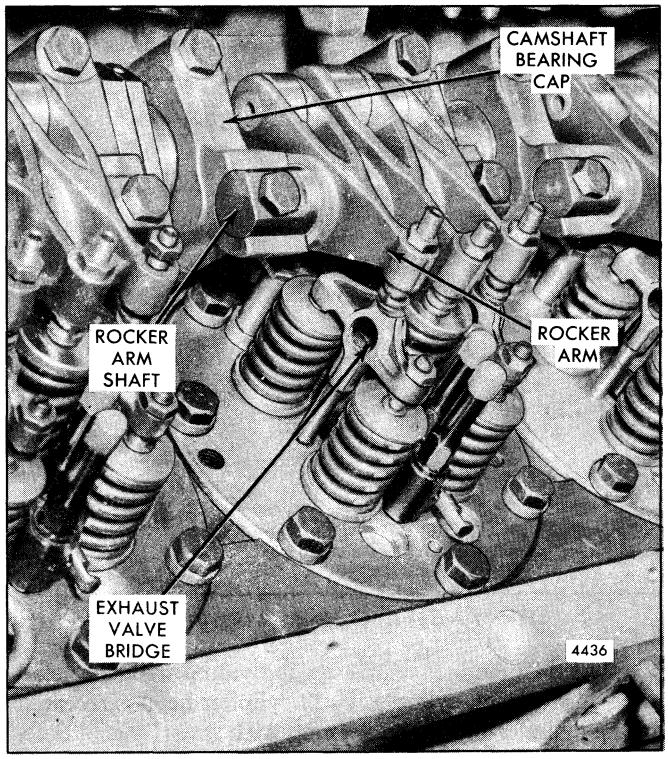



**Fig. 3 - Rocker Arm Mechanism**

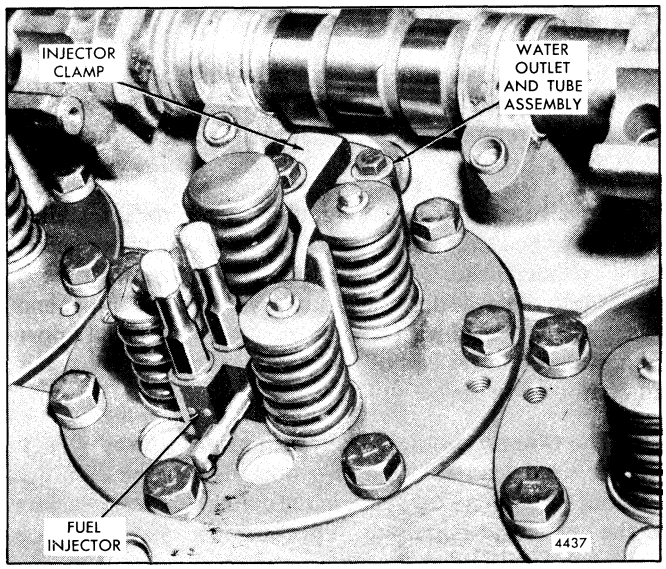



**Fig. 4 - Location of the Fuel Injector and Water Outlet Elbow**

   d. Cover the injector fuel inlet and outlet with protective caps.

6. Remove the two bolts securing the rocker arm shaft to the camshaft bearing caps and remove the shaft and rocker arm mechanism (Fig. 3).
7. Remove the two exhaust valve bridges from the exhaust valve bridge guides.

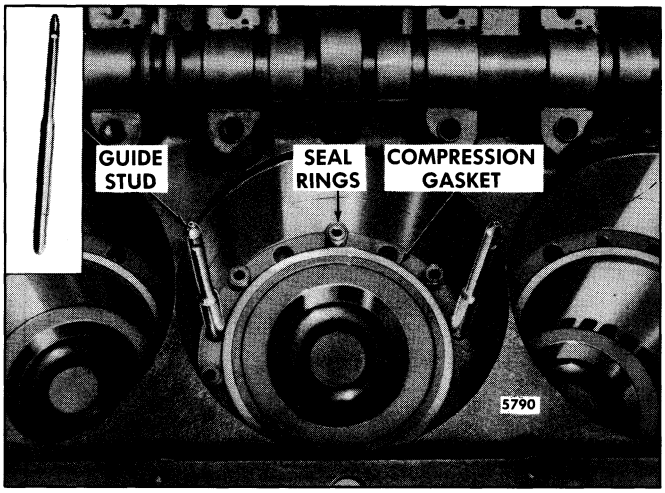



**Fig. 5 - Location of Cylinder Head Compression Gasket and Seal Rings**

8. Remove the fuel injector clamp and remove the fuel injector.

9. Remove the cylinder head water outlet elbow and tube assembly from the cylinder head and block (Fig. 4).

10. Remove the two camshaft bearing caps from the cylinder block. When removing the upper camshaft bearing caps and bearing inserts, matchmark their positions before removing.

11. Remove the seven special bolts and washers securing the cylinder head to the cylinder block and remove the cylinder head assembly, using cylinder lifting handles (Section 1.0) or tool J 24232. Be sure that the camshaft lobes are clear of the cylinder head before attempting removal.

12. Attach the cylinder head to cylinder head holding fixture J 23741-A.

#13. On former counterbored blocks, remove seal rings from counterbores. On current no-counterbore blocks, remove sleeve and spacer assemblies. Discard used seal rings. Remove and discard compression gasket.

If an integral head-to-block water seal assembly is used (no counterbore block), remove it *carefully* and discard the compression gasket. A seal assembly with low part hours (generally, up to 500 hours) may be reused *if it is not damaged.* Before reusing the seal assembly, the compression gasket (identified with red dye on the outside diameter) must be replaced. Compression gaskets are not reusable.

14. After the cylinder head has been removed, drain the lubricating oil from the engine. Draining the oil at this time will remove any coolant that may have worked its way to the oil pan when the head was removed.

## Disassemble Cylinder Head

If complete disassembly of the cylinder head is necessary, proceed as follows:

1. Remove and discard the seal ring (Fig. 1) from the upper perimeter of the cylinder head.

2. Refer to Section 1.2.2 for removal of the exhaust valves and related parts.

## Clean Cylinder Head

After the cylinder head has been stripped of all its component parts and all of the plugs have been removed, thoroughly have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tube and clean the head in the same manner as outlined for cleaning the cylinder block (Section 1.1).

Clean all of the cylinder head components with fuel oil and dry them with compressed air.

**CAUTIONrTo prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

## Inspect Cylinder Head

1. Before a cylinder head can be reused, it must be inspected for cracks. Five prescribed methods for checking a cylinder head for cracks are as follows:

If any method reveals cracks, the cylinder head should be considered unacceptable for reuse.

**Magnetic Particle Method:** The cylinder head is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which cause the magnetic particles in the powder or solution to gather there, effectively marking the crack. The cylinder head must be demagnetized after the test.

**Fluorescent Magnetic Particle Method:** This method is similar to the magnetic particle method, but is more sensitive since it uses fluorescent magnetic particles which glow under a “Black Light”. Very fine cracks, especially on discolored or dark surfaces, that may be missed using the Magnetic Particle Method will be disclosed under the “Black Light”.

**Fluorescent Penetrant Method:** A highly fluorescent liquid penetrant is applied to the area in question. Then, the excess penetrant is wiped off the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection to find the crack is carried out using a “Black Light”.

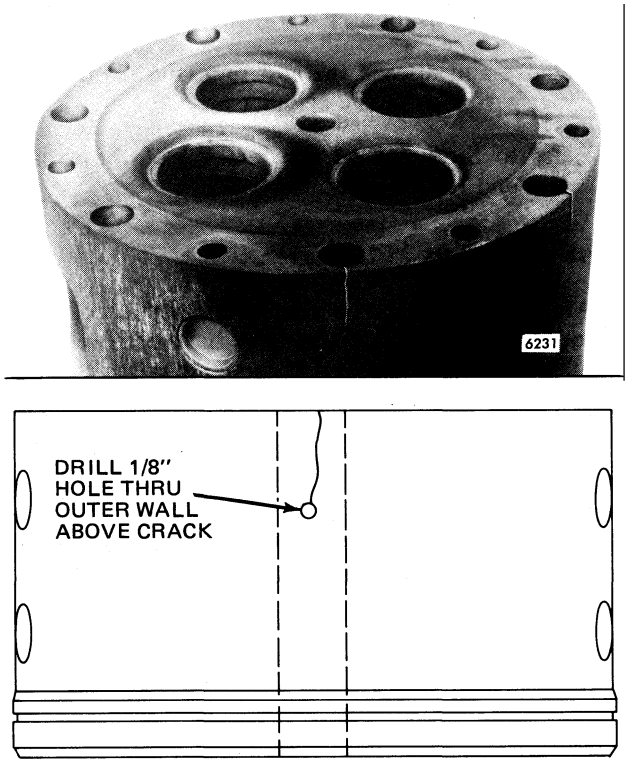



**Fig. 6 - Outside Edge Bolt Hole Cracking (Head Reusable)**

Non-Fluorescent Penetrant Method: The test area being inspected is sprayed with "Spotcheck" or Dye Check. Allow one to thirty minutes to dry. Remove the excess surface penetrant with clean cloths premoisened with cleaner/remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agaitator rattles. Invert spray can and spray short bursts to clear valve. Then spray this developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

The above four methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

Pressure Check Method: Pressure check the cylinder head and inspect it for indications of cracking as follows:

a. Seal off the water holes in the head with suitable plates and gaskets. Drill and tap one of the plates for an air hose connection.

b. Install a scrap or dummy injector to ensure proper seating of the injector tube. A dummy injector can be made from an old injector nut and body — the spray tip is not necessary. Tighten the injector clamp bolt to 46-50 lb—ft (62-68 N#m) torque.

c. Apply 40 psi (276 kPa) air pressure to the water jacket. Then, immerse the cylinder head in a tank of water, previously heated to 180-200°F (82-93°C), for about twenty minutes to thoroughly heat the head. Observe the water in the tank for bubbles which indicate a leak or crack.

d. Relieve the air pressure and remove the cylinder head from the water tank. Then remove the plates, gaskets and injector and dry the head with compressed air.

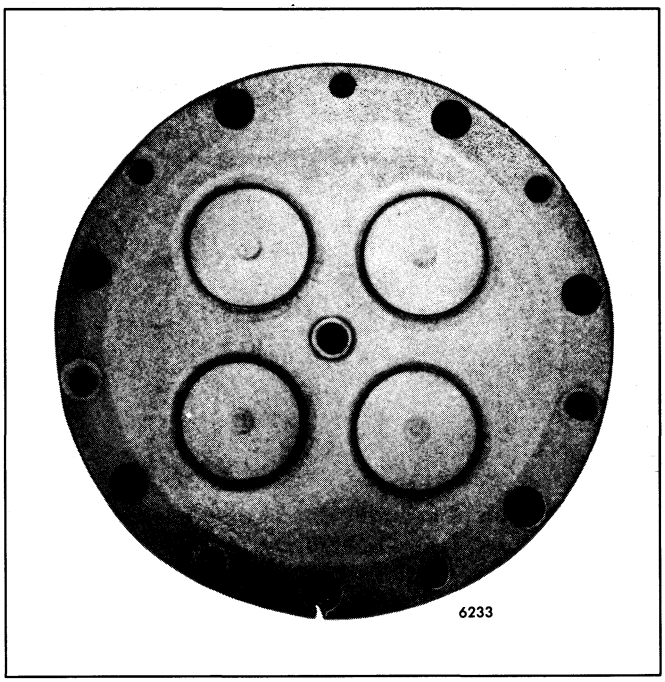



**Fig. 7 - Sunburst Cracks (Head Reusable)**

Minor cracking found on the surface of the cylinder head does not necessarily affect the reliability of the head. Since inspection reveals harmless as well as harmful cracking, interpretation of the cracking is the most important step.

The following is Detroit Diesel's position regarding the reuse of Series 149 cylinder heads which show evidence of cracking:

a. Cylinder heads with outside edge bolt hole cracking can be reused ifa 1/8" hole is drilled through the outer wall above the crack into the bolt hole (Fig. 6). This stops the progression of the crack.

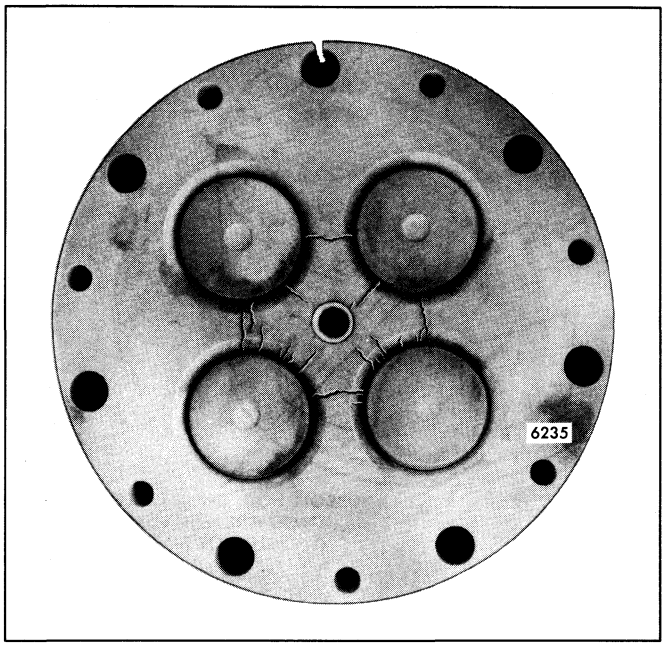



**Fig. 8 - Valve-to-Valve or Valve-to-Injector Tube Hole Cracks (Head Not Usable)**

b. Cylinder heads with valve hole sunburst checking can be reused without resurfacing cylinder heads. However, if any valve hole sunburst cracks intersect with each other, with an adjacent valve hole or with the injector tube hole, the cylinder head must be resurfaced before it can be reused. If resurfacing removes the cracks (Fig. 7), the cylinder head may be reused. If the cracks are still present after resurfacing, the cylinder head should be replaced.

c. Cylinder heads with cracks that extend from valve-to-injector tube hole (Fig. 8) should be considered unacceptable for reuse. The progression of these types of cracks may cause coolant leakage into the cylinder areas, resulting in severe engine damage.

d. Cylinder heads with cracks in the inside edge of the exhaust port bolt hole can be reused if the following criteria are met:

1. The head is cracked in the bolt hole only and the crack does not extend onto the firedeck surface (Fig. 9).

2. The head is cracked in the bolt hole and extends onto the firedeck surface when first checked, but the crack is so minor that, after resurfacing the firedeck, the crack is no longer detectable on the flat surface (Fig. 10).

3. After resurfacing the cylinder head firedeck, break the sharp edge of each bolt hole (7 places) to the following specification: .005”-.025” x 45° ± 5°.

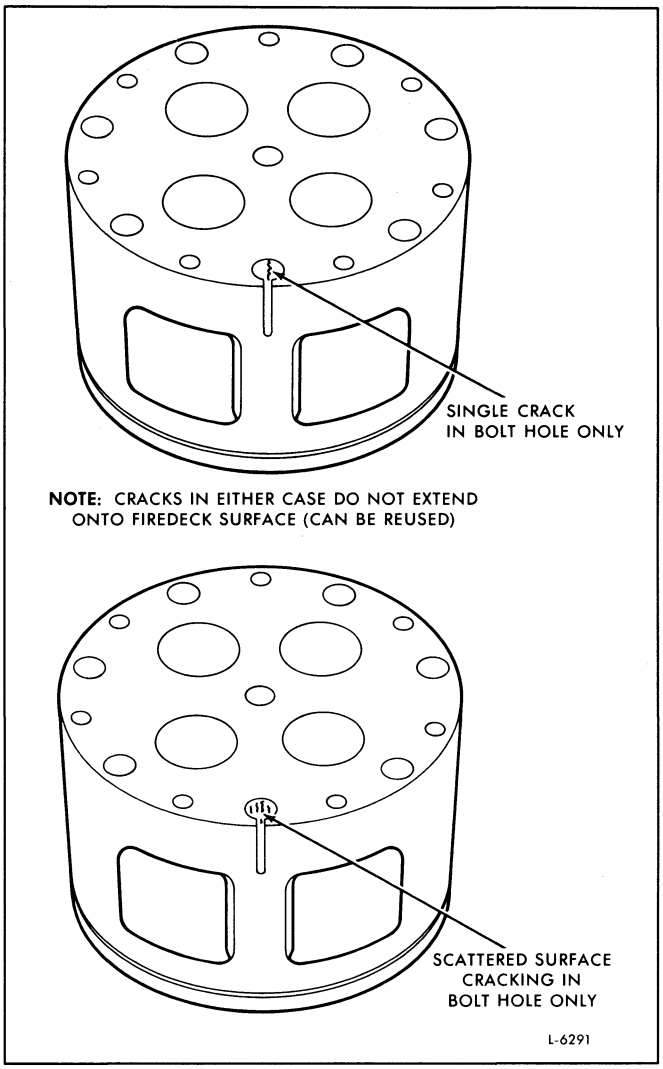



**Fig. 9 – Bolt Hole Crack (Head Reusable)**

4. Heads should not be reused if the bolt hole cracking extends onto the firedeck and *cannot* be removed with normal resurfacing (Fig. 11).

The Series 149 cylinder head will provide satisfactory service life provided the cooling system is properly maintained. Operating an engine with scale deposits in the cooling system, a leaking cooling system, aerated coolant, a low coolant level or inadequate coolant inhibitor may allow the engine to overheat. This can cause head cracking and/or serious engine damage.

2. Check the bottom (fire deck) of the cylinder head for flatness with a heavy, accurate straight edge and feeler gages. The surface must be held flat within .004”. If it becomes necessary to reface the cylinder head, remove the injector tube prior to machining. The distance from the fire deck to the machined surface at the top of the head must not be less than 4.7350”. The height of a new cylinder head is 4.7450” to 4.7550”.

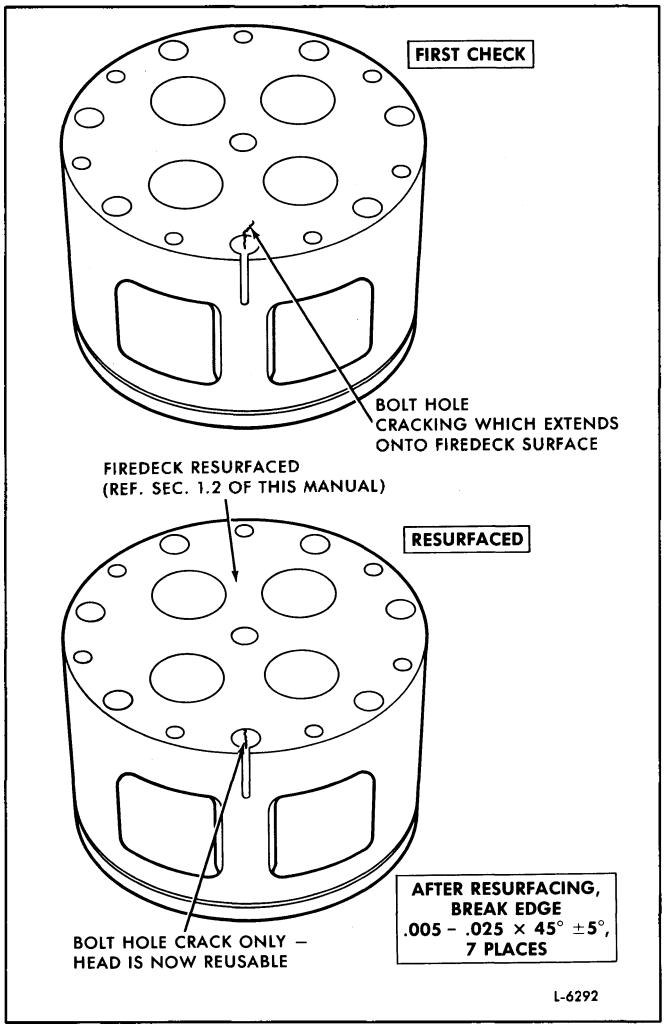



**Fig. 10 - Bolt Hole Crack into Firedeck (Head Reusable - Resurfacing removes Crack)**

**NOTICE:** When a cylinder head has been refaced, critical dimensions such as the protrusion of valve seat inserts, exhaust valves, injector tube and injector spray tip must be checked and corrected.

3. Install a new injector tube (Section 2.1.4) if the old tube leaked or the cylinder head was refaced.

4. Inspect the valve seat inserts and valve guides (refer to Section 1.2.2).

5. Inspect all other components removed from the cylinder head.

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound. Immerse the cylinder head in solvent, mineral spirits or fuel oil, then scrub the head and go through all of the openings with a soft bristle brush. After cleaning, dry the cylinder head with compressed air.

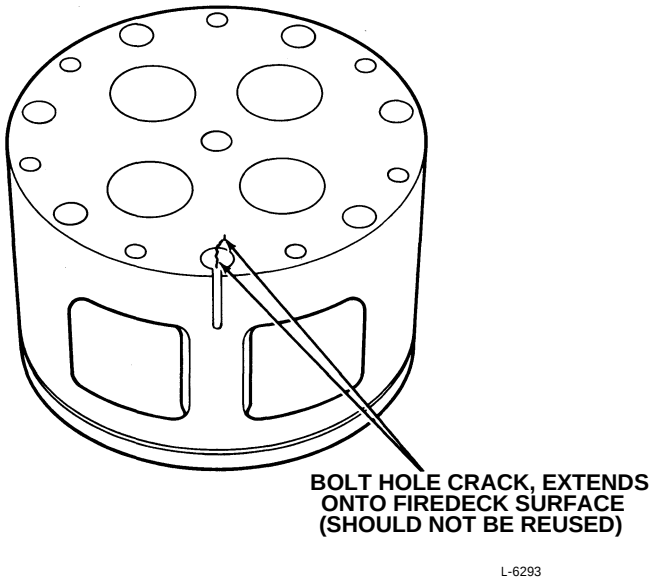



**Fig. 1 1 - Bolt Hole Crack into Firedeck (Head Not Reusable - Resurfacing does not remove Crack)**

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, bridge guides, injector tube and the necessary plugs.

## Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

• 1. Apply a thin, continuous coat of Permatex High Tack Adhesive Sealant 98D or 98H (or equivalent) to the outside diameter of all cup plugs and exhaust valve bridge guides. *Do not use R TV silicone sealan t in these areas, since RTVmay not provide a proper seal.* Refer to the table and install plugs to the proper depth below the surface 6f the cylinder head.

| Size Plug | Quantity | Depth below surface of head |
|---|---|---|
| 1 /2" did.<br>.889" dia.<br>1" dia. | 1<br>6<br>2 | .090"<br>.095"-.105"<br>.095"-.! 10" |

**TABLE 1**

2. Install the exhaust valves, valve seat inserts and springs (Section 1.2.2).

3. Make sure the seal ring groove at the upper perimeter of the head is clean. Then, lubricate a new seal ring with vegetable shortening and place it in the cylinder head groove (Fig. 1).

## Pre-Installation Inspection

Make the following inspections just prior to installing the cylinder head whether the head was removed to service the head only or to facilitate other repairs to the engine.

1. Check the cylinder liner flange height with relationship to the cylinder block (Section 1.6.3).

2. Make sure the piston crown is clean and free of foreign material.

3. Check to ensure that the compression gasket area of the cylinder head is free of nicks.

4. Inspect the cylinder head bolt holes in the block for accumulation of water, oil or any foreign material. Clean the bolt holes thoroughly and check for damaged threads.

5. Uncoated cylinder head mounting bolts replaced coated bolts approximately July 1, 1983, on all Series 149 engines for production and service. When replacing a former cylinder head mounting bolt with the new, all the bolts in a cylinder must be changed. Always install new cylinder head attaching bolts at time of engine overhaul.

## Install Cylinder Head

1. Refer to Fig. 5 and install the seal rings and compression gasket as follows:

   a. Place a new compression gasket on top of the cylinder liner. Never install used compression gaskets or seal rings.

   • b. On former counterbored blocks (Fig. 12) place a new seal in each block counterbore, On current no-counterbored blocks, place a new seal on each end of the sleeve and spacer assemblies and install in block.

   If an integral head-to-block water seal assembly (Fig. 13) is used, make sure the compression gasket (identified with red dye on the O.D. surface) is installed on the seaL A seal assembly removed from an engine with low part hours (generally, up to 500 hours), may be reused if it is not damaged. When checking the seal, look especially for splits or tears in the seven cylinder head bolt sealing areas. Compression gaskets are not reusable and must be replaced.

   Apply a light coating of clean engine oil to the circumference (O.D.) of the seal assembly. With the DDC logo and part number facing up and the narrow edge of the compression gasket pointing down, place the seal assembly into the block bore and more it down until it rests on the cylinder block liner flange surface. If a reusable seal assembly is being installed, make sure the best bolt hole seal is at the 6:00 (exhaust port bolt hole) position.

   **NOTICE:** Seals must drop into position without forcing or bending and must rotate easily for approximate alignment with bolt holes. This is necessary to avoid seal damage when the cylinder head is installed. If a seal hangs up or appears not to fit well, try rotating and moving it as it is being installed. If a seal must be bent or forced into place, remove and do not reuse it.

.2. Install two guide studs (set J 28511-A) at approximately the 9:30 and 2:30 positions in the cylinder block (Fig. 5). These studs ensure correct cylinder head-to-water seal alignment. The lower shaft diameter of the guide studs pilots on the inside diameter of the bolt hole threads.

**NOTICE:** Before installing guide studs on engines with integral head-to-block water seal assemblies, inspect the bottom (larger diameter) ends for burrs which may damage the seal. If necessary remove the burrs with a stone or extra fine emery cloth.

To install guide studs on engines with integral head-to-block water seal assemblies, lubricate the larger diameter ends with clean engine oil and insert these ends through the seal. Work studs into the bolt holes in the block until they bottom.

• 3. Lubricate a new cylinder head seal ring with clean engine oil and install it in the upper seal ring groove in the cylinder head.

4. Attach cylinder head lifting tool J 24232 or lifting handles.

5. Make a final visual check of the compression gasket and seal rings to ensure that they are in place and that the camshaft lobes are clear.

• 6. Wipe the bottom of the cylinder head clean and lower it over the guide studs and into place in the cylinder block. Allow it to slide into the bore as far as it can go.

• 7. Using a plastic or rubber mallet, rap the top of the cylinder head a few times to ensure that the head is all the way down. *Avoid contacting any mechanism on top of the head.*

• 8. Apply a small quantity of International Compound No. 2, or equivalent, to the threads and the underside of the head of each cylinder head attaching bolt. Then install the bolts and washers finger tight. When integral head-to-block water seal assemblies are installed, place five of the seven bolts (with washers) into the bolt holes, allowing them to stand on top of the seal. To'avoid damaging the seal, *Do Not Push Bolts Through.* Thread the bolts through the seal into the head. Run bolts down snug just short of moving the cylinder head downward.

**• NOTICE:** DDC does not recommend reusing cylinder head bolts at major overhaul. Use new bolts. The cylinder head attaching bolts are identified by the dark shank (heat treated) and six *raised* marks on the bolt heads. *Do not use any other type bolts* or severe stretching or bolt breakage may result when the bolts are drawn down to the specified torque. The machined surface under the head of the current bolts has a minimum diameter of .798" to provide additional bolt to washer clamping area.

• 9. After the head is in place, remove the guide studs (by pulling and rotating, if necessary) and the cylinder head lifting tool, and install the remaining bolts and washers. Run all bolts down snug tight with a speed handle - 15-20 lb-ft (20-27 N*m) torque. Use a cross-pattern sequence.

10. Draw the cylinder head down gradually and uniformly to ensure a good seal between the head and the block. Tighten every other bolt gradually and uniformly in 50 lb-ft (68 N*m) increments until all of the bolts are tightened to 140-150 lb-ft (190-204 N*m) torque. Apply a steady pressure for two or three seconds at the prescribed torque to allow the bolts to turn while the gaskets yield to their final designed thickness.

**NOTICE:** Tightening the cylinder head bolts will not correct a leaking compression gasket or seal. The head must be removed and the damaged gasket or seal replaced.

.11. Assemble two (2) seal rings to cylinder head water outlet tube. Coat seal rings with Crisco after installation.

.12, Place one (1) water outlet elbow seal in the counterbore in the cylinder head. Install one end of the tube into the water outlet elbow. Install the other end of the tube in the cylinder block and secure the elbow to the cylinder head with two (2) bolts. Tighten bolts to 13-17 lb-ft (18-23 N«m) torque

13. Install the upper camshaft bearing inserts in the upper bearing caps (if removed) and lubricate them with clean engine oil. Place the camshaft bearing caps over the camshaft and secure them with the top bolts. Do not tighten the bolts at this time.

14. Place the fuel injector in the cylinder head injector tube _ and secure it with the injector retainer clamp and bolt (Fig. 4). Tighten the clamp bolt to 46-50 lb-ft (62-68 N*m) torque. Make sure there is clearance between the injector clamp and the injector spring.

15. Position the two exhaust valve bridges over the bridge guides (Fig. 3). Refer to Section 1.2.2 for the exhaust valve bridge adjustment procedure.

16. Place the rocker arm mechanism in position and secure it to the camshaft bearing cap with two bolts (Fig. 3). Tighten all four camshaft bearing cap bolts to 90-100 lb-ft (122-136 N*m) torque.

17. Install the fuel supply and fuel return pipes (Fig. 2).

**NOTICE:** DDC recommends that the original flared end fuel pipes not be reused. New flared end fuel pipes should be installed.

Use adaptor J 21545 and an appropriate torque wrench and tighten the fuel pipe-to-injector nuts to 18-22 lb-ft (24—30 N*m) torque. Tighten the fuel pipe-to-fuel manifold connector nuts to 18-22 lb-ft (24-30 N*m) torque using fuel line wrench set J 26617. Install the fuel line clips.

**NOTICE:** Do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Fuel Jumper Line Maintenance and Pressurize Fuel System-Check for Leaks* in Shop Notes-Section 2.0) .

*18. Place the injector rack control tube assembly (Fig. 2) in position, with the control tube levers engaged with the injector racks, and secure it with four bolts and lock washers. Tighten to 13-17 lb-ft (18-23 N«m) torque. Adjust assembly until there is no bind.

19. Install the fuel rod-to-injector rack control tube clevis pin.

20. Fill the cooling system and check for leaks.

21. Prime the fuel system, using primer tool J 5956 or a comparable priming device.

22. Refer to Section 13.1 under *Preparation for Starting Engine First Time* and fill the cooling system and lubrication system.

23. Before starting the engine, perform an engine tune-up as outlined in Section 14.

It will only be necessary to perform the engine tune-up on ihe individual cylinder head that was worked on. However, check the adjustment of all injector racks of the cylinder bank to make sure the adjustments have not changed.

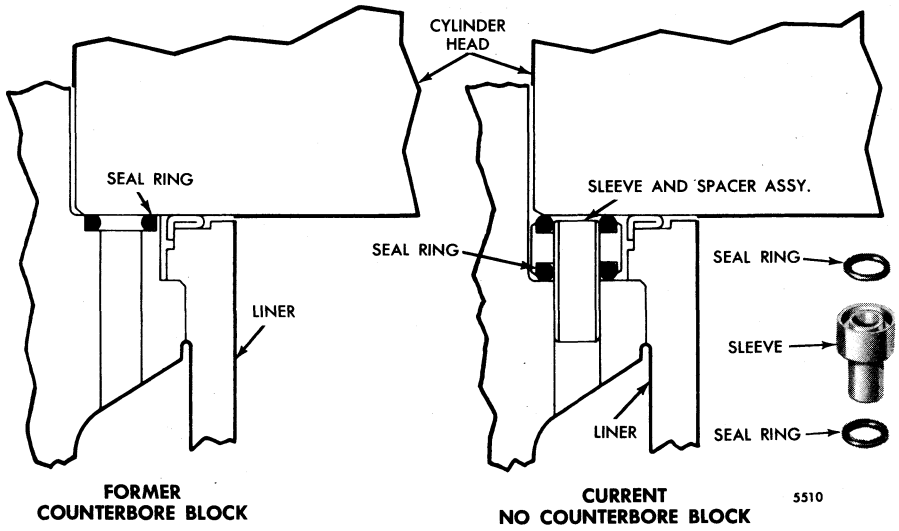
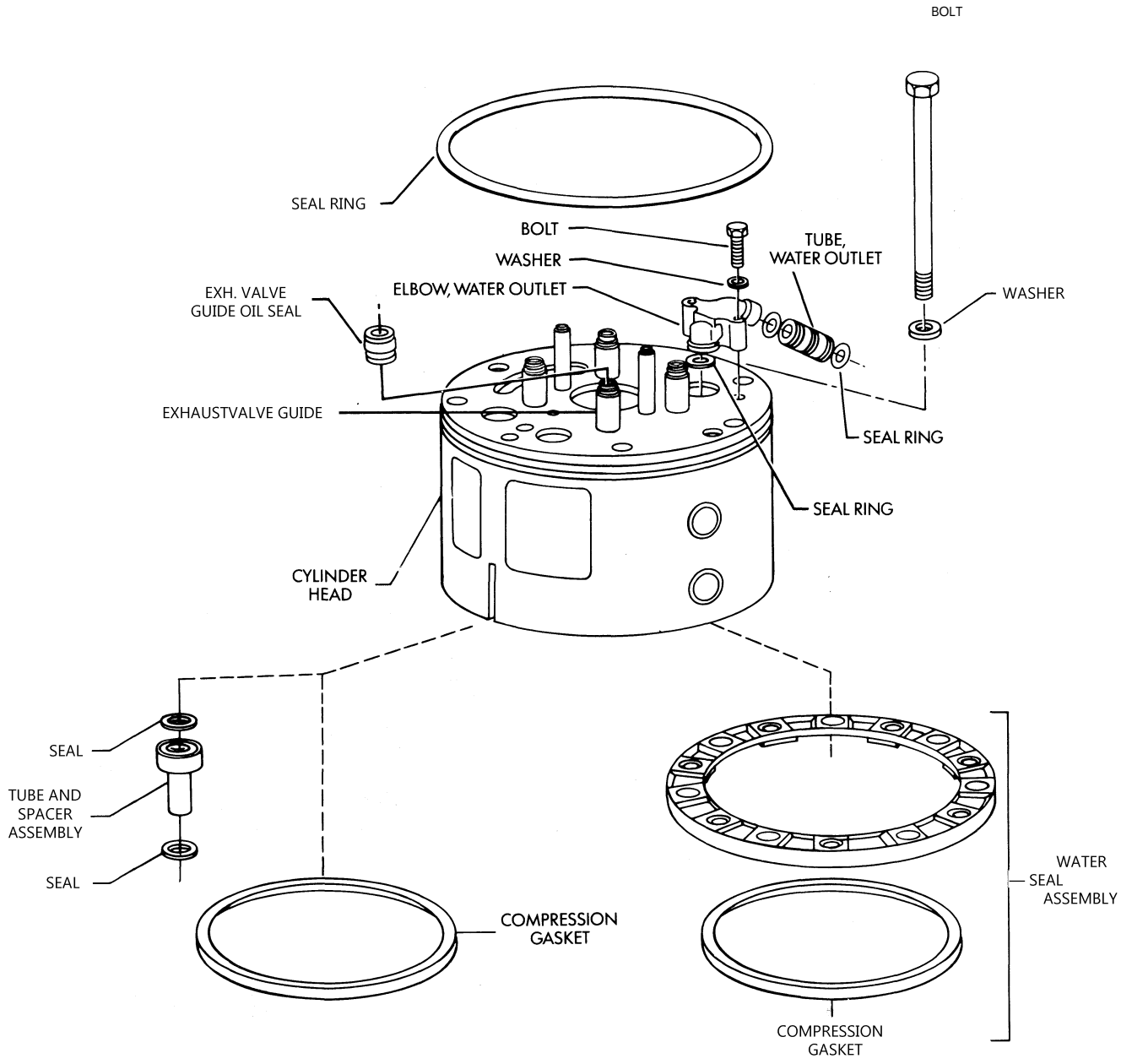



**Fig. 12 - Former and Current Cylinder Blocks and Seal Rings**




**• Fig. 13 - Standard and Optional Cylinder Head-to-Block Seal Seals**

# VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder; the wo outer arms operate the exhaust valves and the center arm operates the fuel injector (Fig. 1).

Each set of three rocker arms pivots on a shaft supported by two camshaft bearing caps. Two bolts secure the shaft to the bearing caps. Removal of the bolts permits removal of the rocker arm assembly and easy access to the fuel injector and exhaust valve springs.

Each rocker arm has a hardened roller at one end which rides directly on the camshaft lobe to actuate an exhaust valve or the fuel injector. This overhead camshaft arrangement gives a positive direct contact of camshaft-to-rocker arm with fewer parts.

To minimize wear, the rocker arms contain bushings for both the rocker arm shaft and the roller pins.

One end of the rocker arm has an adjusting screw, lock nut, valve button and valve button retainer. The valve button offers a positive flat seating surface against the exhaust valve bridge pallet or injector follower. It also reduces wear as it is lubricated from the engine lubricating system.

## Lubrication

The valve and injector operating mechanism is lubricated from the camshaft bearing caps where the lubricating oil is picked up from the grooves in the camshaft bearings. The lubricating oil enters the rocker arm shaft through drilled passages in the bearing caps. From there the oil follows the drilled shaft to each rocker arm where it enters a drilled passage leading to the valve adjusting screw. Lubricating oil is then directed through another drilled passage in the valve adjusting screw where it lubricates the frictional surfaces between the base of the adjusting screw and the valve button.

The contact surface between the camshaft lobes and the rocker arm rollers is lubricated by jets machined into the bearing caps which spray oil onto the rollers.

## Remove Valve And Injector Operating Mechanism

1. Clean and remove the valve rocker cover.

2. Remove the fuel supply and fuel return pipes as follows:

   a. Disconnect the fuel pipe at the injector.

   **NOTICE:** Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

   b. Move the nut back on the pipe and slide a 3/8" I.D. hose over the open end of the pipe, being careful to avoid fuel spillage.

   **NOTICE:** It will be necessary to loosen the fuel pipe nut at the fuel manifold a few turns to permit the fuel pipe to swing away from the injector.

   c. Drain the fuel into a container. This will avoid the fuel in the manifold from draining onto the cylinder head. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

3. Remove the two bolts securing the rocker arm shaft to the camshaft bearing caps and lift off the valve and injector operating mechanism.

   **NOTICE:** After removing the rocker arms, tag all of the parts so they may be reinstalled in their original positions.

4. Remove the two valve bridges from the exhaust valves and guides.

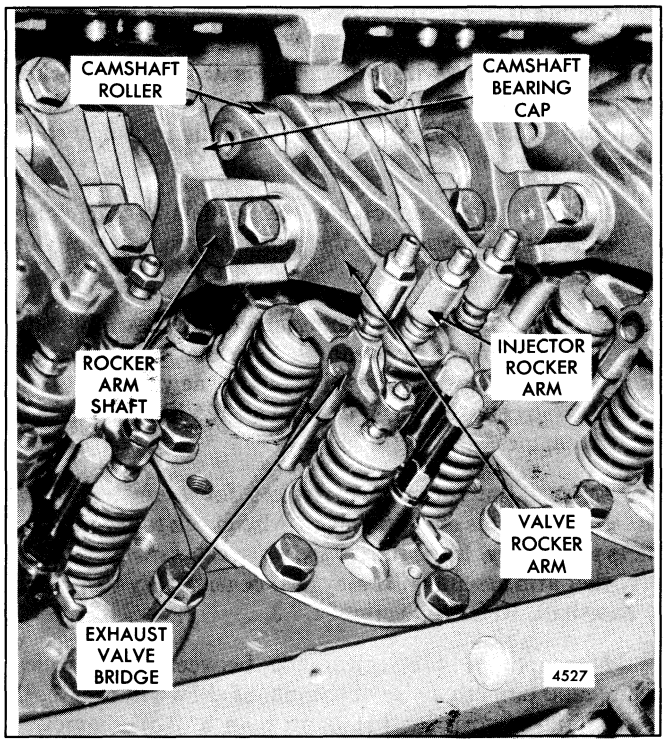



**Fig. 1 - Valve and Injector Operating Mechanism**

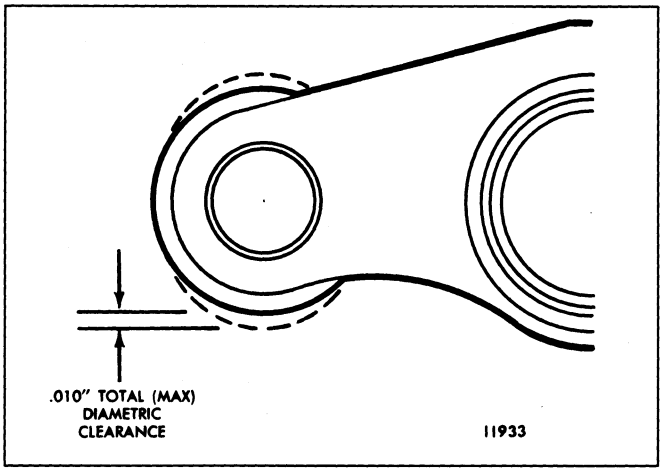



**Fig. 2 - Rocker Arm Roller Wear and Clearance Diagram**

## Inspection

Wash the rocker arm assemblies with lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* Fuel oil working its way in between the roller bushing and pin may cause scoring on initial start-up of the engine since fuel oil does not provide adequate lubrication. Wash the rocker arm shaft and valve bridges in clean fuel oil and dry them with compressed air. Make certain all of the drilled oil passages are open and clean.

Inspect the rocker arm shaft and rocker arm bushings for excessive wear. The diameter of a new rocker arm shaft is 1.2295" to 1.2300" and the inside diameter of a new rocker arm bushing is 1.231" to 1.232". The shaft-to-rocker arm clearance with new parts is .0010" to .0025" and the maximum clearance with worn parts is .004". If the rocker arm assemblies are satisfactory for further service, coat them with clean Cindol 1705 oil before reinstalling them in their original locations.

Examine the contact surface (pallet) of the valve bridges. Replace a bridge if the pallet is severely worn or galled.

• Examine the valve button, retainer and valve adjusting screw contact surface for wear. Be sure that the drilled oil passage in the adjusting screw is open. A new valve button retainer (crab claw design) is used on all 125 horsepower per cylinder engines.

Inspect the rocker arm rollers for excessive wear. Check for flat spots or scuff marks. Also check to see that the rollers turn freely. If the rollers are worn excessively, replace the rocker arm assembly. It may also be necessary to replace the camshaft. Refer to Section 1.7.2. <

Measure. the total clearance between each roller bushing and pin, crosswise of the pin, as shown in Fig. 2. If the bushing is worn so that more than a .010" diametric clearance exists, replace the rocker arm assembly.

## Install Valve And Injector Operating Mechanism

If new rocker arm assemblies are to be installed, remove the preservative by washing with Cindol 1705 and wipe dry. *Do not use fuel oil.*

Before rocker arm assemblies are installed, immerse them in clean Cindol 1705 heated to 100-125T (38-52°C) for at least one hour to ensure initial lubrication of the roller pins and bushings. Rotate the rollers during the soaking period to purge any air from the bushing-roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the roller bushing and pin.

After the rocker arm assemblies are removed from the heated Cindol 1705, the cooling action of any air trapped in the busing and pin area will tend to pull the lubricant into the cavity.

**NOTICE:** Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the rocker arms from touching the bottom of the pail and avoid the possibility of contamination.

1. Lubricate the valve bridge guides with sulphurized oil (E.P. type) and position the valve bridges in place on the guides. Refer to *Exhaust Valve Bridge Adjustment* in Section 1.2.2 and adjust the valve bridges.
2. Apply clean engine oil to the rocker arm shaft.
3. Slide the rocker arm shaft through the rocker arm assemblies. Place the rocker arm shaft in position on the camshaft bearing caps and secure it with two bolts. Tighten the bolts to 90-100 lb—ft (122-136 Nwn) torque. Install used rocker arm assemblies in their original locations.
4. Install new fuel supply and fuel return pipes. Use wrench set J 26617 and tighten the fuel pipe to fuel injector nuts to 18-22 lb—ft (24-30 N#m) torque. Tighten the fuel pipe to fuel manifold connector nuts to 18-22 lb—ft (24-30 N#m) torque. Install the fuel line support clips.

**• NOTICE:** DDC recommends that the original flared-end fuel pipes not be reused. New flared-end fuel pipes should be installed.

**NOTICE:** Do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

5. Adjust the exhaust valve clearances and time the fuel injector as outlined in Section 14.1 and 14.2 before starting the engine.

# EXHAUST VALVES

Four exhaust valves are provided for each cylinder (Fig. 1). The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the exhaust valve bridge. The exhaust valve stems are contained within valve guides which are pressed into the cylinder head.

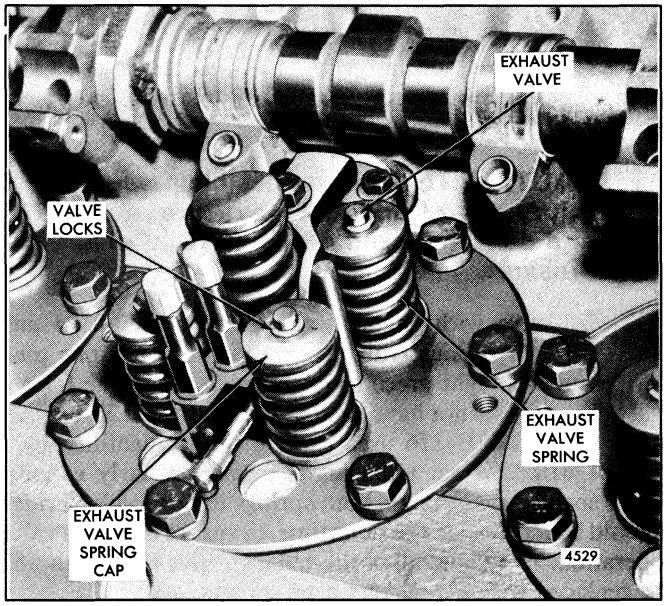



**Fig. 1 - Location of Exhaust Valves**

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head.

The exhaust valve springs are held in place by the valve spring caps and tapered two-piece valve locks.

Excess oil from the rocker arms lubricates the exhaust valve stems. The valve heads are cooled by the flow of air from the blower past the valve heads each time the air inlet ports are uncovered.

## Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leakproof seating, valve stems must work freely and-smoothly within the valve guides and the correct valve clearance (Section 14.1) must be maintained.

Proper maintenance and operation of the engine is important to long valve life. Engine operating temperatures should be maintained between 160°-185°F (71°-85°C). Low operating temperatures (usually due to extended periods of idling or light engine loads) result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubricating oil to sludge.

Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures.

When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide, sticking valves will result. Thus the valves cannot seat properly and pitted and burned valves and valve seats and loss of compression will result.

Lubricating oil and oil filters should be changed periodically to avoid the accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of antifreeze (glycol) into the lubricating oil which forms a soft sticky carbon that gums the valve stems and bent or worn valve guides. Sticking valves may eventually be struck by the piston.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion.

## Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head, as follows:

1. Clean and remove the valve rocker cover. Discard the gaskets.
2. Rotate the crankshaft with tool J 22582 to bring the valve and injector rocker arms in line horizontally. Tool J 22582 bolts to the flywheel housing in the same position as the engine starter. Gear teeth on one end of the topi mesh with the flywheel ring gear. The engine can then be rotated by hand with the aid of a 3/4” drive and ratchet.

   **CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

3. Disconnect and remove the fuel pipes from the injector and the fuel connectors as follows:

   a. Disconnect the fuel pipe at the injector.

b. Move the nut back on the pipe and slide a 3/8" I.D. hose over the open end of the pipe, being careful to avoid fuel spillage. It will be necessary to loosen the fuel pipe nut at the fuel manifold a few turns to permit the fuel pipe to swing away from the injector.

c. Drain the fuel into a container. This will prevent the fuel in the manifold from draining onto the cylinder head. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

**NOTICE:** Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

4. Remove the two bolts holding the rocker arm shaft to the camshaft bearing cap and remove the rocker arms and shaft.

5. Remove the exhaust valve bridges.

6. Remove the cylinder block air box cover so that piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.

7. Thread the valve spring compressor J 22693-01 into the tapped hole in the cylinder head. Then, compress the valve spring and remove the two-piece valve lock.

8. Release the tool and remove the spring cap, valve spring and spring seat.

## Remove Exhaust Valves And Springs (Cylinder Head Removed)

With the cylinder head removed from the engine, remove the exhaust valves and springs, as follows:

1. With the cylinder head holding fixture J 23741-A attached to a work bench (Fig. 2), bolt the cylinder head in the fixture. ,

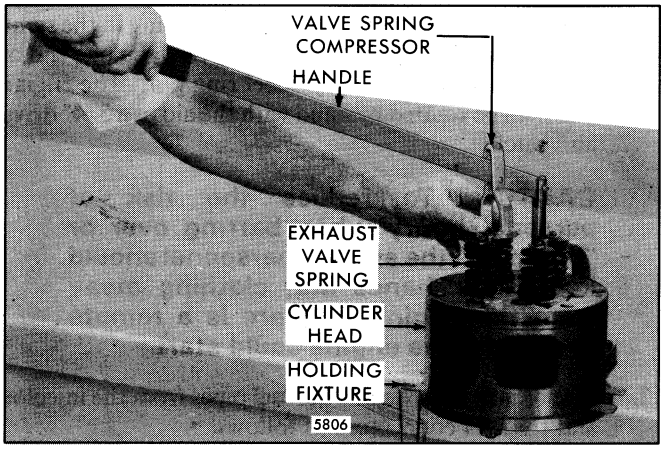



**Fig. 2 - Removing Exhaust Valve Spring**

2. Remove the exhaust valve springs, using valve spring compressor J 22693-11 with handle J 22693-9. Adjust the valve spring compressor to compress the valve spring just enough to remove the exhaust valve locks.

3. If the valves are to be reused, number each valve to facilitate reinstallation in the same location. Then, withdraw the valves from the cylinder head.

## Inspection

Clean the springs with fuel oil, and dry with compressed air. Inspect springs. Replace a pitted or fractured spring.

**CAUTIONrTo prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Effective with engine serial number 12E-5304 and 16E—4743, an exhaust valve spring identified by one pink stripe and one light green stripe is being used. The former valve spring does not have an identifying stripe. 12V engines built prior to 12E-176 used a valve spring identified by a yellow stripe. When replacing a former or early exhaust valve spring in an engine, both springs under a valve bridge should be replaced at the same time, to ensure balanced valve operation. At rebuild all of the exhaust valve springs should be replaced with the current type springs.

The exhaust valve spring and injector follower spring are similar in appearance and if interchanged, serious engine damage may result. The exhaust valve spring is made from ,224/.226" diameter wire and has 6-1/2 coils with the ends of the spring 160-180° opposite each other. The injector follower spring is made from .237/.241" diameter wire and has 6 coils with the ends of the spring directly in line.

• Use spring tester J 22738-02 (Fig. 3) to check the spring load of *new and used* exhaust valve springs before installing them on a cylinder head. Replace an exhaust valve spring if a load of less than 54 lbs will compress it to a length of 2.05". Springs passing this test must then be compressed to 1.54" on spring tester J 22738-02 (refer to Table 1). The force "X-lbs") required to compress the spring to 1.54" must result in the recoil pressure **("Y")** shown. If "X-lbs$^{M}$ and **"Y"** readings for a *new or used" spring do not match, the spring must be replaced.*

| X-lbs | Y | X-lbs | Y |
|---|---|---|---|
| 54 | 250.5 — 260.5 | | |
| 55 | 251.5 — 261.5 | 60 | 256.5 — 266.5 |
| 56 | 252.5 — 262.5 | 61 | 257.5 — 267.5 |
| 57 | 253.5 — 263.5 | 62 | 258.5 — 268.5 |
| 58 | 254.5 — 264.5 | 63 | 259.5 — 269.5 |
| 59 | 255.5 — 265.5 | 64 | 260.5 — 270.5 |

**Table 1**

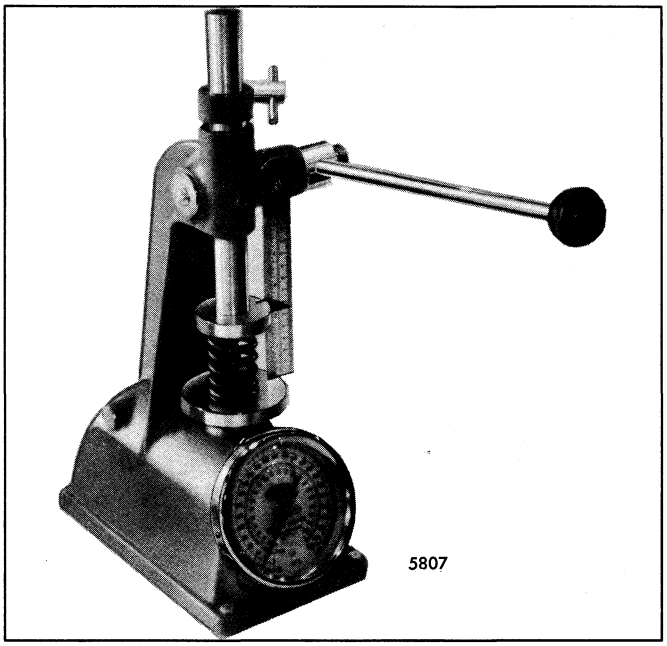



**Fig. 3 - Testing Exhaust Valve Spring using Tool J 22738-02**

• Inspect the valve spring seats and caps for wear. If worn, replace them. *Valve springs, seats, and caps for 125 hp per-cylinder engines are different from the current 100 and 112 hp per-cylinder design.*

Examine the contact surfaces of the exhaust valve bridge guides, bridges and adjusting screws for wear. Replace excessively worn parts.

A new exhaust valve bridge with a .391" drilled cross-hole replaces the former valve bridge with a forged center hole (.500" to .535" diameter). The old and new bridges are interchangeable and only the new bridge will be serviced.

Clean the inside diameter of the valve guides with brush J 5585 (Fig. 4). This brush will remove all gum or carbon deposits from the guides, including the spiral grooves.

Inspect the valve guides for fractures, chipping, scoring or excessive wear. Measure the valve guide inside diameter with a pin gage or inside micrometer and record the readings. After inspecting and cleaning the exhaust valve, measure the outside diameter of the valve stem with a micrometer and record the readings. Compare the readings to obtain the valve-to-guide clearance. If the clearance exceeds .006", replace the valve guides.

Carbon on the face of a valve could indicate blow-by due to a faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too heavy a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures. High operating temperatures are normally due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil.

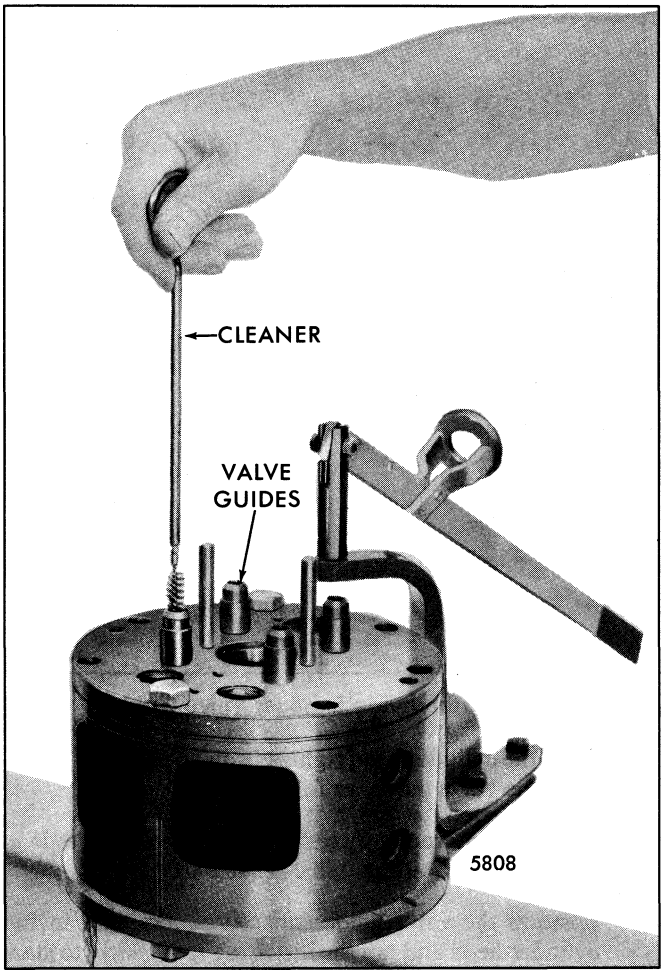



**Fig. 4 - Cleaning Exhaust Valve Guides**

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges,, cracks or pitting. If necessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

Inspect the exhaust valve seat inserts for excessive wear, pitting or cracks.

## Replace Exhaust Valve Guide

Remove an exhaust valve guide, as follows:

1. Remove and discard the oil seal.
2. Drive or press the valve guide out from the bottom of the cylinder head with tool J 23458 (Fig. 5).

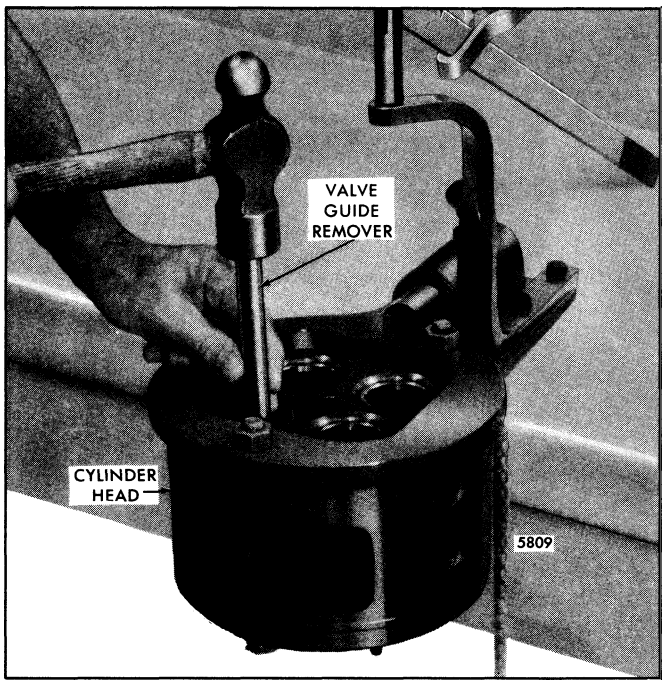



**Fig. 5 - Removing Exhaust Valve Guide**

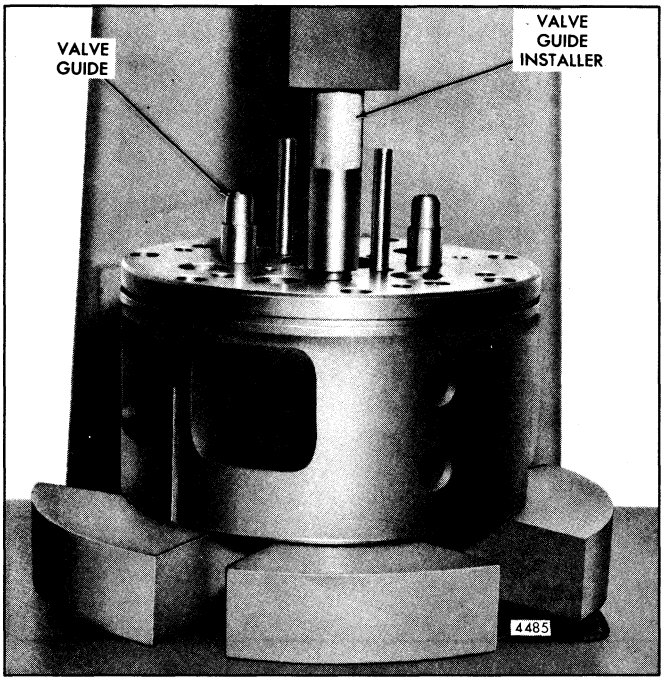



**Fig. 6 - Installing Exhaust Valve Guide**

Turn the cylinder head right side up on the work bench and install the valve guide, as follows:

1. Insert the internally threaded end of the valve guide in valve guide installing tool J 22082-01.

• 2. Position the valve guide squarely in the bore in the cylinder head and tap the installing tool gently to start the guide in place. Then, press the guide in until the tool contacts the cylinder head (Fig. 6). This will position the valve guide to the proper height of 1 • 140"—1.180". *On 125 hp-per-cylinder engine, the valve guides are smaller in diameter than those on the current 100 and 112 hp-per-cylinder engines.*

**NOTICE:** Do not use the valve guides or the valve bridge guides as a means of turning the cylinder head over or in handling the cylinder head. Do not lean the head on the valve bridge guides.

Service replacement valve guides are completely finish reamed during manufacture and, therefore, do not require reaming after installation.

## Remove Exhaust Valve Bridge Guide

1. Grind a notch 1/16" deep in the side of the bridge guide approximately 1 1/2" from the upper end of the bridge guide (Fig. 7).

2. Slide the washer J 7091-3 and bridge guide remover tool J 7091-5 on the bridge guide and tighten the socket head screw in the side of the tool.

3. Place spacer tools J 7091-2 or J 7091-4 over remover J 7091-5.

4. Thread the nut on the remover J 7091-5. Turn the nut clockwise to remove the bridge guide from the cylinder head.

To remove a broken valve bridge guide, drill a hole approximately 1/2" deep in the end of the guide with a No. 3 (.2130") drill (Fig. 8). Then, tap the guide with a l/4"-28 bottoming tap. Thread the remover J 7453 into the guide and attach slide hammer J 2619-01 to the remover tool. One or two sharp blows with the puller weight against the head of the rod will remove the broken guide.

## Install Exhaust Valve Bridge Guide

• 1. Apply a *Thin,* continuous coat of Permatex High Tack Adhesive sealant 98D or 98H (or equivalent) to the exhaust valve bridge guide.

2. Locate the exhaust valve bridge guide squarely in the cylinder head and tap it gently to start it into place.

• 3. With the guide properly started, place the valve bridge guide installer J 22487 over the guide and drive the guide into the cylinder head (Fig. 9). The tool properly positions the guide in the cylinder head. *The 125 hp-per-cylinder head has no bridge guides.*

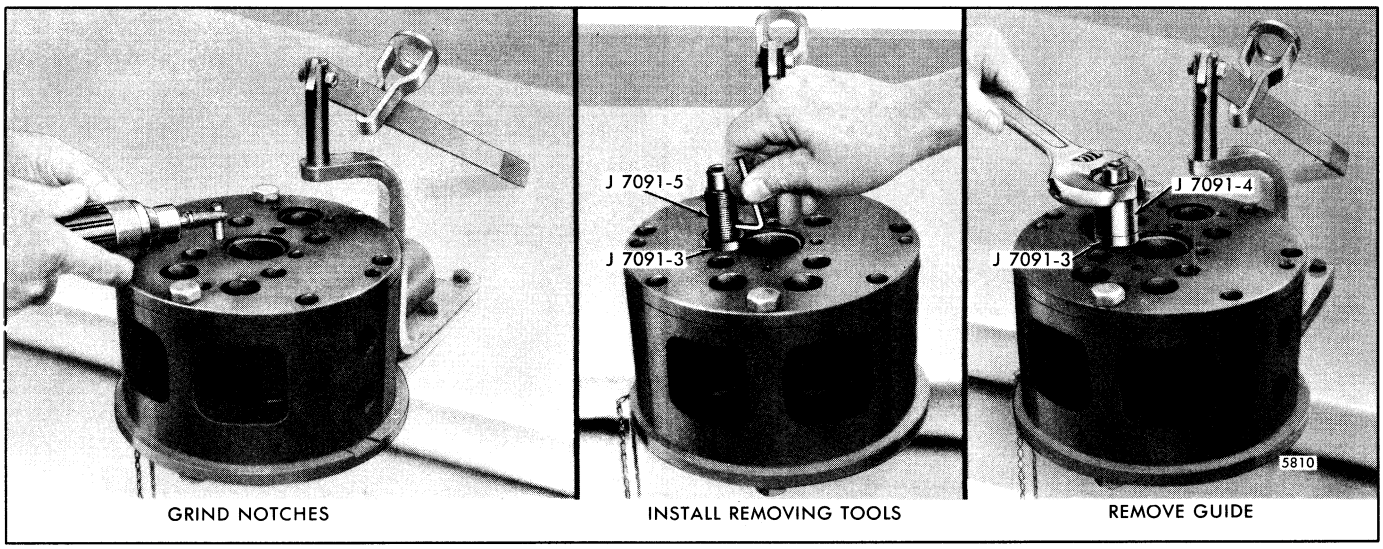



**Fig. 7 - Removing Exhaust Valve Bridge Guide**

## Inspect Exhaust Valve Seat Insert

Inspect the valve seat inserts for excessive wear, pitting, cracking or an improper seat angle. The proper angle for the seating face of the valve is 30° and the angle for the insert is 31°. When a valve seat insert has been ground to such an extent that the grinding wheel will contact the cylinder head, install a new insert.

## Remove Exhaust Valve Seat Insert

The valve seat inserts are pressed into the cylinder head and must be removed as outlined in the following procedure to avoid damage to the cylinder head.

1. Bolt the cylinder head in the holding fixture J 23741-A (Fig. 10).
2. Place the collet of the valve seat insert remover J 23479-D inside of the valve seat insert so that the bottom of the collet is flush with the bottom of the insert.
3. Press down on the handle to remove the valve insert from the cylinder head.

## Install Exhaust Valve Seat Insert

Great care must be used during the installation of a valve seat insert since this part has a press fit in the cylinder head.

If required, a cylinder head may be reworked to accept .010" oversize exhaust valve seat inserts (refer to Section 1.0).

Install the insert in the following manner:

1. Wash the cylinder head with clean fuel oil and dry it with compressed air.

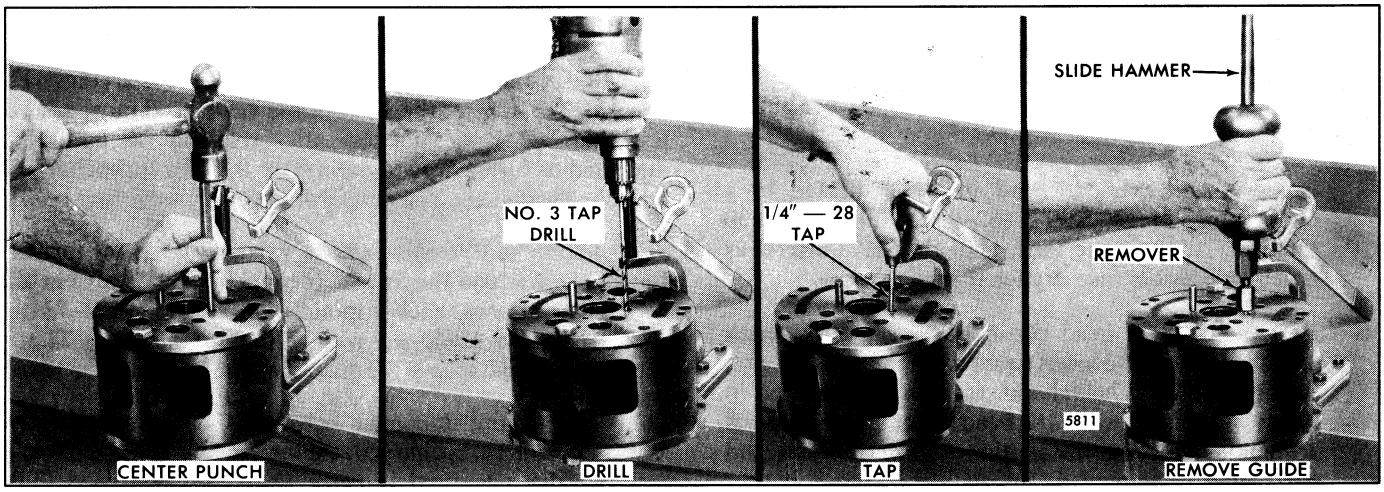



**Fig. 8 - Removing Broken Exhaust Valve Bridge Guide**

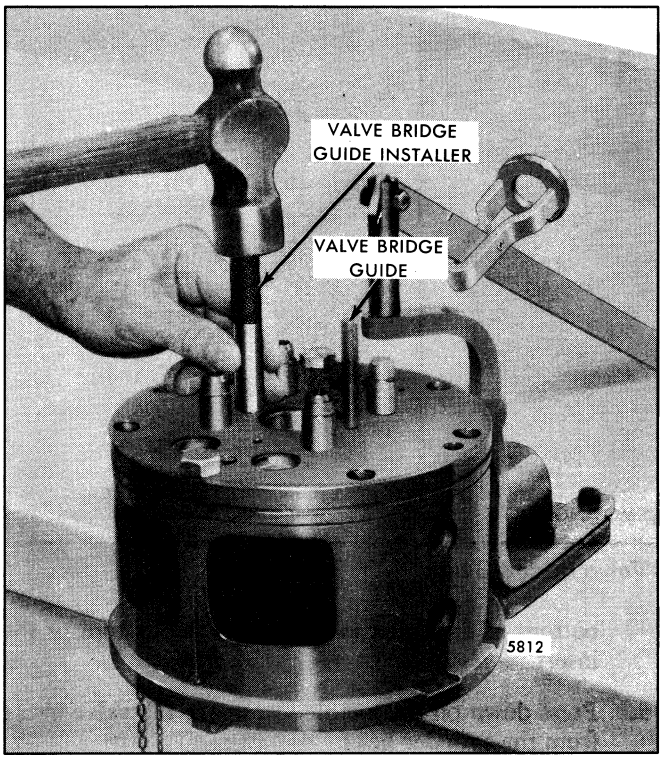



**Fig. 9 - Installing Exhaust Valve Bridge Guide**

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

2. Clean the cylinder head insert counterbores and valve inserts with 1,1,1-trichloroethane. Dry the counterbores and inserts with compressed air.

3. Check the valve seat insert counterbores in the cylinder head for cleanliness, concentricity, flatness and cracks.

4. The counterbore in the cylinder head has a diameter of 1.8965” to 1.8975” and a depth of .401” to .406”. The counterbores must be concentric with the valve guides within .003” total indicator reading.

5. Immerse the cylinder head in water heated to a temperature of 180-200°F (82-93°C) for at least 30 minutes. At the same time, cool the valve inserts as much as possible (use dry ice if available).

6. Rest the cylinder head bottom-up on a work bench and locate the valve insert squarely in the counterbore, seating face up. The valve insert must be installed in the cylinder head while the head is hot and the inserts are cold, otherwise installation will be difficult and parts may be damaged. Inserts are installed with a press fit of .0005” to .0025”.

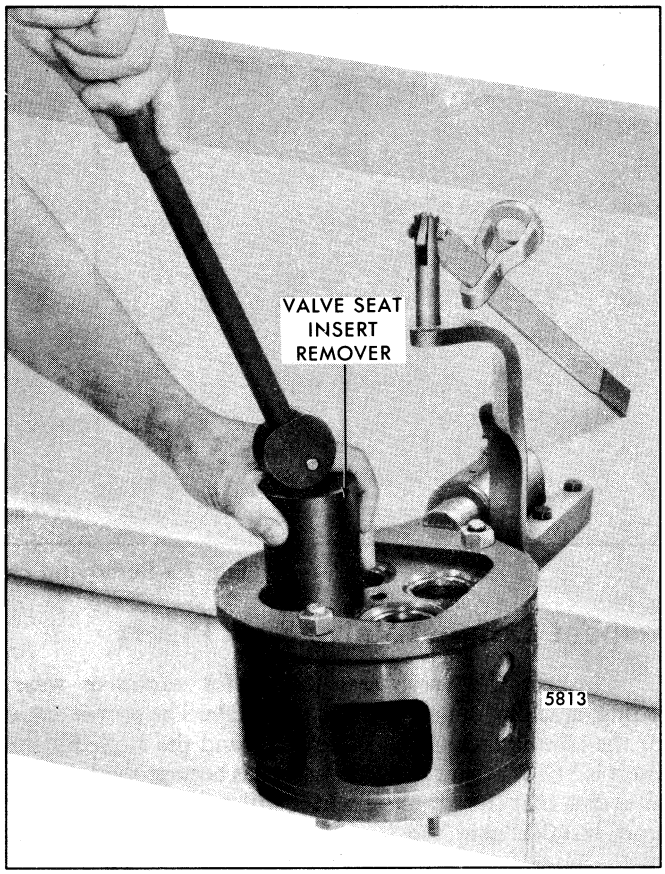



Fig. 10 – Removing Valve Seat Insert

7. Drive the valve insert with installer J 22711 until it seats solidly in the cylinder head (Fig. 11).

8. Grind the valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

## Recondition Exhaust Valve And Valve Seat Insert

• Reface an exhaust valve which is to be reused (Figs. 12 and 13). The edge of the valve at the valve head must not be less than .030” irr thickness after refacing for naturally aspirated or turbocharged engines or .070” for turbocharged intercooled engines. The proper angle of the valve seat is 30°.

• In 1985 a Pyromet exhaust valve replaced the former Inconnel valve and the former Inconnel-Stellite valve in all Series 149 engines, except models 9083-7316, 9123-7316, and 9163-7316 equipped with 270 mm injectors. These engines continue to use the Inconnel-Stellite valve.

• The former Inconnel valve was used in naturally aspirated and turbocharged engines, while the Inconnel-Stellite valve was used in turbo-charged-intercooled (TI) models.

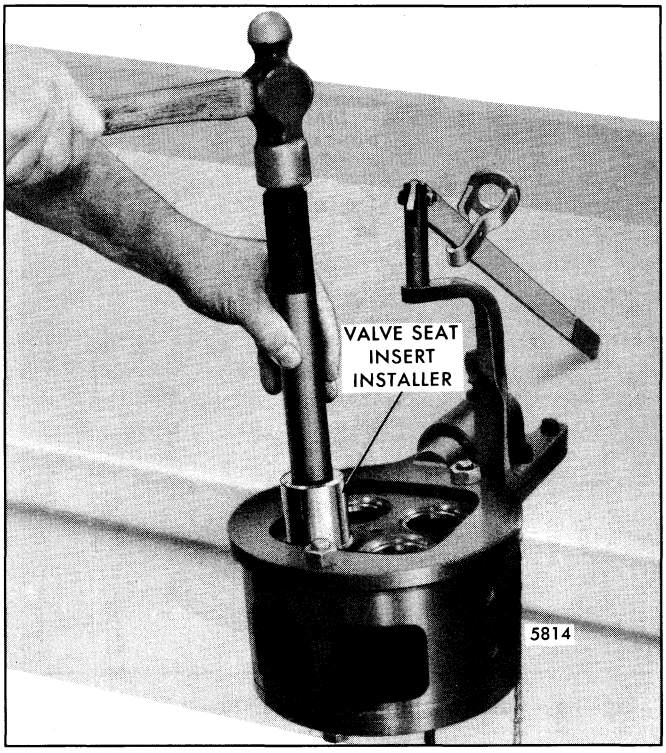



Fig. 11 – Installing Valve Seat Insert

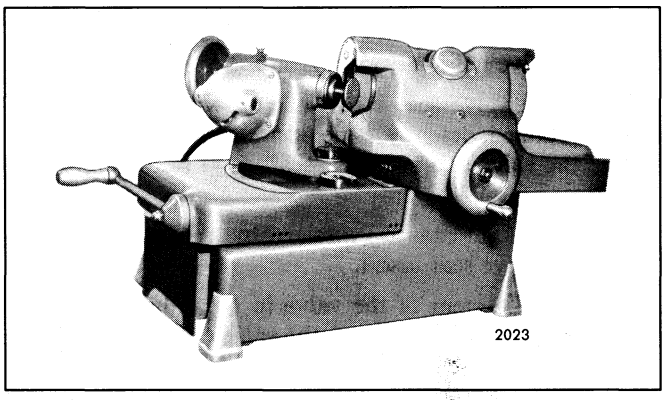



Fig. 12 – Refacing Exhaust Valve

• The Pyromet valve is identified by the letter "U" forged in the center recess of the valve face (Fig. 13). The former Inconnel valve was identified by "J," "J2," or "J4," while the Inconnel-Stellite valve had a "TI" or "J6" identification.

> **NOTICE:** The *stellite faced* valves must be ground in oil. Water coolant or dry grinding can result in cracking of the stellite faced material. After grinding, the valve face should be either dye-checked or zyglo inspected for cracks. Do not magnaflux. •

• *Valves on the 125 hp-per-cylinder head are .034" in diameter with radius bead keeper groove, whereas valves on the 100 and 112 hp-per-cylinder heads are .03Tin diameter.*

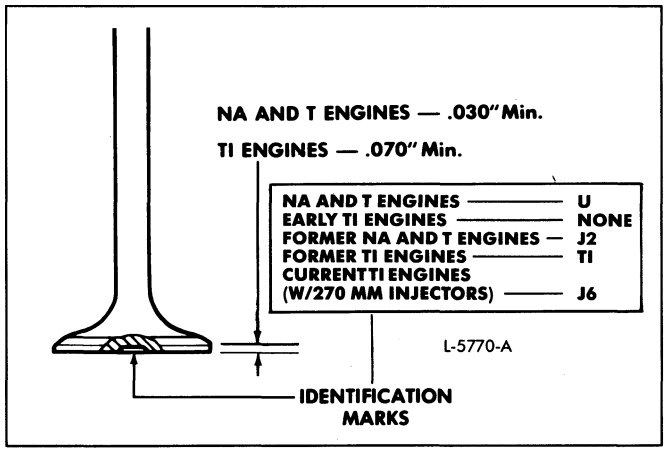



**Fig. 13 - Exhaust Valve Regrind Limits and Identification Marks**

Before installing either a new or used valve, examine the valve seat insert in the cylinder head for proper valve seating. The proper angle for the seating face of the valve insert is 31°.

When a new valve seat insert is installed or an old insert is reconditioned, the work must be done with a grinding tool as illustrated in Fig. 14.

The eccentric grinding method for reconditioning a valve seat insert is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits the operator to feed the grinding wheel into the work .001" at a time.

The eccentric valve seat grinder set J 7040-A used to recondition or grind the valve seat inserts consists of a grinder J 8165-1 and a dial gage J 8165-2. The adaptor set J 4627-02 must be used in conjunction with the grinder set J 7040-A. The adaptor set consists of the following:

1. Pilot J 4627-3.
2. Grinding wheel (15°) J 4627-5.
3. Grinding wheel (31 °) J 4627-2.
4. Grinding wheel (60°) J 4627-4.

Grind the inserts as follows:

1. Apply the 31° grinding wheel on the valve seat insert.
2. Use the 60° grinding wheel to open the throat of the insert.
3. Grind the top surface of the insert with the 15° wheel to narrow the width of the seat to approximately 1/16". Do not permit the grinding wheel to contact the cylinder head when grinding the inserts. If necessary, the grinding wheel may be dressed to the correct seat angle with the tool provided in the grinder set (Fig. 15).

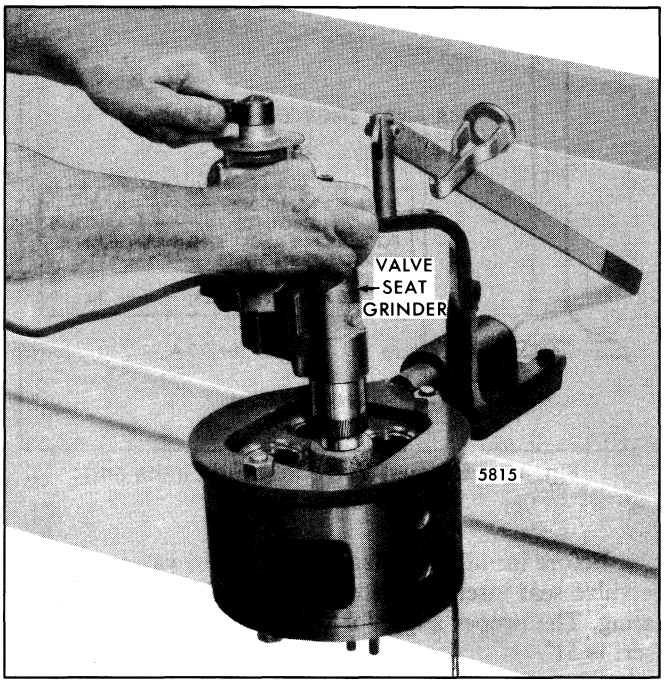



**Fig. 14 - Grinding Valve Seat Insert**

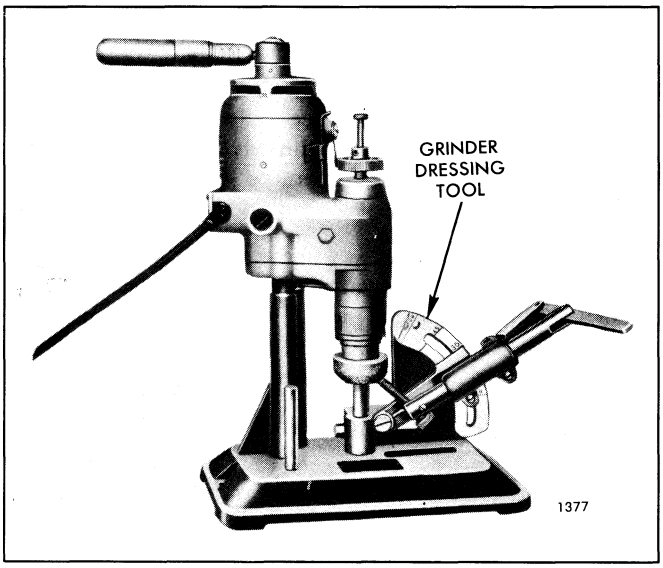



**Fig. 1 5 - Grinding Wheel Dressing Tool**

4. Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. Check the depth of the valve with depth gage J 22273-01 (Fig. 16). If, after several grinding operations, the valve recedes more than .032" below the surface of the cylinder head, replace the valve seat insert.

5. After the grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165-2 in position as shown in Fig. 17 and rotate it to determine the concentricity of each valve seat insert relative to the valve guide. Total runout should not exceed .002". If a runout of more than .002" is indicated, check for a bent valve guide before regrinding the insert.

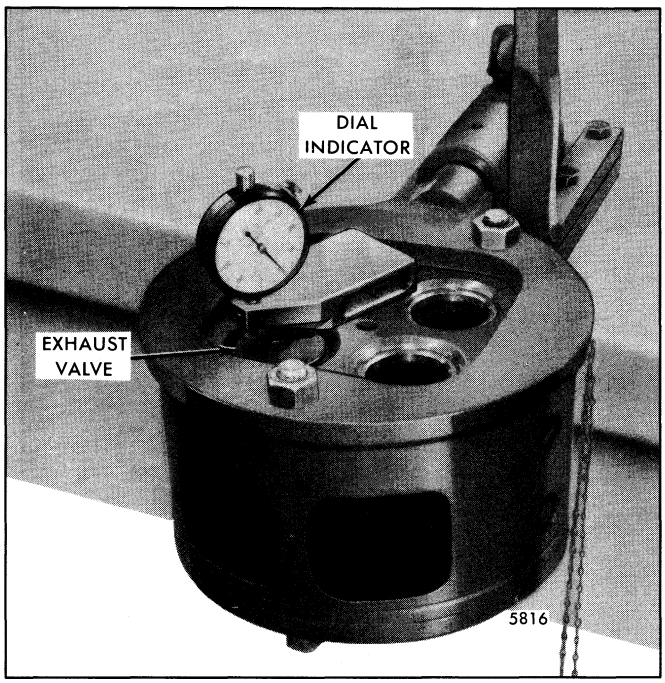



**Fig. 16 - Relationship Between Exhaust Valve and Cylinder Head**

When a valve seat insert runout within the desired limits is obtained, determine the position of the contact area between the valve and the valve seat insert in the following manner:

1. Apply a light coat of Prussian blue, or a similar paste, to the valve seat insert.

2. Lower the stem of the valve in the valve guide and bounce, but do not rotate, the valve on the insert. This procedure will indicate the area of contact on the valve face. The most desirable area of contact is at the center of the valve face.

**NOTICE:** Use of valve lapping compound is not recommended.

After the valy.e seat inserts have been ground and checked thoroughly, clean the cylinder head before installing the valves.

## Install Exhaust Valves And Springs

1. Clean the valve guides.

2. Lubricate the valve stems and valve bridge guides with sulphurized oil (E.P. type) and slide the valves all the way into the guides. If reconditioned valves are used, install them in the same relative location from which they were removed.

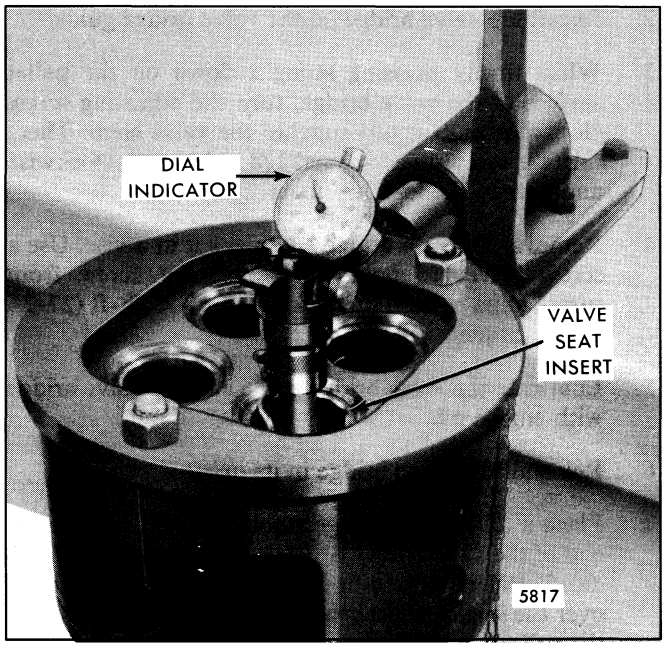



**Fig. 17 - Checking Relative Concentricity of Valve Seat Insert with Relation to Valve Guide**

3. Install the valve spring seats.

4. Install the valve guide oil seals as follows:

   a. Place the plastic seal protector cap on the end of the valve stem. If the cap extends more than 1/16" below the groove on the valve stem, remove the cap and cut off the excess length.

   b. Lubricate the protector cap with clean engine oil and start the seal carefully over the valve stem. Push the seal down slowly until the seal rests on the top of the valve guide (Fig. 18). Tool J 25251 can be used to facilitate installing the seal.

      A new Teflon-lip valve seal is used on the 125 hp-per-cylinder engine.

   c. Remove the plastic protector cap.

5. Install the valve springs and valve spring caps.

• A new exhaust valve rocker arm assembly, new valve lock and new spring cap marked with yellow dye have been released for Series 149 engines. The new spring cap is also identified by a machined spiral in the top of the cap. The new valve rocker arm assembly, is completely interchangeable with the former assembly when the new valve lock and spring cap are also used and only the new components will be serviced. The new valve lock and spring cap may be used with the former rocker arm assembly, but the former valve lock and spring cap should never be used with the new rocker arm assembly. The former valve locks and spring caps should be replaced with the new at time of major engine overhaul. Also, at overhaul, replace all the valve springs with new valve springs.

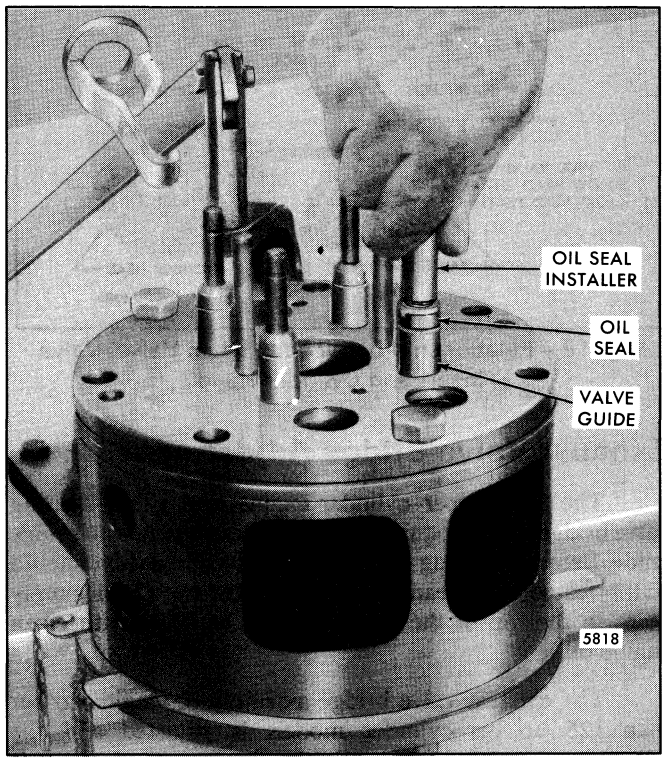



**Fig. 18 - Installing Valve Guide Oil Seal**

6. Refer to Fig. 2 and compress the exhaust valve spring with tool J 22693-11 and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring. Tap the end of the valve stem lightly with a plastic hammer to seat the valve locks.

• The 125 hp-per-cylinder engine has different seats, caps and locks than 112 hp-per-cylinder and smaller engines.

**NOTICE:** Compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the valve guide oil seal.

7. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.

   NOTICE: After the valves have been installed, make sure the valve heads are flush or no more than .017" (new) or .032" (used) below the surface of the cylinder head when the valves are fully closed (Fig. 19).

8. Assemble the cylinder head as outlined in Section 1.2.

9. Install the cylinder head. Refer to *Pre-Installation Inspection* and *Install Cylinder Head* in Section 1.2.

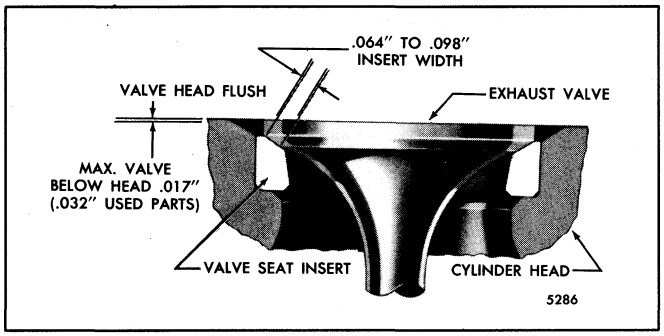



**Fig. 19 - Relationship between Exhaust Valve, Valve Insert and Cylinder Head**

## Exhaust Valve Bridge Adjustment

• The 125 hp-per-cylinder engine uses a free-floating valve bridge which requires no adjustment and has no bridge guide. Before installing the bridge, the top of the valve should be lubricated with clean engine oil and the two (2) oil supply holes in the top of the bridge should be filled with clean engine oil.

• The exhaust valve bridge assembly on engines other than 125 hp per-cylinder models is adjusted and the adjustment screw is locked securely after the cylinder head is installed on the engine. Until wear occurs, or the cylinder head is reconditioned, no further adjustment is required on the valve bridge. A complete valve bridge adjustment is performed as follows:

1. Place the valve bridge in a vise or bridge holding fixture J 21772 and loosen the locknut on the bridge adjusting screw.

   **NOTICE:** Loosening or tightening the locknut with the bridge in place may result in a bent bridge guide or bent rear valve stem.

2. Install the valve bridge on the valve bridge guide.
3. While firmly pressing straight down on the pallet surface of the valve bridge, turn the adjusting screw clockwise until it just touches the valve stem. Then, turn the screw an additional 1/8 to 1/4 turn clockwise and tighten the locknut finger tight.
4. Remove the valve bridge and place it in a vise. Use a screw driver to hold the adjustment screw from turning and tighten the locknut to 20-25 lb—ft (27-34 N#m) torque.
5. Lubricate the valve bridge guide and the valve bridge with engine oil.
6. Reinstall the valve bridge in its *original* position.
7. Place a .0015" feeler gage (tool J 23185) under each end of the valve bridge or use a narrow strip cut from .0015" feeler stock to fit in the bridge locating groove over the inner exhaust valve. While pressing down on the pallet surface of the valve bridge, both feeler gages must be tight. If both of the feeler gages are not tight, readjust the adjusting screw as outlined in Steps 3 and 4.
8. Remove the valve bridge and reinstall it in its *original* position.
9. Adjust the remaining valve bridges in the same manner.
10. Swing the rocker arm assembly into position, making sure the valve bridges are properly positioned on the rear valve stems. This precaution is necessary to prevent valve damage due to mislocated valve bridges. Tighten the rocker arm shaft bracket bolts to the torque specified in Specifications - Section 1.0.

# VALVE ROCKER COVER

A valve rocker cover completely encloses each bank of cylinder heads and the valve and injector rocker arm mechanism (Fig. 1). Each rocker cover is sealed against oil leakage by a gasket.

An option plate is inserted in a retainer attached to one of the covers.

The valve rocker cover assembly on certain engines may include a breather assembly or an oil filler, depending upon the engine application.

Studs are located at each end of the inboard side (top rail) of the cover for ease in locating the cover on the cylinder block. Current covers also have a lifting tab cast into each side of the cover for easier handling.

Effective with engine serial numbers 12E-5672 and 16E-5308 new valve rocker covers are being used in conjunction with the new cast breather body assembly (Section 4.8, Fig. 1). The new covers are required because of breather and turbocharged interference. The new covers are the same as the former covers except the 19.36" dimension locating the breather mounting pad is now 10.08". Both the former and new rocker covers are serviced.

## Remove Valve Rocker Cover

Clean the valve rocker covers and around the covers before removing them from the engine to keep dust or dirt from entering the valve mechanism. Then remove the bolts and washers and stud nuts and washers from the cover and lift each cover straight away from the cylinder block.

## • Inspection

Remove the gasket from the rocker cover and inspect the cover for gouges in the gasket sealing area. Check the cover for flatness and for cracks.

## • Installation

Install a new gasket over the two (2) studs located in the top corners of the block. Install the cover over the studs, and install the required 5/16" - 18 bolts and washers and the two (2) 5/16" - 24 nuts and washers on the studs. Using a crossing pattern from the center of the cover to the edges, tighten the bolts to 13 - 17 lb—ft (18-23 N«m) torque. Then tighten the 5/16" - 24 nuts to 15 - 19 lb—ft (20 - 26 N»m) torque.

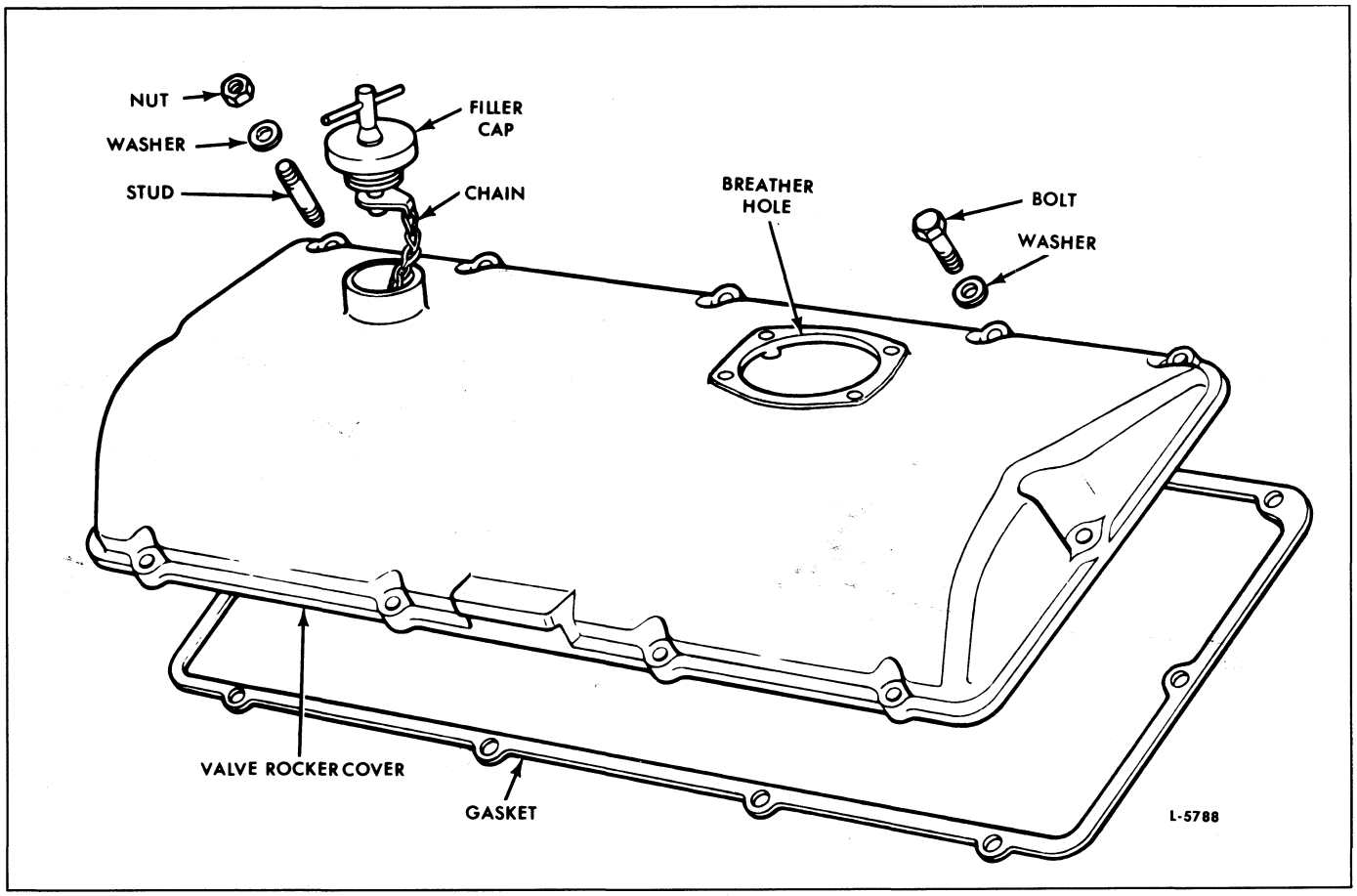



Fig. 1 – Typical Valve Rocker Cover

# CRANKSHAFT

The crankshaft is a steel forging, heat-treated to ensure strength and durability. The two halves of the 12V and 16V crankshafts are bolted together (Fig. 1).

To strengthen the crankshaft, the fillets of the current 12 V crankshaft are induction hardened at the No. 1,2,7 and 8 main journals and the No. 1 and 6 rod journals and the 16V crankshaft fillets are induction hardened at the No. 1, 2, 9 and 10 main journals and the No. 1 and 8 rod journals. These positions are determined from a complete crankshaft assembly.

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end play is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and the cylinder block.

Each main bearing journal is 4-7/8” in diameter and each connecting rod journal is 3-7/8” in diameter.

## Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Clean the exterior of the engine.
2. Drain the cooling system.
3. Drain the engine crankcase.
4. Remove all accessories with attaching parts, as necessary, to permit the engine to be placed upside down on an overhaul stand.
5. Remove the valve rocker covers, valve and injector operating mechanism and the cylinder heads.
6. Install suitable retainers to temporarily hold the pistons and cylinder liners in place. Fig. 2 shows a typical retainer in place and the instructions for its fabrication.
7. Remove the engine from its base and position it upside down on an engine overhaul stand.
8. Remove the lower oil pan, oil pump, brackets and tubing.
9. Remove *the upper oil pan.
10. Remove the flywheel and flywheel housing.
11. Remove the crankshaft cap or pulley retaining bolt and washer at the front end of the crankshaft.
12. Remove the vibration damper, water pump and thermostat housings.
13. Remove the heat exchanger, if so equipped.
14. Remove the outboard bearing support and seal assembly from the front cover.
15. Remove the front cover.
16. Remove the connecting rod bearing caps.
17. Remove the main bearing caps.

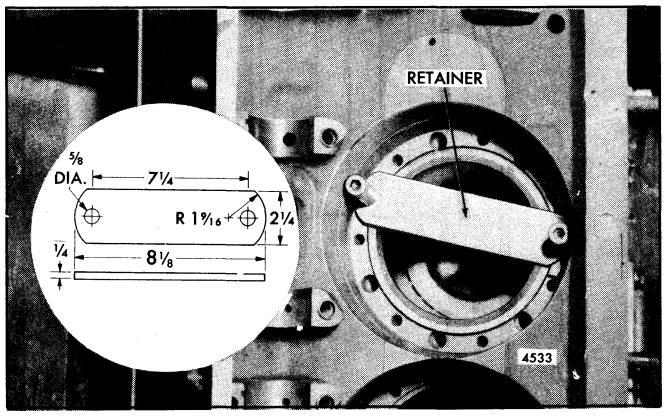



**Fig. 2 - Cylinder Liner Retainer and Instructions for Fabrication**

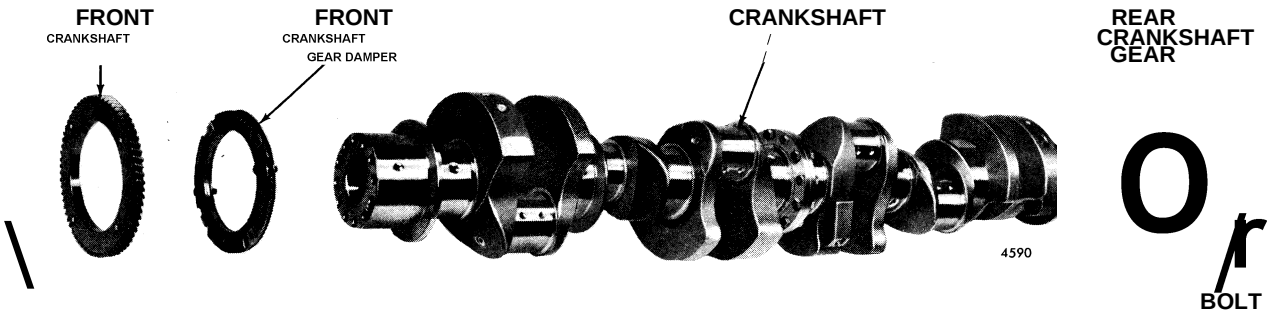



**Fig. 1 - Crankshaft Details and Relative Location of Parts (12V-149)**

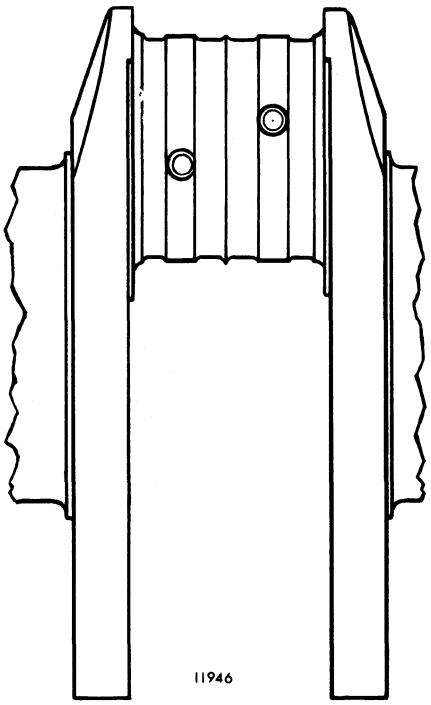



**Fig. 3 - Typical Ridging of Crankshaft**

18. Remove the thrust washers from the rear main bearing cap and the cylinder block.

19. Remove the crankshaft, timing gears (front and rear) and front timing gear damper as an assembly.

20. Remove the crankshaft timing gears and damper from the crankshaft (Section 1.7.5).

## Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then, reinstall the plugs.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heatTreatment has probably been destroyed.

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 3). Ridges exceeding .0002” must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

On current engines, the rear oil seal is pressed into the outboard bearing support and seals on a replaceable sleeve that is pressed on the flywheel or flywheel coupling assembly.

On former 12 V and 16V engines, carefully inspect the rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point. The front oil seal rides on a replaceable sleeve.

If the crankshaft oil seal contact surface on the crankshaft is excessively worn or grooved, install an oil seal sleeve, which provides a replaceable wear surface for the seal. An oversize oil seal will be required with use of the sleeve. Refer to Section 1.3.2 for replacement of the oil seal sleeve.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise it will be necessary to regrind the thrust surfaces.

Check the crankshaft timing gear for worn or chipped teeth. Replace the gear, if necessary.

Inspect the crankshaft for cracks as outlined under *Inspection for Cracks.*

## Crankshaft Measurements

Support the crankshaft on its front and rear journals in the cylinder block and check the alignment at the adjacent intermediate main journals with a dial indicator.

When the high spots of runout on the adjacent journals is in opposite directions, the sum must not exceed .003” total indicator reading. When the high spots of runout on the adjacent journals is in the same direction, the difference must not exceed .003” total indicator reading. When the high spots of runout on the adjacent journals are at right angles to each other, the sum must not exceed .004” total indicator reading, or .002” on each journal. Crankpins must be parrallel with the main journals within .0005” in length of crankpin journal. If the runout limit 4s greater than that given in Table 1, the crankshaft must be replaced.

Measure all of the main and connecting rod bearing journals (Fig. 4). Mesure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the clearance with new connecting rod bearing shells or new main bearing shells exceeds .0045” and .0062” respectively, the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002”. Also, if the journal taper of a used crankshaft exceeds .0015” or the out-of-round exceeds .0010”, the shaft must be reground.

| ENGINE | JOURNALS SUPPORTED ON | JOURNALS MEASURED | MAX. RUNOUT (TOTAL INDICATOR READING) |
|---|---|---|---|
| 8V | No. 1 &No.5 | Outboard<br>No. 2 & No. 4<br>No. 3 | oc£<br>CCJc |
| 12V | No. 1 8c No. | No. 4 & No. 5<br>8 No. 3 & No. 6<br>No. 2 & No. 7 | °°g<br>°°<br>°g |
| 16V | No. 1 &N° .IO | No. 5 & No. 6<br>No. 4 & No. 7<br>No. 3 & No. 8<br>No. 2& No. 9 | .008"<br>.006"<br>.004"<br>.002" |
| CRANKSHAFT HALVES | | | |
| 12V | No. 1 8c No. | 4 Outboard<br>4No. 2 8c No. 3 | .001"<br>.002" |
| 16V | No. 1 8c No. | Outboard<br>5No. 2 8c No. 4<br>No. 3 | .001"<br>.002"<br>.004" |

**TABLE 1 - CRANKSHAFT RUNOUT**

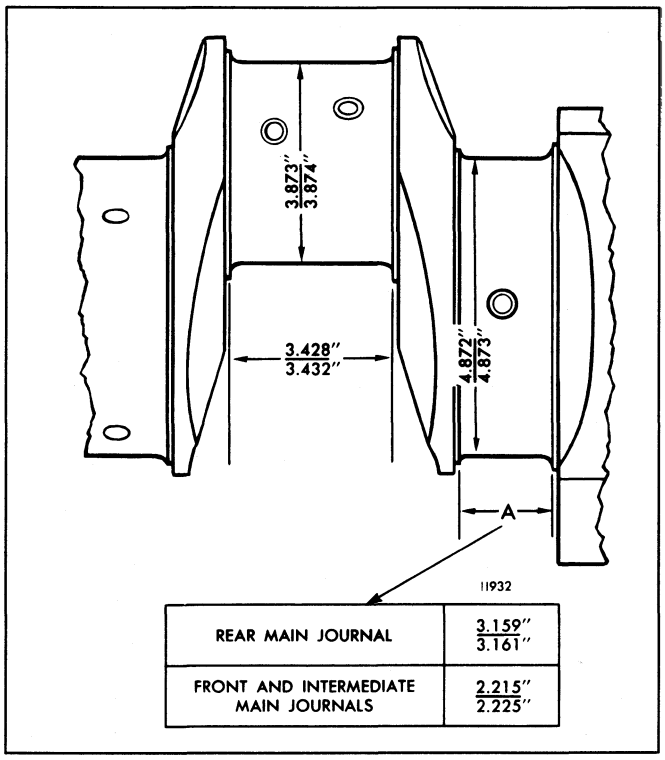



**Fig. 4 – Dimensions of Crankshaft Journals**

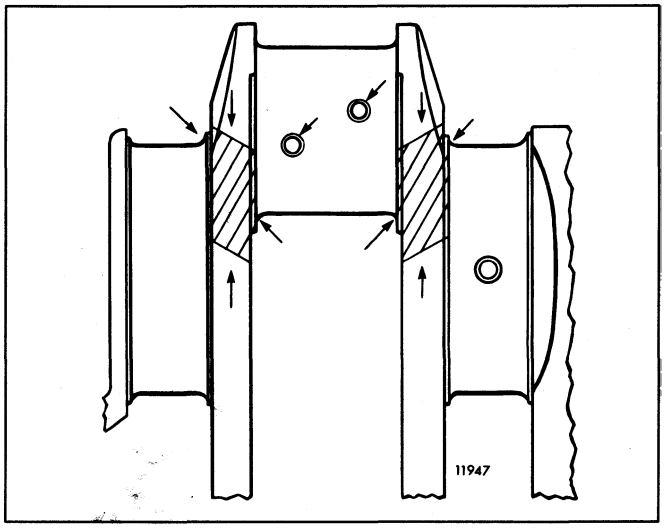



**Fig. 5 – Critical Crankshaft Loading Zones**

## Inspection For Cracks

Carefully check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

**Magnetic Particle Method:** The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be demagnetized after the test.

**Fluorescent Magnetic Particle Method:** This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under "Black Light". Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "Black Light".

**Fluorescent Penetrant Method:** This is a method which may be used on both *non-magnetic and magnetic* materials. A highly fluorescent liquid penetrant is applied to the part. Then, the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "Black Light".

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure. **Interpretation** of the indications is the most important step.

All Detroit Diesel Corporation crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service — a *bending* force and a *twisting* force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Fig. 5).

**Bending fatigue** failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

**Torsional fatigue** failures result from torsional vibration which takes place at high frequency.

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 5.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper or the introduction of improper or additional pulleys or couplings are usual causes of this type of failure. Also, overspeeding of the engine or resetting the governor at a different speed than intended for the engine application may be contributory factors.

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes (Fig. 6). Replace the crankshaft when cracks of this nature are found.

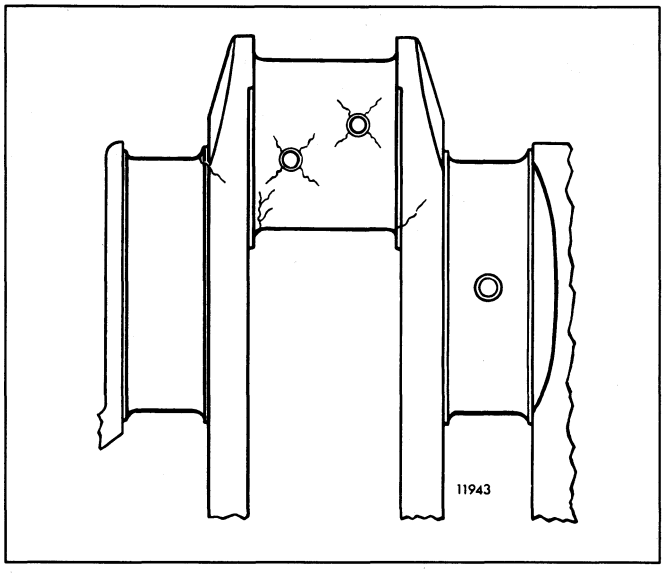



Fig. 6 – Crankshaft Fatigue Cracks

## Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002", .010", .020" and .030" undersize bearings are available. The .002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

If a 12V or 16V crankshaft is to be reground, remove the bolts securing the two crankshaft halves together and proceed as follows:

The 12V and 16V crankshaft outboard bearing surface *must not* be reduced in diameter. The drive hub to crankshaft tolerance must be maintained to provide the proper fit between the mating parts.

Connecting rod and/or main bearing journals which exhibit discoloration due to excessive overheating from bearing failure are *not* acceptable for rework.

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 2 and Fig. 4 and determine the size to which the journals are to be reground.

| Bearing Size | Conn. Rod Journal Dia. | Main Bearing Journal Did. |
|---|---|---|
| Standard | 3.873"/3.874" | 4.872"/4.873" |
| .002" U.S. | 3.871 73.872" | 4.87074.871" |
| .010" U.S. | *3.86373.864" | *4.86274.863" |
| .020" U.S. | *3.853*73.854" | *4.852*74.853" |
| .030" U.S. | *3.84373.844" | *4.842*74.843" |

'Dimension of reground crankshaft.

TABLE 2 - CRANKSHAFT GRINDING CHART

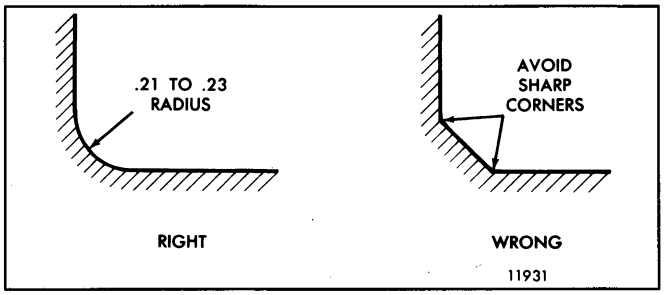



Fig. 7 – Crankshaft Journal Fillets

EXAMPLE - If the main journal measurement of a used crankshaft is 4.865", the crankshaft should be ground to accommodate .010" undersize bearings. However, if the measurements of the main journal are below 4.863", the journals should be ground to accept .020" undersize bearings.

2. If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.

3. All journal fillets must have a .210" to .230" radius between the crank cheek and the journal and must not have any sharp grind marks (Fig. 7). The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.

4. Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

5. If the thrust surfaces of the crankshaft are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .210" to .230" radius between each thrust surface and the bearing journal.

6. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32".

7. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

8. Demagnetize the crankshaft.

9. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

## Assemble Crankshaft Halves (12V And 16V)

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the plugs.

Unless an additional cylinder block is available for crankshaft assembly, prepare the cylinder block being worked on, following Steps 3, 4 and 5 under *Install Crankshaft.*

Assemble the two 12 V or 16V crankshaft halves, using the cylinder block for alignment, as follows:

1. Refer to Section 1.3.4 for main bearing details and install the upper *grooved* main bearing shells in the cylinder block.

2. Apply clean engine oil to all crankshaft journals and place each crankshaft half in position in the cylinder block.

3. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear bearing cap. *The grooved side of the thrust washers must face toward the crankshaft thrust surface.*

4. With the lower main bearing shells (refer to Section 1.3.4) installed in the bearing caps, lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Install all of the bearing caps, **except the two center caps,** and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly.

5. Tighten each set of main bearing cap bolts, starting with the bolts on the outside of the bearing cap and proceeding with the two inner bolts, to approximately 100 lb—ft (136 N«m) torque. Then, using the same sequence, tighten each bolt to 280-290 lb—ft (379-393 N#m) torque. If the bearings have been installed properly, the crankshaft halves will turn freely with the main bearing cap bolts drawn to the specified torque.

6. Position a dial indicator on each of the two journals (No. 4 and No. 5 on 12V or No. 5 and No. 6 on 16 V). Then, check the journal runout (Fig. 8) on each crankshaft half with one end of the cylinder block elevated to pre-load the thrust area.

7. Rotate the crankshaft halves until the crankshaft timing jnarks are in alignment on the two crankshaft end flanges (Fig. 8). Coat the intermediate flange bolt threads with International Compound No. 2 (or equivalent). Wipe excess compound from the bolt threads and install the 7/16" bolts in the crankshaft.

8. Install two 1/2" bolts and nuts 120° apart and 120° from the 7/16" bolt and nut.

9. Snug up the three bolts and nuts and, while slowly rotating the crankshaft, tap the flanges to bring the runout between the two center adjacent journals to within .001".

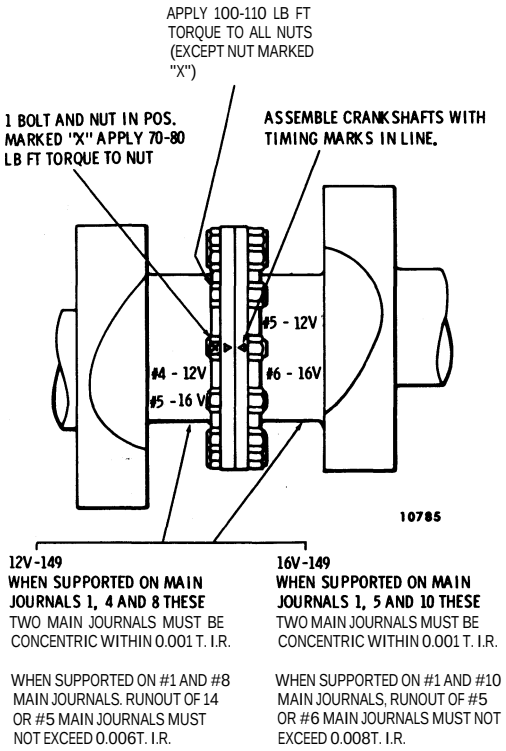



**Fig. 8 - Crankshaft Assembly Instructions**

10. Install the remaining bolts and nuts. Alternately torque each nut (180° apart) until all nuts have been tightened. Tighten the 7/16” nut to 70-80 lb—ft (95-108 Nem) torque and the 1/2” nuts to 100-110 lb—ft (136-150 Nem) torque. However, because of the space limitations, a torque wrench adaptor set J 22897 must be used and the torque wrench reading must be adjusted due to the increase in length of the torque wrench with the adaptor in place. Use the following formula to determine the adjusted torque reading.

$$Tw = Ta \left(\frac{\quad}{1 + a}\right) \quad \ldots\ldots\ldots\ldots\ldots 1$$

EXAMPLE - If the effective length of the wrench (L) is 22” and the adaptor (A) is 3” long, you should have a reading of 66 lb—ft (89 N#m) on the wrench to have the bolt tightened to 75 lb—ft (102 N#m) torque (Fig. 9):

$$Tw = 75 \left(\frac{22}{22 + 3}\right)$$

$$Tw = 75\ (22/25)$$

$$Tw = 66$$

11. Install the crankshaft oil passage plugs as follows:

The plugs are shipped loose with a service crankshaft.

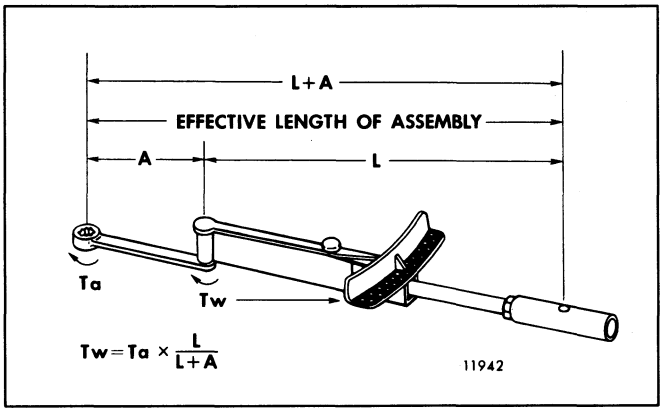



**Fig. 9 - Calculating Torque with an Adaptor**

a. On current engines, the 1/4” pipe plug must be deleted from the rear crankshaft half to allow for lubrication of the rear outboard bearing support. On former engines without a rear outboard bearing support, install the 1/4” pipe plug in the rear end of the crankshaft. The oil passage in the front end of the crankshaft is to lubricate the front outboard bearing support.

• b. The ends of former crankshafts were counterbored to receive 3” cup plugs (Fig. 10). A limited number of former crankshafts were produced with 3 1/8” or 3 1/4” cup plugs. The ends of current crankshafts are drilled and tapped to accept 1/2” - 14 Vibraseal-coated pipe plugs. A few crankshafts were also produced with 3/4” plugs.

Apply a thin coat of Loctite Vibraseal, or an equivalent non-hardening sealant, to the outside diameter of all plugs before installing. Install required plugs in each end of the crankshaft. Tighten current 1/2” pipe plugs to 80 lb—ft (108 N#m) torque. Vacuum test *cup plugs* using cup plug tester J 34728 with vacuum pump J 23738.

c. Install the 3/8” pipe plugs in each crankshaft throw (6 in the 12V engine or 8 in the 16V engine).

## Install Crankshaft

• If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air and install the pipe plugs. Apply a thin coat of non-hardening sealant to the outside diameter of the 1/2” pipe plug(s), install the plug(s), and tighten to 80 lb—ft (108 N»m) torque. Then, install the crankshaft as follows:

When a new or reground crankshaft is installed, ALL new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

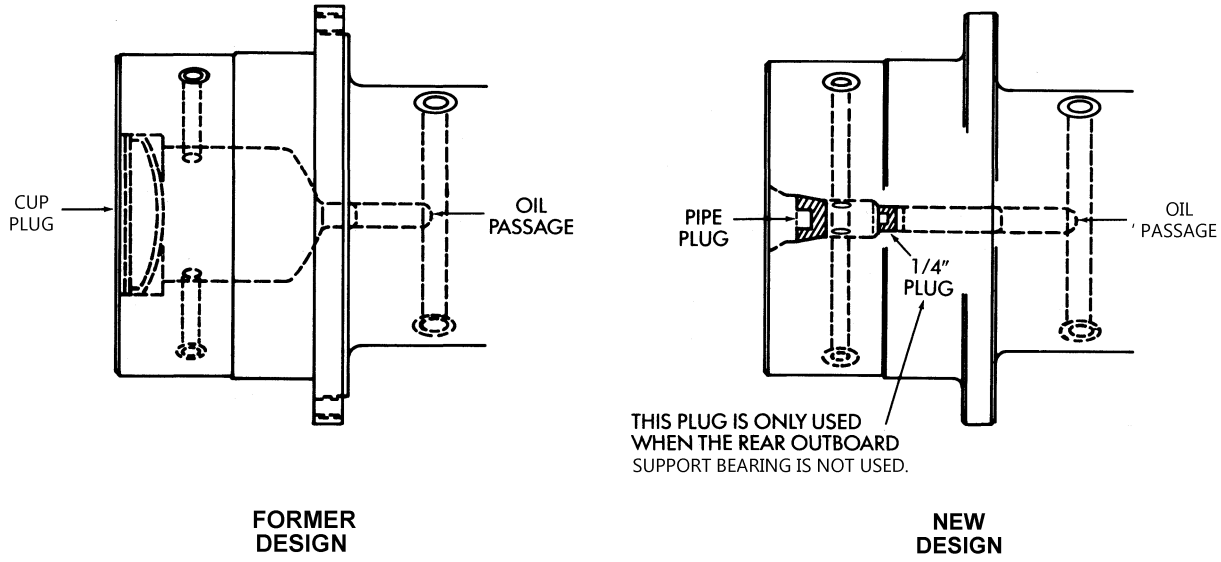



**Fig. 10 - Former and Current Series 49 Engine Crankshaft End Designs**

1. Assemble the crankshaft timing gears and front timing gear damper (Section 1.7.5).

2. Turn the engine so the front end is facing down.

   **NOTICE:** Be careful not to damage the gear train.

3. Remove the piston and cylinder liner retainers.

4. Remove the pistons, connecting rods and cylinder liners from the cylinder block.

5. Turn the engine upside down on the overhaul stand.

6. Refer to Section 1.3.4 for main bearing details and install the upper *grooved* main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed. The two (2) wide bearings are installed at the ends of the cylinder block.

