TECHNICAL MANUAL

ORGANIZATIONAL, DIRECT SUPPORT, AND GENERAL SUPPORT MAINTENANCE MANUAL (INCLUDING REPAIR PARTS AND SPECIAL TOOLS LIST)

FOR

85' AERIAL LADDER FIRE FIGHTING TRUCK

NSN 4210-00-965-1254

HEADQUARTERS, DEPARTMENT OF THE ARMY

7 NOVEMBER 1986

COMPLETE MANUAL TABLE OF CONTENTS

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FOREWORD

Descriptions, instructions and parts listing pertaining to the Model QWT 85 are discussed throughout this manual under the general headings Chassis, Pump and Ladder. Foldout illustrations and schematics are located at the rear of this volume. The foldout format is provided in order that illustrations and schematics may be referred to while the supporting text is being examined and studied.

A detailed description is given in the Introduction of each volume to assist the user in finding the information required to maintain the equipment.

- Operator's Manual (TM 5-4210-227-10)

  This manual is designed to provide the information necessary for a fire fighter or mechanic to properly operate the truck, the pump and the ladder.

- Maintenance Manual (TM 5-4210-227-24&P)

  This manual is divided into 8 volumes and contains the information necessary for an experienced mechanic to-maintain and repair all facets of the apparatus. Each volume is individually indexed for ease of reference. This manual contains all the information necessary to obtain assemblies and subassemblies or individual parts, required to repair and maintain the fire truck.

TABULATED DATA

a) Fire Truck

Federal Stock Number:	4210-00-965-1254
Manufacturer 's Serial No.:	
Registration Nos.:	CM3653 through CM3664
Manufacturer:	Pierre Thibault Inc.
Model:	QWT 85
Contract Number:	DAAJ10-84-A218
Truck Length:	459"
Truck Width:	108"
Truck Height:	138"
Capacity or Payload:	51,000 GVWR
Shipping Weight:	43,880
Ground Clearance:	10.25"
Weight Loaded:	45,940
Front Axle	19,740
Rear Axle	26,200

b) Chassis

Manufacturer:	Duplex
I.D. Number:	I.C. ID91 D31 D6F 1008468
Model:	D350
Wheel Base	230"

c) Engine

Manufacturer:	Detroit Diesel
Model:	8V-71 Turbo
Serial Number:	8VA437868
Fuel:	Diesel

d) <u>Transmission</u>

Manufacturer:	Allison
Model:	HT-740
Serial No.:	2510087501
Capacity:	7 1/2 Gals

e) <u>Firefighting Water Pump</u>

Manufacturer:	Hale
Model:	QSM FHD100
Capacity:	1000 GPM @ 150 psi

f) <u>Front Axle</u>

Manufacturer:	Rockwell International
Model:	FL 941 QX-70
Capacity:	20,000 lbs.
Serial No.:	N766718

f) 1. <u>Front Shock Absorbers</u>

Manufacturer:	Duplex
Model:	7605-1258

f) 2. <u>Front Springs</u>

Manufacturer	Duplex
Model:	7804-6731

g) <u>Rear Axle</u>

Manufacturer:	Rockwell International
Model:	U-170 PX-99
Capacity:	31,000 lbs.
Serial No.:	NW845892

g) 1. <u>Rear Suspension</u>

Manufacturer:	Hendrickson
Model:	Single Axle RS-SA-340

h) Alternator

Manufacturer:	Delco Remy
Model:	
Amp.	145

i) Batteries

Manufacturer:	Harris
Model:	7605-0670
Voltage:	12

j) Battery Isolator

Manufacturer:	Sure Power
Model:	1602
Rated Power:	3709 BHP @ 2,100 rpm

k) Steering Gear

Manufacturer:	Sheppard
Model:	7605-5478

1) Power Steering Pump

Manufacturer:	Vickers
Model:	7605-5256

m) Windshield Wipers

Manufacturer:	American Bosch
Model:	WWC-12L
Type:	Electric

n) Radiator

Manufacturer:	Blackstone
Model:	7605-3750

o) Air Cleaner

Manufacturer:	FAAR
Model:	62891-3

p) Driver's Seat

Manufacturer:	Bostrom
Model:	Four-way Adjustable
Type:	Standard

q) Wheels

Front:	
Manufacturer:	Firestone
Size:	22.5 x 16.5
Rear:	
Manufacturer:	Firestone
Size:	20 x 8.5

r) Tires

Front:	
Manufacturer:	Goodyear
Size:	16.5 R 22.5 - 18 P.R.
Capacity:	20,000 lbs
Rear:	
Manufacturer:	Michelin
Size:	12:00 R 20X - 18 P.R.
Capacity	31,000 lbs.

s) Muffler

Manufacturer:	Nelson
Model:	86130-21

t) AC Inverter

Manufacturer:	Dynamote
Model:	A40-120

u) Siren/PA

Manufacturer:	Code 3
Model:	3100

CAPABILITIES

Fire Truck

Turning Radius - Inside 31.5' - Outside 42.25'
Rated Power: 370 BHP @ 2,100 rpm
Engine Governor Setting: No Load - 2,100; Top Speed 58 mph
Acceleration: 0 - 35 mph - 14 Seconds
Braking: 20 to 0 mph - 15 feet
Angle of Departure: Front - 15 degrees;
Rear - 15 degrees

Pump

Single Stage Centrifugal
Midship Mounted
Driven by the truck engine from the output shaft of transmission
Min discharge - 1000 gpm @ 150 psi
Min discharge - 100 gpm @ 200 psi
Min discharge - 500 gpm @ 250 psi
From dry condition - take suction and discharge water in 30 sec. with a lift of 10 deg. through 20' of 6" suction hose
12 VDC Priming Pump
Water Tank - 200 gals.

Ladder

Basic Weight - 11,560 lbs.,
Outrigger Operation Speed
Lower: Front - 9 sec. Rear - 18 sec.
Raise: Front - 9 sec. Rear - 18 sec.
Complete extension, elevation and 90 degrees rotation within 60 sec.
Hydraulic Tank: 45 gals. (Imp.)

MAINTENANCE MANUAL

SECTION I

1. INTRODUCTION/TABULATED DATA

1.1 INTRODUCTION

1.1.1. TM 5-4210-227-24&P, Organizational, Direct Support, and General Support Maintenance Manual for the 85' Aerial Ladder Fire Fighting Truck is divided into eight volumes. These eight volumes are further subdivided into specific sections consisting of both Government and commercial literature. TM 5-4210-227-10, Operator's Manual for the 85' Aerial Ladder Fire Fighting Truck is one separate manual consisting of four separate sections.

1.1.2. This volume consists of 12 sections and is arranged as follows:

GENERAL INFORMATION

1. Engine (less major assemblies)

2. Fuel System and Governors

3. Air Intake Systems

4. Lubrication System

5. Cooling System

6. Exhaust System

7. Electrical Equipment, Instruments and Protective Systems

12. Special Equipment

13. Operation

14. Tune-Up

15. Preventive Maintenance, Troubleshooting and Storage

NOTE

For the Parts List for the 3V-71 Turbo Engine refer to duplex "Engine - Common-Parts" (on the following page) and "DETROIT DIESEL ENGINES - V71 OPERATORS' MANUAL," Section 8, "BUILT IN PARTS BOOK.1"

IMPORTANT SAFETY NOTICE

Proper service and repair is important to the safe, reliable operation of all motor vehicles. The service procedures recommended by Detroit Diesel Allison and described in this service manual are effective methods for performing service operations. Some of these service operations require the use of tools specially designed for the purpose. The special tools should be used when and as recommended. It is important to note that some warnings against the use of specific service methods that can damage the vehicle or render it unsafe are stated in this service manual. It is also important to understand these warnings are not exhaustive. Detroit Diesel Allison could not possibly know, evaluate and advise the service trade of all conceivable ways in which service might be done or of the possible hazardous consequences of each way. Consequently, Detroit Diesel Allison has not undertaken any such broad evaluation. Accordingly, anyone who uses a service procedure or tool which is not recommended by Detroit Diesel Allison must first satisfy himself thoroughly that neither his safety nor vehicle safety will be jeopardized by the service method he selects.

6SE228 (Rev. 7/82)

Service Manual

Detroit Diesel Engines

V-71

HIGHWAY VEHICLE

Detroit Diesel Allison
13400 W. Outer Drive
Detroit, Michigan 48239

NOTE:
Additional copies of this service manual may be purchased from Detroit Diesel Allison Distributors. See your yellow pages—under Engines, Diesel.

Printed in U.S.A.

FOREWORD

This manual contains instructions on the overhaul, maintenance and operation of the basic V-71 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 sub-assemblies 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 Service Outlet* for information on the latest revisions. The right is reserved to make changes at any time without obligation.

TABLE OF CONTENTS

SCOPE AND USE OF THE MANUAL

This manual covers the basic V-71 on-highway vehicle diesel engines built by the Detroit Diesel Allison Division of General Motors 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 V-71 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 I at the beginning of each subsection. The illustrations are also numbered consecutively, beginning with a new Figure I 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 Allison service parts are available in the United States from authorized distributors and service dealers throughout the world. A complete list of all distributors and dealers is available in the World Wide Parts and Service 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.

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 as shown in Fig. 1. In contrast, a four cycle engine requires four piston strokes to complete an operating cycle; thus, during one half of its operation, the four-cycle engine functions merely as an air pump.

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 as shown in 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 as shown in 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 as shown in 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 fuel injected 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 as shown in 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".

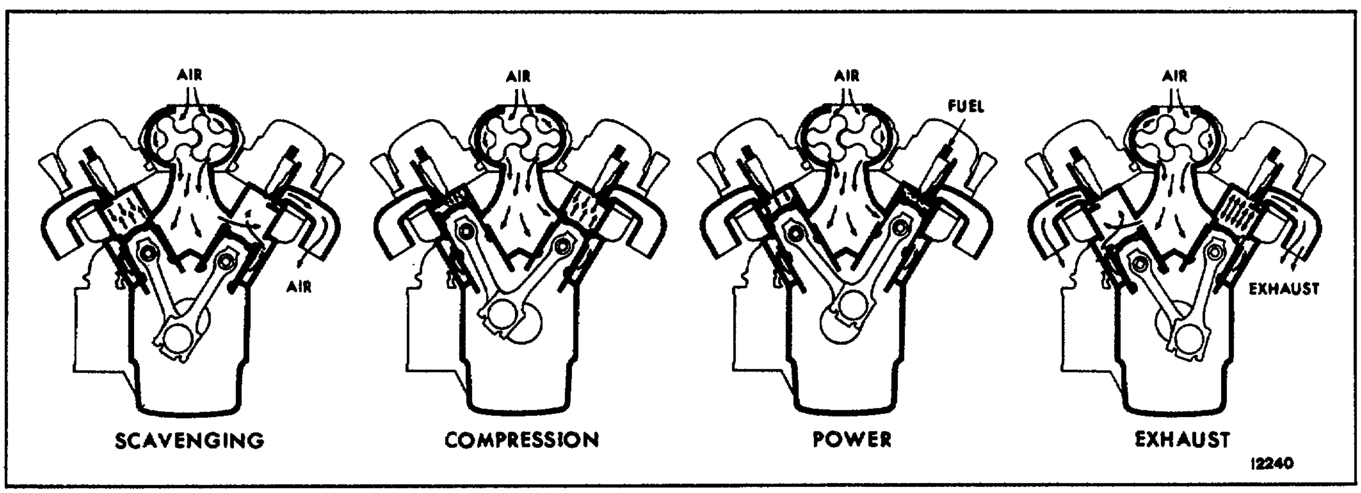


FIG. 1 - The Two-Stroke Cycle

GENERAL DESCRIPTION

The two-cycle diesel engines covered in this manual are produced in 6, 8 and 12 cylinder models having the same bore and stroke and many of the major working parts such as injectors, pistons, connecting rods, cylinder liners and other parts that are interchangeable.

All cylinder blocks are symmetrical in design thus permitting oil cooler or starter installation on the same side or on opposite sides of the engine, depending upon the installation requirements. The engines are built with right-hand or left-hand crankshaft rotation. For example, the crankshaft in an RC engine, viewed from the flywheel end, will rotate counterclockwise, the oil cooler will be mounted on the right-hand side of the engine and the starter will be on the left-hand side (Fig. 2).

The meaning of each digit in the model numbering system is shown in Fig. 2. The letter L or R indicates left or right-hand engine rotation as viewed from the front of the engine. The letter A, B, C or D designates the location of the starter and oil cooler as viewed from the rear of the engine.

Cylinder heads with either two valves or four valves per cylinder are used, as designated by the engine model.

Each engine is equipped with an oil cooler, lubricating oil filter, fuel oil strainer, fuel oil filter, air cleaner, governor, fan and radiator, and starting motor.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings, and to other moving parts within the engine. A gear-type pump draws oil from the oil pan through an intake screen, through the oil filter and then to the oil cooler. From the oil cooler, the oil' flows through passages that connect with the oil galleries in the cylinder block and cylinder heads for distribution to the bearings, rocker arm mechanism and other functional parts.

Coolant is circulated through the engine by a centrifugal-type water pump. Heat is removed from the coolant, which circulates in a closed systern, by the radiator. Control of the engine temperature is accomplished by thermostats which regulate the flow of the coolant within the cooling system. Fuel is drawn from the supply tank through the fuel strainer by a gear-type fuel pump. It is then forced through a filter and into the fuel inlet manifolds in the cylinder heads and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifolds and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and also carries off any air in the fuel system.

Air for scavenging and combustion is supplied by a blower 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. Engine starting is provided by an electric starting motor energized by a storage battery. A battery- charging generator, with a suitable voltage regulator, serves to keep the battery charged.

Engine speed is regulated by a mechanical governor.

7 0 6 7 – 7 2 4 1

SERIES 71 V Engines	NUMBER OF CYLINDERS	APPLICATION DESIGNATION (see below)	BASIC ENGINE ARRANGEMENT (see below)	DESIGN VARIATION (see below)	SPECIFIC MODEL NUMBER

APPLICATION DESIGNATION:

7067-7000 VEHICLE F-F
7088-7000 VEHICLE F-F

BASIC ENGINE ARRANGEMENTS:

Rotation: L (left) and R (right) designates rotation viewed from the front of the engine.

Type: A-B-C-D designates location of starter and oil cooler as viewed from the rear (flywheel) end.

Cylinder Bank: Left and right cylinder banks are determined from rear of engine.