7. Apply clean engine oil 360° around all crankshaft bearing journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to Section 1.7.1 for the correct method of timing the gear train.

8. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. *The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.* If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 6 and Table 3.

| Nominal Size | Thrust Washer Thickness | |
|---|---|---|
| | Min. | Max. |
| Standard | .1630" | .1660" |
| .005" Oversize | .1680" | .1710" |
| .010" Oversize | .1730" | .1760" |

**TABLE 3 - THRUST WASHER SIZE**

9. Install the lower main bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

10. Install the bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells* in Section 1.3.4. If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

11. Check the crankshaft end play by moving the crankshaft toward the gage with a small (less than 12") pry bar (Fig. 11). Keep a constant pressure on the pry bar and set the dial indicator to zero. Then, remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play

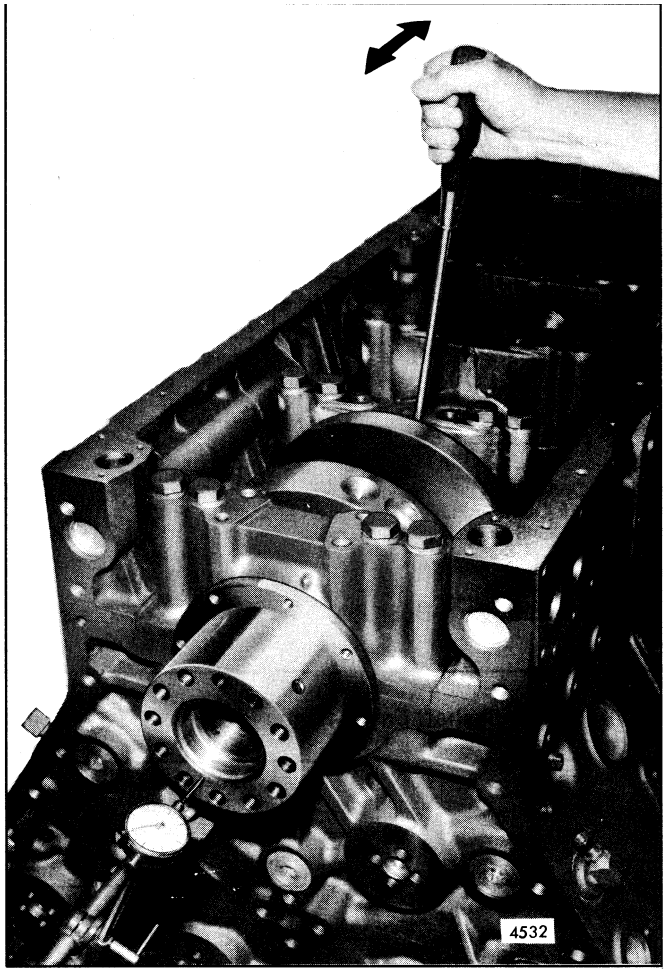



**Fig. 1 1 - Checking Crankshaft End Play**

should be .004M to .014" with new parts or a maximum of .018" with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers. Crankshaft end play must be checked again after installation of the power takeoff assembly, transmission, marine gear or power generator.

12. Position the engine with the front face down, on the overhaul stand, using care not to damage the gear train.

13. Install the pistons, connecting rods and cylinder liners (Section 1.6.3).

14. Install the cylinder liner retainers.

15. Turn the engine right side up on the overhaul stand.

16. Install the front cover (Section 1.3.5).

17. Install the outboard bearing support and seal assembly on the front cover (Section 1.3.5.1).

18. Install the heat exchanger, if so equipped.

19. Install the thermostat housings, water pump and vibration damper.

20. Install the crankshaft cap or pulley retaining bolt and washer at the front end of the crankshaft.

21. Install the flywheel housing (Section 1.5) outboard bearing support - current engines (Section 1.3.5.2) and the flywheel assembly (Section 1.4).

22. Check the crankshaft for **distortion** (bending) at the rear connecting rod journal counterweights *before* and *after* installing a power takeoff assembly, marine gear, transmission or power generator. If improperly installed these components can distort the crankshaft and cause a crankshaft malfunction. Overtightening drive belts can also cause crankshaft distortion. See Section 15.1 for recommended belt tensions.

While in each case one must be guided by the individual circumstances and facts that evolve, generally speaking Detroit Diesel Corporation cannot be responsible for system damage caused by engine-to-driven component interference and/or distortion. Consequently, the engine crankshaft end play check and crankshaft distortion check are *musts.*

Check the crankshaft distortion as follows:

a. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the six (6) o'clock position.

b. Center punch a hole in the inside face of each counterweight cheek, one quarter of an inch from the lower end of each counterweight, to support the gage.

c. Install a gage (Starrett Co. No. 696 dial gage, or equivalent) in the center punch holes in the cheek of each counterweight (Fig. 12).

d. Set the dial indicator at zero, then rotate the crankshaft approximately 90° in both directions. Do not allow the gage to contact the connecting rod caps or bolts. Note and record the dial indicator readings at the 3, 6 and 9 o'clock crankshaft counterweight positions. The maximum allowable variation is .0045" total indicator reading. Remove the tool that was used to rotate the crankshaft when taking the dial indicator readings. >

e. If the reading on the gage exceeds .0045", check the power takeoff assembly, transmission, marine gear, or power generator for improper installation and realign as necessary.

23. Install the upper oil pan (Section 4.7).

24. Install the oil pump, brackets, tubing and lower oil pan (Section 4).

25. Remove the engine from the overhaul stand and place it on its base.

26. Install all of the accessories which were previously removed.

27. Remove the cylinder liner retainers.

28. Install the cylinder heads, valve and injector operating mechanism, and valve rocker covers using new gaskets.

29. After the engine has been completely reassembled, refer to the *Lubrication Recommendations* in Section 13.3 and refill the crankcase to the proper level on the dipstick.

30. Fill the cooling system (Section 5).

31. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the *run-in* schedule (Section 13.2.1).

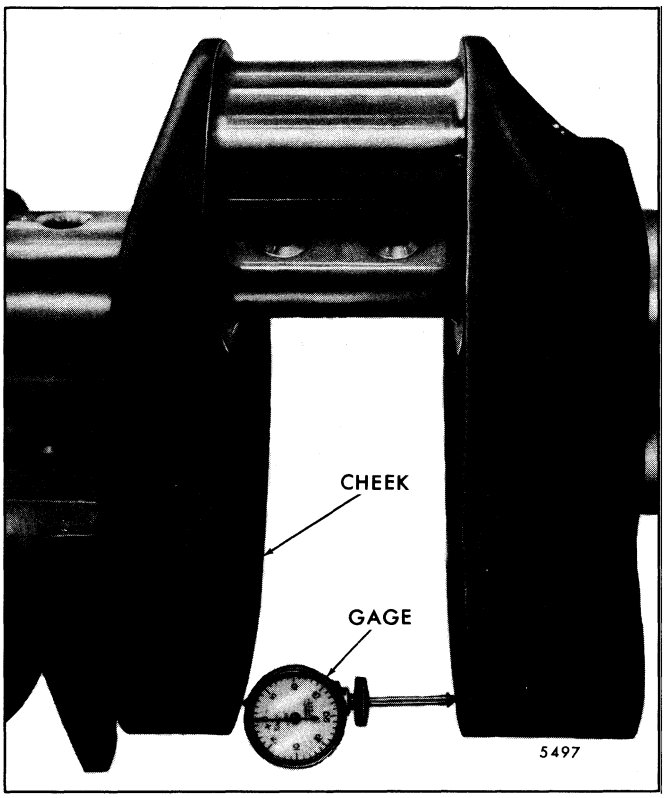



**Fig. 12 - Crankshaft Distortion Measuring Gage Mounted on Crankshaft**

# CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

• Effective with unit serial numbers 8E0002524, 12E0008668, and 16E0008435, fluoroelastomer front and rear oil seals are used in all Series 149 engines. The sealing lips of the new seals are made of a wear-resistant fluoroelastomer rubber material and are *unidirectional* That is, they seal in only one direction of crankshaft rotation. To insure proper installation, the direction of crankshaft rotation is stamped on the seal cases. The former seals had silicone rubber sealing lips and were bi-directional.

> • **NOTICE:** Failure to install the correct seal in relation to the direction of crankshaft rotation can result in seal damage, oil leakage, and possible engine damage caused by a reduced oil level.

• Oil seals are pre-lubricated with a special lubricant. *Do not remove this lubricant* Keep the sealing lip(s) clean and free from scratches. A plastic coating which acts as a sealant is applied to the outer surface of the casing. *Do not remove this coating.* To prevent seal lip damage at start-up, new seals must be lubricated with clean engine oil at assembly.

The front oil seal (Fig. 1) is pressed into the outboard bearing support and seals on a replaceable sleeve pressed on the vibration damper hub adaptor (Section 1.3.6). On current engines, the rear oil seal is pressed into the outboard bearing support and seals on a replaceable sleeve pressed on the flywheel (Fig. 2). The former rear oil seal is pressed into the flywheel housing and seals on the crankshaft (Fig. 3).

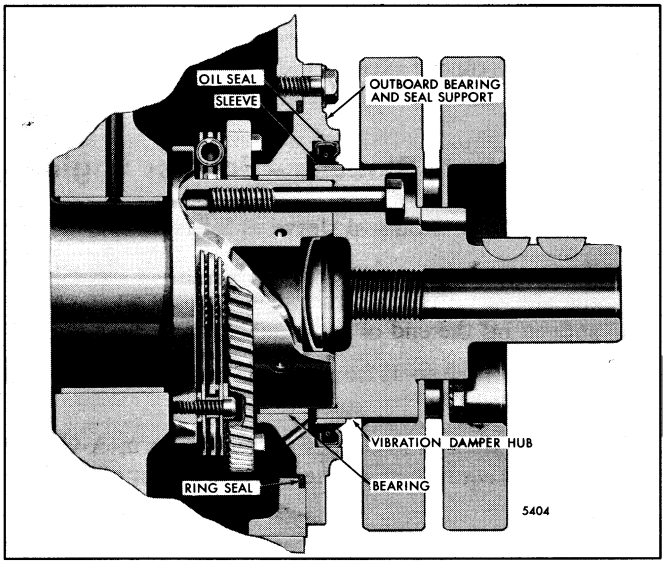



**Fig. 1 - Crankshaft Front Oil Seal**

Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout or grooved sealing surfaces on the crankshaft or oil seal sleeve.

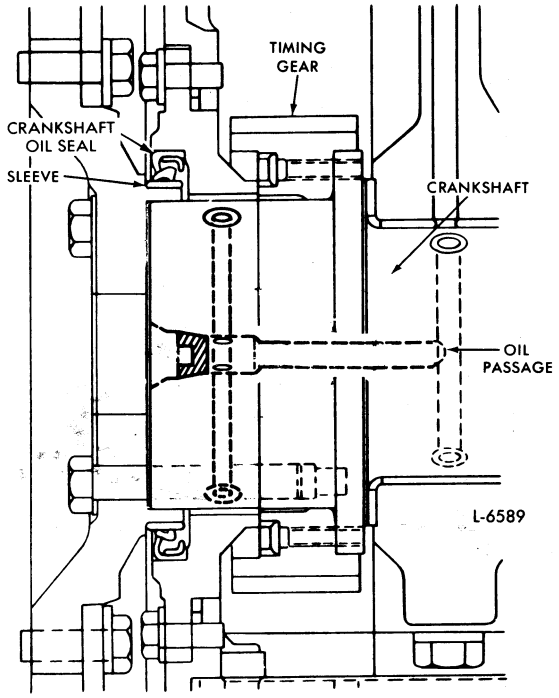
## Remove Crankshaft Front Oil Seal Current And Former

1. Remove the vibration dampers (Section 1.3.6) from the front end of the crankshaft hub.
2. Remove the outboard bearing support from the engine front cover (Section 1.3.5.1).
3. Support the inner face of the outboard bearing support on wood blocks. Then pry the oil seal out of the support.

## Remove Crankshaft Rear Oil Seal

Remove the flywheel (Section 1.4) from the engine. Remove the rear crankshaft oil seal from the flywheel housing as follows:

1. Current rear oil seal:
   a. Remove the outboard bearing support from the flywheel housing (Section 1.3.5.2).




**• Fig. 2 - Crankshaft Rear Oil Seal - Current**

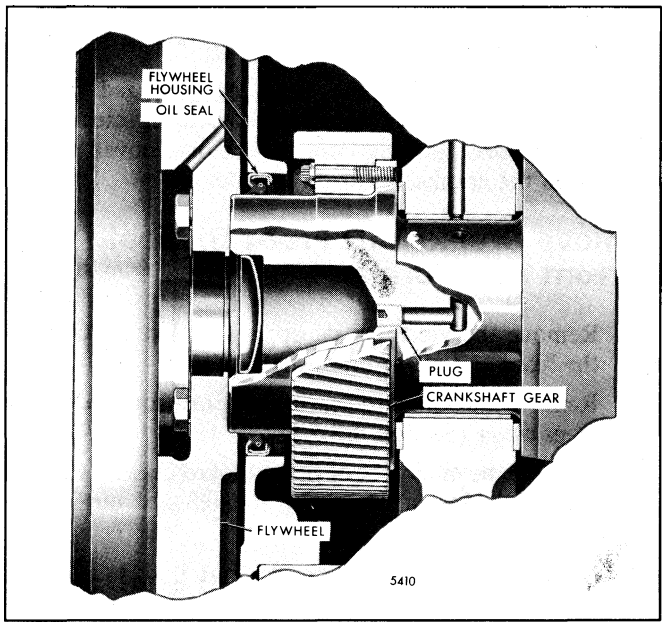



**Fig. 3 - Crankshaft Rear Oil Seal - Fonner**

b. Support the inner face of the outboard bearing support on wood blocks. Then pry the oil seal out of the support.

2. Former rear oil seal:

a. Drill two diametrically opposite holes in the oil seal casing.

b. Thread a metal screw with a flat washer into each hole.

c. Use a pry bar against each of the flat washers to remove the oil seal.

## Install On Seal Sleeves - Current Engines

• To ensure proper sealing, replace the oil seal sleeve whenever a new oil seal is installed. An oversized oil seal must be used with the sleeve.

**NOTICE:** Before installing the crankshaft oil seal sleeve (front or rear), check for sharp corners, scratches, inclusions or nicks. If the sleeve is damaged, replace it.

To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off the end of the crankshaft.

Install the front oil seal sleeve:

1. Support the front vibration damper hub on the bed of an arbor press.
2. Using tool J 22518, press the oil seal sleeve flush with the vibration damper hub.

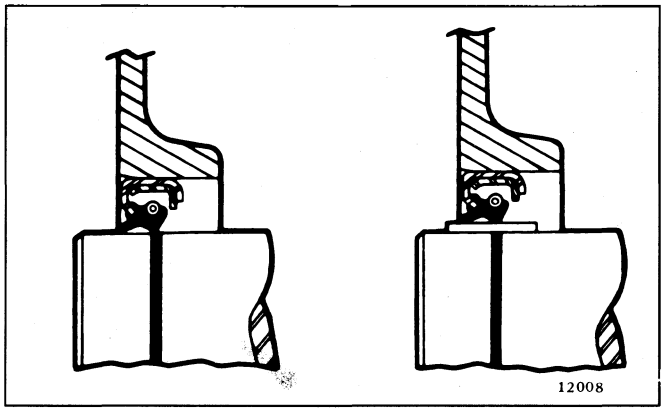



**Fig. 4 - Crankshaft Oil Seal Sleeve - Former**

Install the rear oil seal sleeve:

1. Support the flywheel or flywheel coupling assembly on the bed of a suitable press.
2. Using tool J 22518, press the oil seal sleeve until it seats on the flywheel or flywheel coupling assembly.

## Inspection - Former ReaftSeal

Inspect the rear end of the crankshaft for wear caused by the rubbing action of the oil seal, dirt build-up or fretting by the action of the flywheel. The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under *Inspection* in Section 1.3.

The maximum runout of the oil seal bore in the flywheel housing is .008". The bore may be checked with a dial indicator mounted on the end of the crankshaft in a manner similar to the procedure for checking the flywheel housing concentricity as outlined in Section 1.5. This check must be made with the flywheel housing or the outboard bearing support in place on the engine and the oil seal removed. If the runout exceeds the maximum limits refer to Section 1.5 *Install Flywheel Housing.*

## Install Oil Seal Sleeves - Former Engines

Install the rear oil seal sleeve as follows:

1. To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off the end of the crankshaft.
2. Stone the high spots from the oil seal contact surface of the crankshaft.

• 3. Apply a thin, even coat of Permatex Form-A-Gasket No. 2, or equivalent, to the inside diameter of the wear sleeve.

4. Drive the sleeve squarely on the shaft with oil seal sleeve installer J 22767-1 and guide pins J 22767-2.

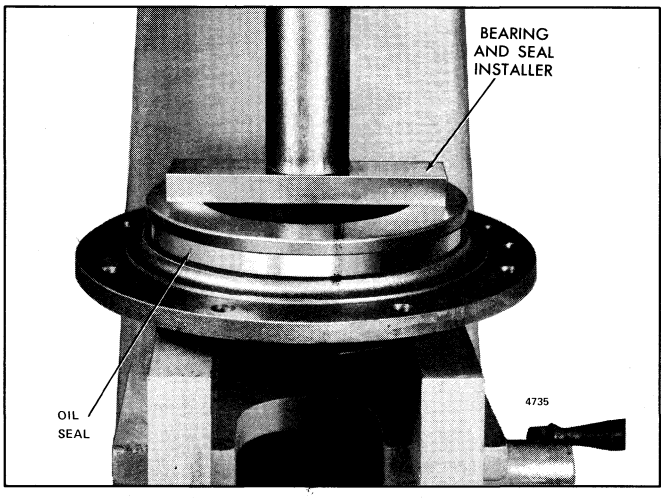



**Fig. 5 - Installing Seal in Outboard Bearing Support**

5. Wipe off any excess sealant.
6. Liberally lubricate the outside diameter of the oil seal sleeve with clean engine oil.

Install the front oil seal sleeve as follows:

• 1. Apply a thin, even coat of Permatex Form-A-Gasket No. 2, or equivalent, to the inside diameter of the wear sleeve.

2. Support the front vibration damper hub on the bed of an art[A]or press.
3. Using tool J 22518, press the oil seal sleeve flush with the vibration damper hub.

## Install Crankshaft Front Oil Seal Current And Former

1. Place the bearing support on the bed of an arbor press. Coat the oil seal bore with a non-hardening sealant, unless the seal case is already pre-coated. Press the new crankshaft oil seal into the outboard bearing support with the lip of the seal facing in towards the bearing with seal installer J 22518 (Fig. 5).
2. Install the outboard bearing support assembly (Section 1.3.5.1).
3. Install the vibration dampers (Section 1.3.6).

## Install Crankshaft Rear Oil Seal Current Seal

1. Place the bearing support on the bed of an arbor press. Coat the oil seal bore with a non-hardening sealant, unless the seal case is already pre-coated. Press the new crankshaft oil seal into the bearing support until it contacts the bottom of the counter bore in the bearing support, using tool J 22518 (Fig. 5).
2. Install the rear outboard bearing support assembly (Section 1.3.5.2).
3. Install the flywheel or flywheel coupling assembly (Section 1.4).

## Install Crankshaft Rear Oil Seal (Flywheel Housing Installed) Former Seal

1. Remove the cup plug from the end of the crankshaft.

’ 2. Remove the pipe plug located inside of the crankshaft end bore.

3. Position the seal expander J 22605 (standard size seal) or J 22766 (oversize seal) against the crankshaft end and thread retainer bolt J 22604-4A through the expander and into the crankshaft pipe plug hole. Tighten the nut against the seal expander to hold it in position.

**NOTICE:** To ensure proper sealing, replace the rear (if used) oil seal sleeve whenever a new oil seal is installed.

4. Slide the seal, with the spring-loaded lip of the oil seal facing inward, over the seal expander and rear hub until the seal is up against the flywheel housing.
5. Remove the seal expander and place the seal installer J 22604-B up against the seal. Thread the bolt J 22604—A through the installer and into the crankshaft pipe plug hole.
6. Draw up the bolt forcing the nut against the installer. Turn the nut while lightly tapping around the edge of the installer with a soft hammer until the seal is properly seated in the flywheel housing bore.
7. Install the pipe plug inside of the crankshaft end bore.
8. Install the cup plug in the end of the crankshaft (Section 1.3).

## Install Crankshaft Rear Oil Seal (Flywheel Housing Removed) Former Seal

If the flywheel housing is removed from the engine, a new oil seal can be installed using seal installer J 22518 and spacer J 22518-4. Refer to Section 1.5 when installing the flywheel housing with the oil seal installed.

**NOTICE:** To ensure proper sealing, replace the rear (if used) oil seal sleeve whenever a new oil seal is installed.

# CRANKSHAFT MAIN BEARINGS

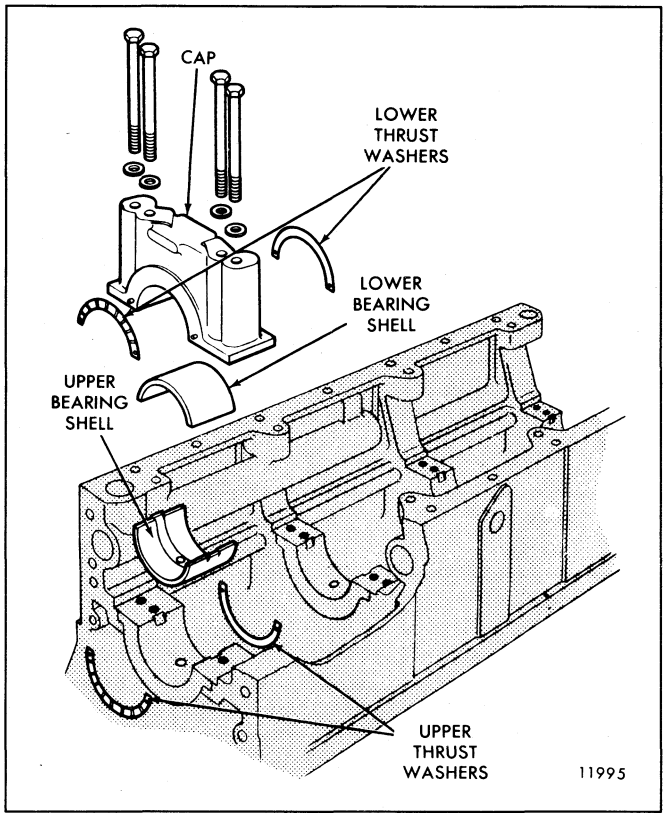



**Fig. 1 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers**

The crankshaft main bearing shells (Fig. 1) are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The upper and lower bearing shells are located in the respective block and bearing cap by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

An oil hole in the groove of each upper end bearing shell and the slot in each current intermediate upper bearing shell (Fig. 2), midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells must not be interchanged.

Thrust washers (Fig. 1), on each side of the rear main bearing, absorb the crankshaft thrust. The lower halves of

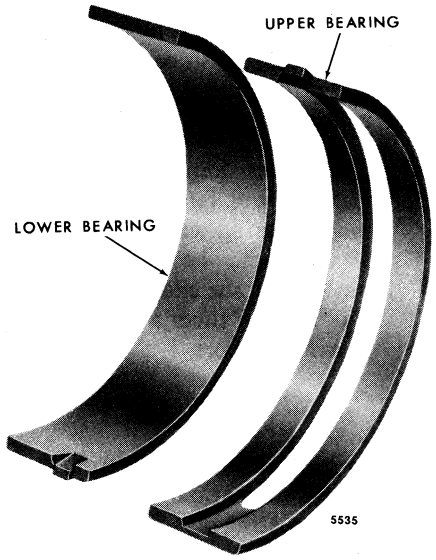



**Fig. 2 - Current Intermediate Main Bearing Shells**

the two-piece washers are doweled to the bearing cap; the upper halves are not doweled.

All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower main bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

## Remove Main Bearing Shells (Crankshaft In Place)

The bearing caps are numered 1, 2, 3, etc., indicating their respective positions, and, when removed, must always be reinstalled in their *original* position.

RemoVA the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.
2. Remove the oil pump and oil inlet pipe assembly. If shims are used between the oil pump and the main bearing caps, save the shims so that they may be reinstalled in exactly the same location.
3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under *Inspection.* Reinstall each bearing shell and bearing cap before removing another bearing cap.

a. To remove the upper main bearing shell, insert a 5/16" x 1" bolt with a 1/2" diameter and 1/16" thick head (made from a standard bolt) into the crankshaft journal oil hole. Then revolve the shaft to the right (clockwise) and roll the bearing shell out of position. The head of the bolt must not extend beyond the outside diameter of the bearing shell.

b. The lower halves of the crankshaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

## Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and replace them, if necessary. Also, check the oil bypass valve to make sure it is operating freely.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching or signs of overheating. If any of these defects are present, the bearings must be discarded. The lower bearing shells, which carry the load, will normally show signs of distress before the upper bearing shells.

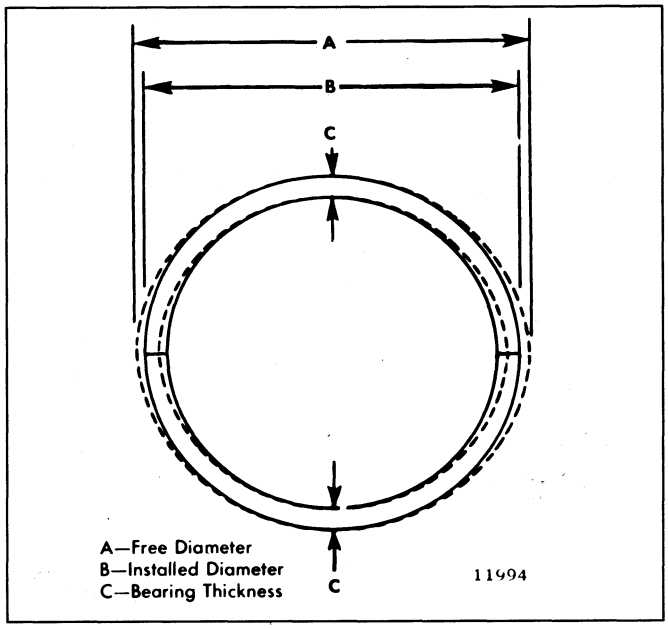



Fig. 3 – Main Bearing Measurements

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point "C", 90° from the parting line, as shown in Figs. 3 and 4. Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is . 1544" and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1550" to .1555". Refer to Table 1.

| Bearing Size | Bearing Thickness | Minimum Thickness |
|---|---|---|
| Standard | .1 550"/.1 555" | .1544" |
| .002" Undersize | .15607.1 565" | .1554" |
| !010" Undersize | .16007.1605" | .1594" |
| .020" Undersize | .1 650"/.1 655" | .1644" |
| .030" Undersize | .1700"/.1705" | .1694" |

**TABLE 1**

In addition to the thickness measurement, check the clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). With the crankshaft removed measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque on the bearing cap bolts.

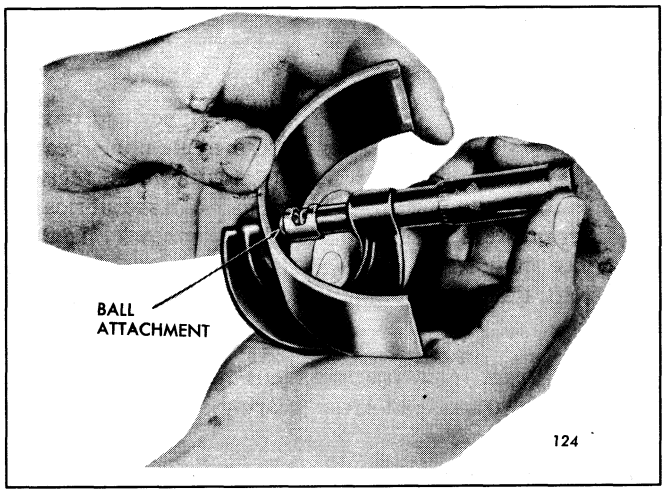



**Fig. 4 - Measuring Thickness of Bearing Shell**

When installed, the bearing shells are .001" larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This *crush* assures a tight, uniform contact between the bearing shell and the bearing seat. Bearing shells that do not have sufficient crush will not have uniform seat contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds .0072", all of the bearing shells must be discarded and replaced. This clearance is .0030" to .0062" with new parts.

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Section 1.3 under *Crankshaft Inspection* for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is used, install all new bearing shells.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3. Undersize bearings (.002") are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

Bearing shells are also available in .020" and .040" oversize on the *outer diameter* for use in cylinder blocks which have been line bored. Bearing shells are NOT reworkable from one undersize to another under any circumstances.

Inspect the crankshaft thrust washers. If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to *Install Crankshaft* in Section 1.3. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1630" to .1660" thick. Thrust washers are available in .005" and .010" oversize.

## Install Main Bearing Shells (Crankshaft In Place)

Make sure all of the parts are clean. Then, apply clean engine oil 360° around each crankshaft bearing journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

Six (6) - (12V) or eight (8) - (16V) narrow intermediate upper and lower main bearing shells and two wide end upper and lower main bearing shells are used in a cylinder block assembly. The end bearing shells are 2.70" wide and the intermediate bearing shells are 1.80" wide.

The upper and lower main bearing shells are not alike. The upper end bearing shells (2.70" wide) are grooved and drilled for lubrication; the upper intermediate bearing shells (1.80" wide) are slotted for lubrication (Fig. 2). The lower main bearing shells are not grooved or drilled. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.

2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

3. Assemble the crankshaft thrust washers before installing the rear main bearing cap. Clean both halves of each thrust washer carefully and remove any burrs from the washer seats — the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then, assemble the lower halves over the dowel pins in the bearing cap. The main bearing caps are bored in position and marked 1,2, 3, etc. They must be installed in their *original positions. The grooved side of the thrust washers must face toward the crankshaft thrust surfaces*,

4. With the lower bearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolt head contact areas. Install the bearing caps and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly.

5. Use tool J 35371 to tighten each set of main bearing cap bolts, starting with the bolts on the outside of the bearing cap and proceeding with the two inner bolts, to approximately 100 lb—ft (136 N*m) torque. Then,

using the same sequence, tighten all bolts (except the rear main bearing bolts) to 280-290 lb—ft (379-393 N*m) torque starting with the center bearing cap bolts and working alternately towards both ends of the block. Strike both ends of the crankshaft two or three sharp blows with a soft hammer to insure proper positioning of the rear main bearing cap in the block saddle. Retorque all bearing bolts to 280-290 lb—ft (379-393 N*m). Do not exceed the specified torque. the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

6. Check the crankshaft end play as outlined under 10. *Install Crankshaft* in Section 1.3.

7. Install the lubricating oil pump intake pipe assembly and oil pump. If shims were used between the pump mounting brackets and the bearing caps, install them in their *original* positions. Then, check the oil pump gear clearance (Section 4.1).

Install the upper and lower oil pans, using a new seal ring.

If g Fill the crankcase to the proper level on the dipstick with *heavy-duty* lubricating oil of the recommended grade and viscosity (refer to *Lubrication Specifications* in Section 13.3).

After installing new bearing shells, operate the engine on a *run-in* schedule as outlined in Section 13.2.1.

# ENGINE FRONT COVER

The engine front cover (Fig. 1) is mounted against the cylinder block at the front end of the engine. The front cover provides mounting positions for the water pump, contains cast water manifolding between the water pump and water manifolds, provides a support for the crankshaft outboard bearing and has provisions for front engine mounts. On former engines, the front cover also served as a housing for the left and right-hand fuel control rods.

## Remove Engine Front Cover

1. Drain the engine cooling system (Section 5).
2. Remove the heat exchanger or engine cooling fan.
3. Remove the engine front lifter bracket.
4. Disconnect the water manifolds and hoses and remove the thermostat housing assemblies from the front cover.
5. Remove the coolant filter and conditioner (if used).
6. Remove the water pump (Section 5.1).
7. Remove the crankshaft pulley and/or vibration damper from the crankshaft (Section 1.3.6).
8. With the engine suitably supported, remove the trunnion mount and hub from the front cover.
9. Remove the crankshaft outboard bearing support (Section 1.3.5.1).
10. On engines with the former style governor and fuel control rod linkage, remove the governor and fuel control rods from the engine.
11. Remove the bolts and lock washers securing the upper oil pan to the front cover.
12. Loosen the upper oil pan-to-cylinder block attaching bolts to allow removal of the front cover without dislodging the oil pan seal strip.
13. Remove the bolts and lock washers securing the engine front cover to the cylinder block and remove the front cover and seal strip.

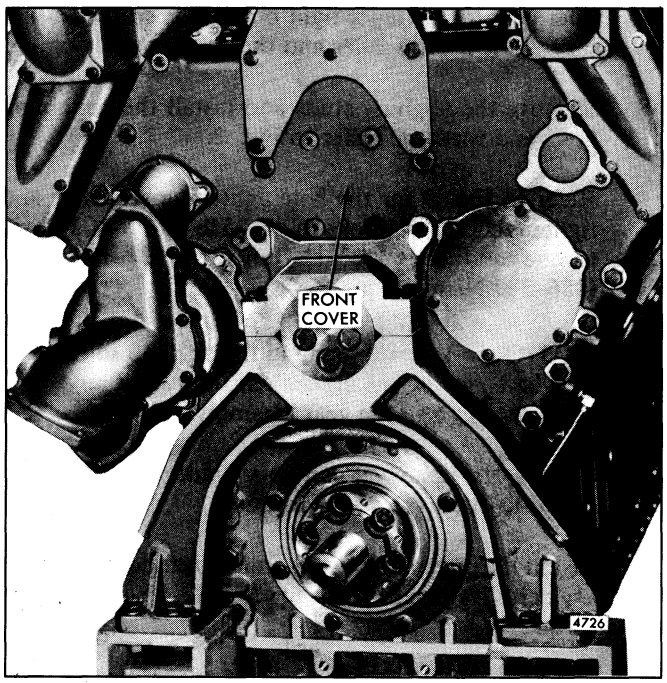



**Fig. 1 - Front Cover Mounting on 1 2V-149 Engine**

## Inspection

Wash the front cover with fuel oil and dry it with compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the cover for cracks or other damage. Pressure test the water manifolding within the front cover. Apply 50 psi (345 kPa) air pressure and check for signs of cracks or leaks.

Inspect the seal strip groove for nicks and burrs. Replace the front cover if extensive damage is found.

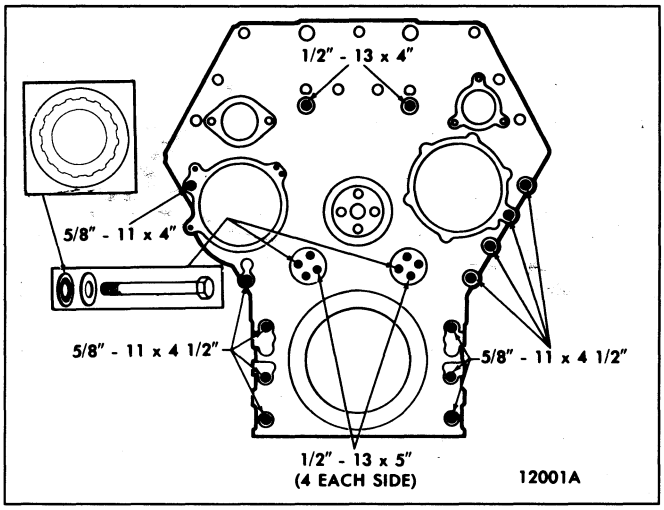



Fig. 2 – Front Cover Bolt Locations

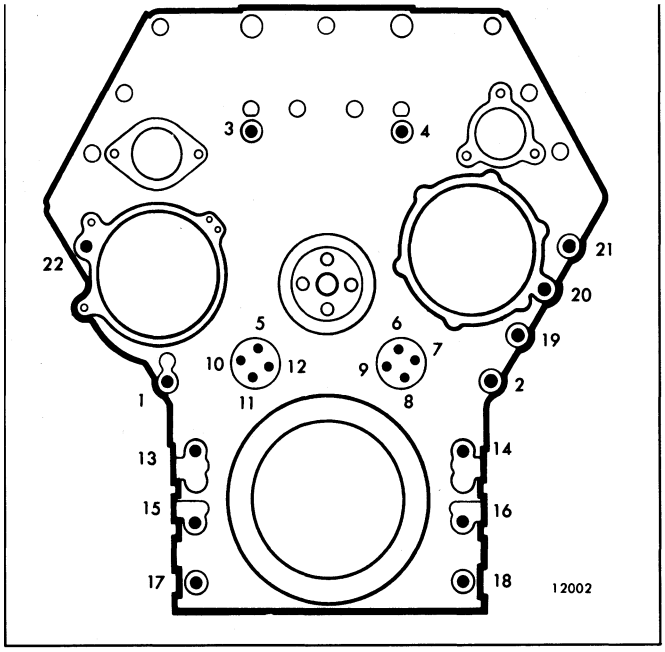



Fig. 3 – Bolt Tightening Sequence

**NOTICE:** The 3 1/8" cup plug is no longer included in a service front cover assembly. The plug is only used on remote mounted transmission torque converter units.

## Install Engine Front Cover

1. Thread two aligning studs into the cylinder block to guide the front cover into position.

   **NOTICE:** Apply cup grease to the thrust washers on the front idler gear hubs to maintain their position when installing the front cover over the guide pins.

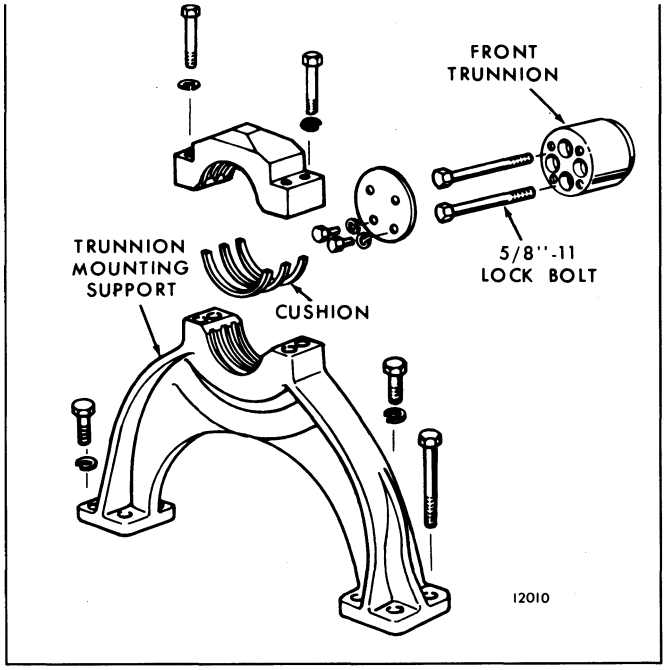
2. Make sure the cylinder block and front cover mating surfaces are clean and free of nicks and burrs.

3. Apply a thin coat of grease in the seal strip groove in the front cover. Then place a new seal strip in the groove in the cover. Cut away the excess seal strip at the bottom of the front cover.

4. Install the O-ring seals in the counterbores of the front cover at the water passages.

   **NOTICE:** The seal strip must lay flat in the groove and must not be twisted.

• 5. Apply a thin coat of spray adhesive on the exposed flat surfaces of the seal strip and O-rings.




**4 - Front Trunnion Mounting (Current Engines)**

6. Position the front cover in place over the aligning studs and up against the cylinder block, aligning the dowel pins in the cylinder block with the dowel pin holes in the front cover.

7. Refer to Fig. 2 and install the 1/2M—13 self-locking bolts and *new* 1/2" seal washers in the holes of the idler gear hubs (finger tight only). The seal washer is between the flat washer and the front cover.

8. Remove the aligning studs and install the remaining bolts and washers. Refer to Fig. 2.

9. Refer to Fig. 3 for the bolt tightening sequence and tighten the l/2"-13 bolts to 71-75 lb-ft (96-102 N«m) torque and the 5/8"-ll bolts to 137-147 lb-ft (186-200 N«m) torque.

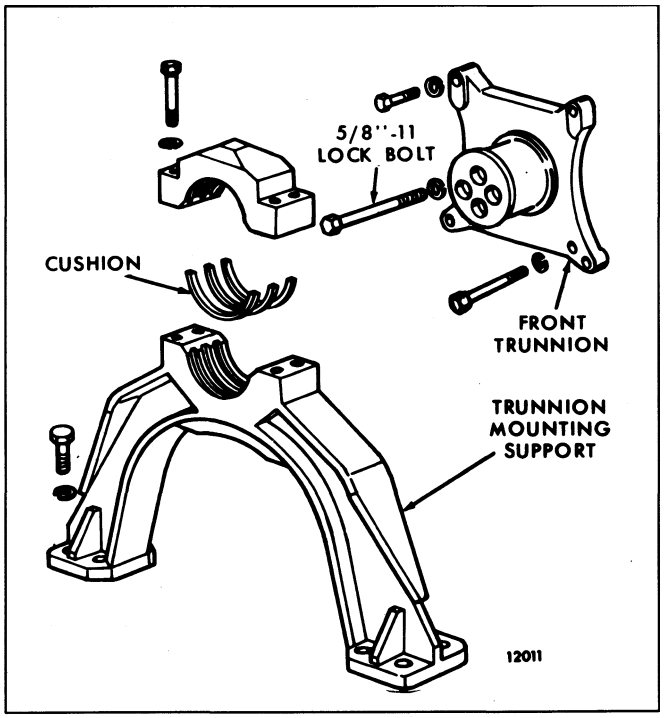
   **NOTICE:** * When tightening the l/2"-13 idler gear bolts, rotate the crankshaft to prevent any bind occurring in the gear assembly.

10. Tighten the upper oil pan-to-cylinder block bolts to 45-50 lb-ft (61-68 N«m) torque.

11. Install the upper oil pan-to-front cover bolts and lock washers. Tighten the bolts to 45-50 lb-ft (61-68 N#m) torque.

12. On former engines, install the governor and fule control rods.




5 – Front Trunnion Mounting (Former Engines)

13. Install the crankshaft outboard bearing support (Section 1.3.5.1).

14. Install the front trunnion mounting support and trunnion (Figs. 4 and 5). Tighten the 5/8"—11 lock bolts to 137-147 lb—ft (186-200 N#m) torque.

15. Install the crankshaft pulley and/or vibration damper on the crankshaft.

16. Install the water pump (Section 5.1).

17. Install the coolant filter and conditioner (if used).

18. Install the thermostat housing assemblies and connect the water manifolds and hoses.

**NOTICE:** Alternately tighten the thermostat housing-to-front cover bolts to 30-35 lb—ft (41-47 N«m) torque.

19. Install the engine front lifter bracket.

20. Install the heat exchanger or engine cooling fan.

21. Fill the cooling system (Section 5.).

# CRANKSHAFT OUTBOARD BEARING SUPPORT (FRONT)

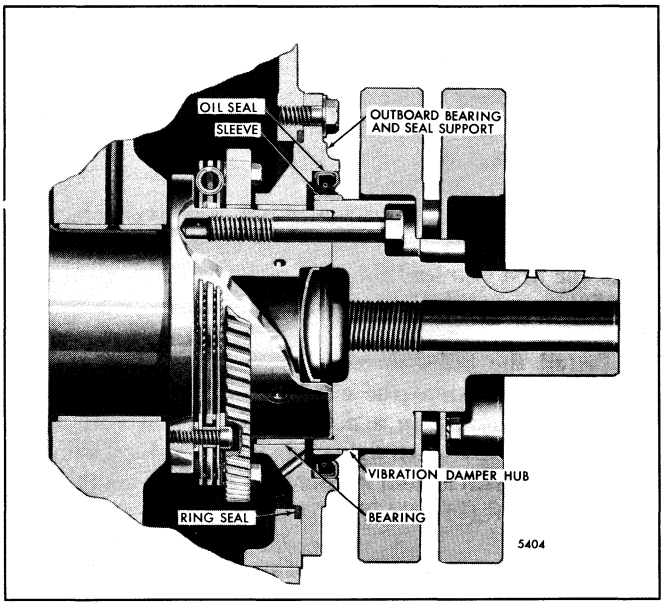



**Fig. 1 – Outboard Bearing and Seal Support Mounting**

The crankshaft outboard bearing support (Fig. 1) houses the crankshaft front outboard bearing (bushing) and the crankshaft front oil seal. The support is a one-piece casting which bolts directly to the engine front cover, providing easy access for removing and installing the oil seal and bearing.

• The bearing is pressure lubricated from the oil supply hole drilled in the front end of the crankshaft. Oil returns through four drilled holes at the bottom of the bearing support. The former outboard support bearing had four (4) grooves. The current bearing is grooveless.

The bearing support must be removed when replacement of the bearing or the crankshaft oil seal is required.

## Remove Outboard Bearing Support

1. Remove the crankshaft pulley (Section 1.3.7) and/or vibration dampers (Section 1.3.6) from the crankshaft.
2. Remove the seven (7) bolts and flat washers securing the outboard bearing support to the engine front cover and remove the support and the seal ring.

## Inspection

Oil leaks are indications of worn or damaged oil seals.

Inspect the vibration damper hub oil seal sleeve for wear due to the rubbing action of the oil seal or dirt buildup. If the seal is worn, install a new oil seal and oil seal sleeve. Refer to Section 1.3.2.

Inspect the bearing for scoring or excessive wear. The inside diameter of a new bearing (installed) is 6.0033* to 6.0087* and the crankshaft journal outside diameter is 5.9990” to 6.000*. This provides a crankshaft to bearing clearance of .0033* to .0097* with new parts.

If the crankshaft is to be reground, *the outboard bearing area must not be reduced in diameter.* The drive hub to crankshaft tolerances must be maintained to permit the proper fit between the mating parts.

To replace the bearing, first remove and discard the crankshaft oil seal. Then, press the old bearing from the support. Place the bearing support on the bed of an arbor press. Coat the oil seal bore in the support with a non-hardening sealant, unless the seal case is already pre-coated. Press a new crankshaft oil seal into the support until it contacts the bottom of the counterbore in the bearing support, using installer J 22518 (Fig. 2).

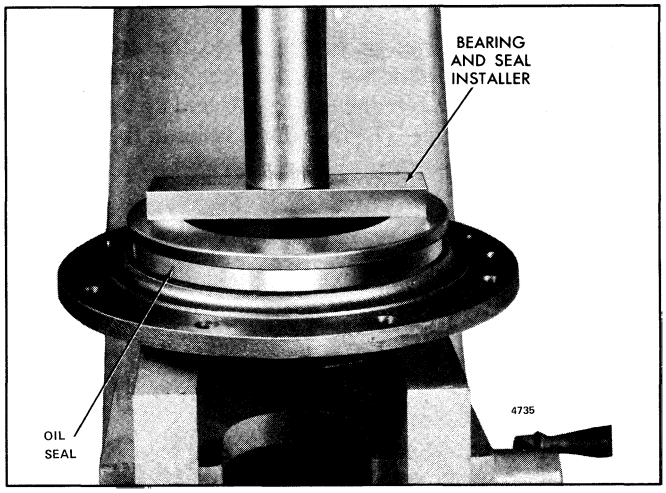



**Fig. 2 - Installing Seal in Outboard Bearing Support**

Turn the support over on the bed of the arbor press and coat the bearing bore with a thin coat of Lubriplate, or equivalent. Position the new bearing in the bore of the support, with the split line 90° from the oil drain holes. Then, press the bearing flush with the inside face of the support, using installer J 22518 (Fig. 3).

## Install Outboard Bearing Support

1. Apply a thin film of Lubriplate, or equivalent, over a new oil seal ring and place the seal ring over the collar on the back side of the bearing support.

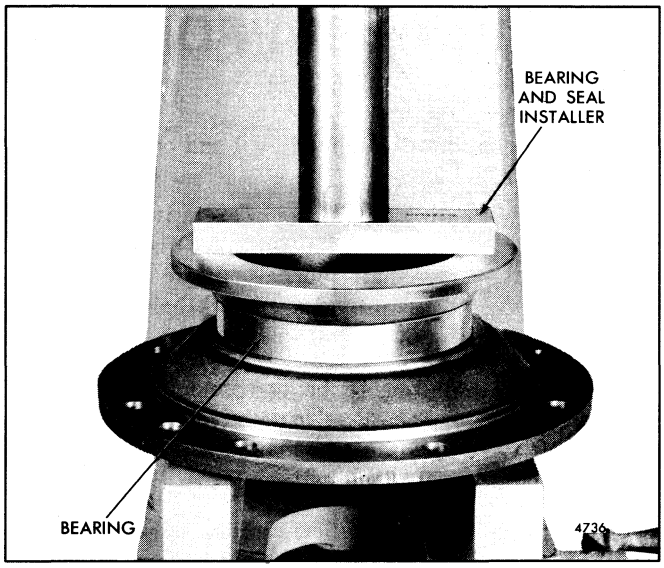



**Fig. 3 - Installing Bearing in Outboard Bearing Support**

**NOTICE:** To ensure proper sealing, replace the front (if used) oil seal sleeve whenever a new oil seal is installed. Before installing the front crankshaft oil seal sleeve, check for sharp corners, scratches, inclusions or nicks. If the sleeve is damaged, replace it.

2. Apply a light coat of engine oil to the area of the crankshaft where the bearing will ride and position the bearing support over the crankshaft and up against the engine front cover. The four drain holes in the support 7. will be at the bottom.

3. Make sure the mating flange surfaces are clean and dry.

4. Slide new, hardened flat washers (.530”-.940” x .120”) on the seven special support attaching bolts. The threads of these special high-tensile strength bolts are coated with an epoxy /graphite locking compound to ensure torque retention. Use new bolts and washers each time the bolts are distrubed for any reason and at time of overhaul.

If the special coated bolts are not available, use standard GM 300M bolts. Coat the threads of the bolts (except the first two lead threads) with Loctite Sealant 271 (J 26558) or an equivalent sealant.

5. Install the bolts through the bearing support and thread them into the engine front cover. Hold the bearing support in a *downward* position with light hand pressure when tightening the bolts. First snug all the bolts with a hand wrench and then tighten them to 71-75 lb—ft (96-102 N*m) torque.

• 6. Check the bearing-to-crankshaft clearance with a 1/4” wide feeler gage. The bearing should be installed so that a *minimum* of .001” clearance exists at the top of the outboard bearing support. The clearance at the bottom of the crankshaft *must not be less than* .0033” or more than .0097” with the bearing support in the downward position.

Install the vibration dampers (Section 1.3.6) and crankshaft pulley (Section 1.3.7).

# CRANKSHAFT OUTBOARD BEARING SUPPORT (REAR)

The rear outboard bearing support is mounted in the flywheel housing to improve the ability of the rear main bearings to sustain loads and bending forces externally induced by driven components.

The rear outboard bearing support assembly also replaces the outboard bearing support assembly presently in the front cover (Fig. 1). The outboard bearing is indexed in the support so that the split line is to the right or left on the horizontal axis. The old front outboard bearing support assembly *cannot* be used in the flywheel housing. The oil seal, seal ring and attaching bolts and washers are the same for both the former and new outboard bearing assemblies.

• The former outboard support bearing had four (4) grooves. The current bearing is grooveless.

The flywheel housing is counterbored to accomodate the new outboard bearing support assembly (Fig. 2). The former flywheel housings will continue to be serviced.

The new R.H. and L.H. flywheel assemblies and flywheel coupling assembly (Fig. 3) incorporate an oil seal sleeve, as the rear crankshaft oil seal seals on a sleeve mounted on the new flywheel or flywheel coupling and not on the crankshaft. The former R.H. and L.H. flywheel assemblies will continue to be serviced; however, only the new flywheel coupling assembly will be serviced.

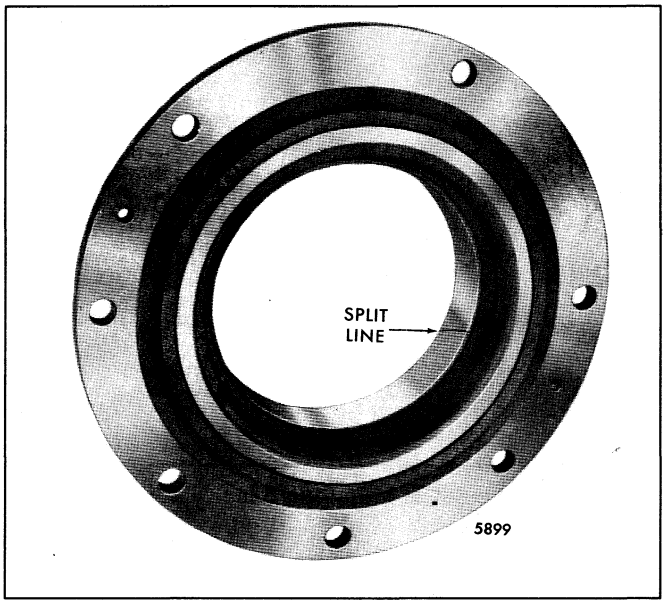



**Fig. 1 - Rear Outboard Support Bearing Assembly**

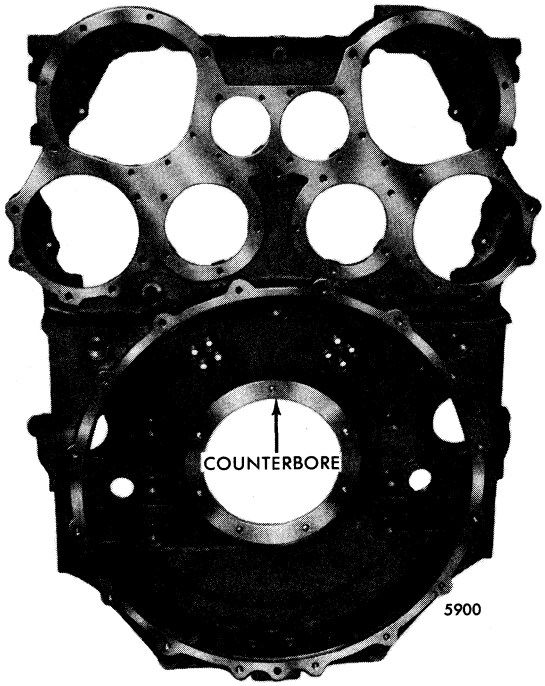
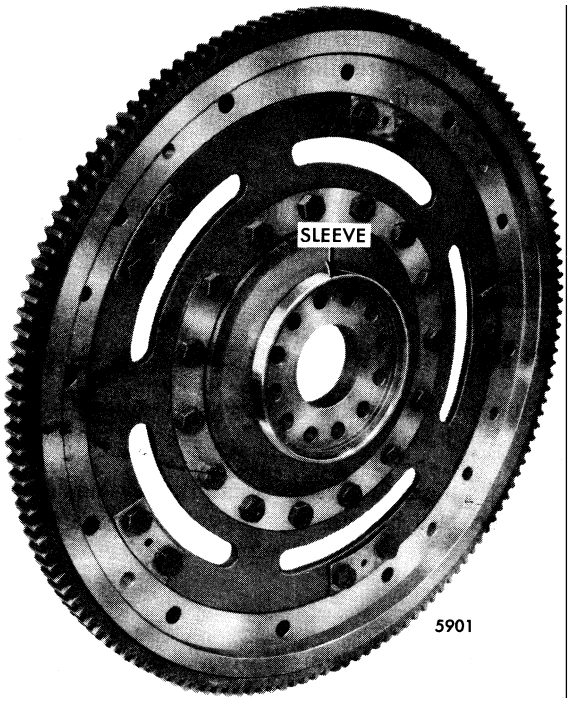



**Fig. 2 - Flywheel Housing with Counterbore**




**Fig, 3 - Flywheel Coupling Assembly**

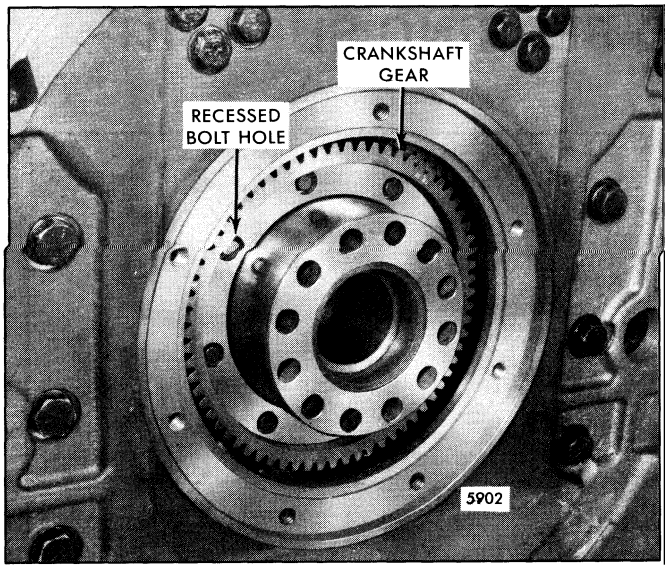



**Fig. 4 - Rear Crankshaft Tinning Gear**

The rear crankshaft timing gears (Fig. 4) have the bolt holes counterbored for the shorter attaching bolts (3/8"-24 x 1.62") which are required to provide clearance for the rear outboard support bearing assembly. The former attaching bolts were 3/8"-24" x 2". The former and new crankshaft timing gear are interchangable on an engine. Only the new crankshaft gears will be serviced; however, the shorter bolts (1.62") must be used with the new rear crankshaft gears.

> **NOTICE:** The former and new crankshafts are the same except that the 1/4" pipe plug (Fig. 5) has been deleted from the rear crankshaft half to allow for lubrication of the rear outboard support bearing. The former crankshaft assemblies will continue to be serviced.

When a former flywheel housing, flywheel or flywheel coupling is replaced on an engine with a new flywheel housing, flywheel or flywheel coupling, all of the new parts must be used together.

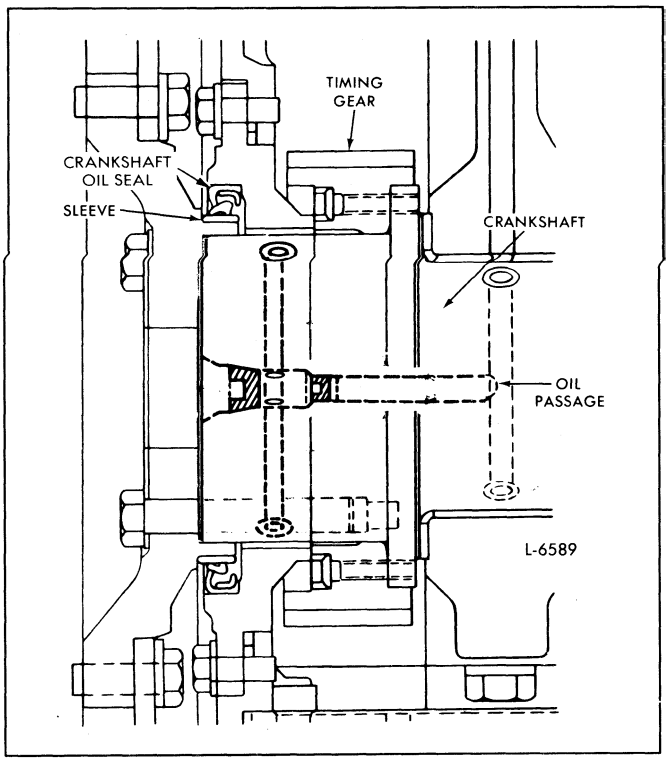
## Remove Rear Outboard Bearing Support

1. Remove the flywheel or flywheel coupling assembly (Section 1.5).

2. Remove the seven (7) bolts and flat washers securing the outboard bearing support to the engine flywheel housing and remove the support and seal ring.

## Inspection

Oil leaks are indications of worn or damaged oil seals. Inspect the flywheel or flywheel coupling assembly oil seal sleeve for wear due to the rubbing action of the oil seal or dirt build up. If the seal is worn, install a new oil seal and oil seal sleeve (refer to Section 1.3.2).




**• Fig. 5 - Lubrication of the Rear Outboard Support Bearing (Current Engines)**

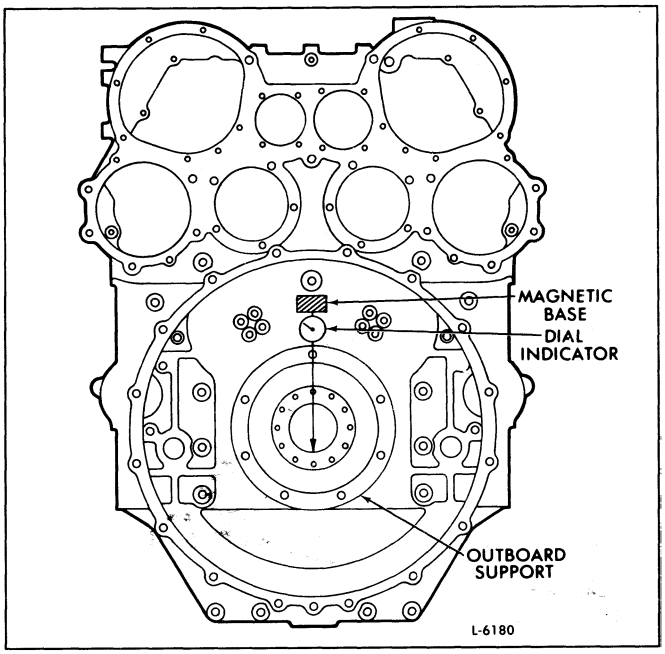



**Fig. 6 - Placement of Magnetic Base Dial Indicator**

> **# NOTICE:** To ensure proper sealing, replace the oil seal sleeve whenever a new oil seal is installed. If a unidirectional seal is used, make sure the correct seal in relation to engine rotation is installed.

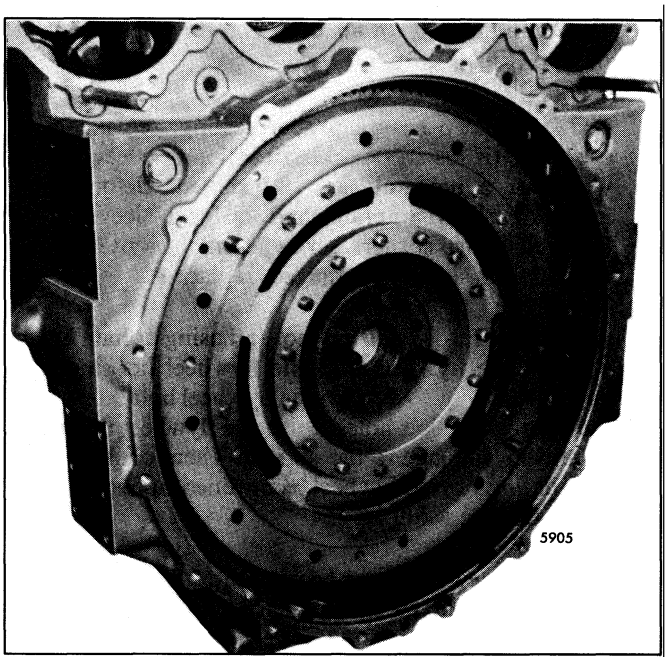



**Fig. 7 - Position Flywheel Using Guide Studs**

## Install Rear Outboard Bearing Support

If the engine was originally built with a rear outboard bearing support, proceed to Step 3. If the engine was *not* originally built with a rear outboard bearing support:

1. Remove the 1/2” pipe plug (current crankshaft) or 3” cup plug (former crankshaft) in the rear of the crankshaft and remove the 1/4” pipe plug in the crankshaft oil passage. This provides pressure oil lubrication to the outboard bearing support. Reinstall the 1/2” pipe plug or 3” cup plug with a suitable sealer.

2. Install a new crankshaft timing gear with counterbored bolt holes as outlined in Section 1.7.1 (Engine Timing). Tighten the 1.62” long bolts to 35-39 lb—ft (47-53 N*m) torque.

3. Install the flywheel housing as outlined in Section 1.5. The oil seal expander will not be required.

4. After verifying the bore and face run outs on the flywheel housing, apply a thin film of Lubriplate, or equivalent over a new seal ring and place the seal ring on the back of the bearing support and install it in the counterbore of the flywheel housing.

5. The outboard bearing support is adjustable in the flywheel housing. The assembly should be positioned upward to the crankshaft when the engine is in the upright position, without lifting the crankshaft.

To ensure the crankshaft is not lifted off of the rear main bearing, place a magnetic base dial indicator on the flywheel housing above the vertical axis of the crankshaft with the indicator probe positioned on the crankshaft cup plug counterbore (Fig. 6).

**NOTICE:** The indicator reading must remain at zero while adjusting the outboard bearing. Under no circumstances should the indicator show the crankshaft has been moved.

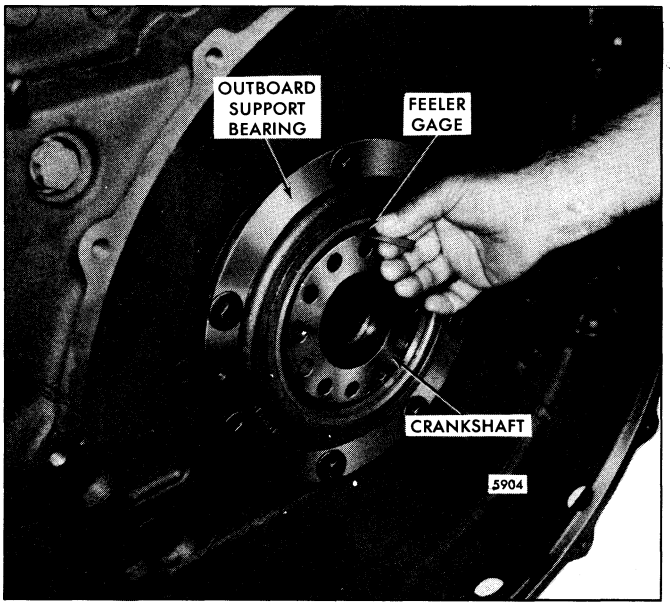



**Fig. 8 - Checking the Clearance Between the Crankshaft and Outboard Bearing**

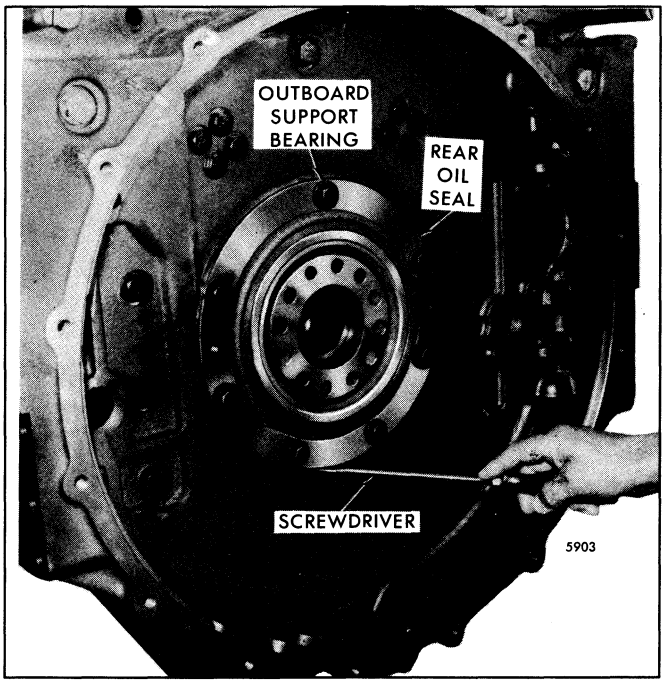



**Fig. 9 - Tightening the Outboard Bearing Support Attaching Bolts**

6. Slide new, hardened flat washers (.530"-.940" x .120") on the seven special support attaching bolts. The threads of these special high-tensile strength bolts are coated with an epoxy/graphite locking compound to ensure torque retention. Use new bolts and washers each time the bolts are disturbed for any reason and at time of overhaul.

   **NOTICE:** If the special coated bolts are not available, use standard GM 300M bolts. Coat the threads of the bolts (except the first two lead threads) with Loctite Sealant 271 (J 26558) or an equivalent sealant.

7. Apply a light upward pressure by prying with a screwdriver (Fig. 7) between the flywheel housing counterbore and the support assembly outside diameter, while tightening the bolts to 71-75 lb—ft (96-102 N*m) torque. Check the clearance between the crankshaft and outboard bearing with a 1/4" feeler gage. The clearance should be a minimum of .001" at the bottom of the crankshaft and not be less than .0033" and no more than .0097" on the vertical axis at the top (Fig. 8).

   **NOTICE:** To ensure proper sealing, replace the rear (if used) crankshaft oil seal sleeve whenever a new oil seal is installed. Before installing the rear crankshaft oil seal sleeve, check for sharp comers, scratches, inclusions or nicks. If the sleeve is damaged, replace it.

8. Attach the flywheel lifting tool and using a chain hoist, position the flywheel into the flywheel housing (see guide studs, Fig. 9). Align the flywheel bolt holes with the crankshaft bolt holes. Push the flywheel in evenly to prevent damage to the oil seal. Then, continue the installation of the flywheel as outlined in Section 1.4 of the Service Manual.

   Install the new outboard bearing support in the engine front cover the same as stated in Section 1.3.5.1 of the Service Manual.

# CRANKSHAFT VIBRATION DAMPER

Vibration dampers (two 12” diameter/one or two 18” diameter viscous type) (Fig. 1) are mounted on the front end of the crankshaft to reduce crankshaft stresses to a safe value. The new 12” and 18” nylon coated flywheel style vibration dampers are now being used on all engines. Only the current nylon coated flywheel style vibration dampers will be serviced. The vibration damper is bolted to a hub which is retained on the front end of the crankshaft.

• Two 18” diameter dampers are used on 16V marine engines when prolonged operation near 1200 rpm is required. Besides standard damper arrangements, other arrangements may be used on engines in other applications.

The vibration damper consists of an inertia mass (flywheel) enclosed in a fluid-tight outer case. A thin wall of viscous liquid separates the outer case from the inertia mass. This viscous liquid is not affected by temperature changes and tends to dampen excessive torsional vibrations in the crankshaft due to its frictional ability to resist any movement of the inertia mass.

The vibration damper(s) must be removed whenever the crankshaft, crankshaft front oil seal, outboard bearing -and seal support or front cover is removed.

## Remove Vibration Damper

8V AND 12V ENGINES (12” Diameter Dampers):

1. Remove the crankshaft pulley (Section 1.3.7).
2. Remove the six bolts and lock washers securing the inner and outer vibration dampers to the vibration damper hub and remove the vibration dampers and spacer (Fig. 2)

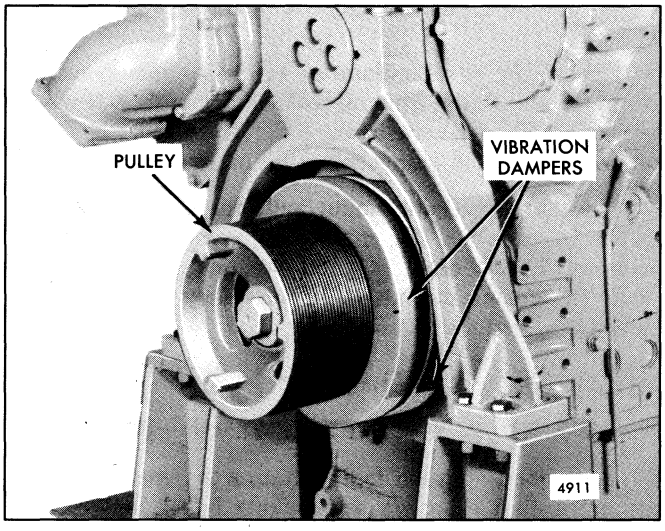



**Fig. 1 - Crankshaft Vibration Damper Mounting**

• **NOTICE:** Use care when handling the vibration damper. *Do not pound on the damper with a hammer or pry with other tools when removing a viscous type damper from the crankshaft.* Dents in the damper outer case may render the damper ineffective. The damper cannot be repaired.

3. Remove the six bolts securing the vibration damper hub and sleeve assembly to the crankshaft and remove the hub and sleeve assembly.

16V ENGINES (18” Diameter Damper):

1. Remove the crankshaft pulley (Section 1.3.7).
2. Remove the eight bolts and lock washers securing the vibration damper to the vibration damper hub and remove the damper (Fig. 3).

. **NOTICE:** Use care when handling the vibration damper. *Do not pound on the damper with a hammer or pry with other tools when removing a viscous type damper from the crankshaft.* Dents in the damper outer case may render the damper ineffective. The damper cannot be repaired.

3. Remove the six bolts securing the vibration damper hub and sleeve assembly to the crankshaft and remove the hub and sleeve assembly.

## • Vibration Damper Safety Shields

The need for a vibration damper safety shield is mandatory in certain industrial and marine applications in which the engine operates without a hood or in an open or unprotected area. A properly designed and installed safety shield prevents direct physical contact with the damper during engine operation. It also keeps the damper from “walking off the crankshaft and causing property damage or injury to personnel working near the engine if the crankshaft pulley bolt should loosen and become detached during engine operation.

Detroit Diesel Corporation does not manufacture, sell, or install vibration damper safety shields as it has no control over the great variety of installations in which DDC engines are applied. Space restrictions in these numerous applications make the supply of a properly designed and shaped vibration damper safety shield the responsibility of the OEM (original equipment manufacturer) or distributor designing and/or manufacturing products in which they apply Detroit Diesel engines. However, DDC believes that the following guidelines should be followed when fabricating or installing shields:

1. Shields should be made from 1/8” to 3/16” perforated steel or heavy steel screen.

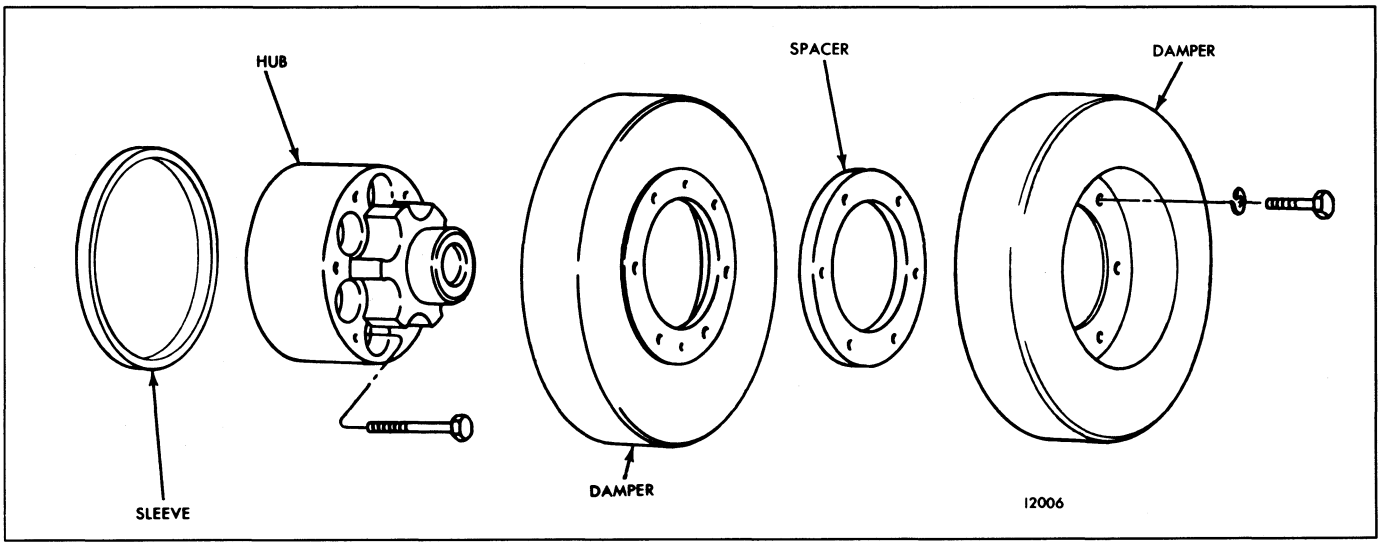



**Fig. 2 - Vibration Damper, Hub and Sleeve Assembly Details and Relative Location of Parts (12V Engine)**

2. The perforated or open screen area of the shield should be equal to, or greater than, the total area of both sides of the damper and its circumference.

3. Shields should be no closer than 1/2" from the damper when installed.

4. In all cases, safety shields *must* permit the vibration damper to be well ventilated during engine operation to prevent vibration damper overheating.

## Inspection

Inspect the vibration damper for leaks, dents, nicks or bulges in the outer casing. Any indications of the above are sufficient for cause for replacement of the damper. Due to close clearances between the damper internal flywheel and the outer casing, dents may render the damper ineffective. Bulges or splits indicate fluid in the damper has deteriorated and has bulged or forced the casing open at its crimped edges.

• **NOTICE:** Shielded vibration dampers are frequently difficult to inspect visually because of the design of the shield and/or end *items* in which the engine is installed. As a result, it is important for OEM's and distributors to supply written instructions to users of their products, cautioning them to periodically inspect the viscous vibration damper for evidence of a split seam, bulged cover, leaks, dents, etc. Any such evidence is sufficient cause for replacement because these conditions can prevent vibration dampers from functioning properly and, as a result, cause serious engine damage.

*Regardless of its condition*, the vibration damper on marine engines must be replaced at 10,000 hours of operation. For industrial engines replace the vibration damper at 20,000 hours or at the time of major engine overhaul. Replace the vibration damper on industrial or power generator engines at time of major overhaul to provide maximum protection for the crankshafts.

**NOTICE:** When two dampers are used, both must be replaced at the same time.

If damage to the vibration damper is extensive, inspect the crankshaft, as outlined in Section 1.3. A loose or defective vibration damper, after extended operation, may result in a cracked crankshaft.

Inspect the vibration damper spacer, hub and the end of the crankshaft for galling or burrs. Slight scratches or burrs may be removed with emery cloth. If seriously damaged, replace the parts and refinish the end of the crankshaft.

Check the outside diameter of the oil seal sleeve for wear at the crankshaft front oil seal contact surface. If worn, replace the oil seal and sleeve. Refer to Section 1.3.2 for installation of anew crankshaft front oil seal.

Also, a loose engine mount could damage the vibration damper by allowing the engine to move slightly during operation. Therefore, it is good practice to periodically inspect the engine mounts to be sure they are not loose, cracked or deteriorated.

## Install Vibration Damper

8V AND 12V ENGINES (12" Diameter Dampers):

1. Install the vibration damper hub on the front end of the crankshaft using six self-locking bolts. Tighten the bolts to 180-190 lb—ft (244-258 N»m) torque.

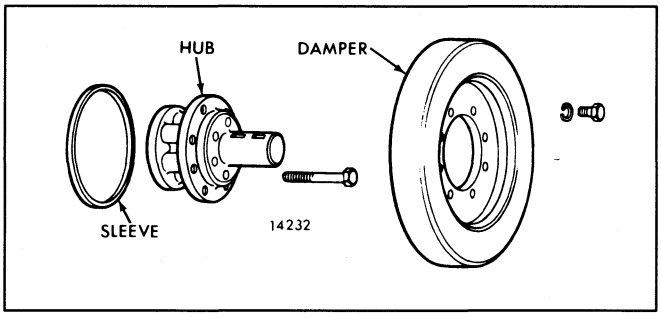



**Fig. 3 - Vibration Damper Hub and Sleeve Assembly (16V Engine)**

**NOTICE:** Use care when positioning the vibration damper hub to avoid damage to the lip of the crankshaft front oil seal.

2. Position the inner vibration damper, spacer and outer vibration damper over the hub and secure them in place with the six 7/16" bolts and lock washers (Fig. 2). Tighten the bolts to 57-61 lb—ft (77-83 N#m) torque.

3. Install the crankshaft pulley as outlined in Section 1.3.7.

16V ENGINES (18" Diameter Damper):

1. Install the vibration damper hub on the front end of the crankshaft using six self-locking bolts. Tighten the bolts to 180-190 lb—ft (244-258 N«m) torque.

**NOTICE:** Use care when positioning the vibration damper hub to avoid damage to the lip of the crankshaft front oil seal.

2. Position the vibration damper over the hub and secure it in place with the eight 1/2" bolts and lock washers (Fig. 3). Tighten the bolts to 71-75 lb-ft (96-102 N»m) torque.

3. Install the crankshaft pulley, as outlined in Section 1.3.7.

# CRANKSHAFT PULLEY

The engines are equipped with a cone mounted, poly-V belt type pulley which is keyed to the vibration damper hub (Section 1.3.6) and secured with a retainer and bolt (Fig. 1).

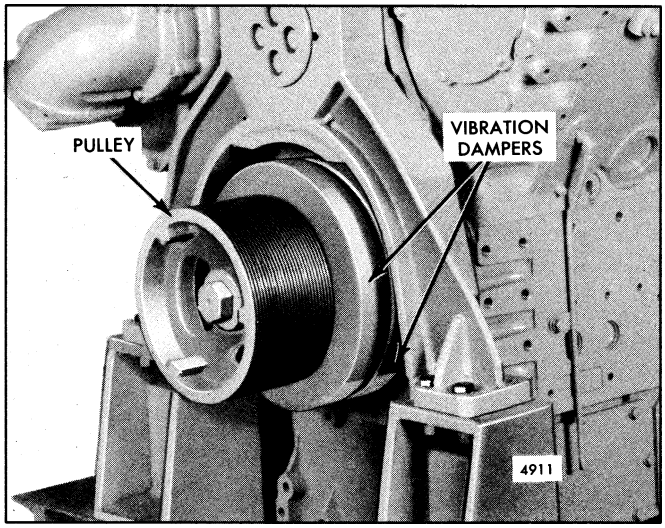



**Fig. 1 - Crankshaft Pulley Mounting**

## Remove Crankshaft Pulley

1. On engines equipped with a crankshaft pulley bolt retaining plate, remove the three bolts and lock washers securing the plate to the pulley. Remove the plate.
2. Remove the pulley retaining bolt and retainer (Fig. 2).
3. Use a soft hammer and tap around the front face of the pullley to loosen the pulley cone.

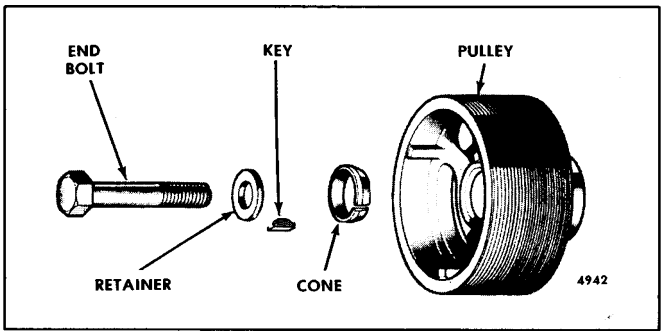



**Fig. 2 - Crankshaft Pulley Details and Relative Location of Parts**

4. Remove the pulley cone and slide the pulley from the hub.
5. Remove the Woodruff key(s) from the slots in the hub.

## Install Crankshaft Pulley

1. Place the Woodruff key(s) in the key slots in the hub.
2. Slide the crankshaft pulley over the hub, aligning the key with the key way in the pulley.
3. Place the cone over the hub and into position against the pulley.
4. Place the pulley retainer on the pulley retaining bolt and thread the bolt into the end of the hub.
5. Tighten the pulley retaining bolt as follows:
   a. Tighten the bolt to approximately 400 lb-ft (542 N«m) torque.
   b. Strike the end of the bolt a sharp blow with a 2 or 3 pound lead hammer.
   c. Tighten the bolt to 450-500 lb-ft (610-678 N#m) torque. *Do not hit the crankshaft end bolt after the last tightening because the clamping effect will be reduced.*

The damper must be securely fastened to the crankshaft. When the bolt is drawn up to the specified torque, the cone will hold the damper rigidly in place.

**NOTICE:** *Do not bar the engine over by turning the crankshaft bolt in a counter-clockwise direction. The bolt may back out slightly, resulting in loosening of the pulley and subsequent engine damage.*

**CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep- their hands and clothing away from the engine as there is a remote possibility the engine could start.**

• 6. On engines equipped with a crankshaft pulley retaining plate, install the plate and three bolts and lock washers. Tighten the bolts to 30 - 35 lb-ft (41-47 N*m) torque.

# FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with twelve self-locking bolts (Fig. 1). A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

Current flywheel and flywheel coupling assembly incorporate an oil seal sleeve, as the rear crankshaft oil seal seals on this sleeve, not on the crankshaft (Fig. 2). A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

The flywheel is machined to provide true coupling alignment for flexible drive lines or a coupling and ring gear adaptor for power generator applications.

The flywheel must be removed for other service operations such as replacing the starter ring gear, crankshaft or flywheel housing.

## Remove Flywheel (Transmission Removed)

1. Remove two diametrically opposite flywheel attaching bolts and install two 5/8”-18 x 6” guide bolts.
2. Remove the ten remaining flywheel attaching bolts.
3. Slide the flywheel out against the heads of the two guide bolts.
4. Place the flywheel lifting tool in position against the flywheel with the lower end of the tool inserted through the center bore of the flywheel as shown in Fig. 3. *Figure 4 illustrates the fabrication of a suitable flywheel lifting tool.*
5. Use a suitable chain hoist to support the flywheel and remove the two guide bolts. Then remove the flywheel from the flywheel housing.

## Inspection

Replace the ring gear if the gear teeth are excessively worn or damaged.

Check the butt end of the crankshaft and flywheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

Inspect the flywheel or flywheel coupling assembly oil seal sleeve for wear. Replace if necessary (refer to Section 1.3.2).

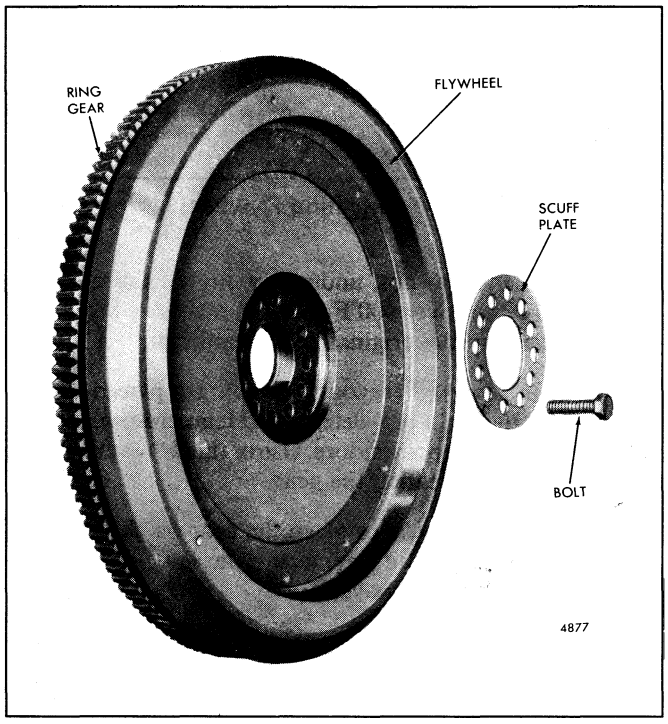



**Fig. 1 - Typical Flywheel Assembly - Former**

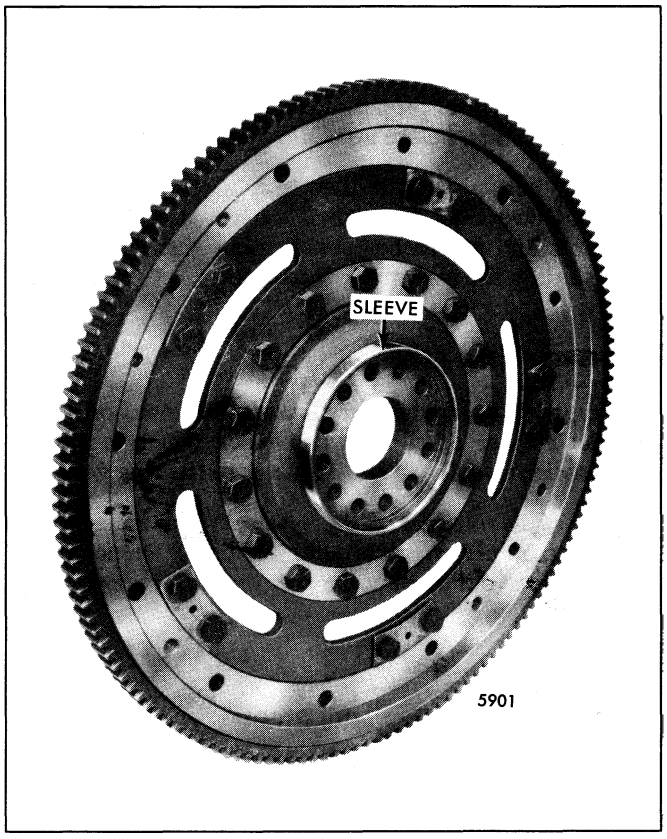



**Fig. 2 - Flywheel Coupling Assembly - Current**

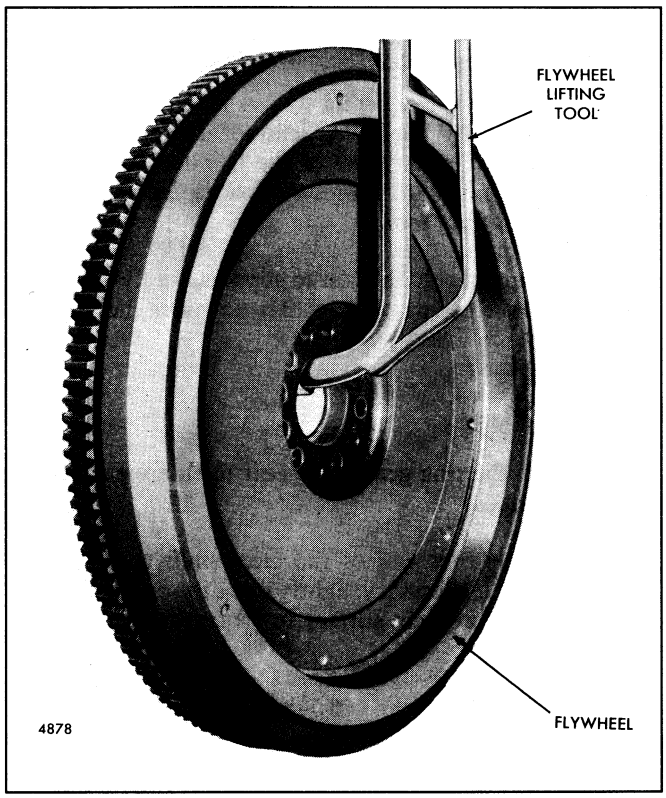



**Figure 3 - Removing Flywheel**

Make sure that the crankshaft and flywheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to insure proper metal-to-metal contact and maximum friction, before attaching the flywheel.

New bolts should be used to mount or remount the flywheel. However, if the original bolts are determined to be serviceable and are to be reused, clean them thoroughly before starting the assembly procedure.

## Remove Ring Gear

1. Support the flywheel, crankshaft side down, on a solid flat surface or a hardwood block which is slightly smaller than the inside diameter of the ring gear.

2. Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.

## Install Ring Gear

1. Support the flywheel, ring gear side up, on a solid flat surface.

2. Rest the ring gear on a flat **metal surface** and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

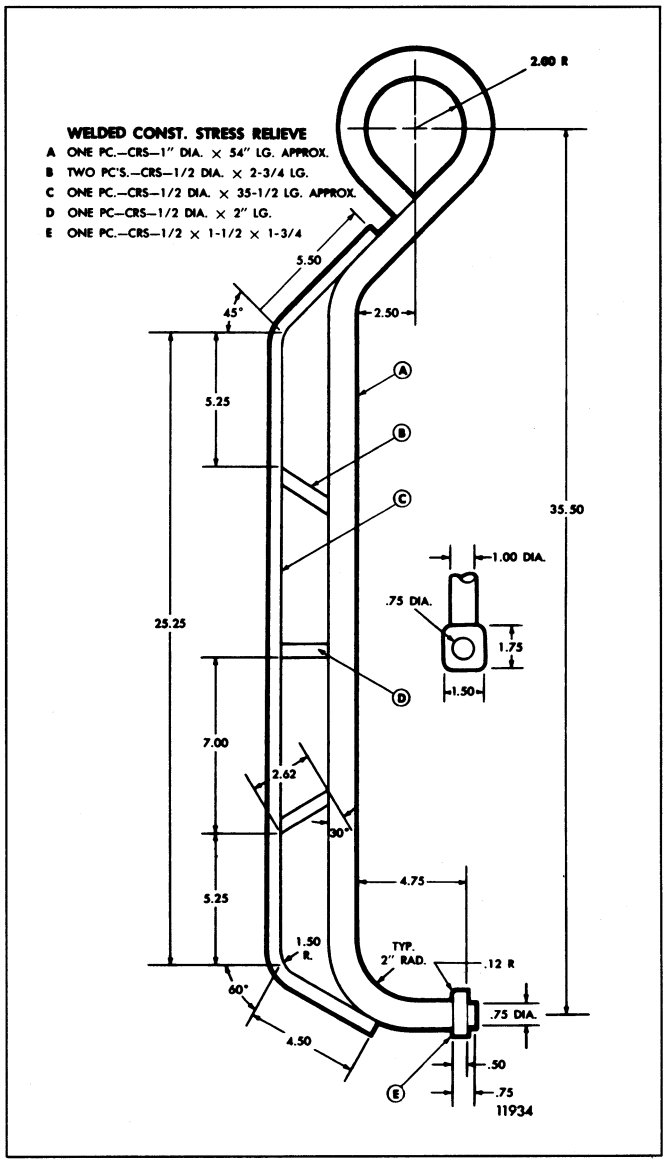



Fig. 4 – Details for Fabricating Flywheel Lifting Tool

**NOTICE:** Do not, under any circumstances, heat the gear over 400°F (204°C); excessive heat may destroy the original heat treatment.

Heat indicating "crayons", which are placed on the ring gear and melt at a pre-determined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.

4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat, noting the above note.

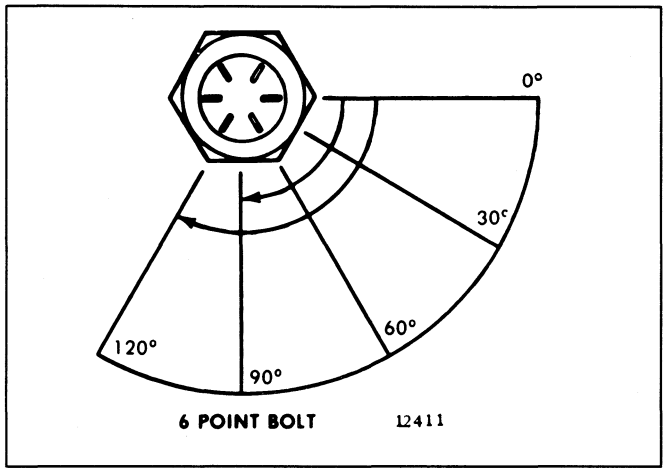



Fig. 5 – Torque–Turn

## Install Flywheel

1. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs (4). Align the flywheel bolt holes with the crankshaft bolt holes.

2. Install the clutch pilot bearing (if used).

3. Install two bolts through the scuff plate 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide bolts.

4. Remove the flywheel lifting tool.

5. Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

   **NOTICE:** International Compound No. 2 must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

6. Install the remaining bolts and run them in snug.

7. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.

8. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb—ft (68 N*m) torque. Then rotate bolts as follows:

| BOLT SIZE | ADDITIONAL ROTATION (DEGREES) |
|---|---|
| **5/8" — 18 x 4" L**<br>**5/8" — 18 x 4.75" L**<br>**3/4" — 16x4" L**<br>**3/4" 16 x 4.75" L** | **120 — 130°**<br>**140 — 150°**<br>**120— 130°**<br>**120— 1 30°** |

**N OTICE:** Since the *torque-turn method* provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

When a clutch pilot bearing is installed, index the flywheel bolts so that the corners of the bolt heads do not overlap the pilot bearing bore in the flywheel. Thus, one of the flats of each bolt head will be in line with the bearing bore. Always rotate bolts in the *increased* clamp direction to prevent underclamping.

9. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is .001” total indicator reading per inch of radius. The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

# FLYWHEEL HOUSING

• The flywheel housing (Fig. 1) is a one-piece casting, mounted against the rear end of the cylinder block, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motors and the adaptor for the generator, PTO, marine gear, or transmission.

The new flywheel housings are counterbored to accommodate the new outboard bearing support assembly (see Section 1.3.2 or 1.3.5.2).

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (Section 1.3.2 or 1.3.5.2).

• A specially drilled and tapped flywheel housing is used on high torque rise 12V-149T and TI engines to permit installing the magnetic pickup components required on these units (refer to Shop Notes in section 1.0).

## Remove Flywheel Housing

1. Remove the engine and place it on an engine overhaul stand.

2. Remove the starting motors, outboard bearing support and all of the accessories and cover plates attached to the flywheel housing.

3. Loosen the bolts securing the upper oil pan to the cylinder block and remove the four (4) bolts, lock washers and shims (if used) attaching the flywheel housing to the oil pan. Record the amount of shims removed. Lower the oil pan just enough to allow removal of the flywheel housing. When removing the flywheel housing in this manner, be careful not to dislodge the upper oil pan O-ring seal.

4. Remove the fly wheel (Section 1.4).

5. Remove the camshaft drive gear assemblies (Section 1.7.3).

6. Remove the seventeen (17) bolts located in the bell of the housing. Install two (2) pilot studs to guide the housing until it clears the crankshaft during removal. Then, remove the remaining bolts around the upper portion of the flywheel housing.

**NOTICE:** The two (2) pilot studs can be fabricated from two (2) 5/8”-l 1 x 8-1/2” bolts. Cut off the heads of the bolts and cut a screwdriver slot in the non-threaded end.

7. Support the flywheel housing by its lifter brackets with a chain hoist, strike the front face of the flywheel housing alternately on each side to free it from the dowels and remove the flywheel housing and seal strip from the engine.

## Inspection

Clean the flywheel housing and inspect it for cracks or any damage. Inspect the oil seal and oil seal sleeve (if used) for wear. If worn, install a new oil seal and oil seal sleeve as outlined in Section 1.3.2.

## Install Flywheel Housing

1. Apply a thin coat of spray adhesive in the flywheel housing seal strip groove and place a new seal strip in the groove.

**NOTICE:** The seal strip must lay flat in the groove and must not be twisted. Cut the excess seal strip flush at the bottom of the flywheel housing on each side.

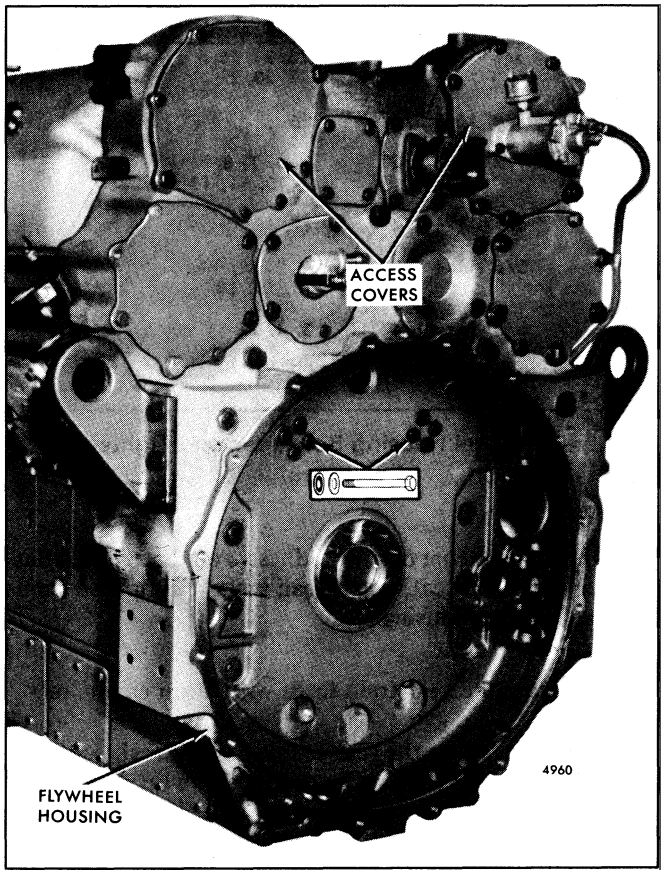
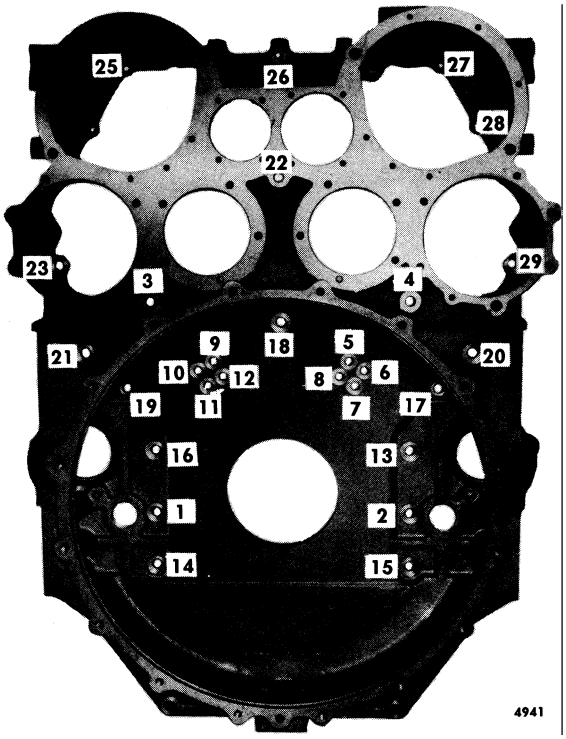



**Fig. 1 - Flywheel Housing Installed on Engine**




| BOIT SIZE | | LOCATION |
|---|---|---|
| 3/8"-16xl | 1/8" | 23, 24, 25 27, 28, 29 |
| 3/8"-16x5 3/4 | | 26 |
| 1 /2"-13x5 | 1/2" | 5, 6, 7, 8, 9, 10, 11, ] |
| 5/8"-11 x4 | 1/4" | 17 , 19 |
| 5/8"-11x4 | 1/2" | 1, 2, 13, 15, 16, 18 |
| 5/8"-11x6 | 1/4" | 3, 4, 22 |
| 5/8"-11x8 | 1/2" | 20, 21 |

**Fig. 2 - Flywheel Housing Bolt Sizes and Tightening Sequence**

2. Apply a thin coat of spray adhesive on the exposed flat surface of the seal strip. Clean any excess grease from the flywheel housing.

3. Lubricate the gear train teeth with clean engine oil.

4. Before installing the rear crankshaft oil seal* coat the cavity between the dust lip and the main lip around the entire circumference of the seal with clean engine oil. Failure to adequately lubricate this area during seal installation can result in seal lip damage at engine start-up.

5. Thread the two (2) pilot studs into the cylinder block to guide the housing in place. Use oil seal expander J 22605 on the end of the crankshaft to pilot the oil seal on the crankshaft. Expander adaptor J 23341 can be used when the rear crankshaft cup plug is in place. If further information is required, refer to Section 1.3.2.

6. With the housing suitably supported, position it over the crankshaft and up against the cylinder block. Remove the oil seal expander.

7. Refer to Fig. 2 and install the eight (8) l/2”-13 x 5-1/2” self-locking bolts, *new* flat washers and *new* 1/2” seal washers in the holes of the crankshaft idler gear hub and idler gear hole spacer, finger tight. The seal washer is between the flat washer and the flywheel housing. To prevent oil leakage, use new, flat washers and seal washers each time the bolts are reinstalled (positions 5-12).

8. Remove the pilot studs and install the seven (7) 5/8”—11 x 4-1/2” housing-to-cylinder block bolts with flat washers, finger tight.

9. Install the remaining flywheel housing attaching bolts with washers, finger tight.

10. Draw the bolts up snug following the bolt tightening sequence (Fig. 2).

11. Refer to Fig. 2 for the final bolt tightening sequence and, starting at number 1, tighten the 5/8”—11 bolts to 137-145 lb—ft (186-197 N-m) torque, the 3/8”-16 bolts to 30-35 lb—ft (41-47 N*m) torque and the 1/2”—13 bolts to 71-75 lb-ft (96-102 N-m) torque.

12. Install outboard bearing support, if used (refer to Section 1.3.5.2).

13. Install the flywheel (Section 1.4).

14. Check the flywheel housing concentricity and bolting flange face with tool set J 9737-C as follows:

    a. Thread the base post J 9737-3 tightly into one of the tapped holes in the flywheel. Then, assemble the dial indicators on the base post.

    b. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

    c. Pry the crankshaft toward one end of the’block to ensure end play is in one direction only.

    d. Adjust each dial indicator to read zero at the *twelve o'clock* position. Then, rotate the crankshaft one full revolution, taking readings at 45° intervals (8 readings each for the bore and the bolting flange face).

- The hex head of the front crankshaft bolt may be used to turn the crankshaft. However, the barring operation should ALWAYS be performed in a clockwise direction. It is very important to make certain that the bolt has not been loosened.

- Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

**• CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.**

Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed .013" for either the bore or the face.

e. If the runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreign material between the flywheel housing and cylinder block which may result in warpage.

f. Reinstall the flywheel housing and flywheel and tighten the attaching bolts in the proper sequence and to the specified torque. Then, recheck the runout. If necessary, replace the flywheel housing.

15. Install the camshaft gear and hub assembly. Since the camshaft gears, idler gears and crankshaft gear in each gear train must be in time with the crankshaft, timing marks are located on the gears. Refer to Section 1.7.1 for timing mark alignment and Section 1.7.3 for installation.

16. Tighten the upper oil pan-to-cylinder block bolts (Section 4.7).

17. Install the four flywheel housing-to-oil pan bolts, lock washers and the same amount of shims (if required) that were removed at the time of disassembly.

18. Install all of the accessories and cover plates removed in Step 2 of *Remove Flywheel Housing.*

# FLYWHEEL HOUSING ADAPTOR

The flywheel housing adaptor (Fig. 1) provides a means of attaching the power generator (Section 7.5) to the engine flywheel housing. The current adaptor ring, made from ductile iron, is interchangeable with the former adaptors.

## Remove Flywheel Housing Adaptor

1. Refer to Section 7.5 and remove the generator from the engine.
2. Remove the drive coupling assembly from the crankshaft (Section 7.5).
3. Remove the sixteen attaching bolts which retain the flywheel housing adaptor to the flywheel housing and remove the adaptor.

## Install Flywheel Housing Adaptor

It is recommended that the former flywheel housing adaptor (with three pilot plates) be replaced by the current flywheel housing adaptor (with pilot) at the time of assembly. *Locating tool NDD-4875 is not required when installing the current flywheel housing adaptor.*

1. Clean the mating surfaces of the flywheel housing and the flywheel housing adaptor.
2. Position the flywheel housing adaptor against the flywheel housing with two of the spot-faced holes on each side of the flywheel housing above the centerline of the crankshaft and one spot-faced hole on each side of the flywheel housing below the centerline of the crankshaft and towards the engine.
3. Apply a small amount of International Compound No. 2, or equivalent, to the threads and install the sixteen l/2”-13 x 1 1/2 self-locking bolts. Tighten the bolts to 71-75 lb—ft (96-102 N#m) torque.
4. On engines equipped with the former design adaptor, position the three pilot plates around the face of the adaptor (120° apart) and secure them loosely with 3/8”-16 bolts and washers. Use pilot plate locating tool NDD-4875 (Fig. 2) to adjust the pilot plates, as follows:
   a. Place the locating tool over the rear end of the crankshaft, with the outer end located in the adaptor pilot plate slots (Fig. 2), and secure it loosely to the crankshaft with two crankshaft bolts and spacers. Slide the tool forward so that the key located at the base of the tool is against the O.D. of the crankshaft. Then tighten the knurled knob at the front end of the base until the locating tool is tight on the end of the crankshaft. Tighten the two crankshaft bolts.

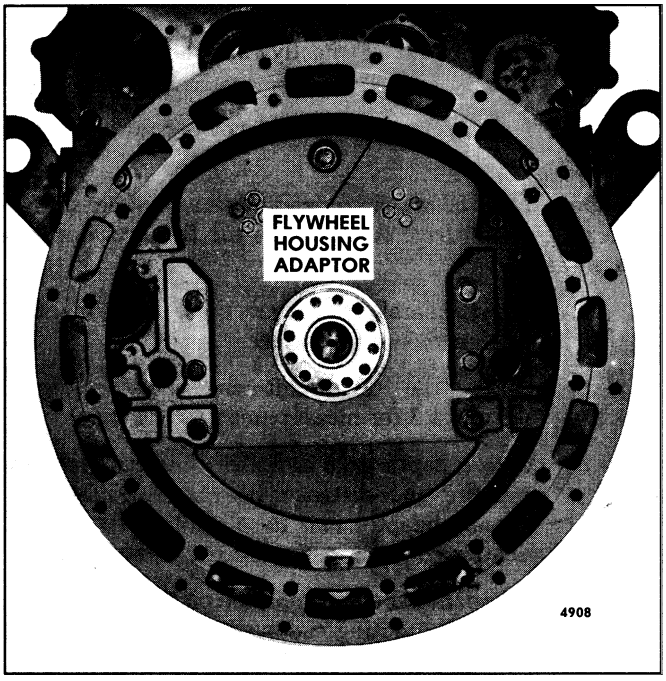



Fig. 1 - Flywheel Housing Adaptor Mounting

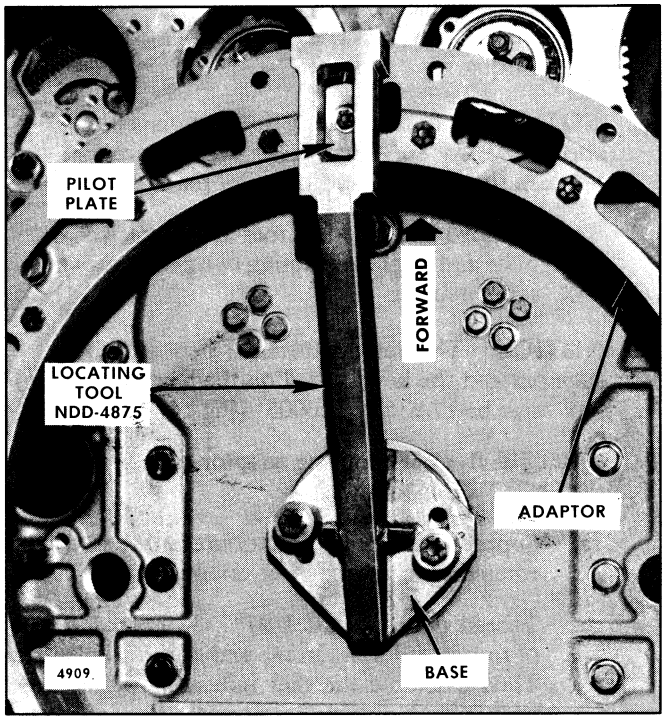



Fig. 2 - Locating Tool (NDD-4875) Positioned on Crankshaft and Flywheel Housing Adaptor (Former Adaptor)

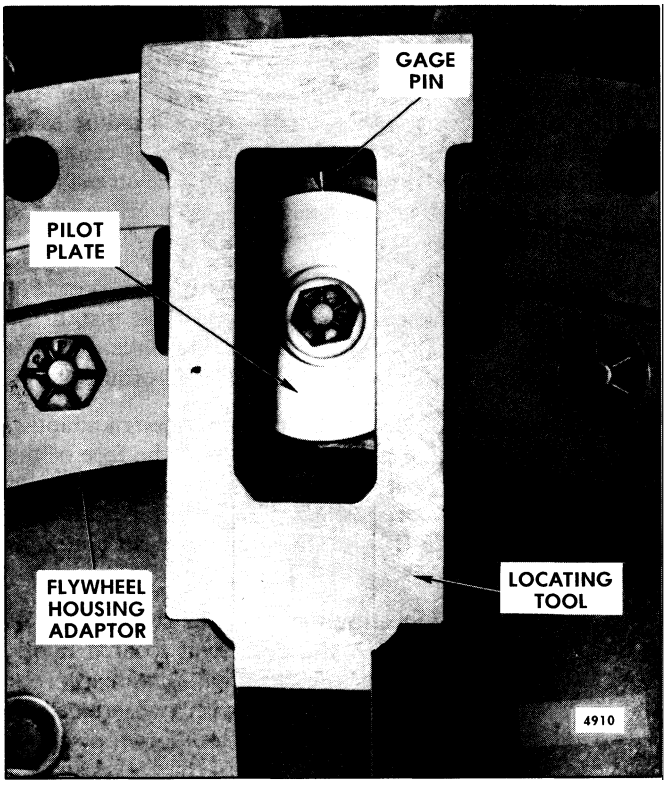



**Fig. 3 - Pilot Plate in Position Against Gage Pin (Former Adaptor)**

b. With the locating tool in position, slide the pilot plate up against the gage pin (Fig. 3). Tighten the pilot plate bolt to 30-35 lb-ft (41-47 N#m) torque.

**NOTICE:** After tightening the pilot plate bolt, check to make sure that there is no clearance between the gage pin and the pilot plate.

c. Remove the locating tool from the first pilot plate and set the remaining two pilot plates in the same manner.

**NOTICE:** The set-up distance between the gage pin and the key located on the base of the tool must be 17.936" ± .0005" (Fig. 4).

5. Check the flywheel housing adaptor runout with tool set J 9737-C, as follows:

a. Support the engine so that the crankshaft can be rotated with a wrench or cranking bar.

b. Thread the base post J 9737-3 tightly into one of the tapped holes in the end of the crankshaft. Then assemble the dial indicator on the base post.

c. Position the dial indicator point on the flywheel 6. housing adaptor machined face.

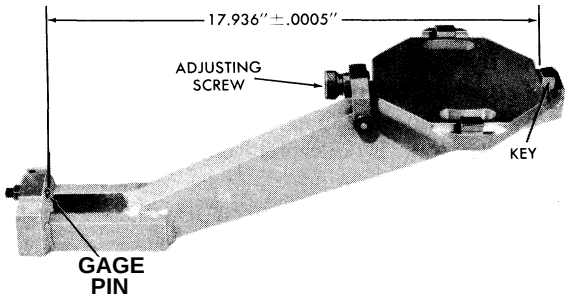



**Fig. 4 - Locating Tool Set-Up Dimension**

d. Rotate the crankshaft.

**NOTICE:** If a bolt or nut is used to rotate the crankshaft, always turn it in a tightening direction.

e. As the dial indicator is rotated, determine the total runout of the flywheel housing adaptor face.

f. The face runout should not exceed a total of .026".

g. Position the dial indicator point on the flywheel housing adaptor machined bore.

h. Rotate the crankshaft.

**NOTICE:** If a bolt or nut is used to rotate the crankshaft, always turn it in a tightening direction.

'*** i. As the dial indicator is rotated, determine the total runout of the flywheel housing adaptor bore.

j. The bore runout should not exceed a total of .026".

Determine the maximum and minimum dimension of the flexible plate (drive coupling) to the flywheel housing adaptor, as follows:

a. Mount a parallel bar across the flywheel housing adaptormounting surface.

b. Center the crankshaft end play (refer to Section *1.3Tor measurement of end play).

c. With a depth gage mounted on a parallel bar, measure the distance between the flywheel housing adaptor and the flexible plate at four locations 90° apart. Record the measurements.

d. Stamp the average dimension on the inside of the flywheel housing adaptor in an accessible location.

Refer to Section 7.5 and install the drive coupling assembly and the power generator.

# PISTON AND PISTON RINGS

## FLOATING-SKIRT PISTON

The non-turbocharged (naturally aspirated) and turbocharged engines use a 17.1 to 1 compression ratio piston. The turbocharged intercooled engines use a 16 to 1 compression ratio piston. These malleable iron pistons are two piece or "floating" pistons, consisting of a piston body and a piston pin carrier (Fig. 1). The top of the piston pin carrier is positioned in a counterbore in the piston body, close to the piston crown. A snap ring, located near the base of the piston, secures the carrier within the piston body. A thrust plate is used between the piston pin carrier and the top of the piston body. This design allows the piston body to rotate freely during engine operation.

A bushing (Fig. 1) is located at the top of the piston pin opening in the piston pin carrier and is prevented from moving endwise by two tangs.

Four compression rings and two oil control rings are used on the piston (Fig. 2). Equally spaced drain holes are located at the oil control ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase.

Internal parts of the piston are lubricated and cooled by the crankcase oil. Oil is forced through a drilled passage in the connecting rod, up through the piston pin, then through the center hole of the bushing and carrier to the underside of the piston. A portion of the oil flows along the grooved passages of the bushing to lubricate the piston pin. Some oil is trapped between the carrier and the piston where it "sloshed" back and forth during piston reciprocation, with most of the oil being drained away through four holes drilled in the skirt of the carrier allowing the oil to return to the crankcase.

### Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to a point where the plating or grooves are gone, the compression should be within operating specifications. The procedure for checking the compression pressure is covered in Section 15.2.

### Remove Piston And Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the lower oil pan and the hand hole covers on the upper oil pan (Section 4.7).
3. Remove the oil pump and inlet and outlet pipes, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

### Disassemble Piston And Connecting Rod

Note the condition of the piston and rings. Then, remove the rings and disassemble the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 22405-02 (Fig. 3).
2. Remove the two bolts and spacers securing the connecting rod to the piston pin and remove the connecting rod.

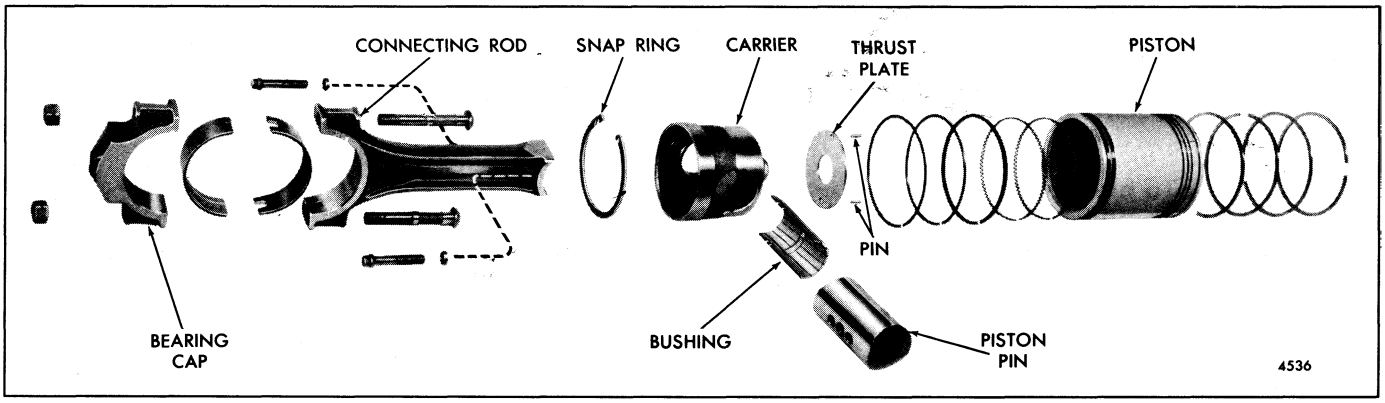



**Fig. 1 - Piston and Connecting Rod and Relative Location of Parts (Piston for Turbocharged Engine Shown)**

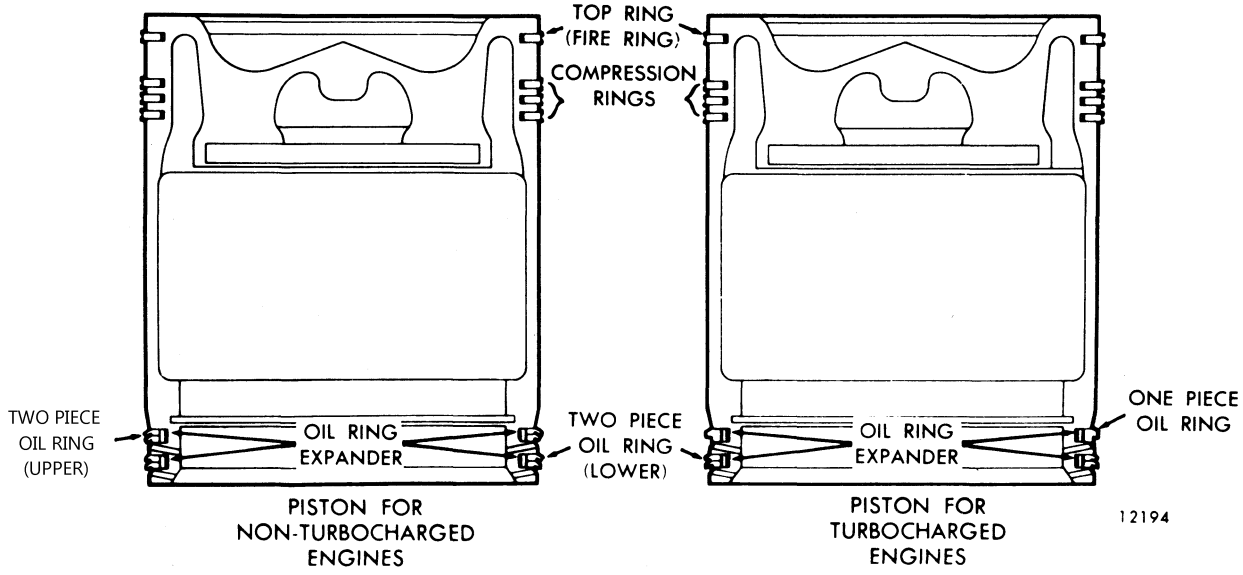



**Fig.** 2 - **Piston Ring Installation**

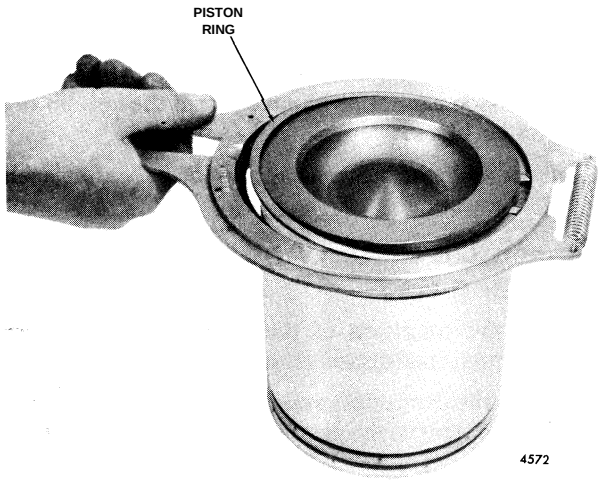



**Fig. 3 - Removing or Installing Piston Rings using Tool**
J 22405-02

## Cleaning

Clean the parts with fuel oil and dry them with compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

If the fuel oil does not remove the carbon deposits, use a chemical solvent that will not harm the tin-plate on the piston. If a chemical solvent is used, refer to the container for "Safe Use Instructions".