DESIGN VARIATIONS:

7067-7000	"N" ENGINE
7067-7100	2 VALVE HEAD ENGINE
7067-7200	4 VALVE HEAD ENGINE
7067-7300	TURBOCHARGED ENGINE
7067-7400	TURBO-AFTERCOOLED ENGINE
7067-7500	CUSTOMER SPEC. ENGINE
7087-7600	CONSTANT HORSEPOWER ENCONOMY (TAE) (CALIFORNIA CERTIFIED)
7087-7700	CONSTANT HORSEPOWER (TT)
7087-7900	CONSTANT HORSEPOWER ECONOMY (TTAE) (CALIFORNIA CERTIFIED)

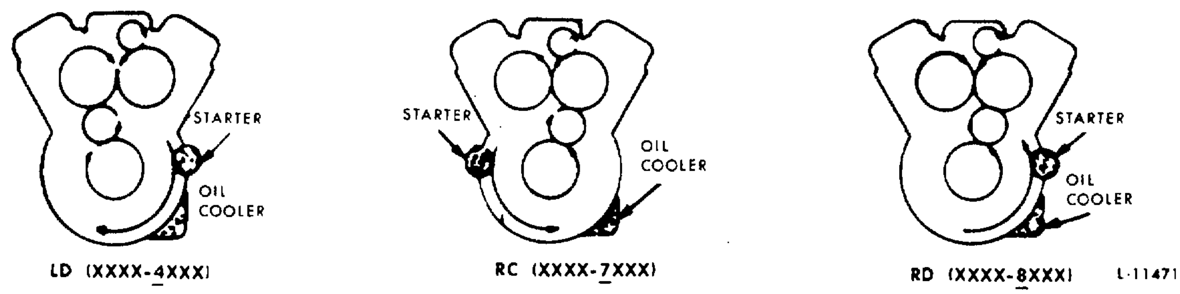


FIG. 2 - Model Numbering, Rotation and Accessory Arrangement

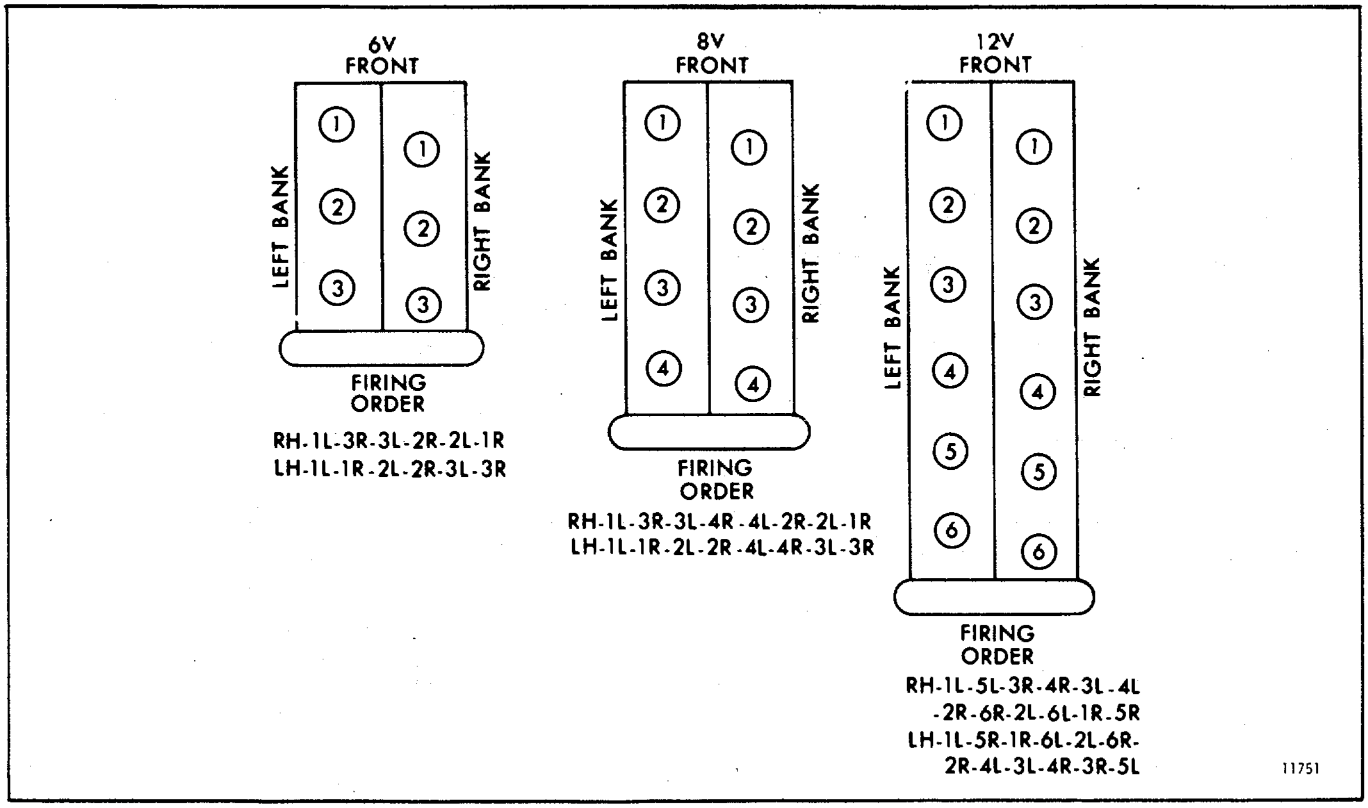


FIG. 3 - V-71 Engine Cylinder Designation and Firing Order

GENERAL SPECIFICATIONS

	6V	8V	12V
Type	2 Cycle	2 Cycle	2 Cycle
Number of Cylinders	6	8	12
Bore (inches)	4.25	4.25	4.25
Bore (mm)	108	108	108
Stroke (inches)	5	5	5
Stroke (mm)	127	127	127
Compression Ratio (Nominal) (Std. & Turbo. Engines)	17 to 1	17 to 1	17 to 1
Compression Ratio (Nominal) ("N" Engines)	18.7 to 1	18.7 to 1	18.7 to 1
Total Displacement - cubic inches	426	568	852
Total Displacement - litres	6.99	9.32	13.97
Number of Main Bearings	4	5	7

ENGINE MODEL, SERIAL NUMBER AND OPTION PLATE

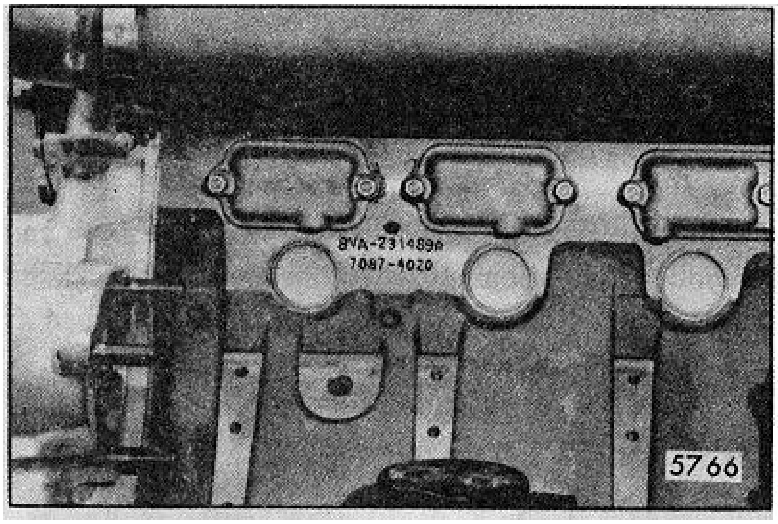


FIG. 4 - Typical Engine Serial Number and Model Number As Stamped on Cylinder Block

The engine serial number and the engine model number are stamped on the right rear side of the cylinder block (Fig. 4). This applies to former 6 and 8V-71 engines and current 12V-71 engines. To allow for easier engine serial number and model number identification on 6 and 8V-71 engines the location has been moved to the upper right front corner of the block.

> **NOTE**: The 12V and 16V-71 engine identification will continue to be stamped at the former location, the right rear side of the cylinder block.

An option plate, attached to one of the valve rocker covers, is also stamped with the engine serial number and model number and. in addition, lists any optional

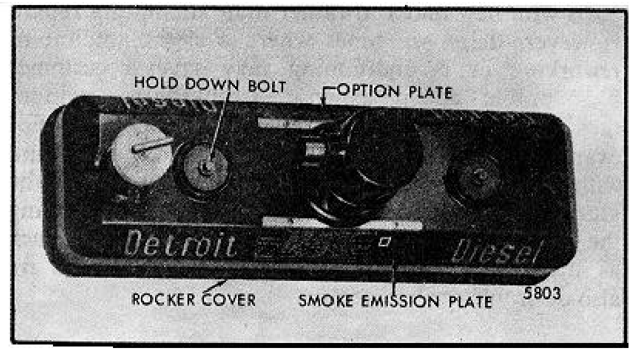


FIG. 5 - Option Plate

equipment used on the engine (Fig. 5).

An exhaust emission certification label. separate from the option plate. is mounted permanently in the option plate retainer. The current label includes information relating to an engine family for the maximum fuel injector size and maximum speed. Due to Federal regulations, the exhaust emission plate should not be removed. from the rocker cover. Refer to Section 14 for further information regarding emission regulations.

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 an engine are standard for the engine model unless otherwise listed on the option plate.

GENERAL PROCEDURE

In many cases, a serviceman is justified in replacing parts with new material rather than attempting repair. However, there are times where 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, water and fuel. Lubricating oil should also be drained from any transmission attached to the engine.

To perform a major overhaul or other extensive repairs. the complete engine assembly, after removal from the vehicle and transmission, should be mounted on an engine overhaul stand; then the various sub- assemblies should be removed from the engine. When only a few items need replacement, it is not always necessary to mount the engine -on an overhaul stand.

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 accomodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 180 ° -200 0 F (82 ° -93 ° 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

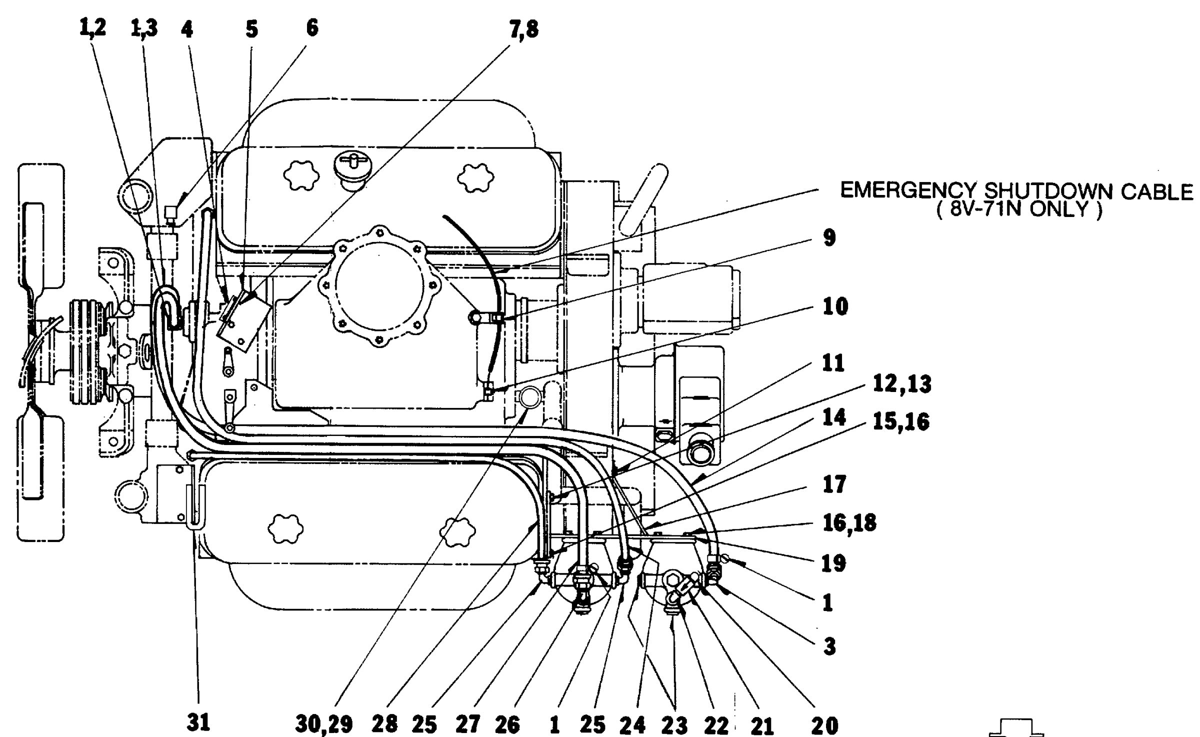
Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete the drying of the parts without the use of compressed air.

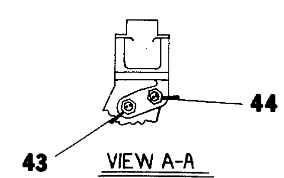
DUPLEX

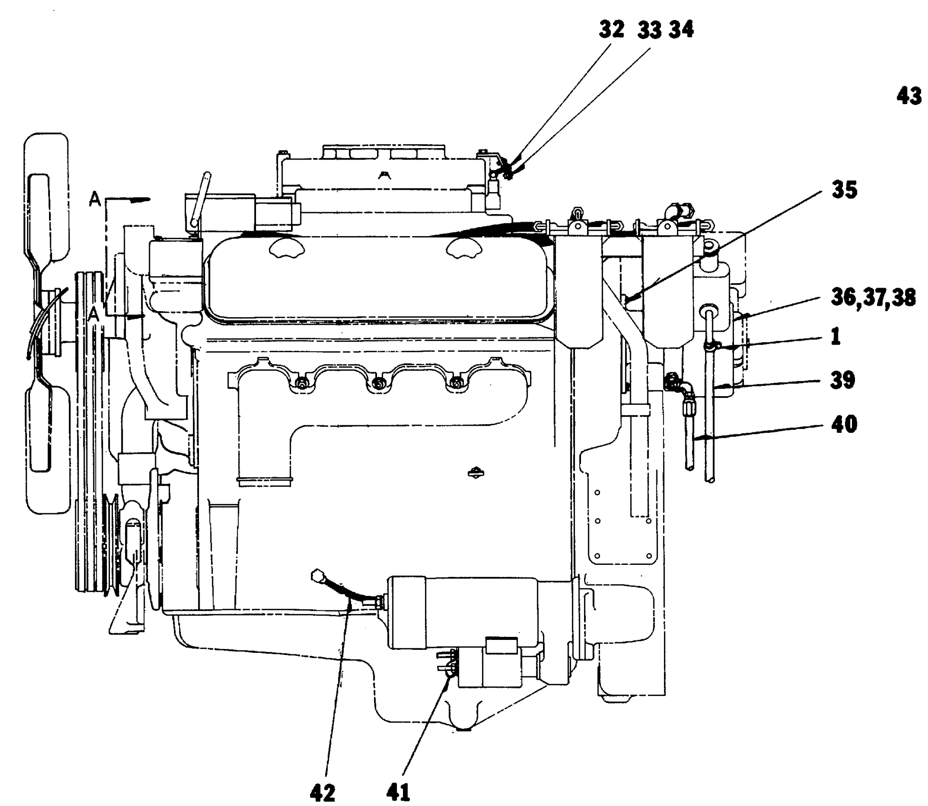
Engine — Common Parts

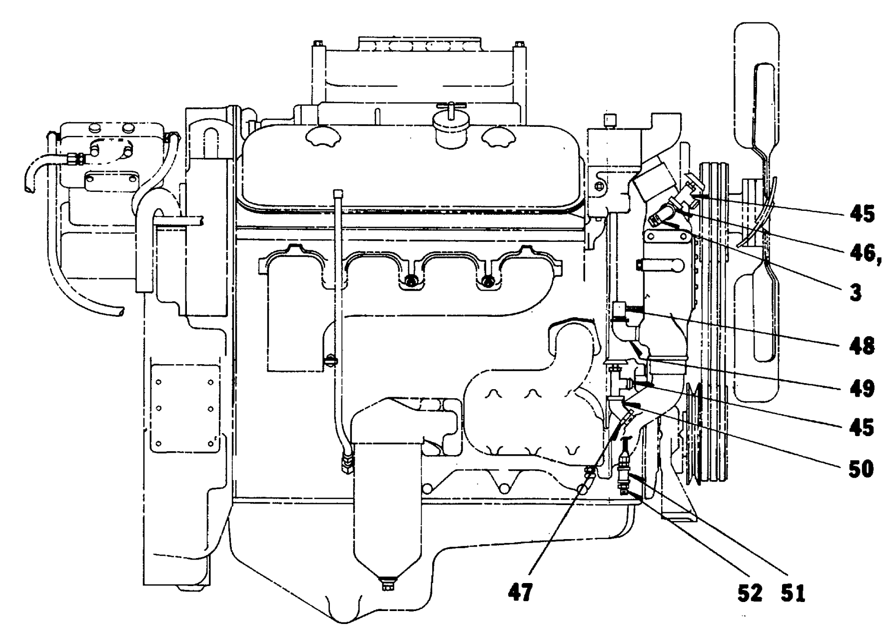
6V-92TA, 8V-71N, 8V-71TA, 8V-92TA

All Models









Item	Part No.	Description	Qty.
1	8867-1187	Hose Clamp	5
2	7604-4244	1/2 Inv. Flare Elbow-1/4 NPT	1
3	8874-3044	3/4-16 x 3/8 NPT 90° Elbow	3
4	7604-4797	Cable Clamp	1
5	7804-9993	Shutdown Bracket	1
6	7605-0244	90° Hose Barb 3/8 NPT-5/8 Hose	1
7	7604-4693	#10-32 x 1/2 LG. Round Head Machine Screw	4
8	8855-1007	#10 Lockwasher	4
9	7604-5227	Cable Support (8V-71N Only)	1
10	7603-3837	Core Fitting (8V-71N Only)	1
11	7601-7020	H.H.C.S. 3/8-16 x 4-1/2 LG.	1
12	8820-1048	H.H.C.S. 7/16-14 x 3/4 LG.	1
13	8855-1012	7/16 Lockwasher	1
14	7604-4170	Hose Assembly	1
15	8820-1033	H.H.C.S. 3/8-16 x 3/4 LG.	1
16	8855-1011	3/8 Lockwasher	5
17	7808-0683	Support Strap	1
18	8820-1036	H.H.C.S. 3/8-16 x 1-1/4 LG.	4
19	7810-6316	Fuel Filter Bracket	1
20	8874-3074	7/8-14 x 3/8 NPT JIC Adaptor	1
21	7604-3252	Check Valve	1
22	8871-2013	3/8 NPT 90° Street Elbow	1
23	8871-1252	3/8 NPT Hex Head Pipe Plug	2
24	7605-1864	Hose Assembly	1
25	8874-3043	3/8 Tube x 1/4 NPT 90° Elbow	2
26	8874-3060	1/2 Tube x 1/4 NPT 90° Elbow	1
27	7604-4173	Hose Assembly	1
28	7604-4172	Hose Assembly	1
29	7604-7510	Pulse Generator	1
30	7604-7511	Drive Key	1
31	7605-0573	Accelerator Bracket	1
32	8202-9592	Conduit Clamp (8V-71N Only)	1
33	8830-1193	#10-32 x 1/2 LG. Machine Screw (8V-71N Only)	2
34	8855-1007	#10 Lockwasher (8V-71N Only)	2
35	8820-1066	H.H.C.S. 1/2-13 x 1-1/4 LG.	4
36	Ref. Only	Power Steering Pump	1
37	7603-2023	Drive Coupling	1
38	7601-6199	Gasket	1
39	7604-5985	Hose Assembly	1
40	7604-6228	Hose Assembly (8V's Only)	1
	7605-2466	Hose Assembly (6V-92TA Only)	1
41	7604-5066	Jumper Wire Assembly	1
42	7810-5160	Ground Cable	1
43	7604-7213	Water Temperature Sender	1
44	7604-7211	Water Temperature Switch	1
45	7601-8899	Shutoff Valve — Heater	1
46	7605-1101	3/8 NPT Street Tee	1
47	8871-1383	1/2 NPT x 3/8 NPT Pipe Bushing	2
48	7605-1023	Nipple Rework	1
49	8871-2015	3/4 NPT 90° Street Elbow	1
50	8871-2033	3/8 NPT 45° Street Elbow	1
51	7605-0478	3/8 NPT x 1/4 NPT Coupling	1
52	8874-3003	1/2 Tube x 3/8 NPT Connector	1

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

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 makes 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 sub-assemblies, 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 26558-92 *pipe sealer with teflon*, or equivalent, be used.

NOTE: Certain plugs, fittings and fastener 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.

IMPORTANT: 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.

WORK SAFELY

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:

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.

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 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. Always use caution when using power tools.

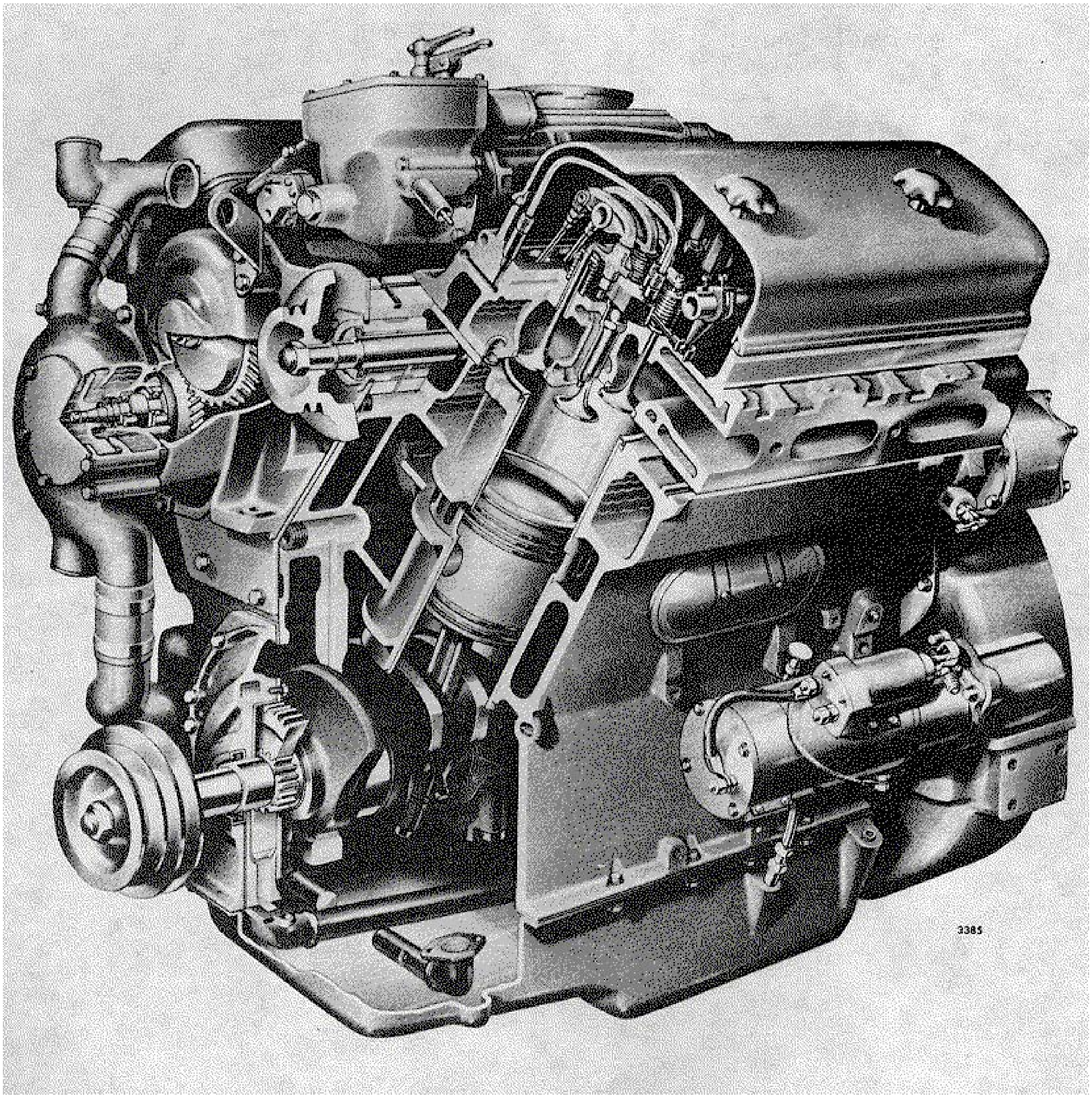
4. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury.

5. Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichlorethylene. However, while less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield and an apron. Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

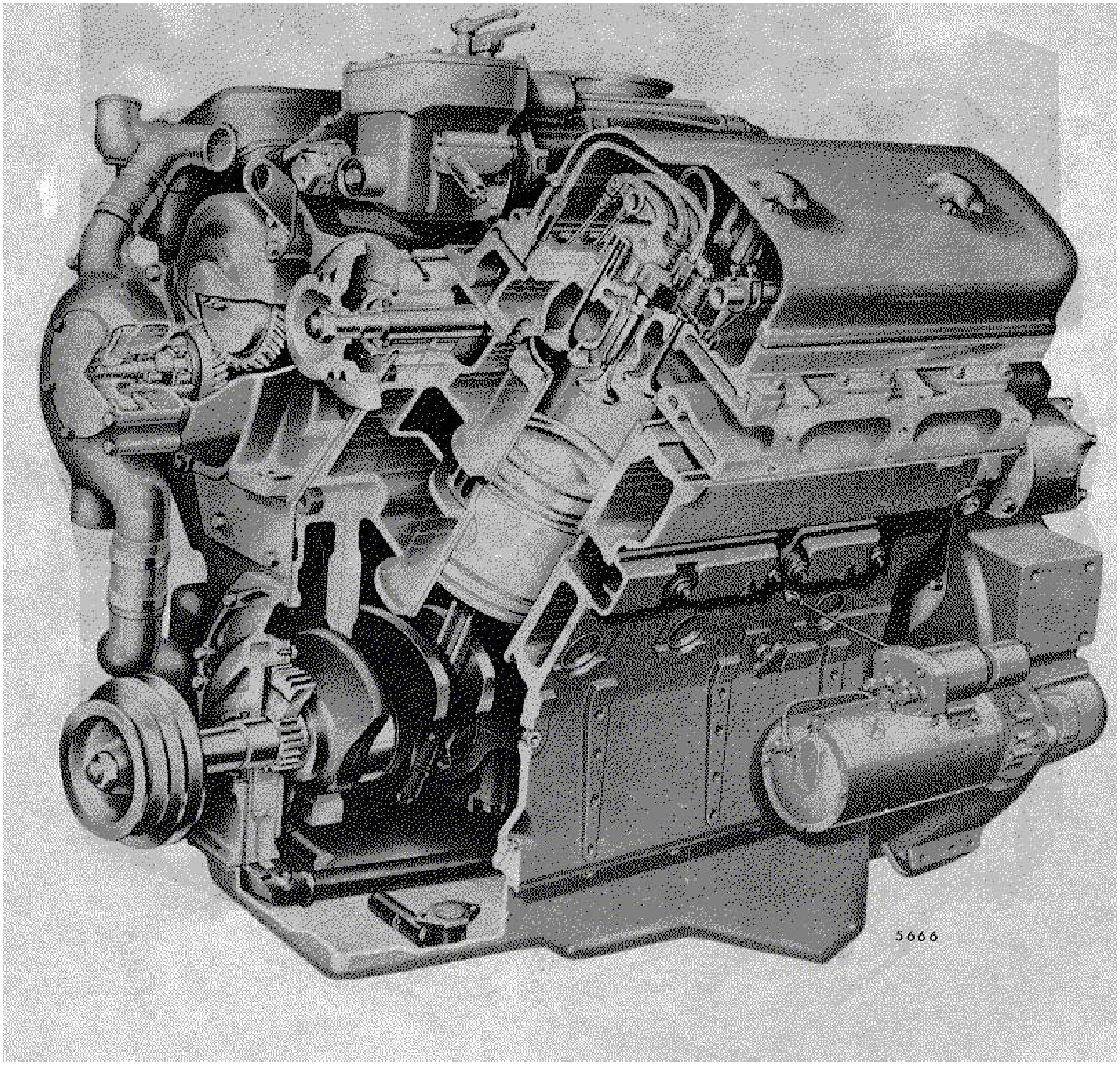
6. Use caution when welding on or near the fuel tank. Possible explosion could result if heat build-up inside the tank is sufficient.

7. 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.

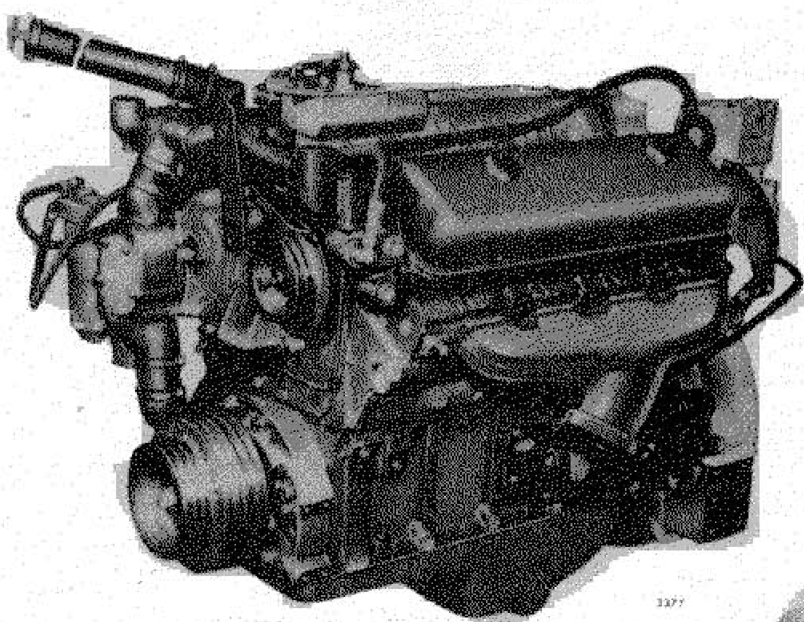
8. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.



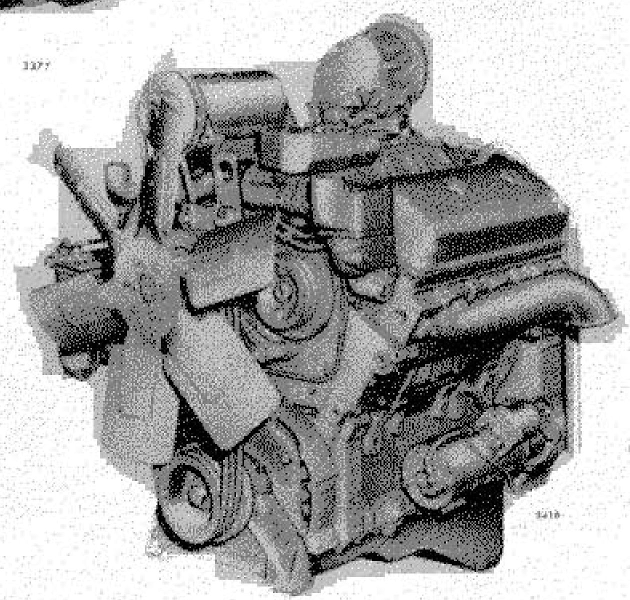
Three-Quarter Cutaway View of V-71 Engine (Dry Block)



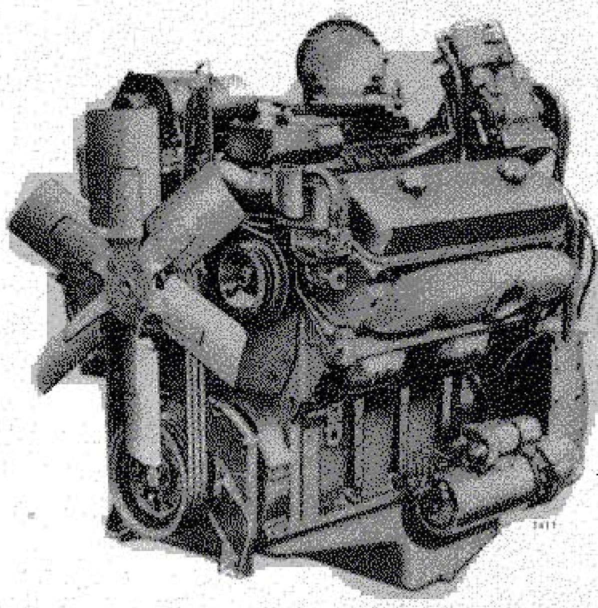
Three-Quarter Cutaway View of V-71 engine (Water-Below-Port Block)



8V Bus Engine



6V Truck Engine



8V Truck Engine

SECTION 1

ENGINE (less major assemblies)

CONTENTS

CYLINDER BLOCK

The cylinder block (Fig. 1) serves as the main structural part of the engine. Transverse webs provide rigidity and strength and ensure alignment of the block bores and bearings under load.

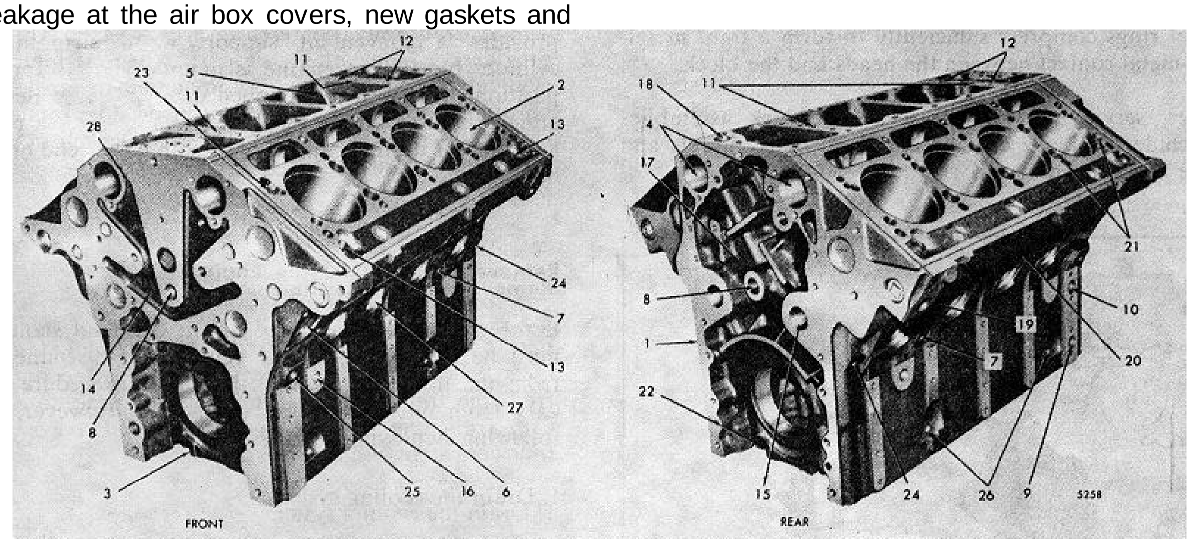
The block is bored to receive replaceable cylinder liners. The current cylinder block is designated as a water-below-port block and is designed to provide water cooling below the air inlet port belt. The former cylinder block was designated as a dry block.