The upper part of the piston, including the compression ring lands and grooves, is not tin-plated and may be wire-brushed to remove any hard carbon. However, care must be taken to avoid damaging the tin-plating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston and the oil return holes in the lower half of the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

## Disassemble Piston And Carrier

After the connecting rod and piston rings have been removed from the piston, disassemble the piston as follows:

1. Remove the snap ring from the piston body and withdraw the piston pin carrier and thrust plate (Fig. 4).

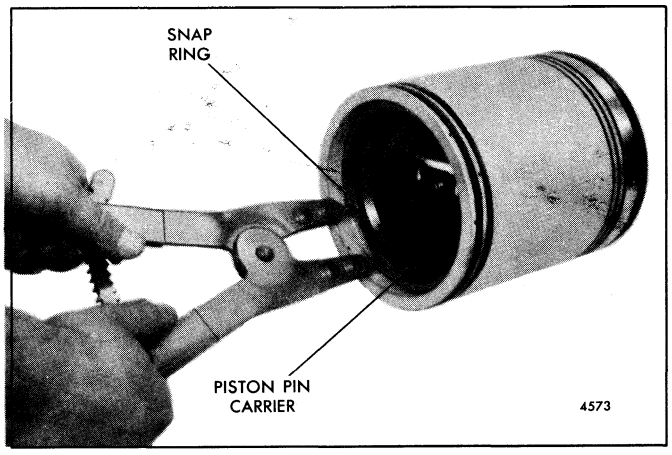



**Fig.** 4 - **Removing Piston Pin Carrier From Piston**

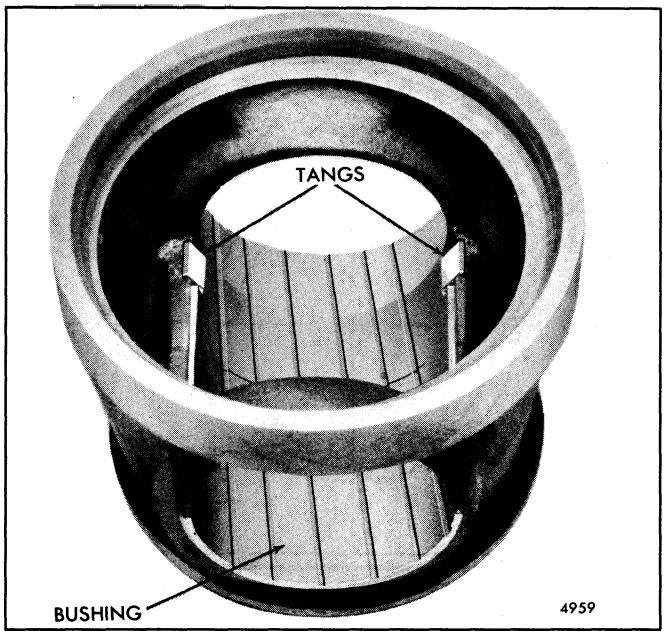



**Fig. 5 - Piston Carrier and Bushing**

2. Remove the piston pin from the carrier.

3. Visually inspect the piston pin bushing. If the babbitt overlay is worn to the point that copper is visible, the bushing must be replaced. If replacement of the bushing is required, straighten the tangs and remove the bushing (Fig. 5). Once the tangs have been straightened and the bushing is removed, it cannot be reused.

## Inspection

If the tin-plate on the piston and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored pistons, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick. ”

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which can be cleaned up may be reused. Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots may be the result of an obstruction in the connecting rod oil passage.

If any cracks are found in the piston, the piston must be replaced. Use the magnetic particle inspection methods outlined in Section 1.3 under *Crankshaft Inspection* for locating cracks in the piston.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

Check the connecting rod and piston pin as outlined in Section 1.6.1. The current piston pin has a thicker wall and requires 1/4” longer pin bolts. When replacing a former piston pin with the current pin, include two l/2”-20 x 2” pin bolts. The former and current piston pins can be mixed in an engine. However, it is recommended that all current pins be installed at time of overhaul on early engines.

Inspect the thrust plate for cracks, wear or any other damage. A new thrust plate is .0995”-. 1010” thick. Replace the plate when it is worn to .0945” in thickness.

Inspect the piston pin carrier thrust plate platform. Slight ridges, gouges or scuffing may be cleaned up. However, the height from the bottom of the carrier to the thrust platform must not be less than 3.605”. This height on a new carrier is 3.606M-3.609” (Fig. 6). The thrust washer surface must be square with the axis through the two finished diameters within .002” total indicator reading.

If replacement of the former 180° piston pin carrier or bushing (Fig. 6) is required, the current 150° carrier and bushing must be installed. The former 180° carrier and bushing are not serviced.

Effective with engine serial numbers 12E-221 and 16E-001, the thrust plate is drilled and retained by dowel pins located in the piston. Inspect the dowel pins for wear. The installed height that a new dowel pin extends from the thrust washer seating surface is .075”-.080” with new parts. If replacement is required, drive the old pins out with a suitable punch and install the new pins with tool J 23574. After installation, the new pin must withstand a 250 pound load without.moving.

Effective” with approximate engine serial numbers 12E-1490 and 16E-233, the piston pin carrier and thrust plate have hardened mating surfaces to provide a more wear resistant thrust surface. The current carrier can be identified by its dull gray finish. The current thrust plate is steel with a nickel-cobalt plating and is tapered approximately .003” from the inside diameter to the outside diameter. The former flat thrust plate was bronze with a lead-tin overlay on the carrier side. Both the current carrier and thrust plate must be used together. One side of the thrust plate is stamped “Piston Side” to aid correct installation. Do not use former and current carriers and thrust plates together.

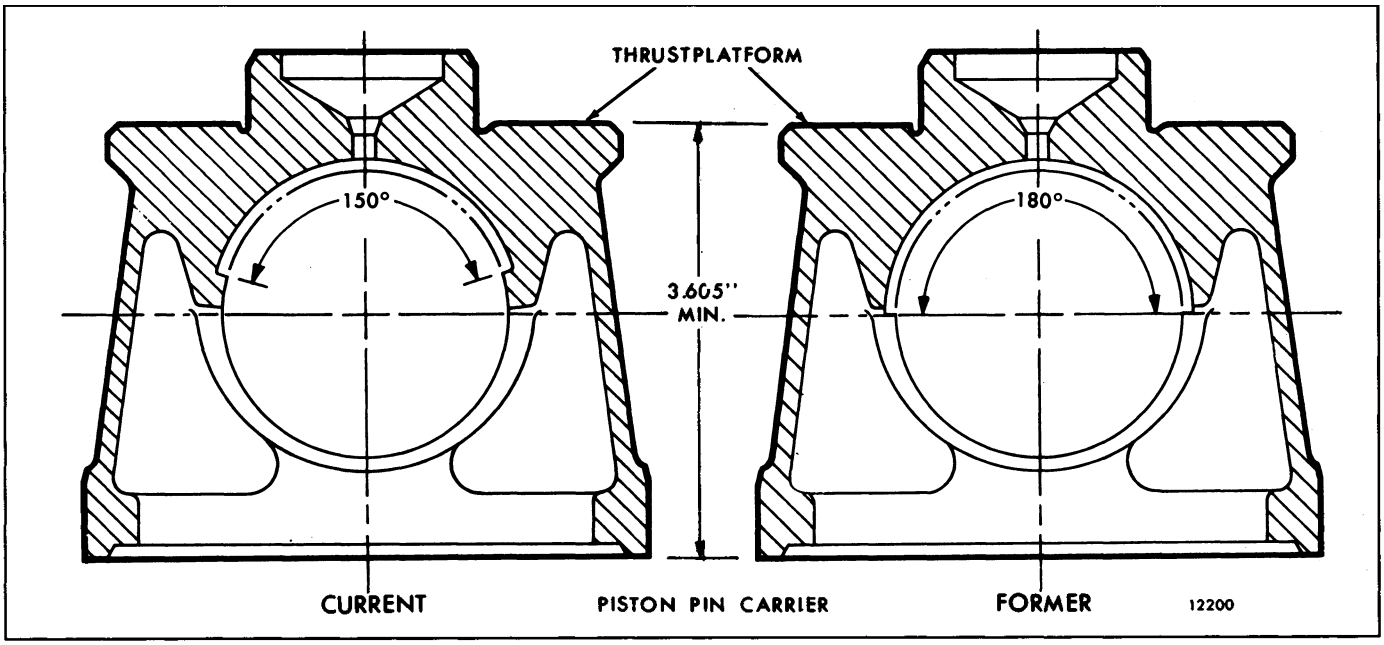



**Fig. 6 - Piston Carrier Dimension**

Check the cylinder liner (Section 1.6.3) and block bore (Section 1.1) for excessive out-of-round, taper or high spots which could cause piston failure.

Current cross-head piston assemblies and floating-skirt piston assemblies may be intermixed within an engine. At time of complete engine overhaul, it is recommended that all floating-skirt pistons in an engine be replaced by the cross-head pistons.

## Fitting Piston

Measure the piston diameter and cylinder bore, preferably at room temperature (70°F or 21°C). Refer to Section 1.0 for the piston and liner specifications.

Effective with approximate engine serial numbers 12E-673 and 16E-016, a new piston with an increased outside diameter and a revised bottom oil control ring land and oil drain holes (Fig. 1) replaced the former piston. With the increased piston diameter, the piston-to-liner clearance was reduced. Effective with engine serial numbers 12E-1463 and 16E-218, the piston-to-liner clearance was further reduced (refer to Section 1.0) by increasing the tin plate thickness on the piston.

## Fitting Piston Rings

Each piston is fitted with a fire ring, three compression rings and two oil control rings (Fig. 2).

The top (fire) ring and the upper compression ring (second groove) are pre-stressed. Both are identified by an oval mark on the top side. In addition, the grooved fire ring has a black or copper oxide coating and is marked "Top-F-GM" on top of the ring. The barrel-faced fire rings are identified with "Top-F-GM" and a circle on the top.The upper compression ring is marked "Top-GM" in addition to the oval mark. The compression ring used in the third and fourth grooves is identified by "Top-GM" only.

A two-piece non-slotted oil control ring (upper ring groove) and a two-piece slotted oil control ring (lower ring groove) are used in the pistons for turbocharged and non-turbocharged engines.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of the ring travel. Use a piston to push the ring down to be sure it is parallel with the top of the liner. Then, measure the ring gap with a feeler gage (Fig. 7). Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is ffom the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must have a .005" to .020" radius which blends into the ring face.

Check the ring side clearance (Fig. 8). Refer to Specifications - Section 1.0 for piston ring clearance specifications.

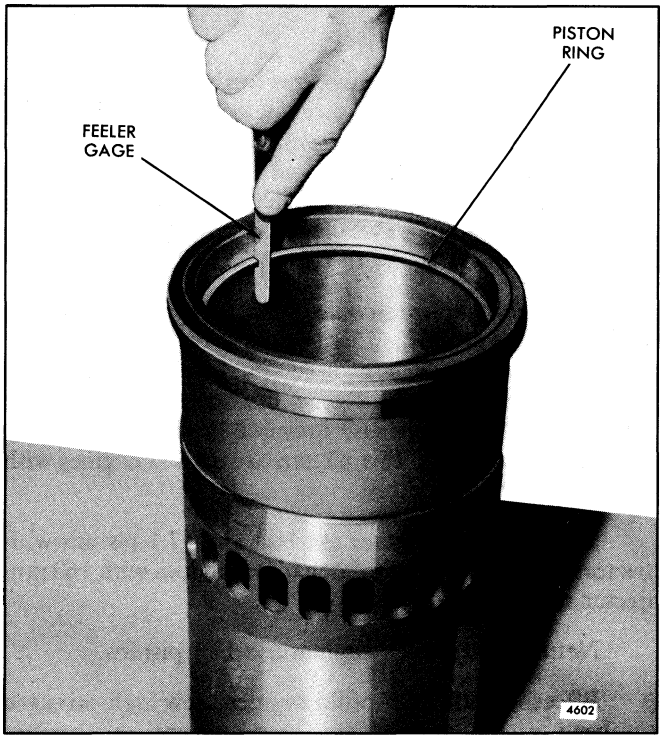



**Fig. 7 - Measuring Piston Ring Gap**

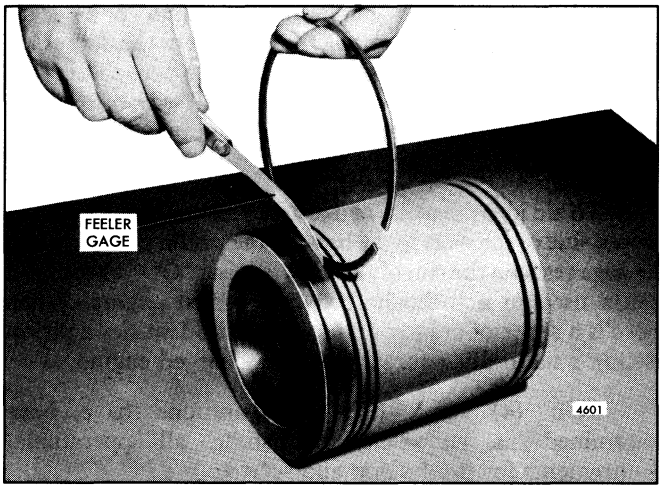



**Fig. 8 - Measuring Piston Ring Side Clearance**

## Install Piston Rings

Before installing the piston rings, assemble the piston as outlined under *Assemble Connecting Rod to Piston* in Section 1.6.1. Then, refer to Figs. 2 and 3 and install the piston rings. Lubricate the piston rings and piston with engine oil before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 22405-02 (Fig. 3). *To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston.* The compression rings have a tapered face. Make sure the side marked “TOP” is toward the top of the piston.

2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

The upper and lower oil control rings used on pistons for current *non-turbocharged* engines consist of two halves (upper and lower). The upper oil control ring used on pistons for *turbocharged* engines is a one-piece ring while the lower ring is a two-piece ring (upper and lower halves). Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves of the piston. When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control ring and result in high lubricating oil consumption.

2. To install the one-piece ring (turbocharged engines), position it over the upper ring groove, using tool J 22405-02, with the gap 180° from the gap in the expander and the scraper edge facing down. Press the ring against the gap side of the expander to prevent the ends of the expander from overlapping, then align the ring with the groove and release the tension on the tool, permitting the ring to slip in position.

Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then, install the lower half with the gap 45° from the gap in the upper half of the ring. Make sure t£e scraper edges are facing down (toward the bottom of *the* piston). The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

3. Install the upper and lower halves of both oil control rings (non-turbocharged engines) as outlined above.

If there is noticeable resistance during installation of the piston, check for an overlapped ring expander.

# CROSS-HEAD TYPE PISTON

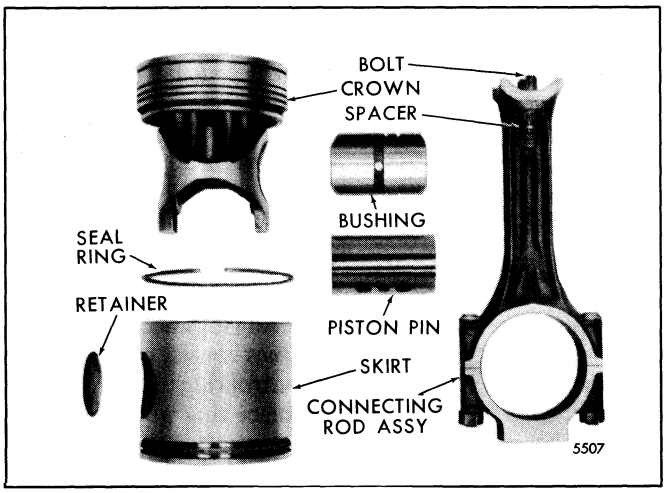



**Fig. 9 - Cross-Head Piston and Connecting Rod Components**

The cross-head piston (Fig. 9) is a two-piece piston consisting of a crown and skirt. An oil seal ring is used between the crown and skirt which are held together by the piston pin. Two bolts and spacers are used to attach the connecting rod (Section 1.6.1) to the piston pin.

Ring grooves are machined in the piston crown for a fire ring and three compression rings. The crown is also machined to accept a 150° slipper type bushing (bearing). The piston skirt incorporates two oil control ring grooves, piston pin holes and piston pin retainer counterbores. Naturally aspirated engines have equally spaced drain holes that are located in the oil ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase.

A new piston skirt and a new two piece upper oil control ring are used in the turbocharged and turbocharged intercooled engines. This is effective with engine serial numbers 12E-5613 and 16E-5212. The new turbocharged piston skirt has all of the drain holes eliminated and replaced with two pressure relief slots or scallops below the lower oil control ring groove, under the piston pin center lines. The former and new parts may be mixed in an engine; however, maximum oil consumption gain will not be realized. The former piston skirt and oil control ring expander (part of oil ring set) will continue to be serviced for naturally aspirated engines. The former one piece (Turbo) oil control ring and expander ring set will not be serviced.

Internal parts of the piston are lubricated and cooled by the engine lubricating oil. Oil is forced through a drilled passage in the connecting rod, up through the piston pin, then through the center hole in the bushing to the underside of the piston crown. A portion of the oil flows along the grooves in the bushing to lubricate the piston pin.

During engine operation, gas loads pushing down on the piston crown are taken directly by the piston pin and bushing. The piston skirt, being separate, is free from vertical load distortion; thermal distortion is also reduced as the piston crown expands. As the connecting rod swings to one side during downward travel of the piston, the major portion of the sideload is taken by the piston skirt.

- *Turbocharged-intercooled engines with blower bypass valves* use 14:1, 15:1, or 16:1 compression ratio pistons. 14:1 pistons are used in high output, 2200 horsepower engines, except generator sets, which use 15:1 pistons. 15:1 pistons are also installed in engines with 190 mm or larger injectors. 16:1 pistons are used in engines with less than 190 mm injectors.

- *Turbocharged engines* use 16:1 and 17:1 pistons with injectors up to 140 mm. Turbocharged engines with 160 mm injector use 16:1 pistons.

- *Naturally aspirated engines* use 17:1 pistons.

- Effective with 1988-build engines, new high-strength crosshead piston domes are used, except on engines requiring 16:1 compression ratio domes with wide fire ring grooves. The new domes are similar to the former domes, except that they have a redesigned piston bowl strut configuration (Fig. 11). Among the changes to the domes are an increased blend radius of strut-to-upper piston pin saddle and the elimination of strut taper. Former and new domes are completely interchangeable and may be mixed in an engine.

To aid identification of a piston, refer to Fig. 10. Fit the proper side of the gage in the bowl of the piston crown. When the gage rests on the rim of the crown, it is a “GO” check for a piston used in a turbocharged-intercooled engine. When there is a space of approximately .050”, it identifies a piston used in a naturally aspirated or turbocharged engine.

Four (4) basic ring configurations have been determined as sufficient to handle all operational requirements for production and service.

The first production ring arrangement uses the narrow grooved chrome fire ring and barrel-faced compression rings, along with what is now an across-the-board oil ring/expander package. This consists of slotted oil rings in the lower groove, non-slotted rings in the upper groove, and low tension (11-17#) expanders. This configuration can be used in engines equipped with 140 to 270 cmm injectors and operating with LOW sulfur fuel.

The second ring arrangement consists of the wide barrei-faced fire ring, grooved chrome compression rings and the standard oil ring package. This arrangement will be used in engines with 140 to 270 cmm injectors, but operating with HIGH sulfur fuel (sulfur content 0.5% and above).

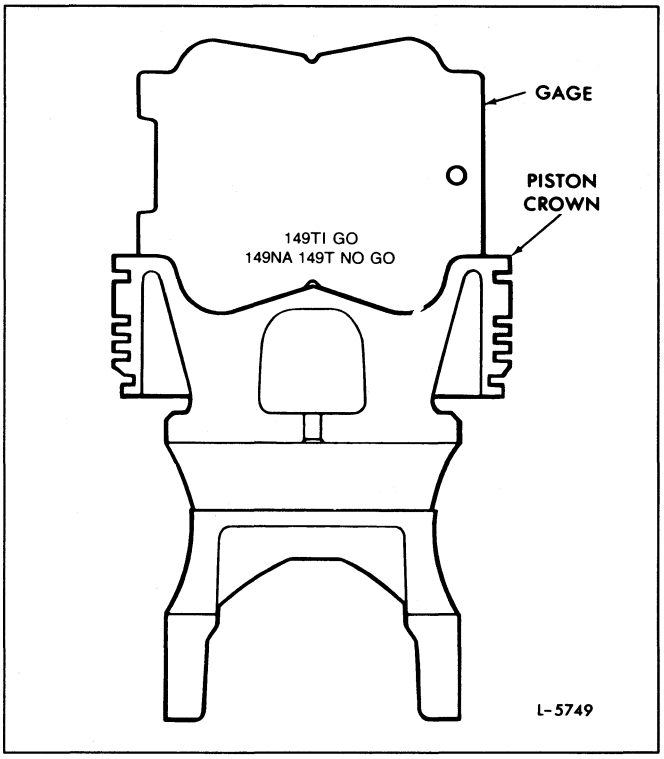



**Fig. 10-Piston Identification using Gage J 25397**

The third ring arrangement uses the wide barrel-faced fire ring and barrel-faced compression rings with the standard oil ring package. This arrangement is used only with 17:1 pistons in low output engines, which includes naturally aspirated engines and turbocharged engines using either 120 or 130 cmm injectors.

The fourth ring arrangement is the all-grooved ring set which uses narrow, grooved chrome fire and compression rings. The most commonly used ring set, it is installed in applications where fuel sulfur is below 0.5% and previous experience with this ring set has been satisfactory.

## Inspect Piston Rings

When an engine is hard to start, runs rough or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to a point where the plating or grooves are gone, the compression should be within operating specifications. The procedure for checking compression pressure is covered in Section 15.2.

## Remove Piston And Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the lower oil pan and the hand hole covers on the upper oil pan (Section 4.7).
3. Remove the oil pump and inlet and outlet pipes, if necessary (Section 4.1).
4. Remove the cylinder head (Section 1.2).
5. Remove the carbon deposits from the upper inner surface of the cylinder liner.
6. Remove the bearing cap and lower bearing shell from the connecting rod. Then, push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

## Disassemble Piston And Connecting Rod

Note the condition of the piston and rings. Then remove the rings and disassemble the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 22405-02 (Fig. 3).
2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushing. Remove the opposite retainer in the same manner.
3. Loosen the two bolts which secure the connecting rod to the piston pin. Then, remove the rod and piston assembly from the vise and place the assembly on the bench. Remove the two bolts and spacers and remove the connecting rod.
4. Withdraw the piston pin.
5. Separate the piston skirt from the piston crown.
6. Remove the seal ring from the piston crown.
7. Remove the piston pin bushing (bearing).

## Cleaning

Clean the piston components with fuel oil and dry them with compressed air.

**CAUTIONiTo prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 Kps) air pressure.**

If the fuel oil does not remove the carbon deposits, use a chemical solvent that will not harm the tin-plate on the piston. If a chemical solvent is used, refer to the container for “Safe Use Instructions”.

The piston crown, including the compression ring grooves, is not tin-plated and may be wire-brushed to remove any hard carbon. *Do not wire-brush the piston skirt* Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston crown and skirt and the oil drain holes in the lower half of the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

Glass beading can be used to clean a piston crown. Mico Bead Glass Shot MS-M (.0029"-.0058M) is recommended. Allowable air pressure is 80-100 psi (552-689 kPa). After cleaning, do not leave glass beads in the piston crown.

**NOTICE:** Do not attempt to clean the piston skirt by glass beading, as it will remove the tin-plating.

## Inspection

If the tin-plate on the piston skirt and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored piston skirts, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

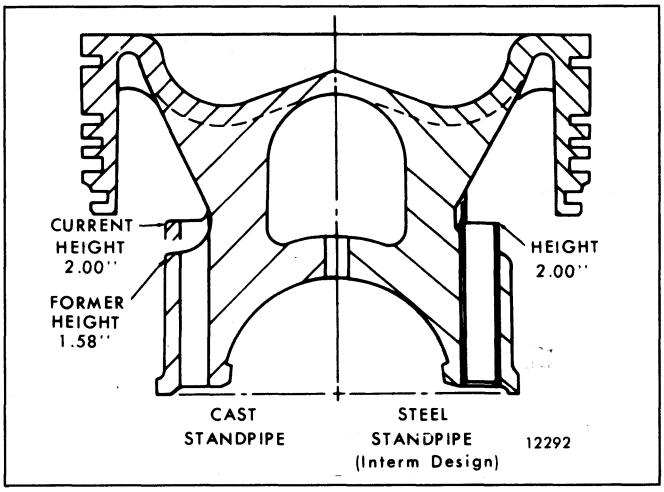



**Fig. 11 - Piston Standpipe**

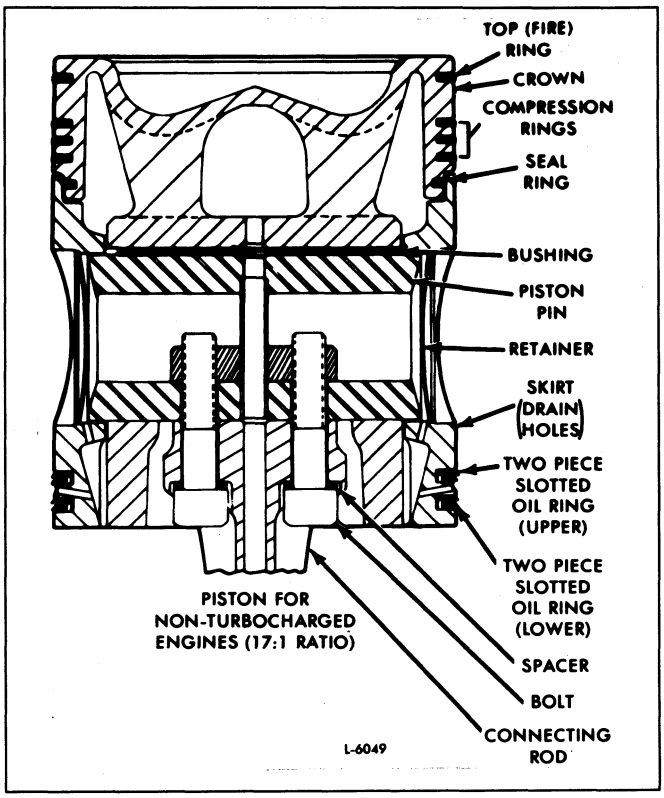



**Fig. 12 - Piston Ring Arrangements (Naturally Aspirated Engines)**

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston skirt and crown for score marks, cracks, damaged ring groove lands or indications of overheating. Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots may be the result of an obstruction in the connecting rod oil passage.

The "standpipe" height in the current piston crown has been increased, thus raising the oil level in the piston to provide improved piston dome cooling. The former and revised piston crowns may be mixed in an engine. Current design pistons may be identified by referring to Figs. 11,12 and 13. . .

Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston (refer to Specifications - Section 1.0).

Inspection of the connecting rod, piston pin and piston pin bushing are covered in Section 1.6.1.

Other factors that may contribute to piston failure include oil leakage into the air box, oil pull-over from the air cleaner, dribbling injectors, combustion blow-by and low oil pressure (dilution of the lubricating oil).

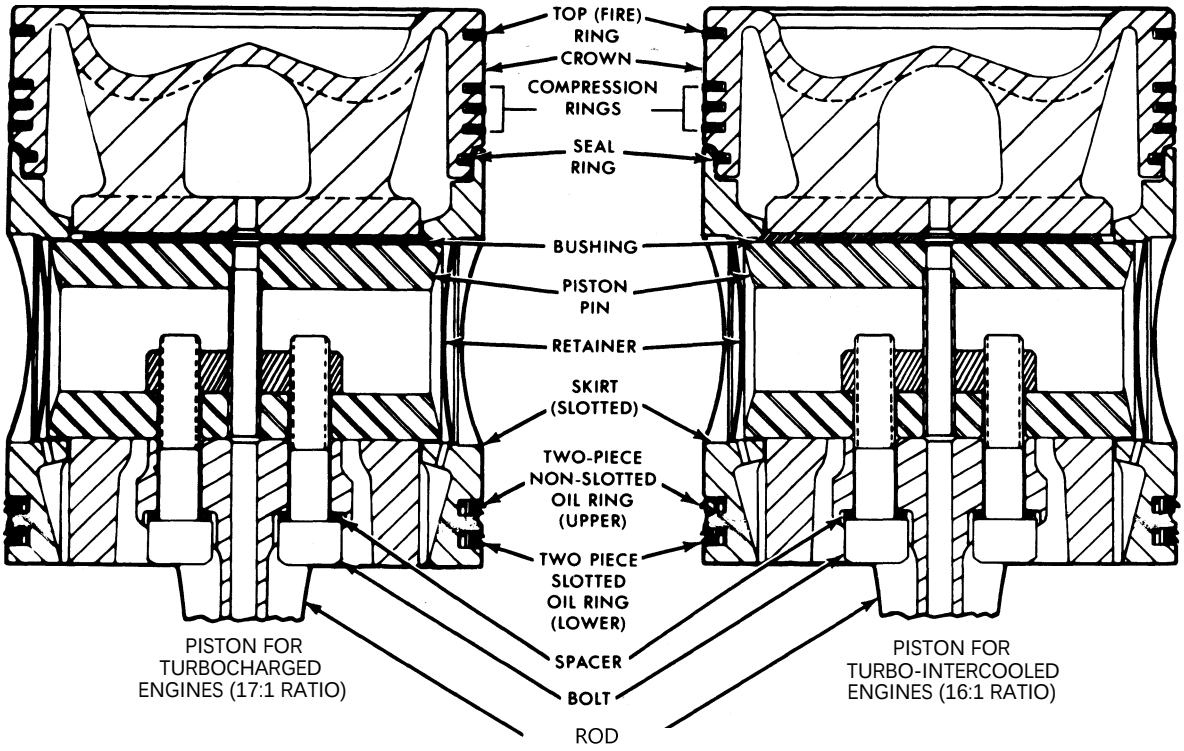



**Fig. 13 - Piston Ring Arrangements (Turbocharged Engines)**


**Fig. 14 - Installing Seal Ring**

## •Lubrication

Use a mixture of clean engine oil and *STP* (or equivalent) on all moving parts of the cylinder kit during assembly. This mixture adheres to the parts for a longer period of time than plain engine oil, thus helping prevent scuffing of parts at engine start-up. The suggested mix ratio is 8:1 (8 parts engine oil to 1 part *STP*, or equivalent).

## Assemble Piston And Connecting Rod

• 1. Install the bearing (bushing) in the piston crown. It should slide into the piston crown with hand applied force. The bearing must be installed before assembling the piston skirt and crown.

The current piston crown, which incorporates a piston bowl support system with eight cast-in struts, should be used in all engine models. The former crown had twelve cast-in *stmts.*

2. Lubricate the fluoroelastomer seal ring liberally with STP, or equivalent and install the seal ring in the piston crown (Fig. 14). *Excessive stretching should be avoided.* If the former metal seal ring is used, lubricate the seal ring (Fig. 13) with engine oil and install it with the face marked “top” facing the piston crown. If the ring is not marked, install it with the countergroove facing the top of the piston crown.

3. Compress the former seal ring with ring compressor J 24421 and push the skirt into position on the piston


**Fig. 15 - Installing Piston Pin**

crown. The fluoroelastomer ring can be compressed by hand before the skirt is pushed into position on the piston crown. *Excessive stretching should be avoided.* Before completely assembling the piston, check to make sure the seal ring does not stick in the ring groove. It is imperative for satisfactory engine operation that the seal ring is free in the piston crown groove. Check the full 360° circumference of the groove to be sure there are no tight spots. When the piston crown, seal ring and piston skirt are assembled, the skirt should spin freely on the crown (crown top down on the bench). If the ring sticks, remove high spots or nicks in the groove with a flat file. If this does not relieve sticking, replace the piston crown.

4. Lubricate the piston pin with the clean engine oil/STP mix and install it in the piston crown and skirt (Fig. 15). Line up the piston pin opening in the piston skirt with the bearing (bushing) opening in the piston crown to prevent damage to the pin or bushing.

5. Install the spacers on the two l/2”-20 x 2-1/4” connecting rod to piston pin attaching bolts.

6. Lubricate the threads and the underside of the heads of the bolts with a small amount of International Compound No. 2, or equivalent.

Effective with engine serial numbers 8E-2502, 12E-8523 and 16E-8110, a new cross-head piston pin and a new rod-to-pin bolt are being used in Series 149 engines. The new pin is machined from solid stock and has a drilled lube oil supply hole and two drilled and tapped piston pin bolt holes (Fig. 16).

• Since the former and the new piston pins and bolts are completely interchangeable and can be mixed in an engine, only the new will be serviced. Detroit Diesel recommends replacing the former piston pin and rod-to-pin bolts with the

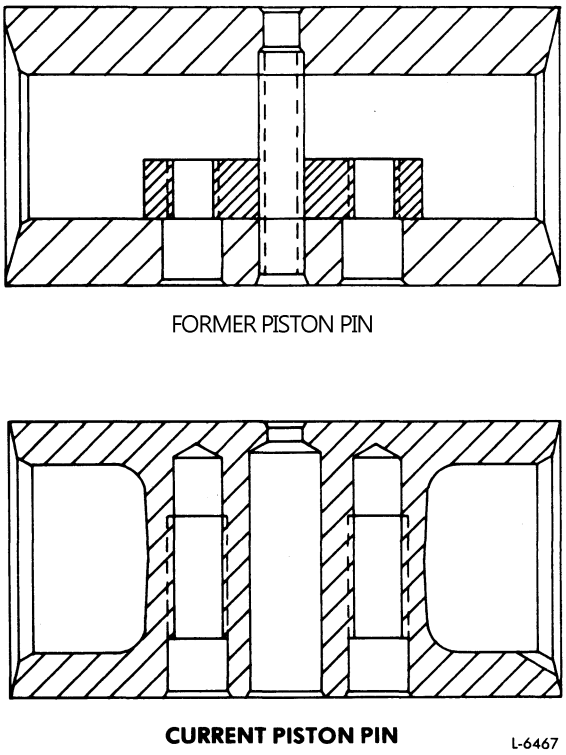



**Fig. 16 - Former and Current Piston Pins**

new piston pin, rod-to-pin bolts and spacers whenever a cylinder kit is *replaced or at time of major engine overhaul. Detroit Diesel does not recommend reuse of former or current piston pin bolts at time of cylinder kit replacement New bolts should be installed.*

7. Insert the bolts through the end of the connecting rod and thread fingertight into the piston pin. Then, clamp the connecting rod in a vise (Fig. 17) and tighten the bolts to 35-45 lb—ft (47-61 N*m) torque, followed by 60° to 80° additional rotation. This method also applies to the former bolts used with either the former or current piston pin.

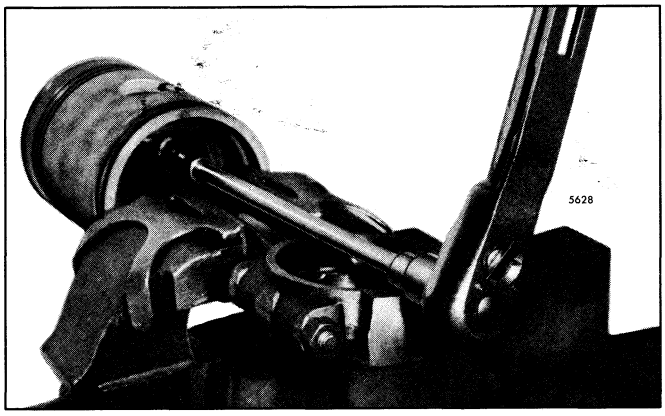



**Fig. 17 - Tightening Connecting Rod to Piston Pin Bolts**

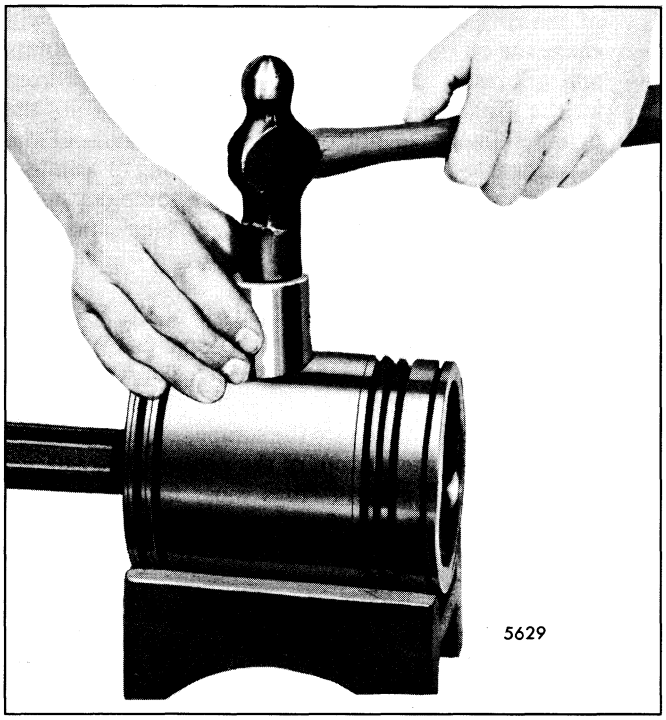



**Fig. 1 8 - Installing Piston Pin Retainer using Tool J 24274-B**

8. Place a new piston pin retainer in position. Then, place the crowned end of installer J 24274-B against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston (Fig. 18). The current piston pin retainer is .025M-.027M thick.

9. Install the second piston pin retainer in the same manner. Due to the size of the counterbore in the piston skirt, be careful when installing the piston pin retainers and inspect them to be sure they are not buckled and that they are fully seated in the counterbores. The width of the land should be even around the retainer.

10. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushing, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23738 (Fig. 19) and vacuum cup J 24629. Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten (10) inches on the gage. A drop in the gage reading indicate air leakage at the retainer.

## Fitting Piston

Measure the piston skirt diameter and cylinder liner bore, preferably at room temperature (70°F or 21°C). Refer to Specifications - Section 1.0 for the piston and liner specifications.

## Fitting Piston Rings

Each piston is fitted with a fire ring, three compression rings and two oil control rings (Fig. 12 and 13).

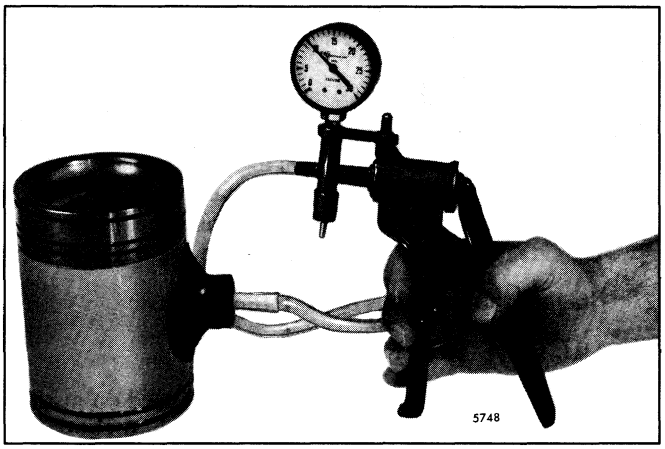



**Fig. 19 - Checking Piston Pin Retainer for Proper Sealing using Tool J 23738 and Adaptor J 24629**

• The top (fire) ring and the upper compression ring (second groove) are pre-stressed. Both are identified by an oval mark on the top side. In addition, the fire ring has a black or copper oxide coating and is marked “Top-F-GM” on top of the ring. The barrel-face fire rings are identified with “Top-F-GM” and a circle on the top. The upper compression ring is marked “Top-GM” in addition to the oval mark. The compression ring used in the third and forth ring grooves is identified by “Top-GM” only.

A two-piece non-slotted oil control ring (upper ring groove) and a two-piece slotted oil control ring (lower ring groove) are used in the pistons for turbocharged and non-turbocharged engines.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed.

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston skirt to push the ring down to be sure it is parallel with the top of the liner. Then, measure the ring gap with a feeler gage (Fig. 7). Refer to Specifications - Section 1.6 for ring gap specifications.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must have a .005” to .020” radius which blends into the ring face.

Check the ring side clearance (Fig. 8). Ring side clearances are specified in Specifications - Section 1.0.

## Install Piston Rings

Lubricate the piston rings and piston with the clean engine oil/STP mix before installing the rings. Refer to Figs. 3, 12 and 13 and install the piston rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 22405-02 (Fig. 3). To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. The compression rings have a tapered face. Make sure the side marked “Top” is toward the top of the piston.
2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

The upper and lower oil control rings used on pistons for *non-turbocharged* and *turbocharged* engines consist of two halves (upper and lower). Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston skirt. When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control ring and result in high lubricating oil consumption.
2. Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then, install the lower half with the gap 45° from the gap in the upper half of the ring. Make sure the scraper edges are facing down (toward the bottom of the piston). The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

If there is noticeable resistance during installation of the piston, check for an overlapped ring expander.

Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

# CONNECTING ROD

## FLOATING-TYPE PISTON

The connecting rod (Fig. 1) is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end. The bearing cap and connecting rod are forged in one piece and bored prior to separation.

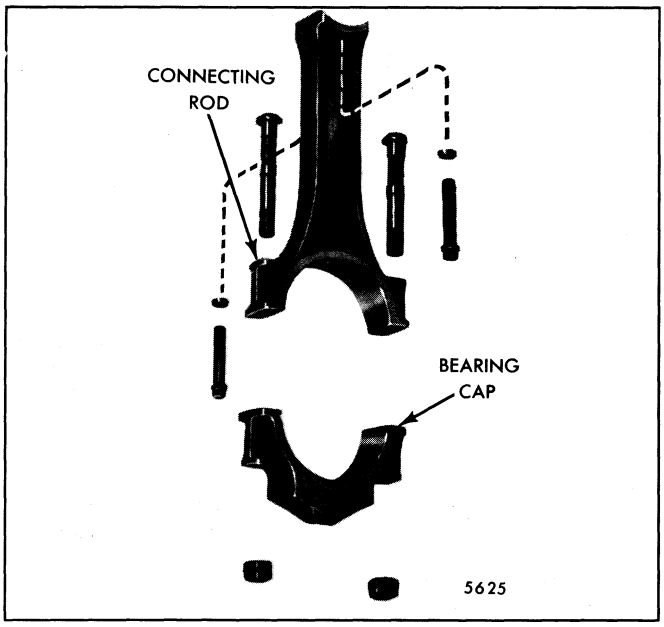



**Fig. 1 - Connecting Rod Details and Relative Location of Parts**

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two self-locking bolts and spacers. The lower bearing cap is secured to the connecting rod by two specially machined bolts and special heat treated nuts.

The current connecting rod (stamped with a letter "O" on the side at the crankshaft bearing end) has an increased radius of .003" to reduce stress between the piston pin and the saddle area of the connecting rod.

Lubricating oil is forced through a drilled oil passage in the connecting rod to the piston pin and the bushing, then out around the carrier and piston.

A service connecting rod includes the bearing cap and the attaching bolts and nuts.

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

### Disassemble Connecting Rod From Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined in Section 1.6.

### Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air. Blow compressed air through the oil passage in the connecting rod to be sure it is clear of obstructions.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Check the connecting rod for cracks (Fig. 2) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clear of obstructions. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear.

The current piston pin has a thicker wall and requires 1/4" longer pin bolts. When replacing a former piston pin with the current pin, include two l/2"-20 x 2" pin bolts. The former and current piston pins can be mixed in an engine. However, it is recommended that all current pins be installed at time of overhaul on early engines.

### Assemble Connecting Rod To Piston

Apply glean engine oil to the piston pin, bushing, thrust plate and carrier and assemble the connecting rod and piston as follows:

1. Position a new bushing in the carrier and lock it in place by bending the tangs on the bushing into slots in the carrier (Fig. 3).

2. Place the piston pin in the carrier.

• 3. Apply a small amount of International Compound No. 2, or equivalent, to the connecting rod-to-piston pin bolt threads and the underside of the bolt heads. *Detroit Diesel does not recommend reuse of piston pin bolts. Use new bolts.*

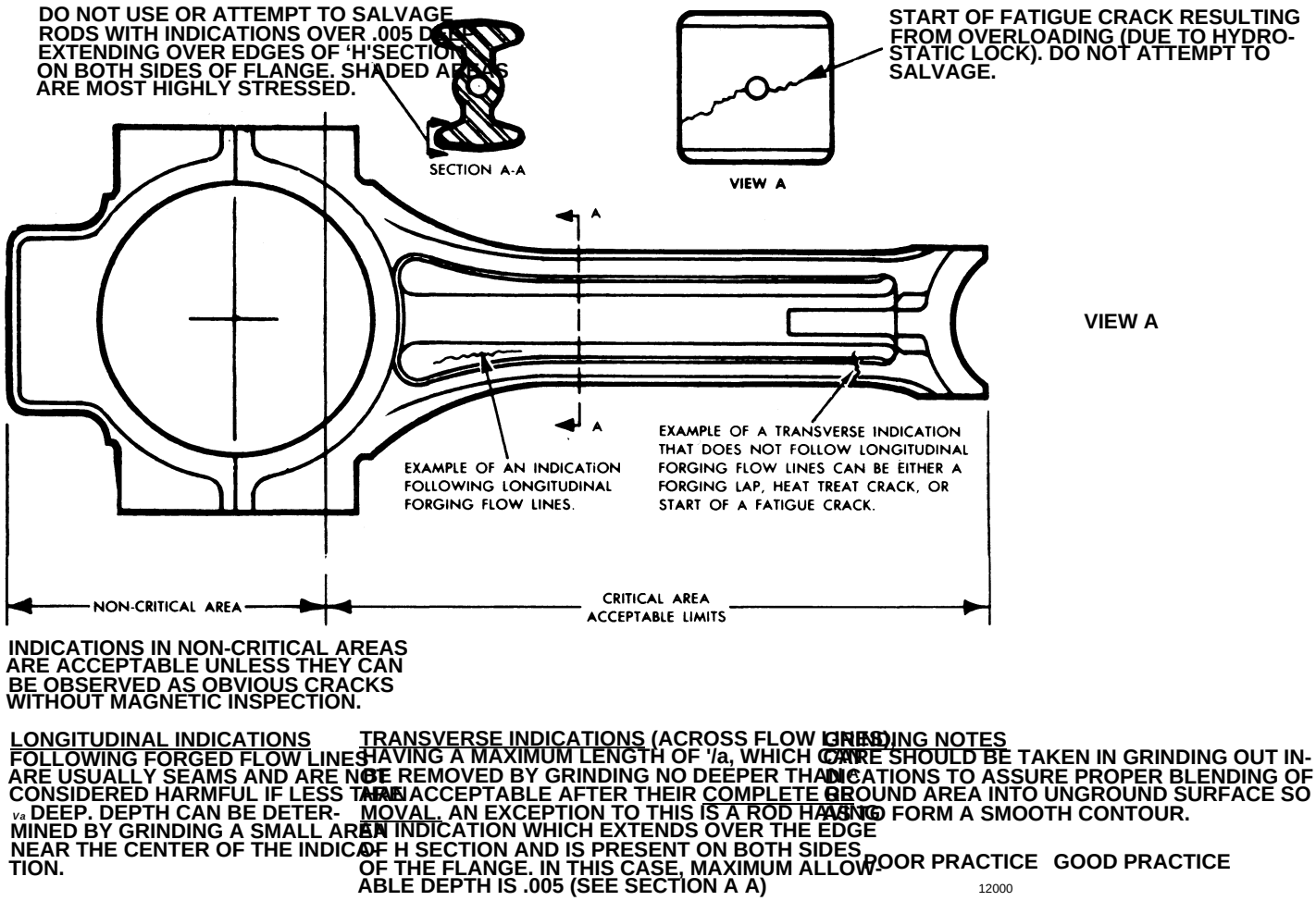



**Fig. 2 - Magnetic Particle Inspection Limits for Connecting Rod**

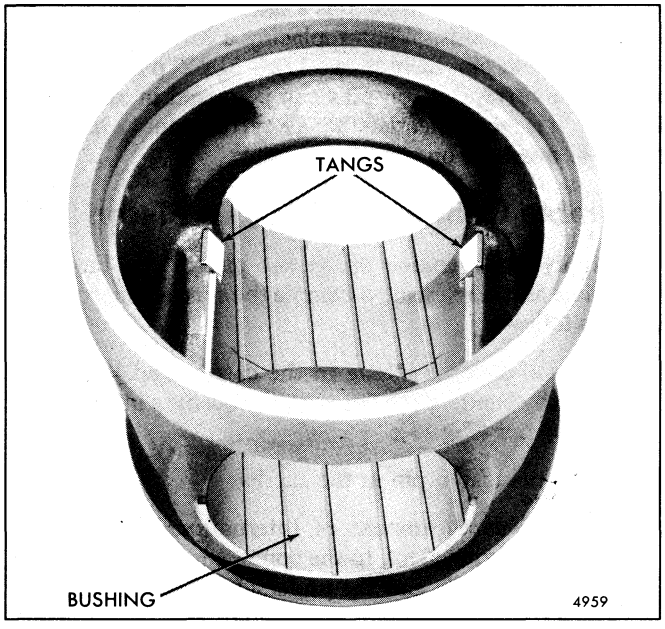



**Fig. 3 - Piston Carrier and Bushing**

4. Attach the connecting rod to the piston pin, using two spacers and two l/2”-20 self-locking bolts. Tighten the bolts to 90-100 lb—ft (122-136 N«m) torque.

   **NOTICE:** Use care when installing the self-locking bolts so that the socket does not bind against the side of the connecting rod, causing the bolts to bend. Do not over-torque.

5. Install the thrust plate in the piston and on the dowel pins, with the side stamped **Piston Side** toward the top of the piston.

6. Slide the carrier assembly into the piston. Secure the carrier in place with a snap ring. Check the snap ring-to-carrier clearance. The specified clearance is .003” to .013”.

7. Install the piston rings on the piston as outlined in Section 1.6.

8. Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

# CROSS-HEAD PISTON

The connecting rod (Fig. 1) used with the cross-head piston (Section 1.6) is similar to the connecting rod used with the floating-skirt piston, but is .401" shorter.

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two self-locking bolts and spacers. The lower bearing cap is secured to the connecting rod by two specially machined bolts and special heat treated nuts.

Lubricating oil is forced through a drilled oil passage in the connecting rod to the piston pin and bushing.

A service connecting rod includes the bearing cap and the attaching bolts and nuts.

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

## Disassemble Connecting Rod From Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined in Section 1.6.

## Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air. Blow compressed air through the oil passage in the connecting rod to be sure it is clear of obstructions.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Use crocus cloth, wet with fuel oil, to remove any trace of fretting and/or corrosion on the connecting rod saddle and piston pin contact surface before reassembly. Never use crocus cloth on the bushing (bearing) side of the piston pin.

Connecting rods being removed from an original engine can be reused as is, after considering the following:

1. Check for visual damage (bent).
2. A previous bearing(s) or related failure.
3. Is the connecting rod blue at the top or bottom end?
4. Fretting at split line between the connecting rod and cap.
5. Excessive pound-in of the bolt head or nut.

If the connecting rod has been subjected to any of the above, scrap the rod.

In qualifying a used connecting rod from a source other than the original engine, the following checks should be made in addition to the above.

1. Check for cracks (Fig. 4) by the magnetic particle method outlined in Section 1.3 under *Crankshaft Inspection.*

2. Determine average bore diameter of the rod, using a dial bore gage and master ring as follows (Fig. 5).

   a. Install the connecting rod cap on the connecting rod and tighten the bolt nuts to 60-70 lb—ft (81-95 N*m) torque.

   **NOTICE:** Do not over torque the connecting rod bolt nuts. Over torque may permanently distort the connecting rod cap.

   b. Measure diameter A and B (Fig. 5).

   c. Obtain average of A and B to obtain size at split line.

   $$\frac{A + B}{2} = X \text{ average of } A + B$$

   d. Measure C. The difference in the results of the measurements X and C gives average bore out-of-round and can be .0005" maximum.

   e. Add C with X and average to obtain average bore size.

   $$\frac{C+X}{2} = \text{average diameter of bore}$$

   which must be within 4.1860" to 4.1880".

   **NOTICE:** If the crosshead connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.

3. Determine taper as follows (Fig. 5):

   a. Substract D1 from D2 to find the difference.

   b. The difference can be .0005" maximum.

• 4. Determine length by finding the distance between El and E2 (Fig. 5). The length of the rod can be measured on connecting rod measurement fixtures marketed by: Sergent Industries, 6300 Stapleton South Drive, Denver, CO 80216.

Specifications: 11.500" to 11.504".

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

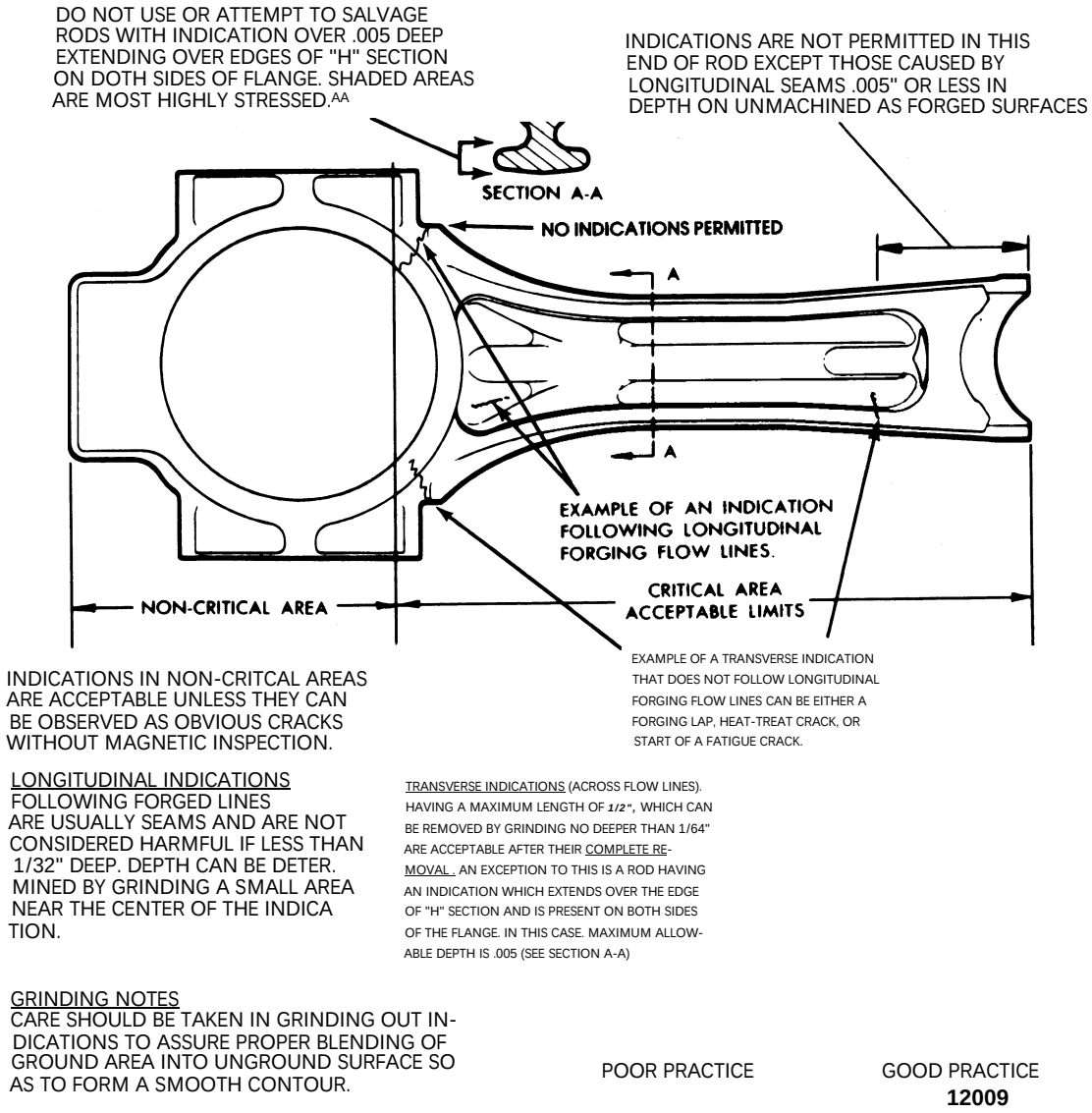



**Fig. 4 - Magnetic Particle Inspection Limits for Connecting Rod**

Clean the rust preventive from a service replacement connecting rod using fuel oil or a mineral spirits based solvent and blow compressed air through the drilled oil passage to be sure it is clear of obstructions. Also, make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell “crush”.

Inspect the bushing (bearing) for indications of scoring, overheating or other damage. Measure the thickness of the bushing along the center. Replace the bushing if it is damaged or worn to a thickness of .0860” or less. A new bushing is .0870” to .0880” thick.

Inspect the piston , pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear. A new piston pin has a diameter of 2.3873” to 2.3877”.

## Assemble Connecting Rod To Piston

Refer to *Assemble Piston* in Section 1.6 for assembly of the connecting rod to the piston.

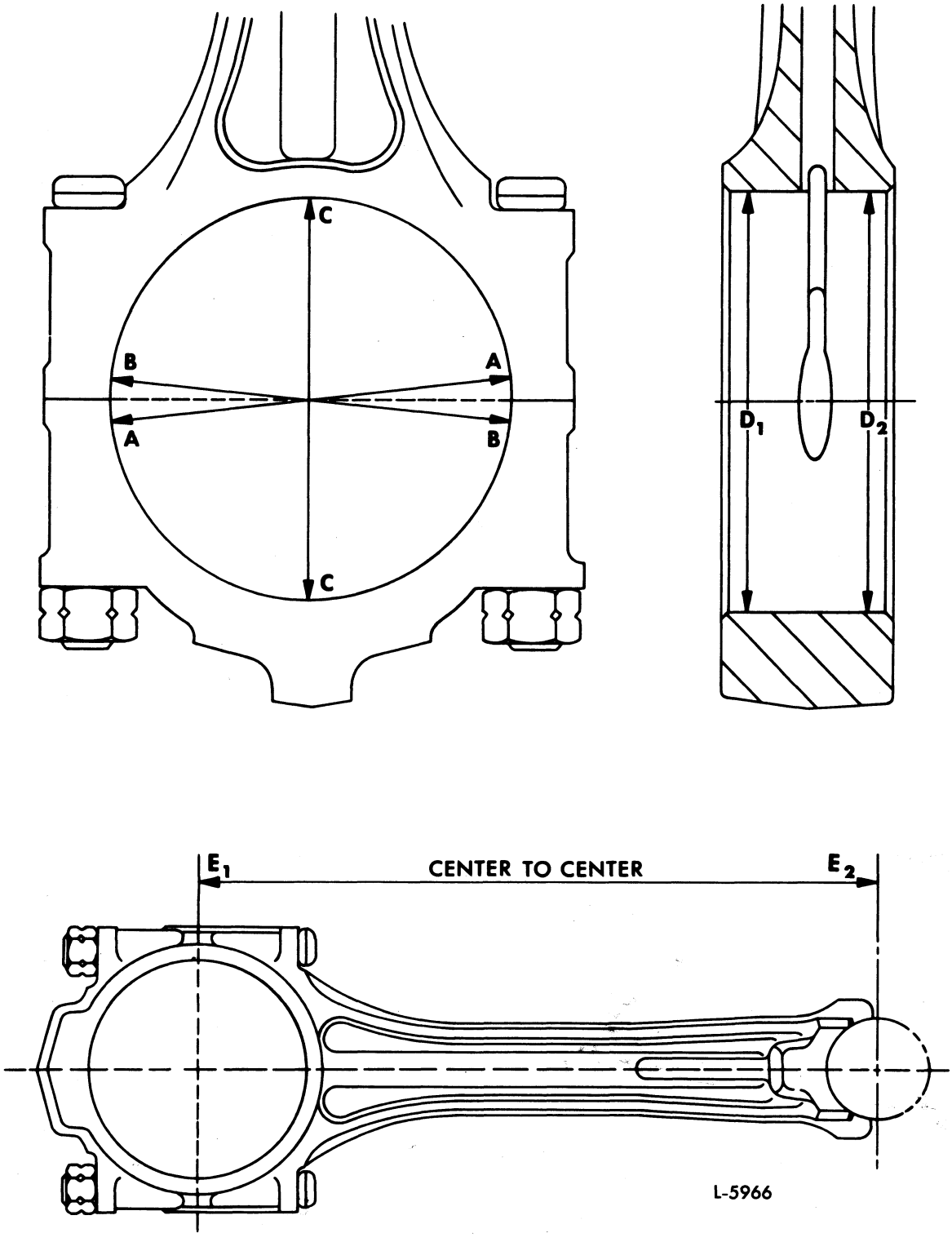



Fig. 5 - Dimensional Inspection of Cross-Head Piston Connecting Rods

# CONNECTING ROD BEARINGS

The connecting rod bearing shells are precision made and are replaceable without shim adjustments (Fig. 1). They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The upper and lower bearing shells are located in the connecting rod by a tang at the parting line at one end of each bearing shell.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell is notched midway between the bearing edges for approximately 3/8 of an inch in from each parting line. In addition, the lower bearing shell has a circumferential oil groove that terminates at the ends of the bearing. The notches maintain registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings and to the piston pin.

## Remove Bearing Shells

The connecting rod bearing caps are numbered 1L, 1R, 2L, 2R, etc., with matching numbers and letters stamped on the connecting rods. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

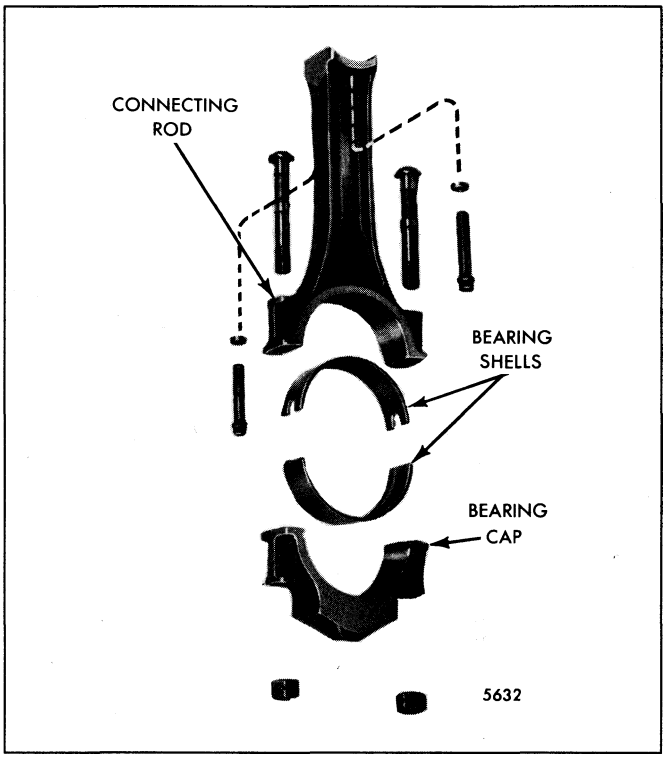



**Fig. 1 - Connecting Rod and Bearing Shells**

Remove the connecting rod bearings as follows:

1. Drain the oil and remove the lower oil pan and intermediate oil pan cover plates (Section 4.7).
2. Disconnect and remove the lubricating oil pump inlet pipe and screen assembly. Remove the oil pump as outlined in Section 4.1.
3. Remove one connecting rod bearing cap. Push the connecting rod and piston assembly up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.
4. Inspect the upper and lower bearing shells as outlined under *Inspection.*
5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

## Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, chipping or signs of overheating.

If any of these defects are present, the bearings must be discarded. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots which indicate they have been shifting in their supports.

If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bores for burrs, foreign particles, etc.

| Bearing Size | *New Bearing Thickness | Minimum (Worn) Thickness |
|---|---|---|
| Standard | .15507.1555" | .1544" |
| .002" Undersize | 15607.1565" | .1554" |
| .010" Undersize | .1600"/.! 605" | .1594" |
| .020" Undersize | .16507.1655" | .1644" |
| .030" Undersize | .17007.1705" | .1694" |

'Thickness 90° from parting line of bearing.

**TABLE 1**

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under *Inspection* in Section 1.3.4. The minimum thickness of a worn standard connecting rod bearing shell should not be less than. 1544" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1550" to .1555". Refer to Table 1.

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes* in Section 1.0). The maximum connecting rod bearing-to-joumal clearance with used parts is .0055".

Before installing the bearings, inspect the crankshaft journals (refer to *Inspection* in Section 1.3).

Do not replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Inspect the crankshaft journals, as outlined in Section 1.3, for wear before replacement bearings are installed.

Bearing shells are available in .002", .010", .020" and .030" undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding* in Section 1.3. Undersize bearings (.002") are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

**NOTICE:** Bearing shells are NOT reworkable from one undersize to another under any circumstances.

## Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod assembly in place, install the connecting rod bearings as follows:

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.
2. Install the upper bearing shell — the one *without* the continuous oil groove — in the connecting rod. Be sure the tang on the bearing shell fits in the groove in the connecting rod.
3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.
4. Note the number and letter stamped on the connecting rod and the bearing cap and install the lower bearing shell — the one with the continuous oil groove — in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.
- 5. Install the bearing and cap. When using new connecting rod bolts and nuts, make sure the protective rust preventive is removed before installing. Apply International Compound No. 2, or equivalent, to the bolt threads and the bearing cap and nut joint. Tighten the connecting rod cap bolt nuts as follows:
   - a. *When working through the sub-oil pan access hole,* tighten nuts to 130 - 140 lb—ft (177 - 190 N«m) torque.
   - b. *When sub-oil pan is removed and there is clear access to all connecting rods,* tighten nuts to 45 - 55 lb—ft (61 - 74 N*m) torque. Then rotate nuts and additional 130 - 150 degrees. This latter method provides more uniform clamp load.

   - **NOTICE:** Make sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut. Failure to observe this precaution can result in serious engine damage.
6. Install the oil pump as outlined in Section 4.1. Install the lubricating oil pump inlet pipe and screen assembly.
7. Install the intermediate oil pan cover plates and install the lower oil pan (Section 4.7).
8. Refer to the *Lubrication Specifications* in Section 13.3 and fill the crankcase to the proper level on the dipstick.

If new bearings were installed, operate the engine on the *run-in* schedule rs outlined in Section 13.2.1.

# CYLINDER LINER

The cylinder liner is of the replaceable wet type, made of hardened alloy cast iron, and is a slip fit in the cylinder block (Fig. 1). The liner is inserted in the cylinder bore from the top of the cylinder block. The flange at the top of the liner rests on a counterbore in the top of the block.

Synthetic rubber seal rings, recessed in the cylinder block bore, are used between the liner and the block to prevent water leakage.

The upper half of the liner is directly cooled by water surrounding the liner. At the air inlet ports, the liner is cooled by the air introduced into the cylinder through equally spaced oval-shaped ports around the liner. The lower half of the liner is cooled by water inside the cylinder block water jacket surrounding the liner.

The air inlet ports in the liner are machined at an angle to create a uniform swirling motion to the air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaner must be serviced regularly according to the surroundings in which the engine is operating.

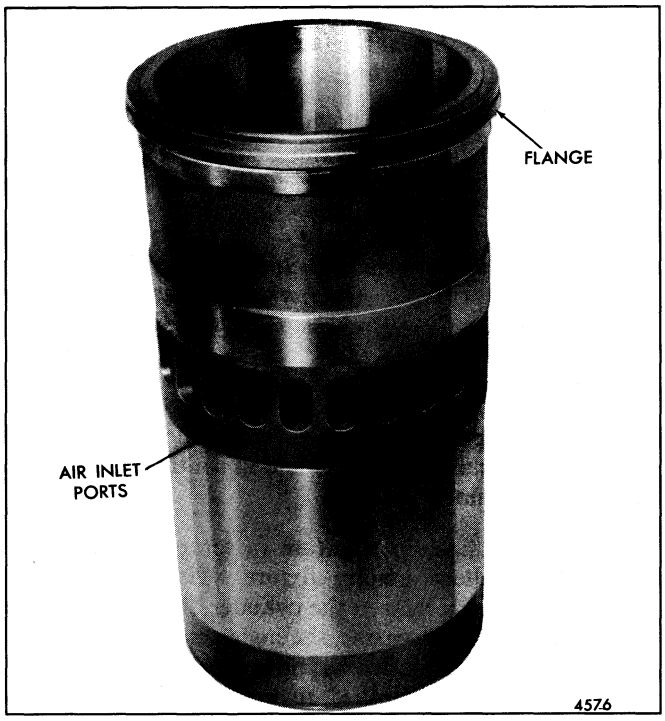



Fig. 1 - Cylinder Liner

## Remove Cylinder Liner

It is very important that the proper method is followed when removing a cylinder liner. *Do not* attempt to push the liner out by inserting a bar in the liner ports and rotating the crankshaft, otherwise the piston may be damaged or the upper piston ring groove may collapse.

To remove a cylinder liner, refer to Fig. 2 and, proceed as follows:

1. Remove the piston and connecting rod assembly, as outlined in Section 1.6.
2. Remove the cylinder liner with tool set **J** 22431, as follows:
   a. Ease the lower shoe and bolt assembly down into the liner. Place the shoe on the bottom edge of the liner with the flat on the shoe parallel with the crankshaft bore.
   b. Hold the lower shoe and bolt assembly in the pulling position. Place the upper shoe with the flat in the same position as the lower shoe over the threaded end of the bolt. Thread the nut down on the bolt assembly and be sure that the pilots on both of the shoes are seated properly.
   c. Place the bridge assembly (open end down) over the upper shoe and down against the block.

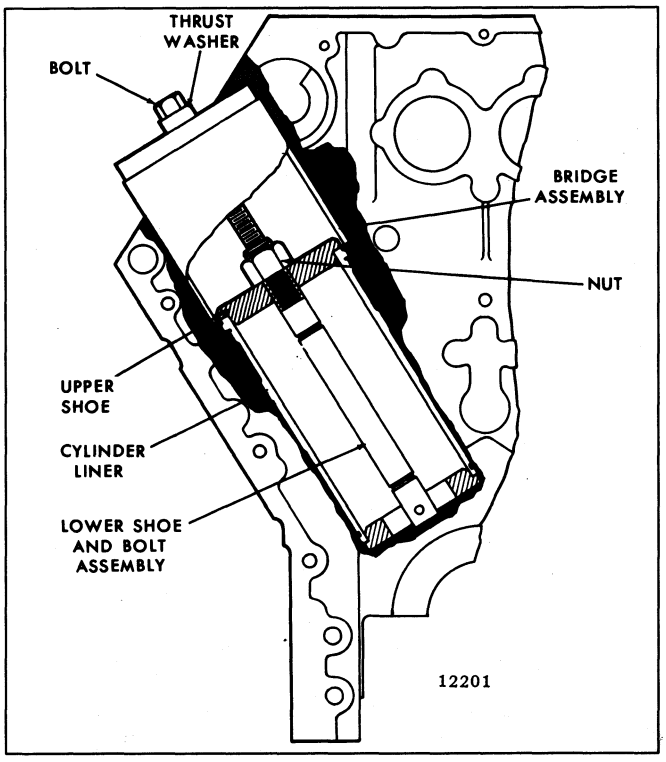



Fig. 2 – Removing Cylinder Liner

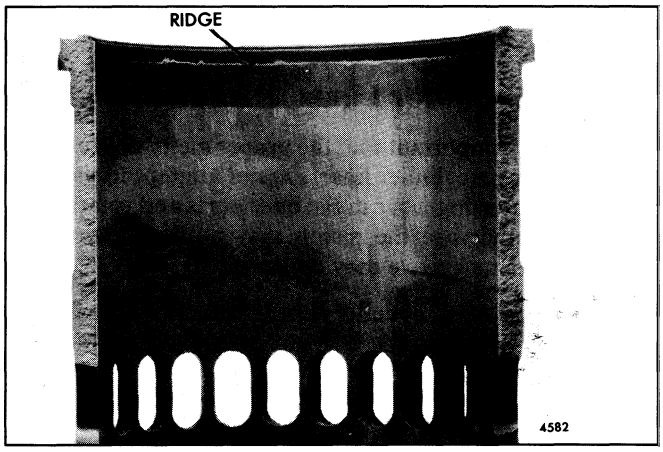



**Fig. 3 - Cylinder Liner Ridge Due to Wear**

d. With the thrust bearing on the bolt, install the bolt through the bridge assembly strap hole.

e. Thread the bolt into the female threaded portion of the bolt assembly.

f. Turn the bolt in a clockwise direction and withdraw the liner from the block. Then, remove the tool from the liner.

g. Remove and discard both cylinder liner seal rings from the grooves in the cylinder block bore.

**NOTICE:** After removing liners from an engine and prior to installing liners, always store them in an upright position until ready for use. Liners left on their side for any length of time can become egg-shaped and distorted, making installation in cylinder bores difficult or impossible.

If tool set J 22431-A is unavailable, tap the liner out with a hardwood block and hammer.

## Inspect Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

1. Cracks
2. Scoring
3. Poor contact on outer surface
4. Flange irregularities
5. Inside diameter
6. Outside diameter
7. Out-of-round
8. Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned-up and reused.

When removing the preservative from new liners, do not steam-clean. Instead, stand the liners upright in a metal basket and immerse in a suitable cold tank containing pure mineral spirits or fuel oil. Steam cleaning may cause internal engine parts to water spot and corrode. Placing liners on their sides for cleaning can lead to liner distortion.

Excessive liner-to-block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant.

Examine the outside diameter of the liner for fretting below the ports. Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone.

Measure the block bore as outlined in Section 1.1. Then, measure the outside diameter of the cylinder liner. To provide effective heat transfer and sealing, it is desirable to maintain the liner-to-block clearance close to the inimum specified (refer to Specifications in Section 1.0). If required, a cylinder liner which is .002” oversize on the outside diameter is available for service.

If an oversize (outside diameter) cylinder liner is used, stamp the amount of oversize on the cylinder block adjacent to the block bore.

A used cylinder liner must be honed for the following reasons:

**NOTICE:** Do not modify the surface finish in a new sepdcfe cylinder liner. Since the liner is properly finished at the factory, any change will advepely Afect seating of the piston rings.

1. To break-the glaze which results due to the rubbing action of the piston rings after long periods of operation. Unless this glaze is removed, the time required to seat new piston rings will be lengthened.

2. To remove the ridge formed at the top by the piston ring travel (Fig. 3). Otherwise, interference with the travel of the new compression rings may result in ring breakage.

Therefore, even though the taper and out-of-round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

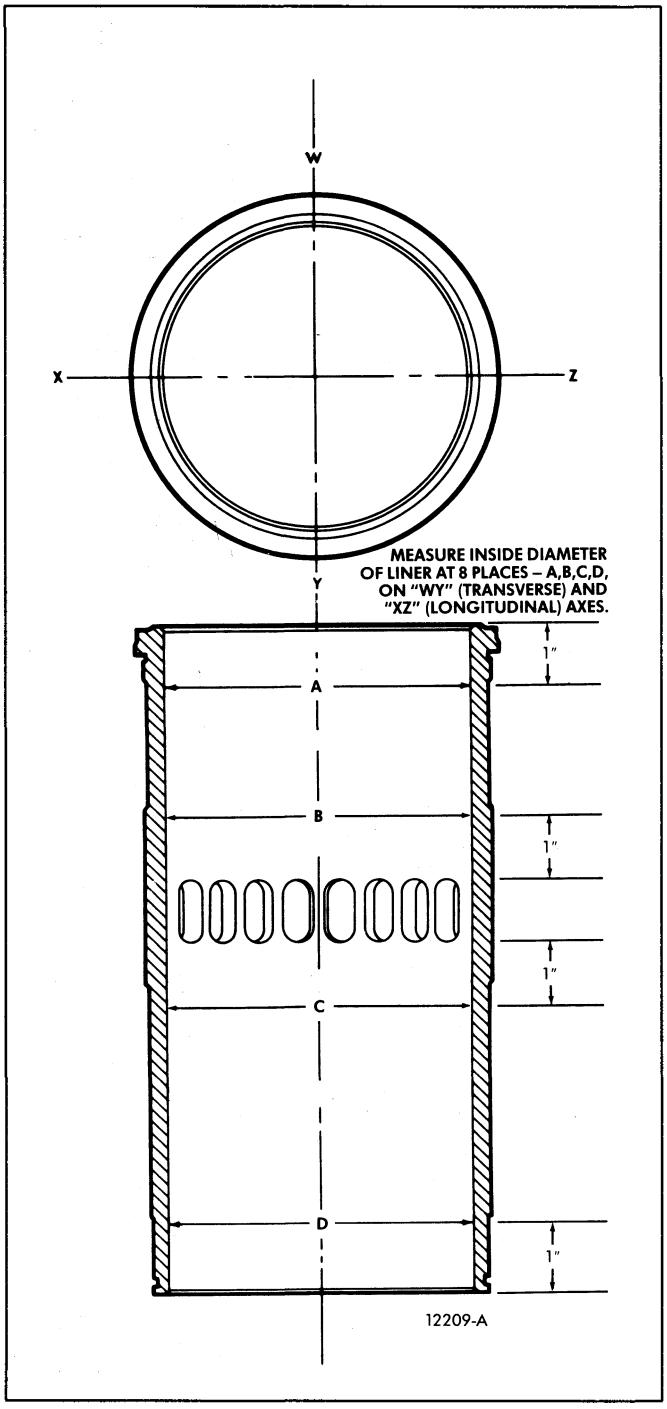



Fig. 4 – Cylinder Liner Measurement Diagram

The hone J 5902-01, equipped with 80 grit stones J 5902-13, should be worked up and down *(it* 300-400 rpm) the full length of the liner a few times in a criss-cross pattern that produces hone marks on a 45° axis.

After the liner has been honed, remove it from the fixture and clean it thoroughly. Then, dry it with compressed air and check the entire surface for burrs.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 Kps) air pressure.**

After honing, the liner must conform to the same limits on taper and out-of-round as a new liner and the piston-to-liner clearance must be within the specified limits (Section 1.0).

Install the liner (new or used) in the proper bore of the cylinder block and measure the inside diameter at the various points (Fig. 4). When installing a new cylinder liner, select one which is as close to the minimum specified liner-to-block clearance (Section 1.1) as possible. The inside diameter of a new service cylinder liner is 5.7488”-5.7513”. Use cylinder bore gage J 5347-01, which has a dial indicator calibrated in .000T’ increments. Set the cylinder bore gage on zero in master ring gage J 22613. Also, check the liner for taper and out-of-round. Master ring gage J 22613 must be at the same temperature as the liner.

• **NOTICE:** To insure accuracy when measuring a cylinder liner, measurements must be taken with the liner at temperatures between 65 - 75° F (18.3-23.9° C)).

The piston-liner clearance must be within the specified limits (Section 1.0). Also, the taper and the out-of-round must not exceed .002” on a used liner. The taper and out-of-round must not exceed .001” on a new liner.

## Fitting Cylinder Liner In Block Bore

1. Wipe the inside and outside of the liner clean and make sure the block bore is clean.
2. Check for and remove any burrs on the cylinder liner or in the cylinder bore.
3. Push or tap the cylinder liner in the cylinder block bore. Do not use excessive force to install the cylinder liner in the block bore.
4. On former counterbored cylinder blocks (Section 1.1), measure the distance from the gasket seating surface of the liner flange to the water hole deck of the block with a dial indicator or depth micrometer. When in place, the top of the gasket seating surface must be .039” to .045” below the water hole deck surface of the block. This step is not required on current non-counterbored blocks.
5. Matchmark the liner and the cylinder block with a felt pen so the liner may be reinstalled in the same position in the same block bore. Place the matchmark on the side opposite the camshaft.
6. Remove the liner from the cylinder block.

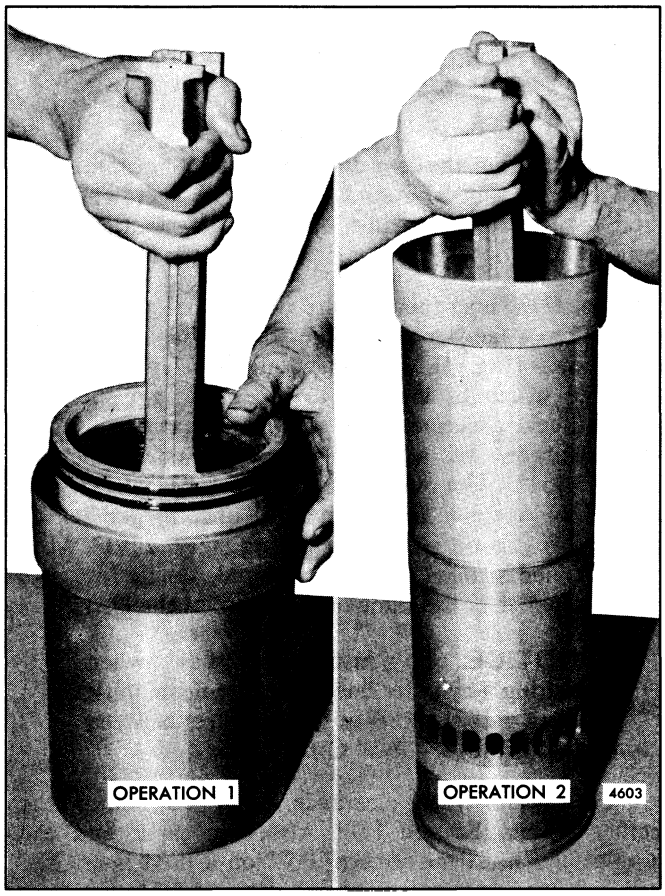



**Fig. 5 - Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner**

## Install Piston And Connecting Rod Assembly

1. With the piston assembled to the connecting rod and the piston rings in place as outlined in Sections 1.6 and 1.6.1, apply clean engine oil to the piston, rings and the inside surface of the piston ring compressor J 22387.

   **NOTICE:** Inspect the ring compressor for nicks or burrs, especially at the non-tapered inside diameter end. Nicks or burrs on the inside diameter of the compressor will result in damage to the piston rings.

2. Place the piston ring compressor on a wood block, with the tapered end of the ring compressor facing up.

3. Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

4. Start the top of the piston straight into the ring 3. compressor. Then, push the piston down until it contacts the wood block ("Operation 1" of Fig. 5).

5. Note the position of the matchmark and place the liner, with the flange end down, on the wood block.

6. Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner ("Operation 2" of Fig. 5). The numbers on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers must be stamped in the same location as on the connecting rod that was replaced.

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor. Do not force the piston into the liner. The peripheral abutment type expanders apply considerable force on the oil ring. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

8. Remove the connecting rod cap and the ring compressor. Then, push the piston down until the compression rings pass the cylinder liner ports.

## Install Cylinder Liner, Piston And Connecting Rod Assembly

**NOTICE:** When installing a cylinder kit, which weighs over 80 pounds, it is very important that the cylinder liner contact area at the flange seating surface not be damaged in any way. Nicks or dents can lead to leaks between the liner flange and block bore and result in corrosion of the head bolts. Development of a major leak could result in hydrostatic lock. To avoid damage, do not allow a cylinder kit to rest on the seating surface of the block while completing installation in another cylinder.
*Load and complete the installation for one cylinder at a time.*

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine, as follows:

1. Make sure the seal ring grooves in the cylinder block bore are elean. Then, install a new seal ring in each groove (Fig. 6). The current type seal rings tend to stiffen and shrink at temperatures below 40°F (4°C). Keep the seal rings at room temperature (approximately 70°F or 21°C) prior to installation.

2. Apply clean engine oil or an ethylene glycol base antifreeze to the inner surface of each seal ring.

   **NOTICE:** Do not use a methoxy propanol base antifreeze as it will damage the seal rings.

   If any of the pistons and liners are already in the engine, use hold-down clamps to retain the liners in place when the crankshaft is rotated.

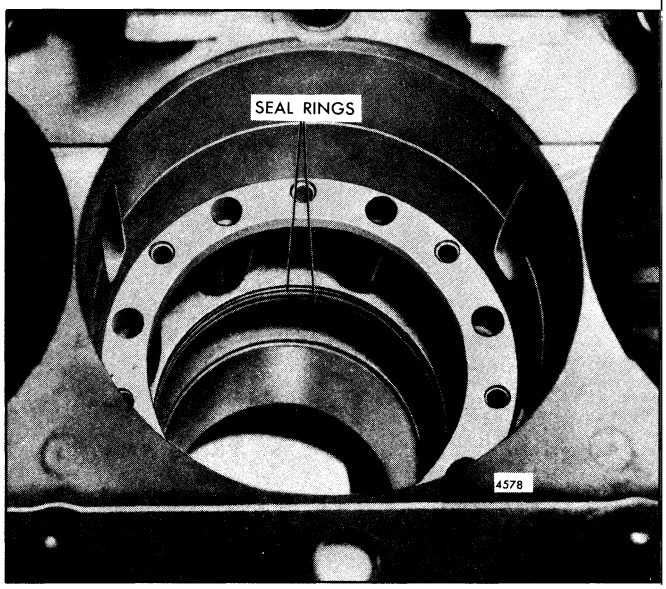



**Fig. 6 - Location of Cylinder Block Bore Seal Rings**

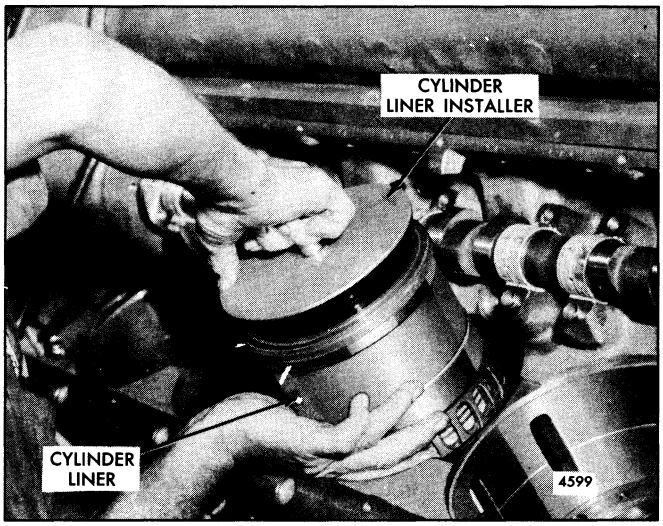



**Fig. 7 - Installing Piston, Rod and Liner Assembly in Cylinder Block**

4. Rotate the crankshaft with barring tool J 22582 until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.
5. Install the upper bearing shell—*the one without the continuous oil groove*—in the connecting rod. Lubricate the bearing shell with clean engine oil.
6. Use cylinder liner installer J 22641 and position the piston, rod and liner assembly in front of the cylinder block bore so that the identification number and letter on the connecting rod face the outer edge of the cylinder block and the matchmarks on the liner and the block are in alignment. Guide the end of the connecting rod through the block bore carefully to avoid damaging or dislodging the bearing shell. Then, slide the piston, rod and liner assembly straight into the block bore until the liner flange rests in the counterbore of the block (Fig. 7). Remove the air box covers to see if the seal rings were dislodged or damaged during liner installation. If the seal ring(s) were damaged, small cut pieces of the seal ring will be noticed.
7. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal. The distance from the vertical center line of the connecting rod bolts to the edges of the rod are not equal. Therefore, when installing the piston and connecting rod assembly, be sure that the narrow side of the two connecting rods on the crankshaft journal are together to avoid cocking of the rod.
8. Place the lower bearing shell — *the one with the continuous oil groove from one parting line to the other*— in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.
- 9. Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. When using new connecting rod bolts and nuts, be sure to remove the protective rust preventive. Apply International Compound No. 2 or equivalent to the bolt threads and the bolt cap and nut joint. Tighten the connecting rod bolt nuts to 130-140 lb—ft (170-190 N#m) torque.

   **NOTICE:** Be sure the connecting rod bolt has not turned in he connecting rod before torque is applied to the nut.
10. Check the connecting rod side clearance. The clearance between each pair of connecting rods should be .018” to .026” with new parts.
11. Install the remaining liner, piston and rod assemblies in the same manner. Use hold-down clamps to hold each liner in place.
12. After all of the liners and pistons have been installed, remove the hold-down clamps.
13. Install new compression gaskets and water seals as outlined in Section 1.2. Then, install the cylinder heads and any other parts which were removed from the engine.
14. After the engine has been completely reassembled, refer to the *Lubrication Recommendations* in Section 13.3 and refill the crankcase to the proper level on the dipstick.
15. Close all of the drains and fill the cooling system.
16. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the *run-in* schedule given in Section 13.2.1.

# ENGINE BALANCE AND BALANCE WEIGHTS

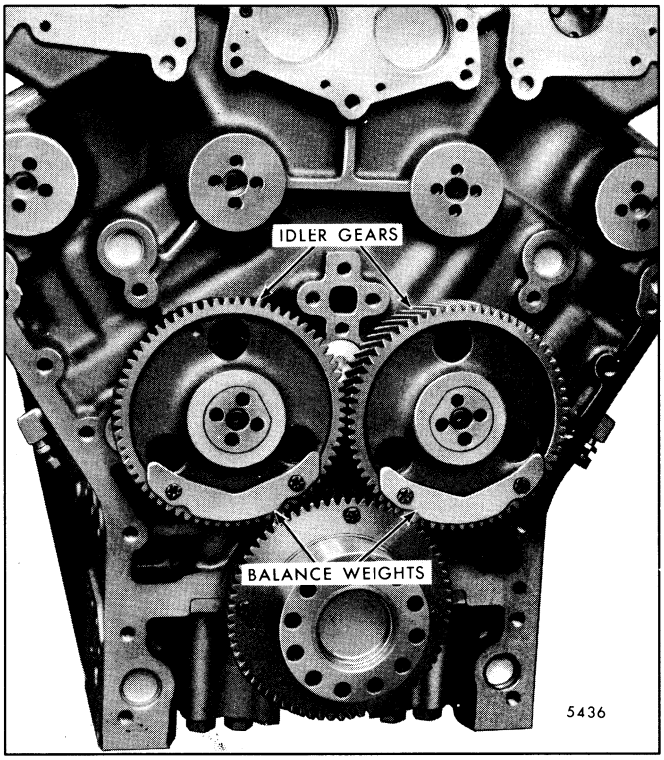
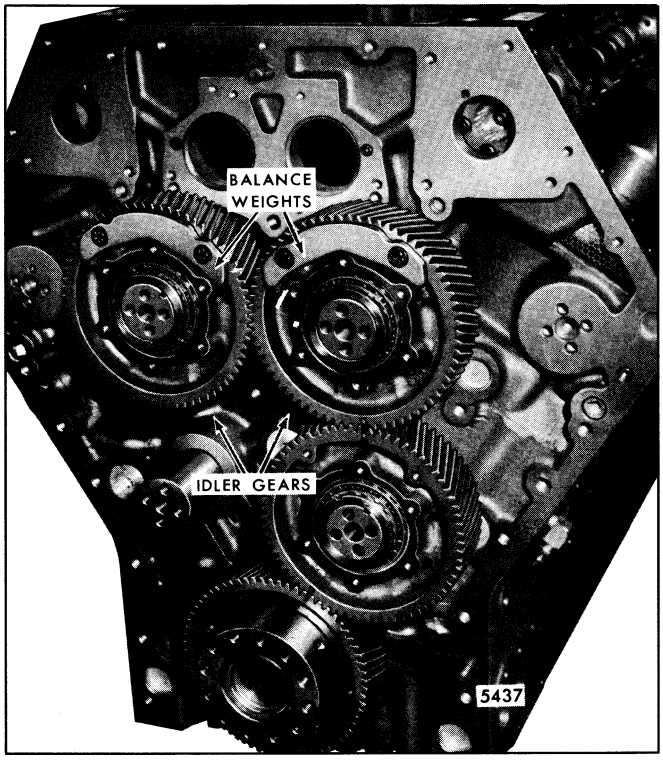



**Fig. 1 - Typical Balance Weights on Front Idler Gears**




**Fig‘ 2 [11] Typical Balance Weights on Rear idler Gears**

In the balance of the two-cycle engine, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds: unbalanced forces and unbalanced couples. These forces and couples are considered as primary or secondary according to whether their frequency is equal to engine speed or twice engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are of small consequence in comparison to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple due to their arrangement on the crankshaft. This unbalanced couple tends to move the ends of the engine in an elliptical path. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights on each of the idler gears, front and rear (Figs. 1 and 2). This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

On the idler gears, each set of bolt-on weights (weights on the outer ends of one cylinder bank comprise a set) rotate in an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, cancelled. The front balance weights act in a direction opposite to the rear balance weights; therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple.

Both the rotating and primary reciprocating forces and couples are completely balanced in the 149 engine. There are no secondary forces present. Consequently, the engine will operate smoothly and in balance throughout its entire speed range.

The bolt-on balance weights for 8V, 12V, and 16V engines are similar, except that the 8V and 12V engine weights are thicker and the bolt holes are counterbored (Fig. 2).

# GEAR TRAIN AND ENGINE TIMING

## GEAR TRAIN

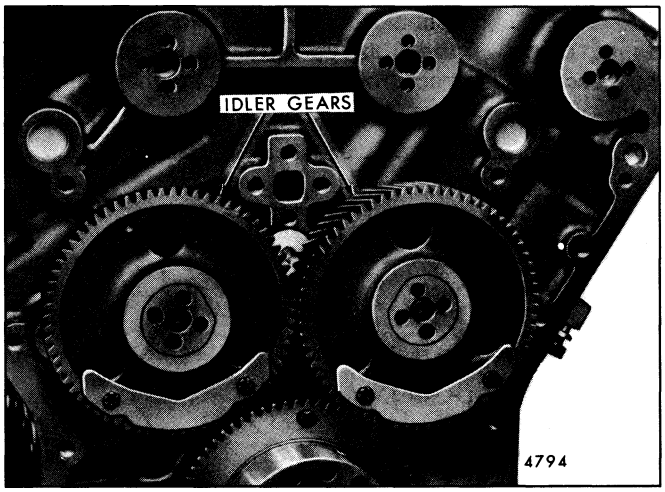



**Fig. 1 - Typical Front Gear Train**

The Series 149 engine utilizes two sets of gear trains - one on each end of the engine. The front gear train consists of a crankshaft gear and two idler gears (Fig. 1). One of the idler gears is used to drive the water pump. The rear gear train consists of a crankshaft gear, three idler gears and two camshaft gears (Fig. 2).

The crankshaft gear in the front gear train is bolted to a damper which is attached to the crankshaft front flange. The crankshaft gear in the rear gear train is bolted directly to the crankshaft rear flange. The idler gears, in both the front and rear gear trains, and the camshaft gears (in the rear gear train) are mounted on stationary hubs.

Since the camshafts must be in time with each other and the crankshaft, timing marks are stamped on the face of the gears to facilitate correct gear train timing. The timing marks stamped on the various gears are shown in Figs. 3, 4 and 5. When assembling the engine, it is important to line up the appropriate timing marks on the gears as each gear is installed on the engine.

The gear backlash between the various mating gears in the gear train should be .0015” to .008” with new parts and should not exceed .010” gear backlash between worn gears.

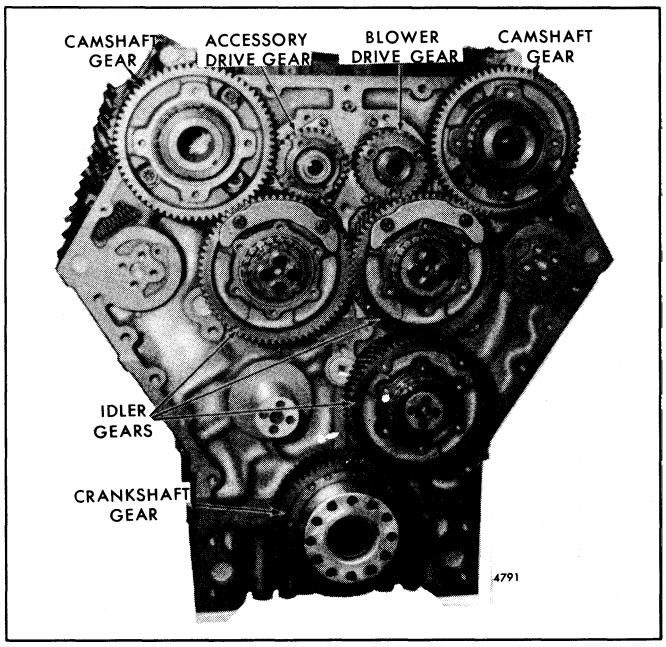



**Fig. 2 - Typical Rear Gear Train**

Gear train noise is usually an indication of excessive gear backlash, chipped, pitted or burred gear teeth or excessive bearing wear. Therefore, when noise develops in a gear train, the flywheel housing or front cover should be removed and the gear train and its bearings and bushings inspected. A rattling noise usually indicates excessive gear backlash, whereas a whining noise indicates too little gear backlash.

### Lubrication

The gear train is lubricated by oil from the longitudinally drilled passages in the camshaft hubs, idler gear center retaining bolts and by oil splash from the oil pan. A certain $mount of oil also spills into the gear train compartment from the blower drive bearing and the idler gear bearings’! The idler gear bearings are lubricated by oil directly from the cylinder block oil gallery.

# ENGINE TIMING

The correct relationship between the crankshaft and the two camshafts must be maintained to properly control fuel injection, the opening and closing of the exhaust valves and engine balance.

The crankshaft timing gears can be mounted in only one position since one attaching bolt hole is offset. Therefore, when the engine is properly timed, the timing marks on the various gears will match (Figs. 3,4 and 5). Early engines did not include a dot in the timing marks.

Special care should be exercised when aligning the timing marks of the front gear train idler gears as the difference in thickness of the two gears may give the appearance of misalignment.

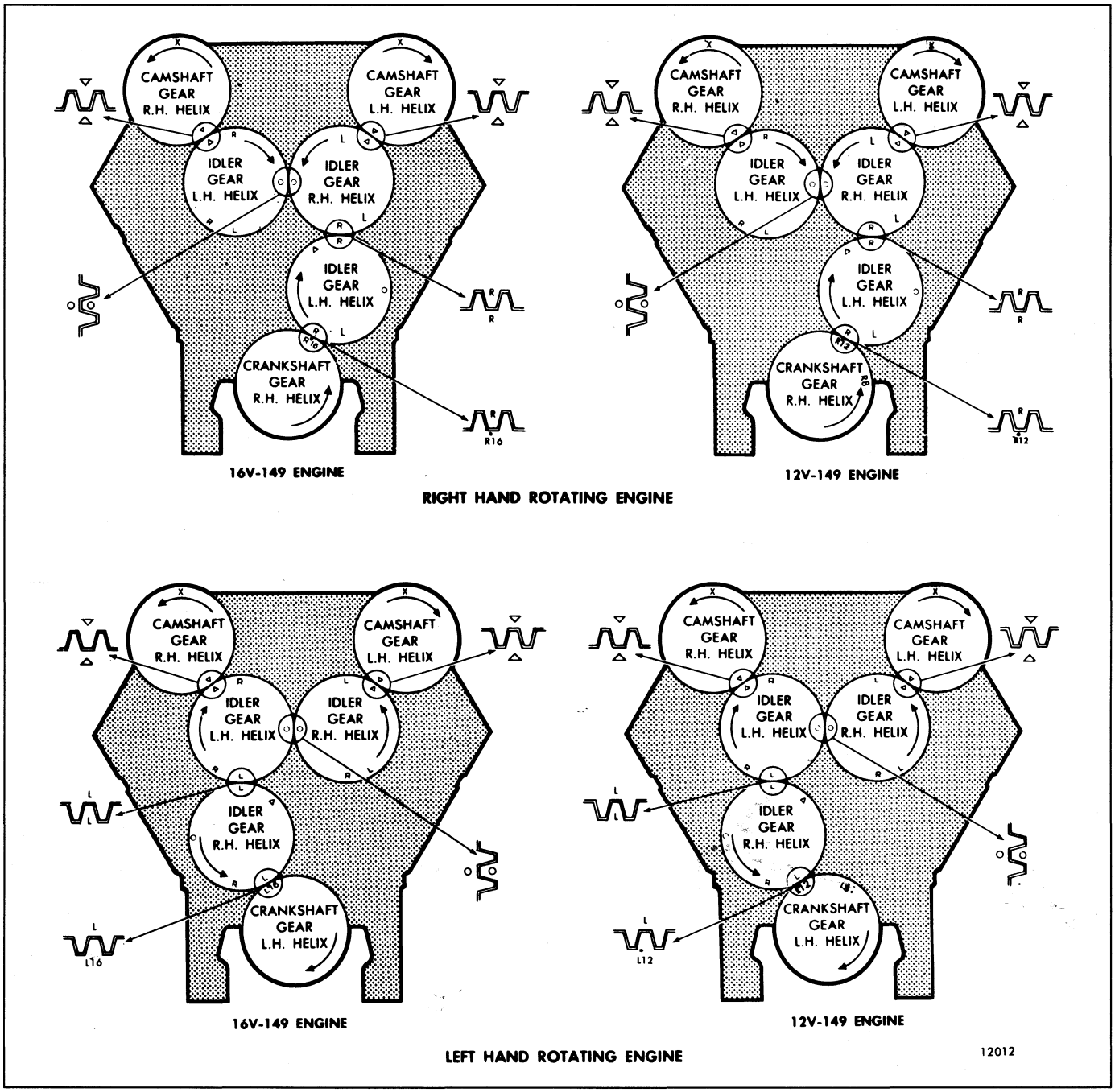
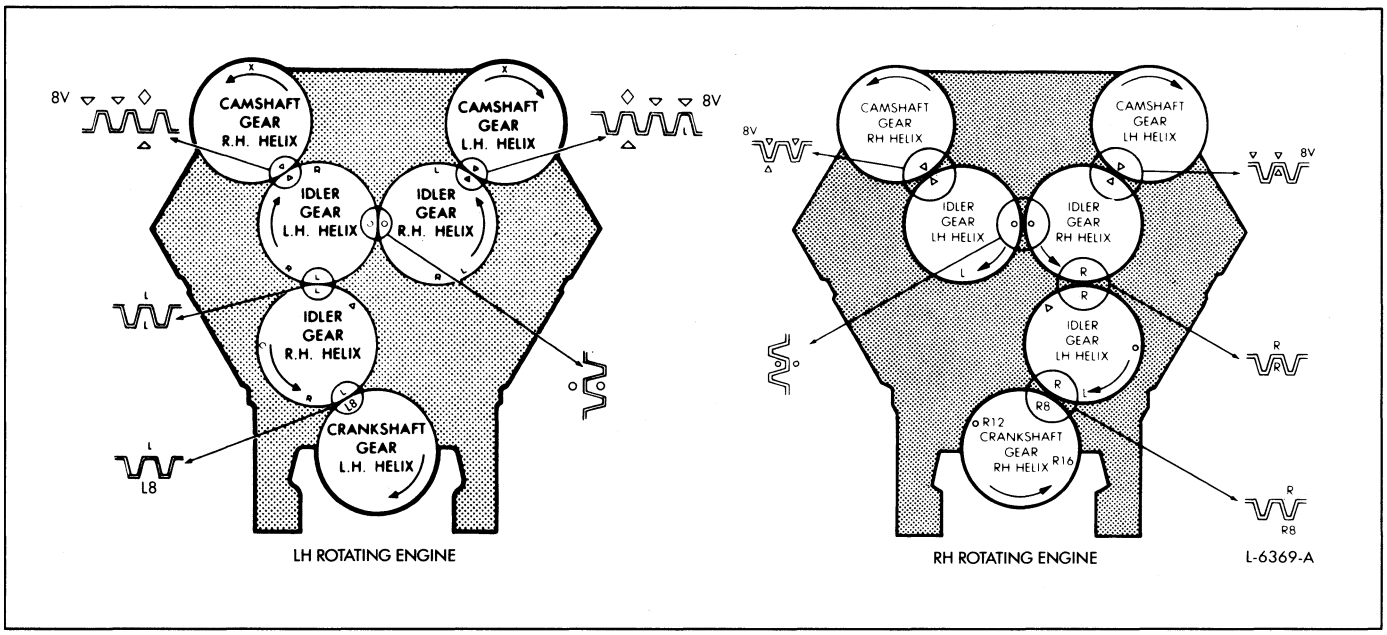



FIG. 3 – Rear Gear Train Timing Marks — 12V And 16V Engines




• Fig. 4 – Rear Gear Train Timing Marks – 8V Engines

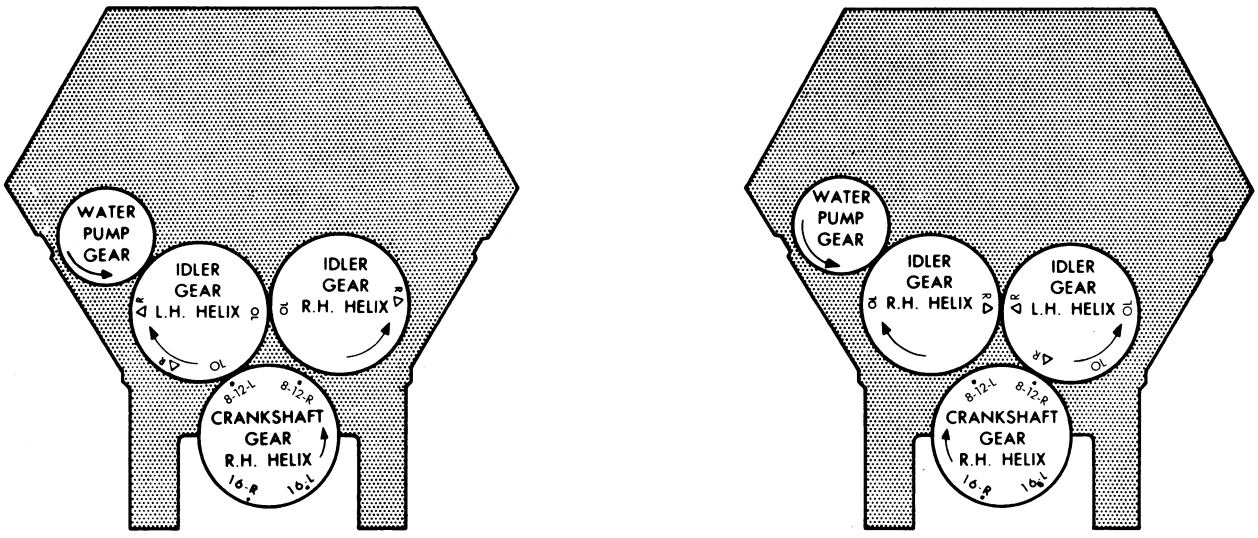
An engine which is *out of time* may result in preignition, uneven running and a loss of power.

When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without having to remove the flywheel and flywheel housing by following the procedure outlined below.

## Check Engine Timing

Access to the vibration damper or crankshaft pulley, to mark the top-dead-center position of the selected piston, and to the front end of the crankshaft (or to the flywheel), for turning the crankshaft, is necessary when performing the timing check. Then, proceed as follows:

1. Remove one valve rocker cover. Discard the gasket.
2. Select any cylinder for the timing check.
3. Remove the injector (at the cylinder selected) as outlined in Section 2.1.1.
4. Carefully slide a rod, approximately 12" long, through the injector tube until the end of the rod rests on top of the piston. Place the throttle in the *no-fuei* position. Then, turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
5. Select a dial indicator with .001" graduations and a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also, select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.
6. Mount the indicator over the injector tube. Check to be sure the indicator spindle is free in the injector tube and is free to travel at least one inch.
7. Attach a suitable pointer to the engine front cover. The outer end of the pointer should extend over the top of the crankshaft pulley (or vibration damper).
8. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
9. Set the dial indicator to zero. Then, turn the crankshaft approximately .075" in the direction of engine rotation. Rotate the crankshaft in the opposite direction to .050" from the zero setting.
10. Scribe a line on the crankshaft pulley (or vibration damper) in line with the end of the pointer.
11. Turn the crankshaft in the opposite direction of engine rotation, through the point where the indicator stops, to approximately .075" from the zero setting. Rotate the crankshaft back in the direction of engine rotation to .050" from the zero setting.
12. Scribe a second line on the vibration damper (or crankshaft pulley) in line with the end of the pointer.




LEFT HAND ROTATING ENGINE

RIGHT HAND ROTATING ENGINE

**• Fig. 5 - Front Gear Train Timing Marks - 1 2V and 1 6V Engines**

13. Scribe a third line half way between the first two lines. This is top dead center. If the crankshaft pulley retaining bolt has loosened, tighten it to 450-500 lb—ft (610-678 N«m) torque.

14. Remove the dial indicator and rod from the engine.

15. Install the injector as outlined in Section 2.1.1. Then, adjust the valve clearance (Section 14.1) and time the injector (Section 14.2).

16. Turn the crankshaft, in the direction of engine rotation, until the exhaust valves in the selected cylinder are completely open. Reinstall the dial indicator so the indicator spindle rests on top of the injector follower. Set the indicator dial on zero, then, turn the crankshaft slowly, in the direction of engine rotation, until the center mark on the pulley is in line with the pointer.

17. Note the reading on the dial indicator and compare it with the following:

    1. If the indicator reading is .306” to .326”, the engine is in time.
    2. If the indicator reading is .268” to .288”, timing is retarded one tooth.
    3. If the indicator reading is .337” to .357”, timing is advanced one tooth.

18. After completing the timing check, remove the dial indicator. Also, remove the pointer from the engine front cover.

19. Using a new gasket, reinstall the valve rocker cover.

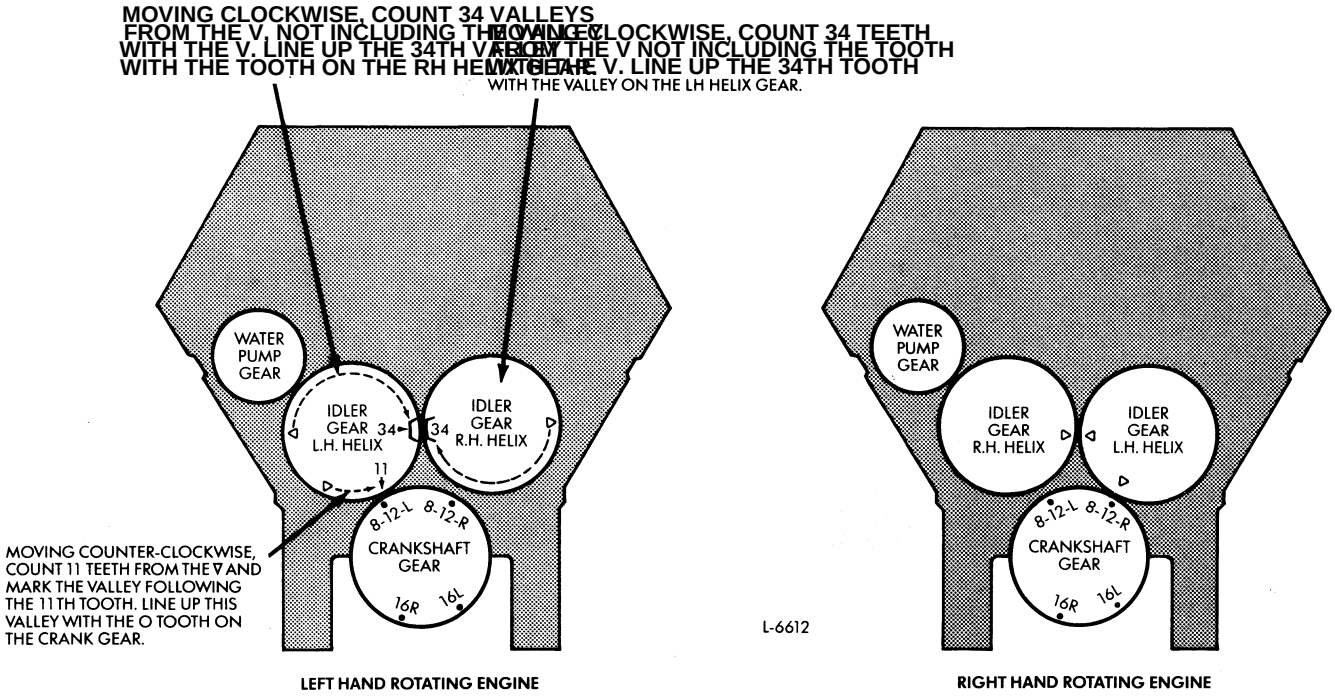



**Fig. 6 - Front Gear Train Timing Marks - 8V-149 Engine**

# CAMSHAFTS AND BEARINGS

• The contrarotating camshafts are located near the top of the cylinder block. There is one set of camshafts in the 8V-149 engine. There are two sets of camshafts in the 12V-149 and 16V-149 engines (two camshafts in each cylinder bank). Each camshaft is supported on upper and lower camshaft bearings (shells) and retained by bearing caps. The camshaft end play on each bank of the camshafts is controlled by a thrust plate attached to one of the rear camshaft bearing caps. On former 12V-149 engines only (prior to engine 12E-705), a thrust plate was installed on each individual camshaft and attached to one of the bearing caps.

The front and rear camshaft in each bank of the 12V-149 and 16V-149 engines is connected by a flexible coupling attached to the flange end of each camshaft (Fig. 1).

On 12 V-149 engines (prior to 12E-705), the camshafts were connected by a splined shaft and two couplings attached to the flange end of each camshaft (Fig. 2).

The camshafts are driven by the rear gear train by flanges attached to the camshaft gear assemblies, couplings attached to the camshafts and splined drive shafts.

The two splined drive shafts at the rear of the engine differ in length; the right-bank drive shaft is 6.920" long and the left-bank drive shaft is 8.420" long. The two center (intermediate) splined drive shafts on former 12V-149 engines are 6.100" long.

Camshafts are etched with letters A, B, C, etc. at each flange end of the camshaft for proper installation at the time of assembly. Refer to Fig. 4 and 5 for detailed instructions.

## Lubrication

Lubrication to the camshafts, bearings, thrust plates and drive shafts is supplied under pressure through drilled passages in the cylinder block. Oil from the main oil gallery flows through these drilled passages to each camshaft bearing. Oil from the bearings enters each camshaft to lubricate the thrust plates and the drive shafts.

## Remove Camshafts (Current And Former)

Whenever an engine is to be completely reconditioned or the camshafts and bearings need replacing, remove the camshafts as follows:

1. Clean and remove the valve rocker covers.
2. Remove the fuel inlet and outlet pipes.
3. Remove the exhaust valve and injector operating mechanisms (Section 1.2.1).
4. Remove the flywheel housing camshaft gear covers (Section 1.5) or accessories attached to the flywheel, housing and driven by the camshaft drive gears (Section 1.7.7).
5. Remove the snap ring and retainer from the camshaft drive flange (Section 1.7.3).

   NOTICE: If removal of the entire camshaft assembly is required on either bank (12V-149 and 16V-149 engines), loosen the intermediate shaft coupling bolts prior to removing the rear camshaft drive shafts.

6. Withdraw the drive shaft from the camshaft and drive flange.
7. On 12V-149 and 16V-149 engines, remove the intermediate shaft couplings as follows:

   a. On current 12V-149 and 16V-149 flexible drive couplings, remove three 7/16"-20 x 1.200" self-locking bolts from the right-bank rear camshaft and left-bank front camshaft. Remove the spacer and note the number of shims (spring plates) when removing these parts.

   b. On former 12V-149 engines (prior to 12E-705) with splined intermediate drive shafts, remove five 7/16"-20 x 1-1/4” (12 pt.) self-locking bolts from the right-bank rear camshaft coupling and left-bank front camshaft coupling. Slide the couplings (toward the center of the block) on the shafts.

8. Remove the camshaft bearing caps and remove the camshafts from the engine.

   NOTICE: Camshaft bearing caps are stamped 1R, 2R, etc. or 1L, 2L, etc. from the front to the rear of the engine on each bank. The cylinder block is stamped with the same number as the bearing cap, directly above the cap, on the rocker cover gasket surface of the block. The bearing caps must be reinstalled in their original positions. Service cylinder blocks are not stamped for camshaft bearing cap location. Refer to the plugging chart in the back of the Service Manual.

9. If required, remove the shaft coupling spacer and spring plates from the camshafts.

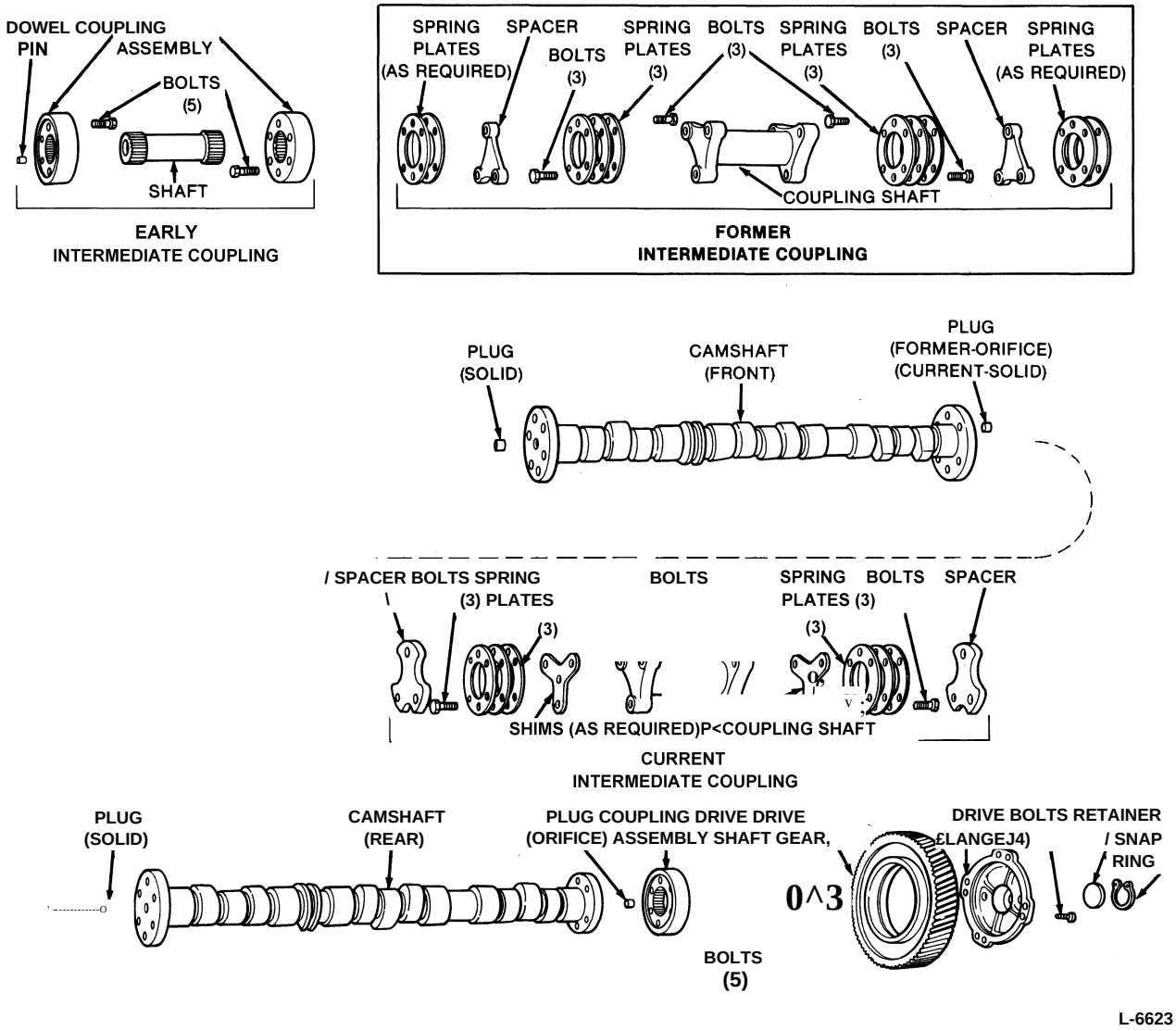



**Fig. 1 - Camshaft Details and Relative Location of Parts**

10. If removal of the camshaft end plugs is required for cleaning or inspection, remove the end plugs as follows:

    a. Clamp the flange end of the camshaft (with the orifice plug) in a vice equipped with soft jaws.

    b. Use the orifice hole in the plug as a center and drill a 5/16” hole through the plug, using a carboloy tip drill. Tap the drilled hole with a 3/8”-16 tap.

    c. Thread a 3/8”-16 adaptor, J 6471-2, into the plug. Then, attach a slide hammer J 6471-1 to the adaptor and remove the plug.

    d. To remove the solid plug at the opposite end of the camshaft, punch a hole as deep as possible with a center punch to break through the hardened surface.

    e. Use a 1/4” carboloy tip drill and drill a hole straight through the plug. Then, enlarge the hole with a 5/16” carboloy tip drill.

    f. Tap the drilled hole with a 3/8”—16 tap.

    g. Remove the plug as in Step c.

    h. Remove the plugs from the other camshafts in the same manner, if required.