An air box between the cylinder banks and extending around the cylinders at the air inlet port belt conducts the air from the blower to the cylinders. Air box openings on each side of the block permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners. The air box openings in the current cylinder block assembly are approximately 1 7/8" x 3 1/8" and are covered with cast covers (Fig. 2). The stamped steel covers used on the former cylinder block covered openings which were approximately 3" x 6 1/2". To prevent leakage at the air box covers, new gaskets and bolts are now being used. The new polyacrylic and cork gaskets replace the former asbestos gaskets. The new lock and seal coated bolt replaces a stud, nut, flat washer and lock washer. The former and new gaskets are interchangeable on an engine, but only the new gaskets are serviced.

The camshaft bores are located on the inner side of each cylinder bank near the top of the block.

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

The top surface of each cylinder bank is grooved to accommodate a block-to-head oil seal ring. Also, each water or oil hole is counterbored to provide for individual seal rings.



1. Cylinder Block
2. Bore for Cylinder Liner
3. Front Main Bearing Cap
4. Bores for Camshafts
5. Air Box
6. Water into Block
7. Water Drain
8. Main Oil Gallery
9. Oil Passage from Pump to Oil Filter
10. Oil Passage from Oil Cooler
11. Oil Drain Passages to Blower
12. Oil Drain Passages from Blower
13. Oil Drain from Cylinder Head
14. Oil Drain Passages
15. Oil Passage (Idler Gear Bearing)
16. Oil Return Passages to Crankcase
17. Crankcase Breather Cavity
18. Crankcase Breather Outlet
19. Air Box Drain
20. Inspection Hole Opening
21. Water Passages to Cylinder Head
22. Rear Main Bearing Cap
23. Oil Passage to Cylinder Head
24. Oil Gallery
25. Oil Gallery
26. Dipstick Hole or Oil Return Passage to Crankcase
27. Core Hole for Water Jacket
28. Oil Tube

FIG. 1 - Cylinder Block (8V Engine)

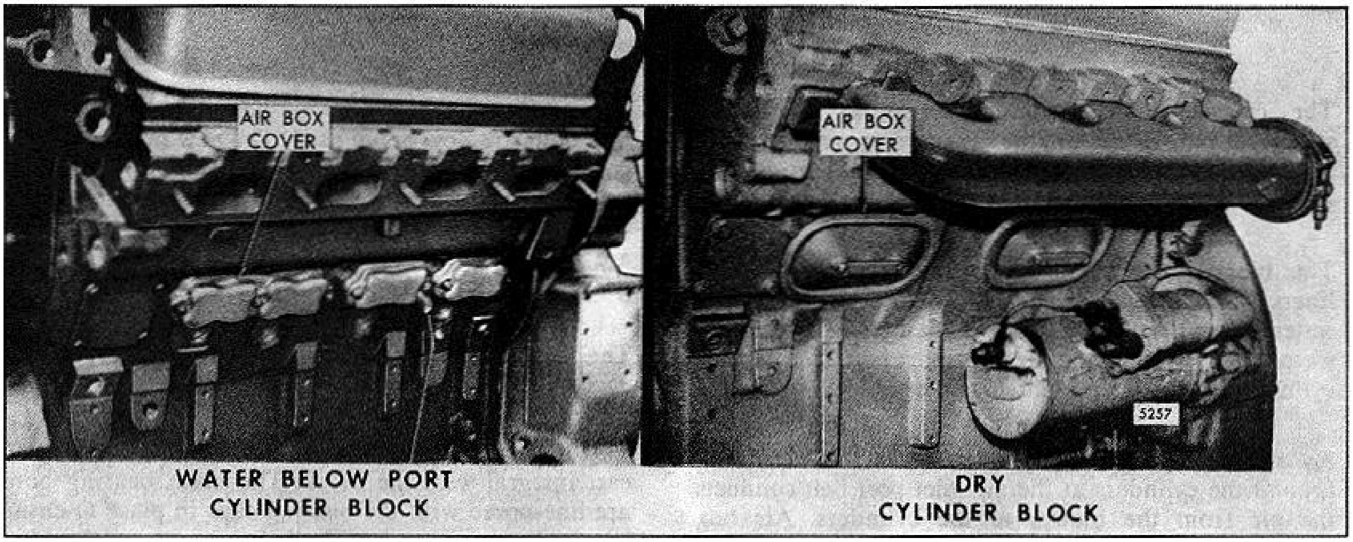


FIG. 2 Comparison of Current and former Cylinder Blocks

Each cylinder liner is retained in the block by a flange at its upper end. The liner flange rests on an insert located in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

When the cylinder heads are installed, the gaskets and seal rings compress sufficiently to form a tight metal-to-metal contact between the heads and the block.

New service replacement cylinder block assemblies include the main bearing caps and bolts, dowels and the necessary plugs. Since the cylinder block is the main structural part of the engine, the various subassemblies must be removed from the cylinder block when an engine is overhauled.

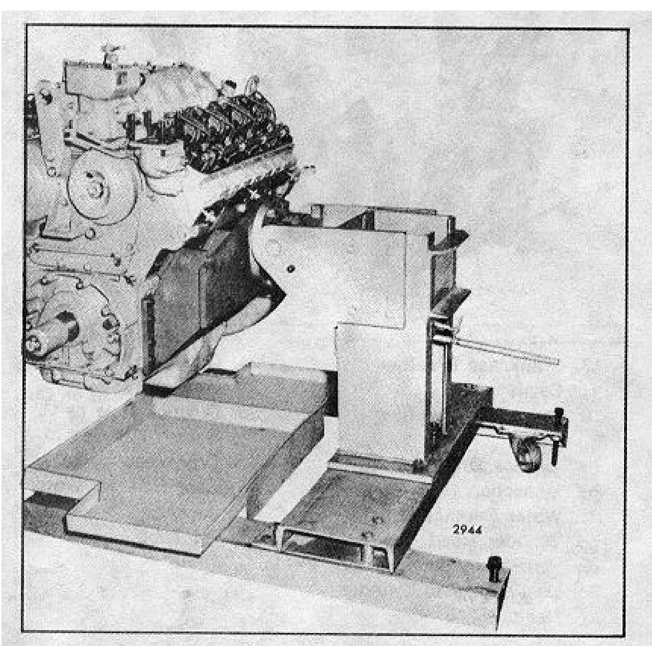


FIG. 3 Engine Mounted on Overhaul Stand

The hydraulically operated overhaul stand (Fig. 3) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction 90°or 180°where it is locked in place and then, if desired, tipped back with either end or the oil pan side up.

Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from the vehicle and disconnected from the transmission. Details of this procedure 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 cleaner and mounting brackets.

5. Remove the turbocharger, 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 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

15. Remove the engine mounting bolts.

16. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base (Fig. 4). 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

NOTE: Do not lift the engine by the webs in the air inlet opening at the top of the cylinder block.

17. Mount the engine on the overhaul stand. For 6V and 8V engines, use overhaul stand J 6837-C with adaptor J 8601-01. For 12V engines, use overhaul stand J 9389-04 and adaptor J 8650.

CAUTION: Check the fastenings carefully to be sure the engine is securely mounted 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. With the engine mounted on the overhaul stand, 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.

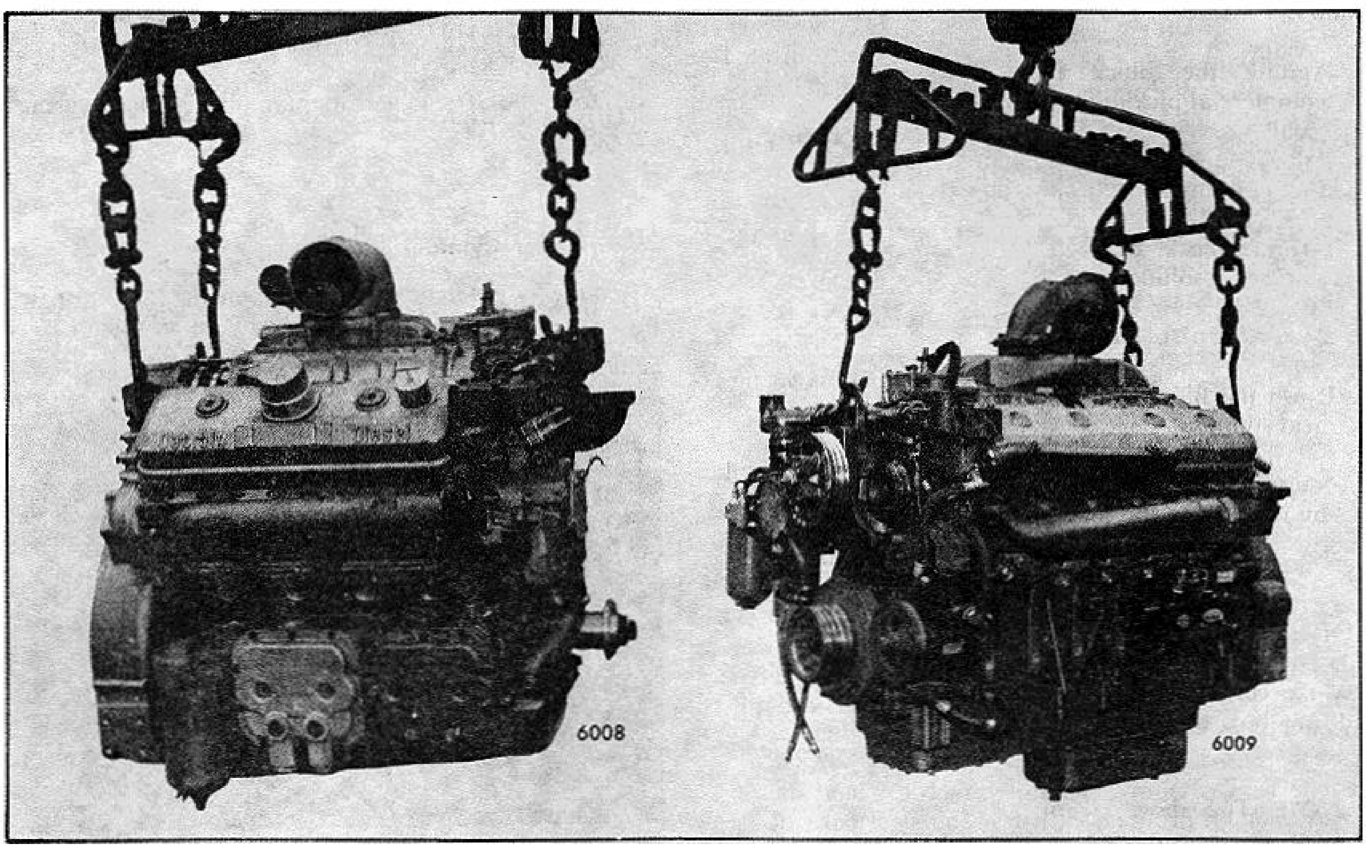


FIG. 4 - Lifting Engine with Spreader and Sling

Clean Cylinder Block

Scrape all gasket material from the cylinder block. Then remove all oil gallery plugs and core hole plugs (except cup plugs) to allow the cleaning solution to contact the inside of the oil and water passages. This permits more efficient cleaning and eliminates the possibility of' the cleaning solution attacking the aluminum core hole plug gaskets (if used).

If a core hole plug is difficult to remove, hold a 3/4" drift against the plug and give it a few sharp blows with a one pound hammer. With a 1/2" flexible handle and a short extension placed in the countersunk hole in the plug, turn the plug slightly in the direction of tightening. Then turn it in the opposite direction and back the plug out.

Clean the cylinder block as follows:

1. Remove the grease by agitating the cylinder block in a hot bath of commercial heavy-duty alkaline solution.

2. Wash the block in hot water or steam clean it to remove the alkaline solution.

3. It the water jackets are heavily scaled, proceed as s: follow

a. Agitate the block in a bath of inhibited commercial pickling acid.

b. Allow the block to remain in the acid bath until the bubbling stops (approximately 30 minutes).

c. Lift the block, drain it and reimmerse it in the same acid solution for 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 acid that may cling to the casting by immersing the block in an alkaline bath.

g. Wash the block in clean water or steam clean it.

4. Dry the cylinder block with compressed air

5. Make certain that all water passages, oil galleries and air box drain openings have been thoroughly cleaned.

NOTE: 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 procedures whenever necessary.

6. After the block has been cleaned and dried, coat the threads of the plugs and the gaskets with clean engine oil and reinstall the air box core hole plugs or adaptor plug. Tighten the 1 3/4"-16 plugs to 150-180 Ib-ft (204-244 Nm) torque. Tighten the 2 1/2"-16 plugs or water inlet adaptor plug (if used) to 230-270 Ib-ft (312- 366 Nm) torque using tool J 23019.

A water inlet adaptor plug and gasket replaces the rear (flywheel housing end) 2 1/2" core hole plug in the cylinder block air box floor on engines built with an aftercooler (refer to Section 3.5.3). Use tool J 25275 to install or remove this adaptor plug. Lubricate with clean engine oil and tighten the adaptor plug to 230- 270 Ib-ft (312-366 Nm) torque.

NOTE: Excessive torque applied to the core hole plugs may result in cracks in the water jacket.

If for any reason the cup plugs in the water jackets were removed, install new plugs as follows:

a. Clean the cup plug holes and apply Permatex No. I sealant, or equivalent, to the outer diameter of the plugs.

b. Drive the plugs in place with handle J 7079-2 and adaptor J 24597 (2 1/2" diameter plugs, Fig. 5) adaptor J 21849 (for 2" diameter plugs) or adaptor J 21850 (for I 5/8" diameter plugs).

c. Drive the aftercooler adaptor plug in place, using tool J 28711.

Pressure Test Cylinder Block

After the cylinder block has been cleaned, it must be pressure tested for cracks or leaks by either one of two methods.

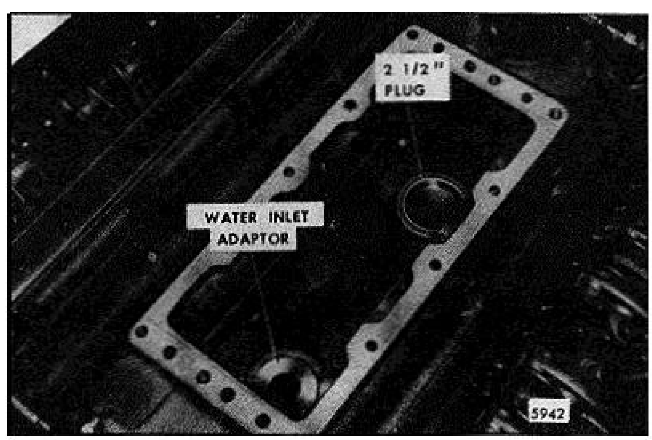


FIG. 5 - Installing Aftercooler Water Plug

METHOD "A"

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

1. Seal off the water inlet and outlet holes air tight. This can be done by using steel plates and suitable rubber gaskets held in place by bolts. Drill and tap one cover plate to provide a connection for an air line.

NOTE: A new service tool (J 29571) has been released to aid in pressure testing V-71 aftercooled engine cylinder blocks. When properly installed, the new tool seals- off the aftercooler water inlet adaptor plug in the air box floor.

2. Immerse the block for twenty minutes in a tank of water heated to 180-200 F (82-93 °C).

3. Apply 40 psi (276 kPa) air pressure to the water jacket and observe the water in the tank for bubbles which' indicate the presence of cracks or leaks in the block. A cracked cylinder block must be replaced by a new block.

4. After the pressure test is completed, remove the block from the water tank. Then remove the plates and gaskets and dry the block with compressed air.

METHOD "B"

This method may be used when a large water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the vehicle. However, it is necessary to remove the cylinder heads, blower, oil cooler, air box covers and oil pan.

1. Attach sealing plates and gaskets as in Method "A". However, before attaching the last sealing plate, fill the water jacket with a mixture of water and one gallon of antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.

2. Install the remaining sealing plate and tighten it securely.

3. Apply 40 psi (276 kPa) air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.

4. At the end of the test period, examine the cylinder bores, air box, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture which will indicate the presence of cracks. A cracked cylinder block must be replaced by a new block.

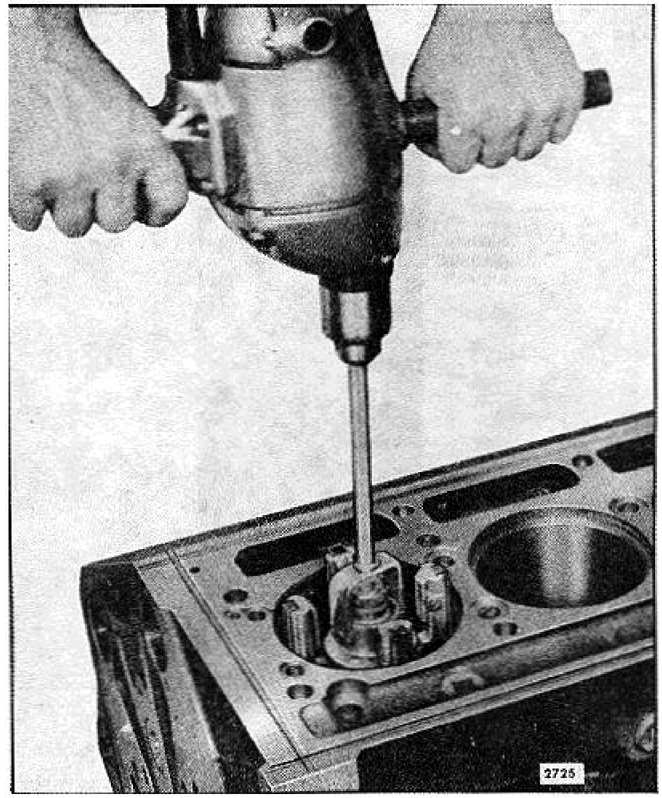


FIG. 6 Honing Cylinder Block Bore

5. After the test is completed, remove the plates, drain the water jacket and blow out all of the passages in the block with compressed air.

Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

Since most of the engine cooling is accomplished by heat transfer through the cylinder liners to the water jacket, a good liner-to-block contact must exist when the engine is operating. Whenever the cylinder liners are removed from an engine, the block bores must be inspected.

NOTE: Before attempting to check the block bores, hone them throughout their entire length until about 75% of the area above the ports has been "cleaned-up".

1. Hone the block bores as follows:

a. Use a hone in which the cutting radius of the stones can be set in a fixed position to remove irregularities in the bore rather than following the irregularities as with a spring-loaded hone. Clean the stones frequently with a wire brush to prevent

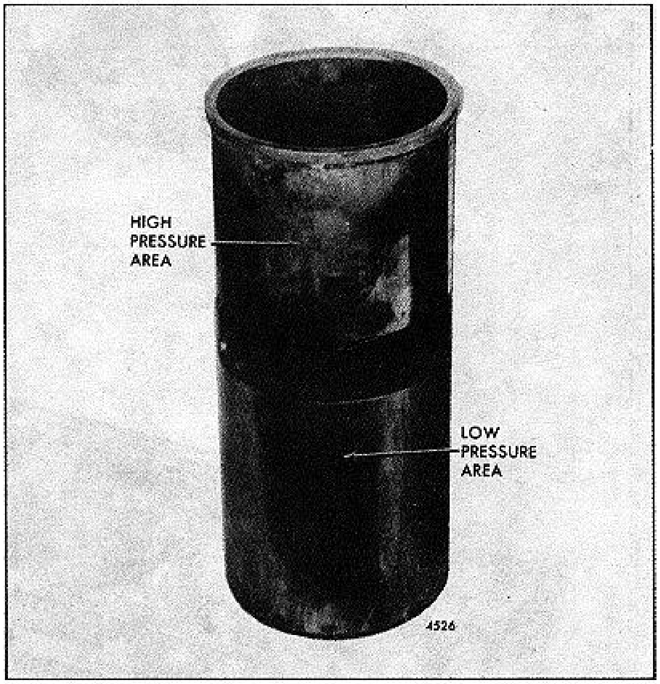


FIG. 7 - High Pressure Areas on Cylinder Liner

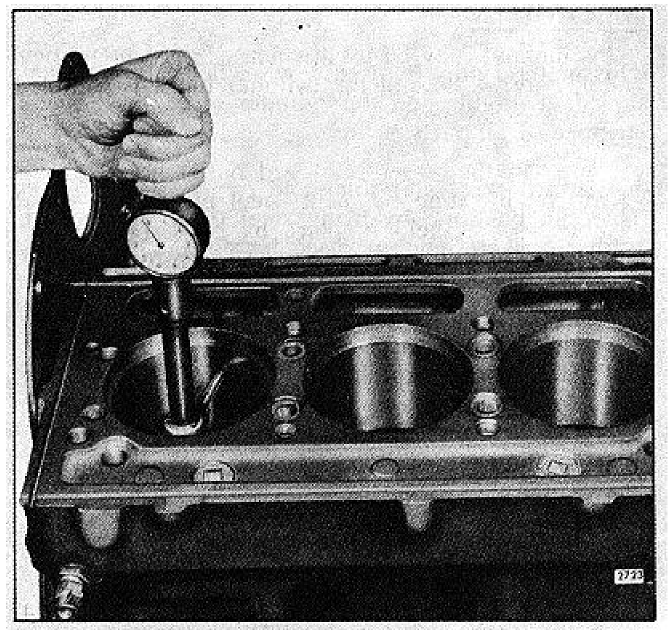


FIG. 8 - Checking Bore of Cylinder Block with Tool J 5347O01

stone loading. Follow the hone manufacturer's instructions regarding the use of oil or kerosene on the stones. Do not use such cutting agents with a dry hone. Use 120 grit stones J 5902-14.

b. Insert the hone in the bore and adjust the stones snugly to the narrowest section (Fig. 6). When correctly adjusted, the hone will not shake in the bore, but will drag freely up and down the bore when the hone is not running.

c. Start the hone and "feel out" the bore for high spots which will cause an increased drag on the stones. Move the hone up and down the bore with short overlapping strokes about I " long. Concentrate on the high spots in the first cut. As these are removed, the drag on the hone will become lighter and smoother. Do not hone as long at the air inlet port area as in the rest of the bore because this area, as a rule, cuts away more rapidly. Feed lightly to avoid an excessive increase in the bore diameter. Some stones cut rapidly even under low tension.

d. When the bore is fairly clean, remove the hone, inspect the stones and measure the bore. Determine which spots must be honed most. Moving the hone from the top to the bottom of the bore will not correct an out-of-round condition. To remain in one spot too long will cause the bore to become irregular. Where and how much to hone can be judged by feel. A heavy cut in a distorted bore produces a steady drag on the hone and makes it difficult to feel the high spots. Therefore, use a light cut with frequent stone adjustments.

e. Wash the cylinder block thoroughly after the honing operation is completed.

2. The cylinder liner is alternately expanding and contracting, during engine operation, due to temperature variations. This may result in irregularities in the block bores (out-of-round and taper), the effects of which will be seen as high pressure areas on the outside diameter of the cylinder liner (Fig. 7). A slight increase in block bore size is normal with high mileage or long periods of engine operation.

If a new liner and piston is installed in the block without properly fitting the liner, galling and seizing of the piston may result. This is caused by the new piston having to travel over the irregularities without time to conform to the particular shape of the block bore.

Check the cylinder block bores as follows:

a. Visually check the contact area as revealed by the honed surface. There must not be any low spots which are larger in area than a half dollar.

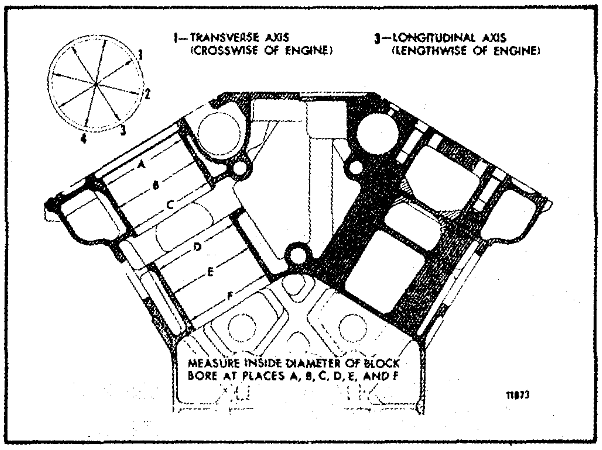


FIG. 9 Cylinder Block Bore Measurement Diagram

b. Measure the entire bore of each cylinder with cylinder bore gage J 5347-01 (Fig. 8) which has a dial indicator calibrated in .0001 " increments. The standard block bore is 4.6260" to 4.6275". Place the bore gage in the master ring gage J 8386-01 which has an I.D. of 4.6270" and set the dial to zero. Take measurements on the cleaned-up surface only at positions A, B, C, D, E and F in the bore on axes 45°apart (Fig. 9). Read the measurements from the zero mark on the gage. The readings may be recorded on a form similar to the one illustrated (Fig. 10).

NOTE: Dial bore gage setting master tool J 23059-01 may be used in place of the master ring gage.

3. The liner-to-block clearance with new parts is zero to .0015". With used parts, the maximum clearance is .0025". After measuring the block bores, measure the outside diameter of the cylinder liners (Section 1.6.3). Then determine the block-to-liner clearance (refer to Section 1.0 for the specified clearances) and whether it will be necessary to bore the block for oversize cylinder liners.

	Trans.	45°	Long.	45°
	1	2	3	4
A				
B				
C				
Port Belt	X	X	X	X
D				
E				
F				

FIG. 10 Block Bore Measurement Record Form

4. If necessary, bore the cylinder block as follows:

a. Each bore in a used block must not be out-of-round or tapered more than .002". If the average block bore is over 4.6285", the block should be bored oversize (refer to Tables I and 2).

For Average Block Bore I.D. Size of	Use Liner O.D. Size	To Give A Liner-to-Block Clearance of
4.6260" / 4.6275"	Standard	.000" to .0025"
4.6270" / 4.6285"	.001" Oversize	.000" to .0025"

TABLE 1

Block Boring Dimensions	Liner O.D. Size	Maximum Block Bore I.D. on a Used Block
4.631" / 4.632"	.005" Oversize	4.6325"
4.636" / 4.637"	.010" Oversize	4.6375"
4.646" / 4.647"	.020" Oversize	4.6475"
4.656" / 4.657"	.030" Oversize	4.6575"

TABLE 2

b. A typical commercially available portable boring bar is illustrated in Fig. 11. Instructions on correct use of the boring bar are provided by the manufacturer.

c. After boring the block for an oversize cylinder liner, check the bore finish to be sure it is smooth (120 RMS). Heat transfer from the cylinder liner to the block will be adversely affected if the block isn't smooth.

d. Wash the block thoroughly after the boring operation.

e. When an oversize liner is used, stamp the size of the liner on the top deck of the block adjacent to the liner counterbore. An oversize liner insert

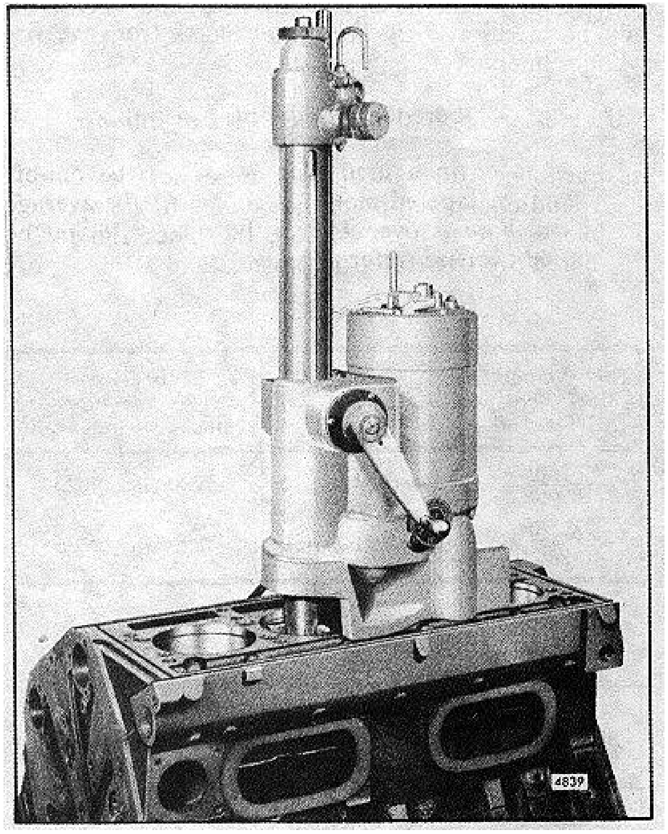


FIG. 11 - Portable Boring Bar

must be installed whenever an oversize liner is used (Section 1.6.3).

5. Check the top of the block (cylinder head contact surfaces) for flatness with an accurate straight edge and a feeler gage (Fig. 12).

a. The cylinder head contact surfaces of the block must not vary more than .003" transversely and not over .006" (6V), .007" (8V) or .009" (12V) longitudinally. It will be difficult to prevent water, oil and compression leaks if these surfaces exceed these tolerances.

b. If it is necessary to machine these surfaces to correct for the above conditions, do not remove more than .008" of metal. Stamp the amount of stock removed on the face of the block. The distance from the centerline of the crankshaft to the top of the cylinder head surface of the block must not be less than 16.176" (Fig. 13).

c. If stock is removed from the cylinder head contact surfaces of the block, check the depth of the seal

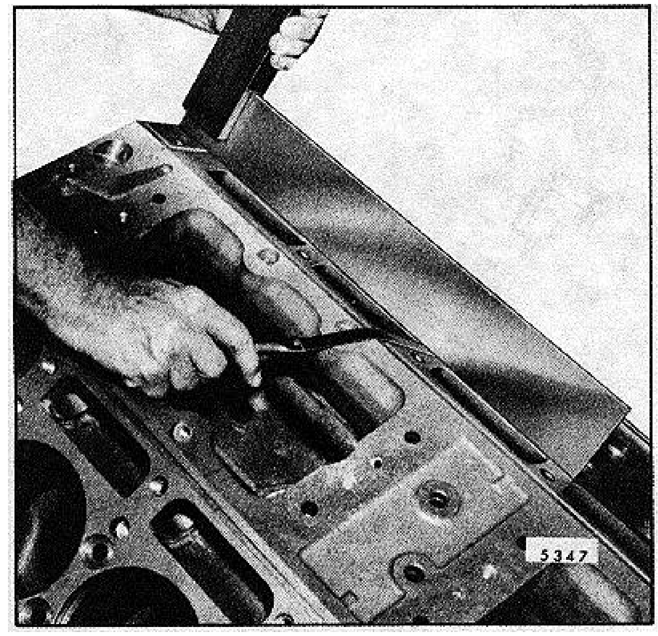


FIG. 12 - Checking Top Surface of Cylinder Block

ring grooves and counterbores. The cylinder head seal strip grooves must be .092" - .107" deep. The large water hole counterbores (between the

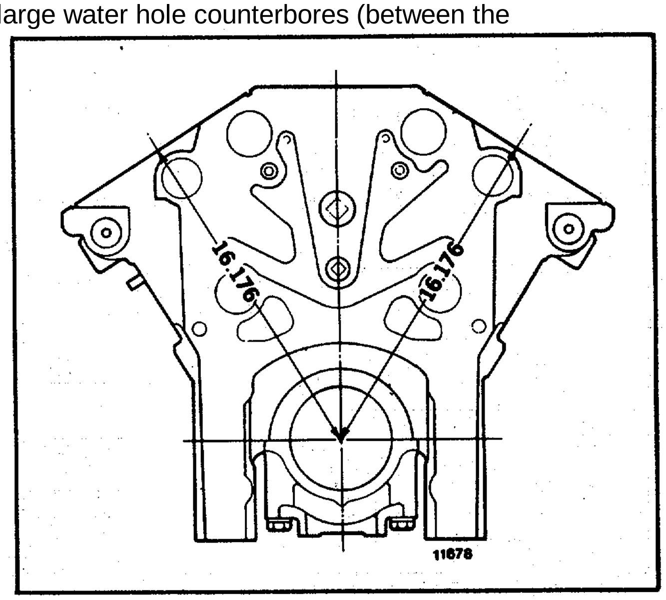


FIG. 13 - Minimum Distance from Centerline of Crankshaft to Top of Cylinder Block

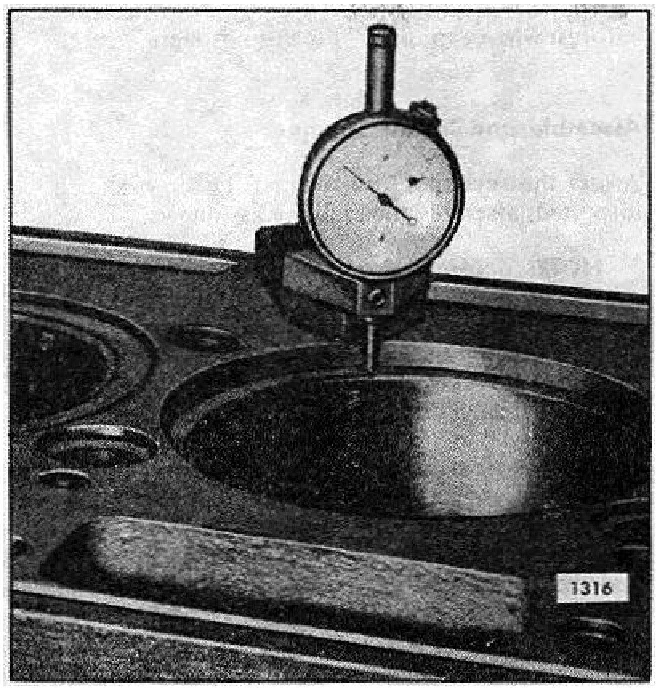


FIG. 14 Checking Depth of Counterbore with Toot J 22273

cylinders) must be .109" - .120" deep, and the combination water and oil hole counterbores and small water hole counterbores must be .087" - .098" deep. If necessary, deepen the grooves or counterbores to the specified limits to retain the proper "crush" on the seal rings. It is not necessary to deepen the counterbores for the cylinder liners since .004" and .008" undersize thickness inserts are available for adjusting the liner position as outlined in Section 1.6.3 under *Fitting Cylinder Liner in Block Bore.*

6. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth

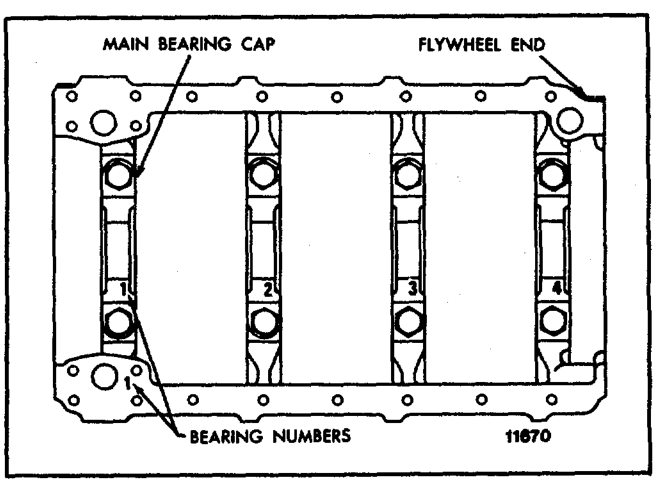


FIG. 15 - Cylinder Block Markings

(Fig. 14). The depth must be .4770" to .4795'a and must not vary more than .0015" throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within .001 " total indicator reading. There must not be over .001" difference between any two adjacent cylinder counter-bores when measured along the cylinder longitudinal centerline of the cylinder block.