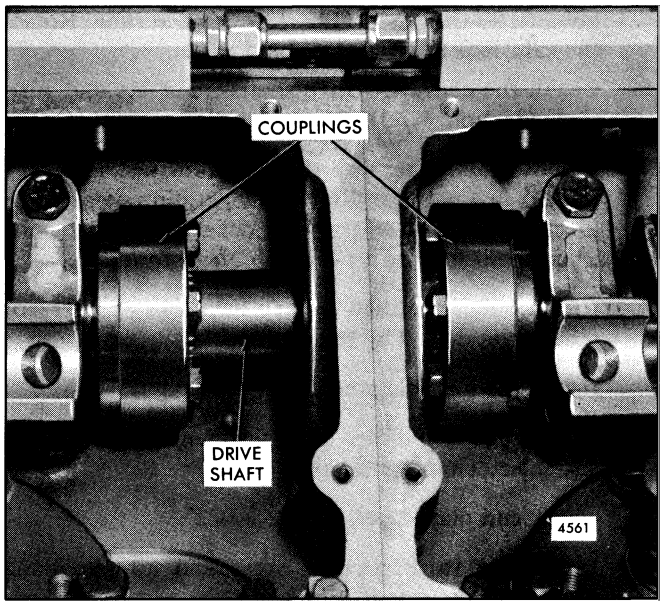



**Fig. 2 - Camshaft Couplings and Intermediate Drive Shaft (Early 12V-149 Engines)**

## Inspection

Soak the camshafts and bearing caps in clean fuel oil. Then, run a wire brush through the oil gallery in the camshaft to remove any foreign material or sludge. Clean the exterior of the camshaft and bearing caps and blow out the oil gallery and the oil holes in the camshaft and the oil holes in the bearing caps with compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

On current engines, the drilled through oil passage in the center of the camshaft and the cross drilling for the intermediate bearing journals has been discontinued. The center hole is now drilled only deep enough from each end and cross drilled to supply oil to the camshaft rear drive coupling and spline shaft. Elimination of the oil holes does not change the supply of lubricating oil to the camshaft intermediate bearings, since they continue to receive oil through drilled holes in the cylinder block.

On former 12V-149 and 16V-149 engines that still have the splined center coupling, it will be necessary to continue to use the orifice plug at the rear of the front camshaft, if replacement of one orifice plug is necessary.

Inspect the cams and journals for wear or scoring. Check the wear on the cam lobes as follows:

NOTICE: Cam lobe wear can be checked with the camshaft in or out of the engine.

1. Measure the flat on the injector rise side of the cam lobes with a tapered leaf set of feeler gages (.0015”-.010”) and a piece of squared hard material 1/8” x 3/8” x 1” (Fig. 3).

2. If the flats measure less than .003” in depth and the camshaft is in otherwise good condition, the camshaft may be considered satisfactory for further service.

3. A slightly worn cam lobe, still within acceptable limits, may be stoned and smoothed over with a fine crocus cloth.

Examine both faces of the camshaft thrust plate. A new thrust plate is .368” to .372” thick. The clearance between the thrust plate and the thrust shoulder on the camshaft is .013” to .022” with new parts or a maximum of .026” with used parts. Check the shoulder surface on the camshafts that contact the thrust plate. Camshaft thrust surfaces that are not scratched too severely may be smoothed down with an oil stone. The distance between the two surfaces is .385” to .390” with new parts.

The face runout on the thrust plate surfaces of the camshaft must not exceed .002” total indicator reading.

Inspect the couplings and splined drive shaft for excessive wear.

Replace excessively scored or worn camshaft bearings. The clearance between the camshaft journals and the bearings is .0059” to .0084” with new parts.

With the camshaft mounted on the end bearing journals, the runout on the intermediate bearing journals must not exceed .002” total indicator reading.

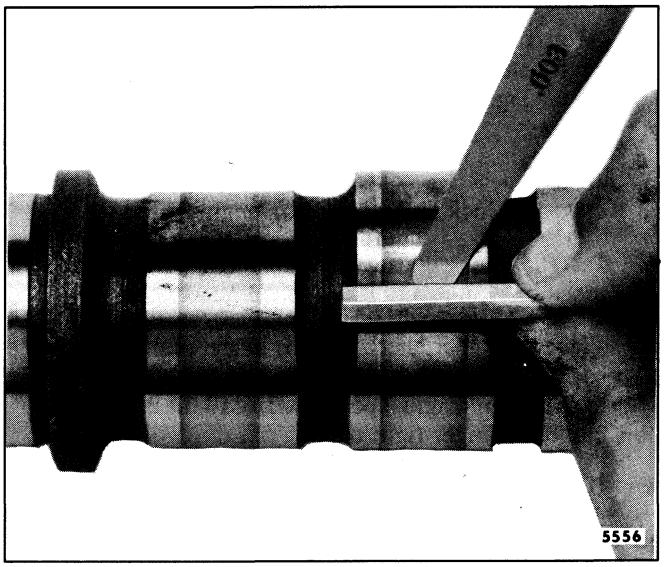



**Fig. 3 - Checking Cam Lobe Wear**

Inspect each camshaft bearing cap for brinelling at the bolt head surface for the short camshaft cap bolt. If brinelling is noted, use a hardened washer under each short bolt at the time of assembly.

**NOTICE:** Current camshaft bearing caps incorporate a drilled lubrication hole. Check the oil hole with compressed air to make sure it is not plugged.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Service camshaft bearing caps are not finished and must be line bored after installation. The finished bore dimension must be 2.151" to 2.152" with the caps in place. The axis of the bored holes must be parallel with the center line of the crankshaft bore within .004". Prior to boring the caps, tighten the retaining bolts to 90-100 lb—ft (122-136 N*m) torque.

On early 12V-149 engines (through 12E-027), the camshaft couplings were bolted to the flanges of the camshafts with five 3/8-24" bolts and one 5/16"-24 bolt. Tighten the 3/8"-24 bolts to 45-50 lb—ft (61-68 N*m) torque and the 5/16"-24 bolt to 20-24 lb—ft (27-33 N*m) torque.

After the camshafts and related parts have been inspected and worn parts replaced, refer to Fig. 5 and proceed as follows:

## Install Camshafts (8V-149 Engine)

1. If removed for inspection or cleaning, install a new orifice plug in the rear end of each camshaft and install a solid plug in the front end of each camshaft.
2. Attach a drive coupling assembly to the rear end of each camshaft with five 7/16"-20 x 1-1/4" (12 pt.) bolts. Tighten the bolts to 57-61 lb—ft (78—83 N*m) torque.
3. Install new lower camshaft bearing shells in the cylinder block and apply clean engine oil to the shells.
4. Install the right-bank and left-bank camshaft assemblies in position in the cylinder block.
5. Place the upper bearing shells in the camshaft bearing caps, apply clean engine oil, and install the bearing caps in their original position. Install the upper bearing cap bolts finger tight only.
6. If removed, install the camshaft thrust plates and tighten the bolts.
7. Place the rocker arm shafts on the bearing caps and install the remaining bearing cap bolts. Tighten the bolts to 90-100 lb—ft (122-136 N*m) torque. Rotate the camshaft to be sure no bind exists.
8. Install the camshaft drive shafts, retainers and snap rings (Section 1.7.3).
9. Remove the rocker arm shaft to allow installation of the exhaust valve and injector operating mechanism (Section 1.2.1). Tighten the rocker arm shaft bolts again to 90-100 lb—ft (123-136 N*m) torque.
10. Install the camshaft gear accessory covers or accessories driven by the camshaft drive gears.
11. Install the fuel inlet and outlet pipes.
12. Check the valve clearance adjustment (Section 14.1) and injector timing (Section 14.2).
13. Check end play. Must be .013"-.022".
14. Install the valve rocker covers and all remaining equipment previously removed.

## Install Former Flexible Drive Intermediate Camshafts (12V-149 and 16V-149 Engines)

After the camshafts and related parts have been inspected and worn parts replaced, refer to Fig. 4 and proceed as follows:

1. If removed for inspection or cleaning, install new end plugs in the camshafts. Refer to Fig. 4 for the proper location of the solid and orifice plugs.

**NOTICE:** The orifice plug is installed in the rear of each of the rear camshafts.

2. Install a drive coupling assembly on the rear drive flange camshafts, with five 7/16"-20 x 1-1/4" (12 pt.) bolts in each coupling assembly. Tighten the bolts to 57-61 lb-ft (77-83 N*m) torque as follows:

**12V-149**

a. R.H. rotation: **B** and **D** flange end.

b. L.H. -rotation: **A** and **C** flange end.

**16V-149**

a. R.H. rotation: **E** and **F** flange end.

b. L.H. rotation: **G** and **H** flange end.

• 3. Preassemble the center coupling shaft for each bank, with three spring plates and shim at each end of the coupling shaft. Install three 7/16"-20 x 1.38" self-locking bolts in each end. Former couplings use 1.200" bolts. Tighten the bolts to 57-61 lb-ft (77-83 N*m) torque.

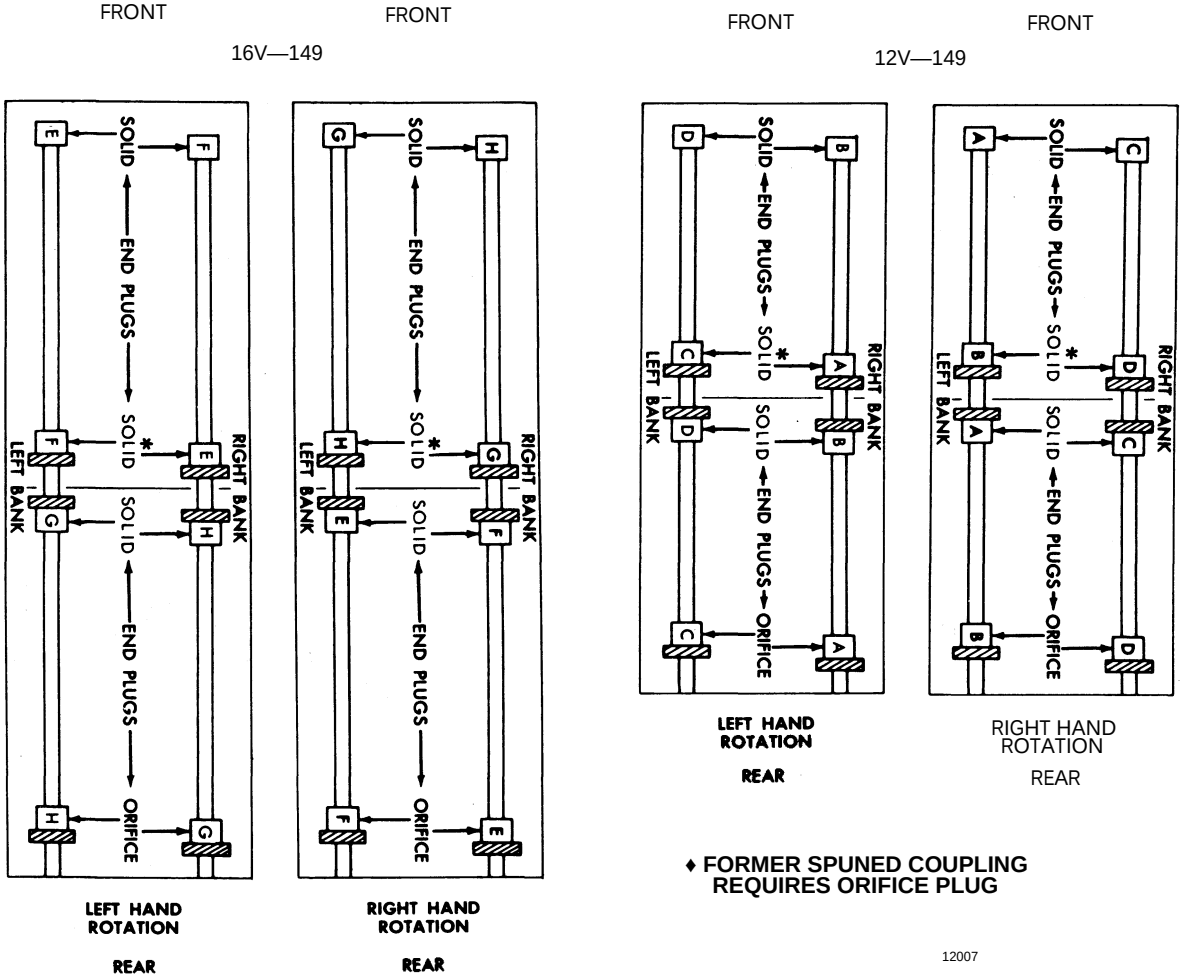



**Fig. 4 - Location of Camshafts and Plugs - 12V, 16V-149**

• 4. On former engines, attach the coupling shaft assembly, spacer and two spring plates (which act as shims) to the camshafts. On current engines, attach the coupling shaft assembly and spacer to the camshaft. Proceed as follows:

**12V-149**

a. R.H. rotation: **D** flange, right-bank front and **A** flange left-bank rear.

b. L.H. rotation: **A** flange, right-bank front and **D** flange left-bank rear.

**16V-149**

. a. R.H. rotation: **G** flange, right-bank front and **E** flange left-bank rear.

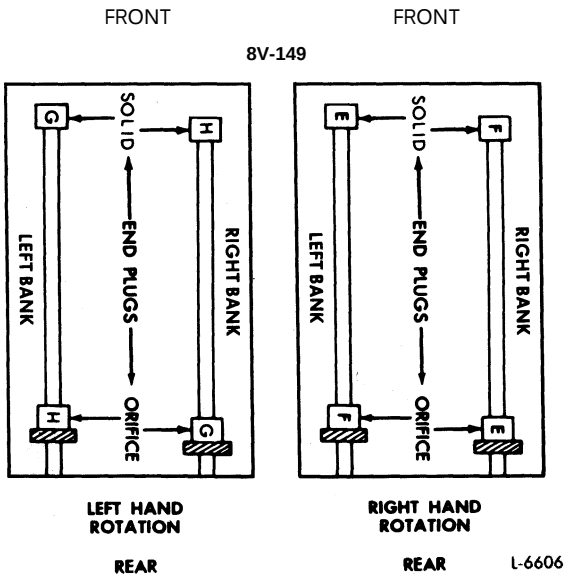
b. L.H. rotation: **E** flange, right-bank front and **G** flange left-bank rear.

• 5. Install three 7/16”-20 x 1.00” self-locking bolts (current coupling) or three 7/16”-20 x 1.200” self-locking bolts (former coupling). Because of space limitations between the coupling and the cylinder block, it is almost a necessity that torque wrench adaptor J 28462 be used. The torque wrench reading must be adjusted with the adaptor in place due to the increased length of the torque wrench and the adaptor. Usfe the following formula to determine the adjusted torque reading:

Tw = Ta (L/L + A)

If the effective length of the wrench (L) is 22” and the adaptor (A) is 2” long, you should have a reading of 55 lb—ft (75 N#m) on the wrench to have the bolt tightened to 60 lb—ft (81 N#m) torque (Fig. 6):

Tw=Ta (L/L + A)
Tw=60 (22/22 + 2)
Tw=60 (22/24)
Tw = 55




**• Fig. 5 - Location of Camshafts and Plug - 8V-149**

Tighten the bolts to 57A-61 lb—ft (77-83 N«m) torque.

NOTICE: It may be necessary to rotate the camshaft to align the three bolt holes.

6. Install new lower camshaft bearing shells in the block and apply clean engine oil to the lower bearing shells.

7. Install the right-bank front and left-bank rear camshaft assembly in position in the cylinder block. Refer to Fig. 4 and Step 4 for rotation and camshaft position.

8. Install the right-bank rear camshaft assembly and left-bank front camshaft in position in the cylinder block.

9. To determine the correct number of spring plates (shims) that will be required between the flange of the right-bank rear camshaft and the flange of the left-bank front camshaft, the following procedure will be required.

   a. Align the camshaft journal oil holes with the oil groove in the lower camshaft bearing shells on the front camshafts.

   b. If removed, install a thrust plate and spacer to the R-l 1 and L-8 bearing caps on a 12V-149 or R-15 and L-10 bearing caps on a 16V-149 engine (Fig. 7). Tighten the bolts. Install the thrust bearing caps in their original position on each bank; this locates the rear camshafts. Install and tighten the upper bearing cap bolts.

   c. Install the spacer and required number of spring plates (which act as shims) between the camshaft flange and coupling shaft spacer.

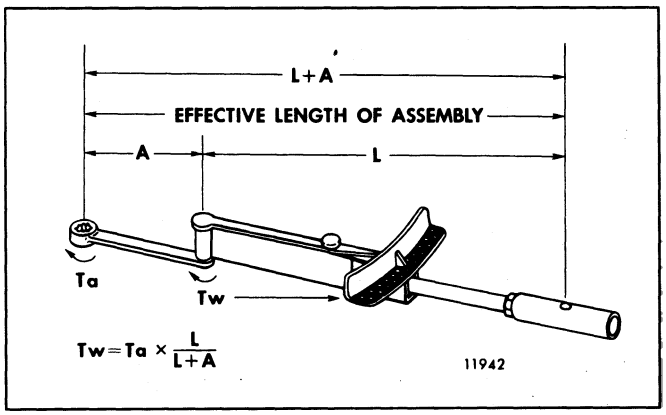



**Fig. 6 - Calculating Torque with an Adaptor**

**NOTICE:** When the correct number of shims have been determined, it may be necessary to equalize the amount of spring plates between the flange of the camshaft and the spacer at each end.

NOTICE: It may be necessary to rotate the camshaft to align the three bolt holes.

   d. Install three 7/16M-20x 1.200” self-locking bolts and tighten them to 57-61 lb—ft (77-83 N*m) torque.

NOTICE: Install the camshaft drive shafts to prevent the camshaft from turning while tightening the bolts.

10. Install the upper shells in the bearing caps and install the upper bearing caps in their original positions. Install the upper bearing cap bolts finger tight only.

11. Place the rocker arm shafts on the bearing caps and install the remaining bearing cap bolts. Tighten the bolts to 90-100 lb—ft (122-136 N#m) torque. Rotate the camshafts to be sure no bind exists.

12. Install the camshaft drive shafts, retainers and snap rings (Section 1.7.3).

13. Remove the rocker arm shaft to allow installation of the exhaust valve and injector operating mechanism (Section 1.2.1). Tighten the rocker arm shaft bolts again to 90-100 Ib-ft (122-136 N*m) torque.

14. Install the camshaft gear accessory covers or accessories driven by the camshaft drive gears.

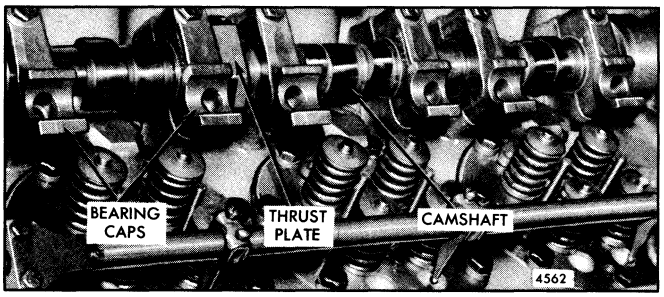



**Fig. 7 - Camshaft Bearing Caps and Thrust Plate**

15. Install the fuel inlet and outlet pipes.

16. Check the valve clearance adjustment (Section 14.1) and injector timing (Section 14.2).

. 17. Check end play. Must be .013”-.022”.

18. Install the valve rocker covers and all remaining equipment previously removed.

## Install Early Solid Drive Intermediate Camshafts (Prior To 12E-705)

After the camshafts and related parts have been inspected and worn parts replaced, refer to Fig. 2 and proceed as follows:

1. If removed for inspection or cleaning, install the new end plugs in the camshafts. Refer to Fig. 4 for the proper location of the solid and orifice plugs.

   **NOTICE:** The orifice plugs are installed in the flange end of the camshafts, towards the rear of the engine.

2. Install a drive coupling assembly on the rear drive flange camshafts with five 7/16”-2o x 1-1/4” (12 pt.) bolts in each coupling assembly. Tighten the bolts to 57-61 lb—ft (77-83 N»m) torque as follows (Fig. 2):

   **12V-149**

   a. R.H. rotation: **B** and **D** flange end.

   b. L.H. rotation: **A** and **C** flange end.

3. Install drive coupling assemblies on the camshafts at , the intermediate positions as follows:

   **12V-149**

   a. R.H. rotation: **D** right-bank front, **A** left-bank rear.

   b. L.H. rotation: **A** right-bank front, **D** left-bank rear.

4. Install five 7/16”-20 x 1-1/4” bolts in each coupling assembly. Tighten the bolts to 57-61 lb—ft (77-83 N#m) torque.

5. Install the camshaft lower bearings shells in the block and apply clean engine oil to the shells.

6. Position the right-bank front and left-bank rear camshafts in place on the lower bearings shells. Refer to Fig. 4 for rotation and position of the camshafts.

7. Install the intermediate drive shafts (6.100” long) in the right-bank front camshaft coupling and the left-bank rear camshaft coupling.

8. Slide the coupling assemblies over the intermediate shafts, toward the center of the block.

9. Install the right-bank rear and left-bank front camshafts.

10. Slide the coupling assemblies against the flanges and install five 7/16”-2 x 1-1/4” (12 pt.) bolts. Tighten the bolts to 57-61 lb—ft (77-83 N#m) torque.

    **NOTICE:** Install the camshaft drive shafts to prevent the camshafts from turning while tightening the bolts.

11. Place the upper bearing shells in the bearing caps and install the bearing caps in their original positions. Install the upper bearing cap bolts finger tight only.

12. If removed, install the thrust plates and spacers to the R-5, L-2, R-ll and L-8 bearing caps (Fig. 7). Tighten the bolts.

13. Place the rocker arm shafts on the bearing caps and install the remaining bearing cap bolts. Tighten the bolts to 90-100 lb—ft (122-136 N#m) torque. Rotate the camshaft to be sure no bind exists.

14. Install the camshaft drive shafts, retainers and snap rings (Section 1.7.3).

15. Remove the rocker arm shaft to allow installation of the exhaust valve and injector operating mechanism (Section 1.2.1). Tighten the rocker arm shaft bolts again to 90-100 lb—ft (122-136 N«m) torque.

16. Install the camshaft gear accessory covers or accessories driven by the camshaft drive gears.

17. Install the fuel inlet and outlet pipes.

18. Check the valve clearance adjustment (Section 14.1) and injector timing (Section 14.2).

• 19. Check end play. Must be .013”-.022”.

20. Install the valve rocker covers and all remaining equipment previously removed.

# CAMSHAFT GEARS AND IDLER GEARS

The right-bank and left-bank camshaft gears (Fig. 1) are mounted on double-row tapered roller bearings which are supported on identical stationary hubs. Each camshaft gear hub is held in position against the block by three (3) bolts. The gear and bearing assembly is held in position on the hub by a special locknut and lock washer.

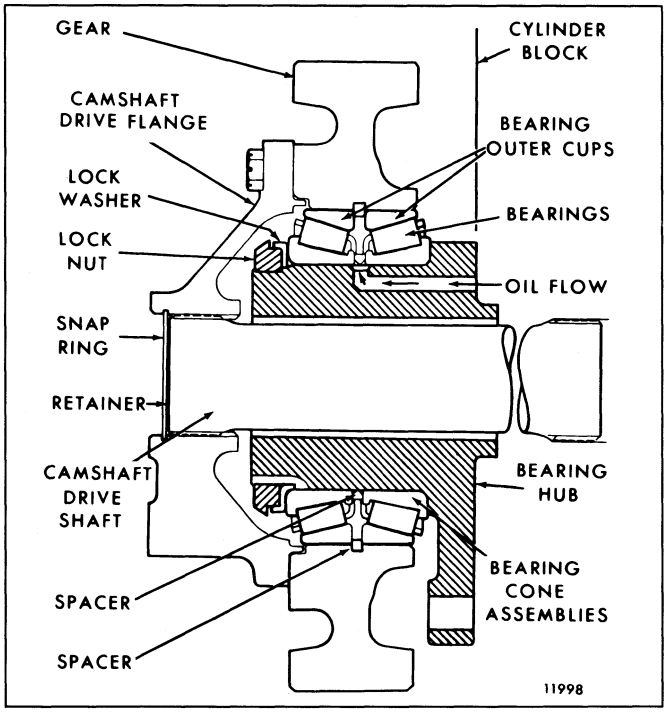



Fig. 1 – Camshaft Gear Mounting

The rear gear train camshaft idler gears and the crankshaft idler gear (Fig. 2) are mounted on double-row tapered roller bearings which are all mounted on identical stationary hubs. The two camshaft idler gear hubs are each held in position against the block by a special drilled center bolt and four outer bolts. The two camshaft idler gear and bearing assemblies are each held in position on the hub by a special locknut and lock washer. The crankshaft idler gear hub and dummy hub (which acts as a spacer for the flywheel housing) are each held in position by a special drilled center bolt and four (4) outer bolts which are installed through the flywheel housing and hubs into the block. The crankshaft idler gear and bearing assembly is also held in position by a special locknut and lock washer.

' The front gear train idler gears (Fig. 3), incorporating bushing type bearings, are used for balancing the engine and driving the water pump. Each idler gear hub is held in position by a special center drilled bolt and four (4) outer bolts which are installed through the front cover and hub and into the block. Two (2) thrust washers are used on each idler gear. The inner washer is held in position by the hub and the outer washer is held in position by the front cover.

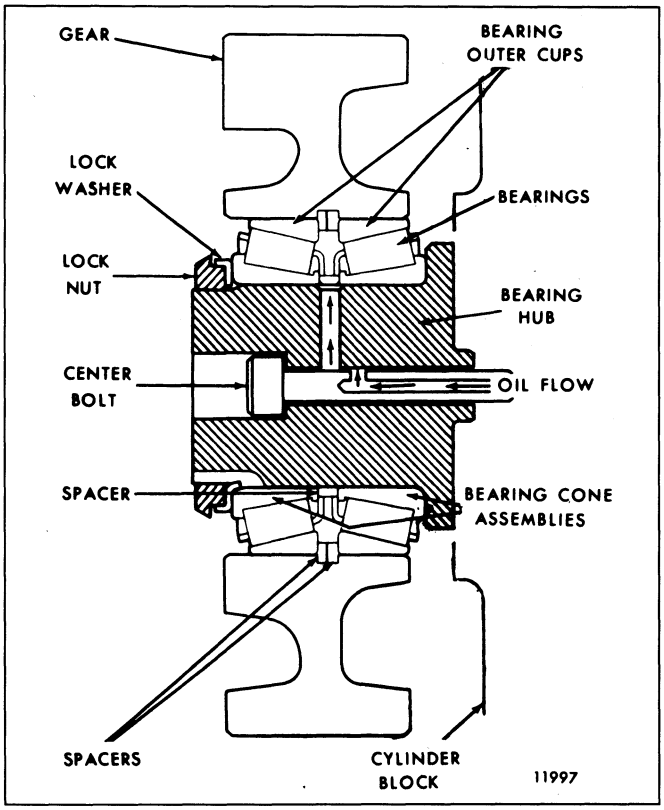



**Fig. 2 - Camshaft Idler Gear and Crankshaft Rear Idler Gear Mounting**

Current 16V turbocharged and intercooled engines use a nitrided hardened right-hand idler gear (68 teeth) and its mating blower drive gear (33 teeth). Both gears are identified by the grayish color taken on by the hardening process. When replacing the former non-hardened right-hand idler gear or its mating blower drive gear in the 16V turbocharged intercooled engine, both gears must be replaced at the same time with the new hardened gears. The former non-hardened right bank idler gear will continue to be used for all other Series 149 engines.

## LubricatiQn

The caihshaft gear bearings are pressure lubricated by oil from tlie cylinder block oil gallery which enters the hub through a longitudinal drilled passage in the hub (Fig. 1). Excess oil leaving the camshaft bearings lubricates the camshaft gears.

The rear camshaft idler gear bearings, crankshaft idler gear bearing and front idler gear bushings are all pressure lubricated by oil from the cylinder block oil galleries. Oil enters all five (5) hubs through a special center drilled bolt on both front and rear gear train idler gears. A hole is drilled in the side of the center bolt allowing oil to flow through a transverse drilled passage in the idler gear hubs. Oil is

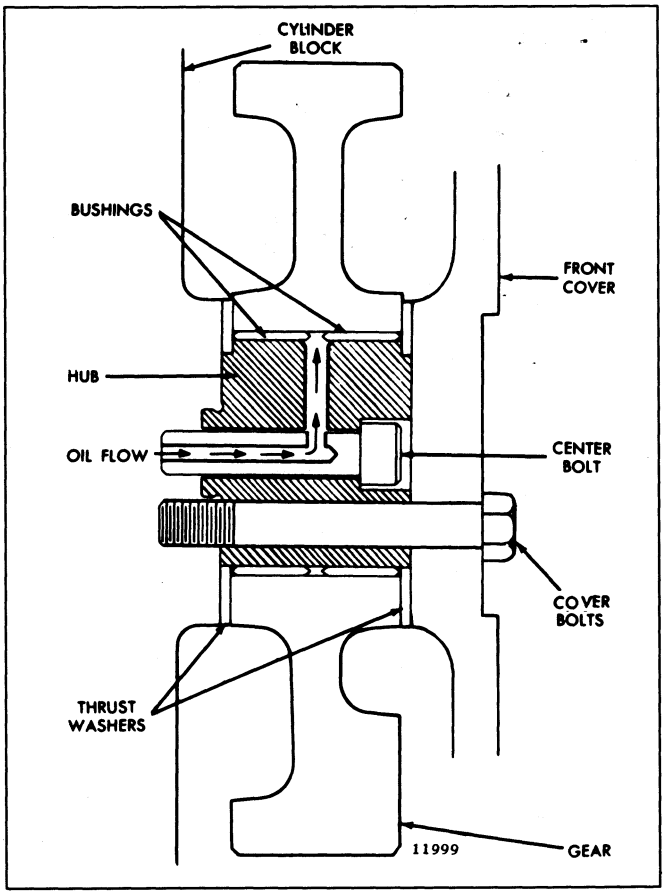



Fig. 3 – Front Gear Train Idler Gear Mounting

circulated around the roller bearings in the rear gear train and the bushings and thrust washers in the front gear train. Excess oil leaving the bearings and bushings lubricates the gears.

## Remove Camshaft Gear Assemblies (Flywheel Housing Installed)

The camshaft gear, hub and bearing assemblies are removed with the flywheel housing in place. If the camshaft idler gear assemblies and crankshaft idler gear assembly must be removed, removal of the flywheel housing will be necessary. Remove the camshaft gear assemblies, as follows:

1. Remove the camshaft gear flywheel housing covers or accessory drive adaptors (Sections 1.5 and 1.7.7).
2. Remove the snap ring and retainer from the camshaft drive flange (Fig. 1).
3. Withdraw the camshaft drive shaft from the camshaft and drive flange.

**NOTICE:** Place a clean, lintless cloth in the flywheel housing, underneath the camshaft gear and bearing assembly, to prevent bolts from accidentally falling into the flywheel housing (when removing or installing bolts).

4. Remove the four (4) bolts securing the drive flange to the camshaft gear and remove the flange.

If disassembly of the camshaft gear assemblies is required, it is advisable to loosen the former locknuts with spanner wrench set J 22556 or the current hex nut set J 29744 before removing the gear assemblies from the engine.

**NOTICE:** When disassembling a cam gear bearing assembly, use a punch to drive the dimpled lip of the locknut out of the hub, before attmepting to remove the nut. Failure to observe this precaution may result in damage to the hub threads.

5. Rotate the camshaft gear until the holes in the gear align with the three (3) camshaft hub to block bolts and remove the bolts.
6. Remove the camshaft gear assembly through the opening in the flywheel housing.
7. Remove the opposite camshaft gear assembly in the same manner.

## Remove Rear Camshaft Idler Gear Assemblies

1. Remove the camshaft gear assemblies as covered above.
2. Remove the flywheel and the flywheel housing (Sections 1.4 and 1.5).

If disassembly of the camshaft idler gear assemblies is required, loosen the former locknuts with spanner wrench set J 22556 or the current hex nut with wrench set J 29744 before removing the gear assemblies from the engine.

**NOTICE:** When disassembling a cam or idler gear bearing assembly, use a punch to drive the dimpled lip of the locknut out of the slot in the hub before attempting to remove the nut. Failure to observe this precaution may result in damage to the hub threads.

3. Remove the four (4) outer bolts and one center bolt securing the camshaft idler gear assembly.
4. Remove the assembly from the block.
5. Remove the opposite camshaft idler gear assembly in the same manner.

## Remove Rear Crankshaft Idler Gear Assembly

1. Remove the camshaft gear assemblies as covered above.
2. Remove the flywheel and the flywheel housing (Sections 1.4 and 1.5).

3. Remove the camshaft idler gear assemblies, if service is required, as covered above.

If disassembly of the crankshaft idler gear assembly is required, it is advisable to install a l/2"-13 x 5" bolt to hold the hub in position while loosening the former locknut with spanner wrench set J 22556 or current hex nut set J 29744.

**NOTICE:** When disassembling a cam or idler gear bearing assembly, use a punch to drive the dimpled lip of the locknut out of the slot in the hub before attempting to remove the nut. Failure to observe this precaution may result in damage to the hub threads.

4. Remove the center bolt and l/2”-l3 x 5” bolt from the crankshaft idler gear hub. Remove the gear assembly from the engine.

5. Remove the idler gear dummy hub if required.

## Remove Front Idler Gear Assemblies

1. Remove the engine front cover (Section 1.3.5).

2. Remove the outer thrust washers and idler gears (Fig. 3).

3. Remove the center bolts securing the idler gear hubs to the cylinder block. Remove the hubs and thrust washers.

## Disassemble Gear, Hub And Bearing Assemblies (Rear Gear Train)

The disassembly and assembly of the various gear, hub and bearing assemblies of the rear gear train are similar, therefore only one procedure will be covered for all assemblies.

Whenever tapered roller bearings are disassembled, all parts must be match marked and kept as a set to be reassembled in their *original* position.

1. Remove the locknut (previously loosened while the gear assembly was attached to the engine) and lock washer.

2. Press the hub from the gear and bearing assembly.

3. Remove the roller bearing cone assemblies and spacer from the gear.

4. Remove the bearing cups from the gear, as follows:

   a. Drive one cup from the gear, using a brass rod.

   b. Turn the gear over and drive the other cup out in the same manner.

5. Remove the spacer(s) from the gear.

## Inspection

Wash all of the parts thoroughly in clean fuel oil and dry them with compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the gear teeth for evidence of scoring, pitting or wear.

Examine the gear hub for wear or damage.

Examine the rear gear train bearings carefully for wear, pitting, scoring or flat spots on the rollers.

Examine the front idler gear bushings for scoring or wear. When replacing the bushings, install them flush to .010" below the face of the hub on both sides of the gear (refer to Section 1.0 for bushing and hub specifications).

Examine the front idler gear thrust washers for wear or scoring.

Replace all worn or damaged parts.

## Assemble Gear, Hub And Bearing Assemblies

When assembling the various gear, hub and bearing assemblies, it is important that the inner race of the bearing and the inner face of the lock washer, used in conjunction with the two (2) camshaft gear bearing locknuts, three (3) idler gear bearing locknuts and accessory gear bearing locknuts, are perfectly dry and free of any lubricant. Before installing and tightening the locknut, apply a light coating of International Compound No. 2, or equivalent, to the threads of the shaft and the contact face of the nut that contacts the lock washer. This will allow the nut to turn freely on the lock washer.

1. Install and torque the current lipped locknuts as follows:

   a. Apply a small quantity of International Compound No. 2 or equivalent to the locknut threads and the face of the locknut that contacts the bearing inner race.

   b. Install the gear and bearingassembly components, then thread the locknut finger-tight onto the hub.

   • c. Using the appropriate socket from tool set J 29744 and an accurately calibrated torque wrench, tighten the locknut to 300-320 lb—ft (407-434 N*m) torque. Rotate the gear while tightening the locknut.

d. With a hammer and rounded punch, dimple the outer lip of the locknut into the slot in the hub to secure the locknut in position. The new cam and idler gear bearing locknuts are reusable and may be dimpled in the same location on the outer lip after being tightened to the proper torque.

2. Bend one or more of the tangs on the lock washer into the slots on the locknut.

3. Perform a bearing pre-load check. *

• 4. Install one outer, one inner spacer in *Former* camshaft and idler gear assembly (Fig. 1). Install two outer spacers and one inner spacer in idler gear assembly (Fig. 2). Assemble the bearing assemblies in the gears with reference to the match marks made during disassembly. The idler gear assemblies use two (2) outer spacers with the gaps installed 180° apart.

• **NOTICE:** On 8 V engines only, use one (1) outer spacer on the front idler gear and make sure spacer gap is aligned with the oil hole.

5. Support the gear in an arbor press. Place one of the bearing cups in the bore of the gear and, using a suitable installer, press the cup into the gear and against the spacer(s). Turn the gear over and install the remaining cup in the same manner.

6. Position the two (2) bearing and cone assemblies and the spacer ring in the gear.

7. Press the gear hub into the gear and bearing assembly, with the oil hole in the hub 180° from the gap in the spacer ring. The gear hub is a light press fit in the gear and bearing assembly.

• 8. On *non-lipped nuts* to be certain that the lock washer has not turned in the process of tightening the locknut, match mark the hub slot and the outer tang of the lock washer at the inner tang. After the nut is tightened to 280-300 lb—ft (379-407 N#m) torque, check to be sure that the match marks have not moved.

9. Position the former slotted lock washer and *castelated* locknut on the hub and against the bearing cone. Use spanner wrench set J 22556 and tighten the locknut to 280-300 lb-ft (379-407 N#m) torque. When tightening the locknut on the hub, it is advisable to install the gear assembly on the engine to hold it while tightening the locknut. *Rotate the gear white tightening the locknut.*

## Check Bearing Pre-Load

The rollers in the bearing are loaded between the bearing cups and the bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a tapered roller bearing assembly, the rollers will be more tightly held between the cones and the cups. A slight pre-load is applied to the bearings, by means of a selected spacer ring between the bearing cones, to provide rigidity of the gear and bearing assembly when it is mounted on its hub. This method of pre-loading is measured, in terms of “pounds pull”, by the effort required at the outer diameter of the gear to turn the bearing cups in relation to the bearing cones.

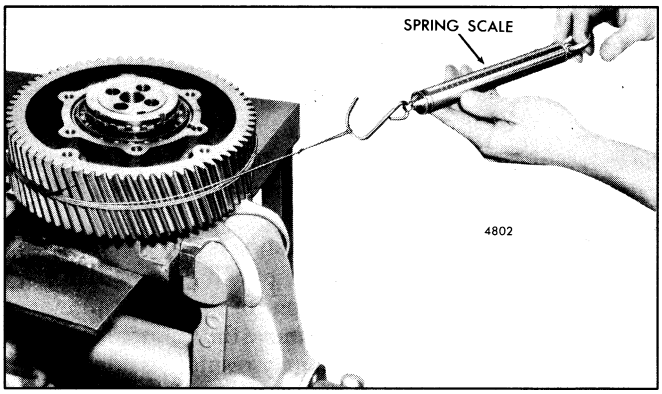



**Fig. 4 - Checking Bearing Pre-Load with Spring Scale J 8129**

Check the bearing pre-load whenever the camshaft or idler gear assemblies are removed from the engine for service or for an engine overhaul.

The bearings must be clean and lubricated with engine oil before checking the pre-load. If a new bearing has been installed, “work in” the bearing by rotating the gear back and forth several times.

Refer to Fig. 4 and tie one end of a piece of lintless cord around a 1/8” piece of wood (or soft metal stock). Place the wood between two of the gear teeth and wrap the cord around the gear several times. Attach the outer end of the cord to spring scale J 8129. Maintain a steady pull on the cord and scale 90° to the axis of the hub and note the pull, in pounds and ounces, required to start the gear rotating. Make several checks to obtain an average reading. If the pull is within 1 lb. minimum to 5 lbs. maximum and does not fluctuate more than 2 lbs. 11 ozs., the gear and bearing assembly is satisfactory for use.

• **NOTICE:** On 8Y engines only, the preload on idler gear is 1/2 to 3 lbs (maximum).

A scale reading which exceeds the specified maximum indicates binding of the bearing rollers or rollers improperly installed. The bearing must be disassembled and inspected. A new spacer may be installed to obtain the proper pre-load (various thickness spacers are available). If necessary, install a new bearing.

## Install Idler Gear, Hub And Bushing Assemblies (Front Gear Train)

1. Place the inner thrust washers (grooved side facing gears) and gear hubs in position on the cylinder block. Install the center special drilled bolts, but do not tighten the bolts at this time (Fig. 5).

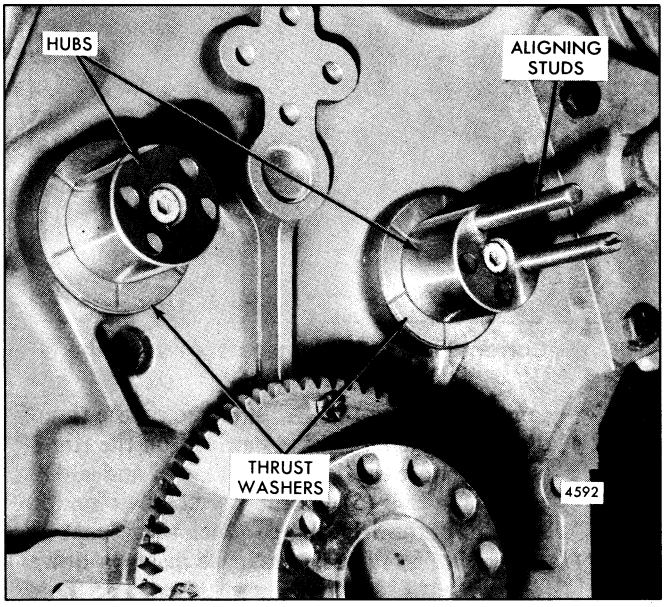



**Fig. 5 - Aligning Front Gear Train Idler Gear Hubs**

2. Fabricate two (2) aligning studs from two (2) 1/2M—13 x 4-3/4" bolts (cut off the heads of the bolts). Place the aligning studs through the hubs and thread them into the block. Tighten the center bolts to 80-90 lb—ft (108-122 N«m) torque (Fig. 6).

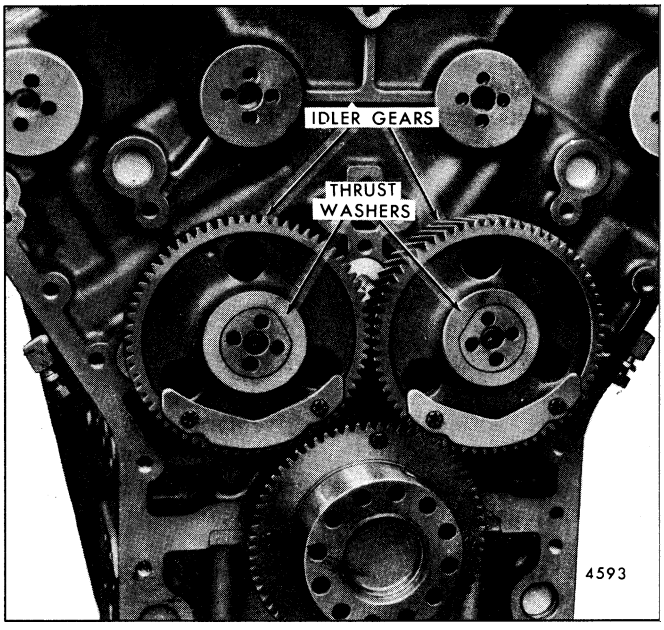



**Fig. 6 - Front Gear Train Idler Gears**

3. Remove the aligning studs.

4. Refer to Section 1.7.1 for the proper timing of the idler gears.

5. Place the two (2) idler gears (thin idler gear first) over the idler gear hubs. Position the outer thrust washers (grooved side facing gear) over the hubs.

6. Check the backlash between the mating gears. The specified backlash is .0015" to .0080" between new gears and must not exceed .0100" between used gears.

7. Install the front cover (Section 1.3.5).

## Install Rear Crankshaft Idler Gear Assembly (Flywheel Housing Removed)

1. If removed, install the idler gear dummy hub; do not tighten the center bolt at this time.

2. Position the crankshaft idler gear, hub and bearing assembly against the block, align the timing marks, as outlined in Section 1.7.1, and install the special drilled center bolt finger tight.

3. Fabricate two (2) aligning studs from 1/2"-13 x4—3/4" bolts (cut off the heads of the bolts).

4. Install the aligning studs through the crankshaft idler gear hub outer bolt holes in the same manner, as shown in Fig. 5 for installing the front idler gear hubs.

5. Tighten the center bolt to 80-90 lb-ft (108-122 N#m) torque. Remove the aligning studs.

6. Install the dummy hub in the same manner, as outlined in Steps 4 and 5.

7. Check the backlash between the mating gears. The specified backlash is .0015" to .0080" between new gears and must not exceed .0100" between used gears.

## Install Rear Camshaft Idler Gear Assemblies (Flywheel Housing Removed)

1. Position the camshaft idler gear, hub and bearing assemblies against the block with the timing marks in alignment (refer to Section 1.7.1). Install the special drilled center bolt finger tight. ...

2. Install the four (4) l/2"-13 x 4-3/4" bolts in each camshaft idler gear hub. Tighten the bolts to 71-75 lb-ft (96-102 N#m) torque.

3. Tighten the center bolts to 80-90 lb-ft (108-122 N#m) torque.

4. Check the backlash between the mating gears. The specified backlash is .0015" to .0080" between new gears and must not exceed .0100" between used gears.

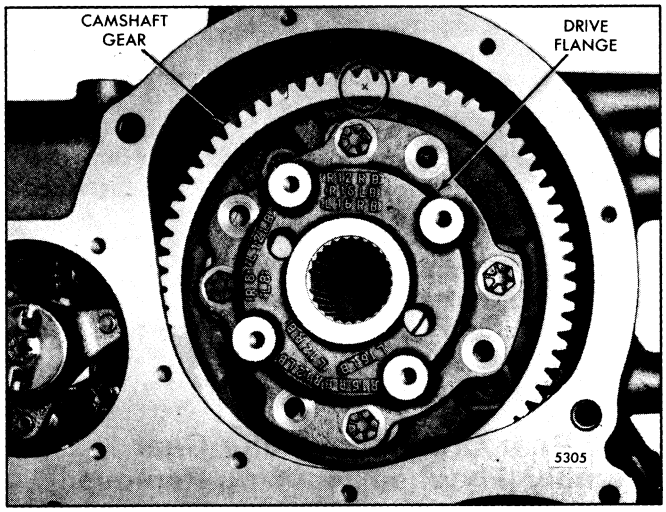



**Fig. 7 - Current Right-Bank Camshaft Drive Flange**

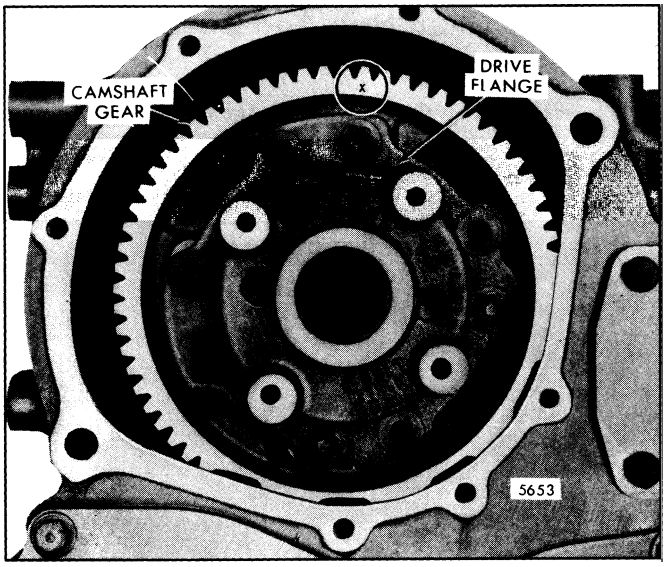



**Fig. 8 - Current Left-Bank Camshaft Drive Flange**

## Install Camshaft Gears (Flywheel Housing Installed)

1. If removed, install the flywheel housing and flywheel (Sections 1.5 and 1.4).

2. Position the camshaft gear, hub and bearing assembly against the block with the timing marks in alignment (refer to Section 1.7.1).

3. Use Locktite #271 on the cam hub retaining bolts and install three (3) 7/161-14 x 1-1/41 self-locking bolts through the camshaft gear and bearing hub and into the block. Tighten the bolts to 60-65 lb—ft (81-88 NSm) torque.

4. Install the opposite gear in the samemanner, as outlined in Steps 2 and 3.

5. Check the backlash between the mating gears. The specified backlash is .0015” to .0080” between new gears and must not exceed .0100” between used gears.

6. Install the camshaft drive flanges on the right-bank and left-bank camshaft gear assemblies, as follows:

CURRENT DRIVE FLANGE

a. Determine engine rotation (as viewed from the front of the engine), number of cylinders and right or left bank camshaft (as viewed from the rear of the engine). Refer to the engine option plate for this information. The current universal drive flange is interchangeable with the former drive flanges and can be installed on either the right-bank or the left-bank camshaft gear.

b. With the gear train in time, locate the sleeve-type dowel which is pressed into the camshaft gear or the “X” stamped on the rim of the gear. A letter “X” is stamped on the rim of the gear above the dowel pin (Figs. 7 and and 8). There are five (5) counterbored holes on the backside of the drive flange which will accept the dowel pin. It will be necessary to mate the dowel pin with the appropriate counterbored hole, identified by the raised letters on the opposite side of the flange.

EXAMPLE - Refer to Fig. 7; “R” indicates right-hand rotation, “12” the number of cylinders and “RB” the right bank camshaft gear assembly.

c. Place a drive flange, with the appropriate counterbored hole in line with the dowel pin or “X”, against the right-bank camshaft gear. Install four (4) 7/16”-20 x 1-1/8” self-locking bolts and tighten them to 57-61 lb—ft (77-83 N#m) torque.

d. Install a drive flange on the left-bank camshaft * gear in the

same manner, as outlined above.

FORMER DRIVE FLANGE

a. The former camshaft drive flanges are stamped on the face of the flange (Fig. 8) to identify their proper location, either on the right-bank camshaft or left-bank camshaft.

EXAMPLE - A flange stamped “LB-RH-12V” must be installed on the left-bank (LB) of a right-hand rotation (RH) 12V engine (Fig. 9).

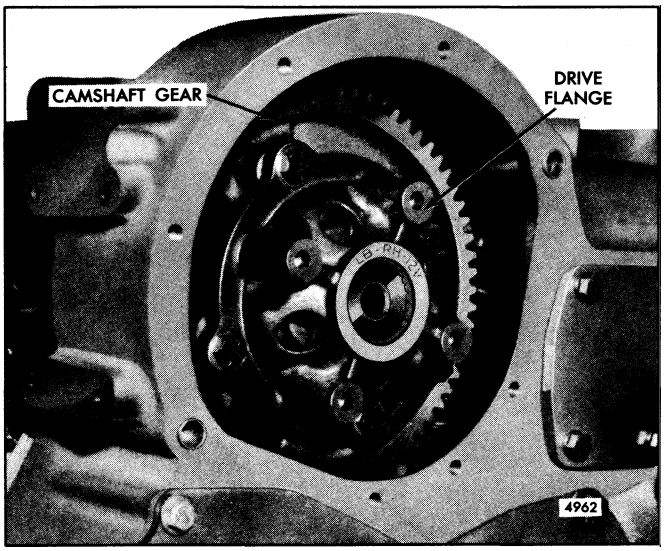



**Fig. 9 - Former Camshaft Drive Flange**

**NOTICE:** Do not interchange camshaft drive flanges under any circumstances. Should the drive flanges become installed incorrectly, engine timing would be affected and severe damage to the engine could result.

b. With the gear train in time, place the appropriate drive flange against the camshaft gear. The counterbored hole on the opposite side of the flange will fit over the sleeve-type dowel pin and will be in line with an "X" stamped on the rim of the gear. Install four (4) 7/16"-20 x 1-1/8" self-locking bolts and tighten them to 57-61 lb—ft (77-83 N#m) torque.

c. Install a drive flange on the opposite camshaft gear in the same manner.

7. Align the ommitted spline on the camshaft coupling by rotating the camshaft on the left bank, in alignment with the omitted spline on the drive flange. Carefully position the ommitted spline on the camshaft driveshaft (8.420") throughthe left-bank camshaft drive flange and into the camshaft coupling. Install the short camshaft drive shaft (6.920") in the same manner on the right-bank.

8. Install the retainers and snap rings.

9. Install the camshaft gear flywheel housing covers or accessory drive adaptors (Sections 1.5 and 1.7.7).

# CRANKSHAFT TIMING GEARS

Two crankshaft timing gears are located on the crankshaft (Figs. 1 and 2). The rear gear is attached to the flange at the rear of the crankshaft. The front crankshaft gear assembly (gear and bushing) is attached to a damper assembly which is mounted on the flange at the front end of the crankshaft.

Since the camshafts must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft gears (refer to Section 1.7.1).

## Remove Crankshaft Rear Timing Gear

1. Remove the flywheel housing (Section 1.5) from the engine.
2. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.
3. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.
4. Remove the eight twelve-point bolts securing the rear timing gear to the crankshaft.
5. Utilizing the two 7/16”-20 tapped holes in the timing gear, use a suitable push puller and step plate adaptor to remove the gear from the crankshaft.

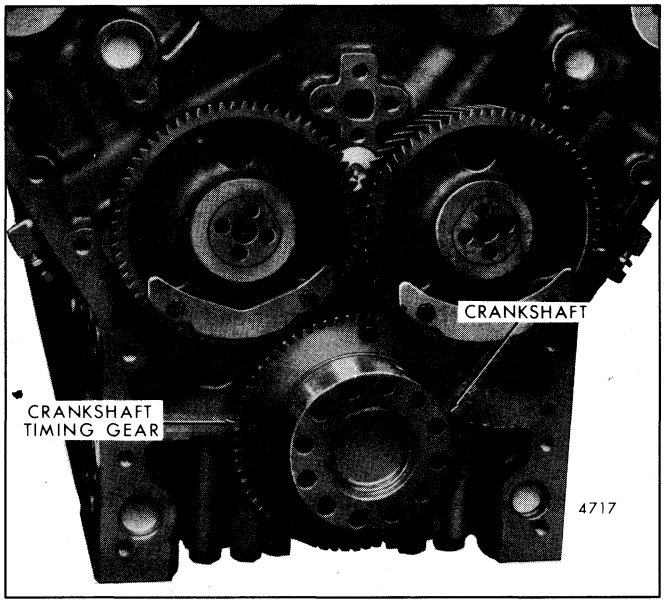



**Fig. 1 - Front Crankshaft Timing Gear Mounting**

## Remove Crankshaft Front Timing Gear And Damper

1. Remove the front cover (Section 1.3.5) from the engine.
2. Remove the four bolts securing the timing gear to the damper and remove the timing gear and bushing assembly from the engine.
3. Remove the four bolts securing the damper to the crankshaft front flange and remove the damper.

## Inspection

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

• Wash the gears in clean fuel oil and dry with compressed air. Inspect the gear teeth and the bushing in the front crankshaft gear for wear, pitting or scoring. The clearance between the crankshaft and the bushing in the front crankshaft gear is .001” to .003” with new parts. The inside diameter of a new gear bushing is 6.012” to 6.013”.

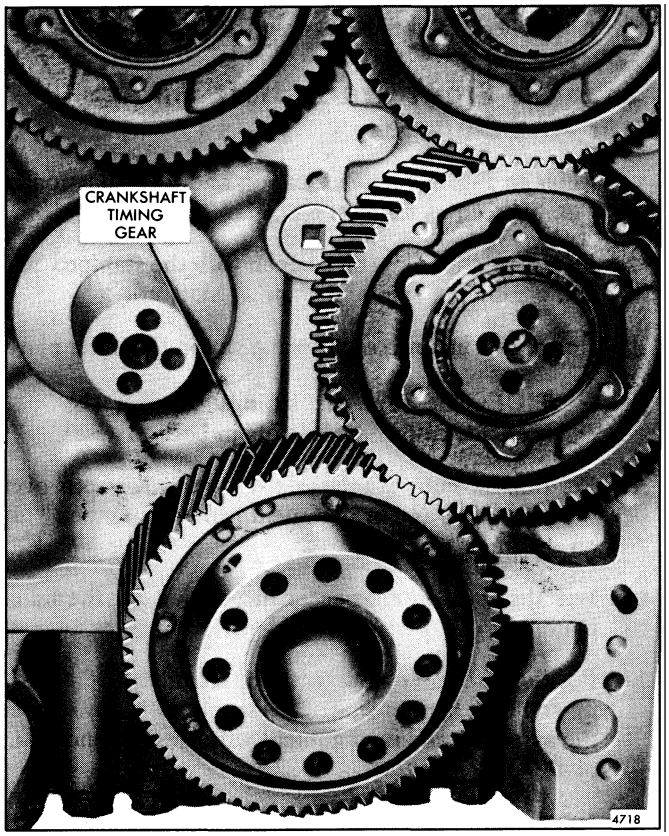



**Fig. 2 - Rear Crankshaft Timing Gear Mounting**

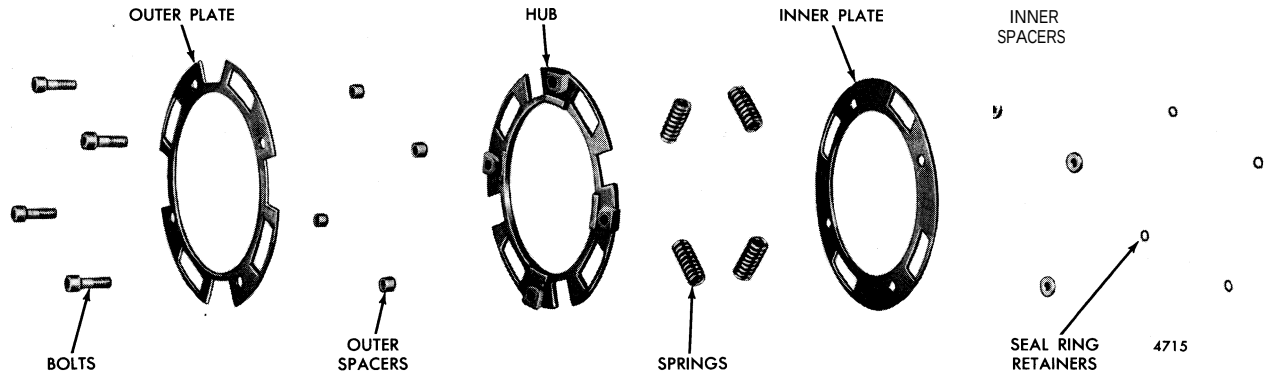



**Fig. 3 - Front Timing Gear Damper Details and Relative location of Parts**

Clean and disassemble the damper (Fig. 3). Examine the damper springs for pitted or fractured coils. Replace defective springs.

A backing plate (Fig. 3) is used in the current damper assembly in place of four inner spacers. Only the current damper assembly is available for service. However, the spacers will continue to be included in the damper overhaul kit for servicing the former damper assembly.

Also, check the other gears in the gear train.

## Assemble Front Crankshaft Timing Gear And Damper

Refer to Fig. 3 for the location and identification of parts and, proceed as follows:

1. Place the inner plate on a bench with the stamped “O” and chamfered side of the spring slots up.
2. Insert a spring into each spring slot in the inner plate.

   **NOTICE:** Be sure the springs seat on the *chamfer side* of the spring slots in both plates.

3. Position the hub with the cast “O” up and directly over the inner plate and in alignment with the stamped “O” on the inner plate.
4. Lay the four outer spacers in position on the inner plate.
5. Position the outer plate, with the stamped *0” or “X” up and the chamfer side of the spring slots down, over the assembly and in alignment with the hub and inner plate.

   **NOTICE:** All three timing marks must coincide with each other.

6. Insert the four socket head bolts through all three plates and position the assembly upside down on the bench.
7. Install the backing plate or four inner spacers (counterbore up) over the bolts.
8. Secure the backing plate or inner spacers in position with the four seal ring retainers.

   **NOTICE:** Be sure the seal ring retainers are seated in the counterbores of the backing plate or inner spacers.

## Install Crankshaft Front Timing Gear And Damper

Refer to Section 1.7.1 for position of the gear train timing marks and, proceed as follows:

1. Position the damper assembly up against the front crankshaft flange and thread the bolts into the crankshaft Aange. Tighten the bolts to 35-39 lb—ft (47-53 Ntm) torque.
2. Position the front timing gear and bushing assembly over the crankshaft front hub and up against the damper assembly. Secure the timing gear to the damper assembly with four bolts. Tighten the bolts to 35-39 lb-ft (47-53 N#m) torque.
3. Install the engine front cover. Refer to Section 1.3.5.
4. Check the backlash with the mating gear. The backlash should be .0015” to .008” with new gears or .010” maximum with used gears.

## Install Crankshaft Rear Timing Gear

Refer to Section 1.7.1 for position of the gear train timing marks and, proceed as follows:

1. Position the crankshaft rear timing gear over the crankshaft rear hub and up against the crankshaft flange.
2. Secure the timing gear to the crankshaft flange using eight twelve-point bolts. Tighten the bolts to 35-39 lb—ft (47-53 N*m) torque.

• 3. On former engines without rear outboard bearing supports install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

#4. Install the flywheel housing (Section 1.5). On current engines the rear oil seal sleeve is incorporated into the flywheel.

# BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

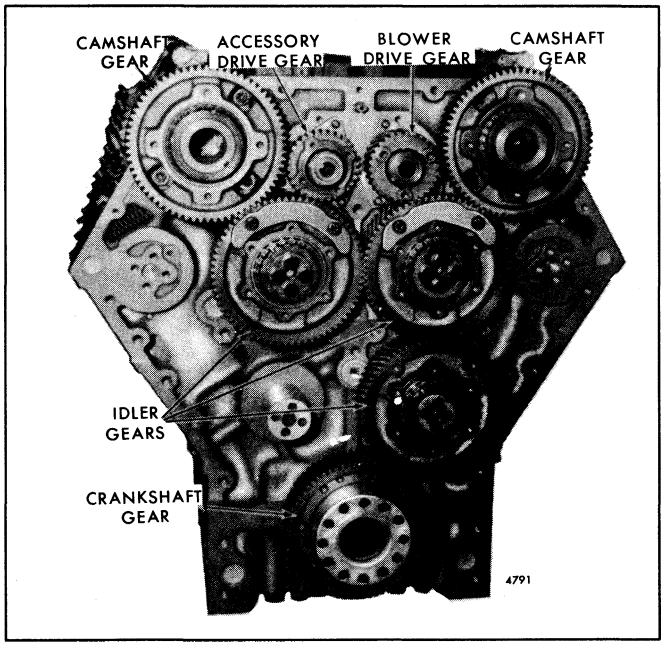



**Fig. 1 - Blower Drive Gear Mounting**

The blower drive gear and support assembly is mounted at the rear of the engine (Fig 1). The assembly consists of a blower drive gear and bushings, blower drive gear support hub, thrust washers, lock washer and nut (Fig. 2). The fuel pump drive coupling disc is bolted to the blower drive shaft.

The blower drive shaft is splined and drives the blower at approximately twice engine speed through a flexible coupling attached to the right-hand helix blower timing gear (Table 1). The other end of the shaft is splined also and is driven by the inner splines of the blower drive gear hub which is bolted to the blower drive gear through a flexible plate.

| ENGINES | RATIO BLOWER TO ENGINE SPEED | NO. TEETH IN BLOWER DRIVE GEAR |
|---|---|---|
| 12 and 16V Naturally Aspirated or Turbocharged | t2.06:l (16V) | 30<br>33 |
| '8V,*12V and 16V Turbo Intercooled TV8401 (8V-16V) TV7101 (12V) or TV8115 (16V) | 2.06:1 | 33 - |
| 12 and 16V Turbocharged Intercooled T18A40 | 2.26:1 (12V)<br>2.06:1 (16V) | 30<br>33 |
| * Effective with 12E-5873 and 16E-5426.<br>fHigh efficiency - 16V turbocharged. | | |

**TABLE 1**

## Lubrication

The blower drive support bushings are pressure lubricated through oil passages in the cylinder block and blower drive support. Excess oil drains back to the crankcase by way of the gear train.

## Remove Blower Drive Gear And Support Assembly

The blower drive gear and support assembly may be removed from the engine with or without the flywheel housing installed.

To remove the blower drive gear and support assembly without removing the flywheel housing, refer to Fig. 2 and proceed as follows:

1. Remove the inspection cover from the rear air box cover plate.
2. Loosen the 12V hose clamps between the rear blower and the blower drive support. Loosen the retainer clip and slide the tube connection into the blower (8V) or rear blower (16V).
3. Slide the hose onto the rear blower (12V and 16 V) or the blower (8V).
4. Remove the fuel lines from the fuel pump. Then remove the pump and adaptor from the flywheel housing (Section 2.2).
5. Remove any accessory from the right bank camshaft and cover (tachometer drive, overspeed governor or accessory drive).
6. Remove the right camshaft drive gear cover.
7. Turn the crankshaft until the timing marks are in line on the camshaft drive gear and the idler gear.
8. Remove the snap ring and retainer from the camshaft drive flange.
9. Remove the cam drive shaft and camshaft drive flange.
10. Remove the camshaft drive gear.
11. Remove the 3/8”-24 x 1” self-locking bolt securing the fuel pump coupling disc to the blower drive shaft. Remove the pump coupling disc.
12. Remove the snap ring from the blower drive coupling hub. Then, thread a 3/8”-24 bolt into the end of the blower drive shaft and withdraw the shaft from the blower drive gear support assembly.
13. Remove the three (3) 7/16”-20 x 7/8” self-locking bolts and remove the spring plates and blower drive coupling hub.

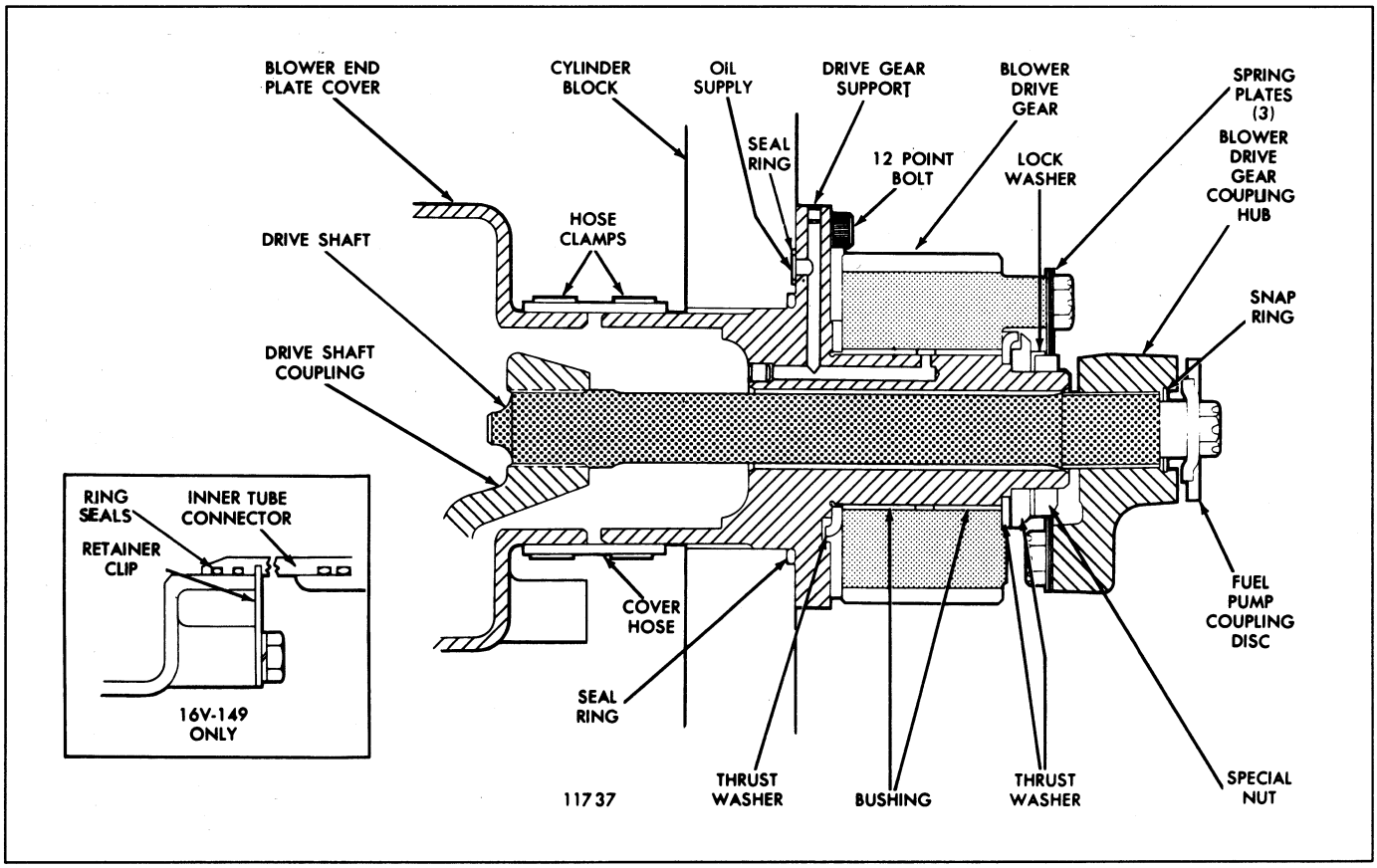



Fig. 2 – Blower Drive Support Assembly

14. Bend back the tabs of the lock washer and remove the nut, lock washer and thrust washers securing the blower drive gear on the hub with socket J 23641.

15. Remove the blower drive gear and remaining thrust washer. Be careful not to drop any of the parts into the flywheel housing.

16. Remove the three (3) 12-point bolts securing the blower drive support to the cylinder block.

17. Pull the blower drive support through the right bank camshaft gear opening in the flywheel housing. Discard the seal ring and the "O" ring located in the counterbore of the block at the oil supply hole.

## Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

**CAUTIONrTo prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Be sure that the oil passage in the blower drive gear support is clean. Sludge accumulations, which might restrict the oil flow, must be removed.

Examine the faces of the gear thrust washers. The thickness of a new gear thrust washer is . 1190" to .1210". Replace excessively scored or worn parts.

Check the inside diameter of the blower drive gear bushings for wear. Also, check the outside diameter of the support hub. The inside diameter of new bushings is 1.877" to 1.878". The clearance between the bushings and support should be .001" to .0025" with new parts and a maximum of .005" with used parts. Install new parts whenever the *clearance* exceeds *the maximum.*

Current 12V and 16V turbocharged and intercooled engines use a nitrided hardened blower drive gear (33 teeth) and right-hand idler gear (68 teeth). Both gears are identified by the grayish color taken on by the hardening process. When replacing the former gear or its mating idler gear in the 12V or 16V turbocharged intercooled engines, both gears must be replaced at the same time with the new hardened gears.

Examine the teeth of the blower drive gear for evidence of scoring, pitting or wear. Replace the gear, if necessary.

## Assemble Blower Drive Gear And Support Assembly

After inspection, assemble the blower drive gear and support assembly as follows:

1. With the blower drive support clamped in the soft jaws of a bench vise, position the inner blower drive gear thrust washer on the support so that the tangs on the thrust washer register with the holes in the support.

2. Lubricate the hub of the support, the bushings in the gear, both thrust washers and the blower drive gear support thrust washer with clean engine oil.

3. Slide the gear on the hub with the flat side of the gear down.

4. Install the second thrust washer on the support with the tangs on the washer facing up (brass side toward the gear).

5. Position the blower drive support thrust washer on the support so that the slots in the thrust washer register with the tangs on the blower drive gear thrust washer.

6. Place the lock washer on the support and against the thrust washer with the small tang in the slot on the thrust washer. Install the locknut and tighten it to 50-60 lb—ft (68-81 N#m) torque and bend the tabs on the lock washer against the flats on the nut to secure the nut.

7. Check the clearance between the blower drive gear support thrust washer and the blower drive gear thrust washer (Fig. 3). The clearance should be .002"-.018".

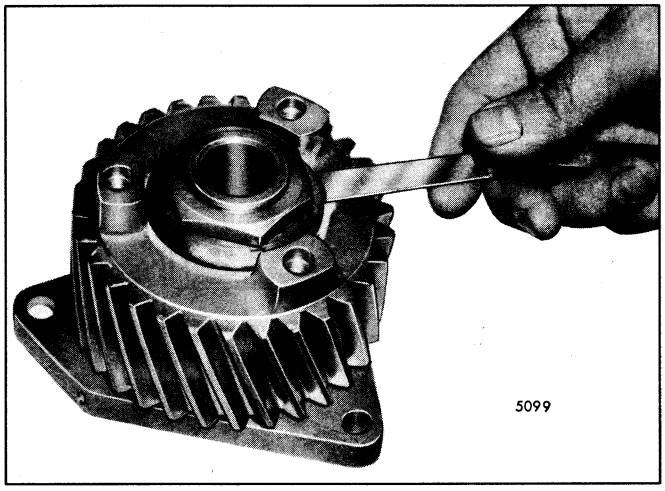



**Fig. 3 - Checking End Play**

## Install Blower Drive Gear And Support Assembly

After the clearances have been obtained, disassemble the blower drive gear and support in order to reinstall the assembly (with the flywheel housing installed).

• 1. Install a new “O” ring in the counterbore of the block at the oil supply hole and a new seal ring on the blower drive support. Then, slip the blower drive gear support through the opening in the flywheel housing of the right bank camshaft gear and attach the support to the cylinder block with three (3) 12-point 3/8”-16 bolts. Coat bolts with Loctite #271 locking compound before installing. Tighten the bolts to 50-55 lb—ft (68-75 N#m) torque.

2. Install the thrust washers, gear, lock washer and nut as described in *Assembly Blower Drive Gear and Support Assembly.*

3. Position the blower drive spring plate and blower drive hub assembly on the blower drive gear and secure it with three (3) 7/16”-20 x 7/8” self-locking bolts. Tighten the bolts to 57-61 lb—ft (77-83 N#m) torque. Then, install the blower drive shaft and snap ring.

• 4. Check the backlash between the blower drive gear and the idler gear. Backlash should be .0015” to .008” with new parts and should not exceed .010” with used parts.

5. Install the fuel pump drive disc and tighten the 3/8”-24 x 1” self-locking bolt to 50-55 lb-ft (68-75 N#m) torque.

6. Install the fuel pump adaptor and the fuel pump (Section 2.2).

7. Slide the hose from the rear blower onto the blower drive support on the 12V engine. Tighten the hose clamps. On the 8 V and 16V engines, slide the inner tube connector into the blower drive support and tighten the retaining clip bolt.

8. Install the camshaft gear and drive flange (Section 1.7.3).

9. Install the cam drive cover and any accessory which may have been removed.

# DUAL BLOWER DRIVE SYSTEM - HYDROFRACTURING UNITS

A new double-shaft drive system has been released to provide direct (shaft) drives to the rotors of both blowers used in Series 149 hydrofracturing units and certain marine applications (Fig. 4). Use of the dual drive system on these engines helps reduce and balance the stresses imposed on all blower drive components. This, in turn, results in increased blower drive component life and more trouble-free blower operation. Should either rear blower drive shaft break, the blower will continue to operate until the engine can be safely shut down.

## Double Blower Drive Shaft Installation

1. Remove both blower assemblies from the engine.
2. Remove the inter-block cup plugs from the blower drive coupling hole on the left side of the front and rear block.
3. Place a shop rag dipped in solvent on the end of a small screwdriver to aid in removal of carbon and clean the inter-block O-ring (air) seal groove. Clean the groove well. A clean groove will make it easier to install the inter-block O-ring seal.
4. Lubricate the O-ring (air) seal and the groove with a silicone spray grease or similar lubricant, then install the seal. Start at the top and press the seal into the groove, working to the bottom. An “inchworm” of extra O-ring will form at the bottom. Work the O-ring

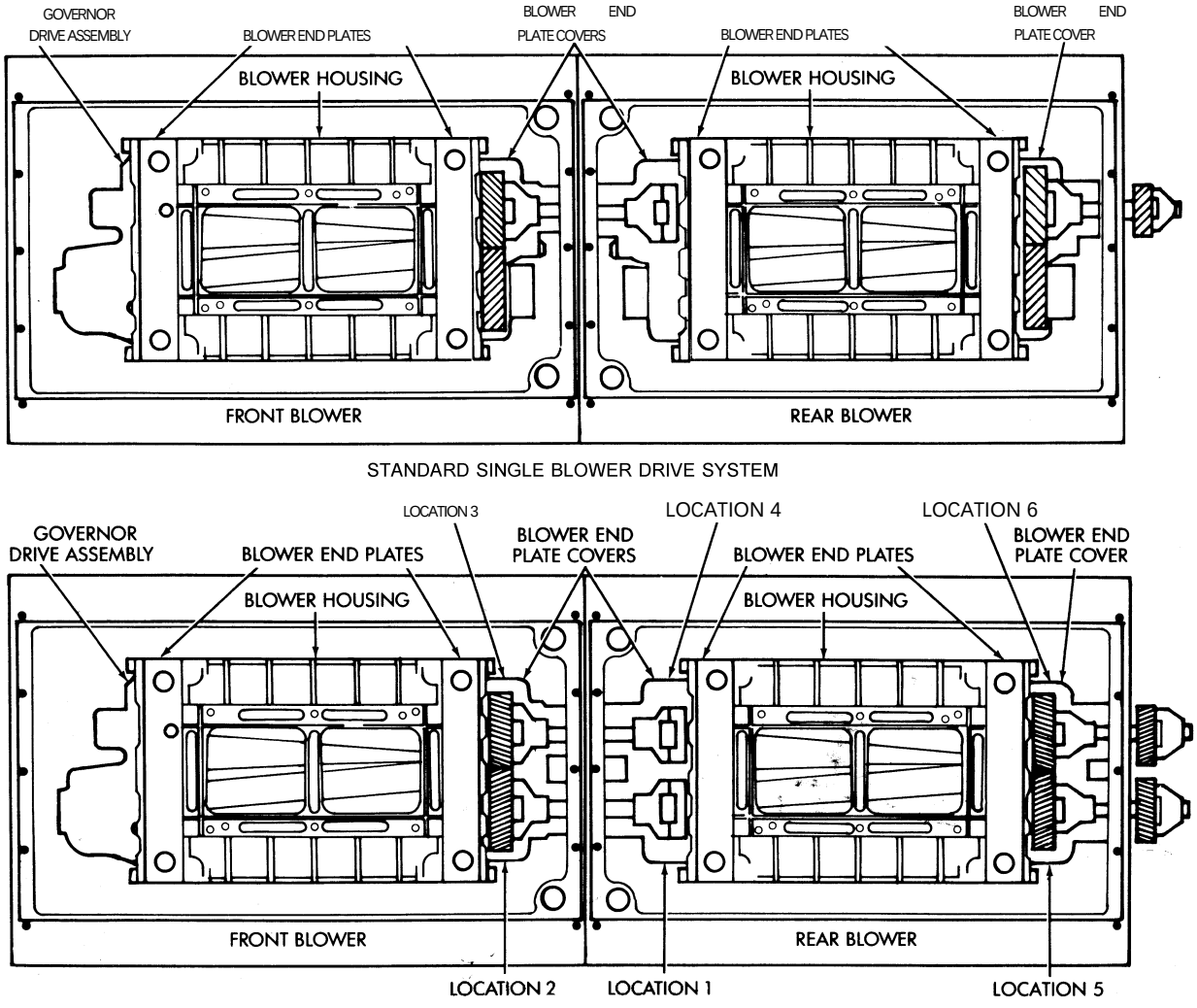



**Fig. 4 - Single and Dual Blower Drive Systems**

around and up from the bottom until the "inchworm" disappears and the seal fits uniformly in the groove.

5. Remove the three end plate covers from the two blowers.

6. Rebuild the rear blower with the new left-side rotor assembly (see Section 3.4). Install a blower rotor coupling hub on the front of both left and right rotor shafts.

7. Refer to Fig. 1 and install new hubs, flex plates and bolts at locations 1, 2, 5 and 6.

8. Fabricate a blower alignment fixture (Fig. 5) and secure both blowers to the fixture. Install an intermediate blower drive shaft on the left side. Position blowers to achieve alignment and spacing, simulating engine installation.

9. Install the right-side intermediate blower drive shaft and flex plates as follows:

   a. Assemble a hub, spring plates (3) and bolts (3). Insert bolts through the holes (not slots) in the spring plates and tighten to 57-61 lb—ft (77-83 N»m) torque. Make sure the slots in all 3 flex plates line up.

   b. Place the hub and plate assembly in position at location 4 and install the right-side intermediate drive shaft. Obtain shaft-to-hub spline engagement at locations 1, 2, 3 and 4.

   c. Install the three flex plate-to-coupling hub attaching bolts. If bolts cannot be installed, disengage the drive shaft splines by sliding the right-side shaft forward and rotating the hub and plate assembly at location 4 approximately 120°. Do not rotate the blower rotors. Reengage the splines and install the bolts. If still unsuccessful, rotate the hub and plate assembly andother 120° in the same direction. If bolts still cannot be installed, disassemble the hub and plate assembly, turn the plates over and reassemble (see Step a). Repeat Step c until the slots in the spring plates line up and flex plate-to-coupling hub bolts can be installed by hand. Tighten bolts to 57-61 lb—ft (77-83 N#m) torque.

   d. After assembly, right and left intermediate drive shafts should be free to slide fore and aft by hand. Loosen bolts and retorque as necessary to achieve this condition.

   e. Paint the right-side shaft with oil-resistant yellow paint for identification.

   f. Remove the composite assembly of parts from the blower alignment fixture and complete the assembly of the blower by adding the end plate covers, clips, etc.

10. Remove the left-bank camshaft gear, accessory drive assembly and right-side blower drive gear from the engine. Blower drive gear removal is not absolutely necessary, but aids in installation of the new left-side blower/accessory drive gear.

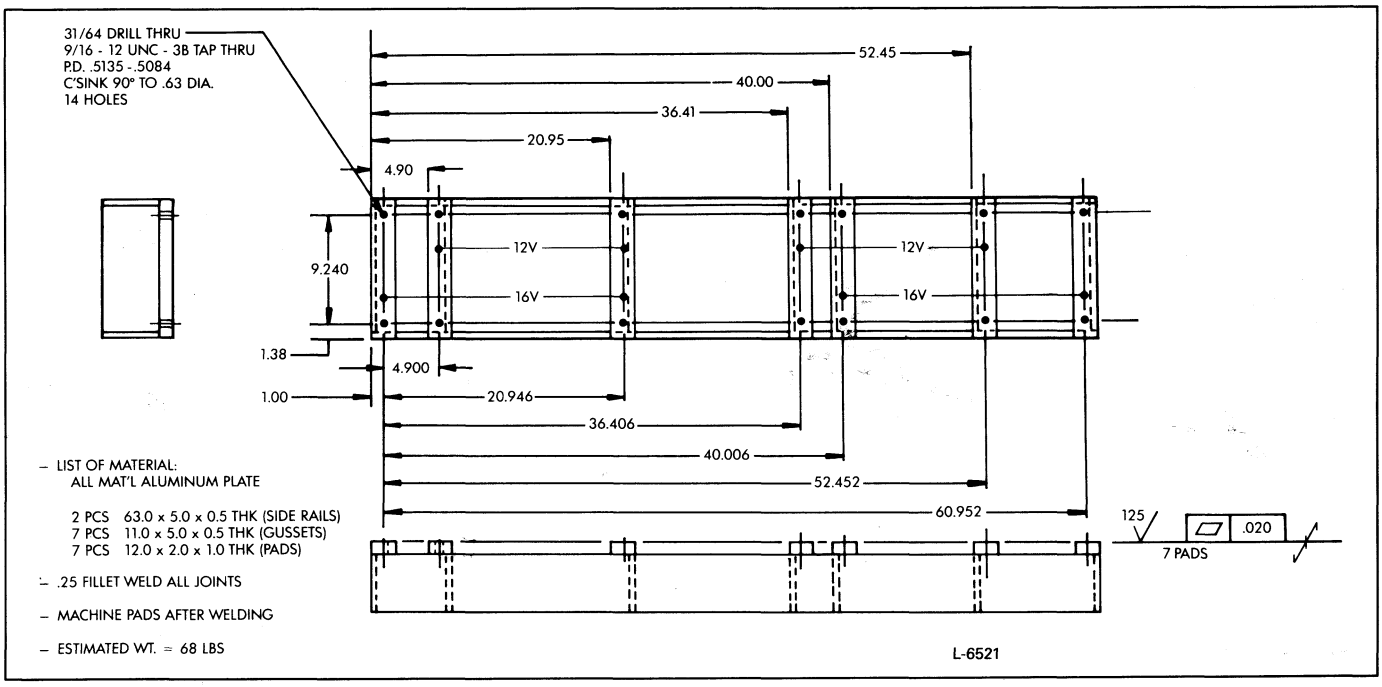



Fig. 5 – Blower Alignment Fixture

11. Assemble the new left-side accessory/blower drive hub and standard flex plates.

12. Position this assembly in the accessory drive hole on the left side. Let it stick out of the flywheel housing as far as possible.

13. Pack the flywheel housing under the accessory/blower drive position with shop rags to catch bolts in case they are dropped. Installation of the accessory/blower drive assembly may be difficult because of limited access to the three (3) bolts which hold the support to the block.

• 14. Install the left-side accessory blower drive assembly. (The extension is not installed yet). Position the three (3) flex plate bolt locations on the gear as accurately as possible in the relief areas of the flywheel housing. Be sure to install the two (2) blower drive support seals. Coat the accessory/blower drive assembly mounting bolts with Locite #271 locking compound and tighten to 50-55 lb—ft (68-75 N*m) torque.

15. Bolt the hub/flex plate assembly (Step 11) to the gear. If necessary to bar the engine over, be sure to install the left bank camshaft gear first. Use a 3/8" drive regular socket and an extension on the flex plate bolts. Tighten the bolts to 57-61 lb—ft (77-83 N*m) torque.

16. Install the blower drive gear support extension and O-ring seal.

17. Reinstall the left bank cam gear if this was not done in Step 15.

18. Reinstall the right-side blower drive gear without flex plates or drive hub if it was removed in Step 10.

19. Install the blowers and extension tubes. Make sure the right intermediate shaft is installed on the right side. Make sure there are extension tubes on both sides.

20. Install the left-side rear blower drive shaft and retaining hardware.

21. Install the right-side rear blower drive shaft, spring plates, hub, etc., as follows:

a. Assemble the hub, spring, plate and 7/16-20 x 7/8 bolt. Tighten the bolt to 57-61 lb—ft (77-83) N»m) torque. Assemble the RR blower drive shaft, retaining ring, fuel pump drive disc and 3/8-24 x 1 bolt. Tighten the bolt to 50-55 lb—ft (68-75) N*m) torque. Bolts are to be placed thru holes (not slots) in spring plates. Check that slots in all three plates line up.

b. Install the hub, plate and shaft assembly on the engine, engaging the blower hub splines and positioning the slots in the spring plates in line with bolt holes in the right-side blower drive gear. Install the remaining bolts (3). If the bolts cannot be installed, disengage the blower splines by sliding the hub, plate and shaft assembly rearward and rotate the assembly approximately 120°. Reengage the splines and install the bolts. If still unsuccessful, rotate the hub, plate and shaft assembly another 120° in the same direction as previously.

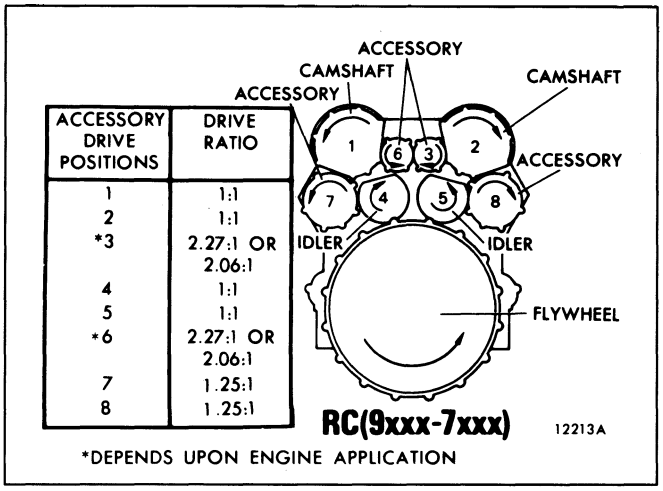
c. Reengage splines and install the bolts.

d. If still unsuccessful, remove the spring plates from the hub, plate and shaft assembly. Turn the plates over and reassemble. Repeat Steps b and c until slots in the spring plate line up with the bolt holes in the left-side blower drive gear and the bolts can be installed by hand. Tighten the bolts to 57-61 lb—ft (77-83 N«m) torque.

22. This completes double blower drive installation. Complete engine assembly by adding air system, fuel pump, alternator, etc.

# ACCESSORY DRIVES




| ACCESSORY DRIVE POSITIONS | DRIVE RATIO |
|---|---|
| 1 | 1:1 |
| 2 | 1:1 |
| *3 | 2.27:1 OR 2.06:1 |
| 4 | 1:1 |
| 5 | 1:1 |
| *6 | 2.27:1 OR 2.06:1 |
| 7 | 1.25:1 |
| 8 | 1.25:1 |

Fig. 1 – Accessory Drive Location

Accessory drives have been provided at the rear of the engine to accommodate both gear driven and belt driven accessories.

For the possible accessory drive locations, drive ratios and rotation of the drive at a particular position, refer to Fig. 1.

The drive for direct gear driven accessories, such as an air compressor or hydraulic pump, is flange mounted on the flywheel housing and is driven through a drive plate which is bolted to the camshaft gear drive flange and a drive coupling which is splined to both the drive plate and a drive hub which is keyed to the accessory drive shaft.

For a belt-driven accessory, a drive shaft is used in place of a drive coupling. One end of the drive shaft is splined to the drive plate with the opposite end supported by a bearing in the accessory drive retainer. The retainer is bolted to the accessory drive adaptor which in turn is bolted to the flywheel housing. An oil seal is pressed into the retainer to prevent oil escaping from the flywheel housing. A drive pulley is keyed to the outer end of the drive shaft and retained by a lock nut.

**NOTICE:** When an accessory drive gear is installed in positions 7 and/or 8 (Fig. 1), an external oil supply tube must be installed to provided proper lubrication to the gear(s). Failure to supply adequate lubrication can result in drive gear bearing damage.

## Remove Accessory Drive

Remove the accessory drive (Figs. 2 and 3) used with a direct-drive accessory as follows:

1. Disconnect any external piping or hoses at the accessory.
2. Remove the bolts and lock washers securing the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing. Remove the gasket.
3. Remove the drive coupling.
4. Place a clean cloth in the flywheel housing opening (under the accessory drive plate) to prevent bolts from accidentally falling into the gear train. Then remove the four bolts (and lockwashers, if used) and withdraw the accessory drive plate.

Remove the accessory drive for a belt-driven accessory (Fig. 4) as follows:

1. Loosen the accessory mounting or adjusting bolts and remove the drive belts.
2. Remove the nut which retains the drive pulley on the accessory drive shaft.

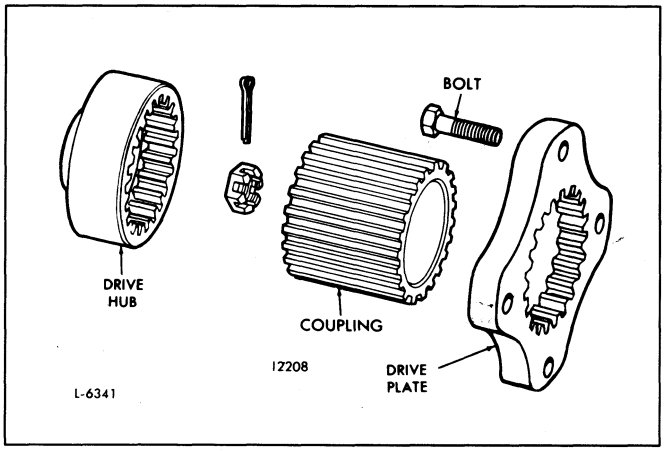



Fig. 2 – Air Compressor Drive

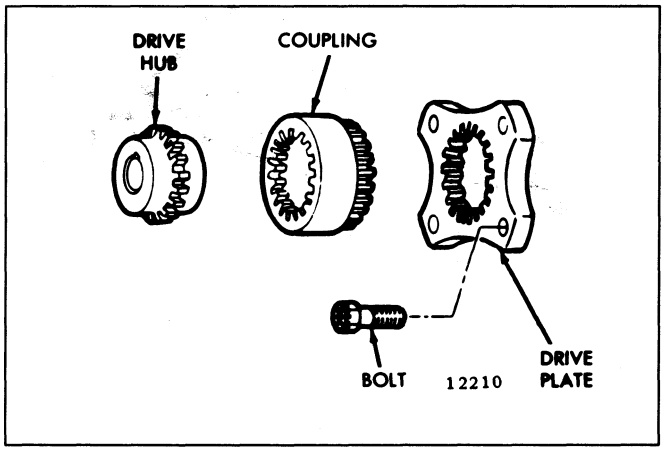



Fig. 3 - Hydraulic Pump Drive

3. Use a suitable gear puller and withdraw the pulley from the shaft. Remove the the key from the shaft.

4. Remove the bolts and washers and withdraw the accessory drive retainer assembly from the adaptor. Remove the gasket.

5. Remove the accessory drive shaft from the retainer.

6. Place a clean cloth in the flywheel housing opening (under the accessory drive plate) to prevent bolts from accidentally falling into the gear train. Then remove the four bolts and withdraw the drive plate.

7. Remove the snap ring and oil seal from the retainer, then press the bearing from the retainer.

## Inspection

Wash all of the parts, except the bearings, with fuel oil and dry them with compressed air. The shielded type bearings cannot be washed because of the difficulty in draining out all of the solvent.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the bearings for rough spots by holding the inner race and revolving the outer race slowly by hand. Any indication of rough spots is sufficient cause for rejection of a bearing. Replace excessively worn or damaged parts.

## Install Accessory Drive

Install accessory drive (direct drive) as follows:

1. Align the bolt holes in the accessory drive plate with the tapped holes in the camshaft gear. Then secure the drive plate with the four bolts (and lock washers, if used). Tighten the bolts to 45-50 lb—ft (61-68 N*m) torque.

2. Install the drive coupling.

3. Use a new gasket and position the accessory in place against the flywheel housing. Rotate it to align the teeth of the drive coupling with those in the drive hub. Then secure the accessory to the flywheel housing with bolts and lock washers.

Install accessory drive (belt driven) as follows:

1. Place the accessory drive retainer on a bench with the mounting flange side up. Lubricate the outside diameter of the bearing with engine oil, then press or tap it (with the protruding face of the inner race toward the retainer) straight in until it contacts the shoulder in the retainer. Then install the snap ring.

2. Turn the retainer over and coat the bore with sealant. Then press a new oil seal, if required, into the bore of the retainer with the lip of the seal facing the bearing. Wipe any excess sealant from the retainer.

3. Turn the retainer over again, bearing side up, lubricate the drive shaft and press it in the bearing until the shoulder on the shaft contacts the bearing.

4. Position the drive plate in the flywheel and install the four bolts (and lock washers, if used). Tighten the bolts to 35-39 lb—ft (47-53 N*m) torque.

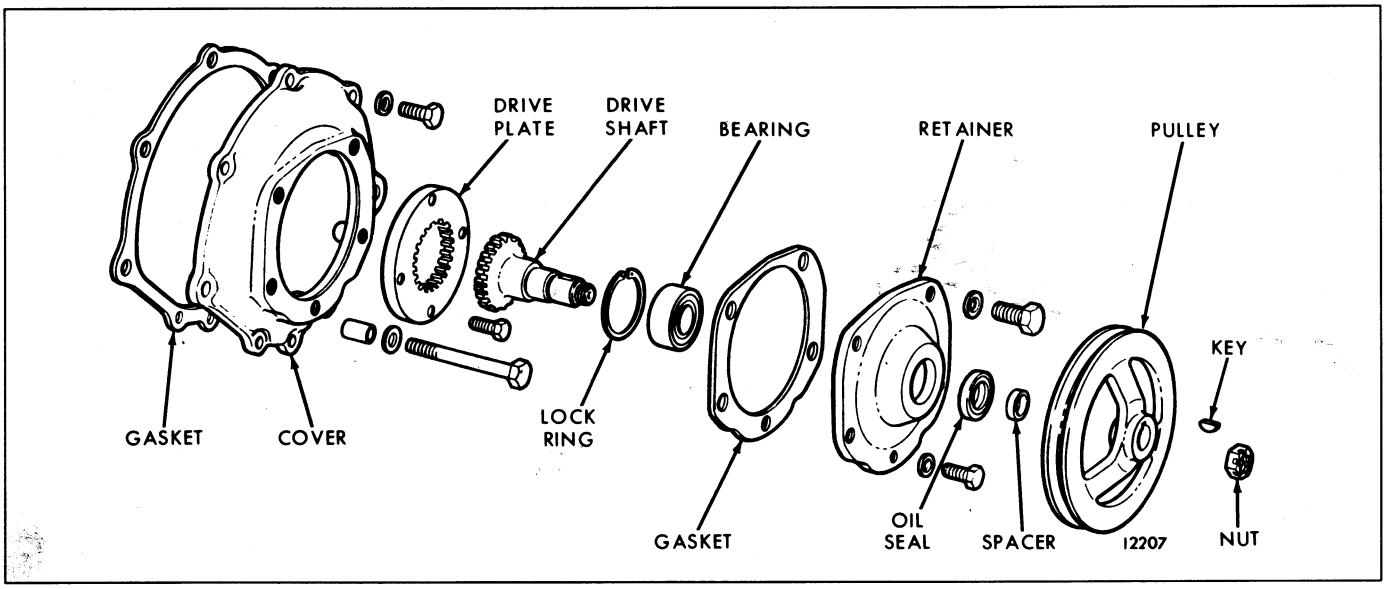



Fig. 4 – Accessory Drive (Belt–Driven)

5. Affix a new gasket to the mounting flange on the retainer. Then position the retainer and shaft assembly against the flywheel housing; rotate the shaft slightly, if necessary, to permit the teeth of the shaft to mesh with the teeth in the accessory drive plate. Secure the retainer to the flywheel housing with five bolts and lock washers. Tighten the bolts to 45-50 lb—ft (61-68 N-m) torque.

6. Install the key on the shaft. Then start the pulley on the shaft and tap it into place. Install the 3/4"-16 retaining nut. Tighten the nut to 120-140 lb—ft (163-190 N-m) torque.

7. Slip the drive belts over the pulleys. Then position the accessory to provide the proper tension on the belts and secure it in place.

**CAUTION:When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.**

# ALTERNATOR DRIVE GEAR AND SUPPORT ASSEMBLY

The alternator drive gear and support assembly is mounted at the rear of the engine. The inner assembly consists of a drive gear and bushings, drive gear support, thrust washers, lock washer and nut (Fig. 5). The drive coupling is bolted to the drive gear.

The outer alternator drive assembly is bolted to the flywheel housing. The assembly consists of a drive pulley, housing, shaft, bearing, oil seal and a drive hub keyed to the drive shaft. The drive hub and the drive coupling are coupled by a drive disc.

## Lubrication

The drive support bushings are pressure lubricated through oil passages in the cylinder block and drive support. Excess oil drains back to the crankcase by way of the gear train.

## Remove Alternator Drive Gear And Support Assembly

The drive gear and support assembly may be removed from the engine with or without the flywheel housing installed.

To remove the inner drive gear with the flywheel housing installed, the left bank camshaft gear and drive flange will have to be removed (Section 1.7.3). This will allow removal of the drive gear support through the camshaft gear opening in the flywheel housing.

1. Loosen four 3/8"—16 x 1 1/4" bolts and remove the outer drive assembly and gasket from the flywheel housing. Discard the gasket.

2. Remove the coupling disc from the coupling.

3. Loosen four 5/16"—18 x 1 3/4" bolts and remove the drive coupling from the drive gear.

4. Bend back the tabs of the lock washer and remove the nut and lock washer securing the drive gear on the support hub.

5. Remove the drive gear and thrust washers.

**CAUTION: Be careful not to drop any of the drive gear support parts in the flywheel housing.**

6. Loosen three 3/8"-16 x 1 1/4" bolts and remove the inner drive gear and support assembly from the cylinder block. Remove and discard the seal ring. Also remove and discard the “O” ring in the counterbore of the block at the oil supply hole.

7. Clamp the gear and support in a vise and remove the gear from the support hub.

## Disassemble Outer Drive Assembly

1. Remove the pulley retaining nut. Then remove the pulley and the key from the shaft.

2. Remove the oil seal spacer.

3. Press the shaft from the hub and remove the key from the shaft.

4. Remove the lock ring and bearing from the housing.

5. Press the oil seal from the housing with a suitable tool. Discard the oil seal.

## Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

**CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

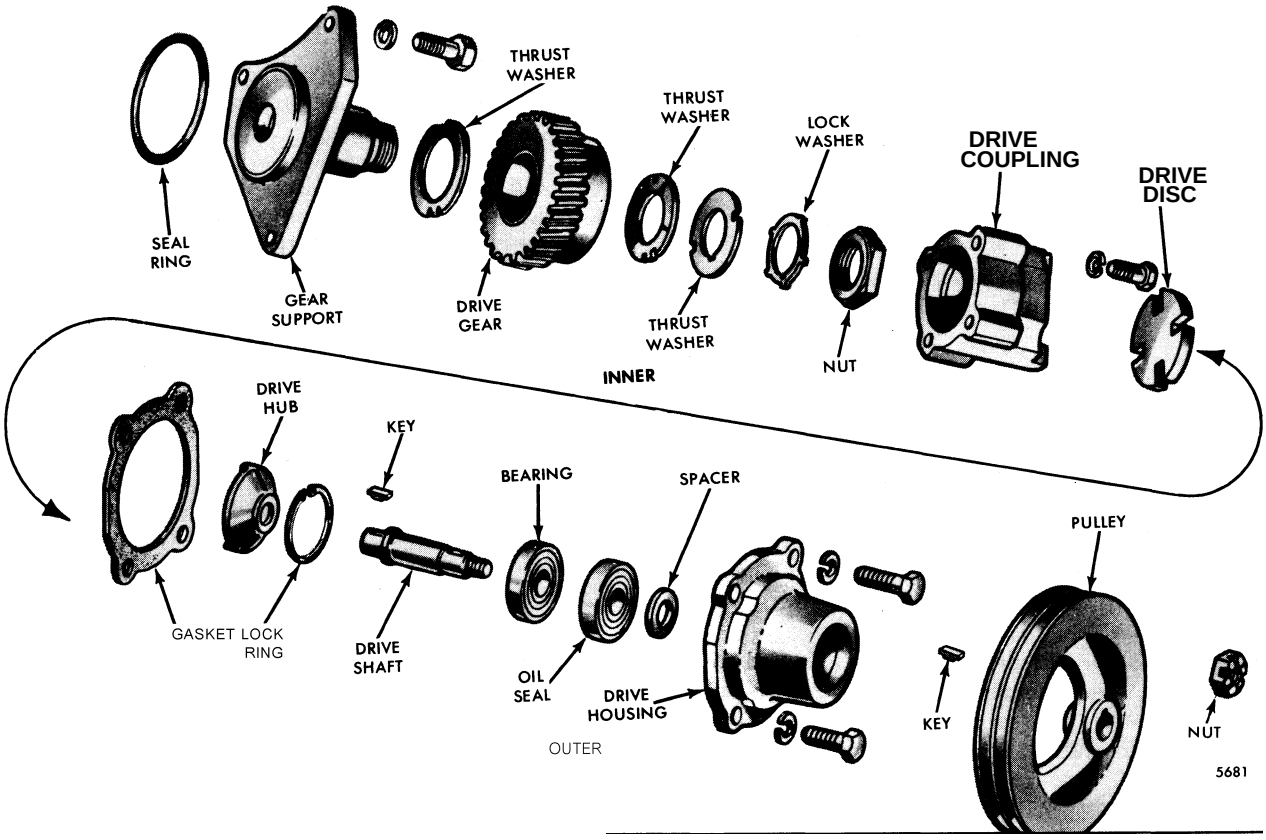



**Fig. 5 - Alternator Drive Support Assembly**

Replace excessively worn or damaged parts. Be sure that the oil passage in the drive gear support is clean. Sludge accumulation, which might restrict the oil flow, must be removed.

Inspect the ball bearing used to support the drive shaft. *Shielded bearings must not be washed,* dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the outside of the bearing clean, then hold the inner race and revolve the outer race slowly by hand. If the bearing is worn or does not roll freely, replace it.

Examine the faces of the gear thrust washers. The thickness of a new gear thrust washer is .1190” to .1210”. Replace excessively scored or worn parts.

Check the inside diameter of the drive gear bushings for wear. Also check the outside diameter of the support hub. The inside diamter of new bushings is 1.877” to 1.878”. The clearance between the bushings and support should be .001” to .0025” with new parts and a maximum of .005* with used parts. Install new parts whenever the clearance exceeds the maximum.

Examine the teeth of the drive gear for evidence of scoring, pitting or wear. Replace the gear if necessary.

## Assemble Alternator Drive Gear And Support Assembly

After inspection, assemble the drive gear and support assembly (Fig. 5) as follows:

1. With the drive support clamped in the soft jaws of a bench vise, position the inner drive gear thrust washer on the support so that the tangs on the thrust washer register with the holes in the support.

2. Lubricate the hub of the support, the bushings in the gear, both thrust washers and the drive gear support thrust washer with clean engine oil.

3. Install the gear on the hub with the flat side of the gear down.

4. Install the second thrust washer on the support with the tangs on the washer facing up (brass side toward the gear).

5. Position the drive support thrust washer on the support so that the slots in the thrust washer register with the tangs on the drive gear thrust washer.

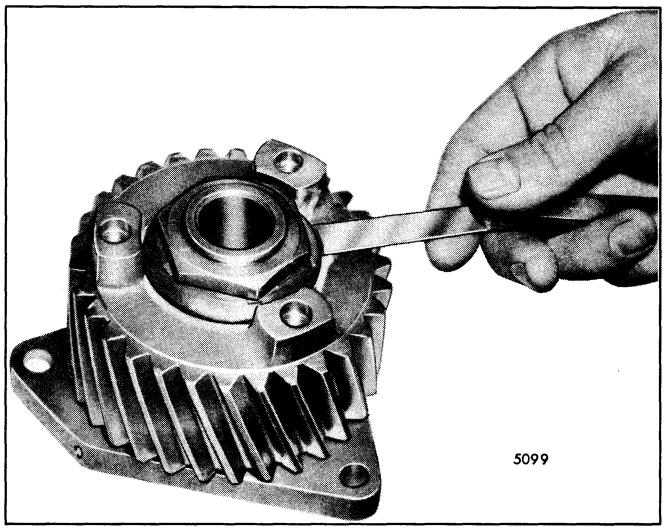



Fig. 6 – Checking End Play

6. Place the lock washer on the support and against the thrust washer with the small tang in the slot on the thrust washer. Install the lock nut and tighten it to 50-60 lb—ft (68-81 N-m) torque and bend the tabs on the lock washer against the flats on the nut to secure the nut.

7. Check the clearance between the drive gear support thrust washer and the drive gear thrust washer. The clearance should be ,002”-.018” (Fig. 6).

## Install Drive Gear And Support Assembly

After the clearances have been obtained, disassemble the drive gear and support in order to reinstall the assembly (with the flywheel housing installed).

• 1. Install a new “O” ring in the counterbore of the block at the oil supply hole and a new seal ring on the drive support. Then slip the drive gear support through the opening in the flywheel housing of the left bank camshaft gear and attach the support to the cylinder block with three 3/8”-16 x 1 1/4” bolts. With Locite #271 locking compound applied to bolts, tighten the bolts to 30-35 lb—ft (41—47 N-m) torque.

2. Install the thrust washers, gear, lock washer and nut as described in *Assemble Alternator Drive Gear and Support Assembly.*

3. Check the backlash between the drive gear and the idler gear. Backlash should be .003” to .008” with new parts and should not exceed .010” with used parts*

4. Position the drive coupling on the drive gear and secure it with four 5/16”—18 x 1 3/4” self-locking bolts. Tighten the bolts to 13-17 lb—ft (18-23 N-m) torque.

5. Install the camshaft gear and drive flange (Section 1.7.3).

## Assemble Outer Drive Assembly

1. Install the key in the hub end of the drive shaft. Lubricate the shaft and press the hub against the shoulder on the shaft.

2. Use a suitable tool and press a new oil seal in the drive housing.

3. Install the bearing and spacer in the drive housing, then install the lock ring.

4. Use a sleeve to support the inner race of the bearing, lubricate the shaft and press the hub and shaft assembly in the bearing until the shoulder on the shaft contacts the inner race of the bearing.

5. Install a key in the pulley end of the shaft. Lubricate the shaft and press the pulley on the shaft until it contacts the inner face of the oil seal spacer.

6. Install the 3/4”—16 pulley retaining nut and tighten it to 120-140 lb—ft (163-190 N-m) torque.

7. Place a new gasket on the mounting flange of the drive housing.

8. Place the slotted drive disc on the hub of the drive assembly. Then align the slots in the disc with the lugs on the drive hub which is attached to the drive gear and carefully position the drive against the flywheel housing. Secure the drive assembly to the flywheel housing with four 3/8”-16 x 1 1/4” bolts and lock washers.

9. Place the drive belts over the pulleys and adjust the tension on the belts. Then tighten the mounting bolts to 30-35 lb—ft (41-47 N-m) torque.

# SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

## SHOP NOTES

## DIMENSIONS FOR LINE-BORING CYLINDER BLOCK

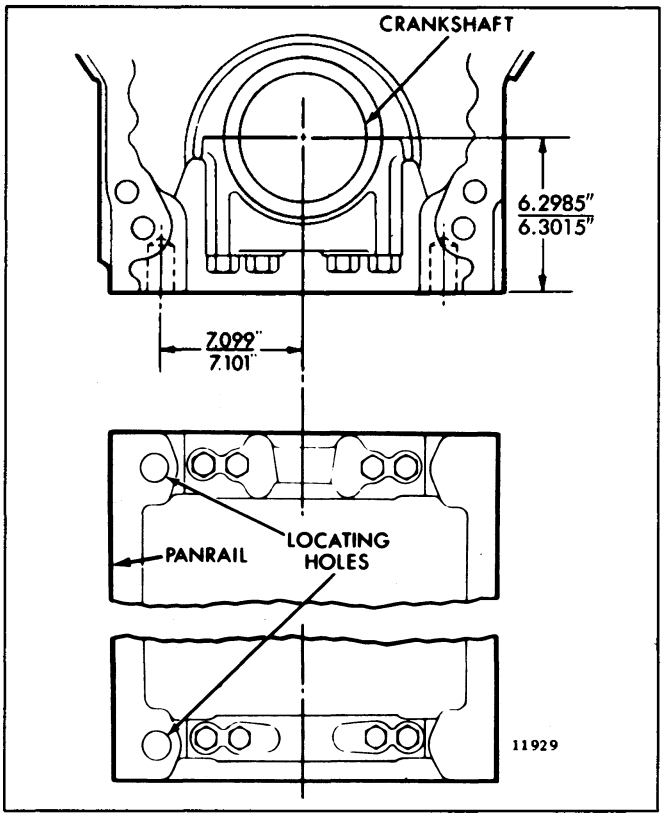



Fig. 1 – Line–Boring Dimensions

When a cylinder block becomes worn or damaged in the main bearing bores and it is desired to salvage the cylinder block by line-boring, there are critical dimensions that must be maintained.

In a given bore, the specified diameter is qualified through averaging. Three diameter measurements are taken at *10, 12 and 2 o'clock* positions, in a single plane located on either side of the oil hole for a particular bore. The three readings are averaged and that average must fall within 5.187”-5.188”. Any of the three individual readings can range between 5.187”-5.1885”. However, the minimum to maximum diameter must not exceed .001”.

Oversize on the outside diameter main bearing shells are available in .020” and .040” oversize only. The bore size diameters for the oversize main bearing shells are listed in Table 1.

| Main Bearing | Main Bearing Bore |
|---|---|
| Standard | 5.1 87" —5.188" |
| .020" oversize | 5.207" —5.208" |
| .040" oversize | 5.227" —5.228" |

TABLE 1

1. The cylinder block assembly must be separated and each half-block line-bored separately. To be properly aligned during assembly, it is necessary that both halves of the cylinder block be bored to the same size.
2. The main bearing caps must be installed in the block and the bolts, with their hardened washers, torqued to 280-290 lb—ft (379-393 N#m) torque. The bearing caps must fit tight in the block. If they are loose they must be replaced. Main bearing cap bolts are specially designed and must not be replaced by ordinary bolts.

The surface from which all critical dimensions are measured for line-boring are the reamed locating holes (1.4365”-1.4380” in diameter) at each end of the right pan rail, looking from the gear train end of the cylinder block. The center line of the crankshaft is **7.099"-7.10r** in from the center line of the reamed locating holes and **6.2980”-6.3020”** up from the pan rail surface (Fig. 1).

4. The straightness of the finished bore must not vary more than .003” from end to end in the cylinder block.
5. Check and assemble the line-bored block halves. When the cylinder block has been bores .020” oversize, use alignment tool J 24542. When it has been bored .040” oversize, use alignment tool J 24543.
6. Stamp all main bearing caps to show they have been bored oversize and the amount (.020” or .040”).

Several diameter measurements are taken at the *12 o'clock* position, each in different planes to determine taper of an individual bore. Main bearing bore taper is a maximum of .001”.

Roundness is determined from the three readings taken for bore diameter. Main bearing bore out of round is a maximum of .001”.

When rebuilding, it is important to remember that cleaning the bores with a solvent type cleaner is acceptable, while further surface enhancement by means which would remove any metal is not acceptable and not recommended.

# PROCEDURE FOR INSTALLING CYLINDER BLOCK COOLANT HOLE SLEEVES

1. Ream the cylinder head-to-block coolant holes in the cylinder block. Use a 25/64" reamer to increase the hole diameter from 3/8" to 25/64". To facilitate reaming, grind a 3/8" diameter pilot 1/2" in length on the end of the reamer.
2. Clean the coolant holes and the seal counterbores thoroughly with a solvent.
3. Apply HVV "Loctite" pipe sealant to the surfaces of the coolant holes.
4. Install the coolant hole sleeves in the coolant holes with sleeve installer J 24233-01. The tool will install the sleeves to the proper depth so the sleeves will extend up into the counterbore sufficiently to retain the seal rings.
5. Clean the "Loctite" thoroughly from the seal ring counterbores.

# BREATHER HOLE PLUGS IN CYLINDER BLOCK

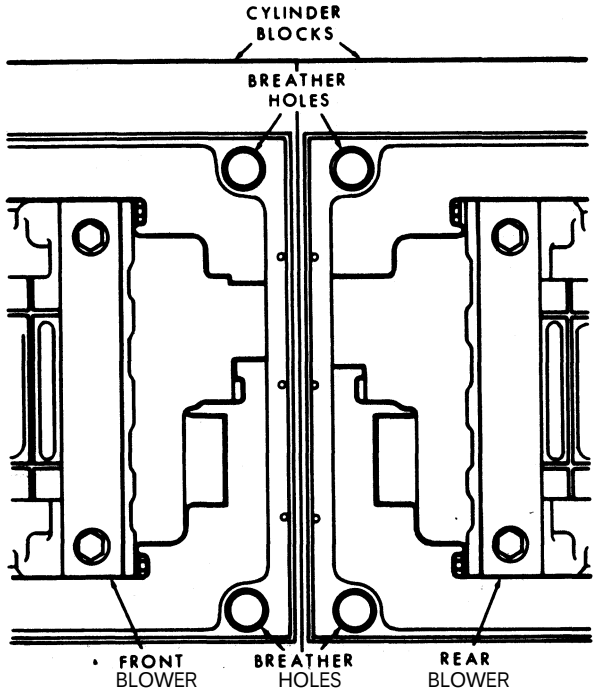



**Fig. 2 - Location of Breather Holes in Cylinder Block**

There are four 1.5625" diameter crankcase breather holes provided at the top of the cylinder block where the front and rear cylinder blocks are bolted together (Fig. 2). Seal rings are used between the air box cover plate and the cylinder block to keep the air from the air box from entering the crankcase.

When rocker cover breathers are used on turbocharged engines, flat plates are used to seal off the breather holes in the cylinder block.

Effective with approximate serial numbers 12E-2601 and 16E-2311, all cylinder blocks are machined to accept breather hole cup plugs. The cup plugs are used in place of the seal rings to seal off the breather holes when rocker cover breathers are used. Use of the cup plugs eliminates the possibility of seal rings being blown into the breather holes and resulting in high crankcase pressure.

To install cup plugs, where required, on former cylinder blocks, proceed as follows:

1. Remove the seal rings from the breather holes.
2. Machine the breather holes to 1.616"-1.620" diameter and .375" deep. Make sure all metal chips are removed after machining.
3. Install the cup plugs, using a suitable sealant, so the plugs are fliish with or slightly below the top of the cylinder Wock. These cup plugs are the same as the plug used in the rear oil gallery hole.

# CYLINDER BLOCK LINER SEAL RING GROOVE REWORK

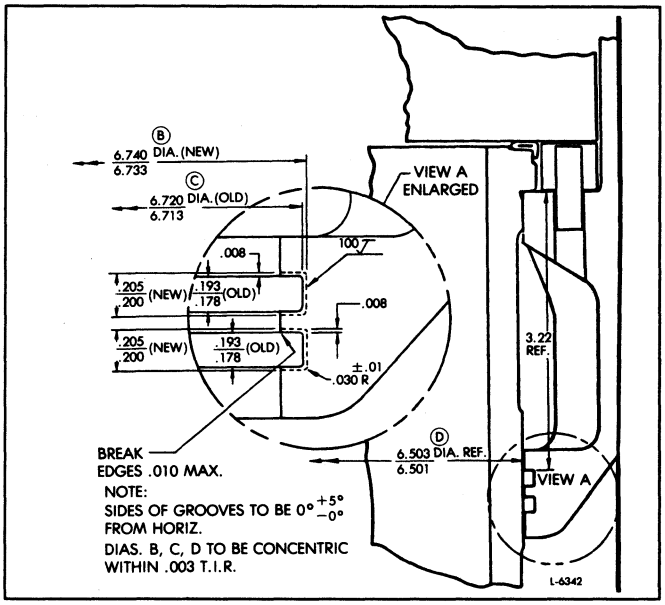



**Fig. 3 - Liner O-Ring Groove Rework Dimensions**

During overhaul of a Series 149 engine, inspection of the block may reveal erosion damage in the liner seal ring groove area. Erosion of the ring grooves can occur if the coolant inhibitor strength is not properly maintained. To permit reuse of the block and provide proper liner-to-block sealing under these circumstances, a .010" oversize seal ring may be used. However, before this seal can be installed, the cylinder block seal ring grooves must be machined larger to allow for the larger seal diameter.

Servicing facilities wishing to use oversize liner seal rings should contact a reliable local machining source and provide them with the liner groove rework dimensions (Fig. 3).

# NEW STAINLESS STEEL CUP PLUGS FOR CYLINDER BLOCKS

Two new oversized O.D. (outside diameter) stainless steel cup plugs have been released for service installation in reworked cup plug holes in the sides of Series 149 engine cylinder blocks (Fig. 4). Standard size and new oversized O.D. plugs are shown in the Chart.

Measure the holes to determine the cup plugs required and make sure that the plugs and bores are clean and free of oil. Before installing cup plugs, apply a light coating of Loctite 277 or Loctite 11474 Sealant or equivalent to the block bores and the O.D. of the plugs. Install plugs flush to .013" below the surface of the boss and make sure they are watertight.

| Cup Plug | Cup Plug Holes Should Measure |
|---|---|
| 2-1/2" dia. | 2.500-2.504 |
| 2-5/8" dia. | 2.625-2.629 |
| 2-3/4" dia. | 2.750-2.754 |

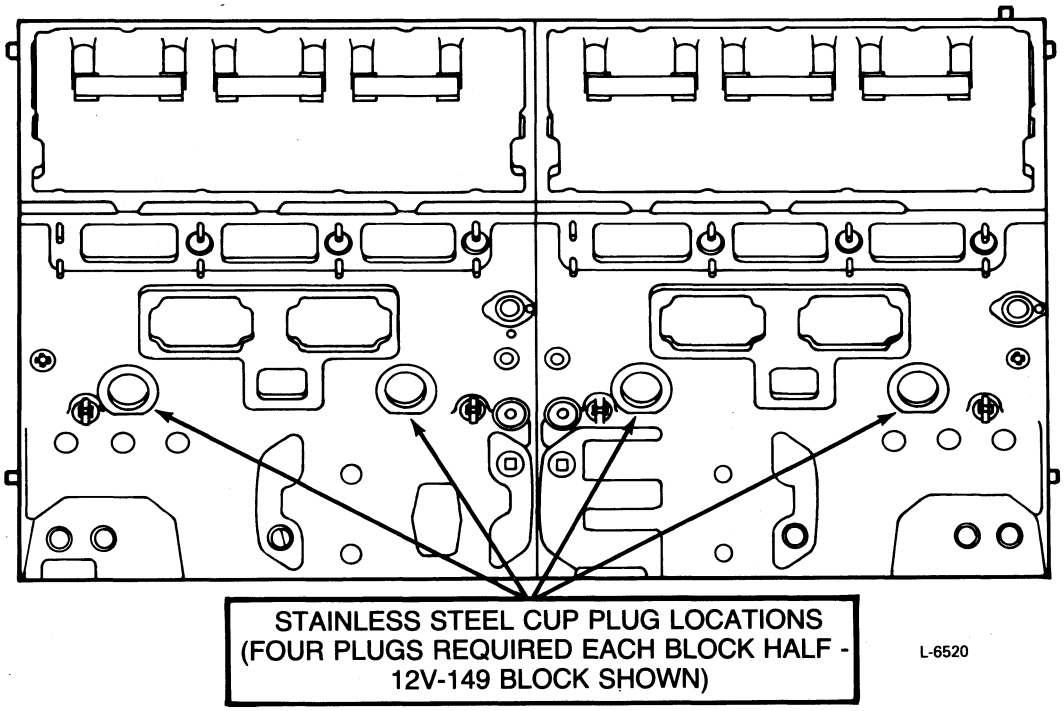



**Fig. 4 - Location of Cup Plug**

# AIR BOX CORE PLUG HOLE THREAD REPAIR PROCEDURE

When minor core plug hole damage is discovered on an otherwise usable new cylinder block, a thread rework procedure is used in production to correct the condition before engine build. Ths procedure should also be used on existing blocks if the core plug hole threads are ever damaged. Core plug holes can be reworked whenever the engine is disassembled for overhaul.

## Procedure:

1. Machine the existing core plug hole threaded opening to 2.9320"-2.9408M.

2. Using a 3.00-16 UN-3B thread tap (2.9594-2.9649 pitch diameter), thread the hole for installation of the service bushing.

**NOTICE:** Since metal particles from the machining and threading operationsa can damage cooling system components, make sure that all metal particles are contained and completely removed from the block after these operations.

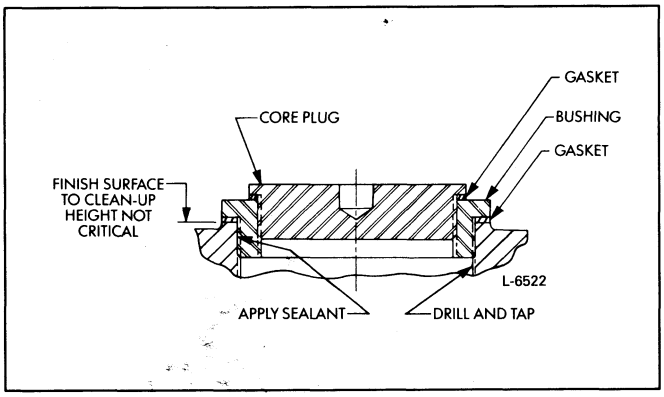



**Fig. 5 - Air Box Core Plug Hole with Service Bushing and Plug Installed**

3. With the new threads thoroughly clean and dry, apply Loctite grade AA thread locking sealant, Loctite 290 or equivalent sealant, to the threaded area.

4. Place the bushing-to-block gasket in place and install the service bushing (Fig. 5).

5. Place the core plug-to-bushing gasket in place and install the core plug. Tighten the core plug to 230-270 lb-ft (312-366 N#m) torque. Allow the sealer to cure for two (2) hours before pressure testing the block. This will help ensure a leak-free installation.

6. Refer to Section 1.1, "Pressure Test Cylinder Block", to determine if the core plug-to-bushing and bushing-to-block threaded areas are providing an adequate coolant seal.

**NOTICE:** Hot tank cleaning of the cylinder block destroys the integrity of the core hole plug and bushing gaskets. Therefore, the core hole plugs, bushings and gaskets must be removed before the block is cleaned. Since the bushings and plugs may be damaged during removal, always use new bushings, plugs and gaskets when rebuilding the block.

# CYLINDER HEAD LIFTING HANDLES

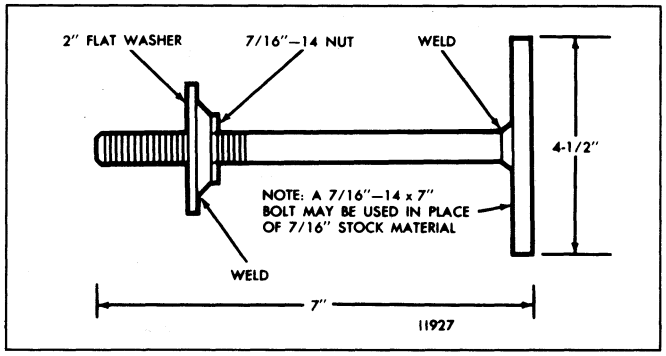



Fig. 6 – Cylinder Head Lifting Handles

Due to the recessed installation of the cylinder heads ("pot" heads) on the Series 149 engine, a pair of "T" handles (Fig. 6) may be fabricated to facilitate cylinder head handling if lifting tool J 24232 is unavailable.

The threaded ends of the lifting handles fit into tapped holes provided on the top of the cylinder head. The nut and washer assemblies provide a surface against which a pry bar can be used to loosen hard-to-budge cylinder heads.

A set of "T" handles will add greatly to the ease and safety with which the cylinder heads can be installed, removed or transferred from one place to another in the shop.

# REWORK CYLINDER HEAD FOR OVERSIZE VALVE SEAT INSERT

| .010" OVERSIZE O.D. COUNTERBORE | |
|---|---|
| Diameter | 1.9065' - 1.9070' |
| Depth | .4010' - .4060' |
| Counterbore Runout/Guide | Within .001' |
| Taper of Counterbore | No Taper Allowed |
| Flatness of Counterbore | Parallel Within .002' |
| Runout of Insert | Within .002' |
| Press Fit | .0010' - .0025' |

TABLE 2

A .010" oversize O.D. (outside diameter) exhaust valve seat insert may be used to extend cylinder head service life. A kit consists of an insert (not serviced separately) and complete installation instructions. An oversize insert is installed after the standard insert is removed and the cylinder head is reworked to the dimensions shown in Table 2.

Because of the critical tolerances involved and to prevent the possibility of cylinder head damage, the rework precedure should be performed by a reliable, professional machine shop.

# WELDING OF ENGINE CYLINDER HEADS

The welding of cylinder heads has been used as a salvage procedure for several years. As a salvage procedure, the resultant product has not been considered as good as a new casting. The use of this procedure has caused some concern because of the differences in what has been called a welded cylinder head.

Detroit Diesel's position on the use of welded cylinder heads has been requested from several areas in the past. It is important to note that no data of statistical significance has been made available by welders or end users. Based on the inquiries received and the amount of cylinder heads being welded in the field, Detroit Diesel has investigated the methods of welding and resultant integrity of welded heads as compared to new cylinder heads used on Detroit Diesel engines. Since the procedure used when welding, subsequent machining and the rebuild methods of the cylinder head may result in unacceptable service life, there should be no implied approval of any welding source or welded components.

The following is Detroit Diesel's position on various aspects related to welded cylinder heads.

1. Welding is considered the process of elevating the original cylinder head casting to approximately 1100°F or 593°C (a temperature that is at least equivalent to stress relieving) and the addition of alloyed cast iron welding rod to the crack area while in the molten state. Low temperature, low voltage welding is considered a cosmetic salvage and should never be accepted., as a structural repair.

2. Mechanical plugging is a salvage procedure that usually results in excessive installation stresses at the repaired area and should never be confused with or accepted as equivalent to welding. This procedure should not be used on cylinder heads.

3. If properly performed, welding of a cylinder head may be a salvage procedure if the welding is done outside of the fire circle. Service life of a welded cylinder head, however, will not be equivalent to a new casting even if the fire circle area of the original casting has not been welded. A cracked casting is usually the result of an overheat and the casting may be damaged in areas other than the visible crack.

4. Comparative testing indicates that welding inside of the fire circle will result in a service life less than 50% of a new casting. This has resulted in the conclusion that welding in the fire circle should not be done. In order to eliminate potential future failures on DDC engines, cylinder heads cracked in the firecircle should be destroyed.

5. Series 149 heads are essentially all "fire circle", and should not be welded on the fire deck, nor in the area of the bolt hole located between the exhaust ports.Cracks in non-critical areas generally have not been observed to any extent.

6. Cylinder heads that have been welded should be checked for acceptability using Sections 1.2 through 1.2.2 of the Service Manual. This includes checking for cracks, thickness of the cylinder head,warpage, camshaft follower clearance and the press fit of all other components. Various conditions have been found with welded cylinder heads that could cause malfunctions of secondary components if these are not checked. If any discrepancy can not be repaired, such as cylinder head thickness, the part should not be used.

7. Components that are used with these cylinder heads should also be checked. Components that are not acceptable should not be used.

**NOTICE:** Secondary damage to other engine components could result from not checking these components.

# CHECKING BEARING CLEARANCES

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially, and is available in three sizes and colors. Type PG-1 (green) has a clearance range of .001" to .003", type PR-1 (red) has a range of .002" to .006", and type PB-1 (blue) has a range of .004" to .009".

The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and crankshaft journal.

**NOTICE:** When checking the main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading can be eliminated by supporting the weight of the crankshaft with a jack under the counterweight adjoining the bearing being checked.

2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 7).

3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

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

5. Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope (Fig. 7). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

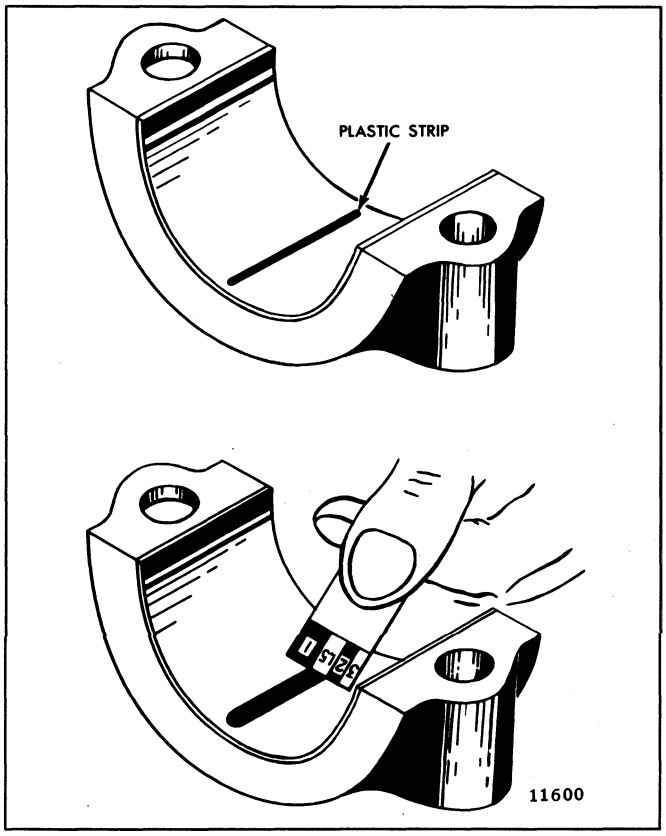
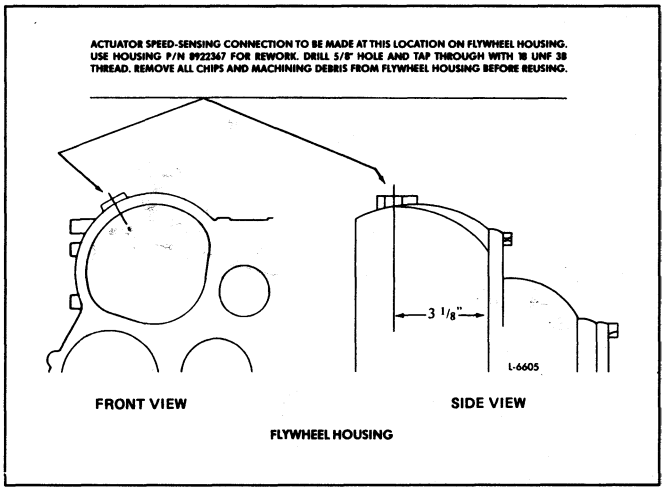


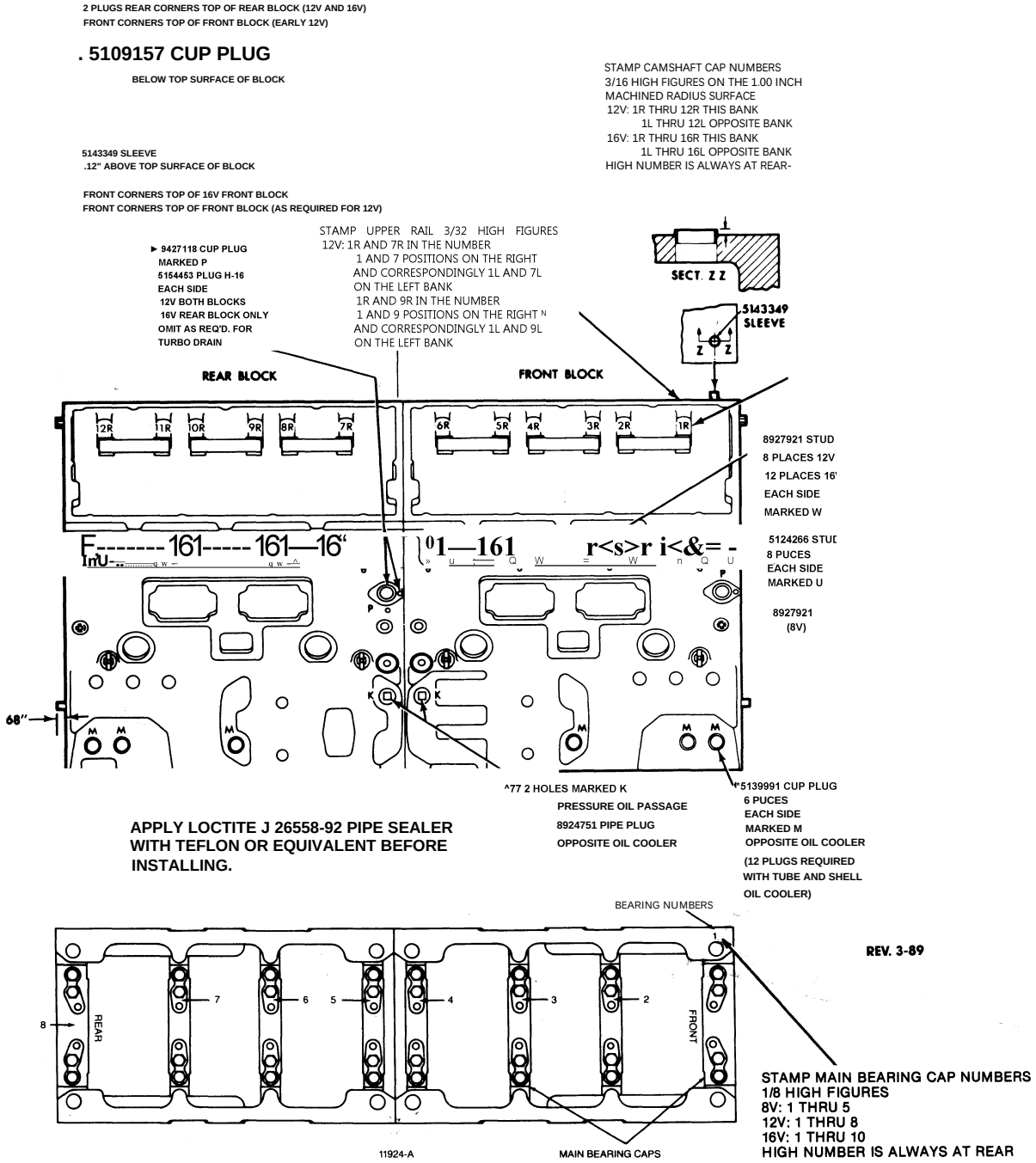

**Fig. 7 - Measuring Bearing-to-Crankshaft Clearance with Plastic Strip**

# REWORK FLYWHEEL HOUSING FOR HIGH TORQUE RISE ENGINE MANGETIC PICKUP

When adding high torque rise features to existing 12V-149T and TI engine models 9123-7300 and 9123-7301, the flywheel housing must be modified as shown to permit installing the magnetic pickup components required on these units.

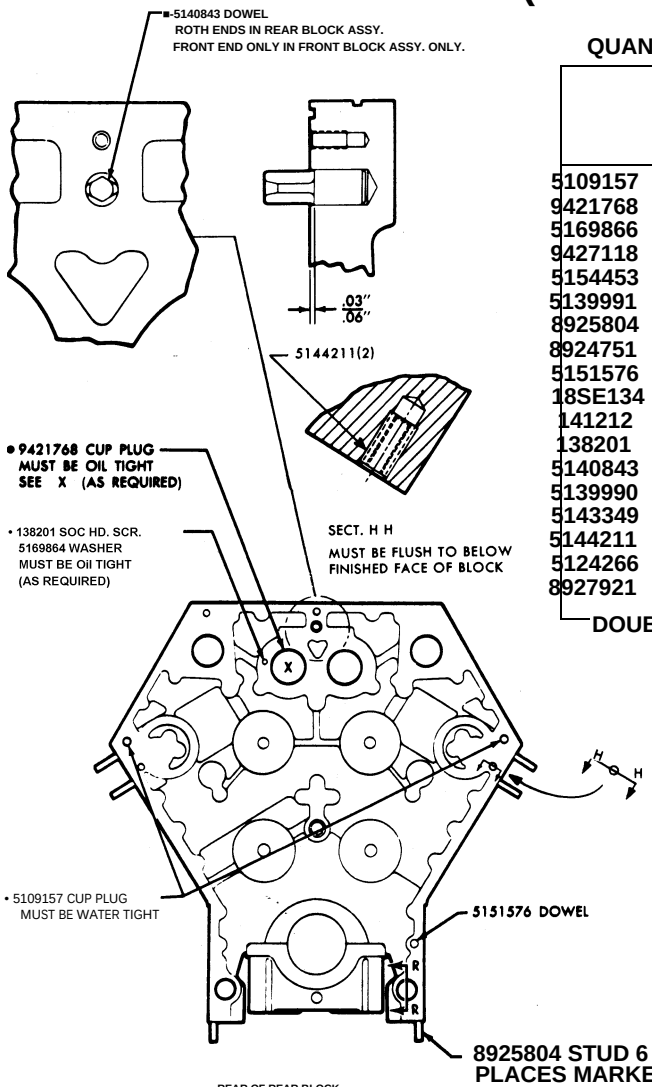


# 8V, 12V AND 16V CYLINDER BLOCK PLUGGING INSTRUCTIONS (12V-149 SHOWN)



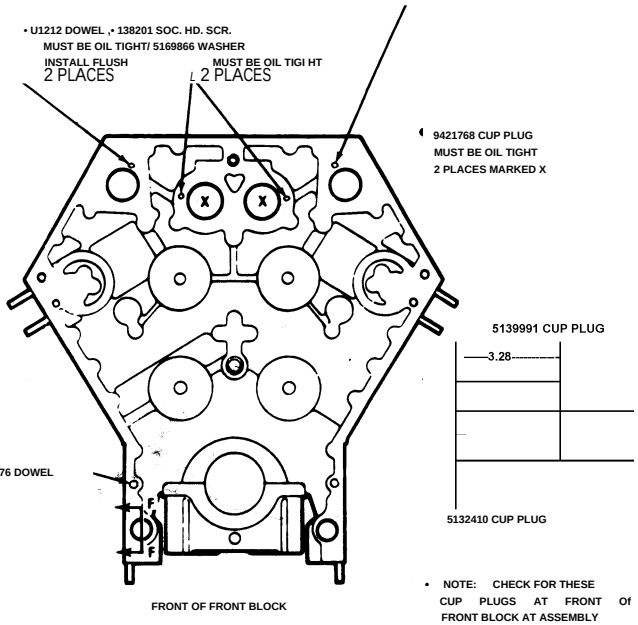
# 8V, 12V AND 16V CYLINDER BLOCK PLUGGING INSTRUCTIONS (12V-149 SHOWN)




QUANTITIES SHOWN ARE FOR A COMPLETE BLOCK ASSEMBLY

| | | FRONT 23501950 12V | 23501951 16V | REAR 23501952 12V | 23501953 16V | 23501954 8V |
|---|---|---|---|---|---|---|
| 5109157 | PLUG, CUP | | | 2 | 2 | |
| 9421768 | PLUG, 3" CUP | 2 | 2 | 1 | 1 | 1 |
| 5169866 | WASHER 7„" COPPER (HOLE) | 2 | 2 | 1 | 1 | 1 |
| 9427118 | PLUG, 1%" CUP (TURBO) | 2 | 2 | 2 | 2 | |
| 5154453 | PLUG, 7." 16 (DRAINS) | 2 | 2 | 2 | 2 | |
| 5139991 | PLUG, 1 '/a" CUP (OIL COOLER HOLES) | 3* | 3* | 3* | 3* | |
| 8925804 | STUD, /i«x2/j* (OIL PAN RAILS) | 3 | 3 | 3 | 3 | 1 |
| 8924751 | PLUG, I%"x7," PIPE | 1 | 1 | 1 | 1 | |
| 5151576 | PIN, ViW," DOWEL | 1 | 1 | 1 | 1 | 2 |
| 18SE134 | INSTR. DRAWING | 1 | 1 | 1 | 1 | |
| 141212 | PIN, 5%,"x7„" DOWEL | 2 | 2 | | | |
| 138201 | SCREW 20.3/4" | 2 | 2 | 1 | 1 | 1 |
| 5140843 | PIN, SPECIAL DOWEL | 1 | 1 | 2 | 2 | 2 |
| 5139990 | PLUG, 1 7u" CUP | 1 | 1 | 1 | 1 | |
| 5143349 | SLEEVE, 1 „ DIA. (GOV. LINK HOLE) | 2 | 2 | | | 2 |
| 5144211 | REDUCER-THD. 7,-11 TO 7,-16 | | | 2 | 2 | |
| 5124266 | STUD 16-"13-20x2.80" (EXH-ENDS) | 8 | 8 | 8 | 8 | |
| 8927921 | STUD V4 -"-13-20 x 2 '/a" (EXH-INTERMEDIA' | 8 | 12 | 8 | 12 | 20 |

DOUBLE QUANTITY WHEN TUBE AND SHELL OIL COOLER IS INSTALLED.




APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT BEFORE INSTALLING.

3 28-

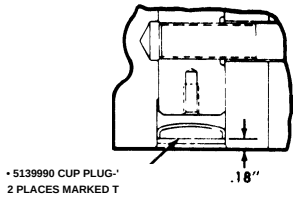
/-5139991 CUP PLUG

XVXV^XXW V

5132410 CUP PLUG

SECT R-R

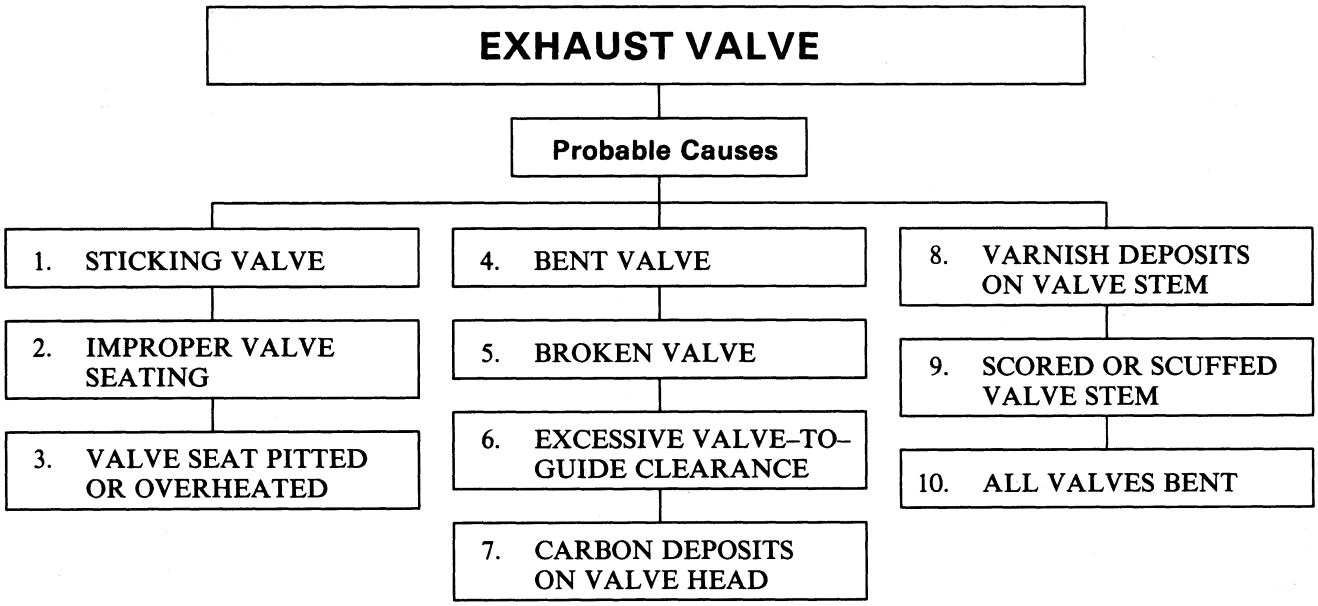
• NOTE ; CHECK FOR THESE
CUP PLUGS AT REAR OF
REAR BLOCK AT ASSEMBLY




REV. 3-89

UNLESS OTHERWISE NOTED, APPLY LOCTITE 230 SEALANT OR EQUIVALENT TO CUP PLUGS BEFORE INSTALLING.

# TROUBLESHOOTING




# SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (glycol) in the lubricating oil. Replace a bent guide. Cleanup and reface the valve. Replace the valve, if necessary.

2. Check for excessive valve-to-guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary.

3. Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder-face valve if the operating conditions warrant.

4. Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge, or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Replace damaged parts.

5. Check for excessive valve-to-guide clearance, a defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder 10. head and piston for damage. Replace damaged parts.

6. Replace a worn valve guide. Check and replace the valve, if necessary.

7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too light a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Cleanup the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.

8. Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.

9. Check for a bent valve stem or guide, metal chips or dirt, or for a lack of lubrication. Cleanup the valve stem with crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap DOES NOT scrape the valve stem.

Check for a gear train failure or for improper gear train timing.

# SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this Chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text,

# TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| CYLINDER BLOCK | | | |
| Block bore: | | | |
| Diameter (upper pilot) | 6.5220" | 6.5240" | 6.5260" |
| Diameter (seal ring lands) | 6.5010" | 6.5030" | 6.5050" |
| Diameter (water jacket) | 6.4000" | 6.4020" | 6.4040" |
| Out-of-round | | .0015" | |
| Taper | | .0015" | |
| •Cylinder liner counterbore: | | | |
| Diameter | 6.9080" | 6.9140" | |
| Depth | .4920" | .4960" | |
| Main bearing bore: | | | |
| Inside diameter | 5.1870" | 5.1880" | |
| Camshaft bearing bore: | | | |
| Inside diameter (former) | 2.1510" | 2.1520" | |
| Inside diameter (current) | 2.1505" | 2.1525" | |
| CYLINDER HEAD . | | | |
| Exhaust valve seat counterbore: | | | |
| Diameter | 1.8965" | 1.8975" | |
| Depth | .4010" | .4060" | |
| Exhaust valve seat insert runout | | .0020" | .0020" |
| Exhaust valve: | | | |
| Stem diameter | .3722" | .3730" | |
| Valve head-to-cylinder head | Flush | .017"recess | .032"recess |
| Exhaust valve guide: | | | |
| Height above cylinder head | 1.1400" | 1.1800" | |
| Diameter—inside | .3750" | .3760" | |
| Clearance—valve-to-guide | .0020" | .0038" | .0060" |
| Exhaust valve bridge guide: | | | |
| Height above cylinder head (press fit) | 2.3900" | 2.4100" | |
| ROCKER ARMS AND SHAFTS | | | |
| Diameter—rocker shaft | 1.2295" | 1.2300" | |
| Diameter—inside (rocker arm bushing) | 1.2310" | 1.2320" | |
| Clearance—shaft-to-bushing | .0010" | .0025" | .0040" |
| Clearance—cam roller bushing-to-pin | | | .0100" |

•Prior to engines 12E-1703 and 16E-361.

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| CRANKSHAFT | | | |
| Journal diameter—main bearing | 4.8720" | 4.8730" | |
| Journal diameter—connecting rod bearing | 3.8730” | 3.8740” | |
| Journal diameter—outboard bearing | 5.9990" | **60000”** | |
| Journal out-of-round | | .00025" | **.0010”** |
| Journal taper | | .0005" | .0015” |
| # Runout on journals—total indicator reading: | | | |
| 12V (mounted on No. 1 and No. 8 journals): | | | |
| At No. 2 and No. 7 journals | | **.0020'** | |
| At No. 3 and No. 6 journals | | .0040" | |
| At No. 4 and No. 5 journals | | .0060" | |
| 16 V (mounted on No. 1 and No. 10 journals): | | | |
| At No. 2 and No. 9 journals | | .0020" | |
| At No. 3 and No. 8 journals | | .0040” | |
| At No. 4 and No. 7 journals | | .0060" | |
| At No. 5 and No. 6 journals | | .0080” | |
| Thrust washer thickness | .1630" | .1660" | |
| End play (end thrust clearance) | .0040" | .0140" | .0180 |
| MAIN BEARINGS | | | |
| Inside diameter (vertical axis) | 4.8760" | 4.8782" | |
| Bearing-to-journal clearance | .0030” | .0062" | .0072' |
| Bearing thickness (90° from parting line) | .1550” | .1555” | .1544' |
| OUTBOARD BEARING | | | |
| ■ Inside diameter (installed) | 6.0033“ | 6.0087" | |
| 'Clearance—bearing-to-journal | ,d033" | .0097” | |
| fL | | | |
| ASTONS (FLOATING SKIRT) | | | |
| Pistdn: | | | |
| Height | 6.6610” | 6.6710" | |
| Diameter at top: | | | |
| Current | 5.7030" | 5.7050" | |
| Former | 5.7010" | 5.7030" | |
| Diameter of skirt (3" below top): | | | |
| Current (effective with 12E-1463 and 16E-218) | 5.7394" | 5.7416" | |
| (2E-673 to 12E-1463 and 16E-16 to 16E-218) | 5.7388" | 5.7410" | |
| Former 'V | 5.7368" | 5.7390" | |
| Clearance—piston skirt-to-liner: | | | |
| Current (effective with 12E-1463 and 16E-218) | .0074” | .0116" | |
| (2E-673 to 12E-1463 and 16E-16 to 16E-218) | .0080" | .0122" | |
| Former | .0100- | .0142" | |
| PISTON CARRIER (FLOATING SKIRT PISTON) | | | |
| Height (bottom to thrust platform) | 3.6060” | 3.6090” | 3.6050' |
| Thrust plate thickness | .0995" | .1010" | .0945 |
| Clearance—snap ring-to-carrier | .0030" | .0130" | |

#Runout tolerance given for guidance when regrinding crankshaft. When runout on adjacent journals is in opposite direction, the sum must not exceed .003" total indicator reading. When runout on adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When high spots of runout on adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading, or .002" on each journal.

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| PISTONS (CROSS-HEAD) | | | |
| Piston crown: | | | |
| Saddle-to-crown distance | 2.7205” | 2.7275" | |
| Diameter: | | | |
| At top edge | 5.7040" | 5.7070" | |
| Below both compression rings | 5.7370” | 5.7410” | |
| Above and below seal ring groove | 5.4110" | 5.4160" | |
| Above and below Bearing saddle | 4.2200” | 4.2250" | |
| Seal ring: | | | |
| Gap (in skirt counterbore) | .0020” | .0270" | |
| Side clearance | .0005” | .0030" | .0040” |
| Piston skirt: | | | |
| + Diameter | 5.7404" | 5.7426" | |
| Clearance—skirt-to-liner (former) | .0064” | .0106" | |
| Clearance—skirt-to-liner (current) | .0066” | .0109" | |
| Seal ring bore | 5.4400” | 5.4450" | |
| Piston pin bore | 2.3909” | 2.3919" | |
| PISTON RINGS | | | |
| Compression rings: | | | |
| Gap (wide gap rings) | .0550" | .0750" | |
| Gap (standard rings) | .0450" | .0550" | |
| Clearance—ring-to-groove: | | | |
| No. 1 (top) | .0045" | .0081" | |
| No. 2 | .0105" | .0130" | |
| No. 3 | .0045” | .0070" | |
| No. 4 | .0045" | .0070" | |
| Oil control rings: | | | |
| Gap | .0170" | .0320" | |
| Clearance—ring-to-groove: | | | |
| Upper | .0015" | .0055" | |
| Upper (turbocharged engine) | .0010" | .0035" | |
| Lower | .0015" | .0055" | |
| PISTON PIN | | | |
| Diameter | 2.3873" | 2.3877" | |
| Slipper bearing (bushing) thickness at center | .0870" | .0880" | .0860" |
| CONNECTING ROD | | | |
| Side clearance (normal) between rods | .0180" | .0260" | |
| CONNECTING ROD BEARINGS | | | |
| Inside diameter | 3.8755” | 3.8775" | |
| Bearing-to-journal clearance | .0015” | .0045" | .0055" |
| Bearing thickness (90° from parting line) | .1550" | .1555" | .1544" |

+ Diameter above and below the piston may be 5.7370".

| ENGINE PARTS (Standard Size, New) | MINIMUM | MAXIMUM | LIMITS |
|---|---|---|---|
| CYLINDER LINER | | | |
| Outside diameter: | | | |
| Upper pilot | 6.5200" | 6.5210" | |
| Below ports | 6.3980" | 6.3990" | |
| Inside diameter | 5.7488" | 5.7513" | |
| Clearance—liner pilot-to-block bore | .0010" | .0040" | |
| Out-of-round (inside diameter) | | .0010" | .0020" |
| Taper (inside diameter) | | .0010" | .0020" |
| ♦Depth of flange BELOW block | .0390" | .0450" | |
| GEAR TRAIN | | | |
| Gear backlash (between all gears) | .0015" | .0080" | .0100' |
| Clearance—Crankshaft-to-bushing (in front crankshaft gear) | .0010" | .0030" | |
| CAMSHAFT | | | |
| Journal diameter | 1.9940" | 1.9945" | |
| Runout at intermediate journal (when mounted on end journals) | | .0020" | |
| Thrust plate thickness | .3680” | .3720" | |
| Clearance—thrust plate-to-camshaft thrust shoulder | .0130" | .0220" | .0260" |
| CAMSHAFT BEARINGS | | | |
| Inside diameter (vertical axis) | 2.0004” | 2.0024" | |
| Clearance—bearing-to-shaft | .0059" | .0084" | .0100" |
| FRONT IDLER GEAR | | | |
| Inside diameter — bushing | 2.6270" | 2.6280" | |
| Outside diameter — idler gear hub | 2.6240" | 2.6250" | |
| BLOWER DRIVE GEAR | | | |
| Inside diameter—bushing | 1.8770” | 1.8780" | |
| Clearance—hub-to-gear bushing | .0010" | .0025" | .0050' |
| Thrust washer (drive support) thickness | .2350" | .2450" | |
| Thrust washer (gear) thickness | .1190" | .1210" | |
| End play (between thrust washers) | .0020" | .0180" | |

Trior to engines 12E-1703 and 16E-361.

# STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| THREAD SIZE | 260M BOLTS TORQUE (lb-ft) | Nam | THREAD SIZE | 280M OR BETTER TORQUE (lb-ft) | Nam |
|---|---|---|---|---|---|
| 1/4-20 | 5-7 | - 7-9 | 1/4-20 | 7-9 | 10-12 |
| 1/4-28 | 6-8 | - 8-11 | 1/4-28 | 8-10 | 11-14 |
| 5/16A8 | 10-13 | - 14-18 | 5/1618 | 13-17 | 18-23 |
| 5/16-24 | 11-14 | - 15-19 | 5/16-24 | 15-19 | 20-26 |
| 3/8-16 | 23-26 | - 31-35 | 3/8-16 | 30-35 | 41-47 |
| 3/8-24 | 26-29 | - 35-40 | 3/8-24 | 35-39 | 47-53 |
| 7/16-14 | 35-38 | _ 47-51 | 7/16-14 | 46-50 | 62-68 |
| 7/16 20 | 43 46 | - 58 62 | 7/16-20 | 57-61 | 77-83 |
| 1/2-13 | 53 56 | - 72-76 | 1/213 | 71-75 | 96-102 |
| 1/7-70 | 62-70 | „ 84-95 | 1/2-20 | 83-93 | 113-126 |
| 9/16-12 | 68-75 | _ 82-902 | 9/16-12 | 90-100 | 122-136 |
| 9/1618 | 80-88 | 109119 | 9/1618 | 107-117 | 146-159 |
| 5/8-11 | 103-110 | 140-149 | 5/8-11 | 137-147 | 186-200 |
| 5/8-18 | 126-134 | 171-181 | 5/8-18 | 168-178 | 228-242 |
| 3/4-10 | 180-188 | 244-254 | 3/4-10 | 240-250 | 325-339 |
| 3/4-16 | 218-225 | 295-305 | 3/4-16 | 290-300 | 393-407 |
| 7/8-9 | 308-315 | 417-427 | 7/8-9 | 410-420 | 556-569 |
| 7/8-14 | 356-364 | 483-494 | 7/8-14 | 475-485 | 644-657 |
| 1-8 | 435-443 | 590-600 | 1-8 | 580-590 | 786-800 |
| 1-14 | 514-521 | 697-705 | 1-14 | 685-695 | 928-942 |

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

| □ -- Grade Identification Marking on Bolt Head | GM Number | SAE Grade Designation | Nominal Size Diameter (inch) | Tensile Strength Min. (psi) |
|---|---|---|---|---|
| None | GM 255-M | 1 | No. 6 thru 1 1/2 | 60,000 |
| None | GM 260-M | 2 | No. 6 thru 3/4<br>over 3/4 to 1 1/2 | 74.000<br>60.000 |
| <J Bolts and Screws | GM 280-M | 5 | No. 6 thru 1<br>over 1 to 1 1/2 | 120,000<br>105,000 |
| — Hex Head Sems Only | GM 275-M | 5.1 | No. 6 thru 3/8 | 120,000 |
| Bol ts and Screws | GM 290-M | 7 | 1/4 thru 1 1/2 | 133,000 |
| Bolts and Screws | GM 300-M | 8 | 1/4 thru 1 1/2 | 150,000 |
| —* Bolts and Screws | GM 455-M | None | No. 6 thru 1 1/2 | 55,000 |

BOLT IDENTIFICATION CHART

# EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| APPLICATION | THREAD | (lb-ft) | (N.m) |
|---|---|---|---|
| Camshaft coupling bolt (early 12 V only) | 5/16-24 | 20-24 | 27-33 |
| Exhaust valve bridge adjusting screw nut | 5/16-24 | 20-25 | 27-34 |
| Camshaft coupling bolt (early 12 V only) | 3/8-24 | 45-50 | 61-68 |
| Exhaust valve adjusting screw nut | 3/8-24 | 30-35 | 41-47 |
| Fuel pump drive coupling disc bolt | 3/8-24 | 50-55 | 68-75 |
| Camshaft coupling bolt (current) | 7/16-20 | 57-61 | 77-83 |
| ♦Crankshaft coupling bolts (2-piece crankshaft) | 7/16-20 | 70-80 | 95-108 |
| Injector fuel pipe nut (large) | 7/16-20 | 18-22 | ' 24-30 |
| Injector fuel pipe nut (small) | 7/16-24 | 18-22 | 24-30 |
| ♦Block attaching bolts | 1/2-13 | 75-85 | 102-115 |
| Camshaft bearing cap bolts | 1/2-13 | 90-100 | 122-136 |
| Fuel pipe connector nut | 1/2-13 | 35-40 | 47-54 |
| Idler gear hub retaining bolt | 1/2-13 | 80-90 | 108-122 |
| Rocker arm shaft bolt | 1/2-13 | 90-100 | 122-136 |
| ♦Block attaching bolts | , 1/2-20 | 85-95 | 115-129 |
| ♦Connecting rod-to-piston pin bolt | 1/2-20 | 35[A]45 + 60 -80° | 47-61.+60°-80° |
| ♦Crankshaft coupling bolts (2-piece crankshaft) | 1/2-20 | 100-110 | 136-150 |
| Exhaust manifold to block stud nuts | 1/2-20 | 50-55 | 68-75 |
| Bearing cap nut (oil pan removed) | 9/16-18 | 45-55 +130°-150° | 61-75 +130-150° |
| Bearing cap nut (oil pan installed) | 9/16-18 | 125-135 | 170-183 |
| ♦Connecting rod cap nut (oil pan installed) | 9/16-18 | 130-140 | 177-190 |
| • * Connecting rod cap nut (oil pan removed) | 9/16-18 | 45-55+ 130°-150° | 61-75 +130-150° |
| ♦Cylinder head bolt | 9/16-18 | 140-150 | 190-204 |
| ♦Block attaching bolts | " 5/8-11 | 160-175 | 217-238 |
| ♦Flywheel bolt (see Sect. 1.4) | 5/8-18 | | |
| Vibration damper hub to crankshaft bolt | 5/8-18 | 180-190 | 244-258 |
| ♦Block attaching bolts [A] | ’ 3/4-10 | 270-290 | 366-393 |
| ♦Main bearing cap bolt | 3/4-10 | 280-290 | 379-393 |
| Accessory drive pulley nut | 3/4-16 | 120-140 | 163-190 |
| Crankshaft pulley bolt ' | 1 1/4-7 | ;450-500 | 610-678 |
| Front PTO hub nut | 1 1/4-12 | ‘ 325-350 | 441—475 |
| Blower drive support nut | 1 7/16-16 | 50-60 | 68-81 |
| Accessory gear locknuts | 2 1/2-18 | 280-300 | 379-407 |
| Idler gear locknuts (spanner, standard hex) | 2.548-18 | 280-300 | 379-407 |
| • Idler gear Locknut (hex w/locking lip) • | 2.548-18 | 300-320 | 407-434 |
| Camshaft gear locknut (spanner, standard hex) | 3.137-12 | 280-300 | 379-407 |
| • Camshaft gear locknut (hex w/locking lip) | 3.137-12 | 300-320 | 407-434 |

♦Lubricate threads with International Compound No. 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12.8000A).

# STANDARD PIPE PLUG TORQUE SPECIFICATIONS

| NPTF SIZE THREAD | TORQUE (lb-ft) | N*m | NPTF SIZE THREAD | TORQUE (lb-ft) | N»m |
|---|---|---|---|---|---|
| 1/8 | 10-19 | 14-16 | 1 | 79-89 | 102-115 |
| 1/4 | 14-10 | 19-22 | 1-1/10 | 89-Q9 | 115-129 |
| 9/8 * | 18—99 | 24-30 | 1-1/4 | os-ins | 129-143 |
| 1/9 | 99-97 | 31-37 | 1-1/9 | 110-190 | 150-177 |
| 3/4..... | .....33-37 | 45-50 | | | |

# SPECIAL PLUG TORQUE SPECIFICATIONS

| APPLICATION | (lb-in) | (N*m) |
|---|---|---|
| Core hole plugs | 150-180 | 204-244 |
| ♦Water core hole plug—-1 3/4a-16 special | 150-20(r | 204-271 |
| # Water core hole plug--2 l/2a-16 special | 220-250 | 298-339 |

♦Lubricate threads and washer face with International Compound No. 2, or equivalent (refer to Parts Cata Section. -12 8000A).
#Coat the threads and washer face with a good grade of coolant resistant sealant.

# STUD TORQUE SPECIFICATIONS

----------->|- *f* ft

| APPLICATION | STUD | (lb-in) | (N.m) |
|---|---|---|---|
| Exhaust manifold stud 4---------- | 1/2-13 | 35-40 | 47-54 |

# SERVICE TOOLS

| TOOL NAME | TOOL NO. |
|---|---|
| **CYLINDER BLOCK** | |
| Core hole plug remover and installer | J23019 |
| Cylinder block bore aligning tool | J 22486 |
| Cylinder block bore aligning tool (.020” oversize) | J 24542 |
| Cylinder block bore aligning tool (.040” oversize) | J 24543 |
| Dial bore gage | J 5347-B |
| Dial bore gage master setting fixture | J 23059-01 |
| • Deck checker | PT-5075-B |
| • Conversion kit (for 149 block) | PT-5071 |
| Pressure testing set | J 24051-B |
| \|Sled gage | J 22273-01 |
| Torque wrench adaptor | J 24533 |
| Water ljole sleeve installer | J 24233-01 |
| • Litter Iflange seat resurfacing tool | PT-2600 |
| **CYLINDER HEAD** | |
| Broken valve bridge guide remover | J 7453 |
| Cylinder head guide stud set | J28511-A |
| Cylinder head holding fixture | J 23741-A |
| Cylinder head remover | J24232 |
| Feeler gage stock (.0015”) | J23185 |
| Fuel line wrench set | J26617 |
| Fuel line socket 9/16” | J21545 |
| Sled gage | J 22273-01 |
| Slide hammer < ” ■ | J 2619-01 |
| Spring tester | J 22738-02 |
| Valve bridge guide installer | J 22487 |
| Valve bridge guide remover | J 7091-01 |
| Valve bridge holding fixture | J21772 |
| Valve seat grinding set | J 4627-02 |
| Valve guide cleaner | J 5585 |
| Valve guide installer | J 22082-01 |
| Valve guide remover | J 23458-A |
| Valve seal installer | J 25251 |
| • Valve seat grinder (model V.I.P.)* | J 7040-A |
| — Grinder | , J 8165-1A |
| — Dial gage | J 8165-2 |
| Valve seat insert installer | J22711 |
| • Valve seat insert remover | J 23479-49 |
| Valve spring checking gage | J 22738-02 |
| Valve spring compressor (cyl. head installed) • * | J 22693-01 |
| Valve spring compressor (cyl. head removed) | J 8062 |

•Consists of Single Dash (-) Items Below

| TOOL NAME | TOOL NO. |
|---|---|
| **CRANKSHAFT AND BEARINGS** | |
| Crankshaft front oil seal installer | J22518 |
| Crankshaft rear oil seal expander | J 22605 |
| Crankshaft rear oil seal expander (oversize seal) | J 22766 |
| Crankshaft rear oil seal expander adaptor | J 23341 |
| Crankshaft rear oil seal installer | J 22604-B |
| Crankshaft rear oil seal sleeve installer | J 22767 |
| Cup plug tester | J 34728 |
| Hand vacuum pump | J 23738-A |
| Engine barring tool | J 22582 |
| Main bearing bolt torquing device | J 35371 |
| Micrometer ball attachment | J 4757 |
| Torque wrench adaptor set | J 22897 |
| **FLYWHEEL HOUSING** | |
| Flywheel housing runout gage | J 9737-C |
| Pilot plate locating tool | NDD-4875 |
| **PISTON - CYLINDER LINER** | |
| Cylinder bore gage | J 5347-B |
| Cylinder hone and glaze breaker set | J 5902-01 |
| Cylinder liner installer | J 22641-A |
| Cylinder liner remover | J 22431-A |
| Dial bore gage master setting fixture | J 23059-01 |
| Feeler gage set | J 5438-01 |
| Spring scale | J 8129 |
| Master ring gage (cylinder liner) | J22613 |
| Piston crown identification gage | J 25397-A |
| Piston pin retainer installer | J 24274-B |
| Piston pin retainer leak detector | J 23738-A |
| Piston Pin retainer leak detector adaptor cup | J 24629 |
| Piston ring compressor | J 22387 |
| Piston ring remover and installer | J 22405-02 |
| Piston seal ring compressor | J 24421 |
| **GEAR TRAIN** | |
| Socket (accessory and blower drive hub nut) | J 23641 |
| Spanner wrench set (cam and idler gear nut) | J 22556 |
| Spring scale | J 8129 |
| **CAMSHAFTS AND BEARINGS** | |
| Cam/idler gear retaining nut socket set | J 29744 |
| Torque wrench adaptor - coupling bolt | J 28462 |

# SECTION 2

## FUEL SYSTEM AND GOVERNORS

### CONTENTS



# FUEL SYSTEM

The fuel system (Fig. 1) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds, fuel pump, fuel strainer, fuel filter, junction block and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter or secondary filter. From the secondary filter, the fuel is directed to a junction block where it is then routed to the inlet fuel manifolds for each injector bank. From the fuel manifolds, fuel reaches the fuel injector by means of a fuel inlet pipe. Surplus fuel returns from the outlet side of the injectors through the fuel outlet pipes to the fuel return manifold. The return fuel then passes through the fuel junction block and back to the fuel tank. All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain the fuel system pressure. Refer to Sections 2.4 and 13.2 for the size fitting required.

A check valve is installed in the fuel junction block on the outlet (spill) side to prevent fuel from draining from a high mounted fuel tank back into the injectors when the engine is not running (refer to Section 2.4).

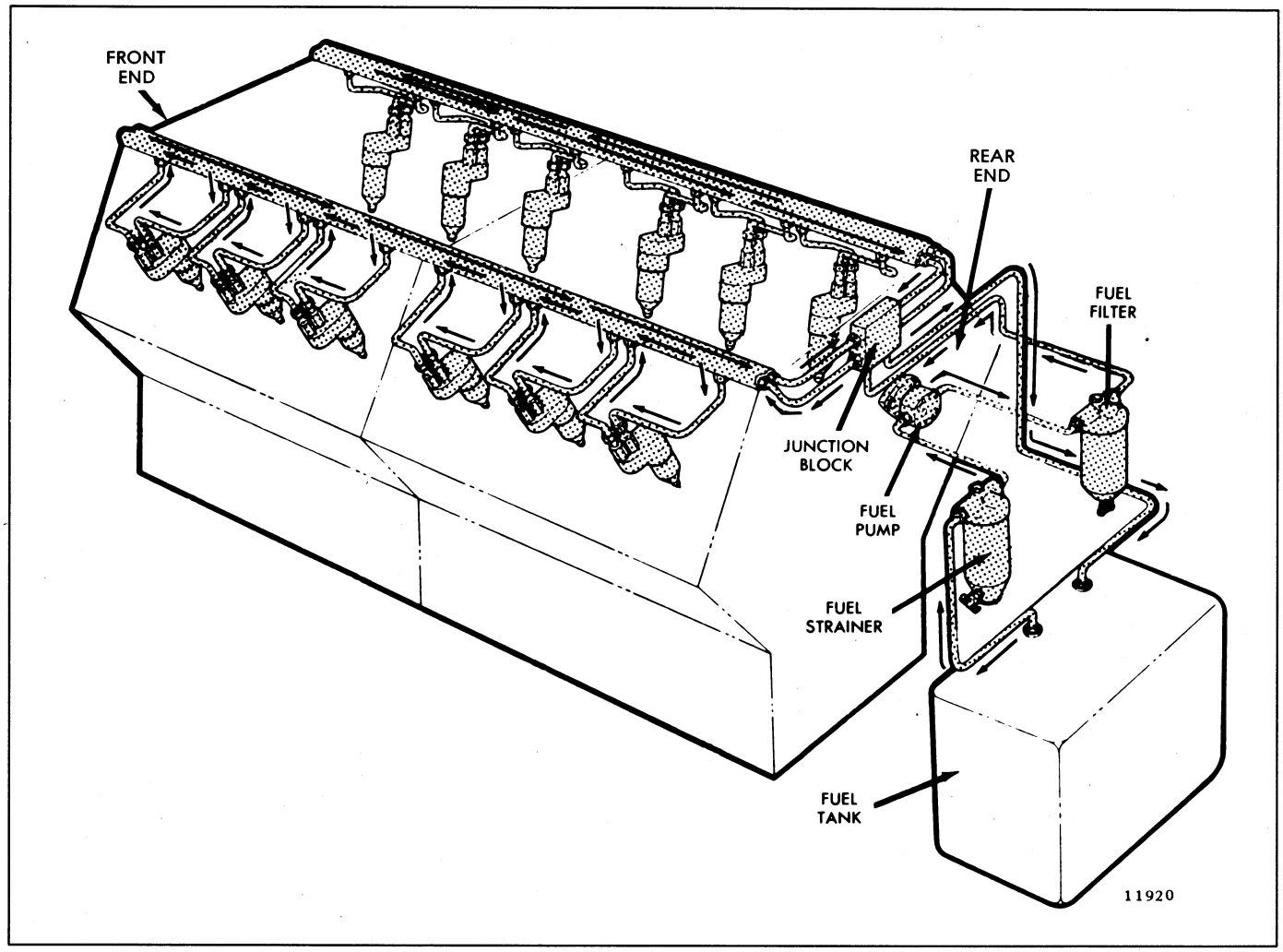



Fig. 1 – Schematic Diagram of Fuel System

# FUEL INJECTOR
## MECHANICAL UNIT INJECTOR (MUI)
## NEEDLE VALVE

The fuel injector (Figs. 1 and 2) is a lightweight compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

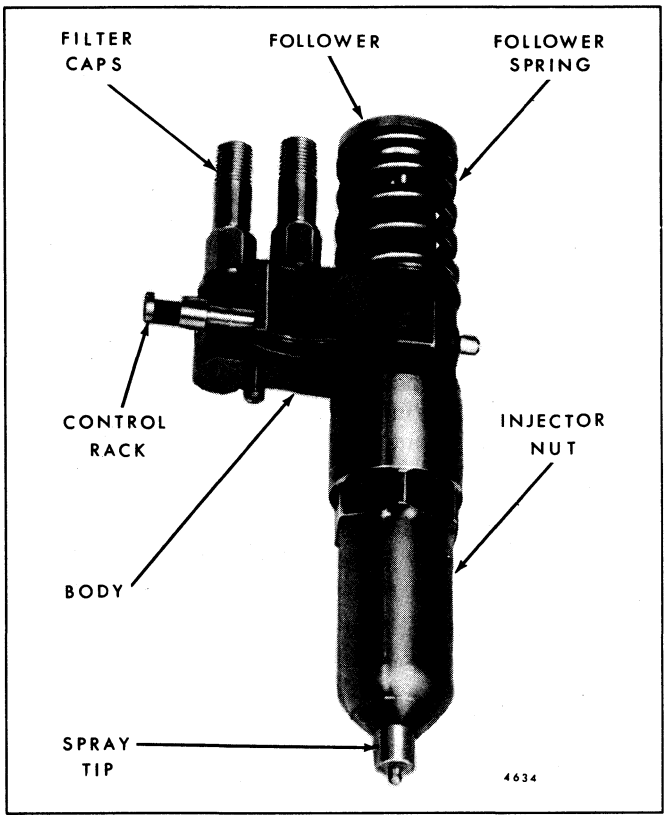



**Fig. 1 - Fuel Injector Assembly**

The fuel injector performs four functions (Times - Atomizes - Meters - Pressurizes):

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber.
3. Meters and injects the correct amount of fuel required to maintain engine speed and to handle the load.
4. Creates the high pressure required for proper fuel injection.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately timed, metered and finely atomized fuel oil into the combustion chamber.

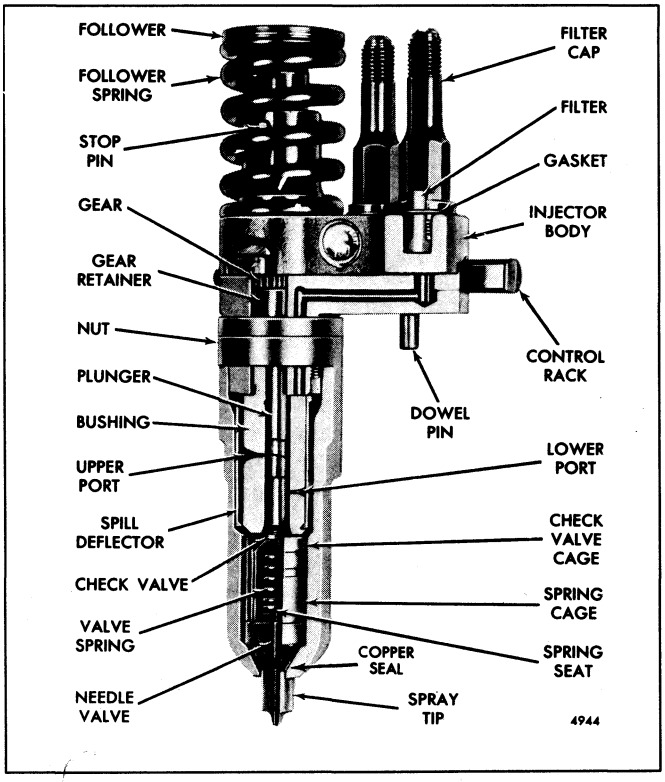



**Fig. 2 – Cutaway View of Fuel Injector**

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Fig. 3 illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

Fig. 4 illustrates the phases of injector operation by the vertical travel of the injector plunger.

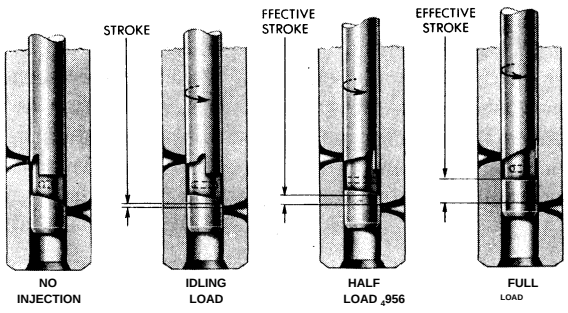



**Fig. 3 - Fuel Metering from No Load to Full Load**

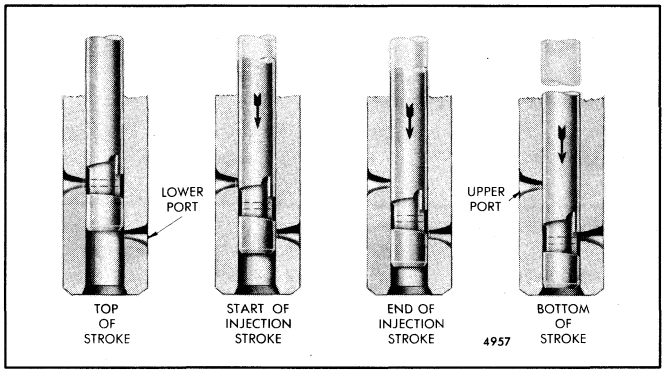



**Fig. 4 - Phases of Injector Operation Through Vertical Travel of Plunger**

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the effective stroke of the plunger and the flow rate of the spray tip.

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 1).

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting or fine tuning of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

## Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the racks (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel-shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 5). In addition to the reciprocating motion, the plunger cap be rotated around its axis by the gear which

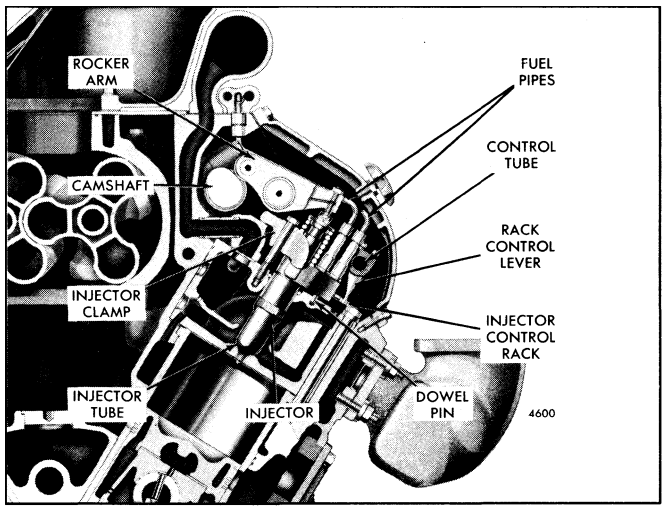



**Fig. 5 - Fuel Injector Mounting**

meshes with the control rack. To accomplish fuel metering, an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered, the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat check valve. The fuel in the check valve cage, spring cage, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed-off of fuel leaking past the needle pilot in the tip assembly.

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its *original* position by the injector follower spring. Fig. 4 shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. Fig. 3 shows the various plunger positions from no load to full load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this *no injection* position to *full injection* position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

## General Instructions For Injector Care And Overhaul

The fuel injector is one of the most important and precisely built parts f the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust-proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or other foreign material.
2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and overhaul of an injector.
3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:
   a. Time the injector.
   b. Position the injector control rack.
4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to Section 15.3).
5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

**NOTICE:** Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

## Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.
2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6), as follows:
   a. Disconnect the fuel pipe at the injector.
   b. Move the nut back on the pipe and slide a 3/8" I.D. hose over the open end of the pipe, being careful to avoid fuel spillage.

**NOTICE:** It will be necessary to loosen the fuel pipe nut at the fuel manifold a few turns to permit the fuel pipe to swing away from the injector.

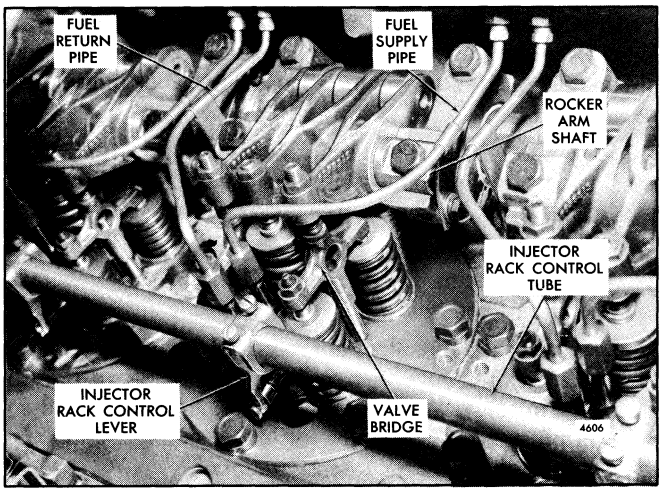



**Fig. 6 - Location of Fuel Pipes and Connectors**

c. Drain the fuel into a container. This will prevent the fuel in the manifold from draining onto the cylinder head. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

d. Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also, protect the fuel pipes and fuel connectors from entry of dirt or foreign material.

3. Remove the two bolts securing the rocker arm shaft to the camshaft bearing caps and remove the shaft and the valve and injector operating mechanism.

4. Remove the two exhaust valve bridges from the exhaust valve bridge guides.

5. Remove the injector clamp bolt, special washer and clamp (Fig. 7).

6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

7. Lift the injector from its seat in the cylinder (pot) head.

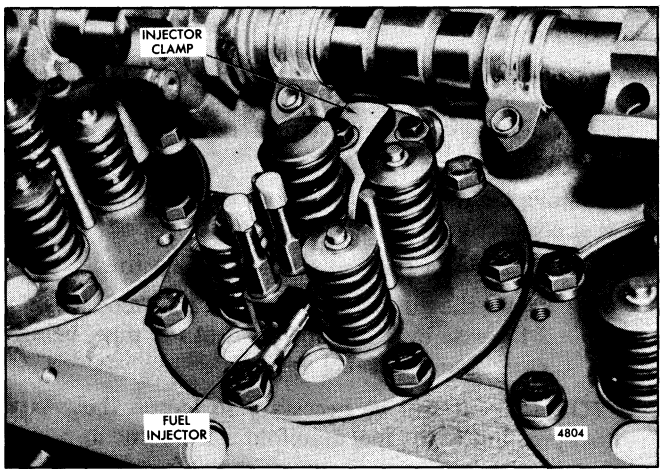



**Fig. 7 - Fuel Injector and Clamp**

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

## Inspect And Test Prior To Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry the injector.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

1. Inspect the following injector parts for external wear, rust and corrosion.

   Follower spring
   Injector body
   Body nut
   Spray tip
   Injector rack
   Filter caps

2. Inspect the following parts for wear or abrasion deterioration.

   Top of the follower
   Follower spring
   Injector body
   Spray tip orifices

3. Check the rack for freeness and the plunger movement in Tester J 22396.

With the injector control rack held in the *no-fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (Fig. 8). If the rack falls freely, the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.

4. Check the injector for leaks using Tester J 23010-A as outlined in Section 2.0 - Shop Notes.

5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010-A as outlined in Section 2.0 - Shop Notes.

6. Perform injector fuel output test using Calibrator J 22410-A as outlined in Section 2.0 - Shop Notes.

If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

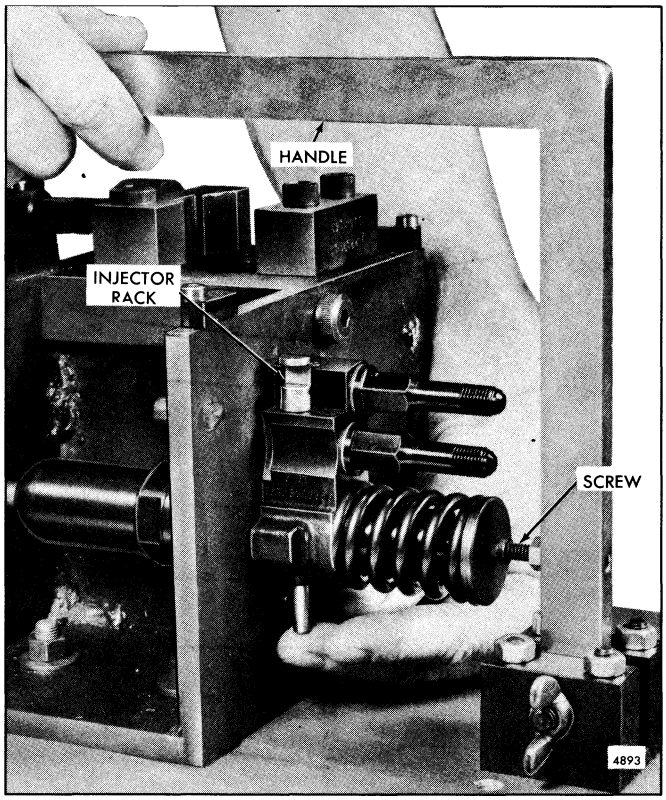



**Fig. 8 - Checking Rack for Freeness in Tester J 22396**

## Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 9) and remove the filter caps, gaskets and filter.
2. Whenever a fuel injector is disassembled, discard the filter and gaskets and replace with a new filter and new gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 10).
3. Compress the follower spring. Then, using a screw driver, press in on the stop pin to release the follower and remove the injector follower, plunger and spring from the injector body.
4. Rotate the injector in the injector assembly fixture and loosen the nut on the injector body, using injector nut socket J 22799 (Fig. 11).
5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly. On a current injector remove the copper seal from the injector nut. Discard the copper seal.

   When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291-02 (Fig. 12).

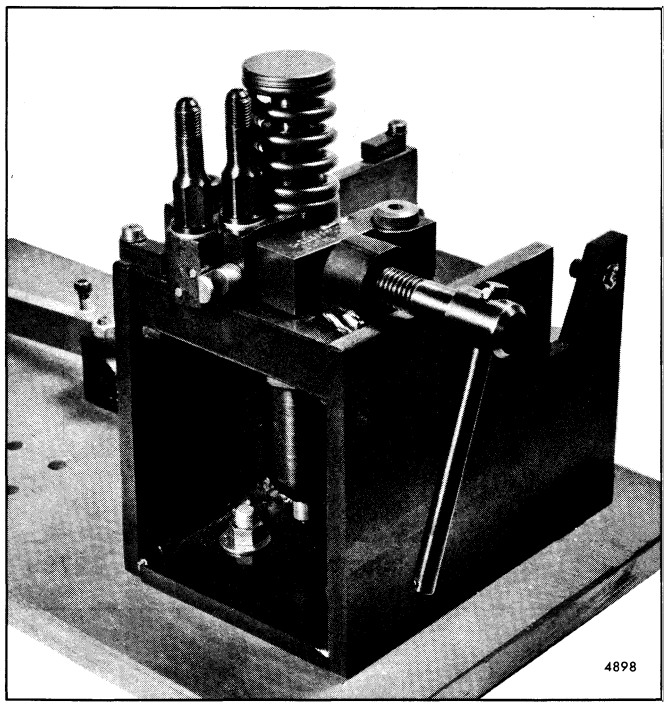



**Fig. 9 - Removing Filter Cap**

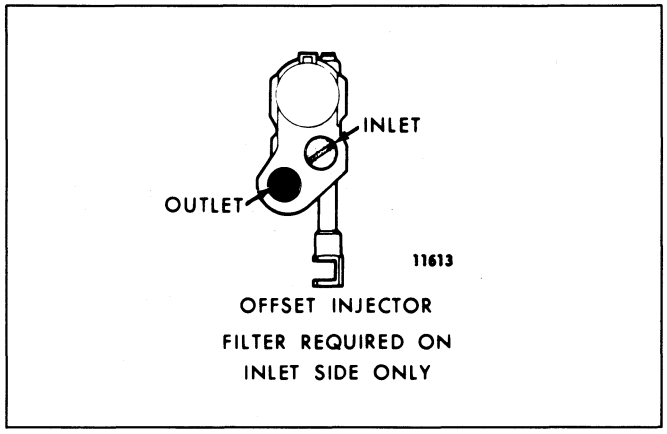



Fig. 10 – Location of Filter in Injector Body

6. Refer to Fig. 13 and remove the spill deflector. Then, lift the bushing straight out of the injector body.
7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.
8. Withdraw the injector control rack from the injector body. Also, remove the seal ring from the body.

## Clean Injector Parts

Since most injector problems are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

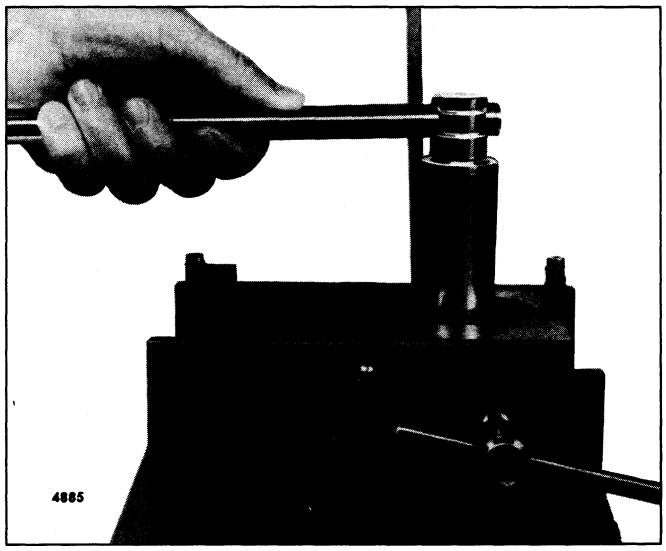



Fig. 11 - Removing Injector Nut using Tool J 22799

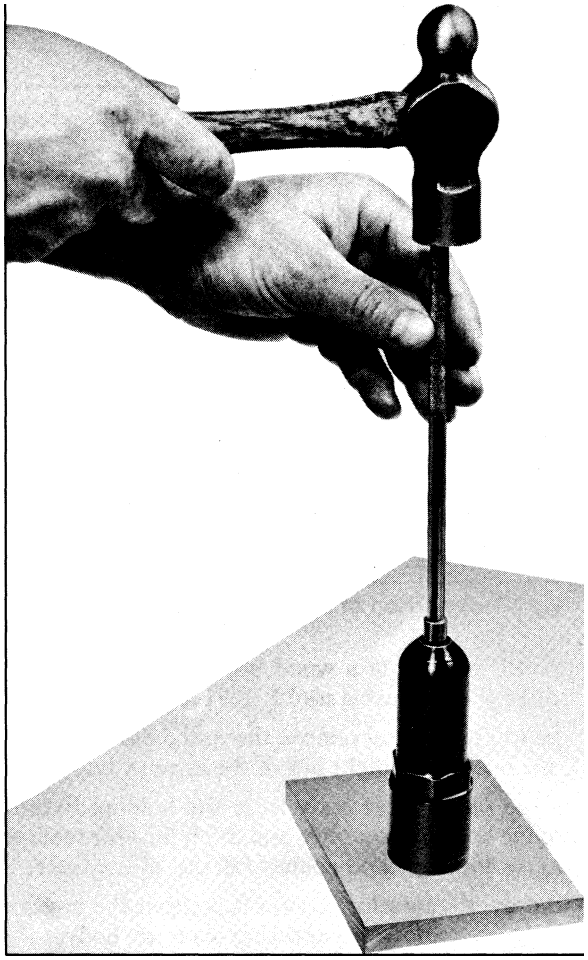


Fig. 1 2 - Removing Spray Tip from Injector Nut using Tool J 1291-02

Wash all of the parts with a suitable cleaning solvent and dry them with clean, filtered compressed air. Use lint free towels to wipe off the parts. Clean out the passages, drilled holes and slots in all of the injector parts.

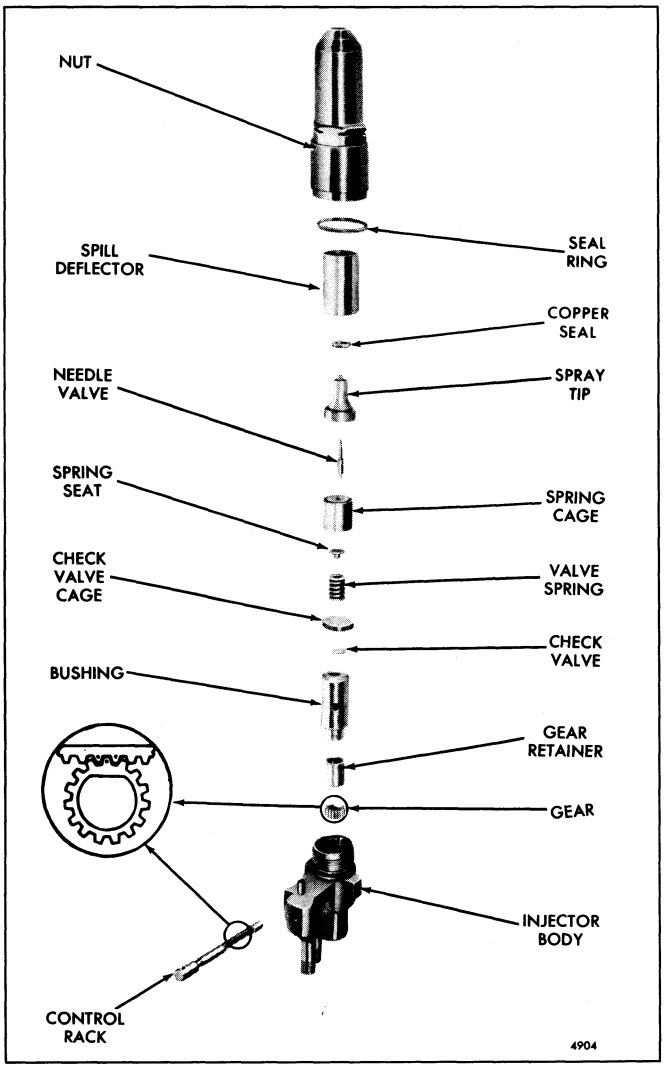



Fig. 13 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately fifteen (15) minutes in a suitable solution prior to the external cleaning and buffing operation.

Clean the spray tip with tool J 22800-01 (Fig. 14).

**NOTICE:** Care must be exercised when inserting the carbon remover J 22800-01 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1 and a .009” cleaning wire J 22995 (Fig. 15).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16” with stone J 8170. Allow the wire to extend 1/8” from tool J 4298-1. Ultra sonic cleaning is also an acceptable method.

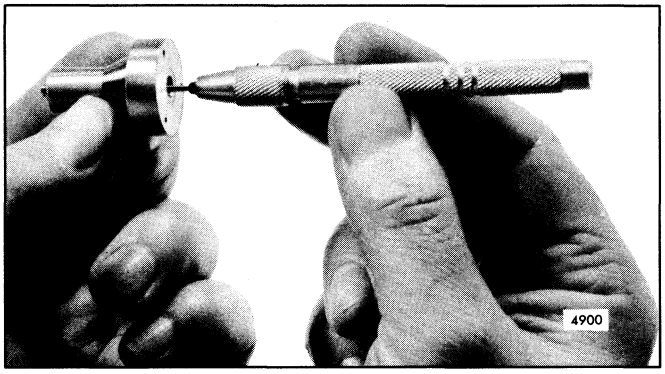



**Fig. 14 - Cleaning Injector Spray Tip with Tool J 22800-01**

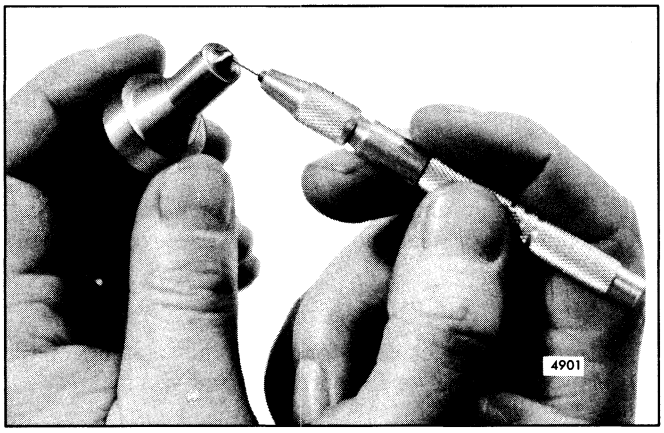



**Fig. 15 - Cleaning Spray Tip Orifices with Tool J 4298-1**

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 24838 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

**NOTICE:** Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully, insert carbon remover tool J 22096-1 in the injector nut. Turn it in a clockwise direction to remove the carbon deposits on the flat spray tip seat. Remove the carbon deposits from the lower end of the injector nut with carbon remover J 22096-2 (Fig. 16) in the same manner.

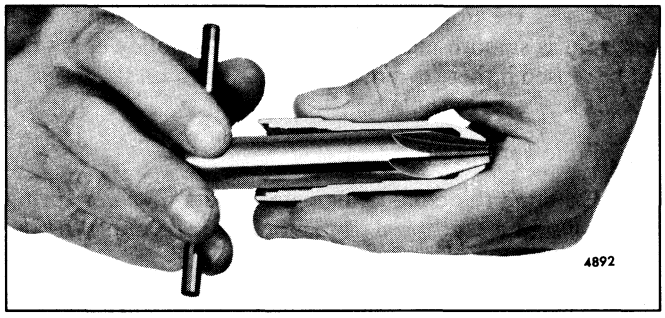



**Fig. 16 - Cleaning Injector Nut Lower End with Tool J 22096-2**

Wash the injector nut in clean solvent and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean solvent and dry them with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. *Keep the plunger/bushing together as they are matched parts.*

After washing, submerge the parts in a clean receptable containing clean test oil. *Keep the parts of each injector assembly together.*

## Inspect Injector Parts (Visual And Dimensional)

• **NOTICE:** Effective with 1988-build engines, the valve nuts, bodies, and filter caps on series 149 injectors are no longer blued. Bluing has no effect on a part's performance or service life.

1. Follower

   Measure between the top of the follower and the slot. This dimension must be 1.728 ± .002" (Fig. 17).

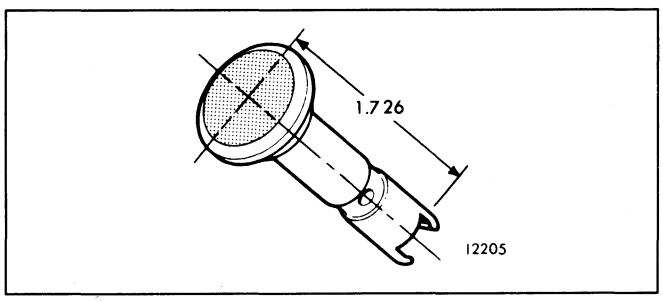



Fig. 17 – Injector Follower

Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002" wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

   Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

   Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

   Check the follower spring tension with spring Tester J 22738-02.

   The current injector follower spring (.237"-.241" diameter wire) has a free length of approximately 2.200" and should be replaced when a load of less than 267 lbs. (current spring) or 290 lbs. (former spring) will compress it to 1.605".

   It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (.237"-.241" diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

3. Injector Body:

   Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces for damage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Cap:

   Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack

   Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

   The notch in the clevis should be .3125" to .3145". A .250" inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer

   Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

7. Bushing

   Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring,

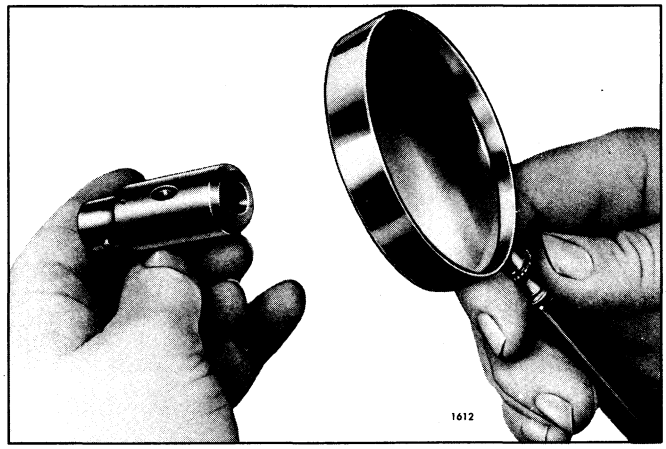



**Fig. 18 - Examining Sealing Surface with a Magnifying Glass**

the condition of the dowell pin and check for corrosion or varnish (Fig. 18).

8. Plunger:

   Check the plunger for corrosion or varnish, scoring, scratching or wear and chips along the edge of the helix (Fig. 19).

9. Check Valve:

   Inspect the check valve for cracks and scratches on the lapped surfaces or for corrosion and varnish.

10. Check Valve Cage:

    Inspect the check valve cage for cracks and scratches on the lapped surfaces or for corrosion, varnish and wear.

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**Advanced stage of erosion caused by foreign matter in fuel due to improper fi ltration.**

**Chipped at lower helix. The above condition can be caused by either lack of fuel at high speeds or water in fuel.**

**Fig. 19 - Unusable Injector Plungers**

11. Valve Spring:

Check the injector valve spring for wear on the coil ends, broken coil ends and notches under the coil ends. Then, check for corrosion, nicks and cavitation erosion on the inside at approximately 1-1/2 coils from the end.

12. Spring Seat:

Check the surfaces for wear.

13. Spring Cage:

Inspect for cracks, corrosion or varnish and scratches on the lapped sealing surfaces. Also, inspect the spring seat surface and the needle valve seating surface for wear.

14. Spray Tip:

Check for cracks, enlarged spray holes, corrosion on the outside diameter taper and oxide scale on the spray hole end. Then, check the nut-to-tip sealing surface and the lapped sealing surface for scratches. Do not reuse if there is scale, cracks or enlarged spray holes.

15. Needle Valve:

Check the spray tip needle valve for erosion at the seat shoulder, scratches and overheating (discolored).

16. Nut:

Check the nut for damaged threads, the condition of the seal ring seating area, the condition of spray tip seating area and the spray tip hole for being corroded irregularly.

Current fuel injectors include a copper seal and a revised injector nut to prevent corrosion of the injector spray tip to nut seat. The angle of the injector nut surface below the spray tip seat has been changed to allow clearance in the injector nut for the installation of the copper seal (Fig. 20).

The new injectors are identified by a notch on the hex corners of the nut.

**NOTICE:** Do not use a former injector nut with the new copper seal. *Never reuse a copper seal.*

17. Spill Deflector:

Inspect both ends of the spill deflector for sharp edges or burrs.

18. Part Thickness:

Check the minimum thickness of the parts (see Table 1).

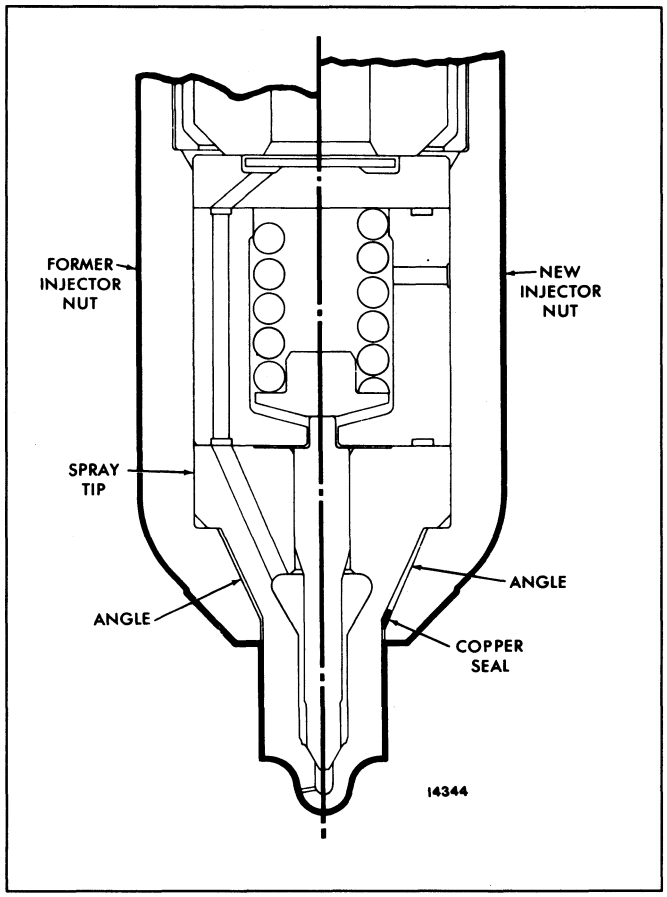



**Fig. 20 - Location of Copper Seal in Injector Nut**

| Part Name | Minimum Thickness |
|---|---|
| Spray Tip (Shoulder) | .296" |
| Cage, Valve Spring | .861" |
| Cage, Check Valve | .186" |
| Valve, Check | .027" |

**TABLE 1 - MINIMUM THICKNESS (Used Parts)**

19. Needle Valve Lift:

Measure the needle valve lift, using tool J 9462-02 (Fig. 21) as follows:

a. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

b. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

c. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be

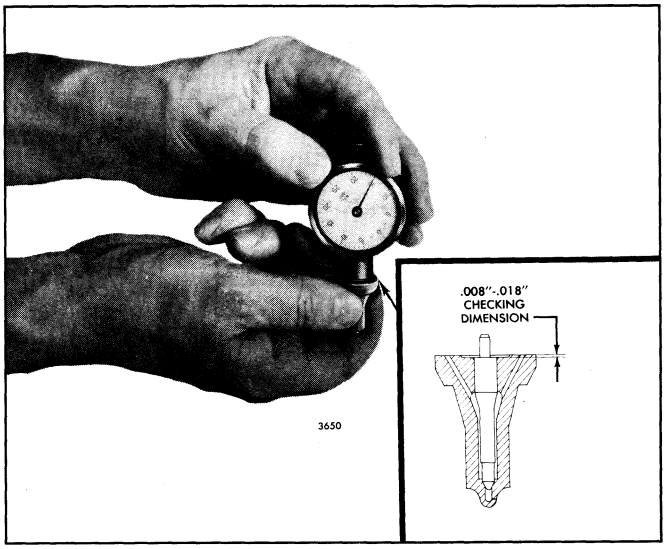



**Fig. 21 - Checking Needle Valve Lift with Tool J 9462-02**

.008" to .018". If it exceeds .018", that tip assembly must be replaced. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.

d. If the needle valve lift is within limits, install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly should be replaced.

20. Classify Spray Tip:

Match the plunger/bushing assembly with the proper spray tip using Flow Gage J 25600-A (see Section 2.0).

## Recondition Injector

If any of the injector parts listed below cannot be reconditioned satisfactorily, use new parts. A1 parts must be cleaned to be free of rust, varnish and carbon before reuse.

1. Follower:

■Resurface or replace if worn beyond dimensional limits.

2. Follower Spring:

■Reuse unless damaged, worn or won't meet test specifications.

3. Body:

■Lap bushing seat.

■Reblue.

■Repair damaged threads.

■Replace body if the clamp radius is badly worn or if the threads are less than 90% good.

4. Filter Caps:

■Recondition tapered seat.

■Clean and deburr hole.

■Reblue.

■ Replace if the threads or sealing surfaces are damaged.

5. Control Rack:

■Deburr teeth - check for straightness.

■Replace if the teeth show significant wear.

6. Gear and Gear Retainer:

■Deburr.

■Replace if cracked or significantly worn.

7. Bushing:

■Replace if scored, cracked or if residue cannot be removed.

■Lap the check valve seat (sealing) surface.

8. Plunger:

■ Clean - remove varnish.

■Replace if scored, chipped or scratched.

9. Check Valve:

■Lap both flat (sealing) surfaces.

■Replace if scratched, cracked or badly worn.

10. Check Valve Cage:

■Lap both flat sealing surfaces.

■Replace if cracked or too thin (see Table 1).

11. Valve Spring:

■Replace. Do not reuse unless there is absolutely no wear or damage.

12. Spring Seat:

■Replace if there is a hole worn in the rounded end where the needle quill touches.

13. Spring Cage:

■Lap both flat (sealing) surfaces.

■Replace if cracked or too thin (see Table 1) or if the needle has worn a pocket around the small hole.

14. Spray Tip:

■Regrind seat.

■Lap flat sealing surface.

■Regrind the needle conicol seat.

■ Replace if beyond flow limits i.e., erroded spray holes.

15. Nut:

■Remove carbon from the seat and tapered I.D.

■Reblue.

■Replace if the threads are damaged more than 10% or if the small I.D. is badly erroded.

16. Spill Deflector:

■Remove burrs.

■Reuse if the ends are smooth and even and the deflector is not cracked.

Normally, new parts do not require lapping prior to use. Wash the service parts in clean solvent to remove the solitified preservative. However, if new parts become nicked or burred during handling, then lapping will be necessary to provide adequate sealing between the flat parts.

## Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in Fig. 22 as follows:

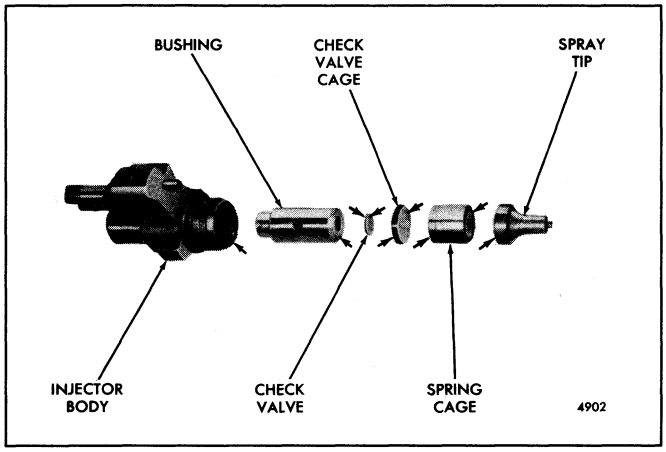



**Fig. 22 - Sealing Surfaces which may Require Lapping**

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.
2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.
3. Place the part to be lapped flat on the block and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.
4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*
5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.
6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again wash the part in cleaning solvent and dry it with compressed air.
7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.
8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

## Assemble Injector

1. Secure the body in vise J 22396-1.
2. Insert new filter(s), dimple end down, slotted end up, in the top of the body (Fig. 23).

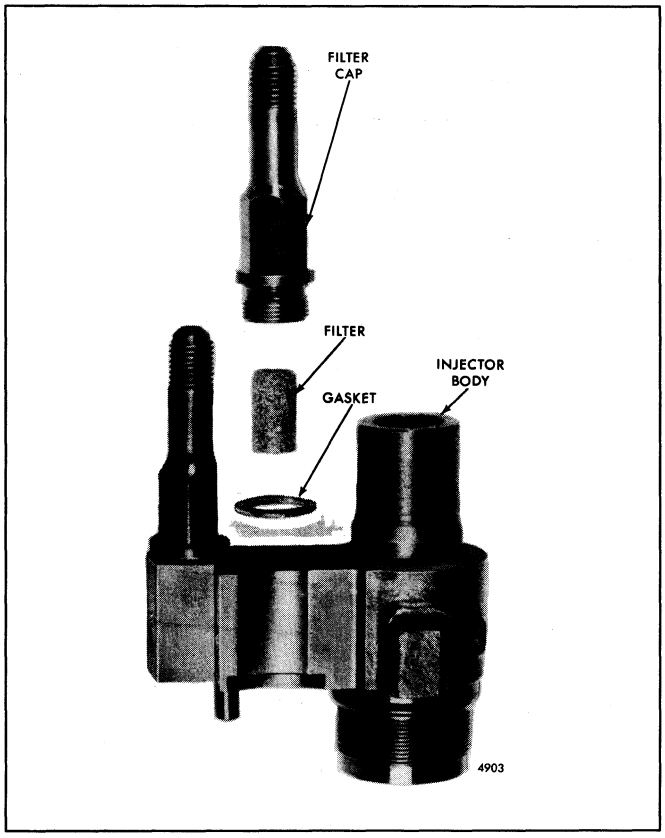



**Fig. 23 - Details of Injector Filters and Caps and Their Relative Location**

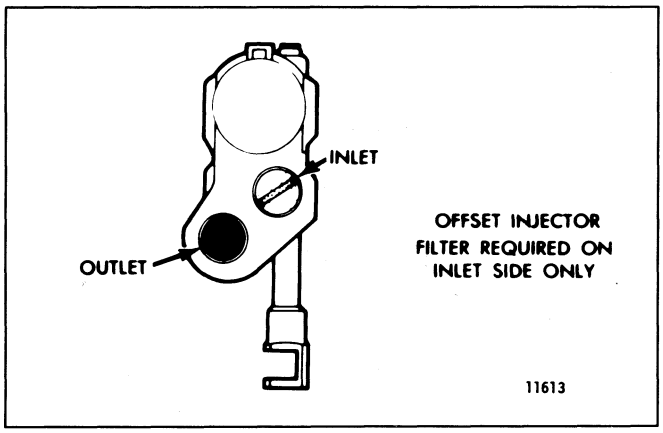



**Fig. 24 - Location of Filter in Injector Body**

Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 24).

• 3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten filter caps as follows:

Blued cap on blued body.....
.....70 lb-ft (95 Nem) torque

Non-blued cap on non-blued body or mixed (blued with non-blued part).....
.....62 lb-ft (84 Nem) torque

4. Install clean shipping caps to protect the sealing surfaces and to prevent dirt from entering the injector.
5. Remove the injector from the vise and hold the injector body, bottom end up.
6. Slide the control rack into the injector body.

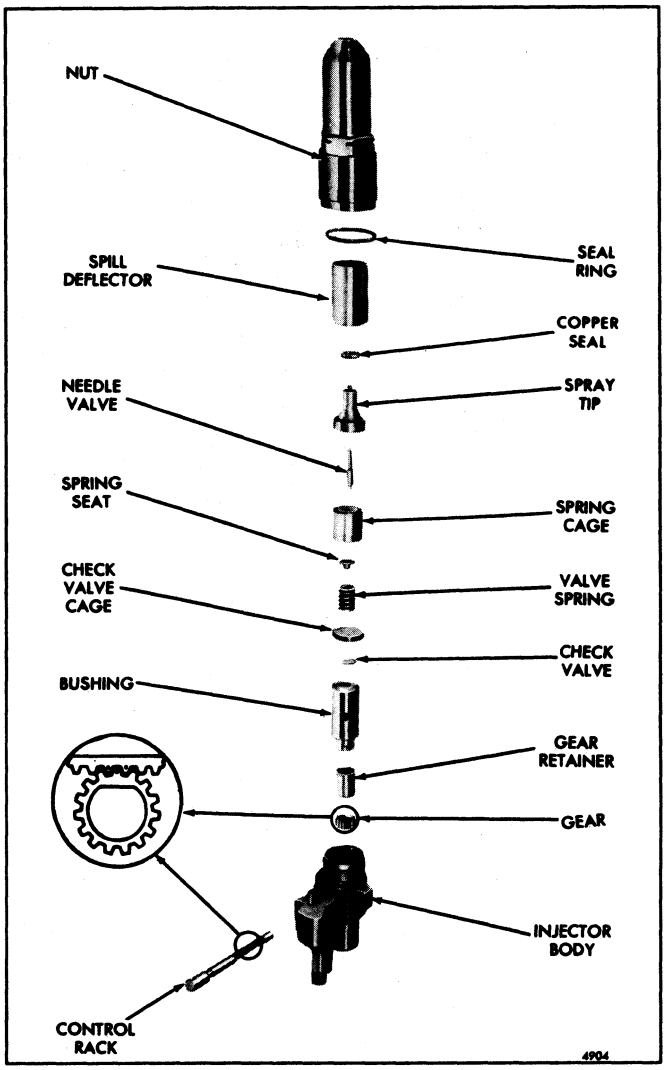



Fig. 25 - Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

7. Refer to Fig. 25 and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.
8. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 25)
9. Place the gear retainer on top of the gear. Install a new seal ring wetted with test oil.

NOTICE: Wet the seal ring with test oil and install the ring all the way down past the threads and onto the shoulder of the injector body. This will prevent the seal from catching in the threads and becoming shredded.

10. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.
11. Support the injector body, bottom end up, in injector vise J 22396-1.
12. Install the spill deflector over the barrel of the bushing.
13. Perform the spray tip test, as outlined in Section 2.0 using injector tip Tester J 22640-A before proceeding with the injector assembly.
14. Place the check valve centrally on the top of the bushing. Then, place the check valve cage over the check valve and against the bushing. The check valve cage must not rest on the check valve.
15. Insert the spring seat in the valve spring, then insert the assembly into the cage, spring seat first.
16. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.
17. Put the needle, tapered end down, into the spray tip (Fig. 26). Then, place the spray tip assembly on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.
18. Place a *new* copper seal (Fig. 20) over the spray tip (current injector nut only).
19. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body. Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

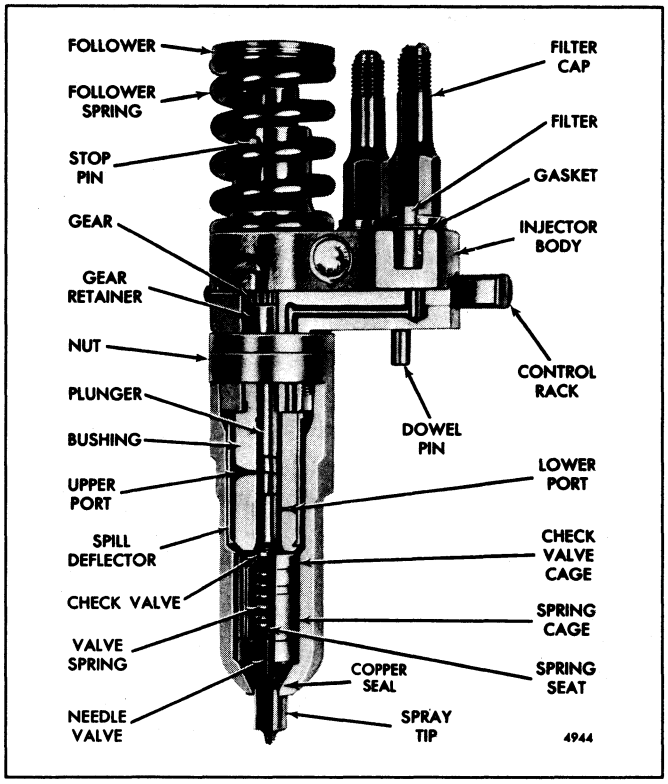



Fig. 26 – Cutaway View of Fuel Injector

• **20. Using socket J 22799 and a torque wrench, tighten injector nut as follows:**

**Blued nut on Blued body..... ..... 130 lb-ft 177 N#m) torque**

**Non-blued nut on blued body..... ..... 85 lb-ft (115 N«n) torque**

**Mixed (blued with non-blued part)..... ..... 108 lb-ft 147 Nbm) torque**

**21. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body-nut crevice.**

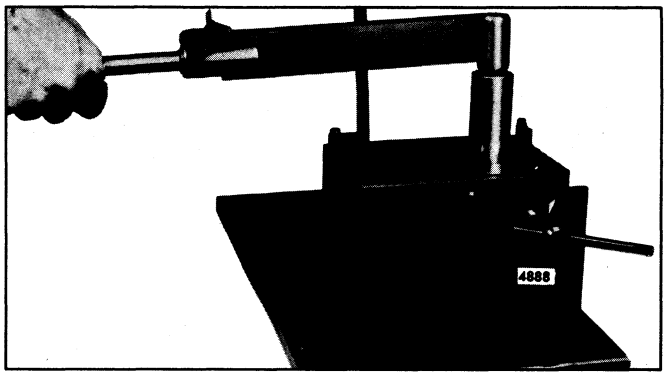



Fig. 27 - Tightening Injector Nut with Torque Wrench using Tool J 22799

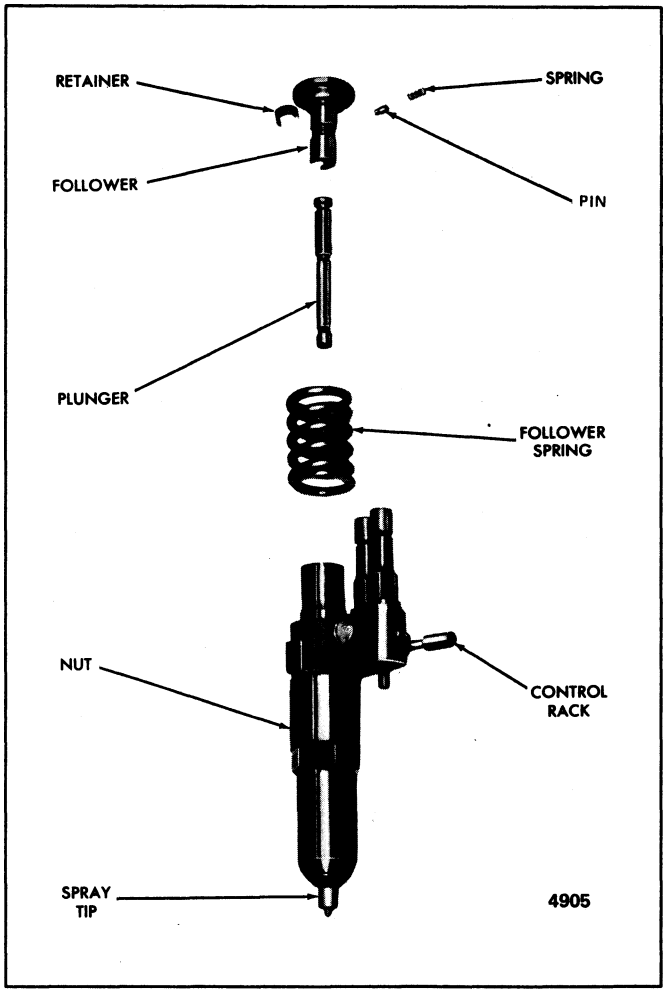



Fig. 28 - Injector Plunger, Follower and Relative Location of Parts

**NOTICE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.**

**22. Turn the injector over and push the rack all the way in.**

**23. Place the follower spring on the injector body.**

**24. Refer to Fig. 34 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.**

**25. Refer to Fig. 28 and slide the head of the plunger into the follower.**

**26. Align the slot in the follower with the stop pin hole in the injector body.**

**27. Align the flat side of the plunger with the flat in the gear.**

**28. Insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.**

## Check Injector Output

Perform the injector fuel output test using Calibrator J 22410-A as outlined in Section 2.0 - Shop Notes.

## Check Atomization And Spray Pattern

This test determines spray pattern uniformity and atomization.

1. Clamp the injector properly and purge the air from the system (Fig. 29).
2. Move lever 4 down.
3. Position the injector rack in the *full-fuel* position.
4. Place pump lever 1 in the *vertical* position.
5. Move lever 3 to the *forward detent* position.
6. The injector follower should be depressed rapidly using pump lever 1 (at 40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray patten to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

## Check Pressure Holding And Test For Leaks

This test determines if the body-to-bushing mating surfaces in the injector are sealing properly and indicates proper plunger-to-bushing fit.

1. Clamp the injector properly in Tester J 23010-A and purge the air from the system (Fig. 29).
2. Close the Thru-Flow valve, but do not overtighten.
3. Move lever 2 to the rear, *horizontal* position.

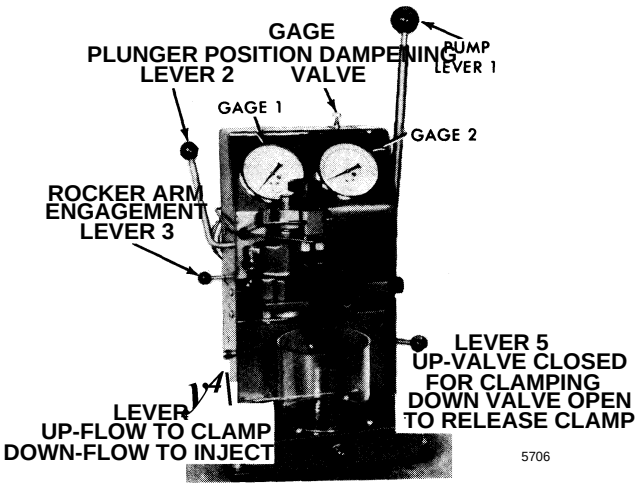



**Fig. 29 - Injector in Position for Testing with Tester J 23010-A**

4. Operate pump lever 1 until gage 1 slowly reaches 100-200 psi (689-1378 kPa), check for injector nut seal ring leaks. Then, increase the gage reading to 1500-2000 psi (10 335-13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs. Note the time for the pressure to drop from 1500 psi to 1000 psi (10 335 kPa to 6890 kPa). This should not occur in less than 7 seconds. This test determines if the body-to-bushing mating surfaces in the injector are sealing properly.
5. Unclamp the injector.
6. Open the Thru-Flow valve to release pressure in the system.
7. Move lever 5 *down* to release the clamping pressure.
8. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clean of the injector filter caps.
9. Carefully, return lever 5 to the *up (horizontal)* position.

## Check Rack Freeness And Spray Tip Concentricity

Place the injector in Tester J 29584 (Fig. 30) and check rack freeness.

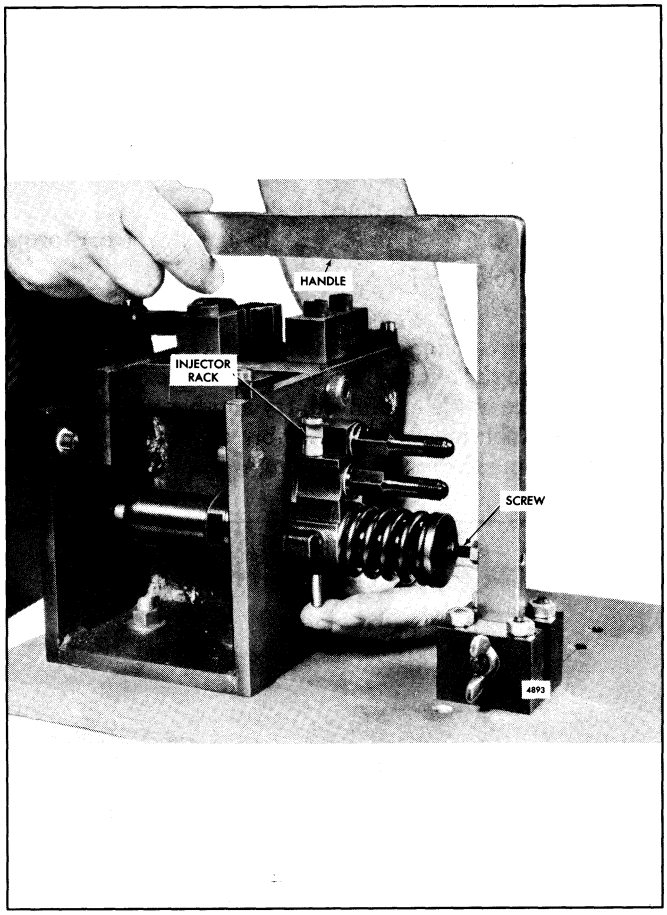



**Fig. 30 - Checking Rack for Freeness in Tester J 29584**

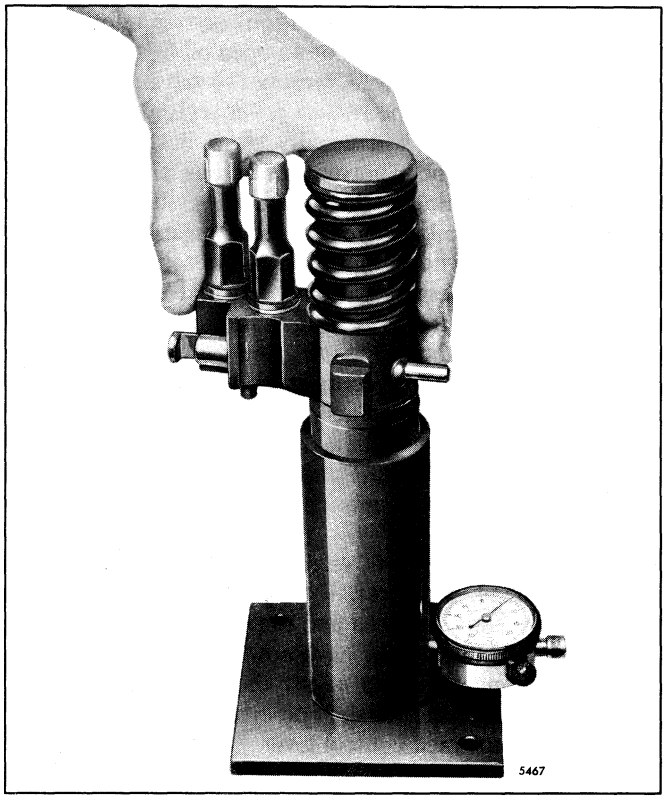



**Fig. 31 - Checking Injector Spray Tip Concentricity using Tool J 23905**

With the injector control rack held in the *no-fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel. If the rack falls freely the injector passes the test.

If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times, if necessary. Generally, this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts or to remove dirt.

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in Tester J 23905 (Fig. 31) and adjust the dial indicator to zero.
2. Rotate the injector 360° and note the total runout as indicated on the dial.
3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 120-140 lb—ft (163-190 NAm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

## Box And Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

## Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 22342-11 or a cylindrical wire brush, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrusion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it ririiSv out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to Fig. 5 and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.
2. Slide the injector rack control lever over so that it registers with the injector rack.
3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 46-50 lb—ft (62-68 N«m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   **NOTICE:** Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.
4. Install the two exhaust valve bridges.
5. Install the valve and injector operating mechanism. Tighten the two rocker arm shaft bolts to 90-100 lb—ft (122-136 N#m) torque.
6. Place the injector rack control tube assembly in position, with the control tube levers engaged with the injector racks, and secure it with four bolts and lock washers. Tighten to 13-17 lb—ft (18-23 N#m) torque.
7. Install the fuel supply and fuel return pipes. The current fuel pipe connector nuts are 9/16" diameter wrench hex at each end. The former connector nuts were 7/16" at the fuel manifold connector end and 9/16" at the injector filter cap end. The former and current fuel pipe assemblies are interchangeable on an engine.

   •**NOTICE:** DDC recommends that the original flared end fuel pipes not be reused. New flared end fuel pipes should be installed.

Use new wrench set J 26617 and tighten both nuts on each fuel pipe to 18-22 lb-ft (24-30 N#m) torque. Then, install the fuel line support clips.

The new handle J 26617-1 can be used to tighten or loosen the connector nuts without any resultant damage to the handle, providing 25 lb-ft (34 N«m) torque is not exceeded. The former tool J 23385 could fracture when tightening a damaged fuel line connector nut and therefore is no longer available and should not be used.

Also, with the use of the new wrench set J 26617 and the fact that the handle is preset to click at 20 lb-ft (27 N#m) torque, it will *no longer be necessary* to use the torque wrench reading procedure as outlined in Section 1.3 under *Assemble Crankshaft Halves.*

**NOTICE:** Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Fuel Jumper Line Maintenance and Reuse* Pressurize Fuel System - Check for Leaks in Section 2.0 - Shop Notes).

An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Use a new gasket and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

8. Perform a complete engine tune-up as outlined in Section 14. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.

# FUEL INJECTOR TUBE

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at thetop with a neoprene ring and upset into a flare on the lowerside of the cylinder head to create water-tight joints at thetop and bottom.

## Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22342-01, as follows:

1. Remove, disassemble and clean the cylinder head, as outlined in Section 1.2.

2. Place the injector tube installer J 22342-1 in the injector tube. Insert the pilot J 22342-3 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. 1).

3. Tap on the end of the pilot to loosen the injector tube. Then lift the injector tube, installer and pilot from the cylinder head.

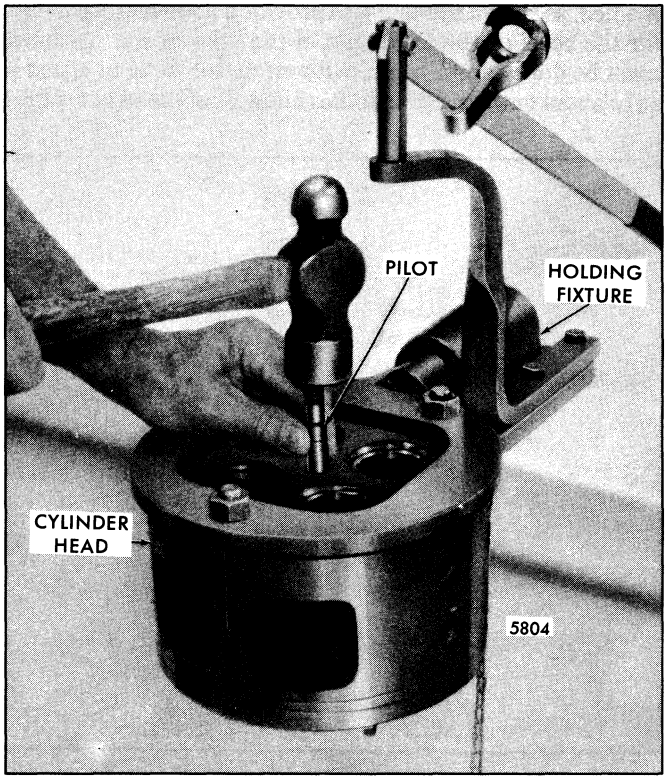



**Fig. 1 - Removing Injector Tube**

## Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove dirt, burrs or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end. Then install the tube, as follows:

1. Place a new injector tube seal ring in the counterbore in the cylinder head.

2. Place the installer J 22342-1 in the injector tube. Then insert the pilot J 22342-3 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2).

3. Slip the injector tube and tool assembly in the injector bore and drive them in place (Fig. 2). The flange at the upper end of the tube will seat on the seal ring and into the counterbore of the cylinder head when the injector tube is properly positioned. Then remove the installer and pilot.

4. With the injector tube properly positioned in the cylinder head, assemble the swaging die and swage the lower end of the injector tube, as follows:

   a. Refer to Fig. 3 and thread stud J 22343-15 into body J 22342-4 until the stud head is approximately 1 1/2" above the top of the body. Place the seat and guide J 22342-12 into the lower end of the body.

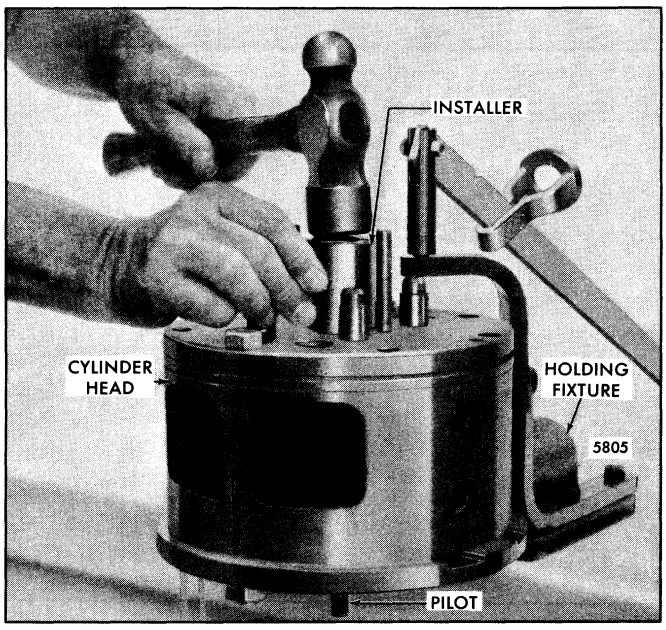



**Fig. 2 - Installing Injector Tube**

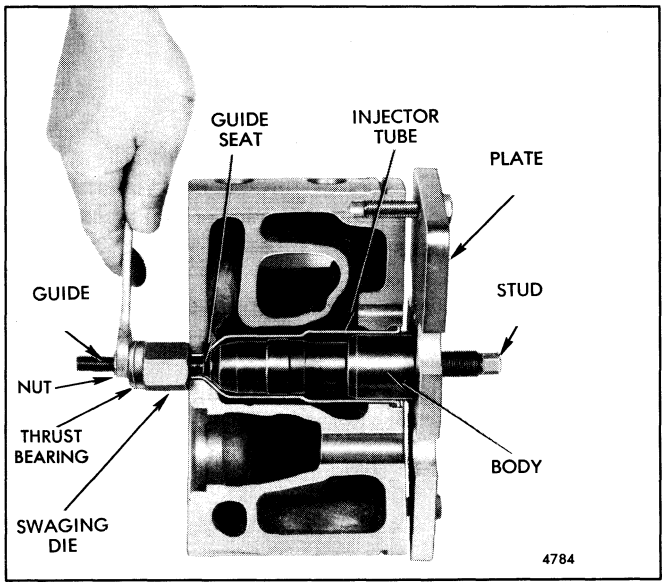



**Fig. 3 - Swaging Injector Tube with Tool Set J 22342-01**

b. Position the body assembly into the injector tube. Place plate J 22342-13 over the body and valve bridge guides, then secure the plate to the cylinder head with two bolts. Tighten the bolts to 5-7 lb—ft (7-10 N«m) torque.

**NOTICE:** The plate (J 22342-13) must be parallel to the cylinder head after the bo ts are torqued.

c. Turn the stud J 22342-15 until the guide seat makes contact with the lower end of the injector tube.

d. Slide swaging die J 22342-16 over seat and guide J 22342-12, with the arrow on the die pointing toward the cylinder head. This will place the flaring end of the swaging die against the injector tube.

e. Lubricate the thrust bearing, nut and flat washer with grease. Place thrust bearing J 22342-18 against the swaging die, then install the flat washer and nut J 22342-19.

f. Tighten the nut to 30-35 lb—ft (41-47 N«m) torque, turn the swaging die four full turns and retorque the nut to 30-35 lb—ft (41-47N#m) torque. Repeat this sequence until the injector tube is fully swaged.