7. 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 the 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. I main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 15). 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 165-175 Ib-ft (224-238 Nm) torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 4.812", to 4.813'. If the bores do not fall within these limits, the cylinder block must be rejected.
NOTE: 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 *fi*nished 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.
NOTE: 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. If a main bearing bore is more than .001" maximum overall misalignment or .0005" maximum misalignment between adjacent bores the block must be line-bored (see Section 1.0) or scrapped. 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 (see Section 1.0).

8. Refer to the *Cylinder Block Plugging Chart* shown as a fold-out at the end of this manual and install the necessary plugs and dowels.

9. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .630".

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.

> **NOTE:** A stepped dowel pin is available to replace loose pins in the rear main bearing cap. Before installing the stepped pins, rebore the dowel holes in the bearing cap with a No. II (.1910") or No. 12 (.1890") drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.

10. If used, replace damaged or broken cylinder head studs. Drive new studs to a height of 4 3/8" ± 1/32" above the block at a minimum of 75 Ib-ft (102 Nm) torque. Also examine the cylinder head retaining bolt holes. If the threads are damaged, use a tap to "clean-up" the threads or install a helical thread insert.

I 1. The tapped holes in the water-below-port cylinder blocks may be tapped with a 5/8"-l I UNC3B thread tap. The stud holes and unplugged bolt holes must have the thread extending 1.850" below the block surface. If the bolt hole in the block is plugged, the plug must be a minimum of 2.040" below the surface of the block and threaded the full distance (1.920" on blocks prior to January, 1975). When replacing a bolt hole plug in the current water-below-port block, refer *to Shop Notes* in Section 1.0.

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

13. 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 polar type rust preventive such as Valvoline Oil Company's "Tectyl 502-C", or equivalent. 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:

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

1. Mount the cylinder block on the overhaul stand.

2. If a new service replacement block is used, stamp the engine serial number and model number on the right-hand side of the cylinder block. Also stamp the position numbers on the main bearing caps (Fig. 15) and the position of the No. I bearing on the oil pan mounting flange of the block.

3. 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.

> **NOTE**: Make sure the cup plug, which blocks the oil cooler adaptor inlet from the adaptor outlet, is installed in the vertical passage.

4. Check the cam pocket drain hole spring pin (if used) in the front end of the block to be sure it is installed with the slot up.

5. Clean and inspect all engine parts and subassemblies and, using new parts as 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.

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

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

8. Operate the engine on a dynamometer, following t*he run-in* procedure outlined in Section 13.2.1.

9. Reinstall the engine in the vehicle.

CYLINDER BLOCK END PLATES

A flat steel plate, one bolted to each end of the cylinder block, provides a support for the flywheel housing at the rear and the balance weight cover at the front of the engine. Gaskets are used between the block and each end plate.

Inspection

When an end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the end plate and the cylinder block. Clean the end plate as outlined under *Clean Cylinder Block* in Section 1. 1.

Inspect both surfaces of each end plate for nicks, dents, scratches or score marks and check the end plates for warpage. Check the plug nuts in the end plates for cracks or damaged threads. If nicks or scratches on the sealing surfaces of the end plates are too deep to be cleaned up, or the plug nuts are damaged, replace the end plates or plug nuts.

When installing a plug nut, support the end plate on a solid flat surface to avoid distorting the plate. Then press the nut in the end plate until the head on the nut seats on the end plate.

Install Cylinder Block Breather Pads

A new breather pad, designed to improve crankcase ventilation, was used beginning with engine 6VA-16943, 8VA-7508 and 12VA-2332.

The new pad differs from the two former pads in width only. To compensate for the decrease in width, two retainers have been provided to hold the new pads in the cavities behind the cylinder block rear end plate (Fig. 2).

> **NOTE**: Turbocharged engines do not require breather pads.

After cleaning the breather pads and prior to installing the cylinder block rear end plate, reinstall the breather pads and retainers, if used, in the block as shown in Fig. 2.

> **NOTE**: Since the former breather pads were not the same size, be sure to reinstall them in their original locations.

The end plates, when assembled to -the block, will apply pressure on the retainers and hold the pads in position.

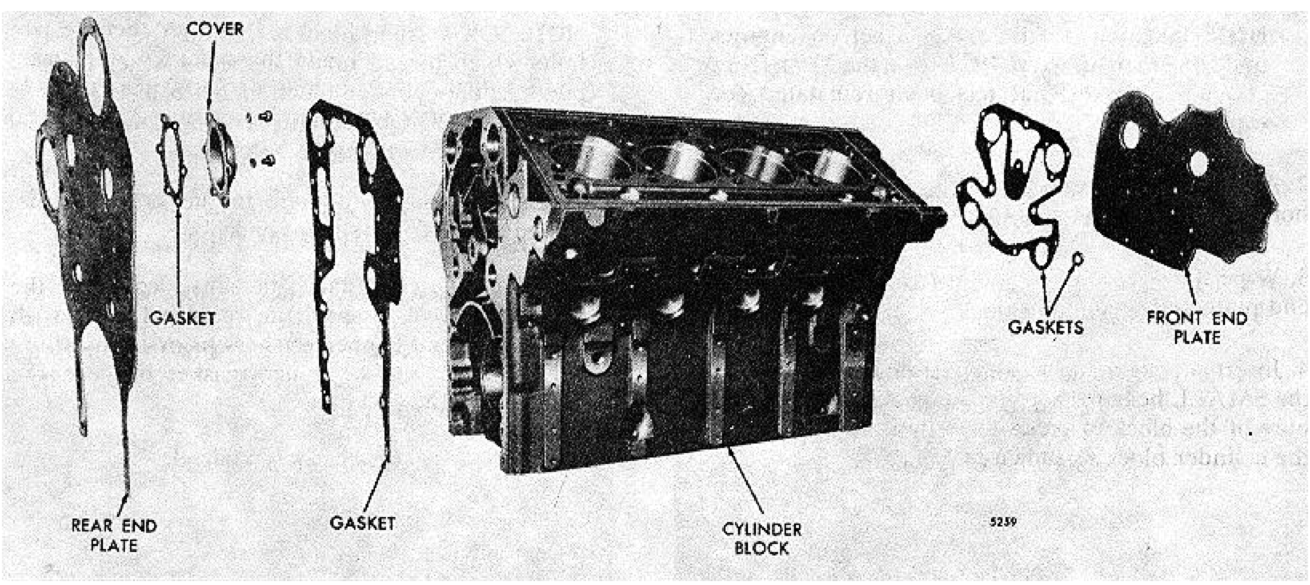


FIG. 1 - Cylinder Block End Plates and Relative Location of Parts

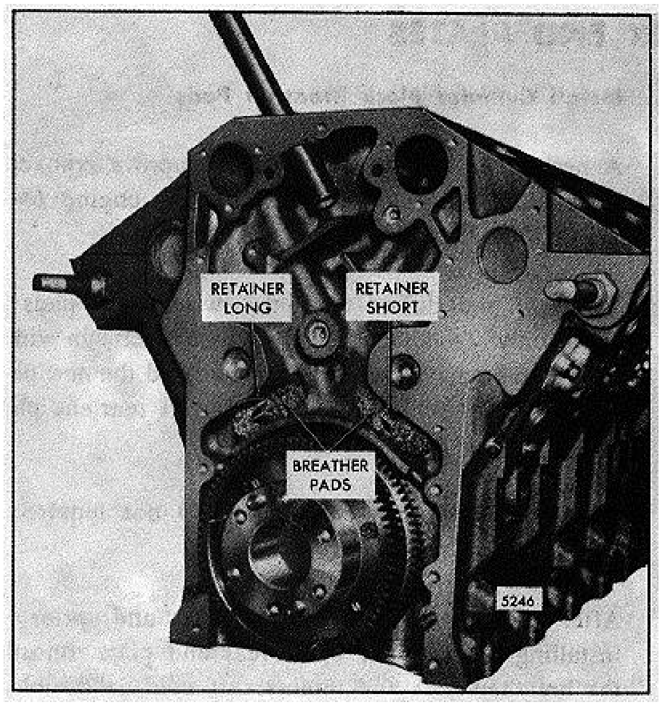


FIG. 2 - Current Breather Pads and Retainers Installed in Cylinder Block

Install End Plates

1. Affix new gaskets to the ends of the cylinder block, using a non-hardening gasket cement. Also apply an even coating of gasket cement to the outer surface of each gasket (the surface next to the end plate). Also attach the small round gasket to the corner at the front end of the cylinder block (Fig. 1).

- **NOTE:** Do not use the V-92 gasket on engines built prior to January, 1977. Use the V-71 front end plate gasket that has been reinstated for service.

2. Attach the front end plate to the cylinder block with bolts and lock washers. Tighten the bolts finger tight.

3. Wipe the excess gasket cement from the bores in the end plate and the cylinder block.

4. Insert the right bank camshaft end bearing through the SMALL bearing bore in the end plate and into the bore of the block to accurately align the end plate with the cylinder block as shown in Fig. 3.

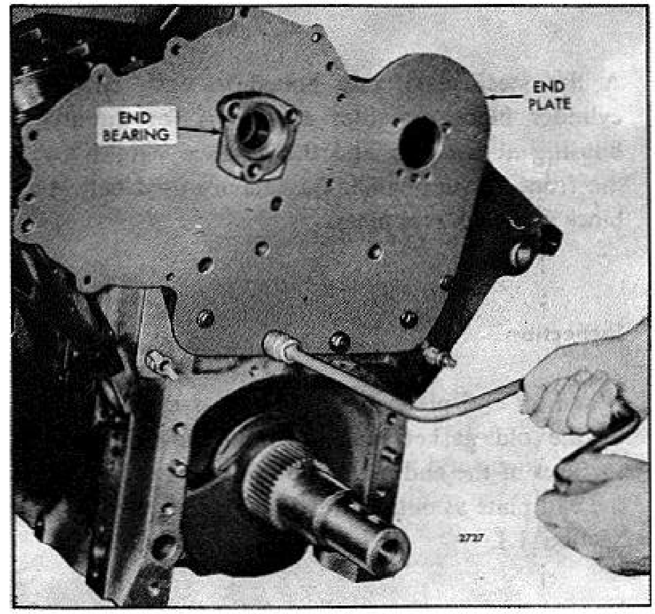


FIG. 3 - Installing Front End Plate (8V Engine)

NOTE: The holes in the front and rear end plates for the camshaft end bearings are not the same size. The smaller hole is accurately machined for alignment purposes and is always located on the right side of the engine as viewed from the rear.

5. With the bearing in place. tighten the 1/2"-13 end plate-to-cylinder block bolts to 71-75 lb-ft (96-102 Nm) torque. Tighten the 3/8"-16 bolts to 3(0-35 lb-ft (41-47 Nm) torque. Then remove the camshaft bearing which served as a pilot while attaching the front end plate.

NOTE: On former blocks, tighten the 3/8"-16 bolts which thread into the special water jacket plugs in the cylinder block to 20-25 lb-ft (27-34 Nm) torque. On certain engines, a special washer is used with these bolts.

6. Install the rear end plate in the same manner as outlined above for the front end plate.

NOTE: If used, attach the small cover to the cylinder block side of the rear end plate with two bolts and copper washers prior to installing the end plate. Use a new gasket between the cover and the end plate.

7. Trim off any excess gasket material.

AIR BOX DRAINS

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 the air box pressure through air box drain tubes mounted on the sides of the cylinder block (Fig. 1, 2 or 3).

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

Certain 6 and 8V upright engines have the air box drain tubes routed to the crankcase at the rear dipstick holes at each side of the engine, rather than to the atmosphere (Fig. 2).

In conjunction with the new drain tubes, a check (control) valve has been installed in the air box drain fitting on each side of the engine to allow drainage only at low air box pressures.

The check valve cutaway shows the valve operating at engine idle speed (Figs. 2 and 3). As the engine speed and air box pressure increase, the valve moves forward and seats, blocking air-flow. The check valve is only serviced as an assembly.

Effective with engines built approximately June, 1981,

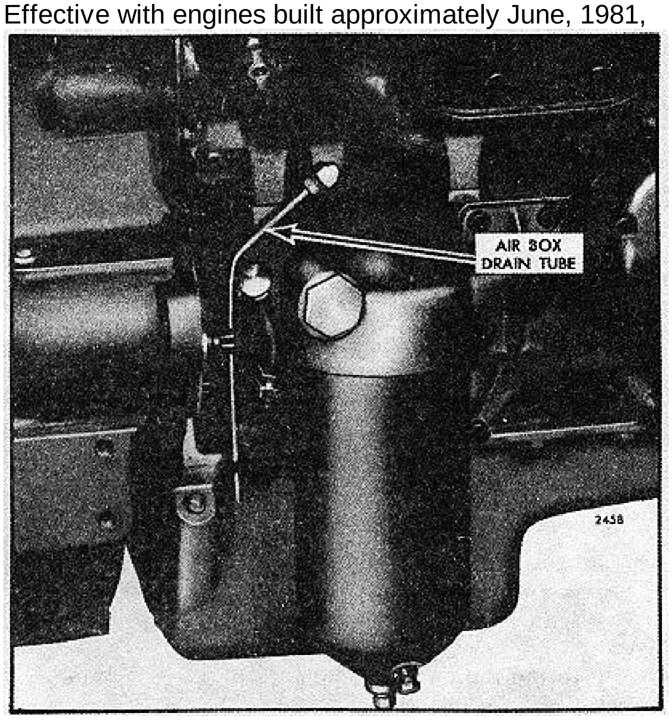


FIG. 1 - Air Box Drain Tube

the air box drains are being routed to the atmosphere (Fig. 3). Engines which have a closed air box drain system (Fig. 2) can be equipped with an open air box system (Fig. 3) - see *Shop Notes* in Section I.0.

Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to Section 15. 1).

> **NOTE**: Engines built prior to January 18, 1979 which use a 1/8"-18 pipe nipple in the sides of the air box drain system should be kept open. If plugged, this could cause a loss of engine lubricating oil.

Inspect the check valve for proper operation as follows:

1. Disconnect the drain tube from the check valve.

2. Run the engine and note the airflow through the valve at idle speed.

3. If the check valve is operating properly, there will be no airflow at engine speeds above idle.

To check the air box pressures on an engine with a closed air box drain system, use an air box cover with a tapped hole for a fitting.