**NOTICE:** Do not exceed the specified torque.

5. Disassemble and remove swaging tools.

## Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations: First, *hand reamedas* shown in Fig. 4, to receive the injector body nut and spray tip; second, *spot-faced* to remove excess stock at the lower end of the injector tube (Fig. 5); and third, *hand reamed*, as shown in Fig. 6, to provide a good seating surface for the bevel or the lower end of the injector nut. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

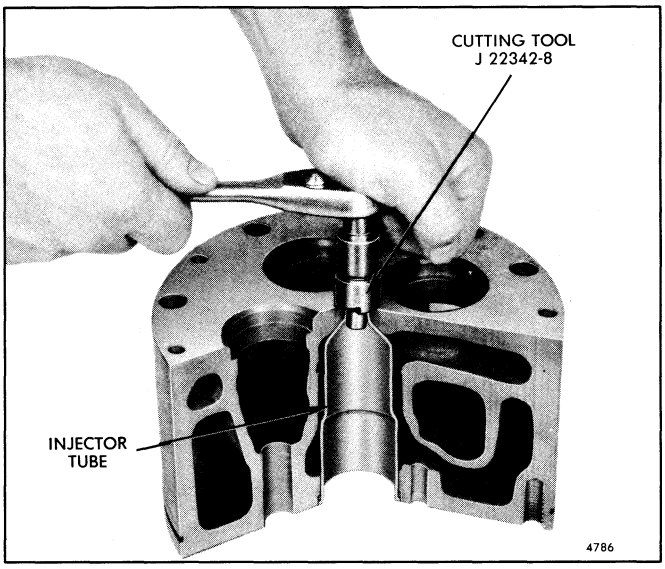



**Fig. 4 - Reaming Injector Tube for Injector Body Nut and Spray Tip with Tool J 22342-5**

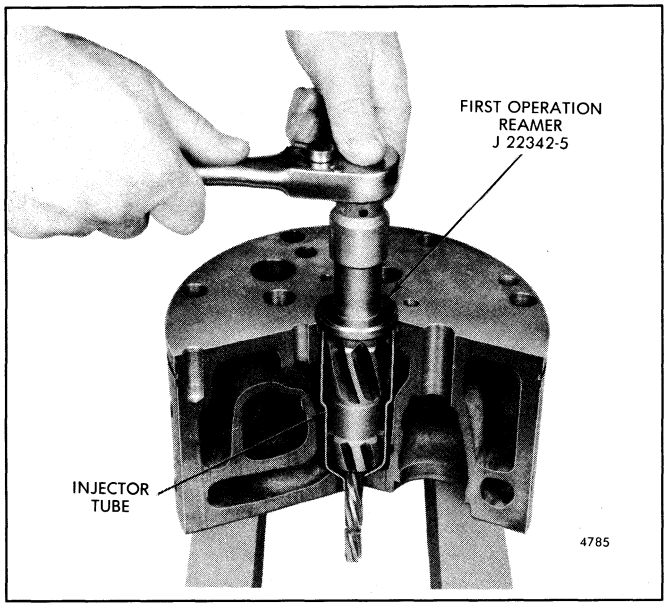



**Fig. 5 - Removing Excess Stock from Lower End of Injector Tube with Tool J 22342-8**

**NOTICE:** The reamer should be turned in a *clockwise direction* only, both when inserting and when withdrawing the reamer, because movement in the opposite direction will dull the cutting edges of the flutes.

1. Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation, as follows:

   a. Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22342-5 in the injector tube.

   b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the collar on the reamer contacts the injector tube (Fig. 4). Clean out all of the chips.

2. Remove excess stock.

   a. With the cylinder head bottom side up, insert the pilot of cutting tool J 22342-8 into the small hole of the injector tube.

   b. Place a few drops of cutting oil on the tool. Then, using a socket and speed handle (Fig. 5), remove the excess stock so that the lower end of the injector tube is from flush to .005” below the finished surface of the cylinder head.

3. Ream the bevel seat in the injector tube.

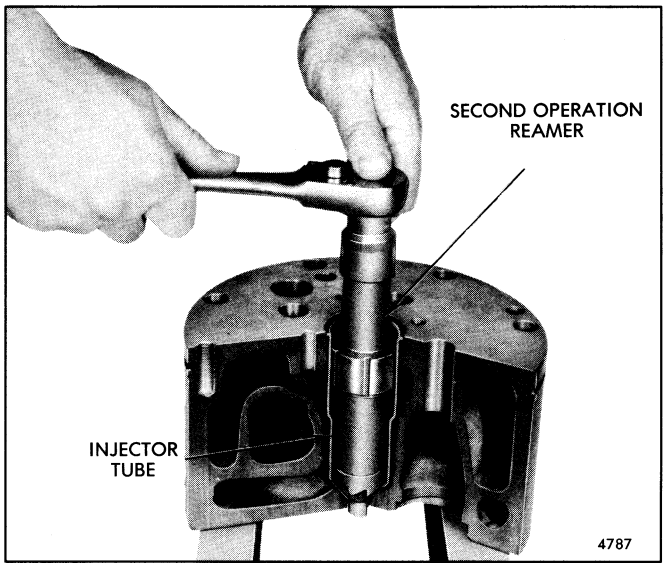



**Fig. 6 - Reaming Injector Tube for Injector Nut with Tool J 22342-11**

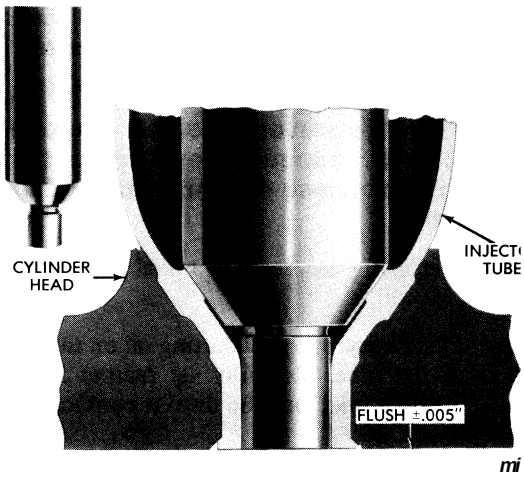



**Fig. 7 - Injector Tube Bevel Seat to Cylinder Head Limits - Gage J 25561**

The tapered lower end of the injector tube must provide a smooth and true seat for the loWer end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber.

Therefore, to determine the amount of stock that must be reamed from the bevel seat of the tube, refer to Fig. 7.

Install gage J 25561. Zero the sled gage, with dial indicator J 22273-01, to the fire deck. The tool J 25561 should be flush to ± .005” with the fire deck of the cylinder head (Figs. 7 and 8).

**NOTICE:** Any fire deck resurfacing work must be done prior to final injector tube seat gaging. Refer to Section 1.2 for resurfacing instructions.

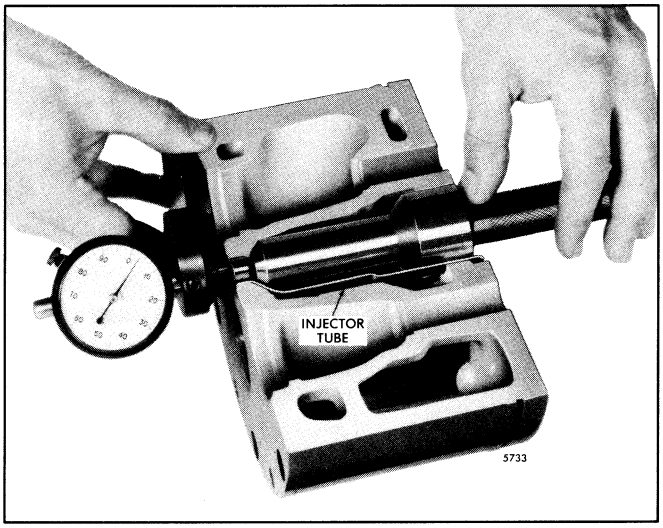



**Fig. 8 - Checking Bevel Seat with Gage J 25561 and Dial J 22273**

With the first reaming operation completed and the injector tube spot-faced, wash the interior of the injector tube with trichloroethylene or clean fuel oil and dry it with compressed air.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Then perform the second reaming operation, as follows:

a. Place a few drops of cutting oil on the bevel seat of the tube. Carefully set reamer J 22342-11 into the injeqtor tube until it contacts the bevel seat.

b. Make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips and look at the bevel seat to see what portion of the seat has been cut.

c. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

d. Remove the chips from the injector tube and, using an injector as a gage, continue the reaming operation until the shoulder of the spray tip is within the limits (Fig. 7). Then wash the interior of the injector tube with trichloroethylene or clean fuel oil and dry it with compressed air.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

# FUEL PUMP

The positive displacement gear type fuel pump transfers fuel from the supply tank to the fuel injectors (Figs. 1, 8 and 9). The pump circulates an excess supply of fuel through the fuel injectors which purges the air from the system and cools the fuel injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

The fuel pump is mounted on an adaptor, attached to the flywheel housing, and is driven off the end of the blower drive gear by a drive coupling fork (Fig. 2). The drive coupling fork is attached to the end of the pump drive shaft and mates with a drive disc attached to the blower drive gear assembly. The fuel pump is a right-hand rotating pump. Regardless of engine rotation, the pump always rotates in a right-hand rotation.

The former fuel pump and drive fork was effective with engine serial numbers 12E-4192 (including 12E-4175,4181) and 16E-3421 (including 16E-3397). The former pump is identified by the number “11” stamped in the pump cover. The former pump (Fig. 4) differs from the early pump in that additional passages have been drilled in the cover, driven shaft and in the pump body to improve lubrication and increase the relief pressure capacity.

A new positive displacement fuel pump with 3/4” thick rotary gears is being used on all Series 149 engines (Fig. 9). The current pump differs from the former pump in that the drive and driven gears of the new are supported by precision anti-friction needle bearings. These bearings are lubricated through angle-drilled holes from the fuel pressure side of the pump. The drive and driven gears in the current pump body (stator) are a slip fit on the shafts. A Woodruff type key between the drive gear and drive shaft and a pin between the driven gear and idler (driven) shaft hold the gears in position. Snap rings on the ends of the gears prevent lateral movement.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surface of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the former cover and body since the pump clearances are set up on the basis of metal-to-metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. A plastic gasket is used to seal the gear housing (cover) and stator (body) and also maintain close gear end clearance for improved efficiency. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The fuel pump body is recessed to provide running space for the pump gears (Fig. 3). Recesses are also provided at the inlet and outlet positions of the gears. The small hole “A” (two holes current pump) permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole JIB” and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole “C” when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole “C”. The cavity “D” provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the flywheel housing (Fig. 5). The oil seals are installed with the lips of the seals facing toward the flanged end of the pump body. A small hole “E”(Fig. 3) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal.

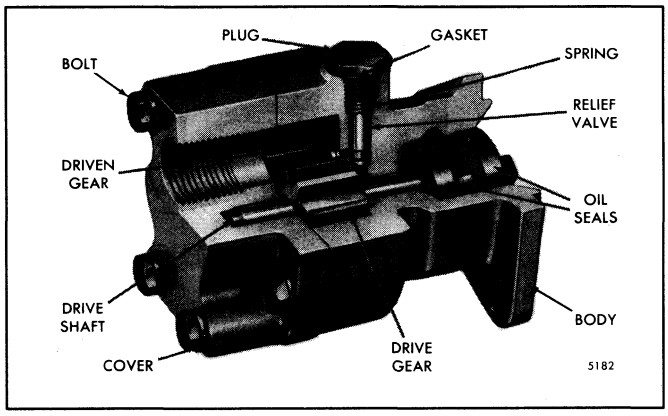



**Fig. 1 - Early Fuel Pump Assembly**

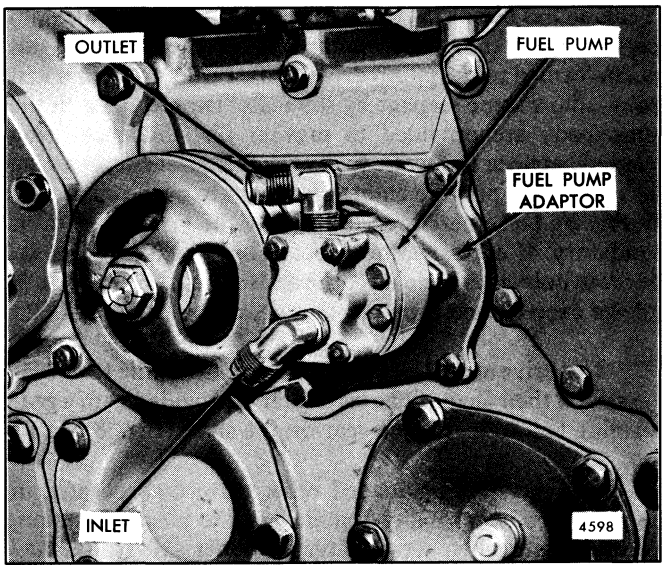



**Fig. 2 - Fuel Pump Mounting**

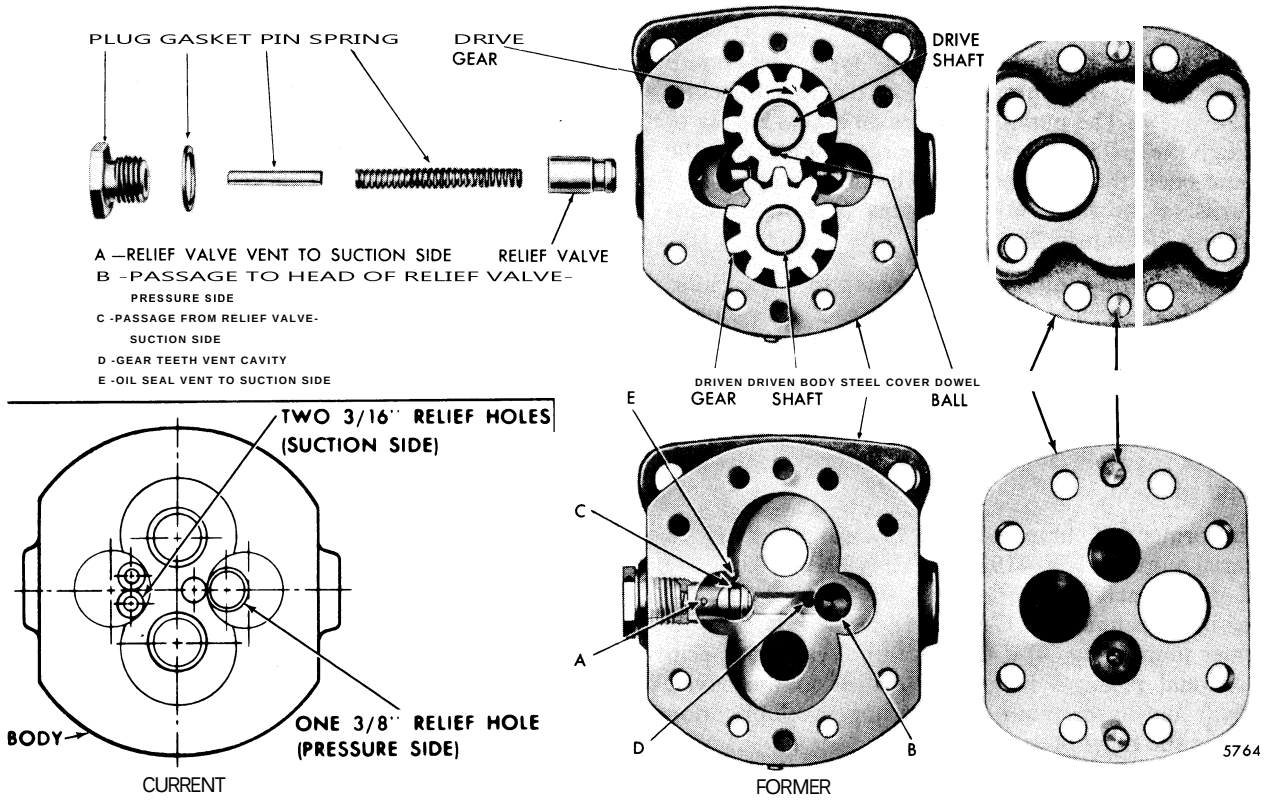



**Fig. 3 - Typical Fuel Pump Valving and Rotation (Early and Former Pumps)**

In addition to the above, the former fuel pump assembly was improved by the addition of the features illustrated in the inset of Fig. 3.

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage by the seals. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. If excessive fuel leakage by the pump seals via the drain holes is experienced, the seals should be changed. If leakage exceeds one drop per minute, replace the seals.

The drive and driven gears are a line-to-line to a .001" press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft (Fig. 8 or 9).

The early spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 70 psi (483 kPa).

The former relief valve spring (identified by an overall red Dykel dye) operates when the fuel pressure on the outlet side (to the fuel filter) reaches approximately 80 psi (552 kPa). The higher opening pressure relief valve spring ensures that the fuel pump relief valve will remain closed during normal engine operation. Since this spring resulted in higher fuel flow through the fuel injection system, a new larger spill orifice had to be used to maintain the same fuel inlet manifold pressure range.

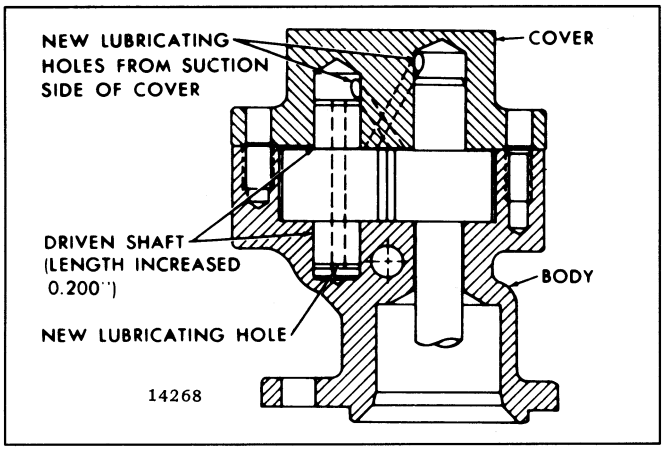



Fig. 4 – Former Fuel Pump

When the former relief valve spring is used a new fuel pressure relief orifice plug, fuel junction block, and 1/4" tee fitting must also be used.

## Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel oil is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by bypassing the fuel from the outlet side of the pump to the inlet side. This occurs when the discharge pressure reaches approximately 60-80 psi (414-552 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold as shown in Section 13.2.

## Remove Fuel Pump

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
2. Disconnect the drain tube, if used, from the fuel pump.
3. Remove the three pump attaching bolts and withdraw the pump from the fuel pump adaptor.
4. If required, remove the fuel pump adaptor and discard the gasket.
5. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

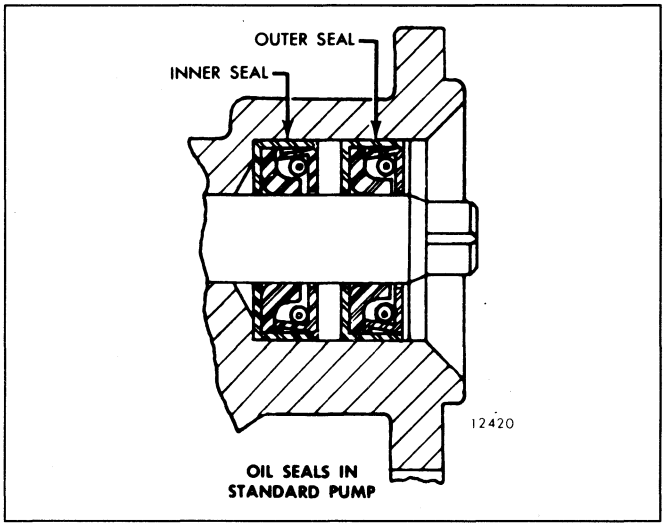
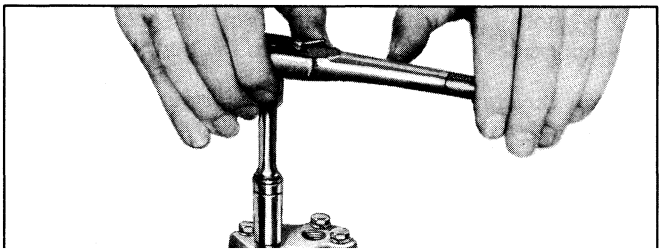



Fig. 5 – Fuel Pump Oil Seals



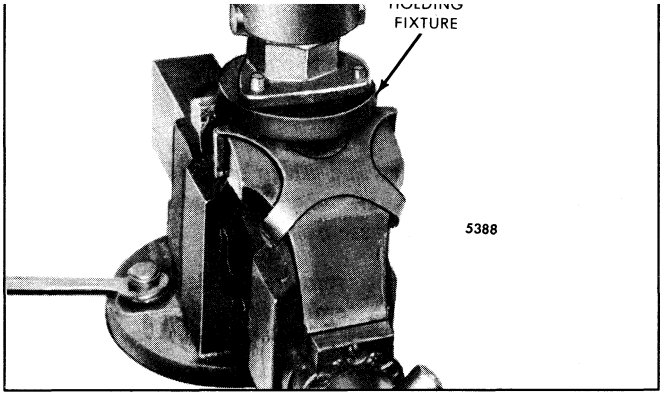



**Fig. 6 - Removing Fuel Pump Cover using Holding Fixture J 1508-10**

## Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 (Fig. 6), refer to Figs. 1, 8 and 9 and disassemble the pump as follows:

1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover. Remove the thin plastic gasket from the current pump.

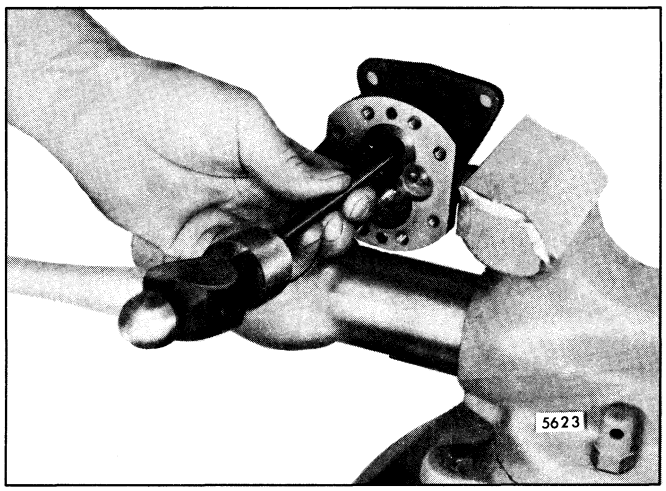



**Fig. 7 - Removing Oil Seals from Fuel Pump Body using Tool J 1508-13**

2. Withdraw the drive shaft, drive gear and gear retaining ball or key as an assembly from the pump body.

3. On the former pump, press the drive shaft just far enough to remove the steel locking ball. Then, invert the shaft and gear assembly and press the shaft from the gear. *Do not misplace the steel ball.* Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.

On the current pump, remove the snap ring from the groove opposite the drive end of the shaft. Remove the gear and the key. The gear is a slip fit and does not require a pressing operation. Use caution to avoid scoring the seal area of the drive shaft.

4. On the former pump, remove the driven shaft and gear as an assembly from the pump body. *Do not remove the gear from the shaft* The driven gear and shaft are serviced only as an assembly.

On the current pump, remove the driven shaft, gear, pin and snap rings as an assembly from the stator (body). Remove the snap ring from either end of the shaft, then remove the gear and pin. The gear is a slip fit on the shaft and does not require a pressing operation.

5. Remove the relief valve plug and copper gasket.

6. Remove the valve spring, pin and relief valve from the valve cavity in the pump body.

7. If the oil seals need replacing, remove them with oil seal remover J 1508—13 (Fig. 7). Clamp the pump body in a vise and tap the end of the tool with a hammer to remove the inner and outer seals. Observe the position of the oil seal lips before removing the seals to permit installation of new seals in the same position.

8. If the needle bearings in the body and cover need replacing, insert bearing remover J 33853 into each needle bearing and tighten until the inside diameter of the bearing is securely gripped by the expanding end of the tool. Remove the bearings by using the slide hammer feature of the tool.

## Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Fuel pumps stamped *2 *or 2D** on the cover have a matched pump body and cover. These pumps may be rebuilt the same as a standard pump, provided the body and cover are kept together and reused in the same pump. If either the body or cover of these pumps require replacement, a complete new fuel pump assembly must be installed.

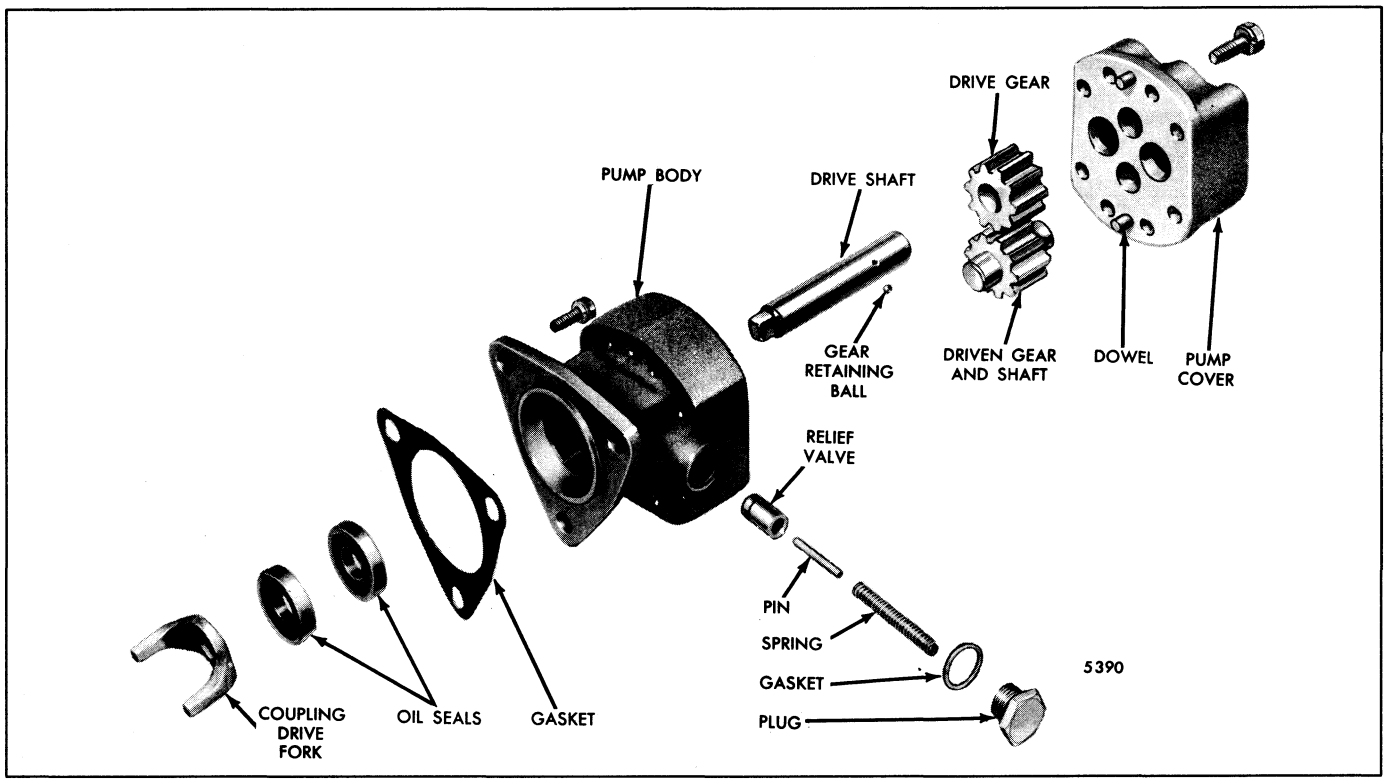



**Fig. 8 - Former Fuel Pump Details and Relative Location of Parts**

Oil seals, once removed from the pump body, must be discarded and replaced with new seals. The lips of the oil seals must fit snug around the pump shaft and must be free of nicks or cracks.

Check the pump gear teeth for scoring, chipping or wear. Check the inside diameter of the gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts, if necessary.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also, check for wear at areas contacted by the gears and shafts. Replace the pump cover or body, if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the relief valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

## Assemble Fuel Pump

Refer to Figs. 1, 3, 8 and 9 and assemble the pump as follows:

1. Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seals in the pump body as follows:

   a. Place the inner oil seal on the pilot of the installer handle J 1508-8 so that the lip of the seal will face in the same direction as the original seal which was removed.

   b. With the pump body supported on wood blocks (Fig. 10), insert the pilot of the installer handle in the pump body so the seal starts straight into the pump flange. Then, drive the seal in until it bottoms.

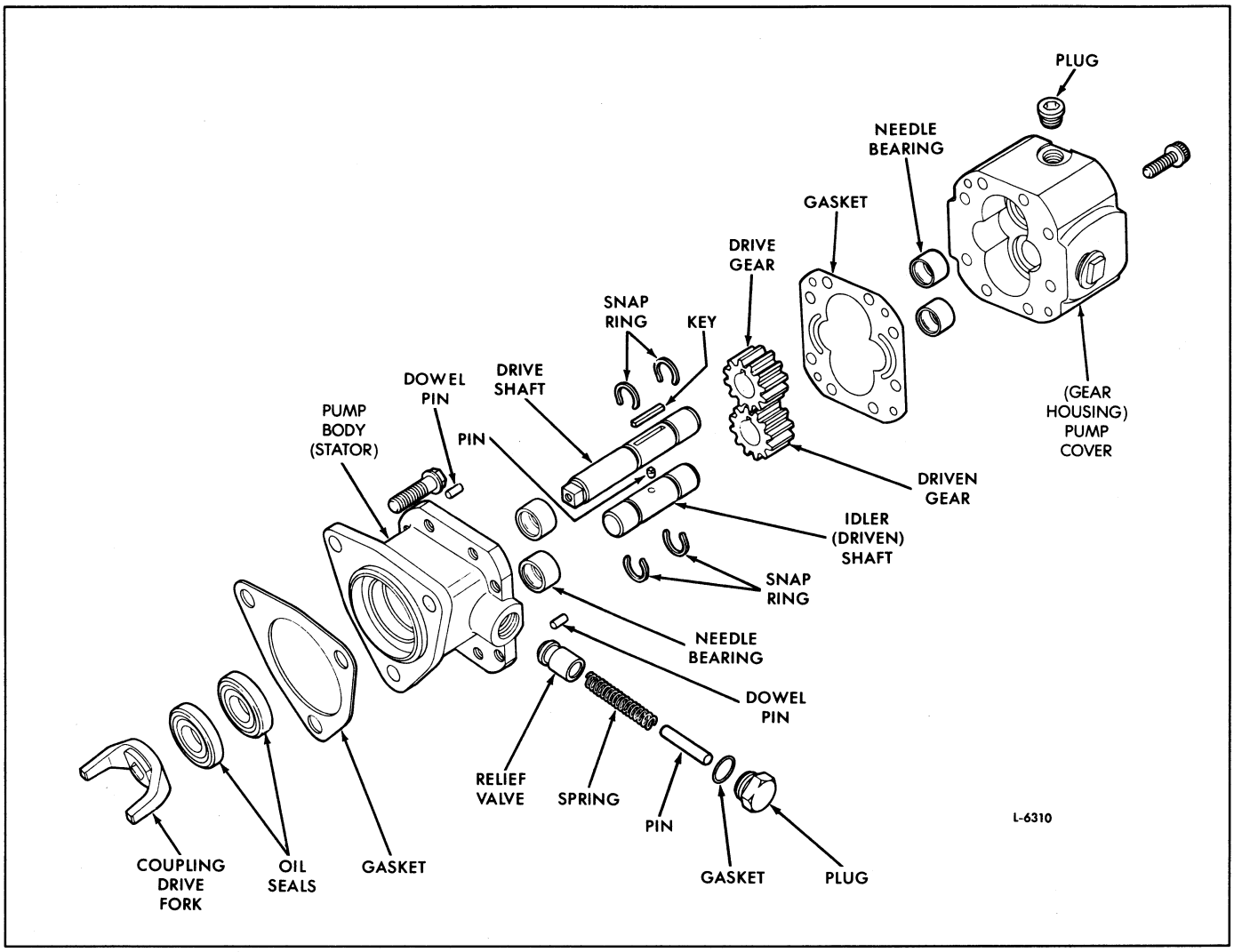



Fig. 9 – Current Fuel Pump Details and Relative Location of Parts

c. Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle (Fig. 11). Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then, insert the pilot of the installer handle into the pump body and drive the seal in until the shoulder of the adaptor contacts the pump body. Thus, the oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new copper gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the plug in the former pump to 18-22 lb—ft (24-30 N«m) torque. Tighten the plug in the current pump to 6-10 lb—ft (8-14 N«m) torque.

3. On the former fuel pump, install the fuel pump drive gear over the end of the drive shaft which is not squared (so the slot in the gear will face the plain end of the shaft). This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining ball detent. Then, place the ball in the detent and press the gear back until the end of the slot contacts the ball.

On the current pump, install one snap ring in the groove on the square end of the drive shaft by pressing it directly into the groove. *Do not slide the snap ring over the sealing area of the drive shaft* This operation is very important, otherwise fine score marks caused by sliding the snap ring into position from the square end of the shaft may cause rapid wear of the oil seals. Insert the long square key in the slot in the shaft. Slide the drive gear over the end of the shaft until the groove in the gear mates with the key in the slot. Install the second snap ring to hold the gear in place.

On the current pump, install one snap ring in the groove on the driven shaft and place the square-head pin in the hole in the shaft. Slide the driven gear onto the shaft until the groove in the gear mates with the pin. Install the second snap ring to hold the gear in place.

4. Lubricate the pump drive shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals (Fig. 12).

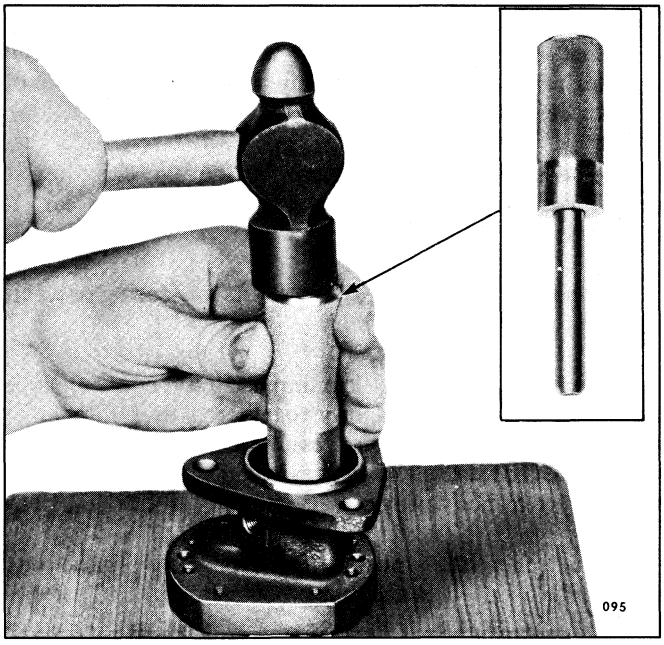



**Fig. 10 - Installing Inner Oil Seal in Fuel Oil Pump Body with Tool J 1508-8**

5. Place the driven shaft and gear assembly in the pump body.

6. Lubricate the gears and shafts with clean engine oil.

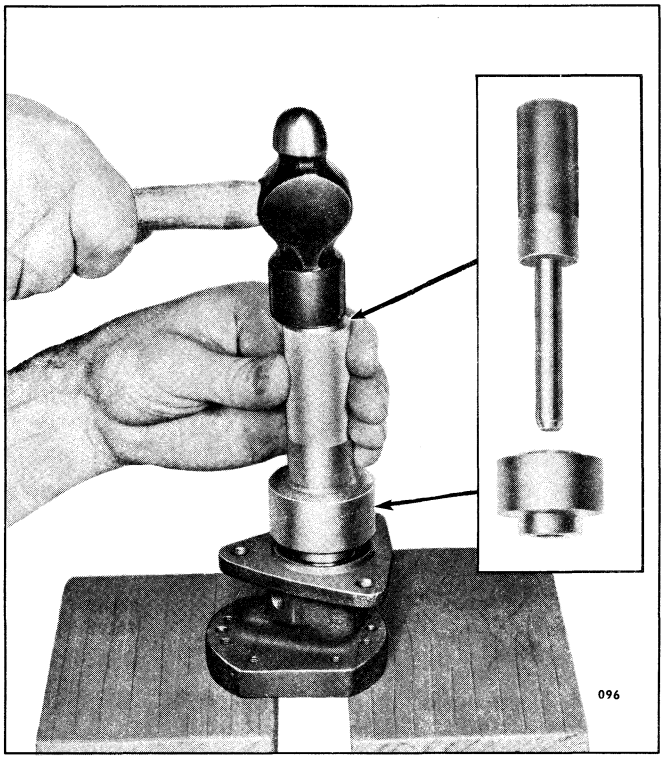



**Fig. 1 1 - Installing Outer Oil Seal in Fuel Oil Pump Body with Tools J 1508-8 and J 1508-9**

7. On the former pump, apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area. Then, place the cover against the pump body with the two dowel pins in the pump cover entering the holes in the pump. The cover can be installed in only one position over the two shafts.

**NOTICE:** The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

On the current pump, place a new thin plastic gasket on the body face. *Sealant is not required between the pump halves and should not be used.*

8. On the former pump, secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.

On the current pump, *with the fuel inlet hole in the gear housing directly over the pressure relief valve in the body, lower the cover onto the shaft and gear assemblies until it rests on the body. Make sure that the dowel pins fit into the proper dowel holes. Using a No. E-8 Torx socket (J 25359-11), secure the housing in place with eight bolt/lock washer assemblies. Tighten the bolts alternately and evenly to a finish torque of 9-11 lb-ft (12-15 Nmm).*

*9.* After assembly, rotate the drive shaft by hand to make certain that the parts rotate freely. When the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.

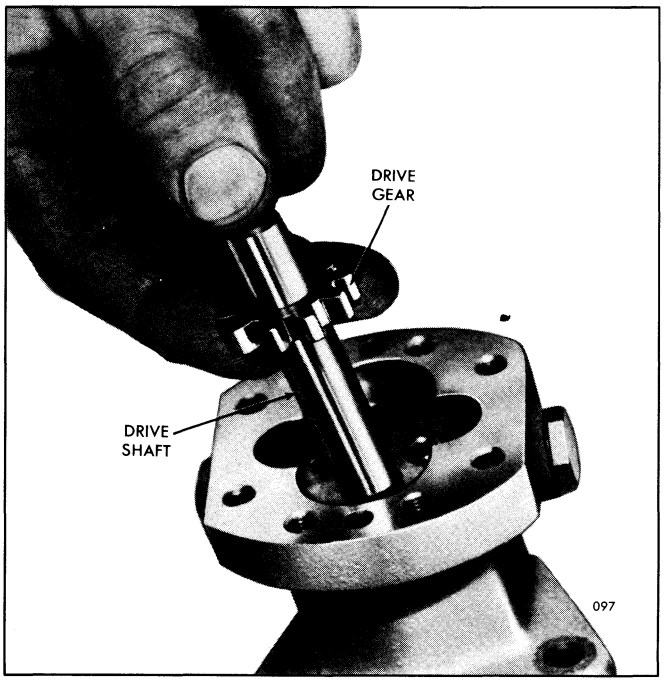



**Fig. 12 - Installing Fuel Pump Drive Shaft**

10. Install 1/8” pipe plugs in the upper unused openings.

11. If the pump is not to be used immediately, place plastic shipping plugs in the lower (drain) opening and the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

## Install Fuel Pump

1. Affix a new gasket to the pump adaptor and install the adaptor on the flywheel housing with four 3/8”-16 x 1” bolts and lock washers. Tighten the bolts to 30-35 lb-ft (41-47 N#m) torque.

2. Affix a new gasket to the pump body mounting flange. Then, place the drive coupling fork on the square end of the drive shaft.

3. Place the fuel pump against the pump adaptor, being certain that the drive coupling fork registers with the slots in the drive coupling disc. Refer to Section 1.7.6 for installation of the drive coupling disc.

4. Secure the pump to the pump adaptor with three nylon patch bolts. To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies. Tighten bolts to 30-35 lb-ft (41-47 N#m) torque.

• 5. If removed, install the inlet and outlet elbows in the pump cover. Before installing, coat the threads lightly with Gasoila, Permatex 2, or an equivalent non-hardening sealant. To prevent sealant from entering the fuel system, do not apply it to the first two (2) threads of the fittings. Tighten fittings to the low end of the torque. If necessary, continue tightening until alignment is achieved, but do not exceed maximum torque. Tighten 1/4” fittings to 14- 16 lb-ft (19 - 22 N#m), 3/8” fittings to 18 - 22 lb-ft (24 - 30 N#m), and 1/2” fittings to 20 - 25 lb-ft (27 - 34 N«m) torque.

**NOTICE:** Do not use Teflon tape or paste on fittings, since this can result in fuel pump cover damage (cracking) before the required torque is reached.

6. Connect the inlet and outlet fuel lines to the fuel pump elbows.

7. Connect the fuel pump drain tube, if used, to the pump body.

8. If the fuel pump is replaced or rebuilt, prime the fuel system with Tool J 5956 before starting the engine. This will prevent the possibility of pump seizure upon initial starting.

# FUEL STRAINER AND FUEL FILTER

• A fuel strainer (primary) and fuel filter (secondary) are used to remove impurities from the fuel (Fig. 1). The fuel strainer is located between the fuel tank and the fuel pump. The replaceable density-type element is capable of filtering out particles of 30 microns (a micron is approximately .00004"). The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable paper-type element can remove particles as small as 10 microns. Fiber glass elements can remove particles as small as 5 microns.

NOTICE: A fuel tank of galvanized steel should never be used for fuel storage, as the fuel oil reacts chemically with the zinc coating to form powdery flakes which will quickly clog the fuel filter and cause damage to the fuel pump and the fuel injectors.

The bolt-on type fuel strainer and fuel filter (Figs. 1,2 and 3) are similar in construction and consist essentially of a shell, cover and a replaceable filtering element. The filtering element sets over the central stud, which is welded to the shell. The shell and element are attached to the cover by a nut or bolt that threads on or into the central stud. A shell gasket and cover bolt gasket seal the assembly against leakage.

• Spin-on type fuel strainer and filter assemblies are used on all current Series 149 engines, except certain marine and military models. The (primary) strainer assembly consists of a dual base adaptor (Fig. 4) and two (2) spin-on elements. The (secondary) filter assembly consists of a single base adaptor and spin-on element (Fig. 5). Spin-on elements include gaskets.

• Filter covers incorporate a threaded sleeve to accept the spin-on elements. The word "Primary" is cast into the fuel strainer cover, and the word "Secondary" is cast into the fuel filter cover.

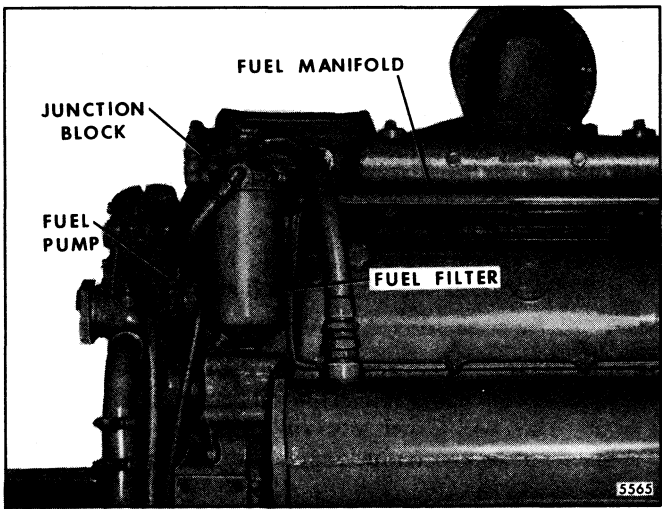



Fig. 1 - Fuel Filter Mounting (Early Engines)

• No drain cocks are provided on spin-on filters. Where water is a concern, a fuel/water separator should be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before installing it.

## Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter,

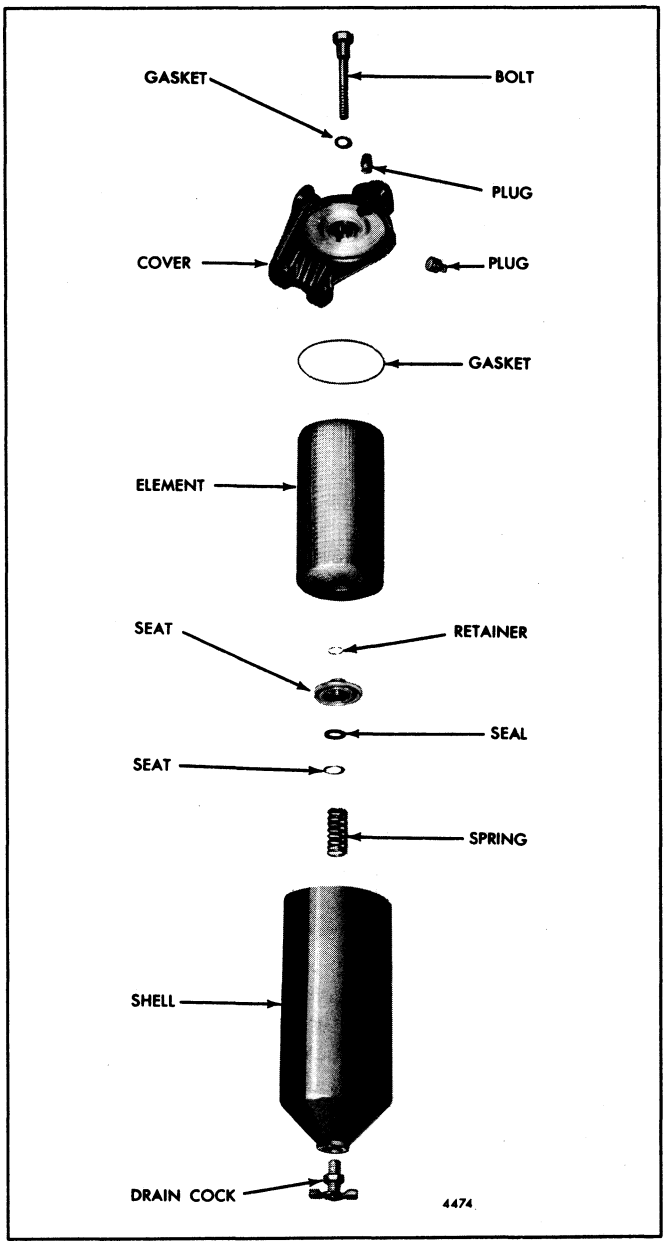



Fig. 2 - Fuel Strainer Details and Relative Location of Parts

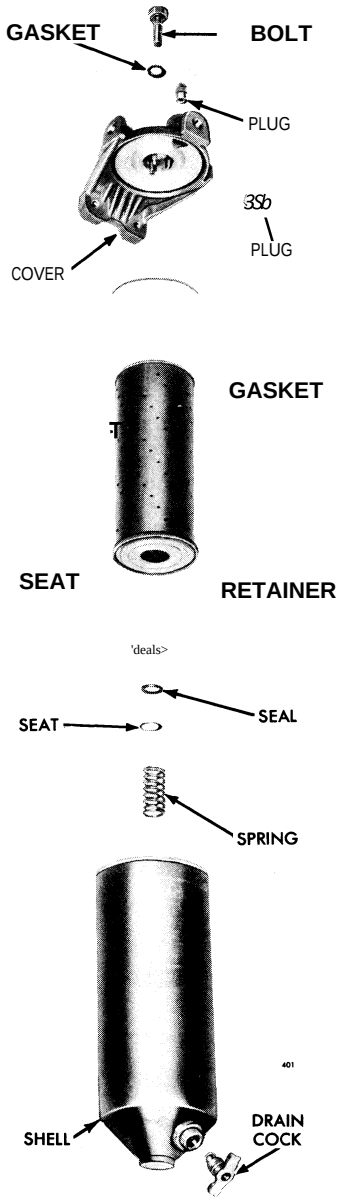



**Fig. 3 - Fuel Filter Details and Relative Location of Parts**

placed between the fuel pump and the fuel inlet manifold, operates under pressure. Fuel enters through the inlet passage in the cover and into the shell which surrounds the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where any impurities are removed. The clean fuel flows to the interior of the filter element, up through the central passage in the cover and into the outlet passage.

If engine operation is erratic, indicating a shortage of fuel or flow obstructions, refer to *Trouble Shooting* in Section 15.2 for corrective measures.

## Replace Fuel Strainer Or Filter Element Bolt-on Type

The procedure for replacing an element is the same for the fuel strainer or fuel filter. Refer to Figs. 2 and 3 and replace the element, as follows:

**NOTICE:** Only filter elements designed for fuel oil filtration should be used to filter the fuel.

1. With the engine stopped, place a container under the strainer or filter and open the drain cock. Loosen the cover nut or bolt just enough to allow the fuel oil to drain out freely. Then close the drain cock.

**NOTICE:** The wiring harness, starting motor or other electrical equipment must be shielded during the filter change, since fuel oil can permanently damage the electrical insulation.

2. While supporting the shell, unscrew the cover nut or bolt and remove the shell and element.

3. Remove and discard the filter element, shell gasket, and the cover nut or bolt gasket.

4. Wash the shell thoroughly with fuel oil and dry it with compressed air.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

5. Examine the element seat and the retaining ring to make sure they have not slipped out of place. Check the spring by pressing on the element seat. When released, the seat must return against the retaining ring.

**NOTICE:** The element seat, spring, washer and seal cannot be removed from the strainer shell. If necessary, the shell assembly must be replaced. However, the components of the filter shell are serviced. Examine the filter retainer seal for cracks or hardening. If necessary, replace the seal.

The current strainer and filter elements include the element, the cover gasket and cover bolt gasket.

6. Place a new element over the center stud and push it down against the element seat. Make sure the drain cock is closed, then fill the shell about two-thirds full with clean fuel oil.

**NOTICE:** Thoroughly soak the density-type *strainer* element in clean fuel oil before installing it. This will expel any air entrapped in the element and is conducive to a faster initial start.

7. Install a new shell gasket in the recess of the shell; also place a new gasket on the cover bolt.

8. Place the shell and element in position under the cover. Then thread the cover bolt into the center stud.

9. With the shell and gasket properly positioned, tighten the cover bolt just enough to prevent fuel leakage.

10. Remove the pipe plug at the top of the cover and complete filling of the shell with fuel. Fuel system primer J 5956 may be used to prime the entire fuel system.

11. Start the engine and check the fuel system for leaks.

## • Replace Fuel Strainer or Filter Element Spin-on Type

A 1" diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation.

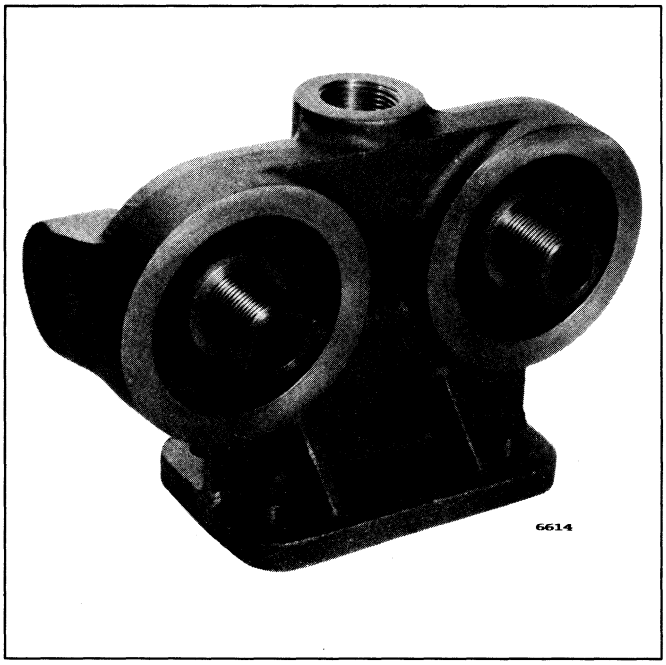



**Fig. 4 Spin-on Fuel Strainer Adaptor**

Replace the filter or strainer element as follows:

1. Unscrew the element and discard it.

2. Fill a new filter replacement element about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new element and tighten it to one-half of a turn beyond gasket contact.

4. Start the engine and check for leaks.

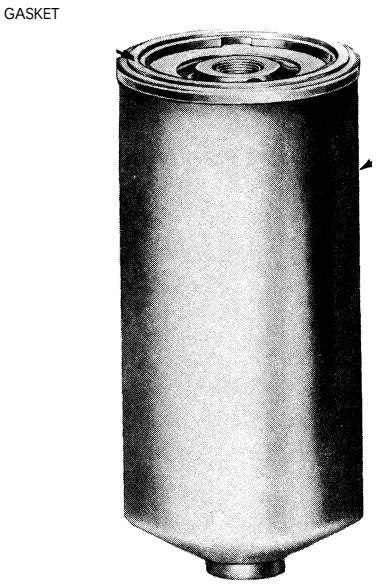



**Fig. 5 Spin-on Filter Details**

# FUEL MANIFOLD

The fuel injectors are supplied with fuel oil through pipes connected to the fuel inlet manifold. Excess fuel oil is returned to the fuel tank from the fuel injectors through pipes connected to the fuel outlet manifold.

The fuel manifolds are attached to the top of the cylinder block on each bank of the engine (Fig. 1). Fuel connectors are installed in the bottom of the manifold and use copper washers to seal the connector to the manifolds. When assembling or replacing fuel connectors, tighten the connectors to 35-40 lb—ft (47-54 N«m) torque.

**NOTICE:** To permit more contact surface with the copper washer, the hex size of the fuel connector was increased from 5/8" to 11/16". The fuel manifold to cylinder block gasket was also revised to accept the new connector. The current gasket can be used with either the new or old connector.

When installing the fuel manifolds to the cylinder block, the fuel supply hole in the end of the fuel manifold will be in an outboard position on each injector bank (Fig. 2).

## Remove Fuel Manifolds

If removal or replacement of a fuel manifold or manifolds is required, proceed as follows:

1. Drain the cooling system (Section 5).
2. Remove the water manifolds (Section 5.2).
3. Clean and remove the valve rocker covers.
4. Disconnect the fuel oil pipes from the injectors and the fuel connectors as follows:
   a. Disconnect the fuel pipe at the injector.
   b. Move the nut back on the pipe and slide a 3/8" I.D. hose over the open end of the pipe, being careful to avoid fuel spillage.

   **NOTICE:** It will be necessary to loosen the fuel pipe nut at the fuel manifold a few turns to permit the fuel pipe to swing away from the injector.

   c. Drain the fuel into a container. This will avoid the fuel in the manifold from draining onto the cylinder head. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.
5. Disconnect the fuel supply and return hoses to the manifolds.
6. Remove the bolts and flat washers securing the manifolds to the cylinder block. Remove the manifolds from the engine and discard the gaskets.

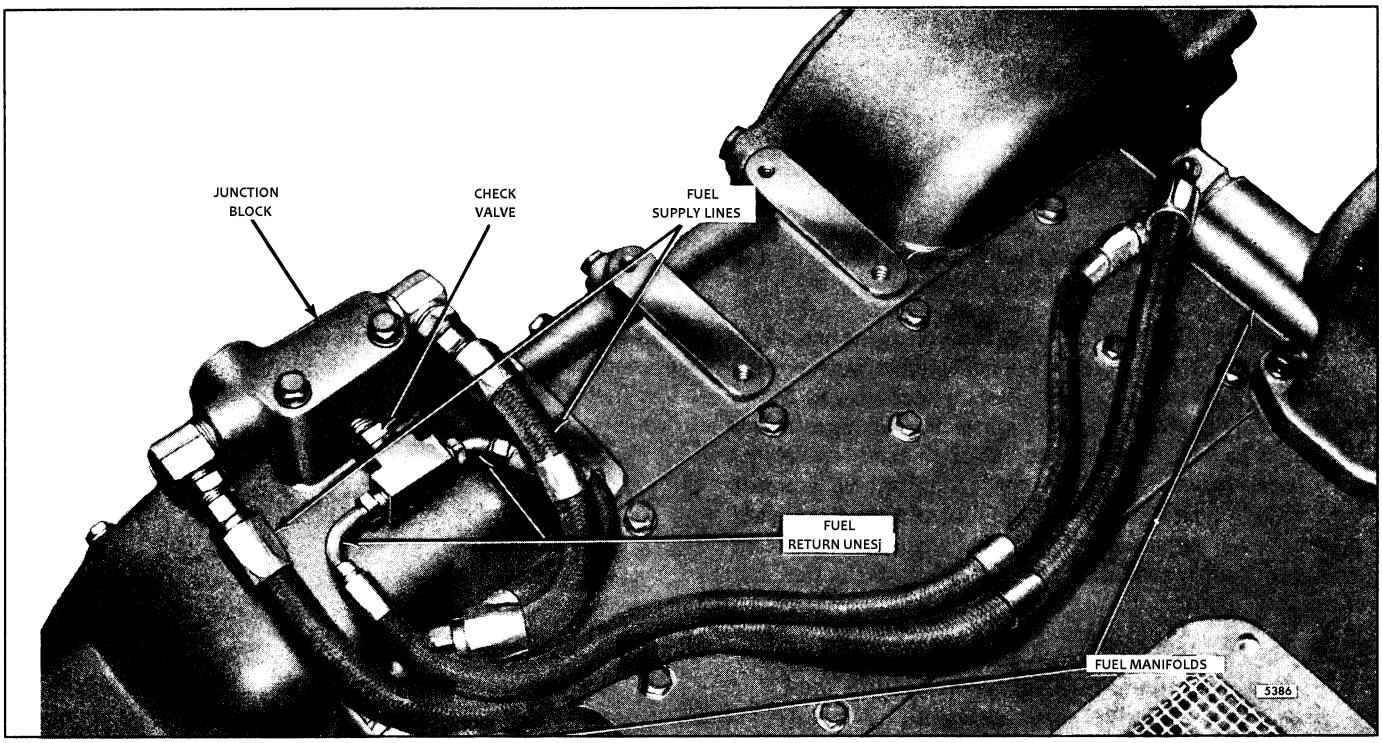



**Fig. 1 - Fuel Manifolds and Piping (Early Engines)**

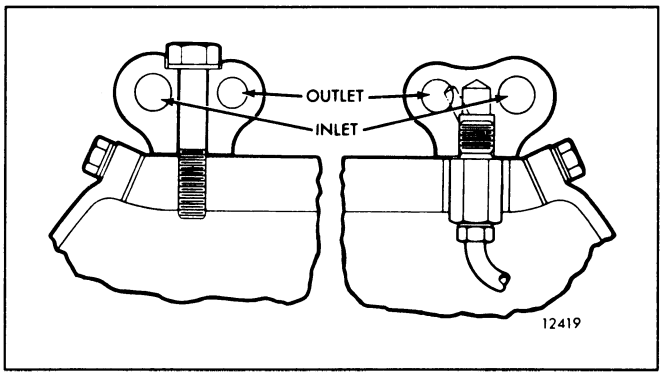



**Fig. 2 - Location of Fuel Manifolds on Engine**

## Inspection

Inspect the gasket surface of the manifold for flatness.

When installing the manifold gaskets, a half-gasket is required on each end of the individual manifold (tear one of the gaskets at the perforation in the middle).

## Install Fuel Manifolds

Prior to installing the fuel manifolds on the cyliner block, remove all of the old gasket material from the manifold and the cylinder block and proceed as follows:

1. If removed, install new copper gaskets on the fuel connectors and tighten the fuel connectors to 35-A0 lb—ft (47-54 N«m) torque.

2. Assemble both manifolds together at the center loosely for each cylinder bank on 12 or 16V-149 engines.

3. Affix new gaskets to the block and positioneach manifold assembly, as shown in Fig. 2, on the block. Install the 3/8”—16 x 2” bolts and flat washers and tighten the bolts to 30-35 lb—ft (41-47 N#m) torque.

4. Connect the fuel supply and return hoses to the manifolds and tighten all of the connections.

5. Install the fuel supply and fuel return pipes. Use adaptor J 21545 and an appropriate torque wrench and tighten the fuel pipe to fuel injector nuts to 18-22 lb—ft (24-30 N#m) torque. Tighten the fuel pipe to fuel manifold connector nuts to 18-22 lb—ft (24-3o N#m) torque. However, due to space limitations, adaptor J 23385 must be used and the torque wrench reading must be adjusted as outlined under ***Assemble Crankshaft Halves*** in Section 1.3. Install the fuel line support clips.

   NOTICE: Do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

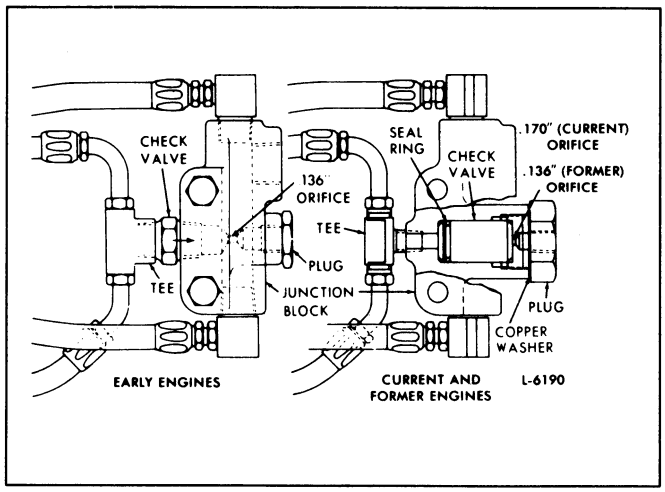



Fig. 3 – Location of Fuel Restriction Orifice

6. Install the water manifolds (Section 5.2).

7. Fill the cooling system (Section 5).

8. Prime the fuel system with tool J 5956 before starting the engine.

## Fuel Lines

Flexible fuel lines are used to facilitate connections between the fuel junction block and the fuel manifolds attached to the cylinder block (Fig. 1). A restricted orifice (.170” current engines or .136” former engines) is drilled in the fuel pressure relief plug or in the junction block (early engines) to maintain pressure in the fuel system.

**NOTICE:** Do fittings anywhere else in the fuel system.

A check valve is installed in the fuel junction block of the fuel system to prevent fuel from draining back to the fuel tank when the engine is shut down.

All of the new parts for the fuel spill system must be used together. Components of the former and current systems are not functionally interchangeable. A new spring and former system will result in excessive fuel pump out pressure. A new system with the former spring will result in low fuel pump out pressure.

**NOTICE:** When the new relief spring is used the new fuel pressure relief orifice plug, fuel junction block and 1/4” tee fitting must also be used.

On engines prior to serial numbers 12E-2330 and 16E-2240, the check valve must be installed with the ***Arrow*** pointing towards the junction block.

On early engines (prior to 12E-317), the check valve is stamped ***Top*** on one of the hex flats and should be installed with the word ***Top*** up. The 1 1/16”-16 check valve plug is tightened to 80-90 lb—ft (108-122 N#m) torque.

When installing flexible fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus the flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all of the lines are installed, ran the engine long enough to determine whether or not all of the connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak.

# MECHANICAL GOVERNORS

Horsepower requirements on an engine may vary due to fluctuating loads. Therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors. The governor is mounted on the front end of the blower and is driven by one of the blower rotors. The following types of mechanical governors are used.

1. Limiting Speed Mechanical Governor.
2. Variable Speed Mechanical Governor.

Engines requiring a minimum and maximum speed control, together with manually controlled intermediate speeds, are equipped with a limiting speed mechanical governor.

Engines subjected to varying load conditions that require automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the operator, are equipped with a variable speed mechanical governor.

Each type of governor has an identification plate located on the control housing, containing the governor assembly part number, type, idle speed range and manufactured date. The maximum engine speed, not shown on the identification plate, is stamped on the option plate attached to one of the valve rocker covers.

## Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine. However, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are speed varations present, check the engine as follows:

1. Make sure the speed changes are not the result of excessive load fluctuations.
2. Check the engine to be sure that all of the cylinders are firing properly (refer to Section 15.2). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in Section 2.1.1.
3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

1. If an injector rack sticks or moves too hard, it may be due to the injector hold-down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the bolt to 46-50 lb—ft (62-68 N«m) torque.
2. An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in Section 2.1.1.
3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in Section 14.
4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their ***no-fuel*** position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in Section 14.
5. A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.
6. Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

# LIMITING SPEED MECHANICAL GOVERNOR

The limiting speed mechanical governor (Fig. 1) performs the following two functions:

1. Controls the engine idling speed.
2. Limits the maximum operating speed of the engine.

The limiting speed governor used on the Series 149 engines is of the double-weight type. Each governor has an identification plate located on the governor housing containing the governor assembly number, type (D.W.-L.S.) and idle speed range (rpm).

The upper governor housing assembly is mounted on the air box cover plate at the front of the engine. The governor weight and drive mechanism, located underneath the air box cover plate, is driven by the left-hand helix blower rotor.

The governor drive and weight housing also serves as an end cover for the blower.

The governor assembly consists of two subassemblies.

1. Control Housing Assembly.
2. Weight Housing.

## Operation

The governor holds the injector racks in the ***advanced fuel*** position for starting when the speed control lever is in the ***idle*** position. Immediately after starting, the governor moves the injector racks to that position required for idling.

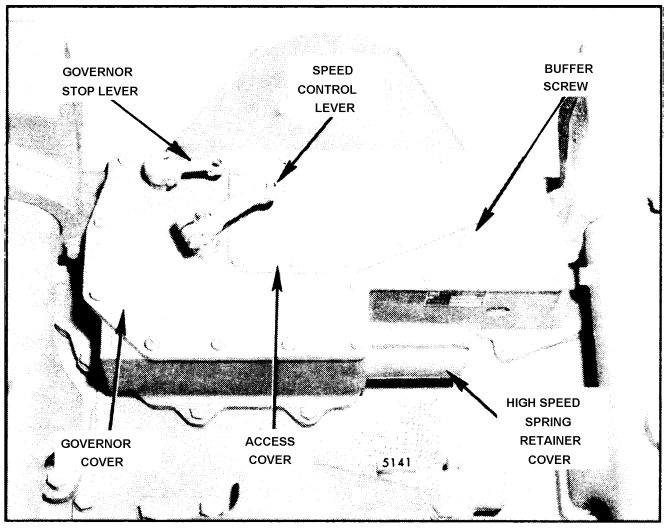



**Fig. 1 - Governor Mounting**

Current engines include a starting aid screw (62), Fig. 2, threaded into the governor gap adjusting screw. This limits fuel input during enginestart-up when the speed control lever is in its ***idle*** position. The current governor also includes lighter low-speed weights to permit an idle speed range of 550 to 750 rpm. Formerly, the idle speed range was 450 to 550 rpm.

To update a former limiting speed governor, remove the governor gap adjusting screw and nut. Install a service only bracket and the current gap adjusting screw and the starting aid screw (Fig. 2). The locknut is not required as both screws incorporate a nylon patch in lieu of the locknut. The former governor can also be reworked to increase the idle speed range by replacing the three low-speed weights with the current lighter low-speed weights. No other changes are necessary.

The centrifugal force of the revolving governor low and high-speed weights (Fig. 2) is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of this lever operates against the high and low-speed springs through the spring cap, while the other end provides a moving fulcrum on which the differential lever pivots.

When the centrifugal force of the revolving governor weights balances out the tension on the high or low-speed spring (depending on the speed range), the governor stabilizes the engine speed for a given setting of the speed control lever.

In the low-speed range, the centrifugal force of the low and high-speed weights together operate against the low-speed spring. As the engine speed increases, the centrifugal force of the low and high-speed weights together compress the low-speed spring until the low-speed weights are against their stops, thus limiting their travel, at which time the low-speed spring is fully compressed and the low-speed spring cap is within .0015” of the high-speed plunger.

Throughout the intermediate speed range, the operator has complete control of the engine because both the low-speed spring and the low-speed weights are against their stops and the high-speed weights are not exerting enough force to overcome the high-speed spring.

As the speed continues to increase, the centrifugal force of the high-speed weights increases until it overcomes the high-speed spring allowing the governor to again take control of the engine, limiting the maximum engine speed.

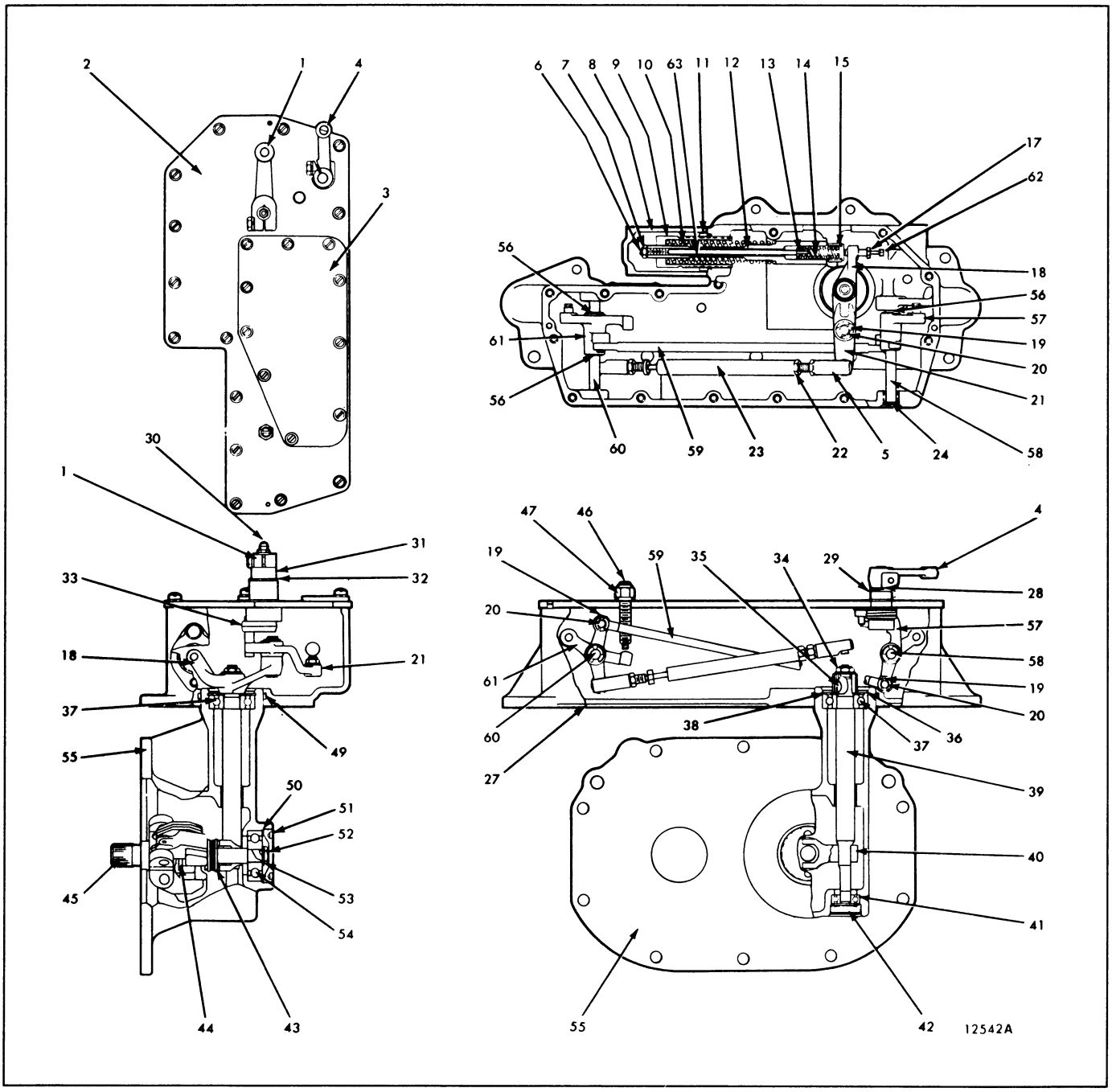



**Fig. 2 - Cross Sections of Limiting Speed Governor (Current)**

The engine idle speed is determined by the force exerted from the governor low-speed spring. When the governor speed control lever is placed in the *idle* position, the engine will operate at a speed where the force exerted by the governor low-speed weights will equal the force exerted by the governor low-speed spring. Adjustment of the engine idle speed is accomplished by changing the force on the low-speed spring by means of the idle adjusting screw (former governor) or the set screw and adjusting pin (current governors).

1. Lever—Speed Control
2. Cover—Governor
3. Cover—Access
4. Lever—Stop
5. Ball Joint Assembly
6. Set Screw—Idle Speed Adjusting
7. Locknut
8. Housing—Spring
9. Retainer—Spring, High-Speed
10. Spring—High-Speed
11. Locknut—Retainer
12. Plunger—Spring, High-Speed
13. Seat—Spring, Low-Speed
14. Spring—Low-Speed
15. Cap—Spring, Low-Speed
17. Screw—Adjusting, Gap
18. Lever—Shaft, Operating
19. Retainer—Spring
20. Washer—Plain
21. Lever—Differential
22. Locknut
23. Rod—Differential Lever Connecting
24. Bearing—Enclosed
27. Housing—Control
28. Spacer
29. Ring—Snap
30. Fitting—Lubrication
31. Spacer
32. Washer—Plain
33. Shaft—Speed Control Lever
34. Nut—Retaining Operating Shaft Lever
35. Woodruff Key
36. Spacer
37. Bearing—Upper, Operating Shaft
38. Ring—Snap
39. Shaft—Operating
40. Fork—Operating
41. Bearing—Lower, Operating Shaft
42. Plug—Cup
43. Bearing—Thrust, Riser
44. Riser
45. Shaft—Weight
46. Screw—Buffer
47. Locknut—Buffer Screw
49. Ring—Seal
50. Gasket—Housing Plug
51. Plug—Housing
52. Bolt—Retaining, Bearing
53. Washer—Lock
54. Bearing—Weight Shaft
55. Housing—Weight
56. Ring—Retaining
57. Lever—Operating Control Link (Left Bank)
58. Shaft—Operating Control Link Lever (Left Bank)
59. Link—Connecting
60. Shaft-Operating Control Link Lever (Right Bank)
61. Lever—Operating Control Link (Right Bank)
62. Screw—Starting Aid
63. Pin—Idle Speed Adjusting

**Fig. 2 - Cross Sections of Limiting Speed Governor (Current)**

The engine maximum no-load speed is determined by the force exerted by the high-speed spring. When the governor speed control lever is placed in the *maximum speed* position, the engine will operate at a speed where the force exerted by the governor high-speed weights will equal the force exerted by the governor high-speed spring. Adjustment of the maximum no-load speed is accomplished by the high-speed spring retainer. Movement of the high-speed spring retainer will increase or decrease the tension on the high-speed spring.

For adjustment of the limiting speed governor, refer to Section 14.3.

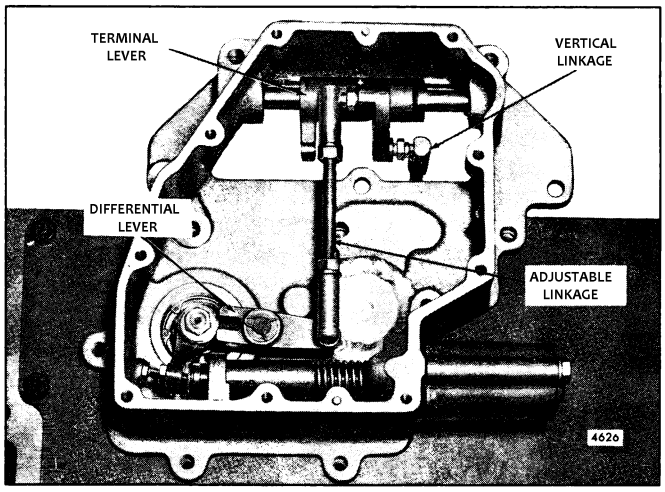



**Fig. 3 - Governor Operating Linkage (Former)**

## Lubrication

The governor is lubricated by a spray of oil from two drilled orifices (holes) in the governor weight housing which direct oil to the governor drive shaft splines and to the bearing thrust riser. Formerly this was done with a spray nozzle located in the blower end plate. The governor weights distribute this oil to all parts of the governor assembly requiring lubrication.

Oil returning from the governor is directed through passages in the blower end plate and cylinder block to the engine oil pan.

## Remove Governor

1. Disconnect the speed control rod from the speed control lever and the control linkage from the stop lever (Fig. 1).
2. Remove the screw and lock washer assemblies securing the cover assembly to the governor housing and remove the cover assembly and gasket.
3. On current governors, disconnect the right and left bank fuel rods from the governor control link operating levers and from the injector control tubes. Then, remove the fuel rods.
4. On former governors, disconnect the vertical linkage from the terminal shaft lever (Fig. 3).
5. Remove the operating shaft lever retaining nut (34), Figs. 2 and 5, and washer and remove the operating shaft lever from the operating shaft.

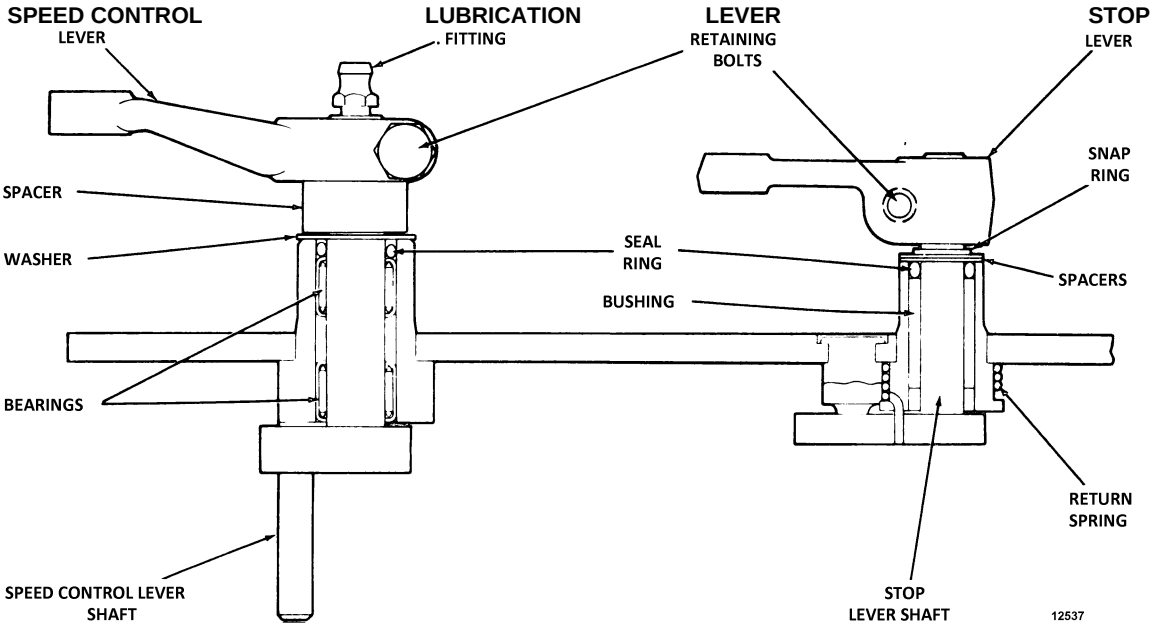



**Fig. 4 - Cross Section of Governor Cover**

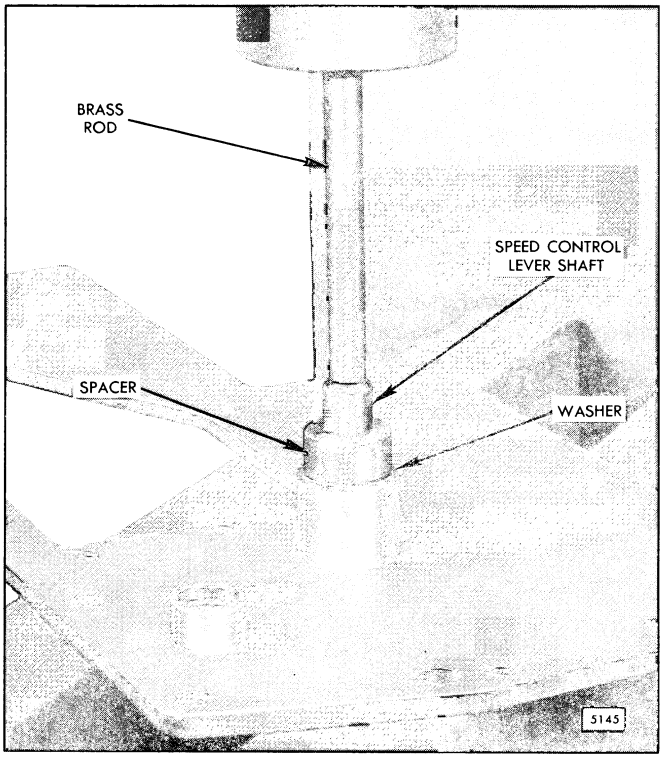



**Fig. 5 - Removing Speed Control Lever Shaft From Cover**

6. Remove the bolts and washers securing the governor housing assembly to the air box cover plate and remove the governor housing assembly and gasket. Remove starting aid screw stop bracket (service only), if used.

7. Remove the seal ring (49) from the control housing.

8. Remove the air inlet housing, water manifolds and any other accessories to gain access to the air box cover plate.

9. Remove the air box cover plate.

10. Remove the blower and governor drive assembly (refer to Section 3.4).

11. Remove the nine bolts and lock washers and one nut securing the governor weight housing assembly to the blower and remove the governor weight housing.

## Disassemble Governor

Before removing any parts from the governor, wash the entire unit in clean fuel oil, dry it with compressed air and inspect for worn or damaged parts which may be repaired or replaced without complete disassembly.

1. Disassemble the governor cover assembly (Fig. 4) as follows:

   a. Remove the screw and lock washer assemblies securing the governor access cover to the governor cover and remove the access cover and gasket.

   b. On current governors, remove the buffer screw from the governor cover. On former governors, remove the buffer screw from the access cover.

   c. Remove the lubrication fitting from the top of the speed control lever shaft. Then, loosen the retaining bolt securing the speed control lever to the speed control shaft and remove the lever.

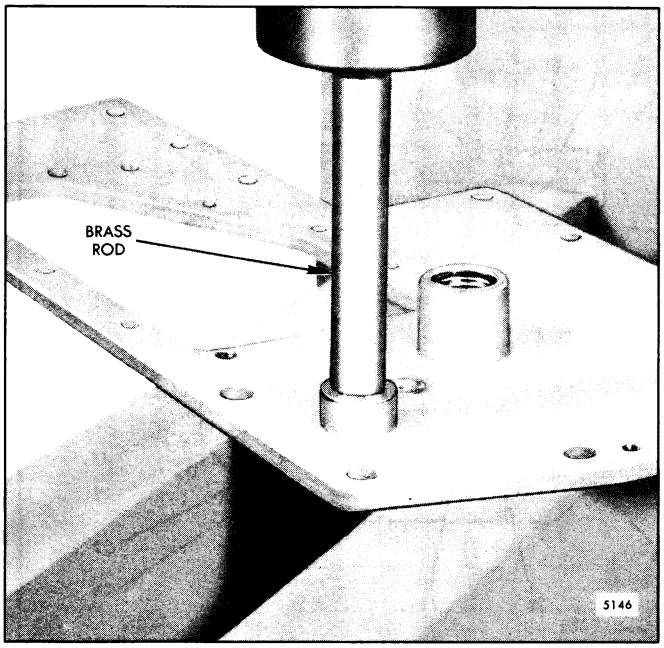



**Fig. 6 - Removing Bushing From Stop Lever Shaft Opening In Cover**

d. Place the cover assembly on the bed of an arbor press with the speed control lever shaft parallel and directly under the ram of the press. Use a suitable brass rod and press the shaft down through the spacer (Fig. 5) and remove the shaft, spacer and washer from the cover assembly.

e. Remove and discard the speed control lever shaft seal ring.

f. Loosen the retaining bolt securing the stop lever to the stop lever shaft and remove the lever.

g. Remove the snap ring and two spacers securing the stop lever shaft in the cover assembly and withdraw the shaft and return spring from the cover.

h. Remove and discard the stop lever shaft seal ring.

i. Wash the cover assembly thoroughly in clean fuel oil and inspect theneedle bearings and bushing for wear or damage. If the bearings or bushing are satisfactory for further use, removal is unnecessary.

j. Place the cover in an arbor press and, using a brass rod, remove the bushing from the stop lever shaft opening (Fig. 6).

k. With the cover in the arbor press, press the two bearings from the speed control lever shaft.

2. Refer to Figs. 2 and 7 and disassemble the spring housing as follows:

a. Place the governor in a vice equipped with soft jaws.

b. Remove the two bolts and copper washers securing the spring housing (8) to the governor control housing (27) and remove the spring housing.

c. Loosen the high-speed spring retainer locknut (11) Remove the spring retainer (9), high-speed spring (10) and related parts as an assembly.

d. Loosen the locknut (7) on the former idle speed adjusting screw and remove the adjusting screw and high-speed spring (10) from the high-speed spring plunger (12). Loosen the locknut (7) on the current idle speed adjusting set screw (6) and remove the set screw adjusting pin (63) and high-speed spring (10) from the high-speed spring plunger (12).

e. Remove the low-speed spring cap (15), low-speed spring (14) and low-speed spring seat (13) from the high-speed spring plunger (12).

3. Disassemble the governor control housing (Figs. 2 and 7) as follows:

a. Remove the differential lever (21) from the differential lever connecting rod (23).

b. Remove the spring retainer (19) and plain washer (20), securing the differential lever (21) to the operating shaft lever (18), and remove the differential lever and operating shaft lever.

c. On a current governor, remove the gap adjusting screw (17) and starting aid screw (62) from the operating shaft lever (18). On a former governor, remove the gap adjusting screw (17) and locknut (16) from the shaft lever (18).

d. On current governors, remove the differential lever connecting rod (23) from the operating control link lever (61).

e. On former governors, remove the differential lever connecting rod (23) from the terminal lever (25).

f. On current governors, remove the spring retainers (19) and washers (20) securing the connecting link (59) to the operating control link levers (57 and 61) and remove the connecting link.

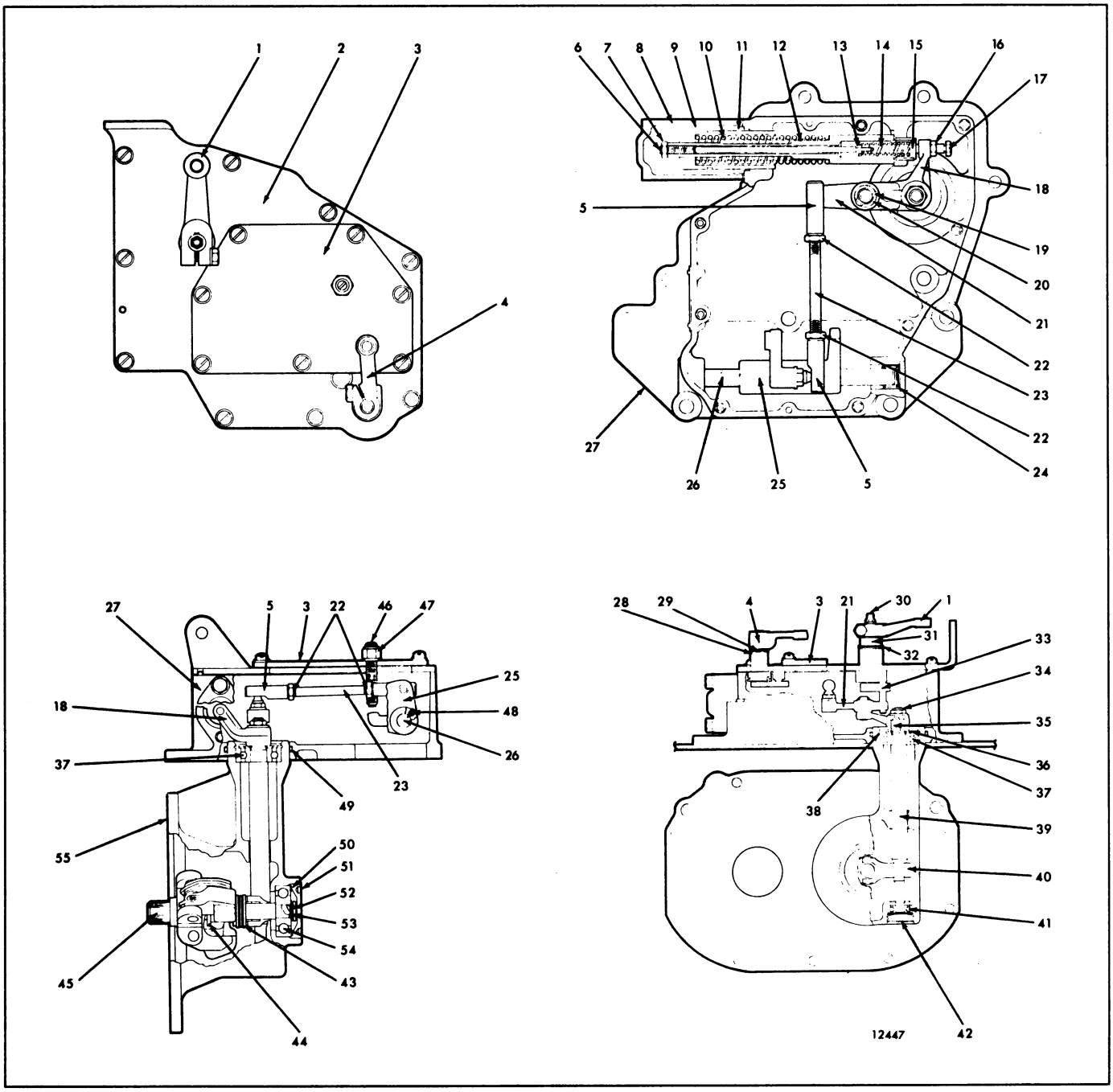



**Fig. 7 - Cross Sections of Limiting Speed Governor (Former)**

g. On current governors, remove the four retaining rings (56) positioning the operating control link levers (57 and 61) on the operating lever shafts.

h. On former governors, loosen the set screw (48) securing the terminal shaft lever (25) in position on the terminal shaft (26).

i. Place the control housing (27) in an arbor press with one of the operating shafts (58 and 60, current governors) or the terminal lever shaft (27, former governors) parallel and directly under the ram of the press. Place a brass rod between the ram and the front end of the shafts (Fig. 8).

1. Lever—Speed Control
2. Cover—Governor
3. Cover—Access
4. Lever—Stop
5. Ball Joint Assembly
6. Screw—Idle Speed Adjusting
7. Locknut
8. Housing—Spring
9. Retainer—Spring, High-Speed
10. Spring—High-Speed
11. Locknut—Retainer
12. Plunger—Spring, High-Speed
13. Seat—Spring, Low-Speed
14. Spring—Low-Speed
15. Low-Speed
16. Screw
17.
18.
19.
20.
21.
22. Connecting
23.
24.
25.
26.
27.
28.
29. Ring—Snap
30. Fitting—Lubrication
31. Spacer
32. Washer—Plain
33. Shaft—Speed Control Lever
34. Nut—Retaining Operating Shaft Lever
35. Woodruff Key
36. Spacer
37. Bearing—Upper, Operating Shaft
38. Ring—Snap
39. Shaft—Operating
40. Fork—Operating
41. Bearing—Lower, Operating Shaft
42. Plug—Cup
43. Bearing—Thrust, Riser
44. Riser
45. Shaft—Weight
46. Screw—Buffer
47. Locknut—Buffer Screw
48. Screw—Set, Terminal Lever
49. Ring—Seal
50. Gasket—Housing Plug
51. Plug—Housing
52. Bolt—Retaining, Bearing
53. Washer—Lock
54. Bearing—Weight Shaft
55. Housing—Weight

**Fig. 7 - Cross Sections of Limiting Speed Governor (Former)**

j. Press the shafts straight through and remove the enclosed bearing assemblies (24) from each end of the shafts. Withdraw the operating shafts, operating levers and needle bearings (current governors) or the terminal lever, terminal lever shaft and needle bearings (former governors).

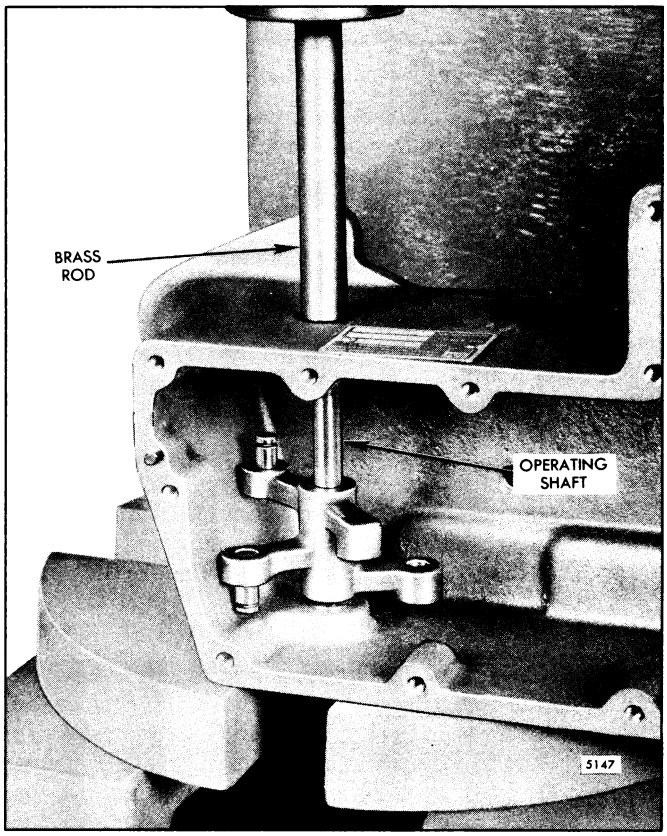



**Fig. 8 - Removing Operating Lever Shaft and Enclosed Bearing Assembly**

4. Remove the governor weight and shaft assembly as follows (refer to Figs. 2 and 7, unless otherwise indicated):

a. Remove the governor weight housing plug (51) and gasket (50) with socket J 23176.

b. Straighten the tang of the lock washer (53) and remove the bearing retainer bolt(52), washer and lock washer.

c. Thread a 5/16”-24 bolt into the tapped hole in the end of the weight shaft and remove the governor weight and shaft assembly, using an arbor press (Fig. 9).

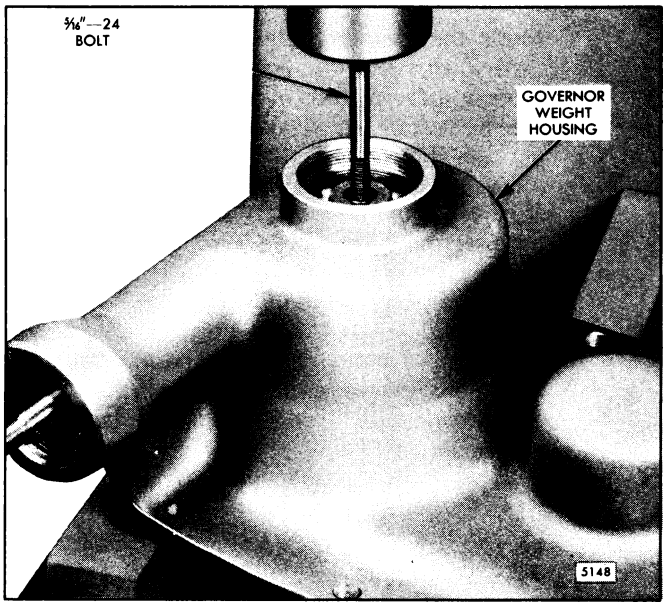



**Fig. 9 - Removing Governor Weight and Shaft Assembly**

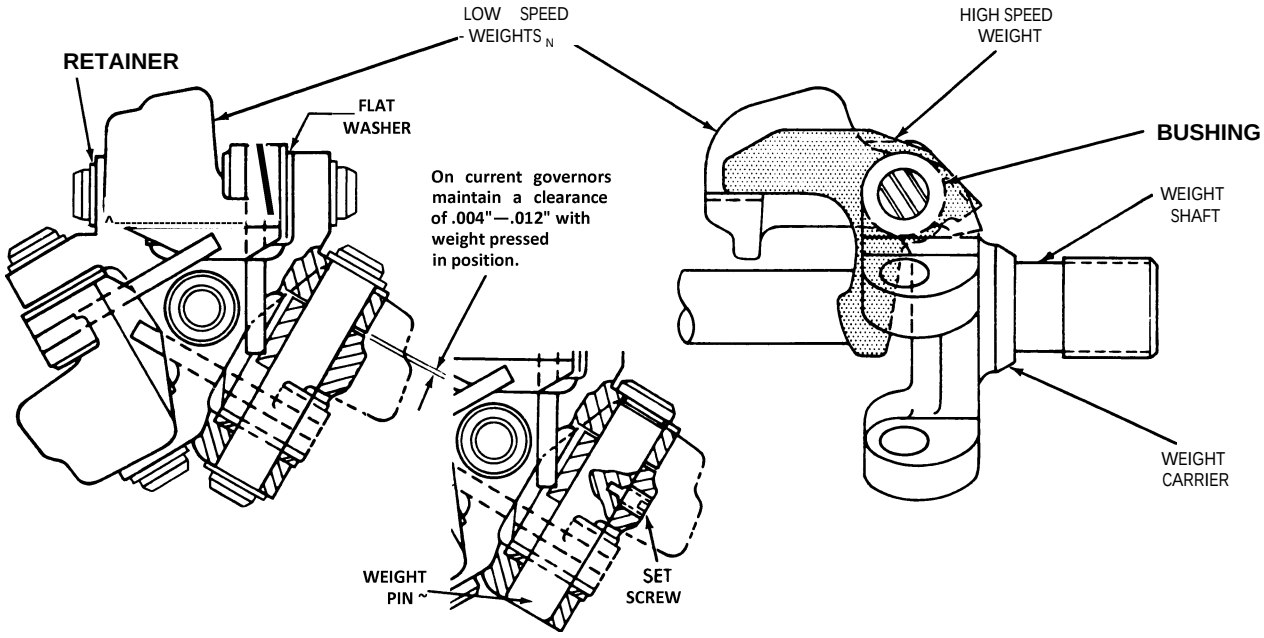



**Fig. 10 - Cross Section of Governor Weight Assemblies**

d. Slide the riser thrust bearing (43) and riser (44) from the shaft.

e. Remove the weight shaft bearing (54) from the governor housing.

5. Disassemble the governor weight and shaft assembly as follows:

a. Mark the low and high-speed weights and carrier with a center punch for identification. Also, note the position of the flat washers so that the parts can be replaced in their original position (Fig. 10).

b. If removal of the weights from the carrier is necessary on current governors, refer to Fig. 10 and remove the retainers from the weight pin. Press the pin from the low-speed weight. The high-speed weight is not a press fit. On former governors, remove the set screw from the low-speed weight with a 3/32" Allen wrench. Then, remove the weight pin and weight from the carrier.

c. Remove the second and third pair of weights from the carrier in the same manner as above.

d. Thread a 5/16"-24 bolt into the tapped hole in the end of the weight shaft and press the weight carrier from the weight shaft (Fig. 11).

e. Position the high-speed governor weight on the bed of an arbor press and press the bushing from the weight, using a suitable brass rod (Fig. 12).

6. Remove the operating shaft (Fig. 2) from the governor weight housing as follows:

a. Remove the Woodruff key (35) from the operating shaft (39).

b. Remove the two spacers (36) and snap ring (38) from the operating shaft.

c. Position the weight housing assembly in an arbor press (Fig. 13). Press down on the operating shaft (39) to remove the cup plug (42) from the bottom of the housing and the shaft from the upper bearing (37). Remove the upper bearing from the housing.

d. Turn the weight housing over and press down on the operating shaft to remove the shaft from the lower bearing (Fig. 15). Continue to press down on the shaft, with the operating fork (40) against the flat shoulder of the housing, to remove the operating fork (40) from the shaft. Remove the shaft, operating fork and lower bearing from the weight housing.

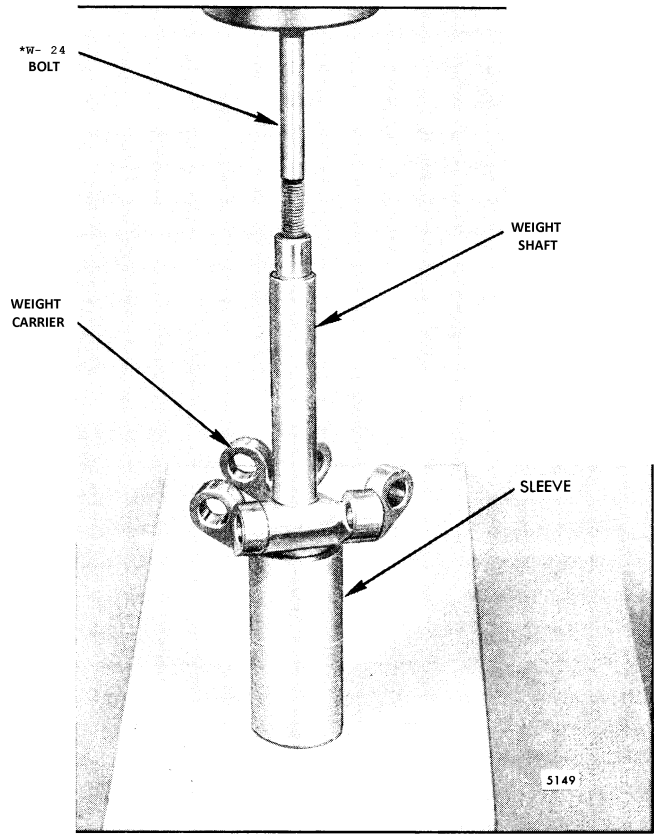



**Fig. 1 1 - Removing Weight Carrier From Shaft**

## Inspect Governor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air prior to inspection.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

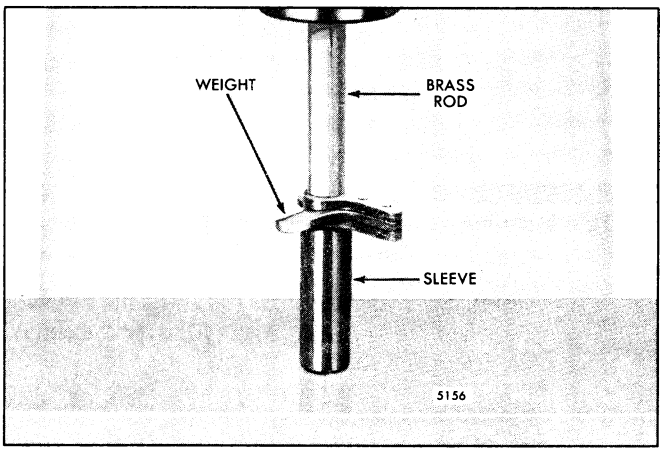



**Fig. 1 2 - Removing High-Speed Weight Bushing**

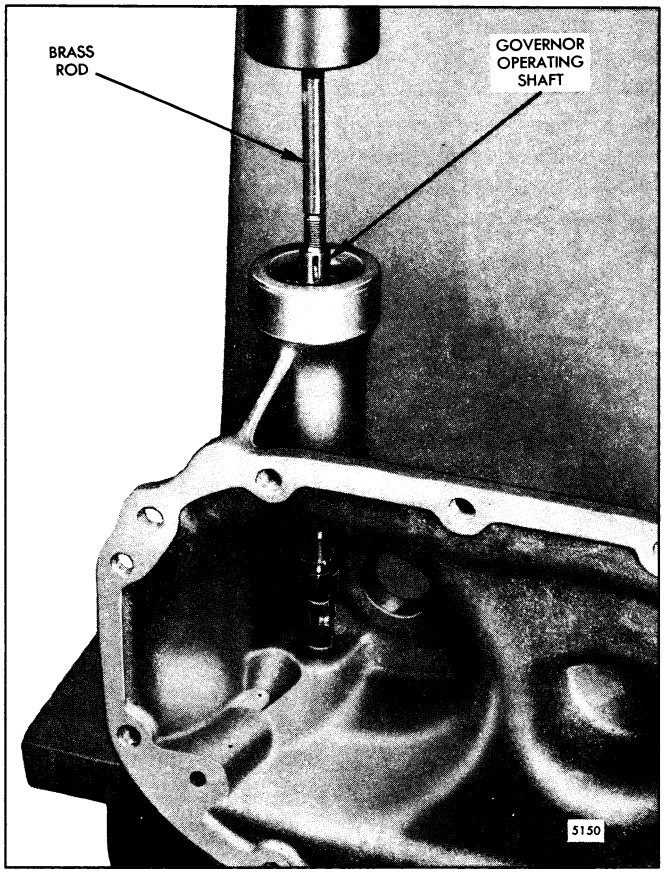



**Fig. 13 - Removing Operating Shaft From Weight Housing Upper Bearing**

Revolve the operating shaft bearings and the governor weight shaft bearing ***slowly*** by hand. Replace the bearings if rough or tight spots are detected.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new thrust bearing assembly.

Inspect thegovernor stop lever shaft and bushingfor excessive wear or flat spots. If one or both conditions exist, install a new shaft and bushing.

Inspect the speed control lever shaft and bearingsfor excessive wear or flat spots at the bearing surface. If one or both conditions exist, install a new shaft and bearings.

Examine the weight carrier pins and weight bushings for excessive wear and flat spots. If either of the conditions exist, install new parts.

Current low-speed governor weights are secured to the weight shaft by a press fit. The former low-speed weights were secured by a set screw. Since the new weights have a smaller diameter bore, a new governor weight pin is required. Also, two retaining rings are required to secure the new weight pin in the weight carrier.

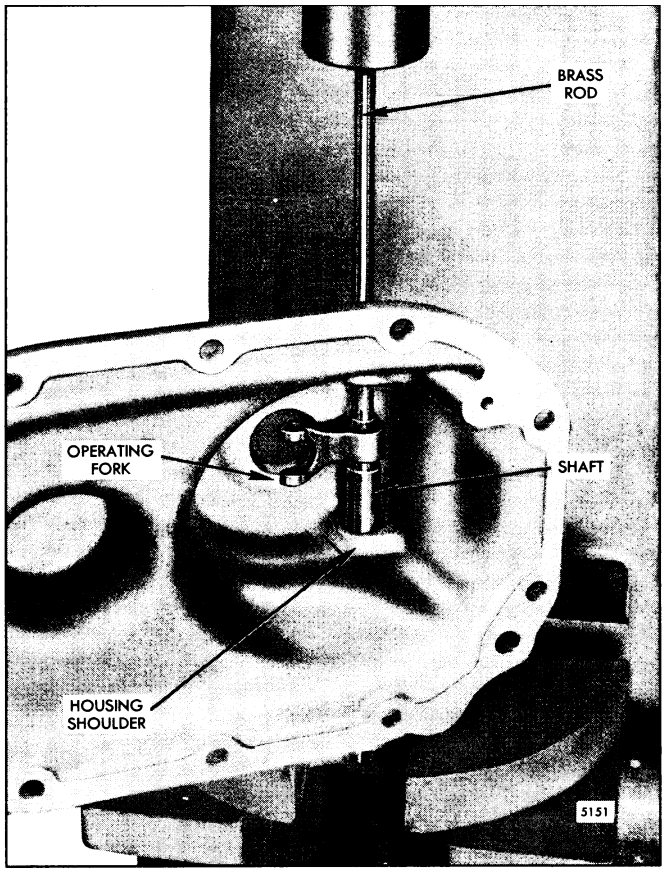



**Fig. 14 - Removing Operating Shaft and Fork From Weight Housing**

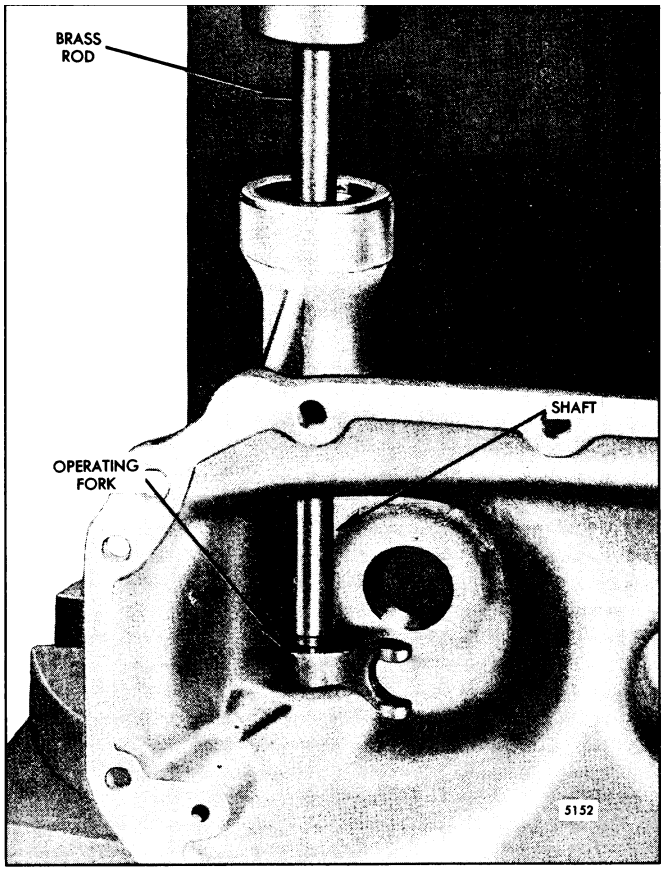



**Fig. 15 - Installing Operating Shaft and Fork in Weight Housing**

The current high-speed governor weight (without needle bearings) has a slip-fit bushing; the former weight had a press-fit bushing. The high-speed weight assembly which incorporates a needle bearing is not affected by the above changes and will continue to be used with the new low-speed weights where required.

When one set of weights requires replacement, it is recommended that both sets be replaced.

If the governor weight housing or the complete governor assembly is replaced on an early engine (prior to engine 12E-296), it will be necessary to remove the spray nozzle (used to lubricate the governor) from the blower front end plate and include a new governor-to-blower gasket. The current governor weight housing includes lubricating oil passages and the spray nozzle in the blower end plate is no longer required.

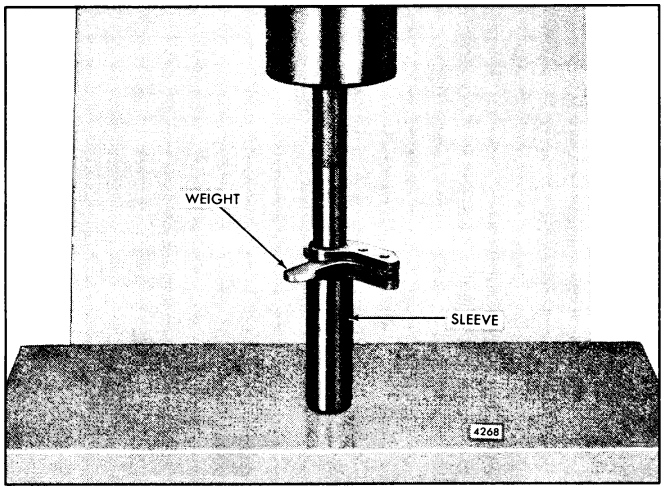



**Fig. 1 6 - Installing Bushing In High-Speed Weight using Tool J 8985**

## Assemble Governor

During assembly, lubricate all needle bearing assemblies with Shell Alvania No. 2 grease, or equivalent.

1. Install the operating shaft in the governor weight housing as follows (Figs. 2 and 7):

   a. Insert the operating shaft (39) into the housing and slide the operating fork (40) over the end of the operating shaft.

   b. Place the weight housing (55) upright on the bed of an arbor press with the operating shaft parallel and directly under the ram of the press.

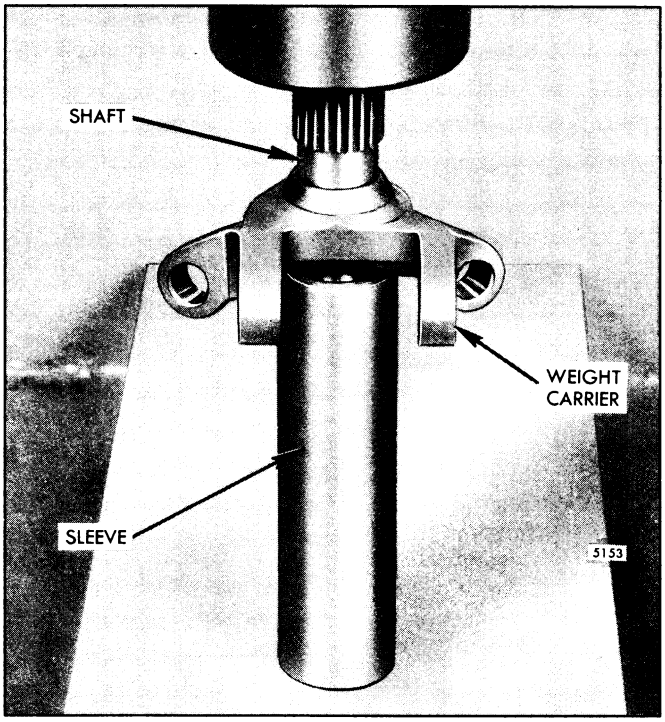



**Fig. 1 7 - Installing Shaft In Weight Carrier**

c. Start the operating fork (40) over its seating shoulder on the operating shaft (39).

d. Lower the operating shaft and fork until the fork is against the housing lower boss and, using a brass rod, press the operating shaft into the fork until the fork bottoms against the shoulder on the shaft (Fig. 15).

e. Turn the housing over and, with the operating shaft suitably supported, press the lower bearing assembly (41) over the lower end of the operating shaft. Install the bearing with the shielded side facing in.

f. Turn the housing back upright again and, using the same method, install the upper bearing (37) with the numbered side facing out. Make sure that the lower bearing assembly is in place in the housing lower bearing bore.

g. Rotate the shaft to make sure that the bearings are installed correctly.

h. Place the two spacers (36) over the top of the operating shaft and install the Woodruff key (35) and snap ring (38).

i. Apply a good quality sealant around the cup plug (42). Tap the plug into position in the weight housing operating shaft lower bearing bore.

2. Assemble the governor weight and shaft assembly as follows:

a. Place the governor high-speed weight on the bed of an arbor press (Fig. 16). Position the bushing in the bore of the weight and, using a suitable sleeve and replacer J 8985, press the bushing into the weight.

b. Slide the weight carrier over the end of the weight shaft. Place the weight carrier and weight shaft on the bed of an arbor press (Fig. 17).

c. Press the weight shaft into the weight carrier until the shaft bottoms against the shoulder of the carrier.

d. With current governors, refer to Fig. 10 and install a retainer on either end of the weight pin. Note the matchmarks placed on the weight carrier and weights at the time of disassembly. Then slide the weight pin through the carrier, flat washer and high-speed weight and its bushing. Place the low-speed weight in position. Then, press the weight pin through the low-speed weight and carrier until the retainer bottoms against the carrier. Maintain a clearance of .004"-.012" with the weight pressed in position. To maintain this clearance, insert a .004"-.012" shim between the low-speed weight and carrier while pressing the pin in position.

Remove the shim and install the second weightpin retainer. Install the second and third pair of weights inthe same manner.

e. With former governors, refer to Fig. 10 and install the governor weights, flat washers, weight pin and set screws. Stake the set screws at two places. Use Locktite sealant grade C or CV or equivalent, and tighten the set screw to 20 **lb-in** (2.26 N«m) torque.

3. Install the governor weight and shaft assembly (Figs. 2 and 7) as follows:

a. Slide the riser (44) over the weight shaft (45) and up against the finished surfaces of the governor weights.

b. Position the riser thrust bearing (43) over the weight shaft with the bearing race having the smaller inside diameter against the thrust riser.

c. Position the weight carrier and shaft assembly in the governor housing with the riser thrust bearing (43) up against the finished surfaces of the operating fork (40).

d. Support the splined end of the weight shaft on the bed of an arbor press. Start the weight shaft bearing (54) into the governor housing and over the end of the weight shaft.

e. Press the weight shaft bearing into the governor housing and over the weight shaft until it bottoms against the shoulder on the weight shaft.

f. Place the lock washer (53) on the bearing retaining bolt (52). Thread the retaining bolt into the tapped hole in the end of the weight shaft. Tighten the bolt and bend the tang of the lock washer against the head of the retaining bolt.

g. Place a gasket (50) against the weight shaft bearing. Apply a sealant such as Loctite grade H, HV or HVW to the threads of the governor housing and the plug (51) and thread the plug into the housing. Tighten the plug to 50-60 lb—ft (68-81 N#m) torque.

Rotate the governor weight assembly to make sure that there is no bind. If a bind exists, remove the housing plug and check to see if the weight shaft bearing is fully seated in the governor housing.

4. Assemble the governor control housing (Figs. 2 and 7) as follows:

a. Press a new enclosed bearing (24) flush with the counter bore in each shaft opening on the outside of the housing (current governors) or in one end of the terminal lever shaft bore (former governors).

b. On current governors, slide the operating levers (57 and 61) over the operating shafts (58 and 60) and place the shafts in the control housing, with one end of each shaft inserted into the enclosed bearings. Refer to Fig. 2 for proper orientation of the operating control link levers. Then, press a new enclosed bearing assembly (24) in each housing bore at the opposite ends of the shafts until there is .040" maximum end play and install four new retaining rings, positioning the operating levers on the operating shafts.

c. On former governors, slide the terminal lever (25) on the terminal shaft (26) and position one end of the shaft and lever assembly into the installed bearing assembly. Then, press a new enclosed bearing assembly (24) in the bore at the opposite end of the terminal shaft and over the terminal shaft end. Tighten the set screw (48) securing the terminal shaft lever to the terminal shaft.

d. On current governors, install the connecting link (59) to the operating levers (57 and 61), using a washer (20) and new spring retainer (19) at each end of the connecting link.

e. On former governors, connect thedifferential lever connecting rod (23) to the terminal lever (25).

f. On current governors, install thedifferential lever connecting rod (23) to the operating lever (61).

g. Connect the differential lever (21) to the differential lever connecting rod (23).

h. Secure the differential lever (21) to the operating shaft lever (18), using a plain washer (20) and spring retainer (19).

i. On current governors, install thestarting aid screw (62) in the gap adjusting screw (17) and thread the assembly into the operating shaft lever (18). On a former governor, thread the locknut (16) on the gap adjusting screw (17) and thread the assembly into the operating shaft lever (18).

j. Install the fuel rods.

5. Refer to Figs. 2 and 7 and assemble the spring housing as follows:

a. Place the low-speed spring seat (13), low-speed spring (14) and low-speed spring cap (15) in the high-speed spring plunger (12).

b. Position the high-speed spring (10) over the high-speed spring plunger (12) and place the high-speed spring retainer (9) over the spring. Place the current idle speed adjusting pin in the spring plunger. Thread the current set screw into the spring plunger (12) and secure the assembly together with the locknut (7). Thread the former idle speed adjusting screw into the spring plunger (12) and secure the assembly with the adjusting screw locknut (7).

c. Thread the spring retainer locknut (11) and position the gasket over the spring retainer (9) and install the assembly in the governor control housing (27).

d. Place the spring housing (8) over the assembly and up against the gasket and governor control housing. Secure it in place with two bolts and copper washers.

6. Assemble the governor cover (Fig. 4) as follows:

Lubricate the O.D. of the bearings with clean engine oil before pressing them in place.

a. Place the governor cover on the bed of an arbor press. Start the upper bearing straight into the bearing bore of the cover with the numbered side of the bearing up. Press the bearing into the cover using installer J 21068 (Fig. 18).

b. Reverse the governor cover in the press. Start the second bearing into the bore with the numbered side of the bearing up. Press the bearing down into the cover until the bearing is flush with the boss surface on the cover.

c. Lubricate the speed control shaft needle bearings with Shell Alvania No. 2 grease, or equivalent.

d. Press the bushing into the stop lever shaft bore using installer J 21068. Press the bushing down into the bore 1/8" below the surface to allow room for the seal ring.

e. Insert the speed control shaft through the bearings in the cover assembly.

f. Slide a new seal ring over the shaft and into the bearing bore.

g. Slide the washer over the shaft and up against the cover boss.

h. Place the cover assembly on the bed of an arbor press.

i. Start the spacer over the end of the speed control shaft and, using a suitable sleeve, press the spacer on the shaft until there is approximately .008" to .012" end play when the shaft is moved within the cover assembly.

j. Position the speed control lever on the speed control lever shaft and tighten the clamping bolt.

k. Install the lubrication fitting at the top of the speed control lever shaft.

l. Insert the stop lever shaft, with the return spring in position (Fig. 4), through the bushing in the cover assembly.

m. Slide a new seal ring over the stop lever shaft and into the bushing bore.

n. Slide the two spacers over the shaft and up against the stop lever shaft boss.

o. Secure the stop lever in the cover assembly with the snap ring.

p. Position the stop lever on the stop lever shaft and tighten the stop lever bolt.

q. On current governors, install the buffer screw in the cover. On former governors, install the buffer screw in the access cover.

r. Assemble the access cover, using a new gasket, to the governor cover.

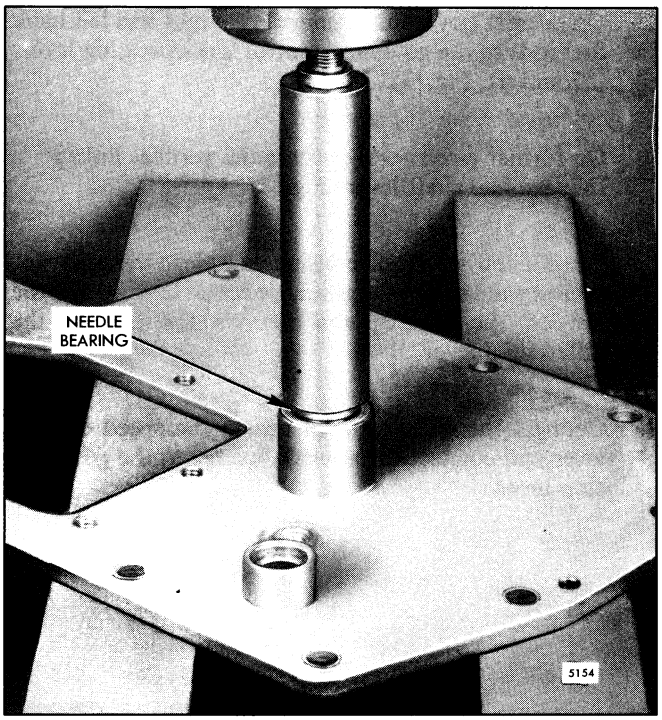



**Fig. 18 - Installing Needle Bearings In Governor Cover using Tool J 21068**

## Install Governor

1. Install the governor-to-blower gasket on the blower and slide the weight housing assembly straight on the dowels in the blower housing. Align the splines of the weight shaft with the splines in the blower rotor. The tab on the gasket is to ensure the gasket is in place.

2. Secure the weight housing assembly to the blower using nine 3/8"—16 x 3-1/4" bolts and one 3/8"-24 nut. Tighten the bolts to 30-35 lb—ft (41-47 N#m) torque and the nut to 35-39 lb—ft (47-53 N«m) torque.

3. Install the blower and the governor drive and weight housing assembly in the engine (refer to Section 3.4).

4. Install the air box cover plate.

5. Install the water manifolds, air inlet housing and any other accessories removed under ***Remove Governor.***

Place a new seal ring (49) in the control housing (Figs. 2 and 7) and position the governor control housing over the drive mechanism and on the air box cover plate. Install and tighten the control housing to air box cover plate hold down bolts and washers. On the former governor, install the starting aid screw stop bracket (if used).

7. Refer to Figs. 2 and 7 and connect the operating shaft lever (18) to the operating shaft (39), using a retaining nut (34) and washer. Tighten the nut to 35-39 lb—ft (47-53 N#m) torque.

8. On current governors, connect the right and left bank fuel rods to the governor control link operating levers (57 and 61, Fig. 2).

9. On former governors, connect the vertical linkage to the terminal shaft lever (Fig. 3).

10. Place a new governor housing gasket on the governor housing and install the governor cover. Be sure that the pin on the throttle shaft enters the slot of the differential lever.

11. Connect the speed control rod to the speed control lever and connect the control linkage to the governor 12. stop lever.

**CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

Perform an engine tune-up as outlined in Section 14.3.

# VARIABLE SPEED MECHANICAL GOVERNOR

The variable speed mechanical governor (Fig. 1) performs the following three functions:

1. Controls the engine idle speed.
2. Limits the maximum no-load speed.
3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The variable speed governor is of the single-weight type. Each governor has an identification plate located on the governor housing. It contains the governor assembly part number, type (S.W.V.S.) and idle speed range (RPM).

The upper governor housing assembly is mounted on the air box cover plate at the front of the engine. The governor weight and drive mechanism is located underneath the air box cover plate where it is driven by the left-hand helix blower rotor. The governor drive and weight housing also serves as an end cover for the blower.

The governor assembly consists of two subassemblies:

1. Control Housing Assembly
2. Weight Housing

## Operation

Two manual controls are provided on the variable speed governor; a stop lever for starting and stopping and a speed control lever. For starting, the stop lever is moved to the *run* position which moves the injector control racks to the *full-fuel* position. Upon starting, the governor moves the injector racks out to that position required for idling. The engine speed is then controlled manually by movement of the speed control lever.

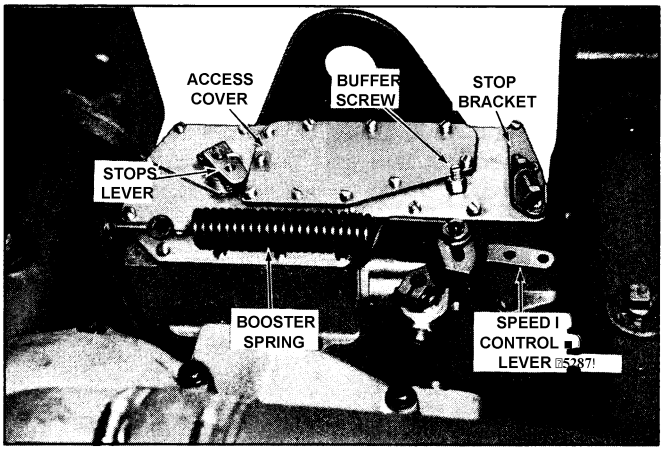



**Fig. 1 - Governor Mounting**

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever (Fig. 2). One end of the operating shaft lever bears against the variable speed spring plunger while the other end provides a changing fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever create an unbalanced force between the revolving governor weights and the tension on the variable speed spring. When the two forces are equal, the engine speed stabilizes for a setting of the speed control lever.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

Adjustment of the engine idle speed is accomplished by changing the tension on the variable speed spring by means of the idle speed adjusting screw.

Adjustment of the maximum no-load speed is accomplished by varying the tension on the variable speed spring by the installation or removal of stops (Fig. 2) and shims, as required.

For adjustment of the variable speed governor, refer to Section 14.4.

## Lubrication

The governor is lubricated by a spray of oil from two drilled orifices (holes) in the governor weight housing, which directs oil to the governor drive shaft splines and to the riser thrust bearing. Formerly this was done with a spray nozzle located in the blower end plate. The governor weights distribute this oil to all parts of the governor assembly requiring lubrication.

Oil returning from the governor is directed through passages in the blower end plate and the cylinder block to the engine oil pan.

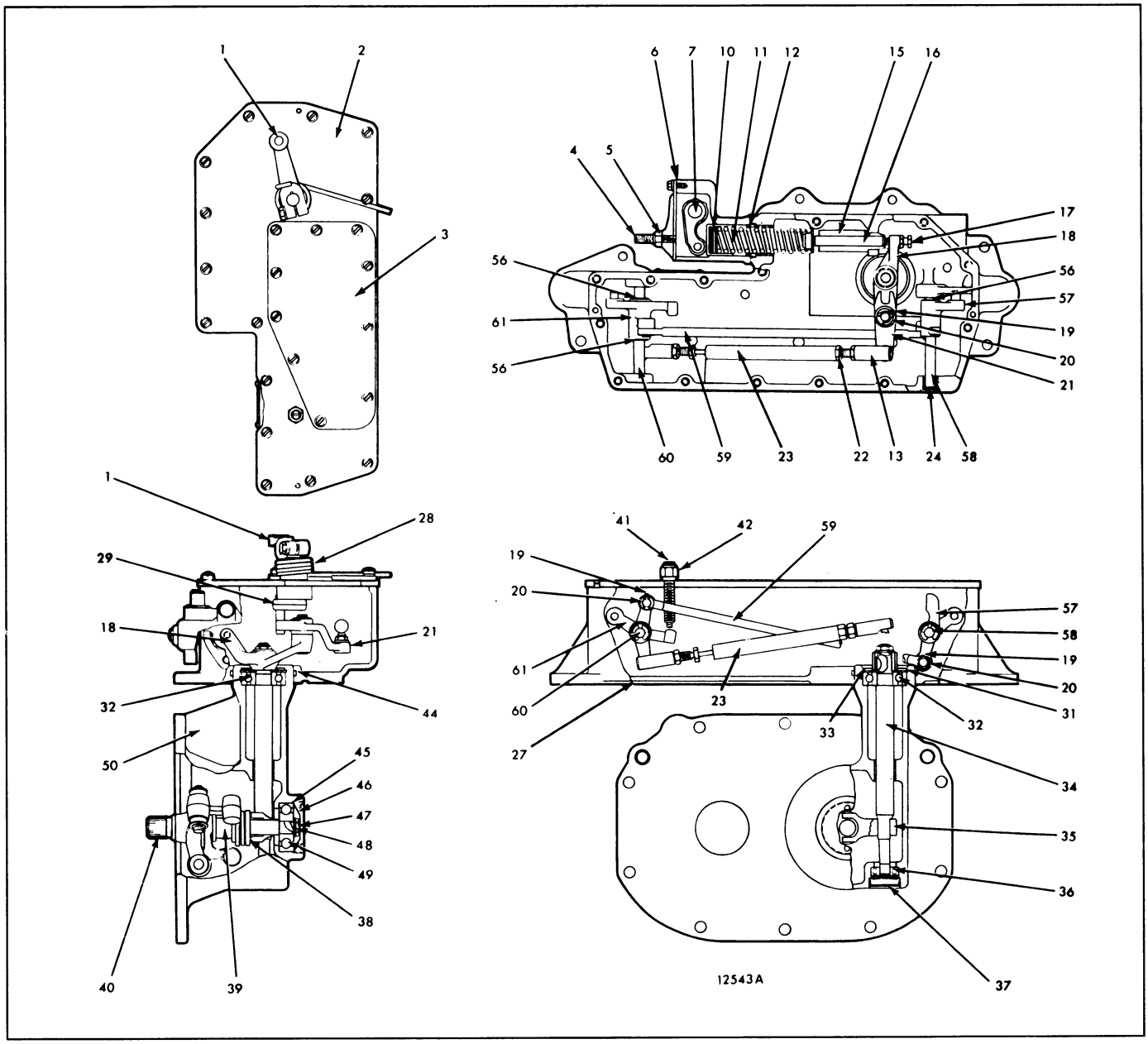



**Fig. 2 - Cross Section of Variable Speed Governor (Current)**

## Remove Governor

1. Remove the starting aid system (refer to Section 14.14) air cylinder and shutdown solenoid (if used) from the governor cover.

2. Disconnect the speed control rod from the speed control lever and disconnect the booster spring from the speed control lever (Fig. 1).

3. Remove the screw and lock washer assemblies and lift the stop bracket (current engines), cover and gasket from the governor housing.

A speed control lever stop bracket with a 3/8"—16 x 1 3/4" adjustment bolt and locknut and a new speed control lever and booster spring hanger are now used effective with engine serial number 12E-359.

4. On current governors, disconnect the right and left bank fuel rods from the governor control link operating levers and from the injector control tubes. Remove the fuel rods.

5. On former governors, disconnect the vertical linkage from the terminal shaft lever (Fig. 3).

1. Lever—Stop
2. Cover—Governor
3. Cover—Access
4. Screw—Idle Speed Adjusting
5. Locknut, Idle Speed Adjusting
6. Housing—Spring
7 Shaft—Speed Control Lever
10. Shim—Governor
11. Spring—Variable Speed
12. Stop—Governor
13. Ball Joint Assembly
15. Guide—Plunger
16. Plunger—V ariable Speed Spring
17. Screw—Gap Adjusting
18. Lever—Operating Shaft
19. Retainer—Spring
20. Washer—Plain
21. Lever—Differential
22. Locknut
23. Rod—Differential Lever-Connecting
24. Bearing—Enclosed
27. Housing—Control
28. Spring—Torsion Retraction
29. Shaft—Speed Control Lever
31. Spacer
32. Bearing—Upper, Operating Shaft
33. Ring—Snap
34. Shaft—Operating
35. Fork—Operating
36. Bearing—Lower, Operating Shaft
37. Plug—Cup
38. Bearing—Thrust, Riser
39. Riser
40. Shaft—Weight
41. Screw—Buffer
42. Locknut, Buffer Screw
44. Ring—Seal
45. Gasket—Housing Plug
46. Plug—Housing
47. Bolt—Retaining, Bearing
48. Washer—Lock
49. Bearing—Weight Shaft
50. Housing—Weight
56. Ring—Retaining
57. Lever—Operating Control Link (Left Bank)
5 8. Shaft—Operating Control Link Lever (Left Bank)
59. Link—Connecting
60. Shaft—Operating Control Link Lever (Right Bank)
61. Lever—Operating Control Link (Right Bank)
62. Gasket—Spring Housing Cover
63. Cover—Spring Housing

**Fig. 2 - Cross Section of Variable Speed Governor (Current)**

6. Remove the operating shaft lever retaining nut and washer and remove the operating shaft lever (18) from the operating shaft (Figs. 2 and 5).

7. Remove the bolts and washers securing the governor housing assembly to the air box cover plate and remove the governor housing assembly and gasket.

8. Remove the air inlet housing, water manifolds and any other accessories to gain access to the air box cover plate.

9. Remove the air box cover plate.

10. Remove the blower and governor drive assembly (refer to Section 3.4).

11. Remove the nine bolts and lock washers and one nut securing the governor weight housing assembly to the blower and remove the governor weight housing.

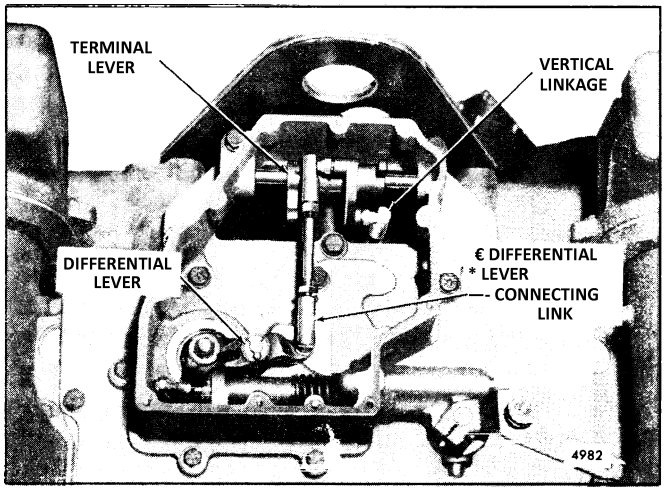



**Fig. 3 - Governor Operating Linkage (Former)**

## Disassemble Governor

Before removing any parts from the governor, wash the entire unit in clean fuel oil, dry it with compressed air and inspect for worn or damaged parts which may be repaired or replaced without complete disassembly.

1. Disassemble the governor cover assembly as follows (Fig. 4):

   a. Remove the screw and lock washer assemblies securing the governor access cover to the governor cover and remove the access cover and gasket.

   b. On current governors, remove the buffer screw from the cover (Fig. 2). On former governors, remove the buffer screw from the access cover (Fig. 5).

   c. Loosen the stop lever retaining bolt and remove the stop lever and torsion retraction spring from the stop lever shaft.

   d. Remove the snap ring and two spacers securing the stop lever shaft in the cover assembly.

   e. Withdraw the stop lever shaft from the cover assembly.

   f. Wash the cover assembly thoroughly in clean fuel oil and inspect the bushings for wear or damage. If the bushings are satisfactory for further use, removal is unnecessary.

   Place the cover assembly (right side up) in an arbor press. Place remover J 21967-01 on top of the bushing and press the bushing out of the cover.

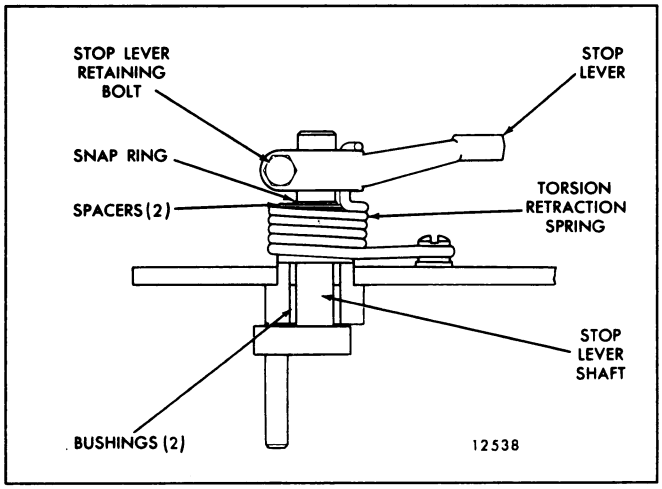



**Fig. 4 – Cross Section of Governor Cover**

2. Remove the variable speed spring housing from the governor housing (refer to Figs. 2 and 6 unless otherwise indicated):

   a. Place the governor housing (27) in a vise equipped with soft jaws.

   b. Remove the two bolts and lock washers securing the variable speed spring housing (6) to the governor housing and withdraw the variable speed spring housing and gasket. Remove the governor stops (12), variable speed spring (11) and variable speed spring plunger (16).

   c. Remove the governor shims (10) and spring retainer (9) from the variable speed spring housing.

   d. Drive the plunger guide (15) out of the housing with a brass rod.

3. Disassemble the governor variable speed spring housing (refer to Figs. 6 and 7):

   a. Loosen the bolt securing the speed control lever to the speed control shaft and pull the lever from the shaft.

   b. Remove the Woodruff key (65) and flat washer (66) from the speed control shaft (7).

   c. On current governors, remove one screw and lock washer and remove the spring housing cover and gasket. Then, remove the set screw from the spring lever.

On former governors, remove the pipe plug from the housing and, working through the opening, remove the set screw from the spring lever.

   d. Place a 3/4" inside diameter sleeve (approximately 1-1/2" long) on the bed of an arbor press. Support the spring housing assembly on top of the sleeve with the cup plug (71) in the side of the housing over the opening of the sleeve.

   e. Place a small brass rod on the end of the shaft and press the plug and bearing out of the spring housing.

   f. Remove the spring lever (8) from the spring housing (6) and the bearing (68) from the speed control shaft (7). If necessary, remove the Woodruff key from the shaft.

**NOTICE:** Due to the key in the speed control shaft, the inner end of the needle bearing will be damaged when pressing the bearing and cup plug out of the spring housing. Do not attempt to reuse the bearing.

   g. At this stage of disassembly, wash the spring housing (containing the remaining bearing) thoroughly in clean fuel oil and inspect the needle bearing for wear and damage. If the bearing is satisfactory for further use, removal is unnecessary.

   h. If removal of the needle bearing is necessary, support the spring housing, bearing side down, on top of the 3/4" inside diameter sleeve on the bed of the arbor press. Insert the bearing remover J 21967-01 through the housing and rest it on top of the bearing. Then, press the bearing out of the housing.

4. Disassemble the governor control housing as follows (Figs. 2 and 5):

   a. Remove the differential lever (21) from the differential lever connecting link (23).

   b. Remove the spring retainer (19) and plain washer (20) securing the differential lever (21) to the operating shaft lever (18) and remove both levers.

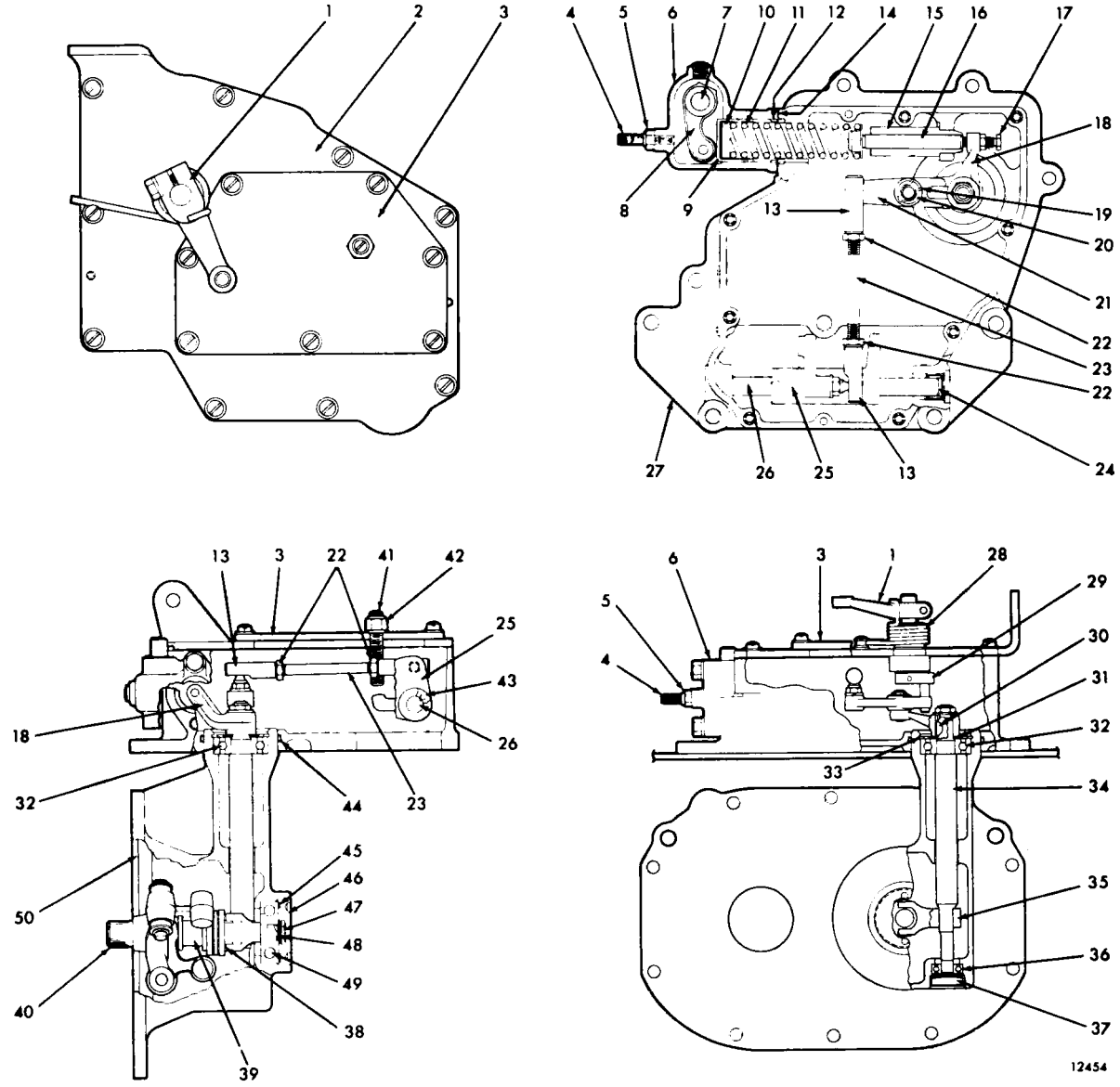
   c. On current governors, remove the differential lever connecting rod (23) from the operating control link lever (61).

   d. On former governors, remove the differential lever connecting rod (23) from the terminal lever (25).

   e. On current governors, remove the spring retainers (19) and washers (20) securing the connecting rod (59) to the operating controllink levers (57 and 61) and remove the connecting rod.

   f. On current governors, remove the four retaining rings (56) positioning the operating controllink levers (57 and 61) on the operating controllink lever shafts.




1. Lever—Stop
2. Cover—Governor
3. Cover—Access
4. Screw—Idle Speed Adjusting
5. Locknut
6. Housing—Spring
7. Shaft—Speed Control Lever
8. Lever—Spring
9. Retainer—Spring
10. Shim
11. Spring—Variable Speed
12. Stop—Governor
13. Ball Joint Assy.
14. Gasket
15. Guide—Plunger
16. Plunger—Spring
17. Screw—Gap Adjusting
18. Lever—Operating Shaft
19. Retainer—Spring
20. Washer—Plain
21. Lever—Differential
22. Locknut
23. Link—Differential Lever Connecting
24. Bearing—Enclosed
25. Leve—Terminal
26. Shaft—Terminal Lever
27. Housing—Control
28. Spring—Torsion Retraction
29. Shaft—Speed Control Lever
30. Woodruff Key
31. Spacer
32. Bearing—Upper, Operating Shaft
33. Ring—Snap
34. Shaft—Operating
35. Fork—Operating
36. Bearing—Lower, Operating Shaft
37. Plug—Cup
38. Bearing—Thrust, Riser
39. Riser
40. Shaft—Weight
41. Screw—Buffer
42. Lock—nut
44. Ring—Seal
45. Gasket—Housing Plug
46. Plug—Housing
47. Bolt—Retaining, Bearing
48. Washer—Lock
49. Bearing—Weight Shaft
50. Housing—Weight

Fig. 5 - Cross Section of Variable Speed Governor (Former)

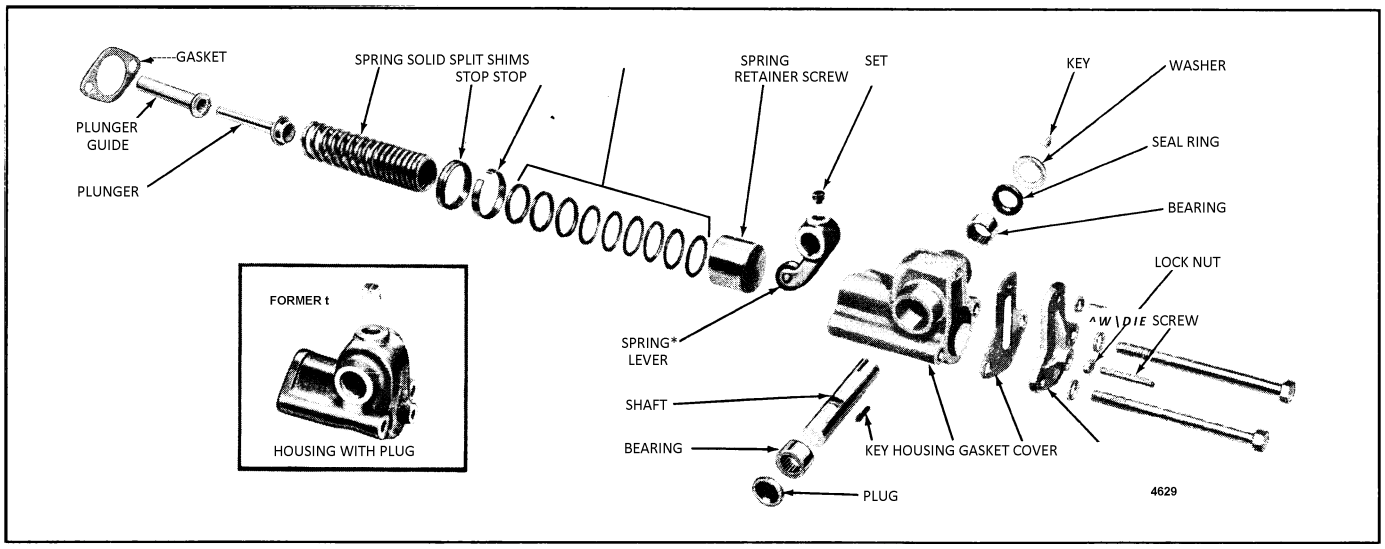



Fig. 6 - Variable Speed Spring Housing and Relative Location of Parts

g. On former governors, loosen the set screw (48) securing the terminal shaft lever (25) in position on the terminal shaft (26).

h. Place the control housing (27) in an arbor press with one of the operating shafts (58 and 60, current governors) or the terminal lever shaft (27, former governors) parallel and directly under the ram of the press. Place a brass rod between the ram and either end of the shafts (Fig. 8). Press the shafts straight through and remove the enclosed bearing assemblies (24) from each end of the shafts. Withdraw the operating shafts, operating levers and needle bearings (current governors) or the terminal lever, terminal lever shaft and needle bearings (former governors).

5. Remove the governor weight and shaft assembly (refer to Fig. 2 unless otherwise indicated):

a. Remove the housing plug (46) and gasket (45) from the end of the weight shaft (40).

b. Straighten the tang of the lock washer (48) and remove the bearing retainer bolt (47) and lock washer.

c. Thread a 5/16”-24 bolt into the tapped hole in the end of the weight shaft and remove the governor weight and shaft assembly, using an arbor press (Fig. 9).

d. Slide the riser thrust bearing (38) and riser (39) from the shaft.

e. Remove the weight shaft bearing (49) from the governor housing.

6. Disassemble the governor weight and shaft assembly:

a. Remove one lock ring from each weight pin. Withdraw the pins, flat washers and governor weights (Fig. 10).

b. Place the weight carrier and shaft assembly on the bed of an arbor press. Thread a 5/16”-24 bolt into the end of the weight shaft and, using a suitable sleeve, press the weight carrier from the shaft.

c. Place the governor weight on the bed of an arbor press (Fig. 11). Press the weight bearing from the governor weight with a suitable sleeve and replacer J 8985.

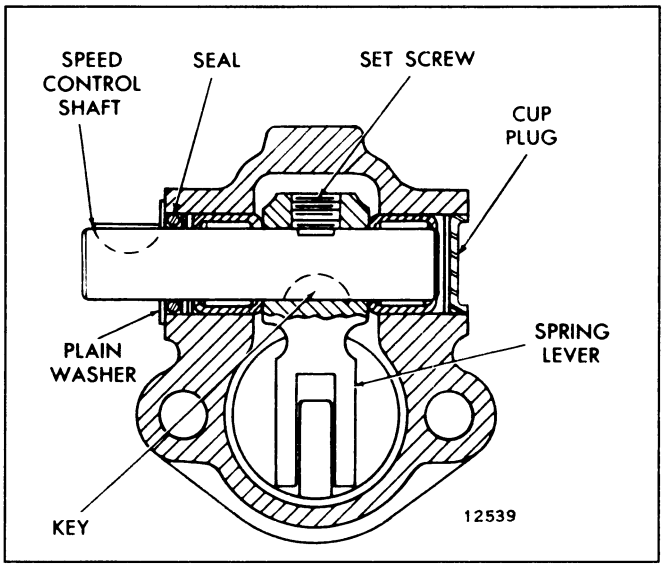



**Fig. 7 - Governor Variable Speed Spring Housing**

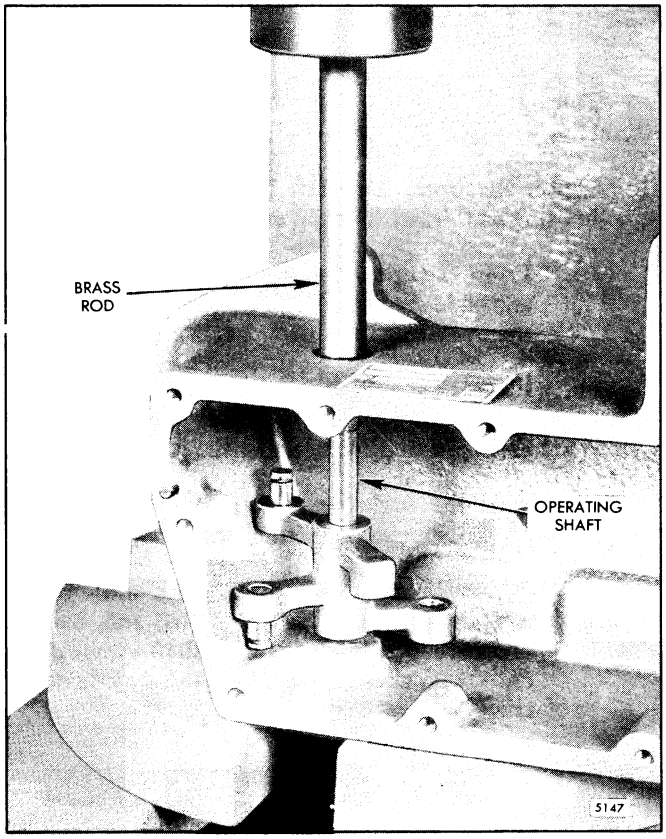



**Fig. 8 - Removing Operating Lever Shafts and Enclosed Bearing Assemblies**

7. Remove the operating shaft from the governor weight housing as follows (Fig. 2):

   a. Remove the Woodruff key (30) from the operating shaft (34).

   b. Remove the two spacers (31) and snap ring (33) from the operating shaft,

   c. Position the weight housing assembly (50) in an arbor press. Press down on the operating shaft (34) to remove the cup plug (37) from the bottom of the housing and to remove the upper bearing (32) from the shaft (Fig. 12).

   d. Turn the weight housing over and press down on the operating shaft (34) to remove the shaft from the lower bearing (36). Continue pressing down on the shaft, with the operating fork (35) against the flat shoulder of the housing, to remove the operating fork (35) from the shaft (Fig. 13).

   e. Withdraw the operating shaft from the weight housing.

   f. Remove the upper and lower bearings from the housing.

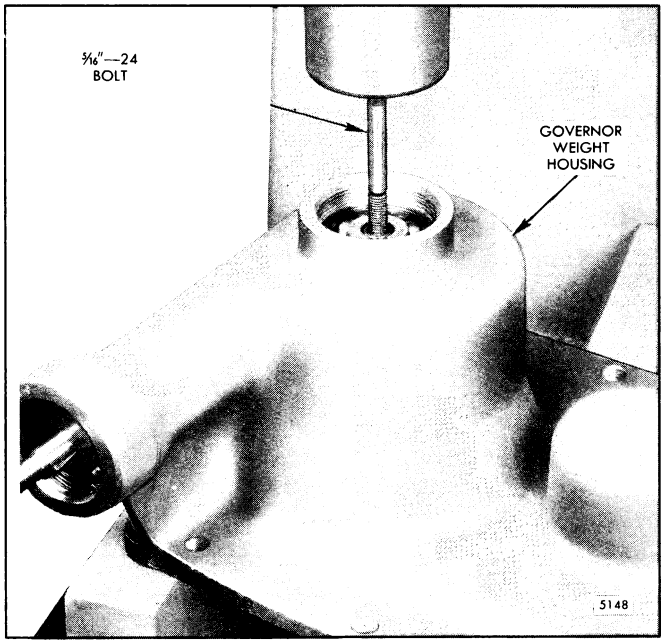



**Fig. 9 - Removing Governor Weight and Shaft Assembly**

## Inspect Governor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Revolve the operating shaft bearings and the governor weight shaft bearing *slowly* by hand. Replace the bearings if rough or tight spots are detected.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, install a new thrust bearing assembly.

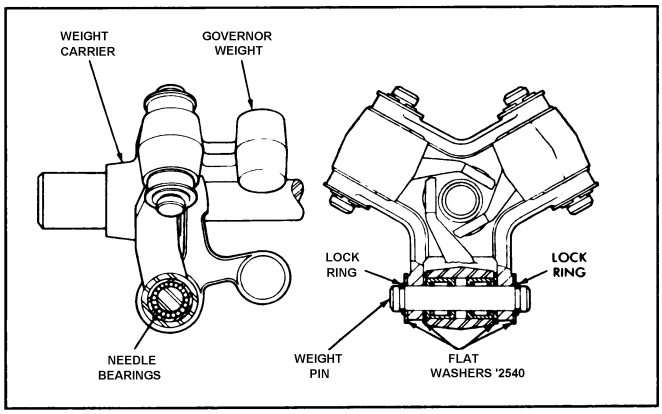



**Fig. 10 - Cross Section of Governor Weight Assemblies**

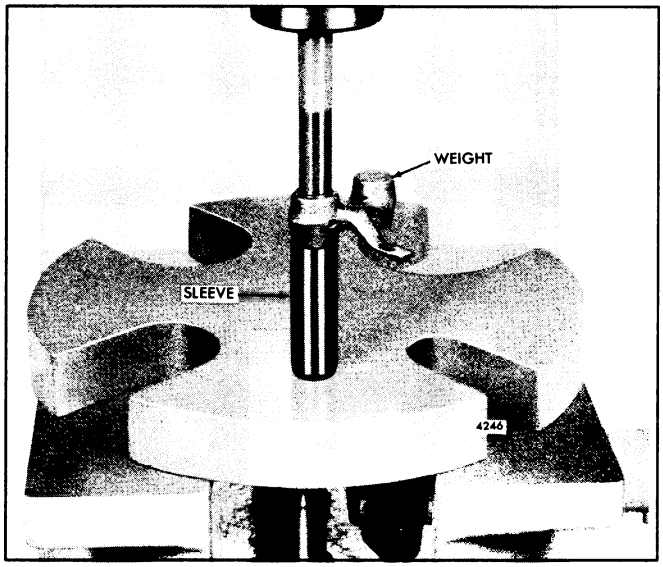



**Fig. 11 - Removing or Installing Governor Weight Bearings using Tool J 8985**

Inspect the governor stop lever shaft and bushing for excessive wear or flat spots. If one or both conditions exist, install a new shaft and bushing.

Inspect the speed control lever shaft and bearings for excessive wear or flat spots at the bearing surface. If one or both conditions exist, install a new shaft and bearings.

Examine the governor weights at the riser contact area for excessive wear. If worn, install a new governor weight.

When replacing the governor weights or riser, the current weight (.280" wide cam) and the current riser (1.31" diameter) must be used together to prevent interference between the weight arm and the riser. The current riser, if used with the narrow weight (.140" wide cam), could hang-up on the weight arm before making contact with the cam and result in erratic governor operation. The current governor weight also incorporates a stop to prevent the possibility of the weight hitting the weight housing at extreme overspeed.

Examine the weight carrier pins and weight bushings for excessive wear and flat spots. If either of these conditions exist, install new parts.

If the governor weight housing or the complete governor assembly is replaced on an early engine (prior to engine 12E-296), it will be necessary to remove the spray nozzle (used to lubricate the governor) from the blower front end plate and include a new governor-to-blower gasket. The current governor weight housing includes lubricating oil passages and the spray nozzle is no longer required.

## Assemble Governor

During assembly, lubricate all needle bearing assemblies with Shell Alvania No. 2 grease, or equivalent.

1. Install the operating shaft in the governor weight housing as follows (Figs. 2 and 5):

   a. Insert the operating shaft (34) into the housing and slide the operating fork (35) over the end of the operating shaft.

   b. Place the weight housing (50) upright on the bed of an arbor press with the operating shaft parallel and directly under the ram of the press.

   c. Start the operating fork (35) over its seating shoulder on the operating shaft (34).

   d. Lower the operating shaft and fork until the fork is against the housing lower boss and, using a brass rod, press the operating shaft into the fork until the fork bottoms against the shaft shoulder (Fig. 14).

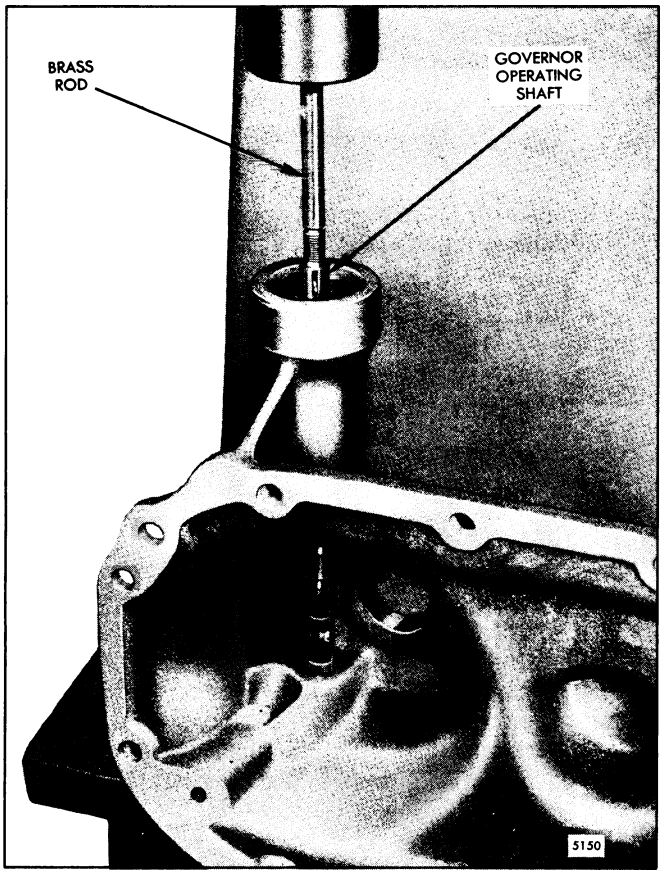



**Fig. 12 - Removing Operating Shaft from Weight Housing Upper Bearing**

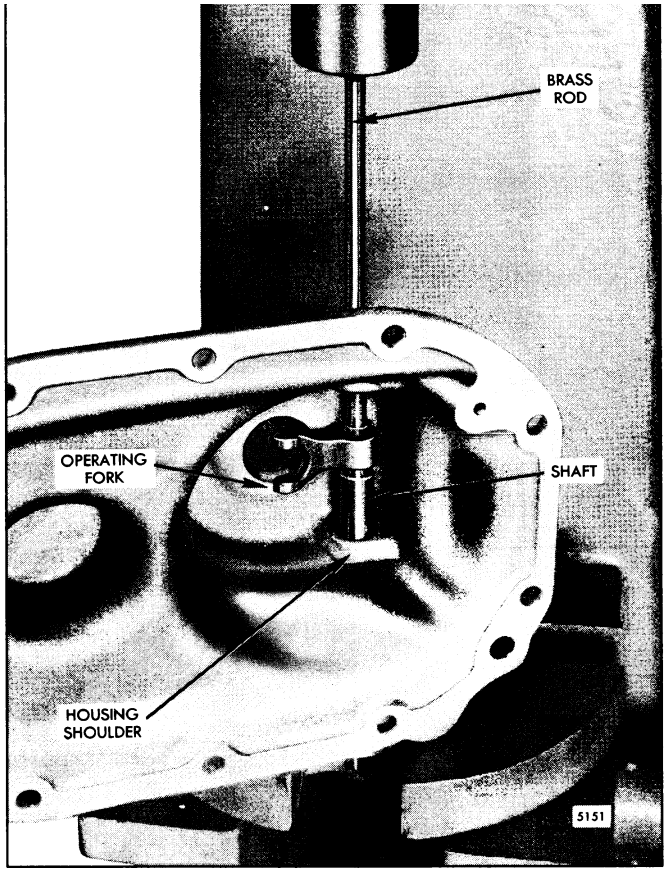



**Fig. 13 - Removing Shaft From Lower Bearing and Operating Fork**

e. Turn the housing over and, with the operating shaft suitably supported, press the lower bearing assembly (36), shielded side in, over the lower end of the operating shaft.

f. Turn the housing back upright again and, using the same method, install the upper bearing (32), numbered side out. Make sure that the lower bearing assembly is in place in the housing lower bearing bore.

g. Rotate the shaft to make sure that the bearings are installed correctly.

h. Place the two spacers (31) over the top of the operating shaft and install the Woodruff key (30) and snap ring (33).

i. Apply a good quality sealant around the cup plug (37). Tap the plug into position in the weight housing operating shaft lower bearing bore.

2. Assemble the governor weight and shaft assembly as follows:

a. Place the governor weight on the bed of an arbor press (Fig. 11).

b. Position the bearing in the bore of the weight and, using a suitable sleeve and replacer J 8985, press the bearing into the weight.

c. Slide the weight carrier over the end of the weight shaft. Place the weight carrier and weight shaft on the bed of an arbor press. Press the weight shaft into the weight carrier until the shaft bottoms against the shoulder of the carrier.

d. Refer to Fig. 10 and install the governor weights, flat washers, weight pin and lock rings.

3. Install the governor weight and shaft assembly (Figs. 2 and 5) as follows:

a. Slide the riser (39) over the weight shaft (40) and up against the finished surfaces of the governor weights.

b. Position the riser thrust bearing (38) over the weight shaft with the bearing race having the smaller inside diameter against the thrust riser.

c. Position the weight carrier and shaft assembly in the governor housing with the riser thrust bearing (38) up against the finished surfaces of the operating fork (35).

d. Support the splined end of the weight shaft on the bed of an arbor press. Start the weight shaft bearing (49) into the governor housing and over the end of the weight shaft. Press the weight shaft bearing into the governor housing and over the weight shaft until it bottoms against the shoulder on the weight shaft.

e. Place the lock washer (48) on the bearing retaining bolt (47). Thread the retaining bolt into the tapped hole in the end of the weight shaft. Tighten the bolt and bend the tang of the lock washer against the head of the retaining bolt.

f. Place a gasket (45) against the weight shaft bearing. Apply sealant such as Loctite H, HV or HVW to the threads of the governor housing and plug (46) and thread the plug into the housing. Tighten the plug to 50-60 lb—ft (68—81 N»m) torque.

Rotate the governor weight assembly to check for bind. If bind exists, remove the housing plug and check to see if the weight shaft bearing is fully seated in the governor housing.

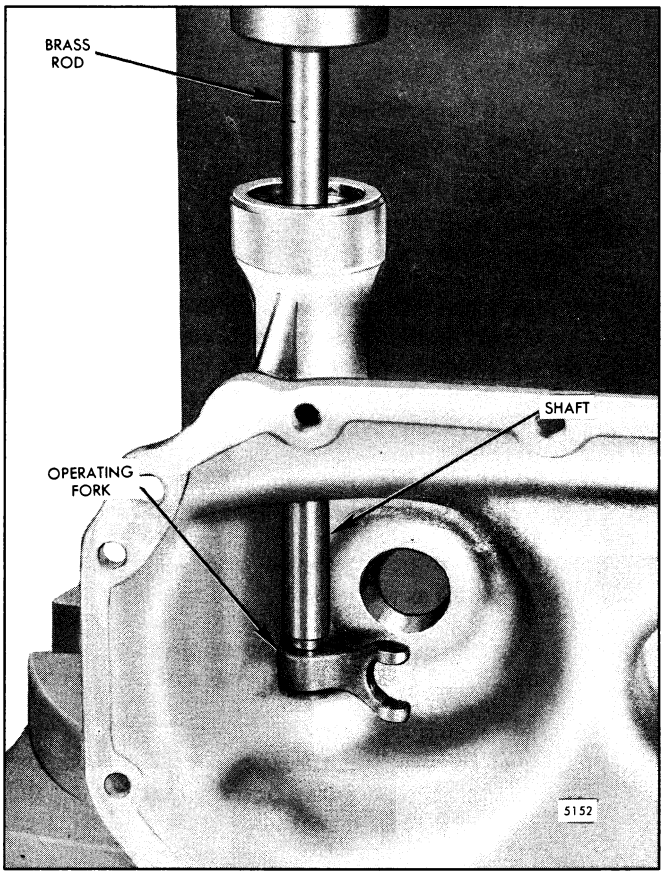



**Fig. 14 - Installing Operating Fork and Shaft in Weight Housing**

4. Assemble the governor control housing as follows (Figs. 2 and 5):

   a. Press a new enclosed bearing (24) flush with the counterbore in each shaft opening on the outside of the housing (current governors) or in one end of the terminal lever shaft bore (former governors).

   b. On current governors, slide the operating levers (57 and 61) over the operating shafts (58 and 60) and place the shafts into the control housing with one end of each shaft inserted into the enclosed bearings. Refer to Fig. 2 for proper orientation of the operating control link levers. Then, press a new enclosed bearing assembly (24) in each housing bore at the opposite ends of the shafts until there is .040" maximum end play and install four new retaining rings, positioning the operating levers on the operating shafts.

   c. On former governors, slide the terminal lever (25) on the terminal lever shaft (26) and position one end of the shaft and lever assembly in the installed bearing assembly. Then, press a new enclosed bearing assembly (24) in the bore at the opposite end of the terminal shaft and over the terminal shaft end. Tighten the set screw (43) securing the terminal shaft lever to the terminal shaft.

   d. On current governors, install the connecting rod (59) to the operating control link levers (57and 61) using a washer (20) and new spring retainer (19) at each end of the connecting rod.

   e. On former governors, connect the differential lever connecting rod (23) to the terminal lever (25).

   f. On current governors, install the differential lever connecting rod (23) to the operating control link levers (61).

   g. Connect the differential lever (21) to the differential lever connecting rod (23).

   h. Secure the differential lever (21) to the operating shaft lever (18) using a plain washer (20)and spring retainer (19).

   i. Install the fuel rods.

5. Assemble the governor variable speed spring housing (Figs. 6 and 7):

   a. Place the Woodruff Key (65) in the center key way of the speed control lever shaft (7). Start the set screw (63) in the spring lever (8).

   b. Lubricate the speed control lever shaft bearings with Shell Alvania No. 2 grease, or equivalent. Then, start one of the bearings, numbered end up, straight in the bearing bore in the right hand side of the spring housing as viewed in Fig. 7.

   c. Install the needle bearing pilot rod J 9196-2 in the installer body J 9196—1 and secure it in place with the retaining screw (Fig. 15).

   d. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press. Then, press the bearing in the housing. When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

   e. Install the current roller type bearing and pin in the spring lever. Press the pin below the surface of the lever and stake it at three places on both sides of the lever. The former ball type bearing (with two washers) is swaged at both ends to retain the bearing in the spring lever.

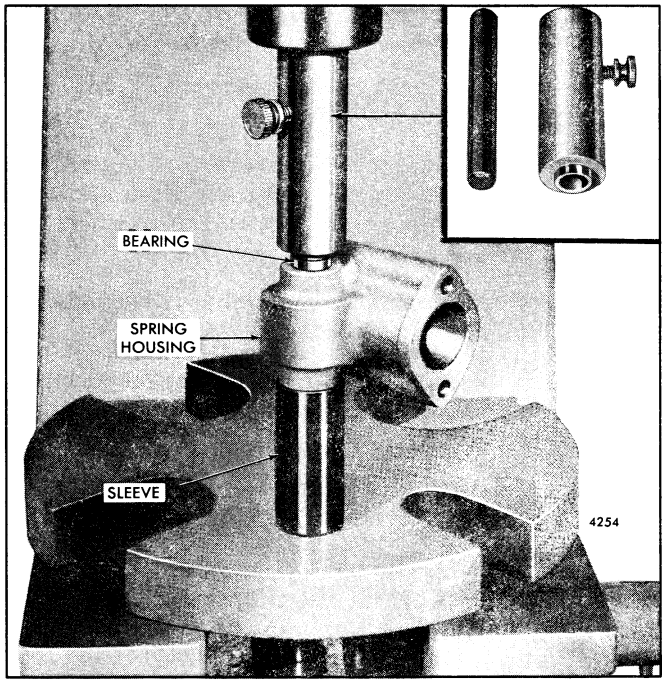



**Fig. 15 - Installing Speed Control Shaft Bearings using Tool J 9196**

f. Place the spring lever (8) between the bearing bores in the spring housing. Align the key in the shaft with the keyway in the spring lever. Push the shaft through the lever until the flat on the shaft is directly opposite the set screw.

g. With the lever centered between the bearing bores, tighten the set screw to 5-7 lb—ft (7-10 N«m) torque and stake the lever to the set screw. Install the plug in the spring housing on former governors.

h. On current governors, use a new gasket and attach the spring housing cover to the spring housing with a screw and lock washer.

i. Place the second speed control lever shaft needle bearing, numbered end up, over the protruding end of the shaft and start it straight in the bore of the housing.

j. Remove the bearing pilot rod J 9196-2 from the installer body J 9196-1 and place the installer body over the end of the shaft and against the bearing. Support the spring housing, bearings and installer on a short sleeve on the bed of an arbor press (Fig. 15). Then, press the bearing in the housing until the shoulder on the installer contacts the housing.

k. Apply some good quality sealant around the cup plug (71). Tap the plug in the shaft opening.

l. Place the seal (67) over the end of the shaft and into the counterbore of the spring housing. Place the plain washer (66) over the end of the shaft and insert the key (65) in the key way of the shaft.

m. Place the speed control lever on the control shaft and secure it with the retaining bolt.

n. Thread the locknut on the idle screw and thread the idle screw in the tapped hole of the spring housing cover (current governors) or the spring housing (former governors).

6. Install the variable speed spring housing on the governor housing (Fig. 2).

a. Drive the plunger guide (15) into the governor housing.

b. Lubricate the small end of the variable speed spring plunger (16) with Cindol 1705 and insert it into the plunger guide.

c. Lubricate the outer diameter of the spring retainer (9) and the inner contact area of the spring housing (6) with Cindol 1705 and place the spring retainer in the spring housing and against the spring lever (8). Insert the shims (10) in the spring retainer. Insert the stops (12) in the spring housing and against the spring retainer.

d. Position the variable speed spring (11) in the spring housing (6) with the tightly wound end of the spring against the shims.

e. On current governors, insert two bolts (with copper washers) through the spring housing cover and spring housing and place a new gasket over the bolts and against the spring housing. On former governors, insert the two bolts through the spring housing (with lock washers).

f. Position the variable speed spring housing (6) and a new gasket (14) against the governor housing (27) with the spring plunger (16) engaged in the end of the variable speed spring (11).

g. Tighten the attaching bolts to 13-17 lb—ft (18—23 N#m) torque.

7. Assemble the governor cover as follows (Fig. 4):

a. Place the governor cover on the bed of an arbor press. Start the bushing straight into the bushing bore of the cover. Press the bushing into the cover using installer J 4649. Press the bushing down into the bore 1/8” below the surface to allow room for the seal ring.

b. Insert the stop lever shaft through the bushing in the cover assembly.

c. Slide a new seal ring over the stop lever shaft and into the bushing bore.

d. Slide the two spacers over the shaft and up against the stop lever shaft boss.

e. Secure the stop lever shaft in the cover assembly with the snap ring.

f. Position the stop lever with the torsion retraction spring on the stop lever shaft and tighten the stop lever bolt.

## Install Governor

1. Install the govemor-to-blower gasket on the blower and slide the weight housing assembly straight on the dowels in the blower end plate. The tab on the gasket is to ensure the gasket is in place. Align the splines of the weight shaft with the splines in the blower rotor.

2. Secure the weight housing assembly to the blower with nine 3/8"-16 x 3-1/4" bolts and one 3/8"-24 nut. Tighten the bolts to 30-35 lb—ft (41-47 N»m) torque and the nut to 35-39 lb—ft (47-53 NAm) torque.

3. Install the blower and the governor drive and weight housing assembly on the engine (refer to Section 3.4).

4. Install the blower cover plate.

5. Install the water manifolds, air inlet housing and any other accessories removed under ***Remove Governor.***

6. Place a new seal ring (44) in the control housing (Fig. 2) and position the governor control housing over the drive mechanism and on the air box cover plate.

7. On current governors, connect the right and left bank 13. fuel rods to the governor control link operating levers (Fig. 2). Then, install the operating shaft lever (18) and secure it with a washer and retaining nut.

8. On former governors, connect the vertical linkage to the terminal shaft lever (Fig. 3).

9. Place a new governor housing gasket on the governor housing and install the governor cover. Be sure that the pin on the governor shutdown lever shaft enters the slot of the differential lever.

10. Install the governor speed control lever stop bracket with three of the cover screws.

11. Connect the speed control rod to the speed control lever and connect the control linkage to the governor stop lever.

12. Install the starting aid system (refer to Section 14.14) air cylinder and shutdown solenoid (if used) on the governor cover.

**CAUTION: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the technician must determine that the injector racks move to the *no-fuel* position when the governor stop lever is placed in the *stop* position. Engine overspeed will result if the injector racks cannotbe positioned at no fuel with the governor stop lever. An overspeeding engine can result in engine damage which could cause personal injury.**

Perform an engine tune-up as outlined in Section 14.4.

# MECHANICAL OUTPUT SHAFT GOVERNOR

The Pierce mechanical output shaft governor is used on certain engines, equipped with a torque converter, to regulate the speed of the output shaft. The output shaft governor (Fig. 1) is mounted on the engine governor and is driven by a flexible shaft from the torque converter output shaft and is connected, through linkage, to the engine governor. The mechanical limiting speed governor on the engine regulates the maximum and idle speeds of the engine while the output shaft governor has control of the engine speed in the intermediate speed range, between maximum and idle engine speed.

The flyweights (Fig. 2) on the output shaft governor are driven through the operating spider and shaft assembly by the governor drive adaptor. A shoulder on the flyweights bears against theriser that transmits the motion of the flyweights, through the riser thrust bearing, to the operating fork. The operating fork is attached to the rocker shaft that rides in the inner and outer ball bearings. Pinned to the rocker shaft are the spring lever and the rocker shaft lever. Connected to the spring lever is the speed adjusting spring that is, in turn, connected through the eyebolt to the speed adjusting spring lever. The speed adjusting spring lever is mounted on the speed adjusting shaft and is controlled by the engine operator when establishing the desired engine speed.

A minimum and a maximum output shaft speed adjusting bolt limits the travel of the speed adjusting shaft and thus the minimum and maximum output shaft speed settings. The linkage that operates the engine governor throttle is connected to the rocker shaft lever. The movement of the rocker shaft lever increases or decreases the speed of the engine.

## Lubrication

The output shaft governor is lubricated by engine oil that is contained within the governor housing. The movement of the governor weights throws the oil to all parts in the governor requiring lubrication.

With the output shaft stopped, fill the governor sump through the hinged cap oiler until the oil begins to drip out of the oil level hole. When the sump is full, the oil will drip from the oil level hole. A plug should be installed in the oil level hole and tightened sufficiently to prevent oil leakage. The oil level should be checked every 8 service hours and changed every 500 hours.

**NOTICE:** Care should be taken to remove all dirt or foreign material from the governor openings before filling or checking the oil level.

The bearing surfaces of the speed adjusting shaft should be lubricated by a hand oiler with engine oil. Rod end ball joints are sealed assemblies and do not require lubrication. The throttle control lever and the levers surrounding its shaft should be lubricated with all purpose grease through the grease fitting.

## Disassembly

After removing the governor and before removing any parts from the governor, wash the entire unit with clean fuel oil and dry it with compressed air. Then inspect for worn or damaged parts that can be repaired or replaced without complete disassembly. The output shaft governor may be disassembled by referring to Fig. 2 and proceeding as follows:

1. Remove the two socket head screws and lock washers that secure the speed adjusting shaft bracket to the governor body. Unhook the speed adjusting spring from the speed adjusting spring lever and the spring lever while removing the bracket.

2. With snap ring pliers J 4880, remove the speed adjusting shaft bracket retaining snap ring from the speed adjusting shaft. Remove the washer and slide the bracket from the shaft.

3. Note the position of the speed adjusting spring lever on the speed adjusting shaft. Then, using a small punch, drive out and discard the 5/32" roll pin that retains the lever to the speed adjusting shaft. After removing the roll pin, tap the end of the shaft with a soft hammer to remove the lever. The minimum and maximum speed adjusting bolts may be removed from the speed adjusting spring lever, if desired.

4. Remove the four socket head screws and lock washers that secure the governor flange to the body. Remove and discard the body to flange gasket. Remove the riser and thrust bearing from the governor operating spider and shaft assembly.

5. Remove the two screws and lock washers that secure the operating fork to the rocker shaft.

6. Remove and discard the oil seals from the governor body.

7. Remove the bearing retaining snap rings from the rocker shaft.

8. Tap the end of the rocker shaft gently and withdraw the shaft from the governor body.

   **NOTICE:** If the governor body is placed in a vise, care must be taken not to overtighten the vise as this could distort the aluminum body.

9. Remove the rocker shaft inner and outer ball bearings. The bearings may have to be tapped lightly to free them from the governor body.

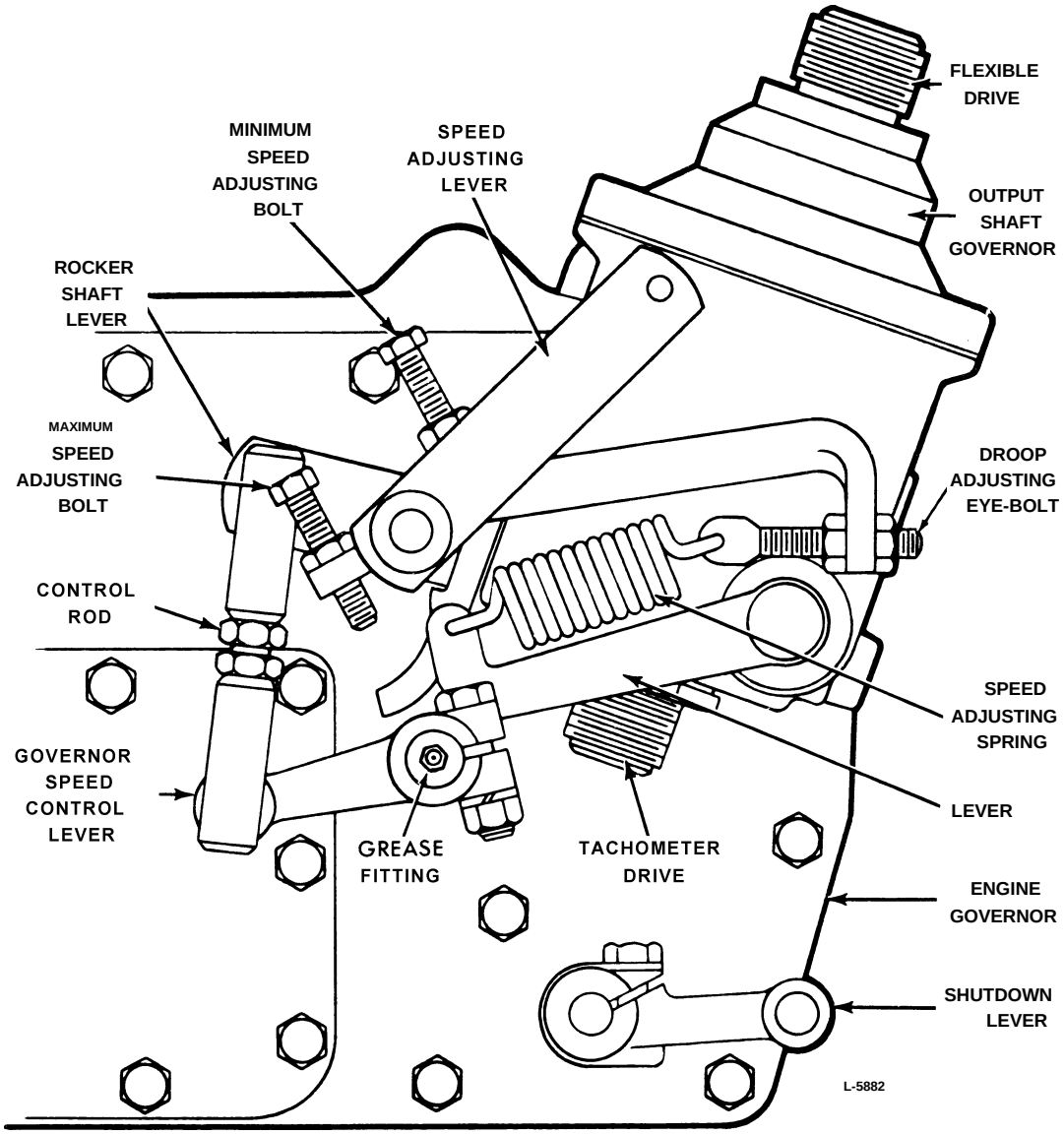



Fig. 1 - Mechanical Cable-Driven Output Shaft Governor and Linkage

10. Use a small punch to drive out the 5/32" roll pins that secure the spring lever and rocker shaft lever to the rocker shaft, after noting the relationship of the levers on the shaft. Then tap the end of the rocker shaft with a soft hammer to remove the levers from the shaft.

11. Secure the governor flange in a vise and, using tool J 4880, remove the lower bearing retaining snap ring.

12. Tap the splined end of the operating spider and shaft assembly lightly to loosen the shaft from the bearing. Remove the operating spider and shaft assembly.

13. Invert the governor base in the vise and remove the internal snap ring retaining the upper bearing.

14. Gently press the bearing out of the counterbore in the governor base.

15. Remove the eight hair pin clips that secure the weights on their supporting pins. Then, using a 5/32" punch, gently tap out the four flyweight supporting pins.

16. Carefully support the lower side of the riser thrust bearing in an arbor press. Then, using a 7/16" rod, gently press the riser from the inner race of the bearing. Use extreme care to prevent damage to the bearing shoulder of the riser.

17. Remove the nut and washer from the tachometer drive connection and remove the connection from inside the governor body.

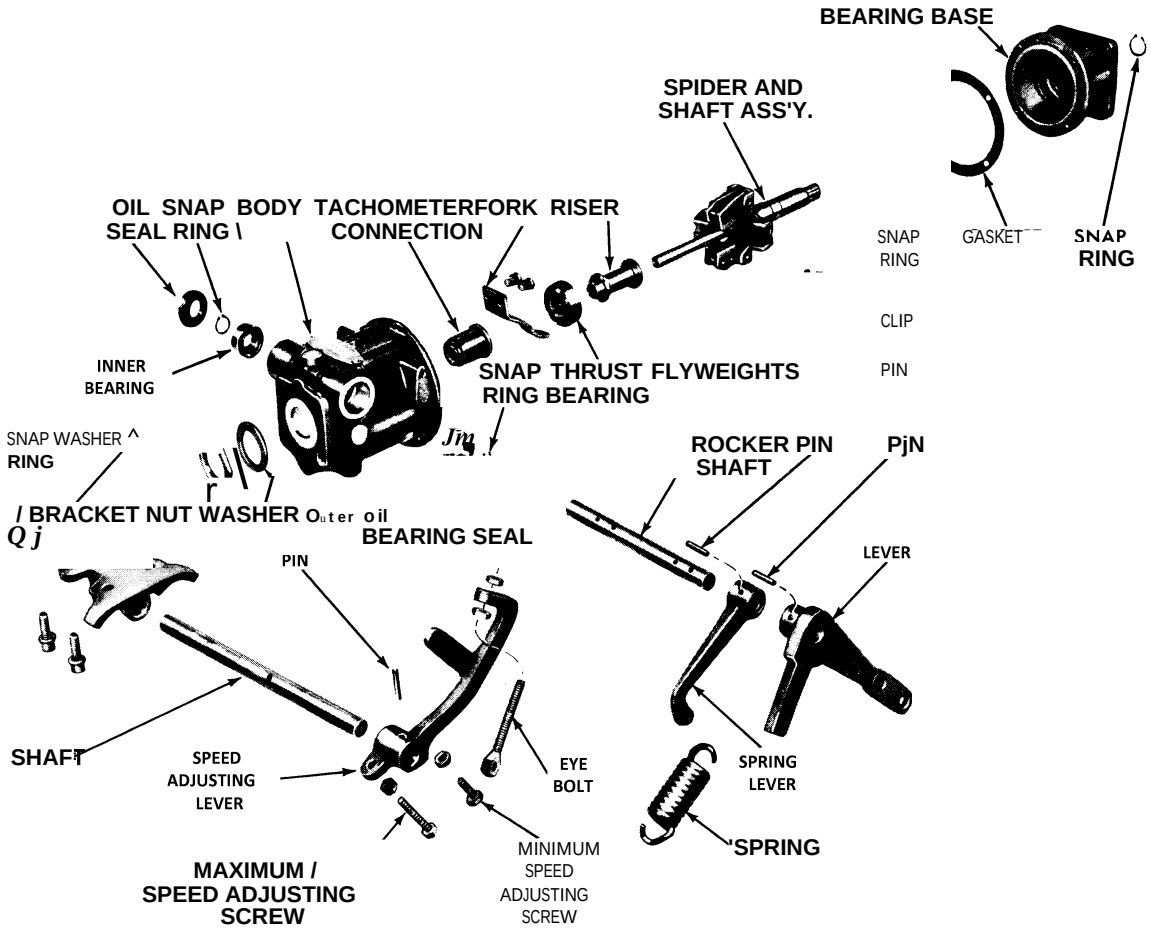



**Fig. 2 - Output Shaft Governor Details and Relative Location of Parts**

## Inspection

After the governor assembly has been disassembled, thoroughly clean each piece in fuel oil and dry it with compressed air.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the rocker shaft bearings for excessive wear. Replace them if necessary.

Inspect the operating shaft bearing for excessive wear.

Replace the rubber oil seal on the governor rocker shaft. The slightest wear on this part can cause oil leakage. It is recommended that when overhauling a governor, a new oil seal be installed.

Inspect the tachometer drive connection for wear to either the bushing or oil seal. If either part appears worn or damaged excessively, replace the entire connecting assembly.

Inspect all of the retaining snap rings to determine if they have been damaged at the time of disassembly. Replace them if necessary.

Inspect the riser bearing surface of the flyweights for excessive wear or a flat spot. If either condition exists, new weights must be installed. The flyweights must work freely on their supporting pins for satisfactory governor operation.

Inspect the governor operating fork for excessive wear or distortion. If either condition exists, install a new fork.

Inspect the governor body for distortion or damage to the bearing seating surfaces and replace it, if necessary.

## Assembly

After all of the parts have been cleaned and inspected, refer to Fig. 2 and assemble the governor as follows:

1. Place the governor base on a bench, bottom side down, and press the bearing into the base with the stamped side of the bearing inner race facing downward.
2. Install the upper bearing retainer internal snap ring into the base.
3. Replace the flyweights by positioning the operating shaft and spider assembly in a vertical position and install the supporting pins from left to right through the spider and weights. Retain the supporting pins with the hair pin clips at each end.
4. Lubricate the governor spider and operating shaft assembly lightly at the bearing end and, using an arbor press, force the shaft gently until it seats on the inner race of the bearing.
5. Install the lower bearing retainer snap ring.
6. Insert the tachometer drive connection into the governor body and retain it securely with the washer and nut.
7. Slide the spring lever and the rocker shaft lever on the rocker shaft, if removed, and pin the levers to the shaft with new 5/32" roll pins.
8. Place a new rubber oil seal (lip facing in) on the governor rocker shaft. Install the outer bearing retainer snap ring on the governor rocker shaft, taking precaution against damaging the bearing surface.
9. Place the outer rocker shaft bearing on the rocker shaft with the stamped side of the bearing facing (outward) the snap ring.
10. Place the governor body on a bench, with the name plate up and the body to base gasket surface facing the serviceman. Then insert the rocker shaft into the governor body from the left side until the bearing seats in the bore of the body.
11. Press the new rubber oil seal into the governor body.
12. Place the inner rocker shaft bearing in place on the shaft and gently press it into the governor body with its stamped side outward.
13. Install the inner bearing retainer snap ring on the rocker shaft. Then install a new rubber oil seal, pressing it firmly into the governor body.
14. Place the governor operating fork in the governor body on the flat section of the rocker shaft and securely tighten the retaining bolts.
15. Slide the speed adjusting spring lever, if removed, on the speed adjusting shaft and pin it securely, using a new 5/32" roll pin. Install the minimum and maximum speed adjusting bolts, if removed.
16. Slide the speed adjusting shaft through the speed adjusting shaft bracket and install the washer and snap ring.
17. Support the riser in a vertical position on an arbor press and place the thrust riser bearing in position on the riser, with the protruding race of the bearing facing upward. Then carefully press the bearing down until it is seated on the shoulder of the riser.
18. Install the riser on the operating spider and shaft assembly (Fig. 2).
19. Install a new body to base gasket and assemble the governor base to the body, using four socket head screws, with the oil drain hole boss in the governor base on the lever side of the governor.
20. Place the governor on a bench with the name plate downward. Hook the speed adjusting spring to the adjusting spring speed lever and rocker shaft spring lever.
21. Install the two socket head screws in the two lower holes of the speed adjusting shaft bracket and fasten them securely to the governor body.
22. Install the governor.
23. Refer to Section 14.10 for adjustment of the governor.

# HYDRAULIC GOVERNORS

Horsepower requirements on an engine may vary due to fluctuating loads. Therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors.

Engines, subjected to varying load conditions that require an automatic fuel compensation to maintain more nearly constant engine speedwith a minimum speed droop, are equipped with a hydraulic governor.

In the hydraulic governor, the fuel is decreased by the action of the governor throttle control terminal lever retracting spring and increased by the opposing action of the power piston. A pilot valve controls the admission of oil flow to the power piston and the movement of the pilot valve in turn is controlled by the governor flyweights. The centrifugal force of these flyweights is opposed by the speeder spring compression which may be varied and yet accurately set and held at any speed between idle and maximum speed. The speed droop, which is the difference between no-load speed and full-load speed, is adjustable to within a very small percentage at maximum speed.

## Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine. However, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations appear, check the unit as follows:

1. Make sure the speed changes are not the result of excessive load fluctuations.

2. Check the engine to be sure that all of the cylinders are firing properly (refer to Section 15.2). If any cylinder is not firing properly, remove and test the injector and, if necessary, replace or recondition it.

3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube. With the fuel rods connected to the injector control tube levers, the mechanism must be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, locate and correct it as follows:

   a. If an injector rack sticks or moves too hard, check the injector hold-down clamp. If it is too tight or improperly positioned, loosen the clamp bolt, reposition the clamp and retighten the bolt to 46-50 lb-ft (62-68 N#m) torque.

   b. An internal dirt accumulation, a defective plunger and bushing or a bent injector control rack can result in bind. To correct this condition, remove the injector, then recondition and test it.

   c. An improperly positioned control rack lever will result in a binding injector rack. To relieve the bind, loosen the control rack lever adjusting screws. Then relocate the lever on the control tube and position it as outlined in Section 14.

   d. If the injector control tube binds in its support brackets, it will prevent free movement of the injector control racks to their no-fuel position. Loosen andre-align the control tube supporting brackets, then tighten the bolts to correct this condition. Reposition the injector racks after re-aligning the support brackets.

   e. Replace an injector control tube return spring which has been bent or otherwise distorted. When the injector control tube and the injector racks are free from bind, the control tube will return to the no-fuel position by action of the return spring.

**NOTICE:** Never stretch or tamper with an injector control tube return spring to change its tension. Use a new spring.

   f. Check for bind in the pins which connect the fuel rods to the injector control tube levers. If necessary, remove the pins and polish them with fine emery cloth.

4. If neither load, engine irregularities or bind are found to be the cause of the speed variations, the trouble is probably in the governor or governor drive. Check as follows:

   a. If the speed changes noted are in rapid oscillation (governor hunting), adjust the speed droop of the governor as outlined in Section 14. This applies only if the governor is overhauled or where the speed droop has been changed from the original factory setting.

   b. Worn blower rotor bearings or rubbing of the rotors on the housing will cause the load on the blower drive coupling (between the gear train and the blower) to vary erratically. This variation in load will be transmitted as a speed change to the governor. The governor will act to compensate for the change by moving the fuel rods. If this condition exists, inspect the blower.

c. If the speed variations are small in magnitude, check the governor drive. Excessive or insufficient clearance between the bevel drive gears can cause this condition.

d. If the speed variations are large and erratic and unaffected (except, perhaps, in magnitude) by changes in the speed droop adjustment, or if the governor fails to control the speed at all, replace or overhaul the governor.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

To be certain whether the governor or engine is at fault, install a new governor (with the same part number) and check the performance of the engine.

# SG HYDRAULIC GOVERNOR

## (VARIABLE SPEED)

The governor is located at the front of the engine (Fig. 1). It is mounted on a control housing (current engines) or an adaptor plate (former engines) which sets over the governor drive housing.

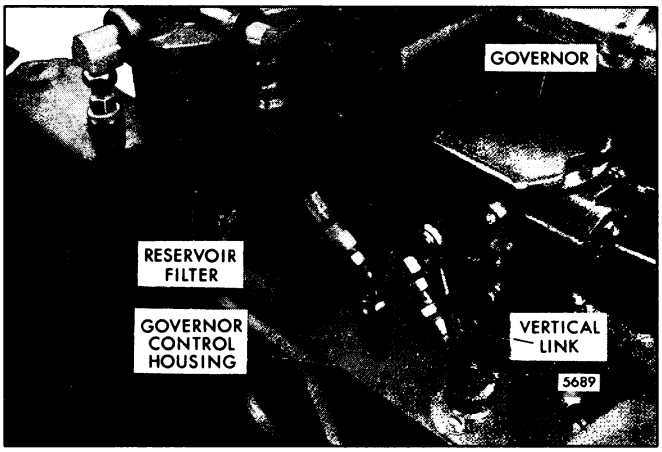



**Fig. 1 - Hydraulic Governor Mounting**

The governor, driven by one of the blower rotors through a bevel gear and shaft arrangement, actuates the injector control tubes through a linkage (refer to Section 2.8.3).

The governor is a hydraulic type with a speed droop stabilization mechanism (Fig. 2). Hydraulic action is transmitted by oil admitted under pressure from the engine lubricating system to an auxiliary oil pump in the governor. The auxiliary pump then develops the oil pressure necessary to actuate the governor mechanism.

To stabilize the governor, a speed droop adjustment is incorporated in the governor mechanism. The speed droop is regulated by a droop adjusting bracket attached to the side of the terminal lever. Movement of the droop adjusting bracket IN toward the center of the governor decreases the speed droop while movement in the opposite direction increases the speed droop.

The governor operates in such a manner that the amount of fuel supplied to the injectors is increased by the hydraulically operated servo-motor piston and decreased by action of the terminal lever return spring.

When starting a cold engine, time is required to develop sufficient oil pressure to operate the governor and thus move the injector control racks to the ***full-fuel*** position so the engine can start. Since this delay is undesirable, the starting time can be shortened by moving the governor operating lever to the ***full-fuel*** position to take control of the injector racks away from the governor.

An oil reservoir is provided to supply the governor with sufficient oil to overcome the delay in governor operation upon starting the engine. The engine can be stopped, regardless of the governor, by moving the governor operating lever to the ***no-fuel*** position.

In addition to its function of regulating the engine speed under varying load conditions, the hydraulic governor acts as an automatic shutdown device in the event of a loss of engine lubricating oil pressure. Should the engine fail to supply oil to the governor, the servo-motor piston will drop, thus allowing the governor operating lever to return to the ***no-fuel*** position.

## Operation

• An oil pickup tube is installed in the top inlet hole of the cover on the oil reservoir assembly and extends down into the reservoir (Fig. 3). An oil supply line is connected between the fitting on the pickup tube and the hydraulic governor oil pump inlet (Fig. 4). A restricted fitting is screwed into one of the “OUT” openings on the cover (the other “OUT” opening is plugged). A line is connected between this restricted fitting and a fitting on the governor control housing. An oil return line runs from the governor oil pump outlet to a solenoid shutdown valve. Another line is connected between the shutdown valve outlet and a fitting on the governor control housing.

• When the engine is cranked, the shutdown solenoid valve closes and the governor oil pump immediately begins drawing oil through the pickup tube in the reservoir to pressurize its hydraulic circuit. This allows the governor to rapidly move the injector racks to the ***full-fuel*** position, permitting start-up with minimum delay.

• After start-up, the shutdown solenoid valve stays closed to maintain system oil pressure. Overflow oil from the filled reservoir is dumped into the governor control housing and returned to the oil pan. When the engine is shut down, the shutdown solenoid valve opens to relieve system oil pressure.

With the engine operating, oil from the engine lubrication system is admitted to the space around the oil pump gears. The gears raise the oil pressure to a value determined by the spring in the relief valve which opposes the relief valve plunger. The oil pressure is maintained in the annular space between the undercut portion of the pilot valve plunger and the bore in the ball head (Fig. 5).

For any given throttle setting, the speeder spring has a definite compressional force which is opposed by the centrifugal force of the revolving flyweights. When the two forces are equal, the land on the pilot valve plunger covers the lower opening in the ball head producing a constant speed condition (Fig. 5).

When the load on an engine is increased, the engine speed will drop momentarily and the governor weights will be forced inward by the speeder spring permitting the pilot valve plunger to uncover the lower port in the ball head. With this port uncovered, oil, under pressure of the governor pump, will be admitted to the cavity at the lower end of the power piston and force the piston and floating pin upward (Fig. 6). The upward motion of the piston is transmitted through the terminal lever and fuel rod to the injector control tube, causing the fuel setting of the engine to be increased.

As the power piston and terminal lever rise, the compressional load on the speeder spring is reduced, allowing the flyweights to again move out to their normal *vertical* position. With the governor weights in a *vertical* position, the land on the pilot valve plunger will again cover the ports in the ball head, trapping the regulating oil under the power piston. With the power piston held in its new position by the trapped regulating oil, the engine will carry the increased load at a slightly reduced speed.

Fig. 7 illustrates the governor reaction as the load on the engine is decreased and the engine speed increases.

**•NOTICE:** Because of its importance to engine starting, technicians servicing or rebuilding this system should always make sure that the oil pickup tube is placed in the reservoir and that oil supply and return lines are properly routed (Fig. 4). ***Under no circumstances should a filter element be installed in the reservoir.*** The oil reservoir/shutdown valve system should be tight and free of leaks to avoid the entrance of air or the possibility of siphon action depleting the reservoir oil supply. All electrical connections on the shutdown solenoid valve should be properly wired and securely fastened.

## Lubrication

Oil seeping past the power piston and pilot valve plunger is vaporized by the revolving governor flyweights, providing lubrication for the moving parts in the governor housing. The governor pump, pilot valve plunger and power piston are all exposed to pressurized oil. The current pilot valve plunger has two oil holes to provide additional lubricating oil to the thrust bearing. Oil which collects on the floor of the governor housing passes through a drilled passage into the governor drive housing, providing lubrication for the governor drive and driven beveled gears and their bearings. In addition, current governors have a cast passage with a drilled orifice in the governor drive housing which sprays oil on the drive splines. On former governors, a spray nozzle pressed into the blower end plate directed oil to the drive splines.

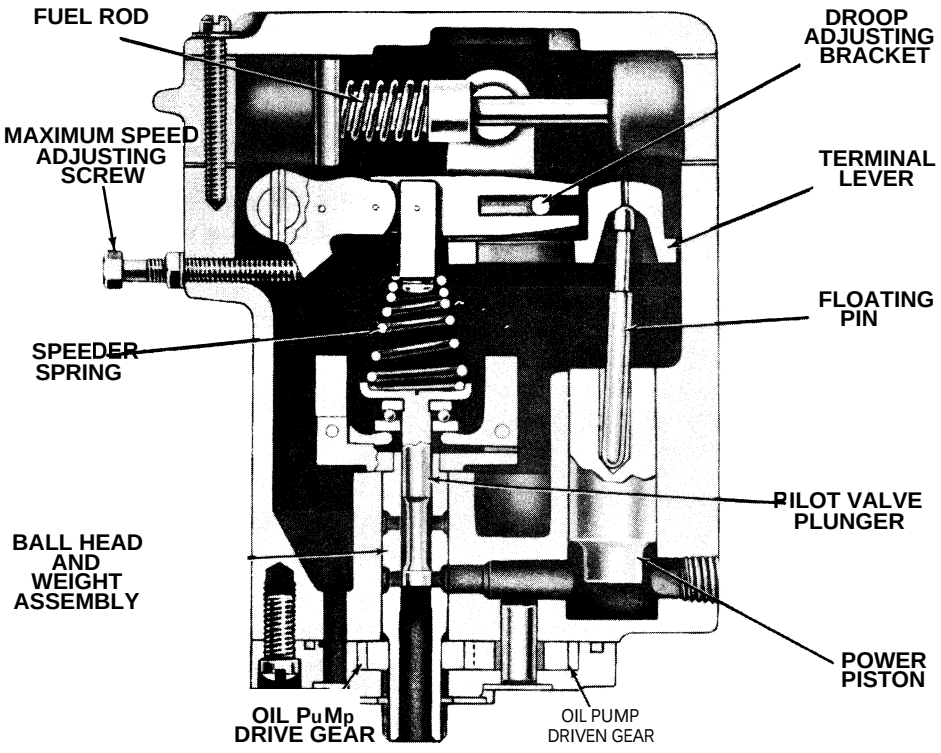
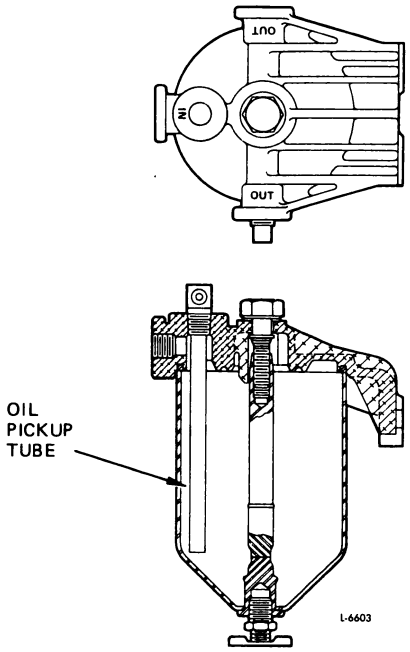



**Fig. 2 - SG Hydraulic Governor Assembly**



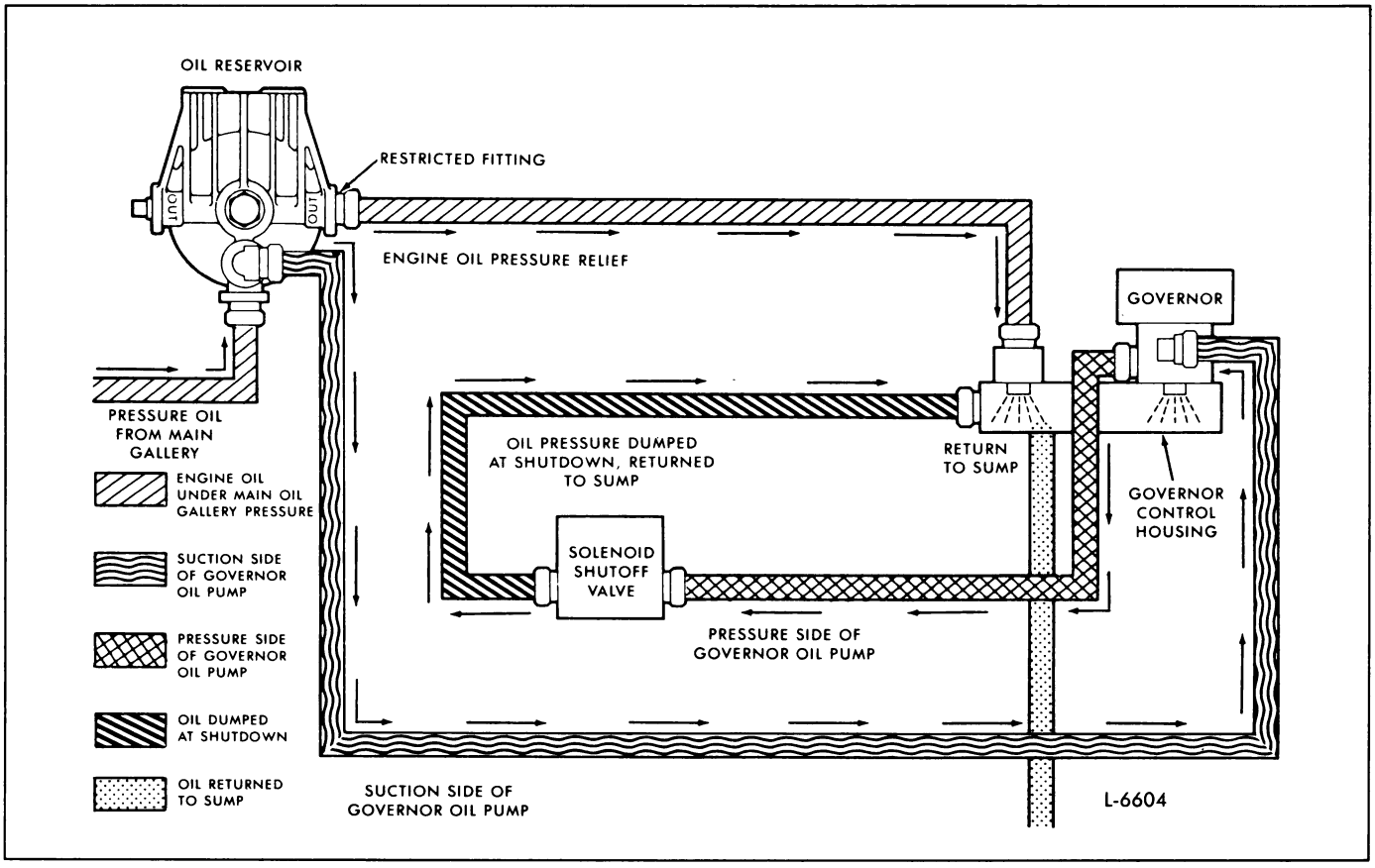

' Fig. 3 - Oil Reservoir Assembly with Pick-up Tube

The surplus oil returns to the engine crankcase through a passage in the bottom of the drive housing and into the gear housing and to the engine crankcase.

## Remove Governor

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect any linkage which may be attached to the governor speed control lever.
2. Drain the oil reservoir, if one is used.
3. Disconnect the vertical link assembly from the governor operating lever.
4. Disconnect the oil supply tube at the governor. Also, disconnect the oil return line, if one is used.
5. Disconnect the wires to the synchronizing motor, if used. Tag the wires to facilitate reassembly.
6. Remove the four (4) nuts or bolts and lock washers which attach the governor to the governor control housing cover (or the adaptor plate on former engines). Lift the governor away from the drive housing. Remove the gasket.




• Fig. 4 – Oil Flow Schematic – SG Hydraulic Governors

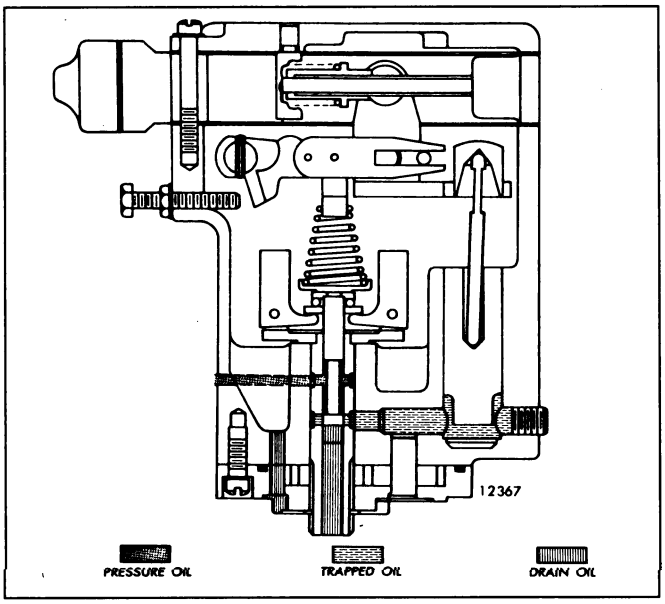



**Fig. 5 - Position of Governor Mechanism when Load is Constant**

Before a Barber-Coleman electronic governor is installed on a Series 149 engine previously equipped with a hydraulic governor, the vertical driven and horizontal drive shafts and bearings must be removed from the governor drive housing.

The shafts serve no useful purpose when the hydraulic governor is replaced by the electronic governor and will cause severe engine damage if not removed. Because the horizontal drive shaft is splined to the blower rotor shaft, both governor shafts will continue to rotate when the engine is operated. However, with the hydraulic governor removed, the horizontal and vertical shafts and bearings will no longer receive adequate support or lubrication and will quickly wear out.

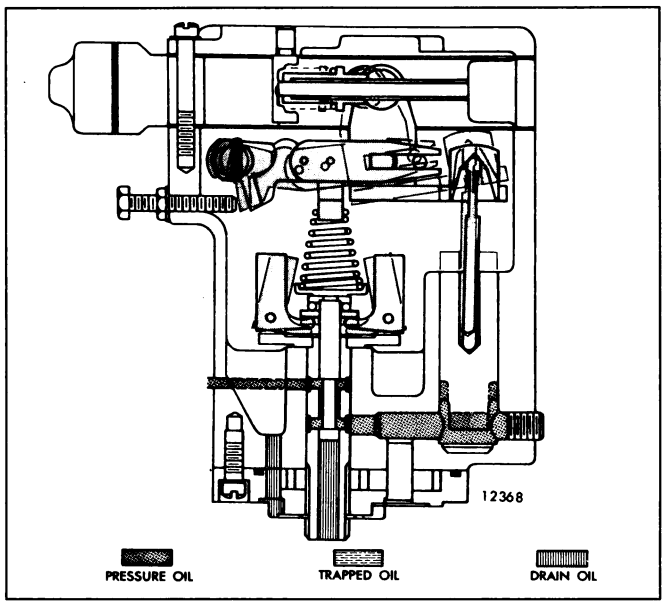



**Fig. 6 - Position of Governor Mechanism as Load Increases and Engine Speed tends to Decrease**

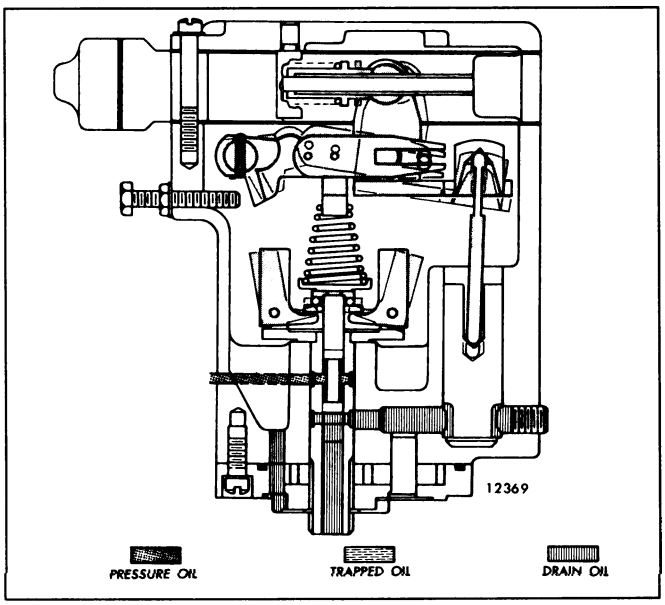



**Fig. 7 - Position of Governor Mechanism as Load Decreases and Engine Speed tends to Increase**

**NOTICE:** Do not remove only the vertical shaft and bearing. If the horizontal shaft and bearing assembly is left in the governor drive housing, the shaft will move freely back and forth during engine operation. This is due to the absence of load on the bevel gear which would normally keep the horizontal shaft in position. The rapid rotation and back-and-forth movement of the horizontal shaft can cause severe damage to the governor drive housing.

Use the following procedure to remove the vertical and horizontal shafts from the hydraulic governor housing before a Barber-Coleman electronic governor is installed:

1. Remove the governor and the upper governor control housing as outlined in Sections 2.8.1, 2.8.2 or 2.8.3.
2. Remove the air inlet shutdown systems as outlined in Section 3.3.
3. Remove the intercooler assembly, if necessary, as outlined in Section 3.5.2.
4. Remove the front blower as outlined in Section 3.4.
5. Remove the governor drive housing assembly from the front blower as outlined in Section 3.4.
6. Remove the snap ring and vertical and horizontal shafts from the governor drive housing as outlined in SEction 2.8.3.

7. Install the governor drive housing on the blower using a new gasket.

8. Install the front blower and cover as outlined in Section 3.4.

9. Install all remaining parts and assemblies. Install the Barber-Coleman governor per the manufacturer's instruction, and perform the tune-up as outlined in Section 14.

## Disassemble Governor

Before removing any of the parts from the governor, wash it thoroughly in clean fuel oil and dry it with compressed air. Then, inspect the governor for worn or damaged parts which can be repaired or replace without completely disassembling it. Disassemble the governor only as far as necessary to correct those difficulties which interfere with proper governor operation.

1. Loosen the governor operating lever clamping bolt and remove the lever.

2. Loosen the governor speed control lever clamping bolt and remove the lever.

3. Refer to Fig. 8 and remove the three (3) cover bolts and lock washers which attach the governor cover to the subcap. Remove the cover and gasket.

4. Refer to Fig. 8 and remove the two screws and lock washers which attach the governor subcap to the governor housing. Lift the subcap assembly off of the housing and remove the gasket.

5. Disassemble the subcap as follows (Figs. 8 and 9):

   a. Remove the two (2) screws and lock washers from the spring pad cover. Remove the cover and gasket.

   b. Withdraw the terminal lever return spring, the spring guide rod and the spring guide rod seat from the subcap.

   c. Loosen the locknut and remove the load limit screw and the copper washer.

6. Remove the screw, copper washer and lock washer from the terminal lever and remove the droop adjusting bracket. Refer to Figs. 8 and 10.

7. Remove the maximum speed adjusting screw and locknut from the governor housing.

8. Use a punch and drive the roll pin out of the speed adjusting lever and shaft (Fig. 11).

9. Drive the speed adjusting shaft and cup plug from the governor housing with a brass rod (Fig. 12). Remove the speed shaft oil seal - (Fig. 8).

10. Refer to Fig. 13 and remove the speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger as an assembly.

11. Refer to Figs. 8 and 10 and remove the two (2) cotter pins securing the terminal lever to the terminal lever shafts.

12. Remove the terminal lever shafts and cup plugs, using a brass rod (Fig. 14). Remove the terminal lever.

13. Remove the thrust bearing, floating pin and power piston from the governor housing (Fig. 8).

14. Refer to Fig. 8 and unscrew the plunger and spring seat from the speeder spring. Unscrew the speeder spring from the spring fork.

15. Straighten the ends of the lock wire and remove the lock wire separating the speed adjusting lever, spring fork and floating lever.

16. Remove the dummy hole plug and gasket from the governor housing.

17. Remove the oil inlet plug, gasket, sleeve retaining spring, relief valve spring, relief valve and relief valve sleeve.

18. Refer to Fig. 8 and remove the lock ring securing the weight assembly shaft to the governor housing and remove the weight assembly.

19. Remove the three (3) screws securing the governor base to the governor housing and remove the base and seal ring. Since the base is doweled to the governor housing, it may be necessary to tap the base lightly with a soft hammer to facilitate removal.

20. Refer to Fig. 8 and remove the oil pump drive and driven gears.

## Inspection

After the governor assembly has been disassembled, each piece should be thoroughly cleaned in fuel oil, dried with compressed air and inspected.

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the fuel rod bushing and seal for excessive wear and replace, if necessary.

Inspect the finished radius of the flyweights for excessive wear or flat spots. If either of these conditions exist, new flyweights must be installed. The flyweights should work freely on their supporting pins for satisfactory governor operation.

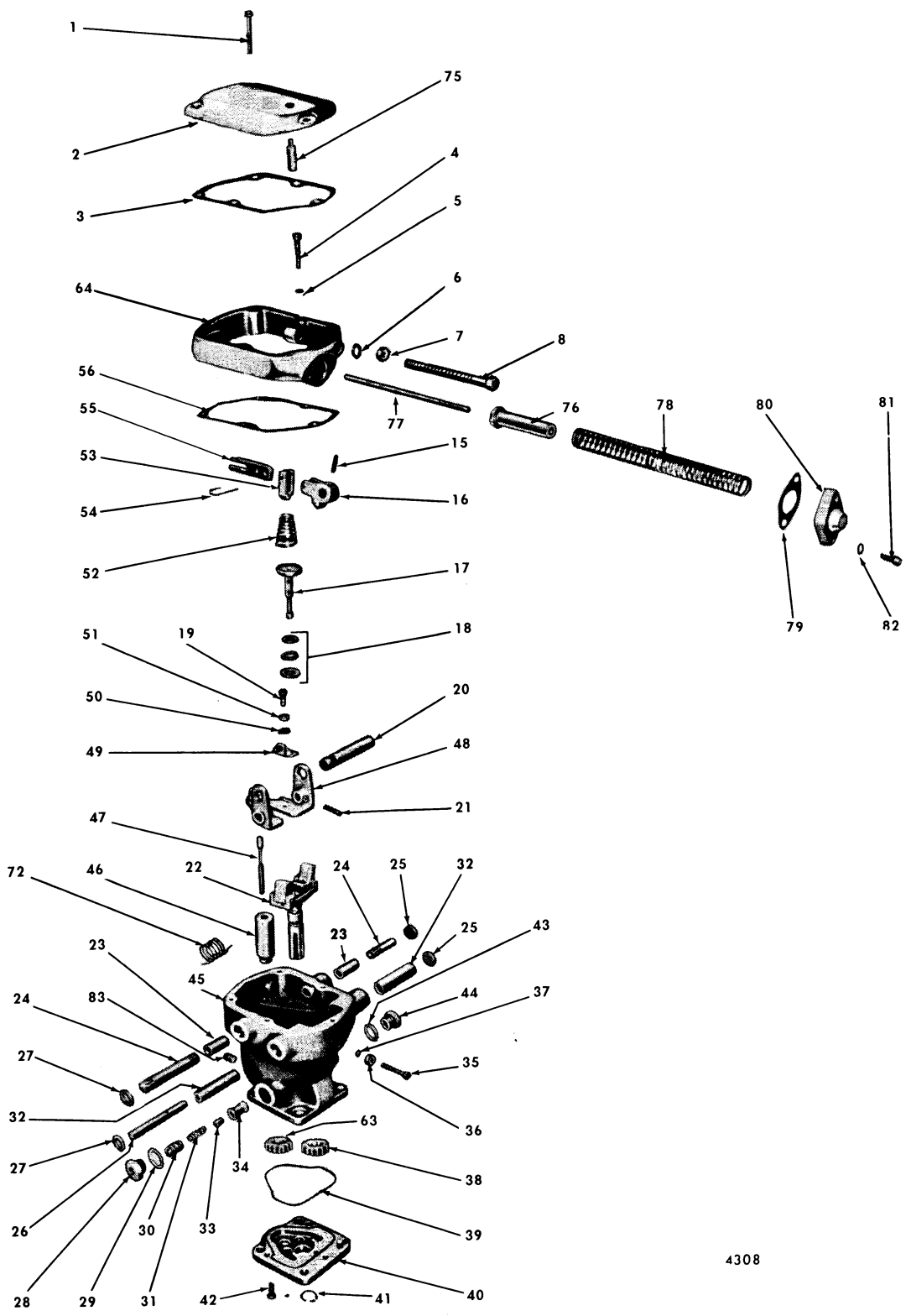



Fig. 8 - Hydraulic Governor Details and Relative Location of Parts

1. Screw - Governor Cover
2. Cover — Governor
3. Gasket — Governor Cover
4. Screw — Subcap-to-Housing
5. Lock Washer
6. Washer — Copper
7. Lock Nut
8. Screw — Load Limit Adjusting
15. Pin —Roll
16. Lever - Speed Adjusting
17. Plunger - Pilot Valve
18. Bearing — Pilot Valve Plunger Thrust
19. Screw — Droop Adjusting Bracket
20. Pin — Terminal Lever Cross
21. Cotter Pin
22. Weight Assembly
23. Bushing — Terminal Lever
24. Shaft — Terminal Lever
25. Plug — Cap
26. Shaft — Speed Adjusting lever
27. Oil Seal
28. Plug — Governor Oil Inlet
29. Gasket - Relief Valve
30. Spring — Sleeve Retaining
31. Spring - Relief V alve
32. Bushing - Speed Adjusting Lever Shaft
33. Valve —Relief
34. Sleeve — Relief Valve
35. S crew — M aximum Speed Adjusting
36. Lock Nut
37. Washer — Copper
38. Gear — Oil Pump Drive
39. Ring — Housing-to-Base Seal
40. Base — Governor
41. Lock Ring
42. Screw — Governor Base
43. Gasket — Spacer Cap
44. Plug — Dummy Hole
45. Housing — Governor
46. Piston — Power
47. Pin — Floating
48. Lever — Terminal
49. Bracket — Speed Drop Adjusting
50. Plain Washer
51. Lock Washer
52. Spring — Speeder
53. Fork — Adjusting Linkage Spring
54. Pin — Spring Fork
55. Lever — Speed Adjusting Floating
56. Gasket — Subcap-to-Housing
63. Gear — Oil Pump Driven
64. Subcap — Governor
69. Bushing — Terminal Shaft
72. Spring — Torsion (Syn. Motors Only)
75. Screw — Low Speed Stop
76. Seat — Guide Rod Spring
77. Rod — Spring Guide
7 8. Spring — Terminal Lever Return
79. Gasket
80. Cover — Spring Pad
81. Screw — Spring Pad
82. Washer — Internal Lock
83. Plug — Housing

**Fig. 8 - Hydraulic Governor Details and Relative Location of Parts**

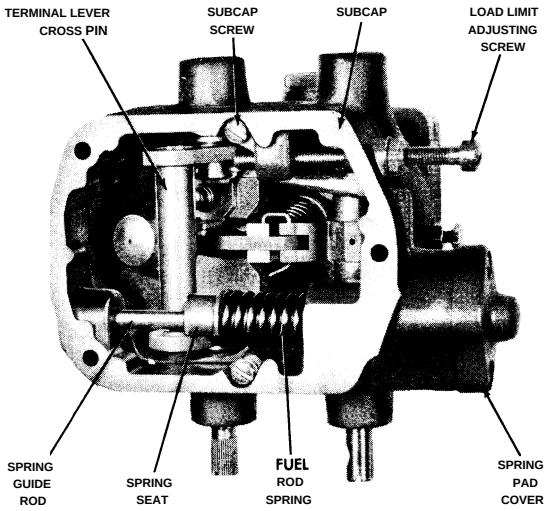



**Fig. 9 - Top View of Governor**

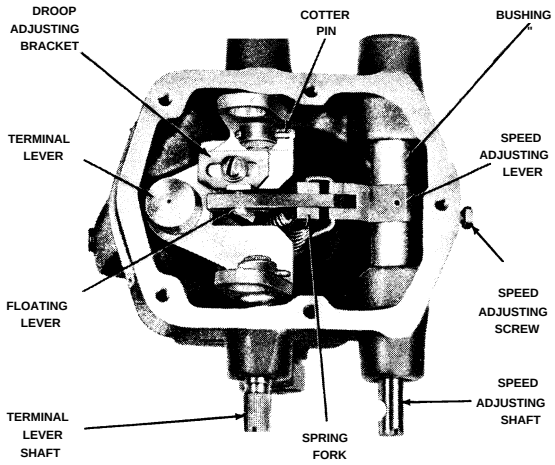



**Fig. 10 - Top View of Governor with Subcap Removed**

Inspect the pilot valve plunger for scratches or burrs. The plunger must work freely in the ball head assembly. Defective areas on the plunger may be dressed with a fine india stone, using extreme care to prevent rounding off the edges of the plunger.

Inspect the pilot valve bearing for excessive wear or flat spots. If either of these conditions exist, a new bearing must be installed.

Inspect the power piston for scratches or burrs. Defective areas may be dressed with a fine india stone, using extreme care to prevent rounding off the edges of the piston.

Inspect the governor ball head for free rotation in the governor housing and base.

Inspect the oil pump gears and driven gear bushing for excessive wear or damage. If either of these conditions exist, install new gears.

Inspect the terminal lever shaft and speed adjusting shaft bushings for scoring or excessive wear. Install new bushings if wear is excessive (Fig. 15).

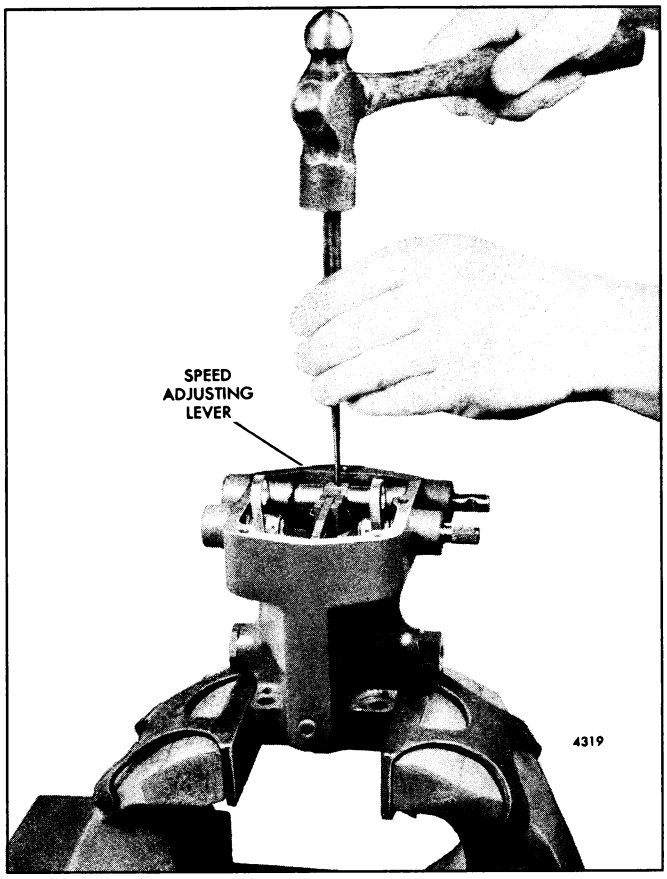



**Fig. 11 - Removing Speed Adjusting Lever Roll Pin**

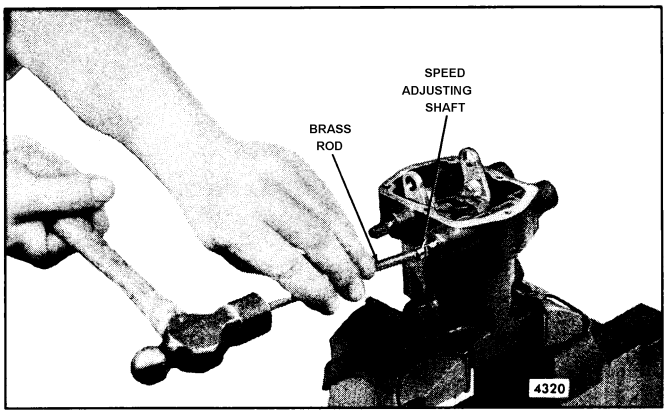



**Fig. 1 2 - Removing Speed Adjusting Lever Shaft Cup Plug from Governor Housing**

## Assembly

After all of the parts have been cleaned and inspected, assemble the governor as follows:

1. Lubricate the two oil pump gears (Fig. 8) and place the gears in their respective positions in the governor base.
2. Place a new seal ring in the groove of the governor base, with the wide side of the seal down in the groove.

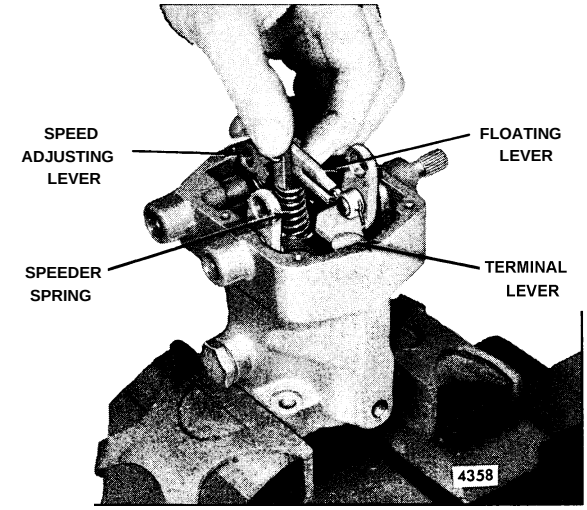



**Fig. 13 - Removing or Installing Speed Adjusting Lever, Spring Fork, Speeder Spring and Pilot Valve Plunger Assembly**

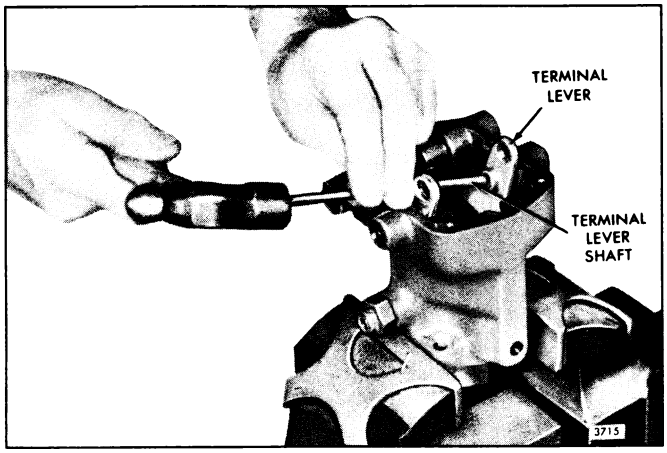



**Fig. 14 - Removing Terminal Lever Shaft Cup Plug from Governor Housing**

3. Set the governor housing on the base with the dowels in the base registering with the holes in the housing and the idler gear stud in the housing registering with the hole in the idler gear. Press the housing down against the base seal ring.
4. Lubricate the shaft of the weight assembly (22) and insert the shaft end of the assembly down through the bore of the housing, drive gear and base.
5. Install the three screws and secure the base to the housing. Revolve the weight assembly to be sure that it is free of bind. If bind exists, loosen the three screws, tap the sides of the base lightly with a plastic hammer and tighten the screws again. Revolve the weight assembly again and check for bind. Repeat, if necessary, until all parts rotate freely.

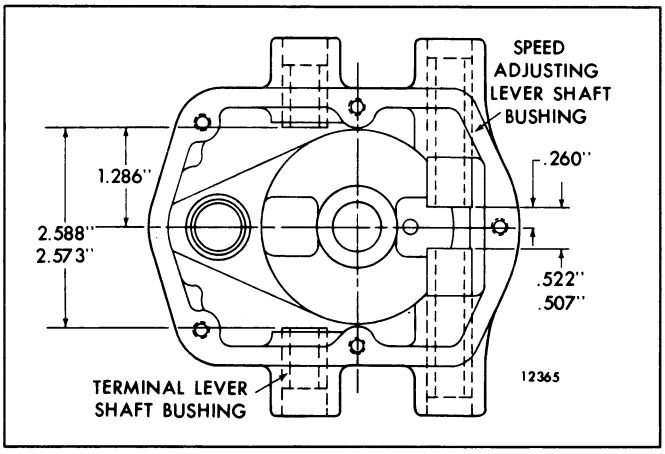



**Fig. 1 5 - Location of Speed Adjusting Lever and Terminal Lever Shaft Bushing in Governor Housing**

6. Install the lock ring in the groove at the lower end of the shaft.

7. Install the relief valve sleeve, relief valve, relief valve spring, sleeve retaining spring, gasket and oil inlet plug.

8. Install the dummy hole plug and gasket.

9. Install a new spring fork pin into the speed adjusting lever, spring fork and floating lever.

10. Thread the small end of the spring fork into the small end of the speeder spring, then thread the large end of the spring into the pilot valve plunger spring seat.

11. Place the plunger (thrust) bearing over the lower end of pilot valve plunger with the bearing washer having the smaller outside diameter against the spring seat.

12. Guide the pilot valve plunger in the opening of the weight assembly, being careful not to apply undue force on the plunger.

13. Install the power piston in the governor housing. Place the floating pin in the power piston on current design governors.

14. Install the terminal lever shafts and terminal lever. Align the holes in the lever shaft with the holes in the terminal lever and install the cotter pins - (Fig. 16).

15. Refer to Fig. 13 and install the speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger as an assembly.

16. Position the speed shaft oil seal into the governor housing. Refer to Fig. 17 and install the speed adjusting lever shaft in the governor housing and adjusting lever.

17. Drive a new roll pin through the roll pin holes and secure the speed adjusting lever to the speed adjusting shaft.

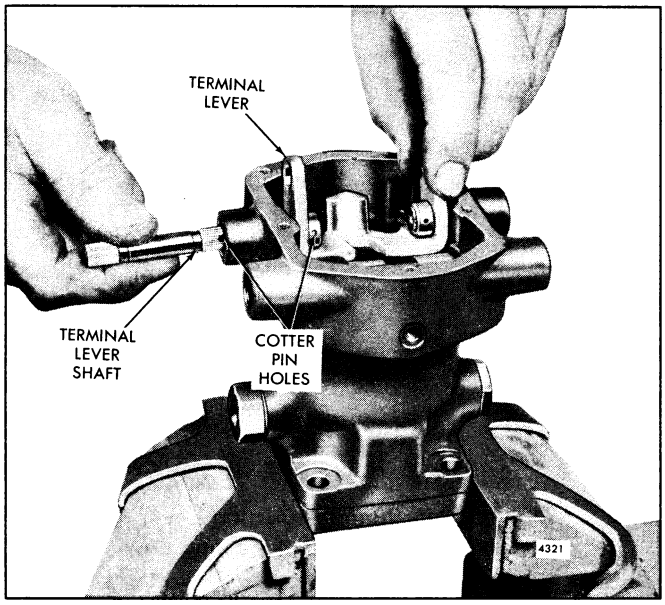



**Fig. 16 - Installing Terminal Lever Shaft in Governor Housing and Terminal Lever**

18. Install the maximum speed adjusting screw and locknut.

19. Press the plugs into the governor housing.

20. Install the droop adjusting bracket, using bolt, washer and lock washer.

21. Install the governor speed control and operating levers.

22. Attach a new subcap gasket to the top of the governor housing.

23. Place the subcap on the governor housing, with the spring pad on the same side as the governor maximum speed adjusting screw. Secure the subcap to the governor housing with two socket head screws and lock washers.

24. Install the terminal lever spring guide rod seat, spring guide rod, spring, spring pad cover and load limit screw in the subcap as follows:

    a. Place the spring guide rod seat in the subcap with the large diameter of the seat facing the terminal lever.

    b. Lubricate the spring guide rod with engine oil. Then, insert the rod through the spring pad opening, through the guide rod seat and into the boss at the opposite end of the subcap.

    c. Insert the spring over the guide rod and the small end of the guide rod spring seat.

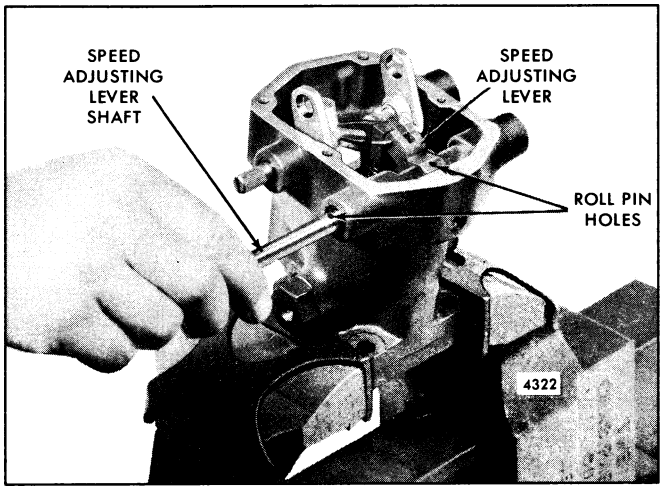



**Fig. 1 7 - Installing Speed Adjusting Lever Shaft in Governor Housing and Adjusting Lever**

d. Attach a new gasket to the spring pad cover. Then, place the cover against the spring. Push the cover to compress the spring and, at the same time, enter the spring guide rod in the hole in the cover. Secure the cover to the subcap with two screws and lock washers.

e. Thread a locknut on the load limit adjusting screw. Then, place a copper washer over the screw and thread the screw into the subcap until it almost contacts the terminal lever.

## Install Governor

1. Place a new gasket on the governor control housing (current governors) or on the adaptor plate (former governors).

2. Place the governor on the governor control housing or adaptor plate. Turn the governor slightly, if necessary, to align the splines of the ball head shaft with the splines in the driven shaft sleeve. Then, secure the governor with four (4) nuts or bolts and lock washers. Tighten the bolts or nuts uniformly.

3. Install the oil supply tube (and oil return tube, if used).

4. Pour approximately one (1) pint of engine oil in the governor to provide initial lubrication. Refill the oil reservoir, if used, with engine oil. Under no circumstances should a filter element be installed in the reservoir.

5. Refer to Fig. 8 and attach a new governor cover gasket to the subcap.

6. If previouslyremoved, install the low-speed stop screw on the underside of the governor cover. Secure the stop to the cover with a stop nut and copper washer.

7. Before installing the governor cover or connecting the governor linkage, perform a complete engine tune-up as outlined in Section 14.7.2.

# PSG HYDRAULIC GOVERNOR

The governor is located at the front of the engine and is mounted on a control housing which sets over the governor drive housing (Fig. 1). It is driven by one of the blower rotors through a bevel gear and shaft arrangement and actuates the injector control tubes through a linkage (Section 2.8.3).

The governor is an isochronous hydraulic type with a speed droop stabilization mechanism. Hydraulic action is transmitted by filtered oil admitted under pressure from the engine lubricating system to an auxiliary oil pump in the governor. The auxiliary pump then develops the oil pressure necessary to actuate the governor mechanism.

The isochronous feature of this governor is its ability, at zero droop, to hold the engine at a constant speed regardless of the load, provided the load is within the capacity of the unit.

The governor operates in such a manner that the amount of fuel supplied to the injectors is increased by the hydraulically operated servo-motor piston and decreased by action of the terminal lever return spring.