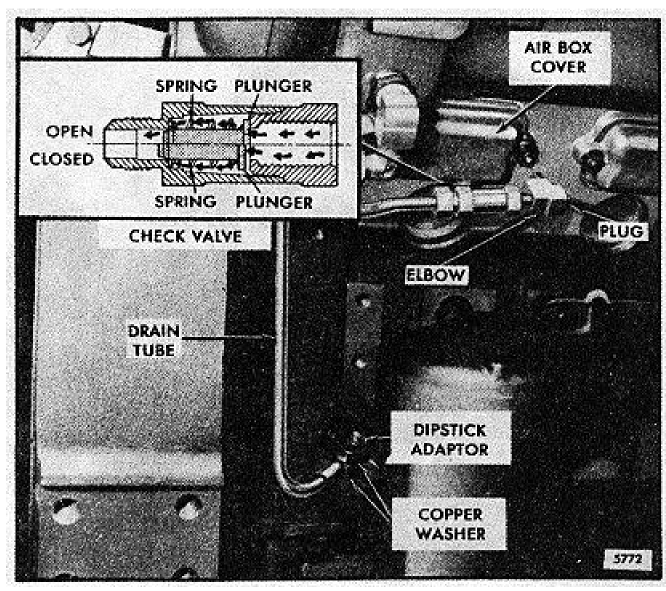


FIG. 2 - Closed Design Air Box Drain Tube and Check Valve System (6 and 8V Engines)

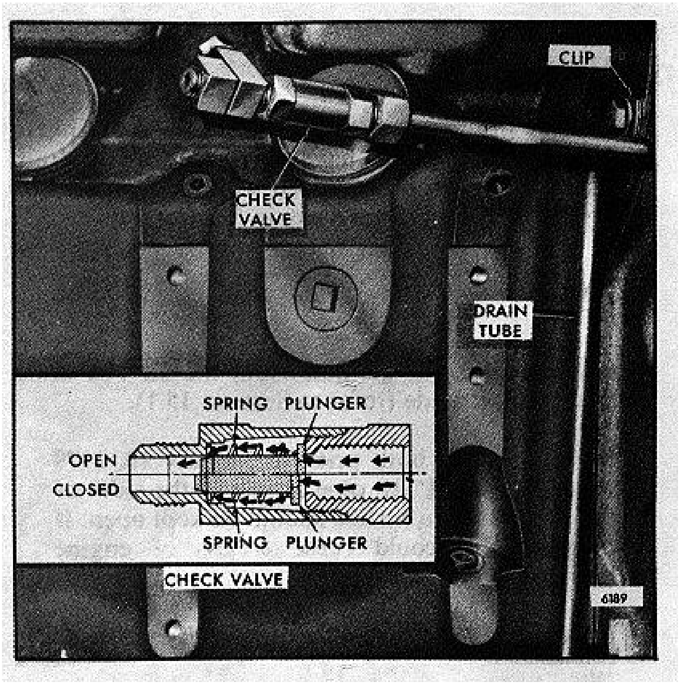


FIG. 3 - Open Design Air Box Drain Tube and Check Valve System

1. Remove the plug in the cover.

2. Install a fitting and short drain tube.

3. Attach a manometer to the end of the drain tube and check the air box pressure as stated in Section 13.2.

CYLINDER HEAD

The cylinder head (Figs. 1, 2 and 3), one on each cylinder bank, is a one-piece casting securely held to the cylinder block by special bolts.

The exhaust valves, fuel injectors and the valve and injector operating mechanism are located in the cylinder head.

Depending upon the engine application, either two or four exhaust valves are provided for each cylinder.

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

To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube (Fig. 4) which passes through the water space 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

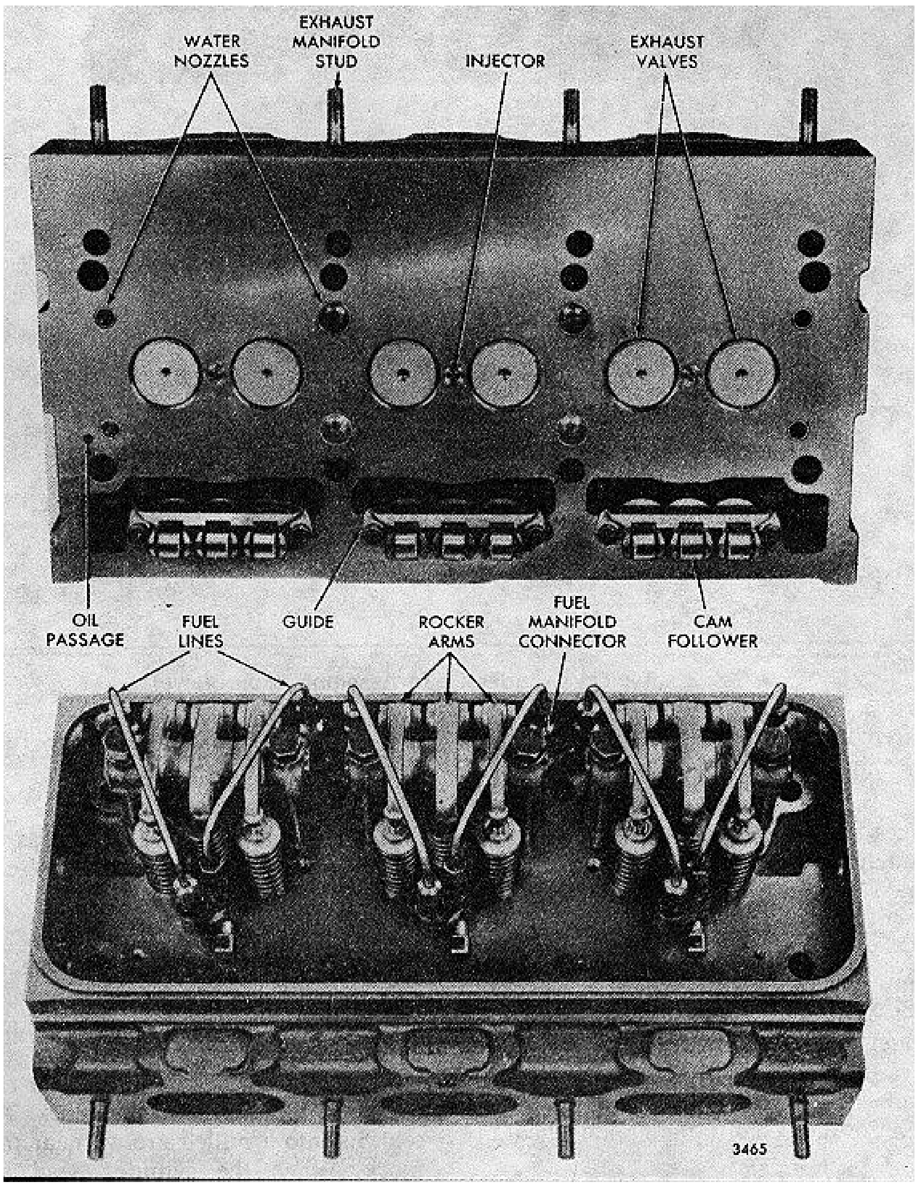


FIG. 1 - Typical Cylinder Head Assembly (Two-Valve)

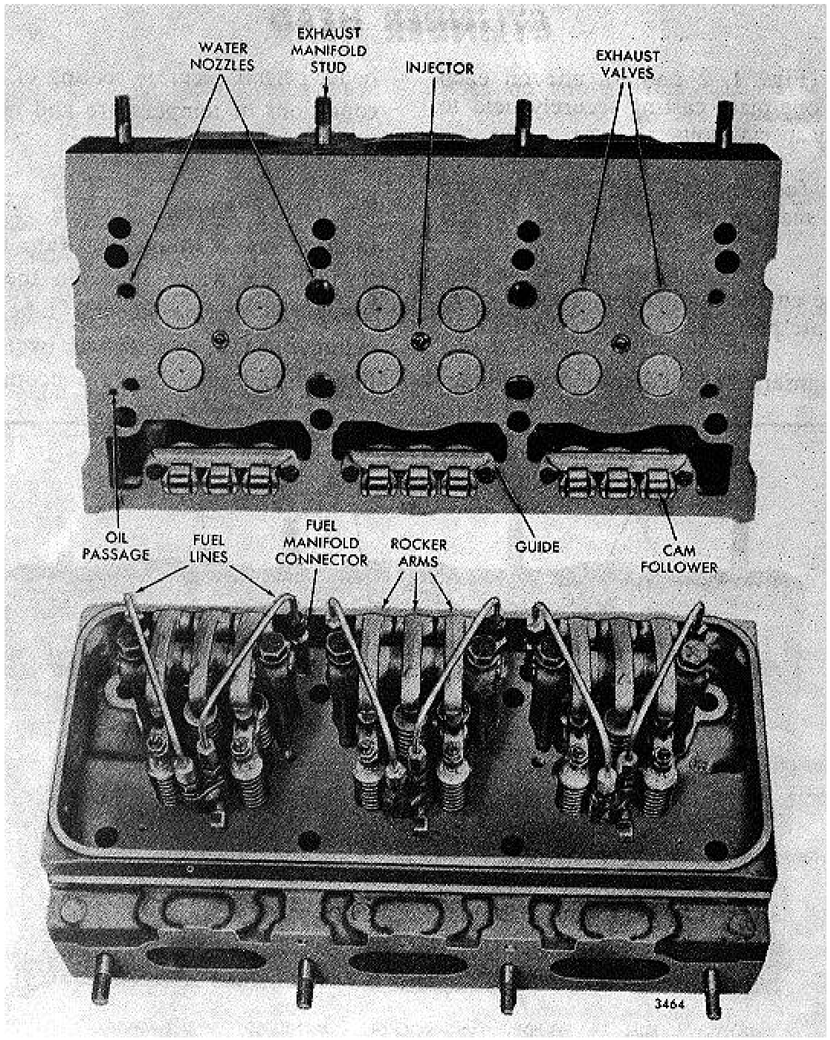


FIG. 2 - Typical Cylinder Head Assembly (Four-Valve)

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 lead through a single port to the exhaust manifold. The exhaust passages and the injector tubes are surrounded by engine coolant.

In addition, cooling of the above areas is further ensured by the use of water nozzles (Figs. 5 and 6) pressed into the water inlet ports in the cylinder head.

The nozzles direct, the comparatively cool engine coolant at high velocity toward the sections of the cylinder head which are subjected to the greatest heat.

The fuel inlet and outlet manifolds are cast as an integral part of the cylinder heads. Tapped holes are Page 2 provided for connection of the fuel lines at various points along each manifold.

The water manifold is also cast as an integral part of the cylinder head for 6V and 8V engines and certain current 12V engines.

To seal compression between the cylinder head and the cylinder liner,, separate laminated metal gaskets are provided at each cylinder. Water and oil passages between the cylinder head and cylinder block are sealed with synthetic rubber seal rings which fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block. When the cylinder head is drawn down, a positive leakproof metal-to-metal contact is assured between the head and the block.

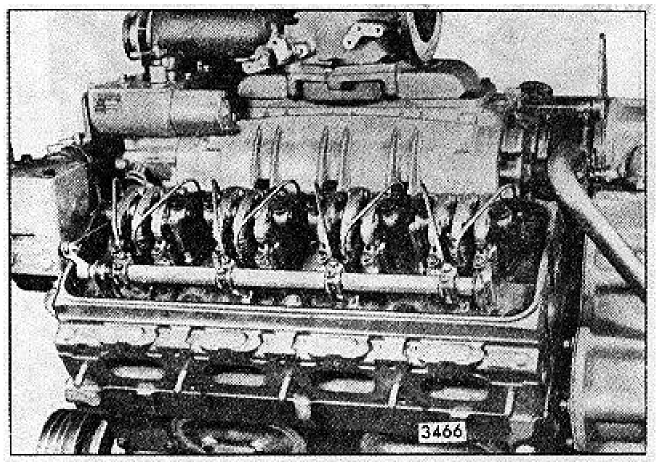


FIG. 3 - Cylinder Head Mounting

To make the cylinder heads more tolerant of abnormal coolant temperature, relief areas have been cast in the current four valve cylinder heads. These stress relief areas, which are shaped like a "dog bone", are cast in the fire deck of the cylinder head between the cylinders (Fig. 7). For visual identification of the current cylinder head on an engine, two bosses (at a later date a raised boss the shape of a "dog bone") are cast on the fuel manifold side of the three cylinder heads (6V engines) and a raised boss the shape of a "dog bone" is cast on the exhaust manifold side of the four (8V engines) and six (12V engines) cylinder heads

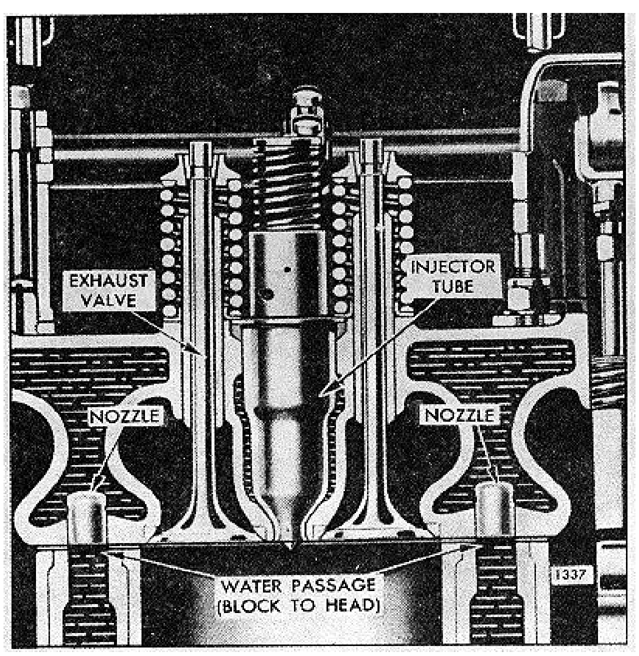


FIG. 4 - Coolant Passages Around Exhaust Valves and Fuel Injectors (C 1980 General Motors Corp.

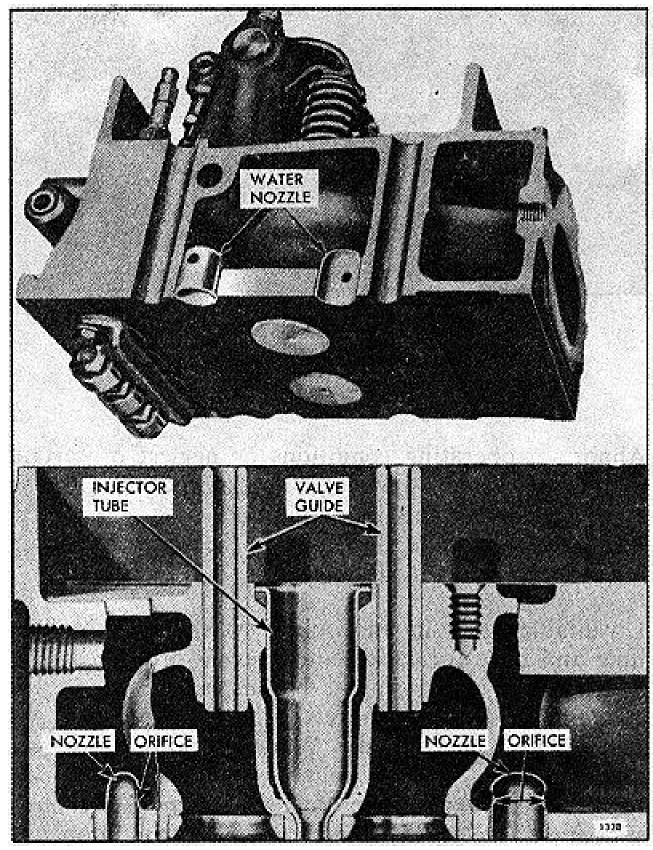


FIG. 5 - Water Nozzles in Two-Valve Cylinder Head

(Fig. 8). The current service cylinder heads which include the stress relief areas in the fire deck also include the nonmagnetic turbo exhaust valve inserts identified by the letter "T" stamped on the face of the cylinder head.

NOTE: Production non-turbocharged cylinder heads include cast steel exhaust valve seat inerts which have magnetic qualities. An easy method for determining the type of exhaust valve seat insert in a cylinder head is with a magnet. The magnet will be attracted to the non-turbo insert (will stick). The magnet will not be attracted to the turbo insert, it will jump to the cyliner head.

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. The cylinder head fire deck will overheat and crack in a short time if the coolant does not cover the fire deck surface. When necessary, add coolant slowly to a hot engine to avoid rapid cooling which can result in distortion and cracking of the cylinder head (and cylinder block).

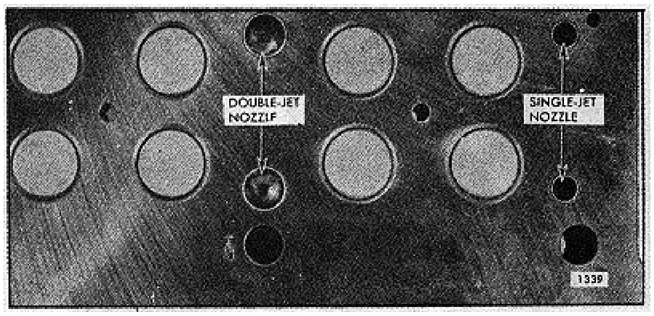


FIG. 6 - Water Nozzles in Four-Valve Cylinder Head

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 find the cause and avoid a recurrence of the failure.