• When starting a cold engine, time is required to develop sufficient oil pressure to operate the governor and thus move the injector control racks to the ***full-fuel*** position so the engine can start. Since this delay is undesirable, the starting time can be shortened by moving the governor operating lever towards the ***full-fuel*** position while cranking

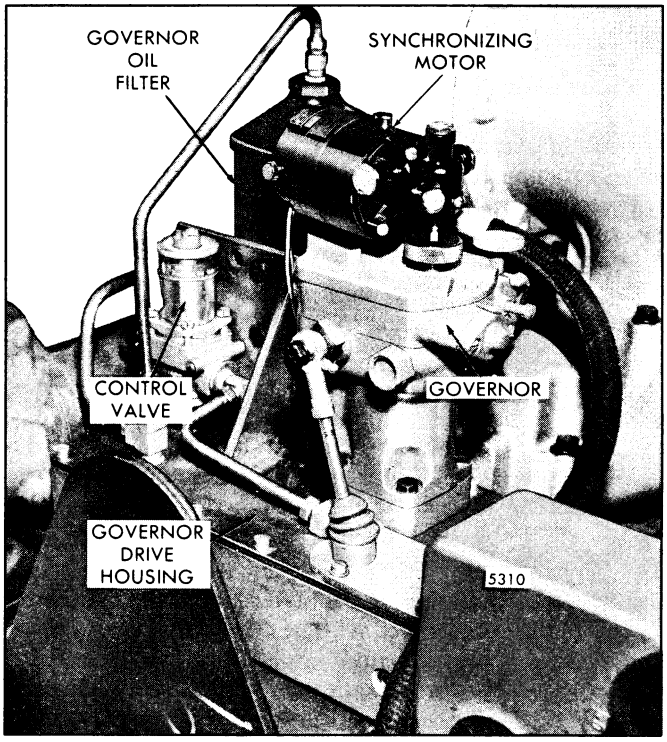
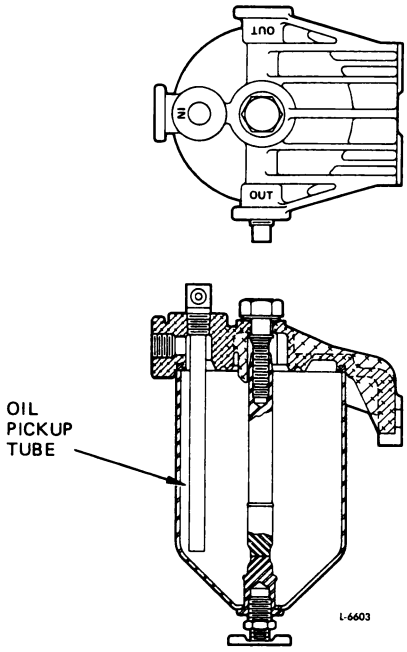



**Fig. 1 - Governor Mounting**



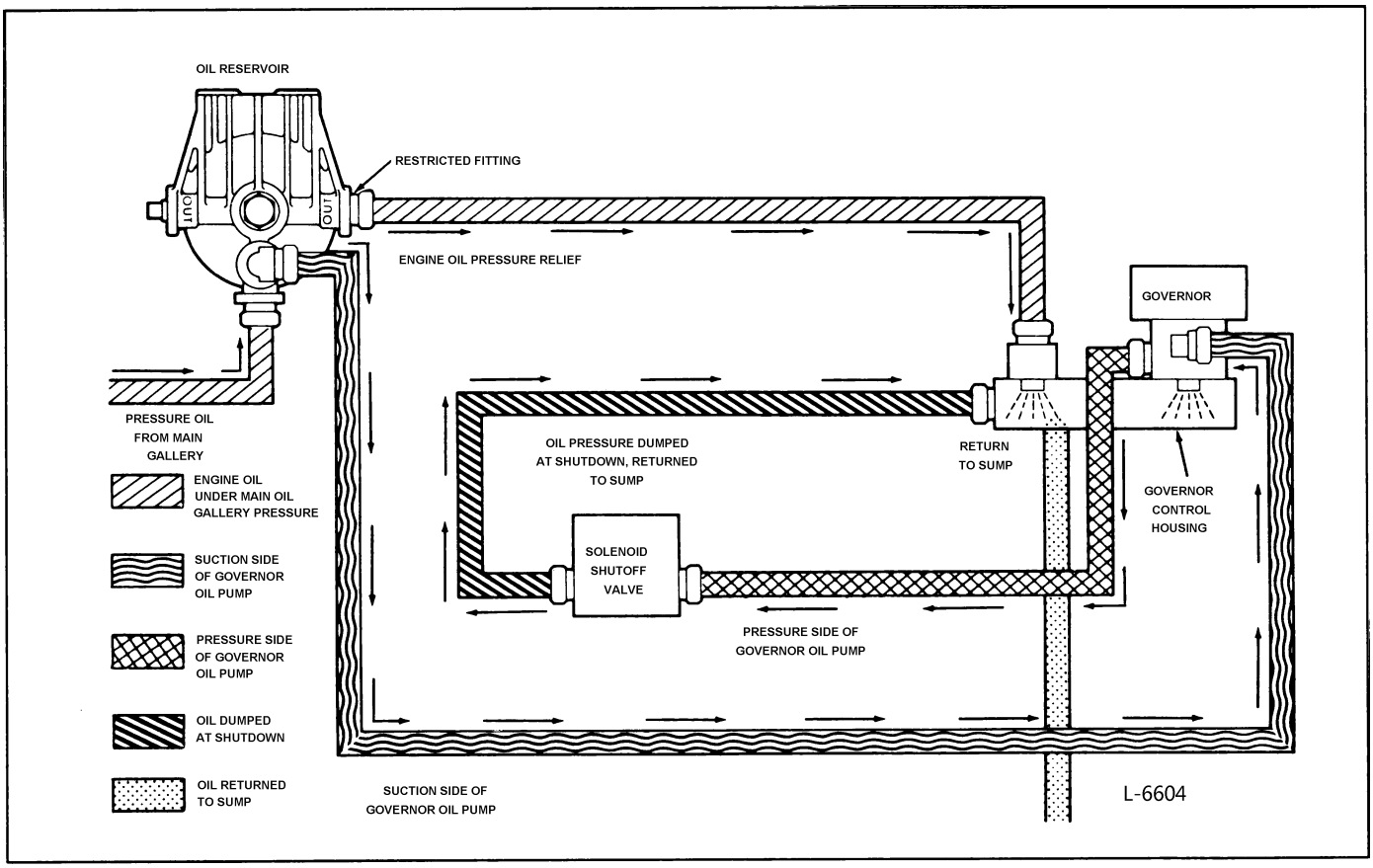

**• Fig. 2 - Oil Reservoir Assembly with Pick-up Tube**

the engine. This takes control of the injector racks away from the governor. On certain installations, such as units equipped with automatic starting, an oil reservoir is provided to supply the governor with sufficient oil to overcome the delay in governor operation upon starting the engine. The engine can be stopped by moving the governor operating lever to the ***no-fuel*** position.

In addition to its function of holding theengine speed constant under varying load conditions, the hydraulic governor acts as an automatic shutdown device in the event of a loss of engine lubricating oil pressure. Should the engine fail to supply oil to the governor, the servo-motor piston will drop, thus allowing the governor operating lever to return to the ***no-fuel*** position.

## Operation

• On units equipped with oil reservoirs, an oil pickup tube is installed in the top inlet hole of the cover on the oil reservoir assembly and extends down into the reservoir (Fig. 2). An oil supply line is connected between the fitting on the pickup tube and the hydraulic governor oil pump inlet (Fig. 3). A restricted fitting is screwed into one of the "OUT" openings on the cover (the other "OUT" opening is plugged). A line is connected between this restricted fitting and a fitting on the governor control housing. An oil return line runs from the governor oil pump outlet to a solenoid shutdown valve. Another line is connected between the shutdown valve outlet and a fitting on the governor control housing.




• Fig. 3 - Oil Flow Schematic - SG Hydraulic Governors

• When the engine is cranked, the shutdown solenoid valve closes (normally open valve) and the governor oil pump immediately begins drawing oil through the pickup tube in the reservoir to pressurize its hydraulic circuit. This allows the governor to rapidly move the injector racks to the *full-fuel* position, permitting start-up with minimum delay.

• After start-up, the shutdown solenoid valve stays closed to maintain system oil pressure. Overflow oil from the filled reservoir is dumped into the governor control housing and returned to the oil pan. When the engine is shut down, the shutdown solenoid valve opens to relieve system oil pressure.

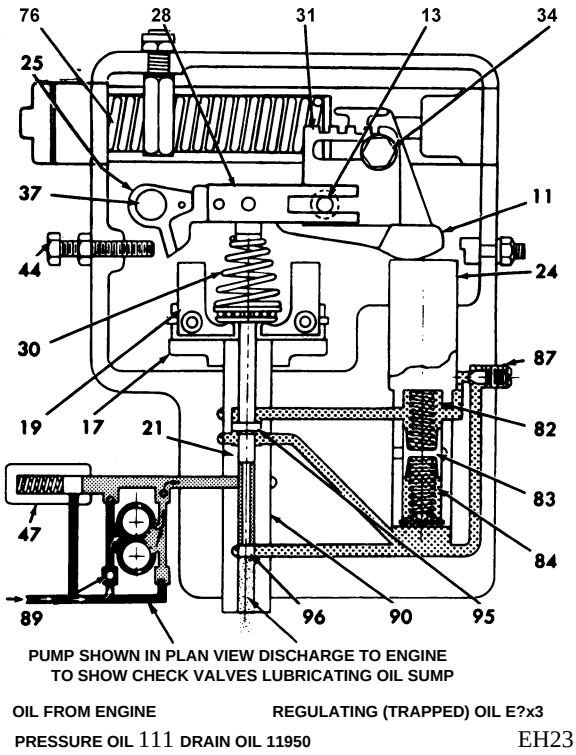
**•NOTICE:** Because of its importance to engine starting, technicians servicing or rebuilding this system should always make sure that the oil pickup tube is placed in the reservoir and that oil supply and return lines are properly routed (Fig. 3). ***Under no circumstances should a filter element be installed in the reservoir.*** The oil reservoir/shutdown valve system should be tight and free of leaks to avoid the entrance of air or the possibility of siphon action depleting the reservoir oil supply. All electrical connections on the shutdown solenoid valve should be properly wired and securely fastened.

With the engine operating, oil from the engine lubricating system is admitted to the space around the governor pump gears. The pump gears raise the oil pressure to a value determined by the spring in the relief valve which opposes the relief valve plunger. The oil pressure is maintained in the annular space between the undercut portion of the pilot valve plunger and the bore in the pilot valve bushing (Fig. 4).

For any given throttle setting, the speeder spring exerts a definite force which is opposed by the centrifugal force of the revolving flyweights. When the two forces are equal, the control land on the pilot valve plunger covers the lower ports in the pilot valve bushing.

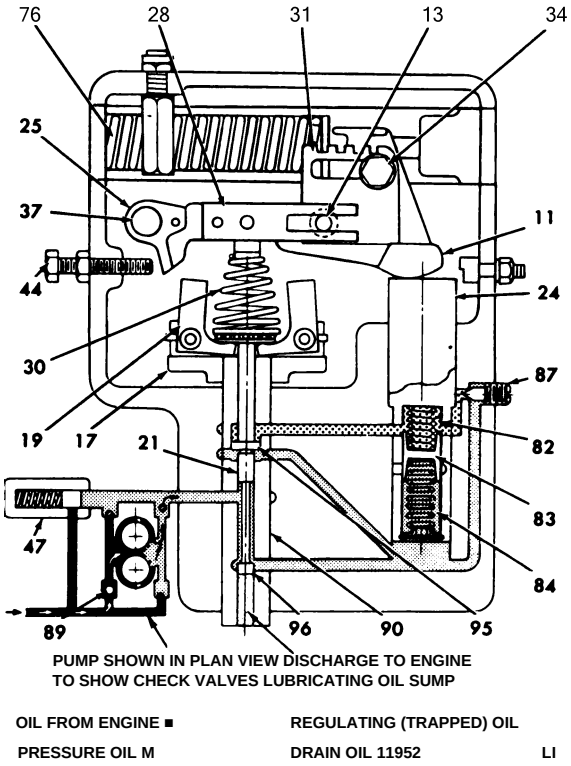
Under these conditions, equal oil pressure is maintained on both sides of the buffer piston and tension on the two buffer springs is equal. The oil pressure is also equal on both sides of the receiving compensating land of the pilot valve plunger, due to oil passing through the compensating needle valve. Thus, the hydraulic system is in balance and the engine speed remains constant.




11. Lever—Terminal
13. Shaft—Terminal (long)
17. Ball Head Assy.
19. Flyweight
21. Plunger—Pilot V alve
24. Piston—Servo-Motor
25. Lever—Speed Adjusting
28. Lever—Floating
30. Spring—Speeder
31. Bracket—Droop Adjusting
34. Bolt—Droop Adjusting
37. Shaft—Speed Adjusting
44. Screw—Maximum Speed Adjusting
47. Valve—Relief
76. Spring—Terminal Lever Return
82. Spring—Buffer (upper)
83. Piston—Buffer
84. Spring—Buffer (lower)
87. Valve—Compensating Needle
89. Valve—Check
90. Bushing—Pilot Valve
95. Land—Receiving Compensating
96. Land—Pilot Valve Control

**Fig. 4 - Stable Position of Governor When Load on Engine is Constant**




11. Lever—Terminal
13. Shaft—Terminal (long)
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19. Flyweight
21. Plunger—Pilot Valve
24. Piston—Servo-Motor
25. Lever—Speed Adjusting
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34. Bolt—Droop Adjusting
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82. Spring—Buffer (upper)
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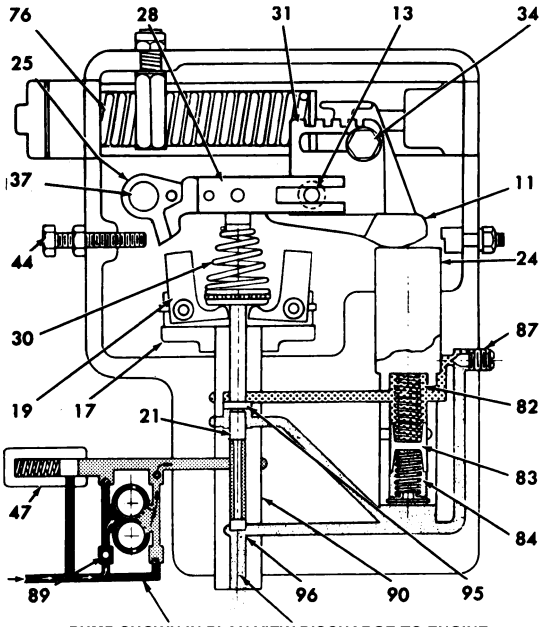
84. Spring—Buffer (lower)
87. Valve—Compensating Needle
89. Valve—Check
90. Bushing—Pilot Valve
95. Land—Receiving Compensating
96. Land—Pilot Valve Control

**Fig. 5 - Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease**

Refer to Fig. 5 and assume that a load increase is applied to the engine. The engine speed will momentarily drop and the governor flyweights will be forced inward, thus lowering the pilot valve plunger. Oil under pressure will be admitted under the servo-motor piston causing it to rise. This upward motion of the servo-motor piston will be transmitted through the terminal lever and the linkage to the injector control tubes, causing the fuel setting of the engine to be increased.

The oil which forces the servo-motor piston upward also forces the buffer piston upward because the oil pressure at each side of the buffer piston is unequal. This upward motion of the piston compresses the upper buffer spring and relieves the pressure on the lower buffer spring.

The oil cavities above and below the buffer piston (Fig. 5) are common to the receiving compensating land on the pilot valve plunger. Since the higher pressure is below the compensating land, the pilot valve plunger is forced upward, re-centering the flyweights and causing the control land of the pilot valve to close off the regulating port. Thus the upward movement of the servo-motor piston stops when it has moved far enough to make the necessary fuel correction.




11. Lever—Terminal
13. Shaft—Terminal (long)
17. Ball Head Assy.
19. Flyweight
21. Plunger—Pilot Valve
24. Piston—Servo-Motor
25. Lever—Speed Adjusting
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83. Piston—Buffer
84. Spring—Buffer (lower)
87. Valve—Compensating Needle
89. Valve—Check
90. Bushing—Pilot Valve
9 5. Land—Receiving Compensating
96. Land—Pilot Valve Control

**Fig. 6 - Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase**

Oil passing through the compensating needle valve equalizes the pressure above and below the buffer piston, thus allowing the piston to return to its center position which, in turn, equalizes the pressure above and below the receiving compensating land. The pilot valve plunger then moves to its central position and the engine speed returns to its original setting because there is no longer any excessive outward force on the flyweights.

Figure 6 illustrates the governor reaction as the load on the engine is decreased and the engine speed returns to normal. With a decrease in the load, the engine speed will momentarily increase and the flyweights will move outward, thus raising the pilot valve plunger.

This allows the oil below the buffer piston (and below the receiving compensating land) to flow to the drain passage, thus reducing the pressure on the lower side of the buffer piston and on the lower side of the receiving compensating land. This allows a downward movement of the servo-motor piston which is transmitted through the terminal lever and linkage to the injector control tubes, causing the fuel setting of the engine to be decreased.

The compensating mechanism produces stable engine operation by permitting the governor to move instantaneously in response to a load change and to make the necessary fuel adjustment to maintain the initial engine speed.

The speed changes previously described were the result of load changes. Similar governor movements occur through movement of the governor speed control lever. Movement of the speed control lever (through the vernier control and connecting linkage) changes the tension on the speeder spring, thus causing the pilot valve plunger to raise or lower.

## Lubrication

Oil passes up through a drilled passage in the pilot valve plunger and is directed at the thrust bearing from where it is thrown onto the moving parts in the governor housing by the revolving flyweights. The governor pump gears, pilot valve plunger, servo-motor piston and buffer piston are all exposed to pressurized oil. Oil which collects on the floor of the governor housing passes through a drilled passage into the governor drive housing, thus lubricating the governor drive and driven gears and shafts and their bearings. Surplus oil returns to the engine crankcase through connecting drilled passages in the blower end plate and cylinder block.

## Remove Governor

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect any linkage which may be attached to the governor speed control lever.
2. Drain the governor oil filter.
3. Disconnect the oil supply tube between the governor and the filter.
4. Remove the oil filter element and clean the filter housing. Install a new filter element.
5. Disconnect the vertical link assembly from the governor operating lever.
6. Disconnect the wires to the synchronizing motor, if used. Tag the wires to facilitate reassembly.

7. Remove the four bolts and lock washers that attach the governor to the control housing. Lift the governor away from the control housing. Remove the gasket.

## Install Governor

1. Place a new gasket on the governor control housing.
2. Place the governor on the governor control housing. Turn the ball head slightly, if necessary, to align the splines on the pilot valve bushing with the splines in the driven shaft sleeve. Then secure the governor to the control housing with four bolts and lock washers. Tighten the bolts uniformly.
3. Install the oil supply tube.
4. Pour approximately one pint of engine oil in the governor to provide initial lubrication.
5. Attach a new governor cover gasket to the subcap.
6. If previously removed, install the speed adjusting lever stop on the underside of the governor cover. Secure the lever stop to the cover with a lock nut and copper washer.
7. Before installing the governor cover or connecting the governor linkage, perform a complete engine tune-up as outlined in Section 14.

# HYDRAULIC GOVERNOR DRIVE AND GOVERNOR OPERATING LINKAGE

The governor is driven by one of the blower rotors through a horizontal drive shaft and bevel gear and an integral vertical shaft and bevel gear (Fig. 1). Each gear is mounted on a ball bearing and is contained in a drive housing that also serves as the blower front cover.

Splines on the horizontal drive shaft engage the splines in the blower rotor shaft that provides the drive. Splines on the lower end of the governor ball head register with the splines in the upper end of a sleeve that is pressed on the vertical driven shaft and gear.

On current engines, the fuel rods from each injector control tube are connected to operating levers in the governor control housing and the vertical link connects the governor operating lever with the left bank operating lever (Fig. 2).

On former engines, the fuel rods are connected to a bell crank attached to the front end of the cylinder block. The governor is connected to the bell crank by a vertical linkage attached to the governor operating lever (Fig. 3).

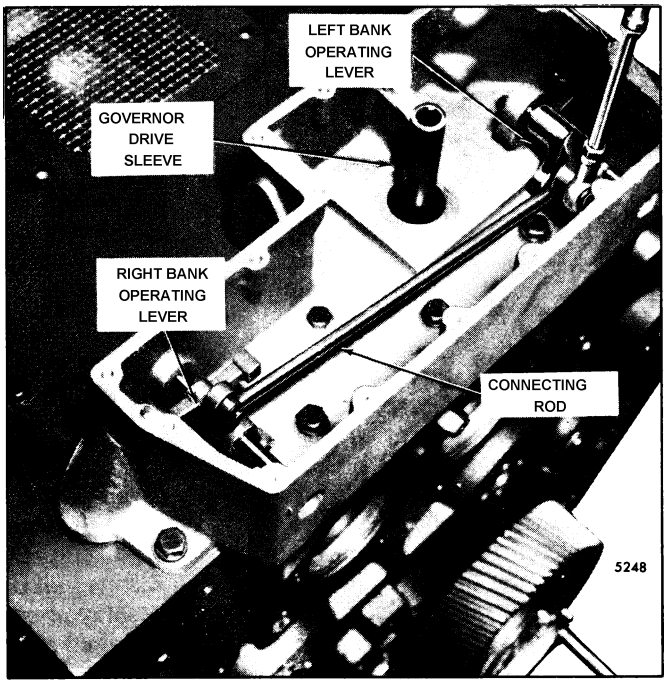



**Fig. 2 - Governor Operating Linkage (Current)**

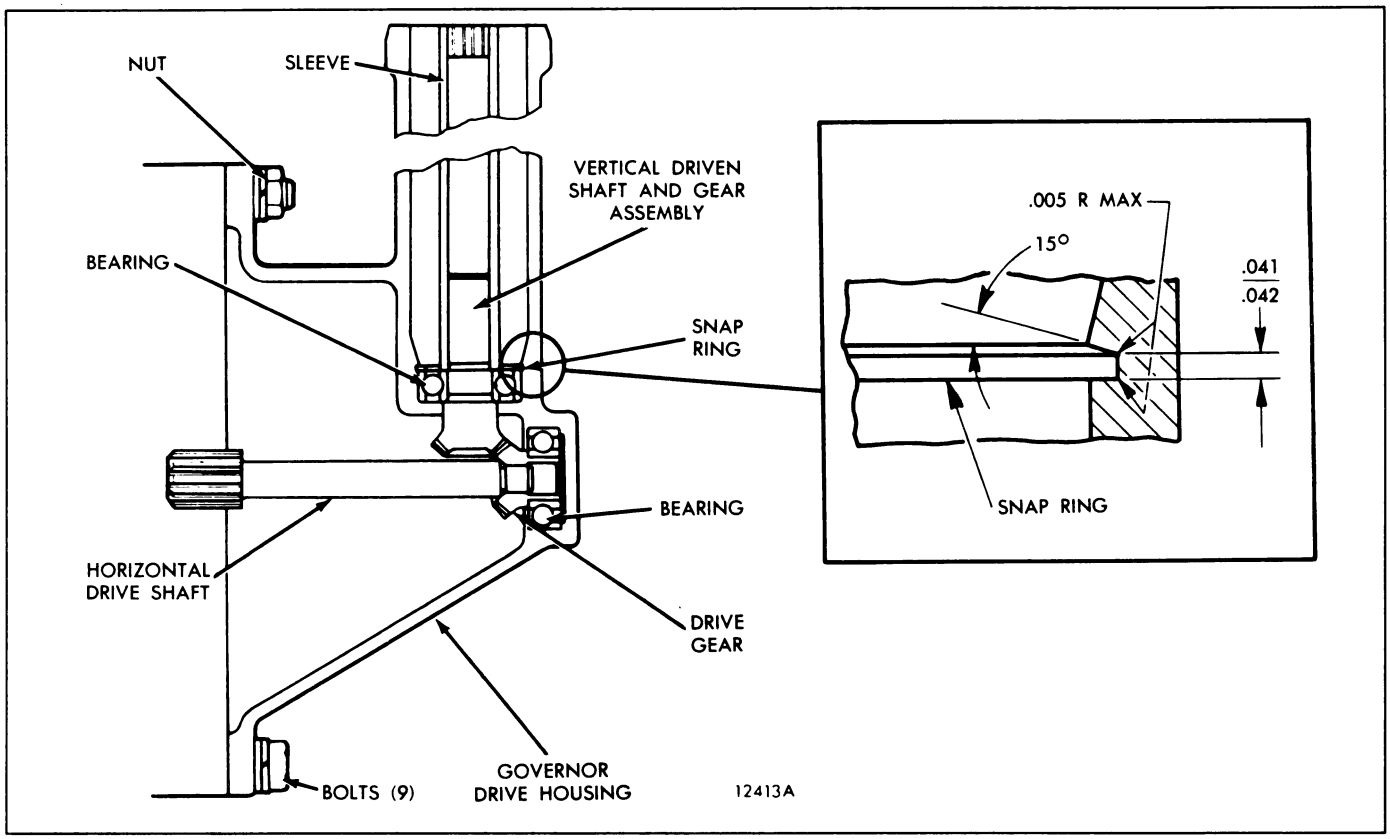



Fig. 1 – Governor Drive Assembly

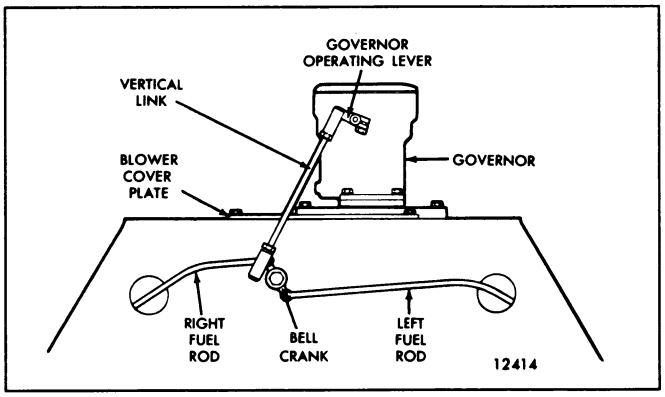



**Fig. 3 - Governor Operating Linkage (Former)**

## Lubrication

The gears and bearings in the governor drive assembly are lubricated by surplus oil from the governor which spills over from the moving parts. On current engines, two drilled orifices in the oil passages in the governor drive housing direct a spray of lubricating oil on the drive shaft splines and the beveled drive and driven gears and their bearings. On former engines, there was one orifice which directed oil on the drive shaft spline only. On early engines, a spray nozzle pressed into the blower end plate directed lubricating oil to the drive shaft splines. The oil returns to the crankcase through drilled passages in the blower end plate and the cylinder block.

The rod end bearings of the vertical link assembly are lubricated with grease through fittings provided.

## Disassemble Governor Linkage

If the governor is slow to react to load changes, the problem may be in the governor linkage. Check for bind in the linkage or for bent or damaged fuel rods. If necessary, disassemble the linkage, a§ follows:

CURRENT LINKAGE

1. Remove the governor (refer to Section 2.8.1).
2. Remove the valve rocker covers and disconnect the fuel rods from the injector control tube levers.
3. Remove the governor control housing cover.
4. Remove the spring retainers and washers securing the connecting rod to the right and left bank operating levers (Fig. 2).
5. Disconnect the fuel rods from the operating levers.
6. Remove the bolts securing the governor control housing to the engine. Remove the control housing.

FORMER LINKAGE

1. Remove the governor (refer to Section 2.8.1).
2. Remove the plate from the top of the engine front cover to expose the governor operating linkage.
3. Remove the valve rocker covers and disconnect the fuel rods from the injector control tube levers.
4. Disconnect the vertical link from the bell crank (Fig. 3).
5. Disconnect the fuel rods from the bell crank.
6. Remove the shoulder bolt securing the bell crank to the cylinder block. Remove the bell crank.

## Remove Governor Drive

If the governor fails tocontrol the engine speed properly, the fault may lie in the governor drive. To function properly, there must be .001” to .003” clearancebetween the governor drive and driven gears.

With the governor and linkage removed, the governor drive assembly may be removed as follows:

1. Remove the air inlet housing, and any other accessories, to gain access to the blower cover plate.
2. Remove the blower and governor drive assembly from the engine (refer to Section 3.4).
3. Remove the nine (9) bolts and one nut (and lock washers) securing the governor drive assembly to the blower. Remove the governor drive assembly.

   **NOTICE:** Do not pry the housing off of the dowels as this will damage the finished surface.

4. Remove the drive housing gasket.

Before a Barber-Coleman electronic governor is installed on a Series 149 engine previously equipped with a hydraulic governor, the vertical driven and horizontal drive shafts and bearings must be removed from the governor drive housing (Fig. 1).

## Disassemble Governor Drive

Refer to Fig. 1 and disassemble the governor drive, as follows:

1. Remove the snap ring securing the driven gear bearing in the drive housing.
2. Pull the driven gear, bearing and sleeve assembly from the housing.
3. Place the split bearing remover J 4685 between the driven gear and the bearing, with the beveled side of the remover facing the gear.
4. Support the gear and bearing assembly on an arbor press. Place a brass rod inside of the sleeve and press the gear from the sleeve and bearing (Fig. 4).

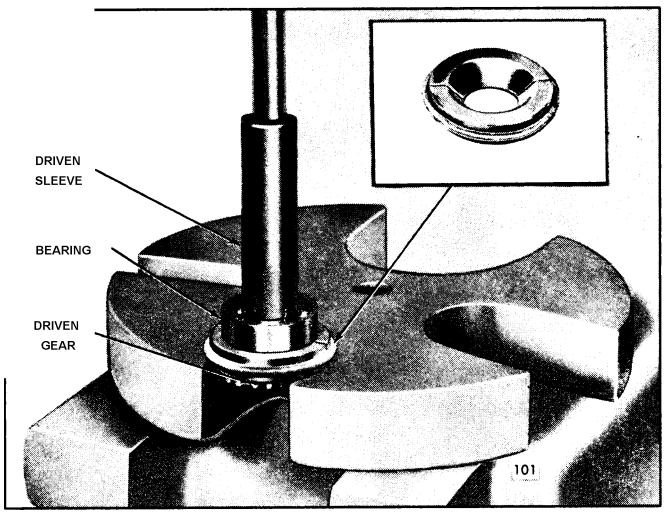



**Fig. 4 - Removing Sleeve and Bearing from Driven Gear with Tool J 4685**

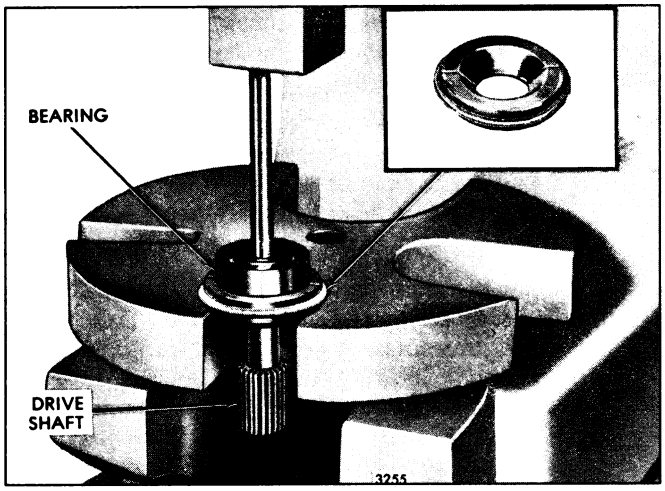



**Fig. 5 - Removing Bearing from Drive Gear with Tool J 4685**

5. Pull the governor drive gear, shaft and bearing assembly out of the housing.

6. Place the split bearing remover J 4685 between the drive gear and the bearing, with the beveled side of the remover facing the gear.

7. Support the gear and bearing assembly on an arbor press. Place a brass rod on the end of the shaft and press the gear and shaft from the bearing (Fig. 5).

8. Place two brass plates beneath the teeth of the drive gear and support the assembly on an arbor press (Fig. 6). Then, place a brass rod on the end of the drive shaft and press the shaft from the gear.

## Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

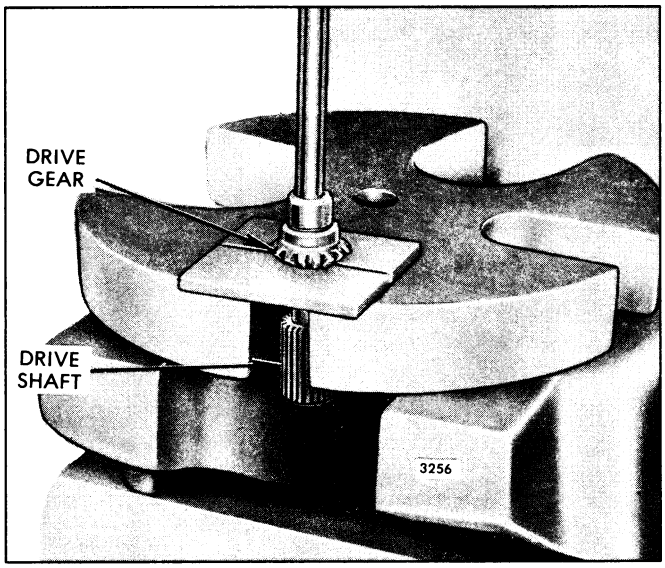



**Fig. 6 - Removing Gear from Drive Shaft**

**CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Inspect the gears for worn, scored or chipped teeth. Replace the gears, if necessary.

Examine the splines on the drive shaft, driven sleeve and the mating parts for wear.

On current engines, the governor drive coupling (part ofthe EGB and LSG hydraulic governor assemblies) has been eliminated and the governor drive driven shaft sleeve lengthened 1.29” to offset the drive coupling.

The drive coupling must be removed from the governor when replacing the former governor drive sleeve with the current governor drive sleeve.

Check each ball bearing for indications of corrosion or pitting. Lubricate the bearing with light engine oil. Then, while holding the inner race, revolve the outer race slowly by hand. Any rough spot in the bearing is sufficient cause for rejection.

Inspect the needle bearings and spherical rod end bearings for wear and free movement. If a new bearing is required in the bell crank, press it in flush with the flat side of the bell crank.

Replace worn or damaged parts.

If the former governor drive assembly or housing is replaced by the current type, remove and discard the drive shaft oil slinger and the spray nozzle from the blower end plate.

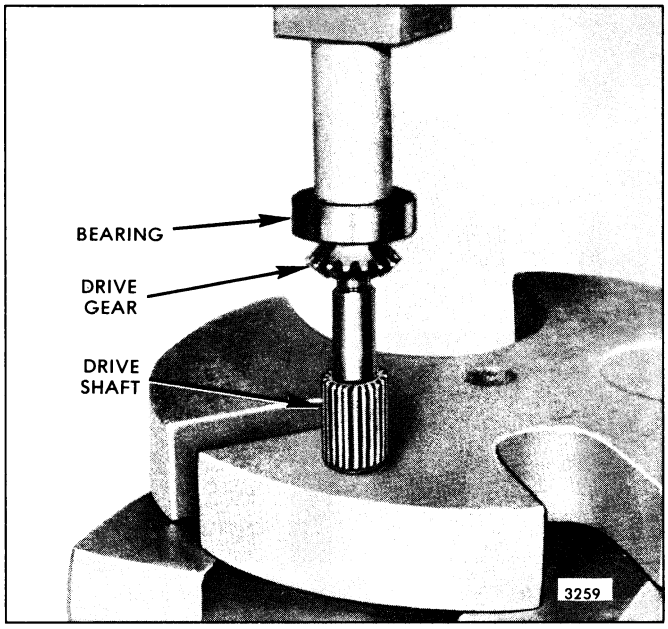



**Fig. 7 - Installing Gear and Bearing on Governor Drive Shaft**

## Assemble Governor Drive

Refer to Fig. 1 and assemble the governor drive, as follows:

1. Install the bearing and gear on the governor drive shaft, as follows:
   a. Lubricate the bearing with engine oil. Then, start the bearing, numbered side up, straight on the end of the drive gear.
   b. Place the beveled end of the drive gear on an arbor press. Then, place a sleeve on the inner race and press the bearing tight against the shoulder on the drive gear.
   c. Lubricate the small end of the drive shaft with engine oil. Then, start the drive gear straight on the shaft with the gear teeth facing the splined end of the shaft.
   d. Place the shaft, gear and bearing assembly on an arbor press with the gear end up. Place a sleeve or brass bar on the inner race of the bearing and press the gear tight against the shoulder on the shaft (Fig. 7).
2. Lubricate the bearing with engine oil. Then, insert the drive shaft, gear and bearing assembly in the governor drive housing.
3. Install the bearing and sleeve on the driven gear, as follows:
   a. Lubricate the bearing with engine oil and start it, numbered end up, straight on the driven gear.

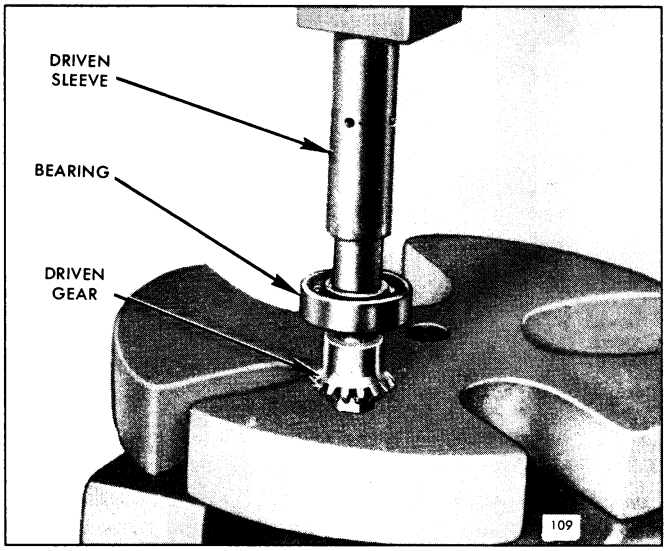



**Fig. 8 - Installing Bearing and Sleeve on Driven Gear**

   b. Lubricate the inner diameter of the sleeve with engine oil. Then, start the sleeve, splined end up, straight on the end of the driven gear.
   c. Place the driven gear, bearing and sleeve assembly on an arbor press, with a spacer under the gear to support the gear teeth above the bed of the press (Fig. 8). Then, press the sleeve and bearing tight against the shoulder on the gear.
4. Lubricate the bearing with engine oil. Then, insert the driven gear, bearing and sleeve assembly through the top of the governor drive housing and start the bearing straight into the bearing bore in the housing. Push the gear assembly down until the teeth of the drive and driven gears mesh (if necessary, rotate one of the gears slightly to align the gear teeth) and the bearing rests on the shoulder in the housing.
5. Install the snap ring in the groove in the housing next to the bearing. When installing the snap ring in its tapered groove in the hydraulic governor drive housing, be sure that the taper on the snap ring mates with the groove taper in the housing (Fig. 1).

   **NOTICE:** If the snap ring is not properly positioned in the groove, the bearing can work the snap ring and itself out of the drive assembly.
6. Rotate the drive and driven gears to check for freeness. The clearance between the gear teeth should be .001" to .003".

## Install Governor Drive

1. Place a new gasket against the blower end plate. Then, with the splines of the governor drive shaft and the blower rotor shaft in alignment, insert the drive shaft into the rotor shaft and slide the governor drive housing on the dowels and against the blower end plate.

2. Install the nine (9) attaching bolts and one nut, with ten (10) plain washers and ten (10) lock washers, to secure the drive housing to the blower end plate. Tighten the bolts and nut to 30-35 lb—ft (41-47 N#m) torque.

3. Install the blower and governor drive assembly on the engine (refer to Section 3.4).

4. Install the blower cover plate and air inlet housing.

## Assemble Governor Linkage

CURRENT LINKAGE

1. Install the governor control housing on the blower cover plate, using a new gasket.

2. Connect the right and left bank fuel rods to the governor control operating levers (Fig. 2).

3. Connect the fuel rods to the injector control tube levers.

4. Install the connecting rod to the operating levers.

5. Install the vertical link to the left bank operating lever. Lubricate the end bearings with grease through the grease fittings.

6. Use a new gasket and install the control housing cover.

7. Install the governor (refer to Section 2.8.1).

FORMER LINKAGE

1. Attach the bell crank to the cylinder block with the shoulder bolt.

2. Connect the right and left bank fuel rods to the bell crank.

3. Connect the fuel rods to the injector control tube levers.

4. Connect the vertical link to the bell crank. Lubricate the end bearings with grease through the grease fittings.

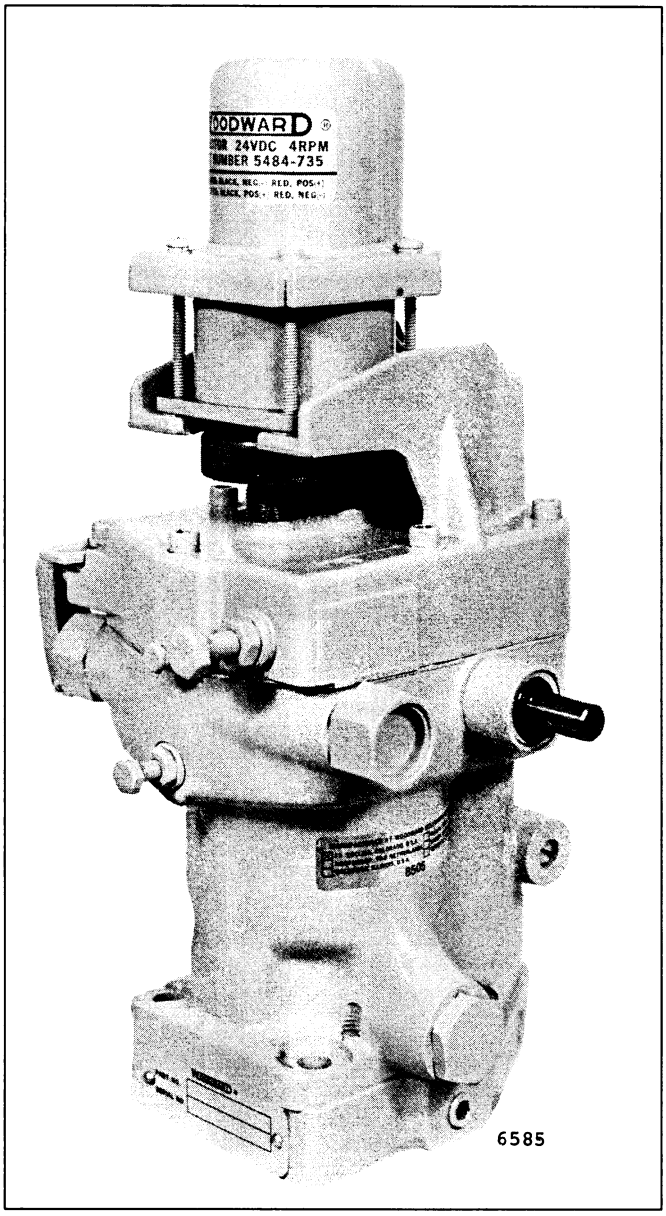
5. Position the adaptor plate, with a new gasket, on top of the engine front cover.

6. Slide the rubber boot over the vertical link and on the sleeve in the plate.

7. Install the governor (refer to Section 2.8.1).

Connect the throttle control linkage to the governor speed control lever. Refill the cooling system, if previously drained. Perform an engine tune-up as outlined in Section 14.7.2.

# HYDRAULIC GOVERNOR SYNCHRONIZING MOTOR




**• Fig. 1 - Woodward Synchronizing Motor Mounting**

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover (Fig. 1). This motor, used in place of a vernier control knob, permits close adjustment of the engine speed from a remote control point. This feature is especially valuable when synchronizing two generators from a central control panel.

• Bodine motors (Fig. 2) are mounted horizontally on the governor covers and use a 90 degree offset drive connected through a reduction gear on the motor and a friction drive.

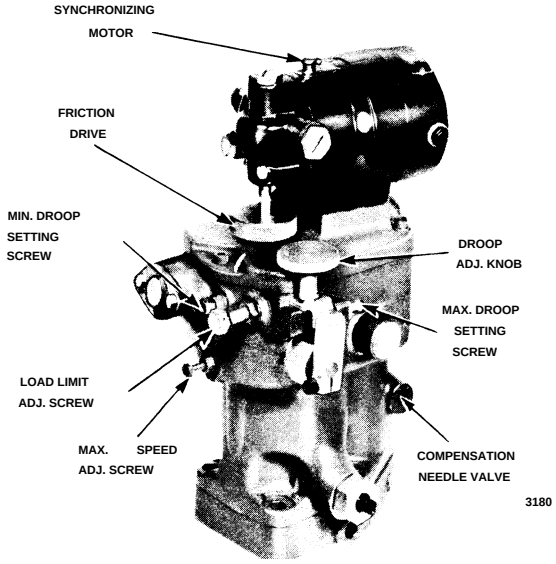



**Fig. 2 - Bodine Synchronizing Motor Mounting**

• Woodward motors (Fig. 1) are mounted vertically on the governor covers and connected to the governor speed adjusting shaft through a short gear train.

• A double pole, double throw switch is used to change the motor speed setting. Connect the switch to current motors as shown in Fig. 3.

## Operation

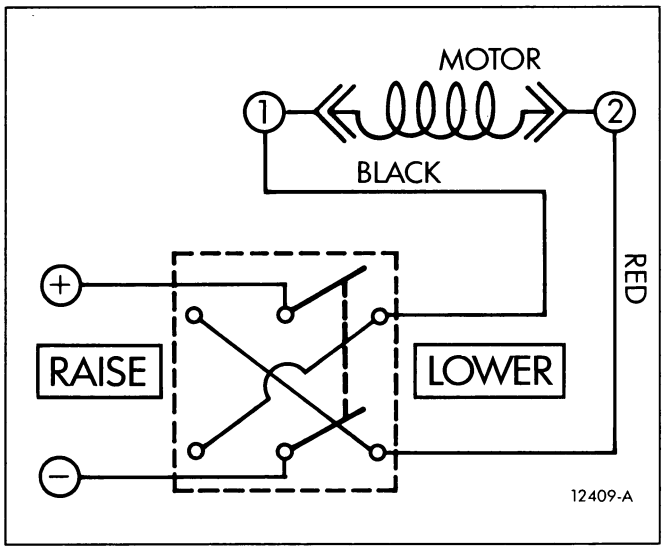
The synchronizing motor is used to change the engine speed when the unit is running alone, or to adjust the load when the unit is operating in parallel with other units. When the two-way control switch on the control panel is closed, the motor shaft turns the governor speed adjusting shaft by means of the reduction gear and friction drive. The direction of rotation (clockwise or counterclockwise) is dependent upon the position of the switch. When the desired engine speed is indicated on a tachometer or frequency meter on the control panel, the switch is returned to the ***off*** position by the operator.

If the switch is held in the ***lower*** speed position too long, the synchronizing motor will continue to lower the engine speed until it ultimately shuts the engine down. If the switch is held too long in the ***raise*** speed position, the motor will turn the governor speed adjusting shaft until it strikes the maximum speed adjusting screw, after which the friction drive will slip and the motor will continue to run at a slightly reduced speed without further effect.

## Service

The synchronizing motor is constructed to render long satisfactory service. However, if the motor is damaged or fails to operate, replace the entire motor as an assembly.

The spring washer of the friction drive on the motor must be strong enough to permit the motor to carry the speed adjusting lever up against the maximum speed adjusting screw without slipping, yet it must be loose enough to slip after the lever contacts the screw.




• Fig. 3 – Synchronizing Motor Wiring Diagram

# FUEL INJECTOR **CONTROL** TUBE

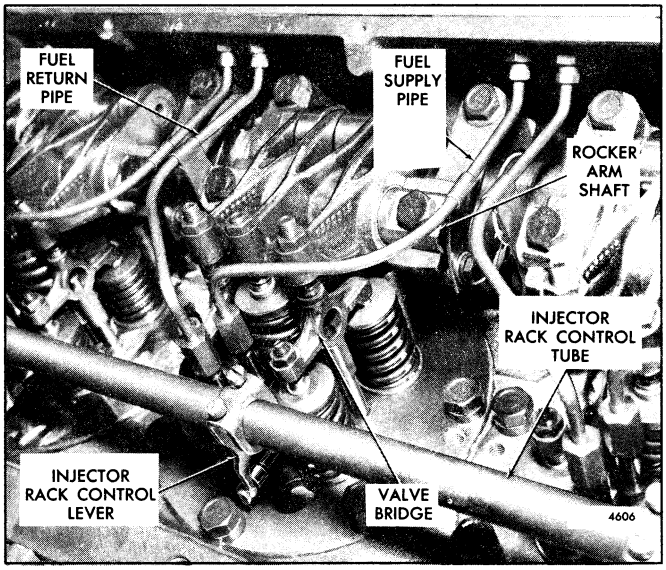



**Fig. 1 - Injector Control Tube Mounting**

The fuel injector control tube assemblies (Fig. 1) are mounted on the left and right bank of the cylinder block of the engine and consist of a control tube, injector rack control levers, a return spring and injector control tube lever mounted in two bracket and bearing assemblies attached to each bank of the cylinder block.

• The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with one adjusting screw (current engines) or two adjusting screws (early engines). The lever return spring enables the rack levers to return to the *no-fuel* position. Two separate control tubes on each bank are connected through a connecting link and control lever and operate as one unit. Engines with hydraulic or electronic governors use white and red-colored control tube return springs. Engines with mechanical governors use yellow and green control tube return springs. The injector control tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine governor. Refer to Section 14 for positioning of the injector rack control levers.

Current engines use spring-loaded injector control tube assemblies (Fig. 2) and they have a yield spring at each injector rack control lever and only one screw and locknut to keep each injector rack properly positioned. This enables an engine to be brought to a lesser or no-fuel position if there is an inoperative fuel injector rack whereas with the non-spring loaded two screw injector control tube (early engines) this could not be done. The above also permits the use of an air inlet housing with no emergency air shutoff valve as is required in some applications.

**NOTICE:** Do not replace the spring-loaded fuel injector control tube and lever assembly with the two screw design control tube assembly without including an air inlet housing that incorporates an emergency air shutoff valve. However, when the spring-loaded fuel injector control tube and lever assembly is installed on an engine and the emergency shutdown mechanism is removed from the air inlet housing, the shaft holes at each end of the housing must be plugged. Ream the shaft holes to .6290" and install a 5/8" cup plug at each end of the housing.

Engine shut down (normal or emergency) is accomplished on the spring-loaded fuel injector control tube (one screw design) by pulling the governor stop lever to the stop position. With the two screw design injector control tube and lever assembly, emergency engine shutdown is accomplished by tripping the air shutoff valve in the air inlet housing. Normal shut down is accomplished by pulling the governor stop lever to the stop position. Adjustment of the single screw and locknut on each injector rack control lever and the two screw design rack control lever are outlined in Section 14.

## Remove Injector Control Tube

1. Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.
2. Remove the two attaching bolts and lock washers at each bracket. Disengage the rack levers from the injector control racks and lift each control tube assembly from the cylinder block.

## Disassemble And Assemble Injector Control Tube

The injector control tube assemblies are available as service assemblies. When any part of these assemblies need replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for the injector control tube assemblies are not included.

## Install Injector Control Tubes

• 1. Install injector rack guard screens on 12V and 16V-149 engines.

**NOTICE:** Injector rack guard screens (Fig. 3) are used in place of cylinder block drain screens on all current 12V-149 and 16V-149 engines. Guard screens protect the injector control tube linkage passing through the front and rear block halves by preventing debris from wedging between the block and the injector control tube lever, jamming the racks. If racks are jammed at full-fuel, an overspeed condition and serious engine damage may result. ***Guard screens must be replaced if removed.***

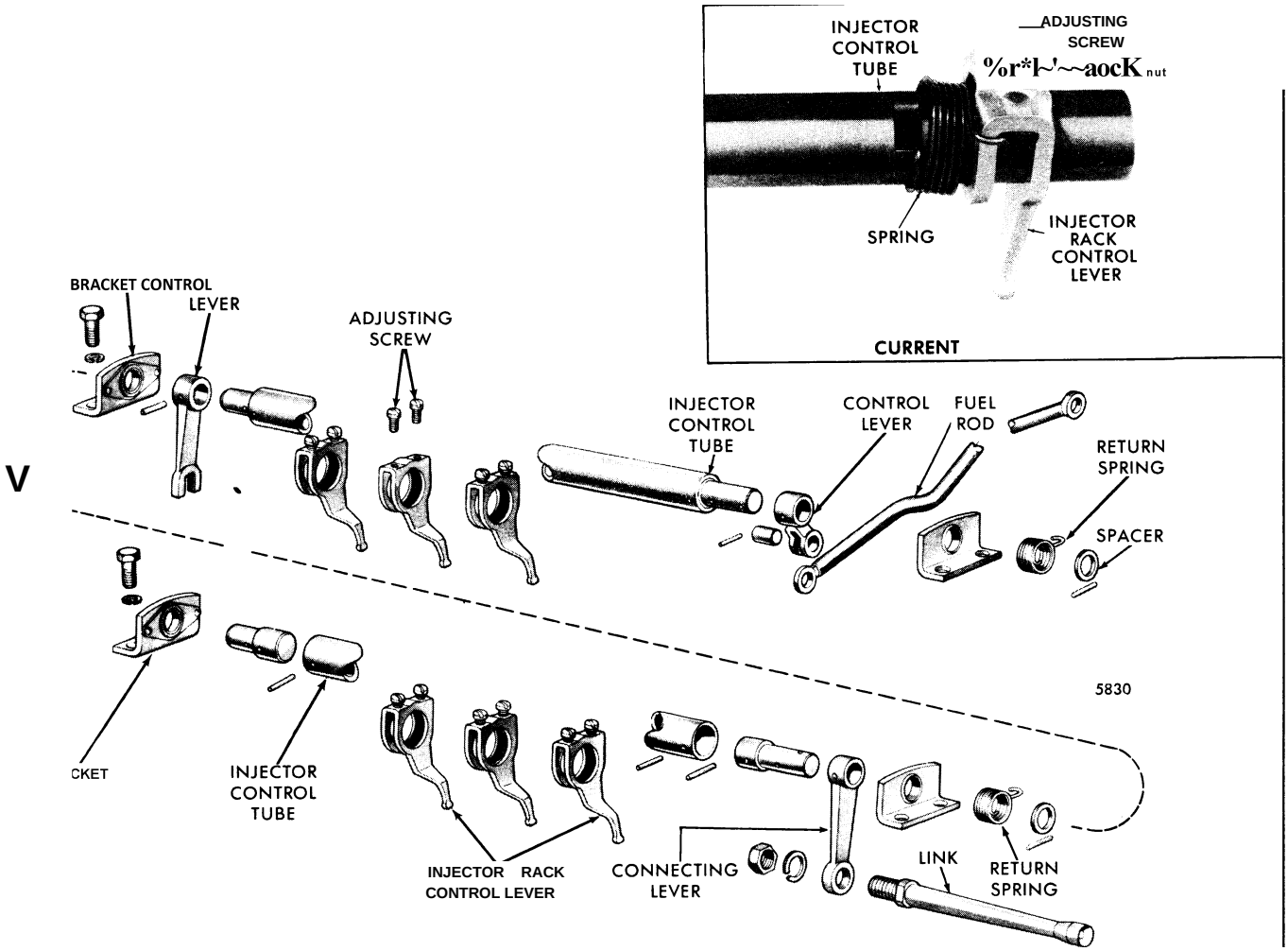



**Fig. 2 - Injector Control Tube Details and Relative Location of Parts**

2. Engage the injector rack control levers of the rear control tube assembly with the injector control racks and place the brackets over the mounting holes on the cylinder block.

3. Engage the injector rack control levers of the front control tube assembly with the injector control racks and the control lever engaging the connecting link in the rear control tube assembly and place the brackets over the mounting holes in the cylinder block.

4. Install the two 5/16”-18 x 3/4” bolts and lock washers at each bracket to attach the injector control tube assemblies to the cylinder block. Tighten the bolts to 13-17 lb—ft (18-23 N#m) torque.

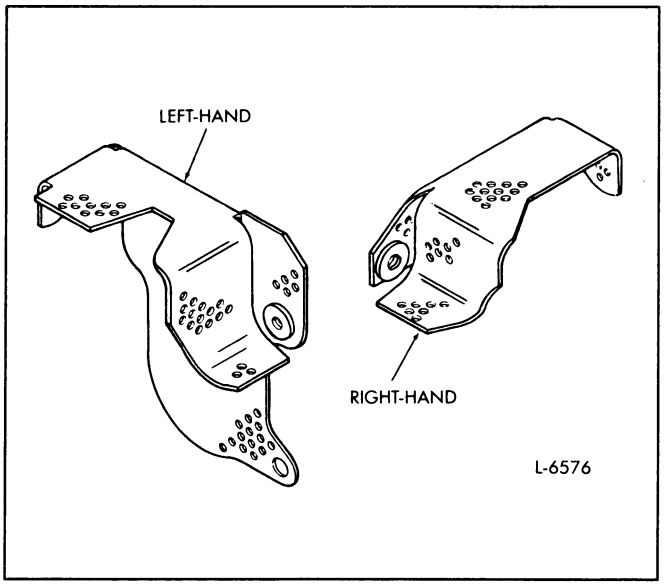
5. Check the control tubes to be sure they are free in the brackets. Tap the control tubes lightly to align the bearings in the brackets, if necessary.

6. Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.

7. Refer to Section 14 and position the injector rack control levers. Be sure the injector rack control levers can be placed in a no-fuel position before restarting the engine.

**CAUTION: Loss of shutdown control could result in a runaway engine which could cause personal injury.**




• Fig. 3 – Injector Rack Guard Screens

# SHOP NOTES - TROUBLESHOOTING SPECIFICATIONS - SERVICE TOOLS

## SHOP NOTES

## INJECTOR TESTER J 23010-A

**CAUTION: The fuel spray from an injector can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.**

Use injector test oil J 26400 in the injector tester.

### Installing Fuel Injector In Tester

1. Select the proper clamping head (Fig. 1). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 2).

2. Connect the test oil delivery piping into the clamping head.

3. Connect the test oil clear discharge tubing onto the pipe on the clamping head.

4. Locate the adaptor plate on top of the support bracket by positioning the 3/8" diameter hole at the far right of the adaptor plate onto the 3/8" diameter dowel pin. This allows the adaptor plate to swing out for mounting the fuel injector.

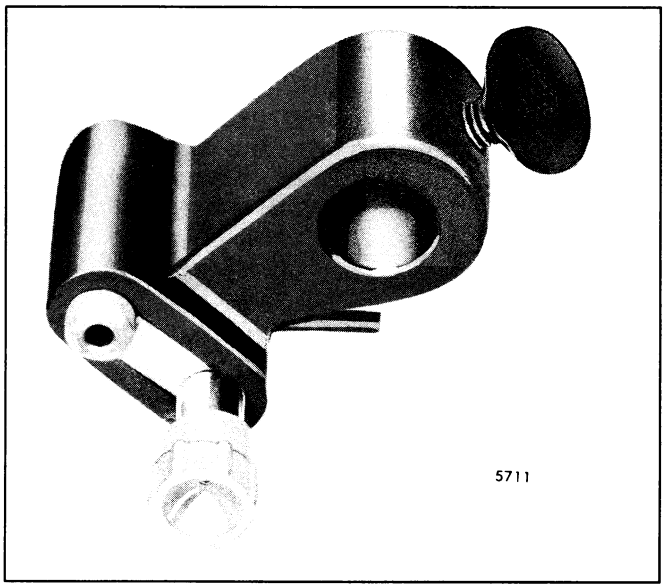



**Fig. 1 - Injector Tester J 23010-A Clamping Head (J 23010-169)**

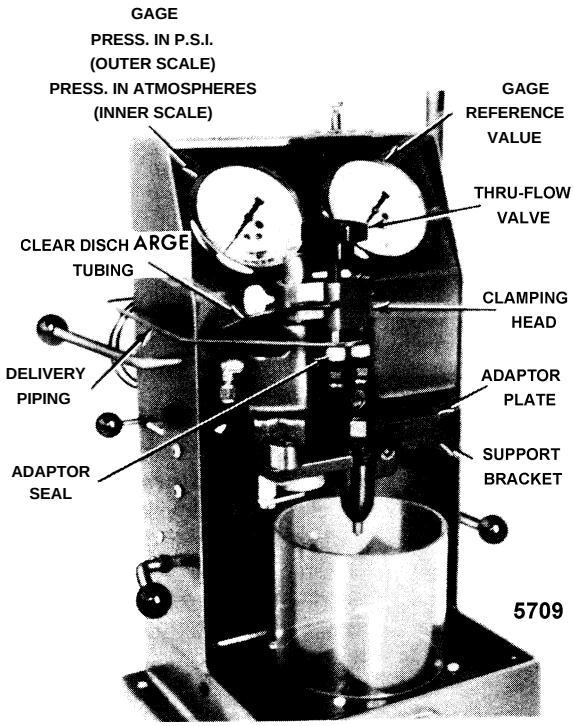



**Fig. 2 - Injector Installed in Tester J 23010-A with Clamping Head**

5. Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 1).

6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

### Clamping The Fuel Injector

1. Refer to Fig. 3 and position the injector tester levers as follows:

   Lever 2 up and to the rear

   Lever 3 in the rear detent

   Lever 4 up (horizontal)

   Lever 5 up (horizontal)

2. Align the clamping head seals over the injector filter caps (Fig. 2).

3. Back off the Thru-Flow valve about half-way to allow the self-aligning fuel connector adaptors to seat properly during the clamping operation.

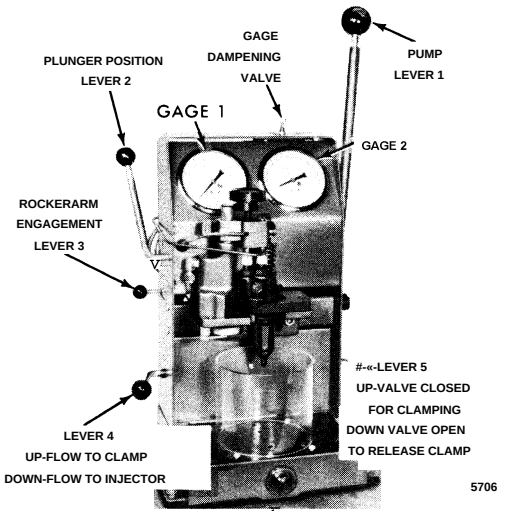



**Fig. 3 - Injector in Position for Testing with J 23010-A**

4. Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever 1 evenly to move the clamping head *down* to seal the filter caps. The Thru-Flow valve should still turn freely. If it dows not, turn the valve counterclockwise until it rotates freely and reapply clamping pressure.

**NOTICE:** Excessive force on lever 1 during clamping can damage the seals in the valves operated by levers 4 and 5.

## Purging Air From The System

Move lever 4 down and operate pump lever 1 to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

Check the injector for leaks as follows:

1. Operate pump lever 1 until gage 1 slowly reaches 100-200 psi (689-1378 kPa). Check for injector nut seal ring leaks. Then, increase gage reading to 1500-2000 psi (10 335-13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs.

2. Note the time for the pressure to drop from 1500 psi to 1000 psi (10 335 kPa to 6890 kPa). This should not occur in less than 7 seconds. This test determines if the body-to-bushing mating surfaces in the injector are sealing properly.

## Injector Valve Opening Atomization And Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the valve opens and injection begins.

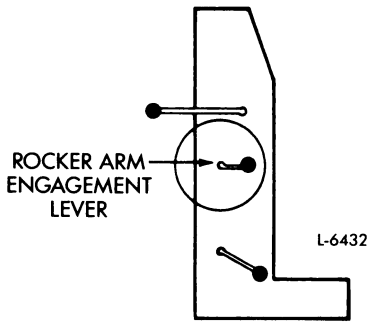



**Fig. 4 - Position of Rocker Arm Engagement Lever**

1. Position the injector rack in the *full-fuel* position.

2. Place pump lever in the *vertical* position.

3. Move the rocker arm engagement lever to the forward detent (Fig. 4).

4. Turn the gage damping valve knob (Fig. 3) clockwise to the *closed* position, then open the vlave slightly to control the rate of return of the gage hand. This valve is deleted on the current testers.

5. Operate the pump lever uniformly and observe the spray pattern produced.

Some experimentation may be necessary to determine the most effective rate at which the injector should be stroked. The correct rate is the one that produces the highest gage reading, too fast or too slow will give low readings.

The highest pressure indication will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector (245 Min. - 265 Max.).

The reference values obtained when pop testing the needle valve injectors is to be used as a troubleshooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by the needle valve tip test using the J 23010-A tester and tip tester adaptor on the J 22640 auxiliary tester.

## Unclamping The Injector

1. Open the Thru-Flow valve to release pressure in the system.

2. Move lever 5 *down* to release the clamping pressure.

3. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.

4. Carefully, return lever 5 to the *up (horizontal)* position.

# CHECKING INJECTOR TESTER J 23010-A

The injector tester J 23010-A should be checked monthly to be sure that it is operating properly. The following check can be made very quickly using a test block.

Fill the supply tank in the injector tester with clean injector test oil J 26400. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all of the air is out of the test block, then clamp the fuel outlet connector onto the test block. Break the connection at the gage and operate the pump handle until all of the air bubbles in the fuel system disappear. Tighten the connection at the gage. Operate the pump handle to pressurize the tester fuel system to 2400-2500 psi (16 536-17 225 kPa.) Close the valve on the fuel supply line. After a slight initial drop, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector.

Occasionally, dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested.

When the above occurs, loosen the fuel inlet connector clamp and operate the tester pump handle in an attempt to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually correct a dirt condition. The pump check valve in J 23010-A must be replaced.

If an injector tester supply or gage line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines or the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test.

If it is suspected that the lines have been altered, i.e. by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

# INJECTOR SPRAY TIP TESTER (J 22640-A)

Valve Opening, Spray Pattern and Atomization.

1. Operate the pump handle until a clear flow of test oil is obtained at the tip mounting pedestal.
2. Place the tip assembly, valve spring with cage and check valve cage on top of the pedestal. Tighten the injector nut (Fig. 5).

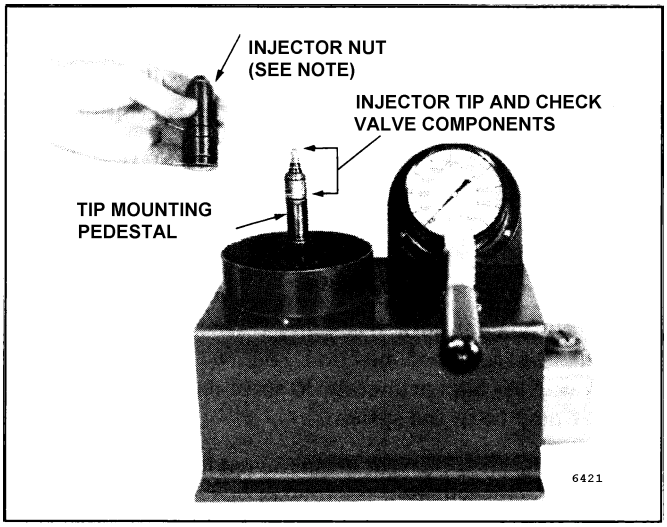



**Fig. 5 - Installing Injector Nut**

3. Place the shield on the tester and operate the pump handle until the needle valve has opened several times to purge air from the system (Fig. 6).

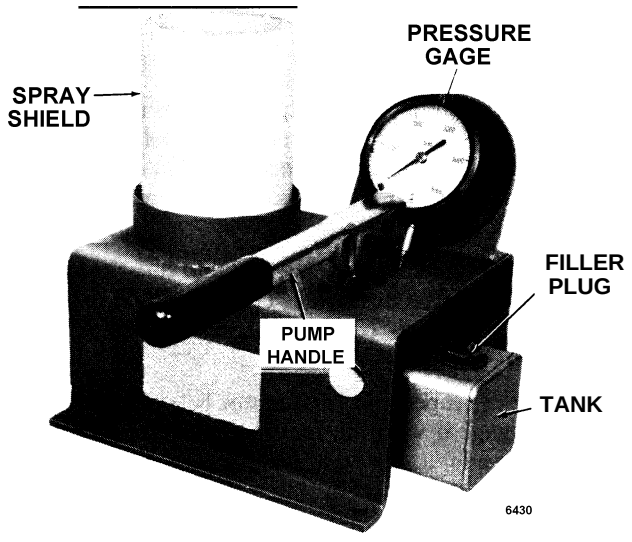



**Fig. 6 - Tester J 22640-A with Shield Installed**

**CAUTION: Do not operate the tester without the shield. The fuel spray can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.**

4. Operate the pump lever rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine. Note the pressure at which the test oil delivery occurs. Test oil delivery should occur between 2200 and 3300 psi (15 158 and 22 737 kPa). When using the high V.O.P. spring, the oil delivery will occur at 2900-3900 psi (19 981-26 871 kPa). The beginning and ending of delivery should be sharp and the test oil should be a finely atomized spray.

If the valve opening pressure is below the minimum specified limits or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within specified limits, proceed to check for spray tip leakage as follows:

When testing for spray tip leakage, be sure to use the proper spring for the valve tip being tested.

a. Actuate the pump lever several times and hold the pressure at 1500 psi (10 335 kPa) for 15 seconds.

b. Inspect the spray tip for leakage. There should be no fuel droplets, although a slight wetting at the spray tip is permissable.

Field Modification Kit (J 22640-51) consists of a pump and reservoir with hardware which is used to convert auxiliary tester J 22640 to J 22640-A. Tester J 22640 was previously connected to the pump of the pop stand.

# INJECTOR SPRAY TIPS

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector may be varied by replacing the spray tip.

Flow gage J 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

Field Modification Kit (J 25600-103) upgrades plunger and bushing/tip flow gage J 25600 to J 25600-A. A newly designed spray tip receiver/holder is included with the kit along with instruction decals to be applied to the tester. This kit greatly upgrades the function of J 25600 by improving operation and repeatability.

# CHECK INJECTOR OUTPUT

Perform the injector fuel output test in calibrator J 22410-A (Fig. 7).

1. Before testing injector output, be sure calibrator test oil is supplied to the injector fitting located over the rack. To change the flow from the calibrator, exchange the positions of the braided and the clear fuel lines (Fig. 8).

2. Place the cam shaft index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch to preheat the test oil to 95-105°F (35-40°C).

3. Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin. Then, slide the adaptor forward and up against the fuel block face.

4. Place the injector seat J 22410-226 into the permanent seat (cradle handle in the ***vertical*** position). Clamp the injector into position by operating the injector clamp-up valve.

Set the counter (Fig. 9) at the appropriate number of strokes, 500 or 1,000. If for any reason this setting has been altered, reset the counter for the correct number of strokes. Calibrators with Serial No. 1175 or lower were manufactured as 1,000 stroke machines, but may have been converted to 500 stroke machines with a conversion kit (J 22410-516). Refer to the calibrator instruction manual for information on setting the counter and any additional information required.

5. Pull the injector rack out to the ***no-fuel*** position.

6. Turn on the main power control circuit (vial light) switch. Then, start the calibrator by turning on the motor starter switch. The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

7. After the calibrator has started, set the injector rack into the ***full-fuel*** position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

8. After the air is purged, press the red button on the test switch. This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after the correct number of preset strokes are counted.

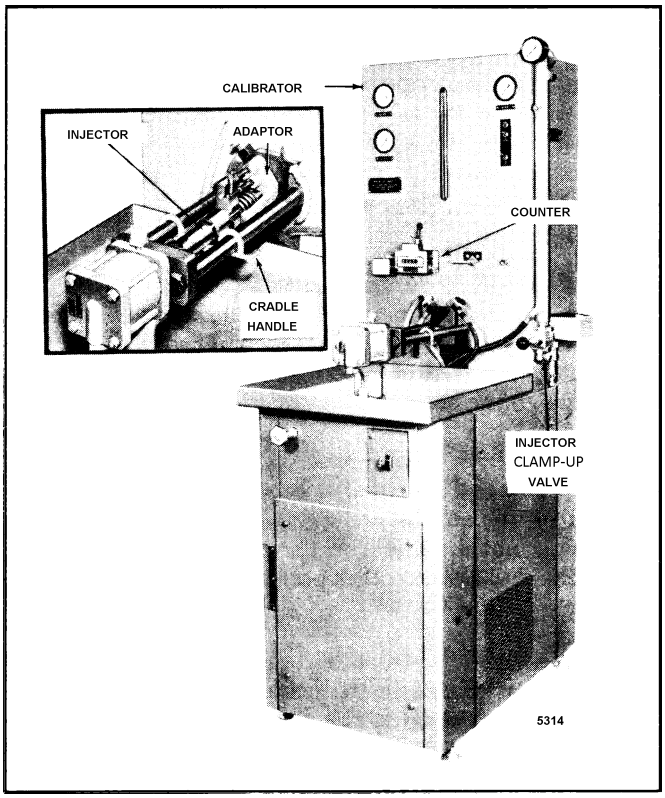



**Fig. 7 - Injector in Calibrator J 22410-A**

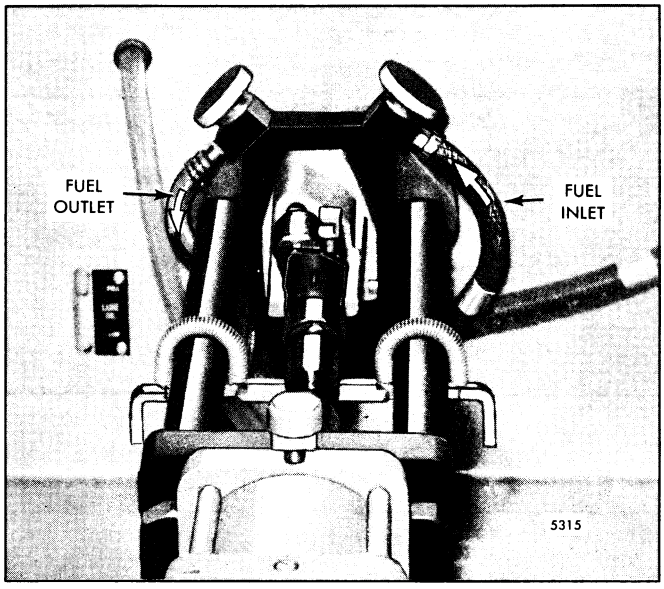



**Fig. 8 - Position of Calibrator Fuel Flow Pipes**

9. Shut the calibrator off when two consecutive tests show the same output. Usually, 3 tests are sufficient.

10. Observe the vial readings and refer to Table 1 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to

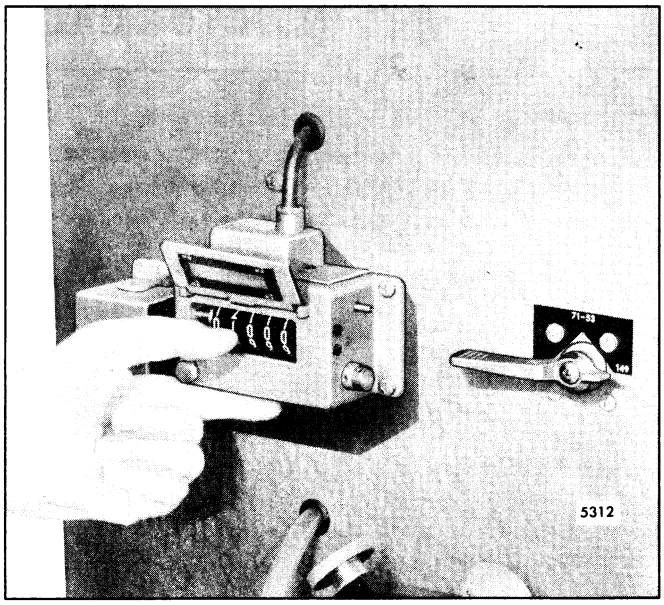



**Fig. 9 - Setting Calibrator Stroke Counter**

| INJECTOR | FUEL OUTPUT MIN. | MAX. |
|---|---|---|
| 120 | 118 | 126 |
| 130 | 138 | 146 |
| 140 | 150 | 158 |
| 145# | 166 | 174 |
| 150 | 168 | 176 |
| 155 | 173 | 181 |
| 160 | 184 | 188 |
| 165 | 184 | 192 |
| 170 | 187 | 197 |
| 180 | 195 | 205 |
| 185 | 202 | 212 |
| 190* | 210 | 217 |
| 195 | 222 | 234 |
| 230 | 219 | 233 |
| 240 | 230 | 242 |
| 270 | 262 | 268 |
| 6810 | 282 | 296 |
| 7110* | 210 | 224 |

**# Rack Stamped 145A**
*** Do not mix 190 and 7110 injectors in the same engine.**

**• TABLE 1**

*Troubleshooting Chart 6* for the cause and remed;
See *Injector Calibrator Readings* for different facto
that may affect the injector calibrator output readin

The calibrator may be used to check and select a set injectors which will inject the same amount of fuel in ea< cylinder at a given throttle setting, thus resulting in a smoo running, well balanced engine.

An injector which passes all of the above tests may put back into service. However, an injector which fails pass one or more of the tests must be rebuilt and checked the calibrator.

Any injector which is disassembled and rebuilt must tested again before being placed in service.

# MASTER INJECTOR CALIBRATING KIT

Use Master Injector Calibrating Kit J 26298 or J 34998 to determine the accuracy of the injector calibrator.

With the test fluid temperature at 100°F ± 1°F (38°C + 1°C) and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within two (2) of the values assigned to the calibrated masters, the calibrator can be considered accurate. Injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2 cm variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

# PLUNGER/BUSHING AND TIP FLOW GAGE

The injector fuel output is largely dependent upon the combined output of its plunger/bushing and spray tip assemblies. To assist in the rebuilding of fuel injectors that will calibrate within specified limits, it is desirable to preselect and match plunger/bushings and tips according to their output prior to assembly into the injector.

The J 25600-A Plunger/Bushing and Tip Flow Tester, using low pressure air, has the capabilities to measure the output of plunger/ bushing and spray tip assemblies. The flow (output) of the spray tip can be correlated to high pressure fuel flow during calibration however, used spray tips because of the worn condition of their spray holes will often flow higher then indicated on a low pressure air tester.

Records should be maintained which indicate the output values of both plunger/bushing and spray tip assemblies being matched with resultent calibration in order to develop a useful matching chart.

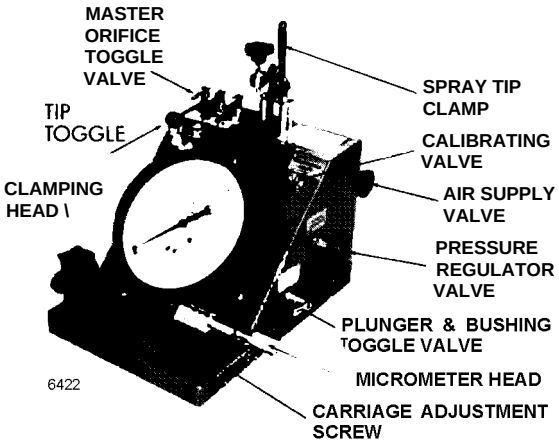



Fig. 12 - Plunger/Bushing and Tip Flow Gage J 25600-A

## Installation

Place the flow gage unit in a clean well lighted area that has an air supply of 40 psi (276 kPa), but not more not more than 100 psi (1034 kPa). Turn off the air supply valve (on the rear of the flow

gage) and connect your air line. Familiarize yourself with the various components on the unit (Fig. 12).

## Regulated Pressure Adjustment

1. Set all toggle valves in the *closed* position (Fig. 12).
2. Open the calibrating valve approximately 4 turns.

   **NOTICE:** DO NOT use this valve as an air shutoff. Tight closing of this valve may result in valve seat damage.

3. Turn the pressure regulator knob in a counterclockwise direction until it spins freely.
4. Open the air supply valve approximately 3 turns. The pressure regulator is a constant bleed type (.04 cubic feet per minute), the air supply valve is provided as a convenient shutoff to avoid compressed air waste when the flow gage is not in use.
5. Adjust the pressure regulator by rotating the knob in a clockwise direction until the gage needle is aligned exactly on the regulated pressure mark.

## Calibration To Master Orifice

When no air is leaking through a master orifice, injector tip or plunger/bushing, the gage needle will go to the regulated pressure mark. The master orifices (A, B and C) are provided as controlled air leak passages. Flow tests are conducted comparing an injector tip or a plunger/bushing, to an air leak through a master orifice.

1. Be sure all toggle valves are in the off position. The gage needle will be at the regulated pressure mark.
2. Open master orifice valve C. The gage needle will move away from the regulated pressure mark.
3. Adjust the calibrating valve, so that the gage needle is exactly at the “set line” (Fig. 13).

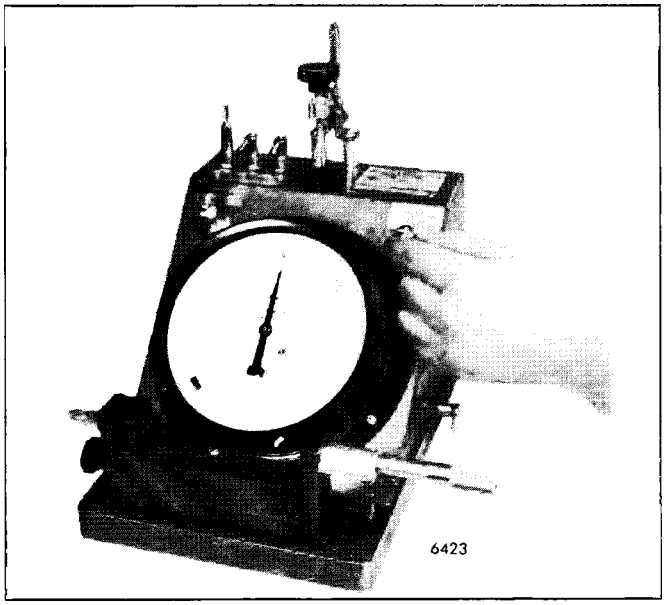



**Fig. 13 - Adjusting the Calibrating Valve**

4. Close the master orifice toggle valve (needle will return to the regulated pressure mark).
5. You are now ready to perform a flow measurement.

## Measuring Spray Tip Flow

1. Clean all spray tips thoroughly (correct flow rate is dependent on a clean spray tip).
2. Observe the number and size of the spray tip holes marked on the narrow end of the spray tip and calibrate to orifice C. Refer to the Chart for the flow values.

| TIP STAMP | NOMINAL VALUE FLOW | MASTER ORIFICE CALIBRATION |
|---|---|---|
| 6-.012 | 85 | |
| 7-.0095 | 50 | C |
| 7-.010 | 50 | |

3. Remove the needle valve, if installed, and clamp the spray tip on the unit (Fig. 14).
4. Open the tip toggle valve and observe the gage reading.
5. The tip can now be compared to the specification sheet and sorted into groups; high, low, mean, etc.

## Plunger/Bushing Effective Stroke Measurement

The objective of flowing plunger/bushing assemblies is to measure the effective stroke (port closing to opening), in thousandths of an inch. To find the closing and opening

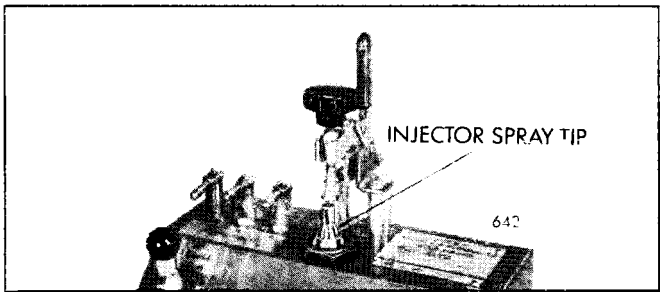



Fig. 14 - Spray Tip Installed in Tester

points a controlled air leak is required (‘.‘C” master orifice is used as reference). When the plunger is moved close to the port *closed* position, the gage needle will be at the set line. At this position, the air leaking out the bushing port matches the air that would leak out the “C” orifice.

As the plunger is moved inward, the leak stops and the gage needle goes to the regulated pressure mark. When the plunger is moved further, air begins to leak again. The gage needle moves away from the regulated pressure mark and moves toward the set line. When the plunger is moved far enough to read the effective stroke, the gage needle will be at the set line again. The distance the plunger has moved as indicated on the micrometer, is the effective stroke. This stroke is measured while the plunger/ bushing is held in the *full-fuel* position.

1. Select the proper cradle for the plunger/bushing to be tested and mount on the fixture (Fig. 15).
2. Calibrate to the “C” orifice, see “Calibration to Master Orifice”. All plunger/bushing tests use the “C” orifice as reference.
3. Close all toggle valves, gage needle will be at the regulated pressure mark.
4. Adjust the micrometer to zero reading (all zeros).
5. Place the plunger/bushing in the cradle. Be sure the plunger flat and locating pin or slot is properly positioned (Fig. 15). To check in *full-fuel* position, rotate bushing until the bushing pin contacts the rear locating surface.

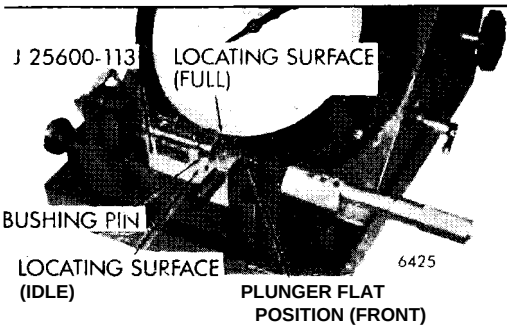



Fig. 15 Cradle Mounted on Fixture

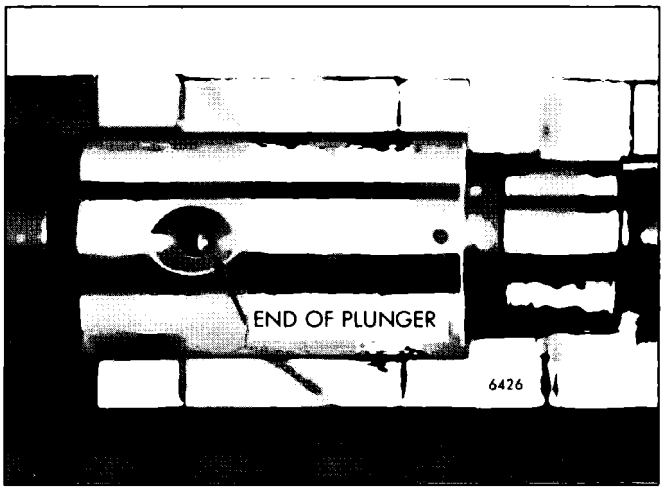



Fig. 1 6 - End of Plunger Shown in Port

6. Adjust spring loaded buttom until enough force is exerted on the plunger flat to hold the plunger steady, but not enough to restrict sliding movement when air pressure is applied.

7. Hold the plunger against the micrometer and rotate the carriage adjustment screw until the plunger almost closes the port (Fig. 16).

8. Open the plunger and bushing toggle valve.

9. If the plunger has not closed the port far enough, an air leak will be heard and the gage needle will be left of the set line. If it has closed the port too far, it will be to the right of the set line, toward or at the regulated pressure mark.

10. Turn the carriage adjustment screw until the gage needle is at approximately 20.

11. Turn the carriage adjustment screw clockwise very slowly until the gage needle is exactly at the set line. Always adjust in this manner, with the needle moving from approximately 20 to the set line.

12. Turn the micrometer thimble clockwise. The gage needle will move toward, and go to the regulated pressure mark. Very little air will be heard leaking.

13. Continue turning clockwise until the gage needle begins to move away from the regulated pressure mark (air from the bushing will again be heard leaking). Turn very slowly until the gage needle reaches the set line.

14. Observe and record the micrometer reading. The number shown is the effective stroke in thousandths of an inch.

15. Turn the micrometer back to zero. Gage needle should return to or very near the set line.

16. Turn off the plunger /bushing test toggle valve.

17. Loosen the clamping knob and remove the plunger /bushing.

18. Only minor carriage adjustment will be required for other plunger/bushing of the same type.

19. Chart the stroke readings and compare to the specifications. Sort into groups, high strokes, low strokes and mean strokes.

## REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refmished from time to time.

It is good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks.

To refinish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together (Fig. 17). Alternate the blocks from time to time. For example, assuming the blocks are numbered 1,2 and 3, work 1 and 2 together, then 1 and 3, and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections.

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory


Fig. 1 7 - Refinishing Lapping Blocks

when the entire surface is a solid dark grey. Bright or exceptionally dark spots indicate defects and additional lapping is required.

After the surfaces have been finished, remove the powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

## EFFECT OF PREIGNIT N ON FUEL INJECTOR

Preignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures and may eventually cause burning of the injector spray tip and lead to failure of the injectors in other cylinders.

When preignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of preignition to avoid recurrence of the problem. Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

## INJECTOR TIMING

If it is suspected that a fuel injector is “out of time”, the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in *(full-fuel* position), the flat side of the plunger will be visible in the hole, indicating that the injector is “in time”. If the flat side of the plunger does not come into full view (Fig. 18) and appears in the “advanced” or “retarded” position, disassemble the injector and correct the rack-to-gear timing.

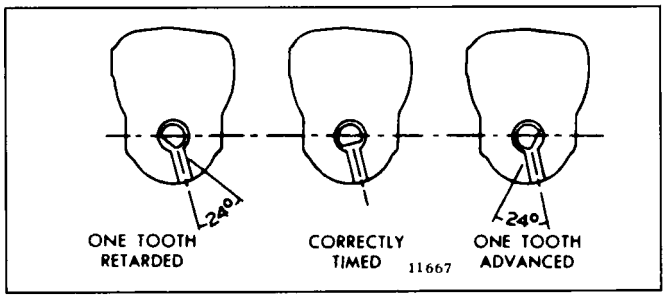



Fig. 18 – Injector Rack–to–Gear Timing

## FUEL LINES

Flexible fuel lines are used to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

Be sure a restricted fitting of the proper size is used to connect the fuel return line to the fuel return manifold. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus, flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, run the engine long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also, check the filter cover bolts for tightness.

## LOCATING AIR LEAKS IN FUEL LINES

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also, check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return line in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observing the fuel filter contents after the filter is bled and the engine is operated for fifteen (15) to twenty (20) minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

# PRESSURIZE FUEL SYSTEM - CHECK FOR LEAKS

Always, check the fuel system for leaks after injector or fuel pipe replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a serious fuel leak in this area can lead to dilution of the lube oil and bearing and/or cylinder kit damage.

## Prime And Purge

Prime and/or purge the engine fuel system before starting the fuel leak check. *Prime* the system by blocking or disconnecting the line from the fuel pump, then apply fuel under pressure (60-80 psi or 413-552 kPa) to the inlet of the secondary filter. If the system is to be *purged* of air as well, allow the fuel to flow freely from the fuel return line until a solid stream without air bubbles is observed.

## Check For Leaks

Use one of the following methods to check for leaks.

**Method 1**. Use when the engine has been operating 20-30 minutes.

After operating the engine, shut it off and remove the rocker covers. Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel pipes join the fuel pipe nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking. Disassemble, inspect and correct or replace the suspect part (connector washer, connector, injector or jumper line). Test and reinspect.

**Method 2.** Use when the engine is not operating, such as during or after repairs.

Remove the rocker covers. Pour lube oil over all fuel pipes and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method 1. Block off the fuel return line and disconnect the fuel pump supply line at the secondary filter. Install a pressure gage in the filter adaptor, then apply 60-80 psi (413-552 kPa)fuel to the outlet side of the secondary filter with the inlets plugged. Severe leaks will show up immediately. Minor leaks caused by nicks or burrs on sealing surfaces will take longer to appear. After maintaining 40-80 psi (276-552 kPa) for 20 to 30 minutes, a careful puddle inspection should reveal any suspect connectors. Inspect and repair or replace connectors as necessary. Test and reinspect.

**Method 3.** Use while the engine is operating at 400-600 rpm.

Apply an outside fuel source capable of 60-80 psi (413-552 kPa) to the outlet side of the secondary filter. Pour lube oil over jumper lines and connectors so that oil puddles form where lines and connectors meet. Install a valve and a pressure gage in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 70 psi (483 kPa). After ten to twenty minutes inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

> **NOTICE:** With the engine at rest, as in Method 2 all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off.

Slightly worn plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exists.

If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method 2. Injectors should be removed from the engine and tested for pressure-holding capability (see Section 2).

## Points To Remember

Lube oil puddle inspection is the key to pressure testing the fuel system for internal leaks. This test can be performed any time the rocker covers are removed, after the fuel pipes and connectors have been splashed with oil and there is normal fuel pressure in the system. The weak or missing puddles show where the leaks are.

All leakage or spilage of fuel during leak detection testing further dilutes the lube oil, so the final step in maintenance of this type should include lube oil and lube oil filter changes.

# DETECTING INTERNAL FUEL LEAKS

Used lube oil analysis often identifies a potential source of engine trouble before it occurs. One of the most serious conditions this test can uncover is the presence of excessive fuel in the lubricating oil. Inadequate bearing surface lubrication caused by lube oil dilution is a potential cause of engine malfunction and damage.

While used lube oil analysis can indicate the presence of fuel in engine lubricating oil, other methods must be used to determine its source. Two particularly effective methods involve the use of dye additives.

## Red LTO 1140 Dye

The use of Red LTO 1140 dye (a product of Chemserve Corporation, 9505 Copland Ave., Detroit, MI 48209) is effective when bench pressure-testing complete cylinder head assemblies or when pressure testing head assemblies on new or newly overhauled *operating* engines which have *new, clean lubricating oil.* The red dye is most visible when clean lube oil is used. Prepare the dye as follows:

Mix two (2) ounces (59 ml) of Red LTO 1140 dye with fine (5) gallons (18.93 liters) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent accidental use and be resealable to prevent contamination when not in use.

### Bench Testing

1. To bench test a complete cylinder head assembly, fill a fuel system priming pump (J 5956 or equivalent) with the red dye/fuel mixture.

2. Connect the outlet hose of the priming pump to the fuel inlet manifold. Connect a drain hose from the fuel outlet back to the test fuel container. Make sure that the required restricted fitting is installed in the fuel outlet. This will allow sufficient fluid pressure to build up.

3. Prime the cylinder head fuel system and check for leaks. The test fuel will show up as bright red.

4. Eliminate the cause of any leaks discovered. Wipe off the head components and retest until no further leaks occur.

### Running Test

1. To pressure test the cylinder head on a new or newly overhauled engine, isolate the fuel system so that the fuel supply and return lines are connected only to the test container.

2. Start and run the engine on the test fuel at maximum no-load speed for approximately five minutes to bring it to operating temperature. Periodically check the level in the test fuel container to ensure an adequate supply. If necessary, replenish the test fuel by adding one ounce (30 ml) of Red LTO 1140 dye to each 2.5 gallons (9.463 liters) of make-up fuel. Three to five engines can normally be tested before replenishing the fuel.

3. Stop the engine and remove the rocker covers. Check the cylinder head and all fuel connections for any sign of fuel leakage. The test fuel will show up as bright red.

4. If any leaks are discovered, eliminate their cause. Wipe all head surfaces and fuel connections clean, then start the engine and retest.

5. When all leaks have been eliminated, replace the rocker covers, reinstall the original fuel lines and connect the engine to its normal fuel source. It is not necessary to change the fuel filter or strainer. Start and run the engine to purge any air from the system.

## J 28431 Fluorescent Dye

The use of J 28431 fluorescent dye and a "black light" (ultraviolet light) is preferable when testing an engine that has been in service and has dark lubricating oil (from engine operation). Use the following procedure:

1. Mix four (4) ounces (11 ml) of fluorescent dye additive J 28431 with four (4) gallons (15.14 liters) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent its accidental usage and be resealable to prevent contamination when not in use.

2. Isolate the engine fuel system so that the supply and return lines are connected only to the test fuel container.

3. Start and run the engine on the test fuel at maximum no-load speed for approximately five minutes to bring it to operating temperature. Periodically, check the level in the test fuel container to ensure an adequate supply. If necessary, replenish the test fuel by adding one ounce (30 ml) of fluorescent dye for each gallon (3.79 liters) of make-up diesel fuel. Normally, three to five units can be tested before replenishing the fuel.

4. With the engine idling and the rocker covers removed, shine the "black light" over the head assembly. Lube oil will show up as a dull blue. A fuel leak will glow a bright yellow. This type of test is best conducted in a darkened or shadowed area. The darker the area surrounding the unit being tested, the easier it is to see the fluorescent dye.

5. If bright yellow dye is detected, determine the cause of the fuel leak and eliminate it. Wipe the cylinder head and fuel connections clean, start and idle the engine and reckeck the head area.

6. When all leaks have been eliminated, install the fuel lines and connect the engine to its normal fuel source.

**•NOTICE:** DDC Recommends that the original flared end fuel pipes not be reused. New flared end fuel pipes should be installed.

It is not necessary to change the fuel filter or strainer. Start and run the engine to purge any air from the fuel system.

### Normal Fuel Weepage

Some fuel weepage may normally be encountered from the follower and/or rack on DDC injectors while performing this test. Special consideration must be given to this weepage and the fact that it should not be allowed to exceed the DDC guidlines for pressure holding test (see Section 2.1.1) and the specification for lube oil dilution (2.5).

Since all leakage or spillage of fuel during leak detection testing dilutes the lube oil, the final step in maintenance of this type should include lube oil and lube oil filter changes.

## FUEL JUMPER LINE MAINTENANCE

Maintenance and service personnel should be aware that severe engine damage could result from fuel oil leakage into the lubricating oil and should therefore, follow proper procedures when removing, handling and installing fuel jumper lines (fuel pipes).

The fuel jumper lines which carry fuel to and from the fuel injectors must be handled and installed very carefully to prevent line damage that can result in severe engine damage.

**NOTICE:** Severe fuel leakage, if not detected, can also result in an over-filled crankcase (oil pan) which can cause an abnormal amount of fuel and lubricating oil vapor to escape from the engine and crankcase breathers. An abnormal concentration of fuel and lube oil vapors is flammable and could ignite in a closed engine compartment.

The following are some of the conditions that can result in fuel jumper line leakage:

1. Improper handling and storage of jumper lines when servicing the engine can result in physical damage and contamination.

2. Careless use of special tool (socket) J 21545 during removal or installation can cause a jumper line to bend and be permanently distorted.

3. Excessive tightening of the jumper line nut will distort and fracture the flared end of the jumper line, resulting in a fuel leak.

4. Damaged threads and flare seats on the injector and cylinder head jumper line connectors can also result in fuel leakage.

5. Leaks can also occur at injector filter nut gaskets and/or cylinder head connector washers due to distortion, damage or incorrect torque.

Fuel jumper lines are pre-formed to facilitate easy installation on the injector and cylinder head jumper line connectors. Do not attempt to straighten distorted or bent jumper lines for reuse because the straightening process may cause the jumper line to weaken or fracture and result in fuel leakage.

The following troubleshooting procedure is recommended after installation of fuel jumper lines and/or connectors to determine if fuel leakage is present.

### Checking For Fuel Leaks

Always check the fuel system for leaks after injector or fuel jumper line replacement and any time the fuel connections under the rocker cover are suspected of leaking.

**NOTICE:** Failure to correct a fuel leak in this area can lead to dilution of the lube oil.

Use one of the following methods to check for leaks.

#### METHOD A

***Use when the engine has been operating 20-30 minutes.*** After operating the engine, shut it off and remove the rocker cover(s). Discard the gasket(s). Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel jumper lines join the fuel line nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking. Disassemble, inspect and correct or replace the suspect part (connector washer, connector, injector or jumper line). Test and reinspect.

#### METHOD B

***Use when the engine is not operating such as during or after repairs.*** Remove the rocker cover(s). Discard the gasket(s). Pour clean lube oil over the fuel jumper lines and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form

at the joining surfaces as mentioned in Method A. Plug the fuel return line at a convenient location (cylinder head or fuel tank, for example). Disconnect the fuel pump supply line at the inlet of the secondary filter. Connect an external source of pressurized fuel (60-80 psi or 414—552 kPa) to the inlet of the secondary filter cover. Install a pressure gage (0-100 psi or 0-689 kPa) at the outlet of the filter cover. Gage installation can be accomplished by installing a “T” fitting between the filter cover and outlet line or by removing the pipe plug at the outlet in the cover. Use of a gage will allow ready reference to the fuel pressure being maintained for this test. Severe leaks are immediately visible and minor leaks take longer to appear. It may be necessary to maintain fuel pressure for a period of 20 to 30 minutes in order to find minor leaks. Leaks may be repaired by replacing damaged parts or determining if the part is loose and below torque specifications. Test and reinspect.

If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method B. Injectors should be removed from the engine and high pressure tested as outlined in Section 2.1 or 2.1.1.

### METHOD C

***Use while the engine is operating at 400-600 rpm.***

Apply an outside fuel source capable of 60-80 psi (414-552 kPa) to the outlet side of the secondary filter. Pour lube oil over the fuel jumper lines and connectors so that oil puddles form where jumper lines and connectors meet. Install a valve and a pressure gage in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 60-80 psi (414-552 kPa). After 10-20 minutes, inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

Slightly worn injector plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exist.

### METHOD D

***Fluorescent dye fuel leak testing.*** When testing an engine that has been in service, it will be preferable to use the fluorescent dye and black light method of testing. Proceed as follows:

1. Mix 4 oz. of fluorescent additive J 28431 with 4 gallons (15 liters) of clean diesel fuel **(1 or 2) in a clean container. The container should be marked "Test Fuel" and be resealable so that it won't be contaminated when not being used.**
2. Isolate the engine fuel system so that the supply and return fuel lines are connected only to the test fuel container. It will be necessary to intermittently check the fuel level to maintain an adequate supply.
3. Warm up the engine by operating it at maximum no-load speed for approximately 15 minutes.
4. With the engine idling and the rocker cover removed, shine the black light over the head assembly. The lube oil will show a dull blue. If a fuel leak is present, the fuel with the fluorescent dye will glow a bright yellow.
5. After the cause of the fuel leak has been determined and corrected, wipe the area and fuel connections clean and recheck with the black light. When no leaks are present, reassemble the unit with the original fuel lines and normal fuel source. It is not necessary to change the fuel filters. Run the engine to purge the air from the fuel system.

With the engine at rest, all injectors will leak to some extent when pressurized. The leakage occurs because there is no other place for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off. Special consideration must be given to this weepage. If considered to be excessive, the injector should be removed and tested for pressure holding capabilities.

**NOTICE:** Since all leakage or spillage of fuel during leak detection testing dilutes the lube oil, the final step in maintenance of this type should include lube oil and lube oil filter changes.

Use new gasket(s) and reinatall the valve rocker cover(s).

## POINTS TO REMEMBER

1. Lube oil puddle inspection is one method of testing the fuel system for internal leaks. The missing puddles show where the leaks are. This test can be performed any time the rocker covers are removed, after the fuel jumper lines and connectors have been splashed with clean lube oil and there is normal fuel pressure in the system.
2. All leakage or spillage of fuel during leak detection testing further dilutes the lube oil.
3. The final step in maintenance of this type should include lube oil filter changes if a fuel leak is detected.
4. Oil level above the dipstick “full” mark or a decrease in lube oil consumption may indicate internal fuel leaks.
5. Improper storage, handling or installation of jumper lines can cause fuel leakage, resulting in lube oil dilution and severe engine damage.

# TROUBLESHOOTING

# FUEL PUMP

The fuel pump is so constructed as to be inherently trouble free. By using clean, water-free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the level in the fuel tank, then make sure the fuel supply valve is open. Also, check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through the pump flange drain hole, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then, lubricate the valve and check it for free movement throughout the entire length of its travel. Reinstall the valve.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

# CHECKING FUEL FLOW

1. Disconnect the fuel return hose from the fitting at the fuel tank and hold the open end in a convenient receptacle.

2. Start and run the engine at 1,800 rpm and measure the fuel flow. Refer to Section 13.2 for the specified quantity per minute.

3. Immerse the end of the fuel hose in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.

4. If the fuel flow is insufficient for satisfactory engine performance, then:

    a. Replace the element in the fuel strainer. Then, start the engine and run it at 1,800 rpm to check the fuel flow. If the flow is still unsatisfactory, perform Step “b” below:

    b. Replace the element in the fuel filter. If the flow is still unsatisfactory, do as instructed in Step “c”.

    c. Substitute another fuel pump that is known to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault.

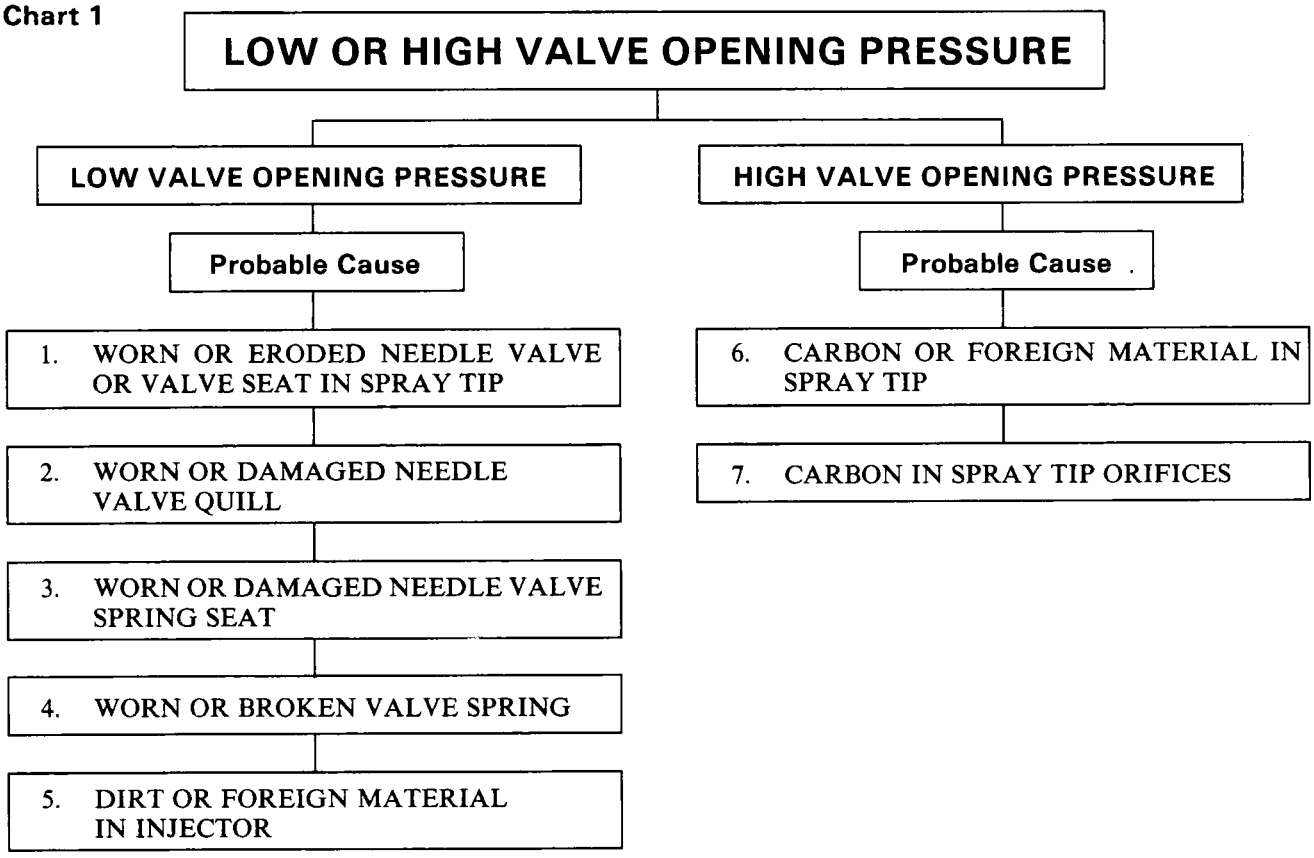
Check to see that the injectors are receiving fuel as follows:

1. Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.

2. Hold a finger over the injector fuel outlet and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector must be removed for service.

# NEEDLE VALVE INJECTORS

Chart 1



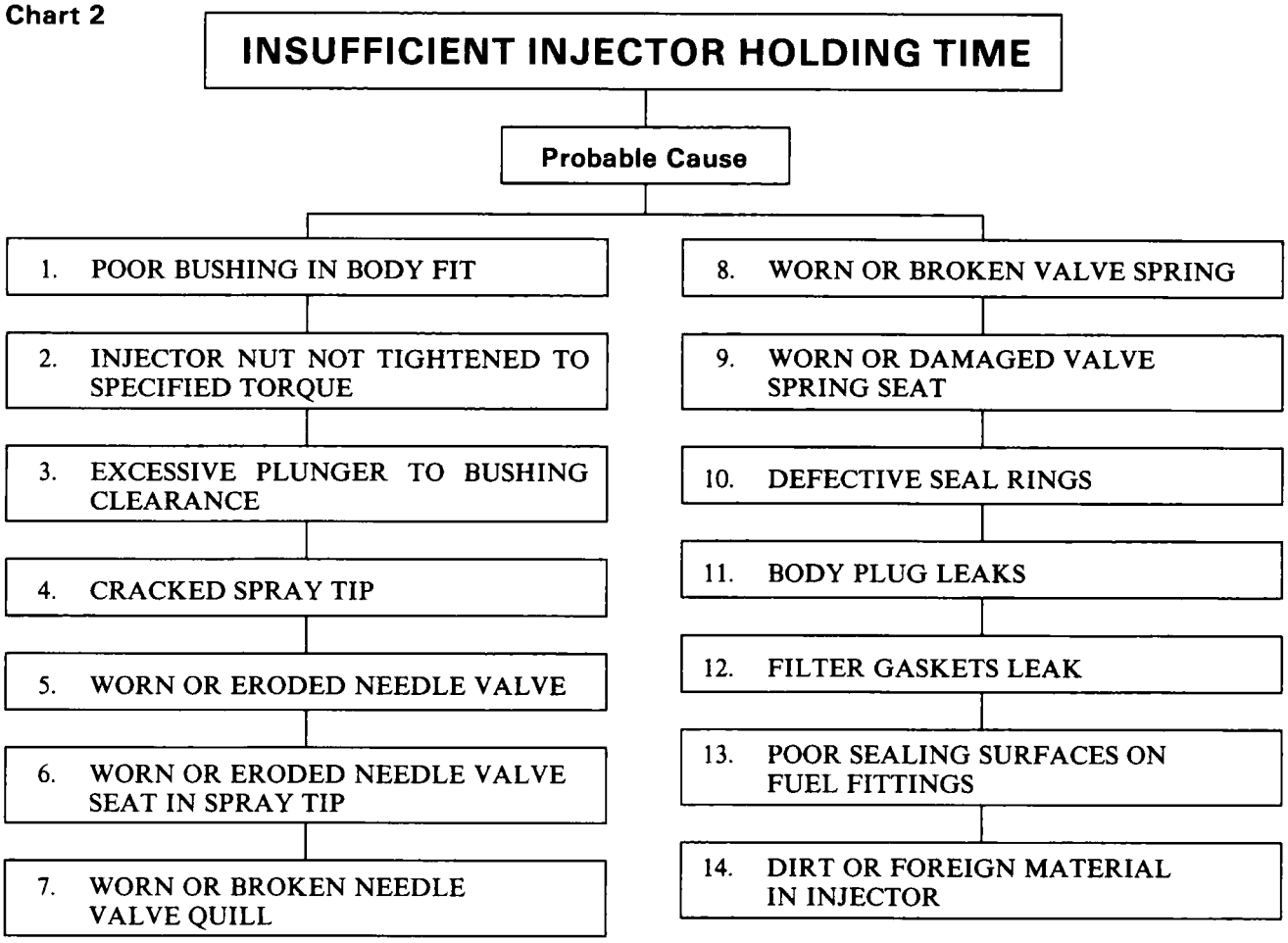

## SUGGESTED REMEDY

1. Replace the needle valve andspray tip assembly.
2. Replace the needle valve andspray tip assembly.
3. Replace the spring seat.
4. Replace the valve spring.
5. Disassemble the injector and clean all of the parts.
6. Remove the carbon in the spray tip with tool J 22800-01 which is especially designed and ground for this purpose.
7. Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

# NEEDLE VALVE INJECTORS

Chart 2

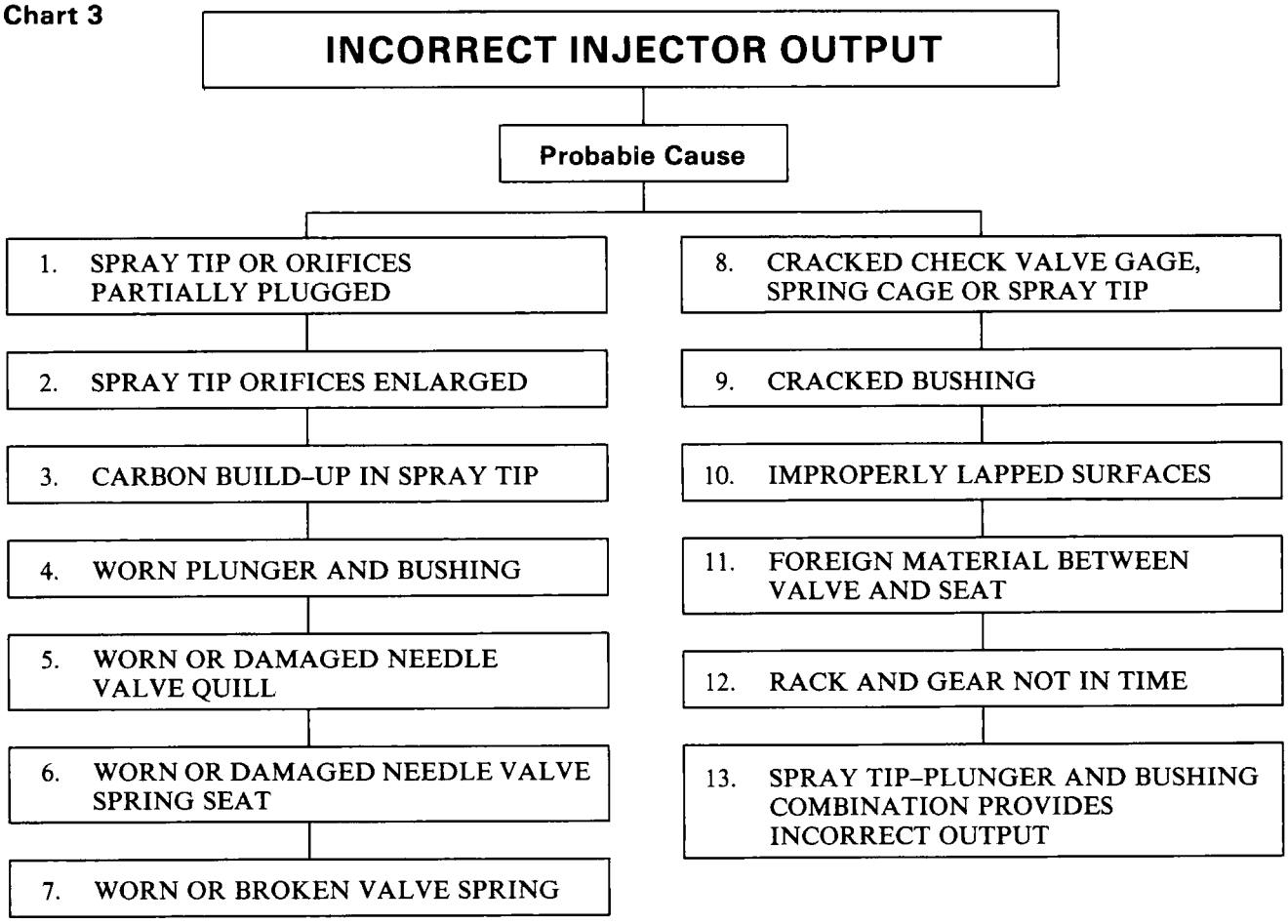



# SUGGESTED REMEDY

1. Lap the injector body.
2. Tighten the injector nut to 120-140 lb—ft (163-190 N*m) torque. Do not exceed the specified torque.
3. Replace the plunger and bushing.
4, 5, 6 and 7. Replace the needle valve and spray tip assembly.
8. Replace the valve spring.
9. Replace the valve spring seat.
10. Replace the seal rings.
11. Install new body plugs.
12. Replace the filter cap gaskets and tighten the filter caps to 65-75 lb—ft (88-102 N*m) torque.
13. Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.
14. Disassemble the injector and clean all of the parts.

# NEEDLE VALVE INJECTORS

**Chart 3**




# SUGGESTED REMEDY

1. Clean the spray tip as outlined under *Clean Injector Parts.*
2. Replace the needle valve and spray tip assembly.
3. Clean the spray tip.
4. After the possibility of an incorrect or faulty spray tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the *Fuel Output Check Chart,* try changing the spray tip. However, use only a tip specified for the injector being tested.

5. Replace the needle valve and spray tip assembly.
6. Replace the spring seat.
7. Replace the valve spring.
8. Replace the cracked parts.
9. Replace the plunger and bushing assembly.
10. Lap the sealing surfaces.
11. Disassemble the injector and clean all of the parts.
12. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth on the rack.
13. Replace the spray tip and the plunger and bushing assembly to provide the correct output.

# SPECIFICATIONS

## STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| THREAD SIZE | 260M BOLTS TORQUE (lb-ft) | Nam | THREAD SIZE | 280M OR BETTER TORQUE (lb-ft) | Nam |
|---|---|---|---|---|---|
| 1/4-20 | 5-7 | 7 9 | 1/4 20 | 7 9 | 10 12 |
| 1/4-28 | 6-8 | 8-11 | 1/4 28 | 8 10 | 11 14 |
| 5/16-18 | 10-13 | 14-18 | 5/16 18 | 13 17 | 18 23 |
| 5/16-24 | 11-14 | 15-19 | 5/16 24 | 15 19 | 20-26 |
| 3/8-16 | 23-26 | 31-35 | 3/8-16 | 30 35 | 41-47 |
| 3/8-24 | 26-29 | 35-40 | 3/8-24 | 35 39 | 47 53 |
| 7/16-14 | 35-38 | 47-51 | 7/16-14 | 46 50 | 62 68 |
| 7/16-20 | 43-46 | 58-62 | 7/16-20 | 57 61 | 77-83 |
| 1/2-13 | 53-56 | 72-76 | 1/2—13 | 71 75 | 96-102 |
| 1/2-20 | 62-70 | 84-95 | 1/2 20 | 83 93 | 113-126 |
| 9/16-12 | 68-75 | 92-102 | 9/16 12 | 90 100 | 122-136 |
| 9/16-18 | 80-88 | 109 119 | 9/16 18 | 107 117 | 146-159 |
| 5/8-11 | 103-110 | 140-149 | 5/8-11 | 137-147 | 186-200 |
| 5/8-18 | 126-134 | 171-181 | 5/8-18 | 168-178 | 228-242 |
| 3/4-10 | 180-188 | 244-254 | 3/4-10 | 240-250 | 325-339 |
| 3/4-16 | 218-225 | 295-305 | 3/4-16 | 290-300 | 393-407 |
| 7/8-9 | 308-315 | 417-427 | 7/8-9 | 410-420 | 556-569 |
| 7/8-14 | 356-364 | 483-494 | 7/8-14 | 475-485 | 644-657 |
| 1-8 | 435-443 | 590-600 | 1-8 | 580-590 | 786-800 |
| 1-14 | 514-521 | 697-705 | 1-14 | 685-695 | 928-942 |

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

| Grade Identification Marking on Bolt Head | GM Number | SAE Grade Designation | Nominal Size Diameter (inch) | Tensile Strength Min. (psi) |
|---|---|---|---|---|
| None | GM 255-M | 1 | No. 6 thru 1 1/2 | 60,000 |
| None | GM 260-M | 2 | No. 6 thru 3/4<br>over 3/4 to 1 1/2 | 74.000<br>60.000 |
| Bolts and Screws | GM 280-M | 5 | No. 6 thru 1<br>over 1 to 1 1/2 | 120,000<br>105,000 |
| — Hex Head Sems Only | GM 275-M | 5.1 | No. 6 thru 3/8 | 120,000 |
| ' Bolts and Screws | GM 290-M | 7 | 1/4 thru 1 1/2 | 133,000 |
| 5,C Bolts and Screws | GM 300-M | 8 | 1/4 thru 1 1/2 | 150,000 |
| - Bolts and Screws | GM 455-M | None | No. 6 thru 1 1/2 | 55,000 |

BOLT IDENTIFICATION CHART

# EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

| APPLICATION | THREAD | (lb-ft) | (N«m) |
|---|---|---|---|
| Fuel pump drive coupling disc bolt | 3/8-24 | 50-55 | 68-75 |
| Fuel jumper line nut to injector | 7/16-20 | 18-22 | 24-30 |
| Fuel jumper line nut to fuel manifold connector | 7/16-24 | 18-22 | 24-30 |
| Fuel manifold connector nut | 1/2-13 | 35-40 | 47-54 |
| .Injector filter cap | | | |
| Blued cap on blued body | | 70 | 95 |
| Non-blue cap on non-blued body or mixed (blue with non-blued part) | | 62 | 84 |
| •Injector body nut | | | |
| Blued nut on blued body | | 130 | 177 |
| Non-blue nut on non-blued body | | 85 | 115 |
| Mixed (blued with non-blued part) | | 108 | 147 |

# STANDARD PIPE PLUG TORQUE SPECIFICATIONS

| NPTF SIZE THREAD | TORQUE (lb-ft) | N»m | NPTF SIZE THREAD | TORQUE (lb-ft) | N*m |
|---|---|---|---|---|---|
| 1/8 | 10-12 | 14-16 | 1 | 75-85 | 102-115 |
| 1/4 | 14-16 | 19-22 | 1-1/16 | 85-95 | 115-129 |
| 3/8 | 18-22 | 24-30 | 1-1/4 | 95-105 | 129-143 |
| 1/2 | 23-27 | 31-37 | 1-1/2 | 110-130 | 150-177 |
| 3/4..... | .....33-37 | 45-50 | | | |

# SPECIAL PLUG TORQUE SPECIFICATIONS

| APPLICATION | THREAD | (lb-ft) | (N*m) |
|---|---|---|---|
| Fuel pump valve plug | 1/2-20 | 18-24 | 24-33 |
| Fuel junction block check valve plug | 1-1/16-16 | 80-90 | 108-122 |
| Governor housing plug | 1-15/16-16 | 50-60 | 68-81 |

# SERVICE TOOLS

| TOOL NAME | TOOL NO. |
|---|---|
| INJECTOR | |
| Auxiliary injector tester | J 22640-A |
| Field modification kit | J 22640-51 |
| Fuel hole brush | J 8152 |
| Fuel line torquing set | J 26617 |
| Injector fuel line nut socket | J 21545 |
| Fuel system primer | J 5956 |
| Injector calibrator | J 22410 |
| Injector nut carbon remover set | J 22096-02 |
| Injector nut socket | J 22799 |
| Injector spray tip driver | J 1291-02 |
| Injector test oil (5, 15, 30 or 55 gal.) | J 26400-(-5,-l 5,-30-55) |
| Injector tester | J 23010-B |
| Injector tester modification package (J 23010-A) | J 23010-195 |
| Injector tip concentricity gage | J 23905 |
| Injector vise and rack freeness tester | J 22396 |
| Injector wire sharpening stone | J 8170 |
| Lapping block set | J 22090-A |
| Master injector (149 Injector Only) | J 34998 |
| Pin vise | J 4298-1 |
| Polishing compound | J 23038 |
| Rack hole brush | J 8150 |
| Reamer (part of J 22342-01 set) | J 22342-11A |
| Spray hole wire (.009") | J 22885 |
| Spray tip carbon remover | J 22800-01 |
| Spray tip gage (needle lift) | J 9462-02 |
| Spring tester | J 22738-02 |
| Wire brush (brass) | J 7944 |
| INJECTOR TUBE | |
| Dial Indicator | J 22273-01 |
| Injector tip protrusion gage | J 25561 |
| Injector tube reconditioning set | J 22342-C |
| FUEL PUMP | |
| Fuel pump tool kit | J 34607 |
| Fuel pump tool set | J 1508-E |
| Fuel pump wrench | J 4242 |
| Fuel system primer | J 5956 |

| TOOL NAME | TOOL NO. |
|---|---|
| MECHANICAL GOVERNOR | |
| Control link bearing remover/installer | J 8985 |
| Hydraulic governor drive gear and sleeve remover | J 4685 |
| Governor cover bearing installer | J21068 |
| Governor cover and spring housing bearing remover | J 21967-01 |
| Governor weight housing plug remover/installer | J23176 |
| Governor weight shaft retaining ring installer | J 36840 |
| HYDRAULIC GOVERNOR | |
| Governor drive gear and sleeve remover | J 4685 |