Unsuitable water in the cooling system may result in lime and scale formation and prevent proper cooling. 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 non-corrosive 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.

Overtightened injector clamp bolts may also cause head cracks. Always use a torque wrench to tighten the bolts to the specified torque.

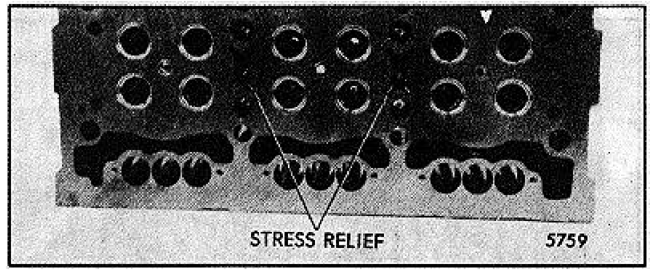


FIG. 7 - Current Four Valve Cylinder Head

Other conditions which may eventually result in cylinder head cracks are:

1. Excess fuel in the cylinders caused by leaking injectors.

2. Slipping fan belts can cause overheating by reducing air flow through the radiator.

3. Accumulation of dirt on the radiator core which will reduce the flow of air and slow the transfer of heat from the coolant to the air.

4. Inoperative radiator cap which will result in loss of coolant.

Remove Cylinder Head

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

1. Remove and install pistons.

2. Remove and install cylinder liners.

3. Remove and install exhaust valves.

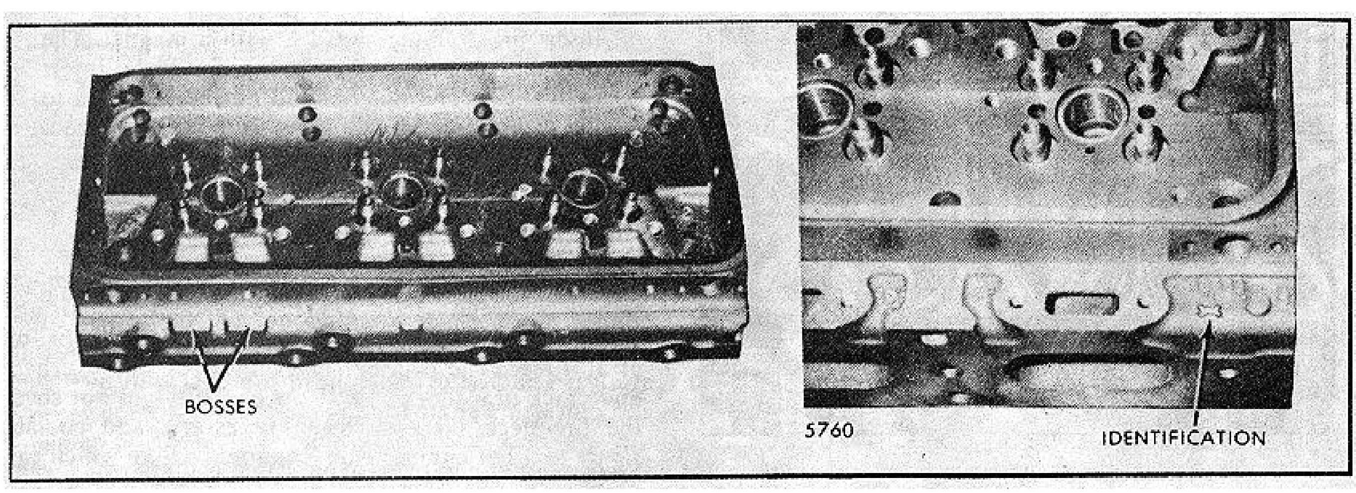


FIG. 8 - Current Four Valve Cylinder Head Identification

4. Remove and install exhaust valve guides.
5. Recondition exhaust valves and valve seat inserts.
6. Replace fuel injector tubes.
7. Install new cylinder head gaskets and seals.
8. Remove and install camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of the cylinder head are covered. If the engine is equipped with 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. Disconnect the exhaust piping at the exhaust manifold. On turbocharged engines, remove the connections from the exhaust manifold to the turbocharger. Remove the turbocharger, if necessary.
3. Disconnect the fuel lines at the cylinder head.

4. Loosen the hose clamps and remove the hose attached to the thermostat housing cover.

5. Loosen the hose clamps at each end of the water bypass tube and remove the tube.

6. Remove the thermostat housing assembly.

7. Clean and remove the valve rocker cover and governor cover.

8. Disconnect the fuel rod from the injector control tube lever and the governor. Remove the fuel rod.

9. Loosen the fuel rod cover hose clamps. Then slide the hose up on the fuel rod cover toward the governor.

10. Remove the exhaust manifold.

11. Remove the water manifold, if used.

12. Remove the injector control tube and brackets as an assembly.

13. If the cylinder head is to be disassembled for reconditioning of the exhaust valves and valve seat inserts or for a complete overhaul, remove the fuel pipes and injectors at this time. Refer to Section 2.1 or 2.1.1 for removal of the injectors.

14. Check the torque on the cylinder head bolts and stud nuts (if used) before removing the head. Then remove the bolts and stud nuts (if used) and lift the cylinder head from the cylinder block with tool

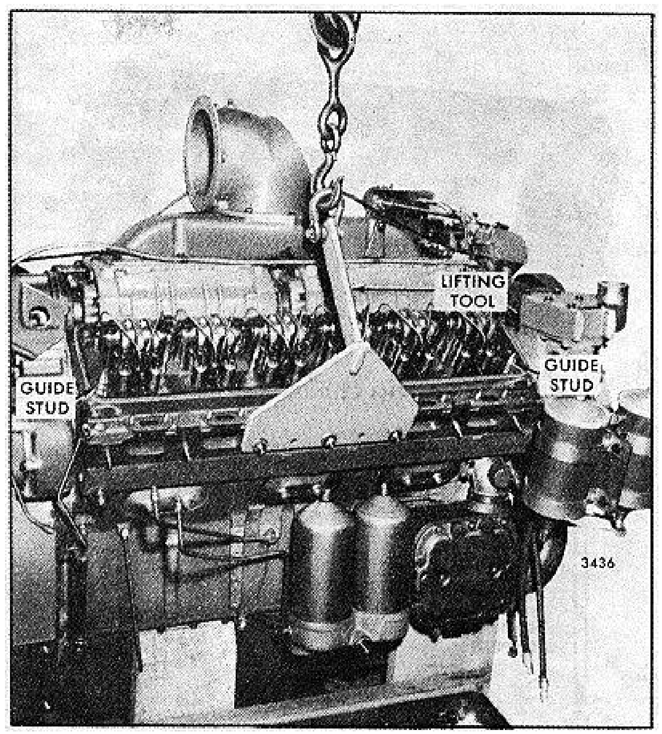


FIG. 9 Removing or Installing Cylinder Head with Tool J 22062-01

J 22062-01 (Fig. 9). If interference is encountered between the rear end of the right-bank cylinder head and any of the flywheel housing attaching bolts, loosen the bolts. Checking the torque before removing the head bolts and' examining the condition of the compression gaskets and seals after the head is removed may reveal the causes of any cylinder head problems.

NOTE: When placing the cylinder head assembly on a bench, protect the cam followers and injector spray tips, if the injectors were not

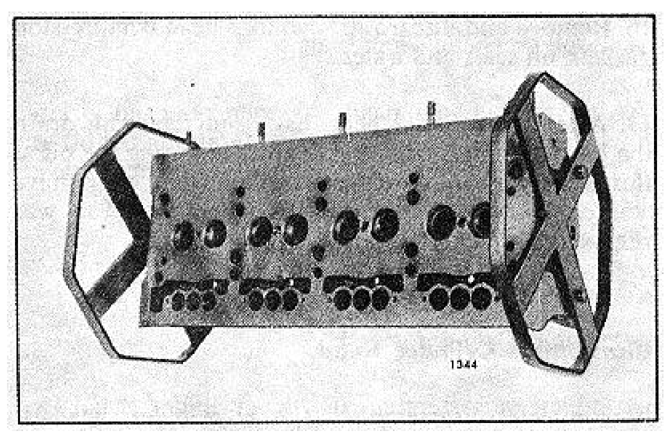


FIG. 10 - Cylinder Head Mounted on Holding Plates (J 3087-01)

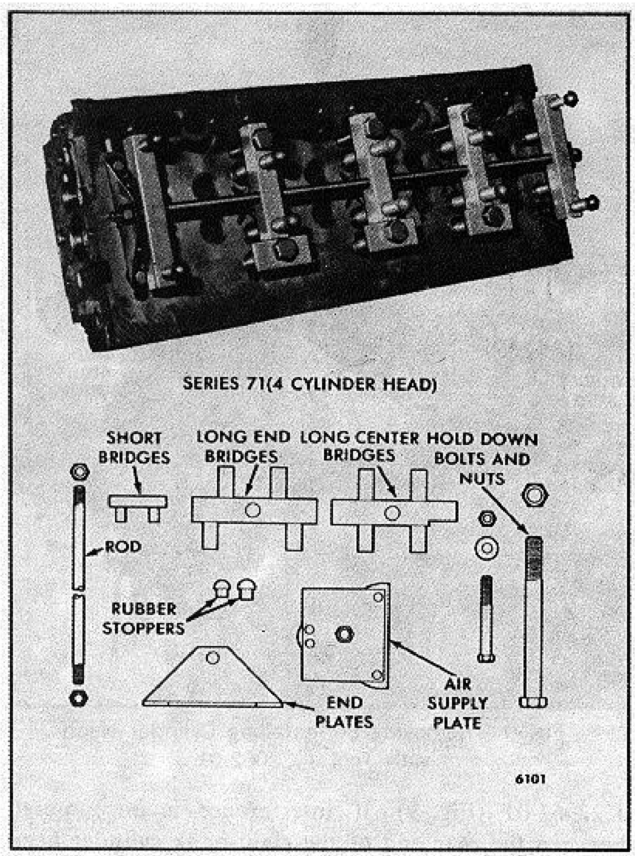


FIG. 11 - Cylinder Head Prepared for Pressure Testing using Tool J 28454

removed, by resting the valve side of the head on 2 " wood blocks.

15. Place the cylinder head on its side and remove the engine lifter brackets and gaskets. Then attach the cylinder head holding plates J 3087-01 (Fig. 10) to raise the head above the work bench.

16. Remove and discard the cylinder head compression gaskets, oil seals and water seals.

17. 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, refer to Sections 1.2.1 and 1.2.2 for removal of the exhaust valve and injector operating mechanism.

Clean Cylinder Head

After the cylinder head has been disassembled and all of the plugs (except cup plugs) have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes and water nozzles. Then clean the cylinder 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.

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:

> **NOTE**: 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.

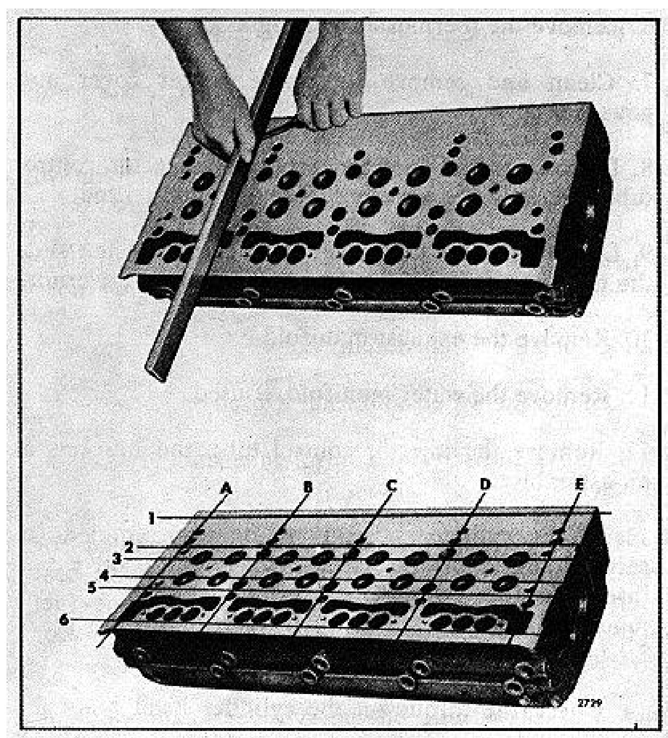


FIG. 12 - Checking Bottom Face of Cylinder Head

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".

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 as follows:

a. To seal off the water holes in the cylinder head. assemble tool set J 28454 as follows (Fig. 11):

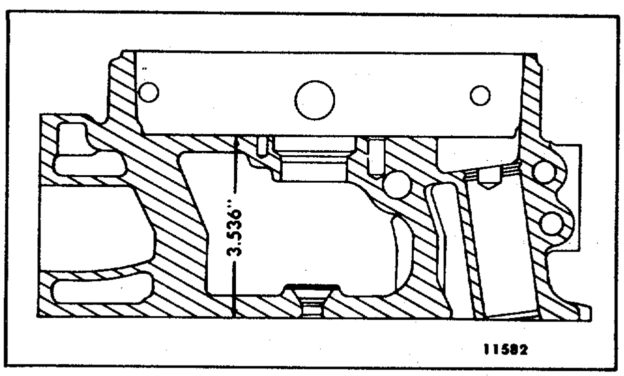


FIG. 13 - Minimum Distance Between Top and Bottom Faces of Cylinder Head

1. Install the rubber stoppers on the bridges.

   a. Large stoppers are installed on the long center bridge feet opposite the notch and on the long end bridge feet closest together.

   b. Small stoppers are installed opposite the large stoppers on center bridge and end bridge feet and on all short bridges.

2. Install the necessary parts, loosely, on the cylinder head.

3. Tighten the hold down bolts until the stoppers start to distort. A 5 Ib-ft (7 Nm) torque is usually sufficient.

NOTE: Do not overtighten the hold down bolts. The rubber stopper could distort enough to seal both the inner and outer diameter of the water nozzles. If the outer diameter is sealed, a leak from the outer diameter would not be detected.

4. Install the air supply plate.

NOTE: Do not hook onto the pressure checking tool, or any part of it, to move the cylinder head from one location to another. If this is done it could result in permanent damage to the tool.

b. Install scrap or dummy injectors to ensure proper seating of the injector tubes. Dummy injectors may be made from old injector nuts and bodies --the injector spray tips are not necessary. Tighten the injector clamp bolts to 20-25 Ib-ft (27-34 Nm) 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. Check for leaks at the top and bottom of the injector tubes, oil gallery, exhaust ports, fuel manifolds and at the top and bottom of the cylinder head.

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

2. Check the bottom (fire deck) of the cylinder head f(or flatness:

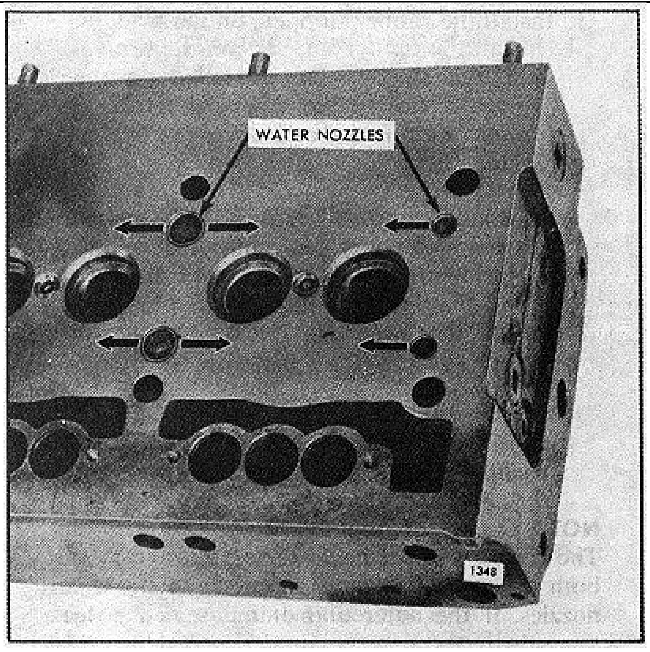


FIG. 14 - Correct Installation of Water Nozzles in Two-Valve Cylinder Head

a. Use a hedvy, accurate straight-edge and feeler gages, tool J 3172, to check for transverse warpage at each end and between all cylinders. Also check for longitudinal warpage in six places as shown in Fig. 12. Refer to Table I for maximum allowable warpage.

b. Use the measurements obtained and the limits given in Table I as a guide to determine the

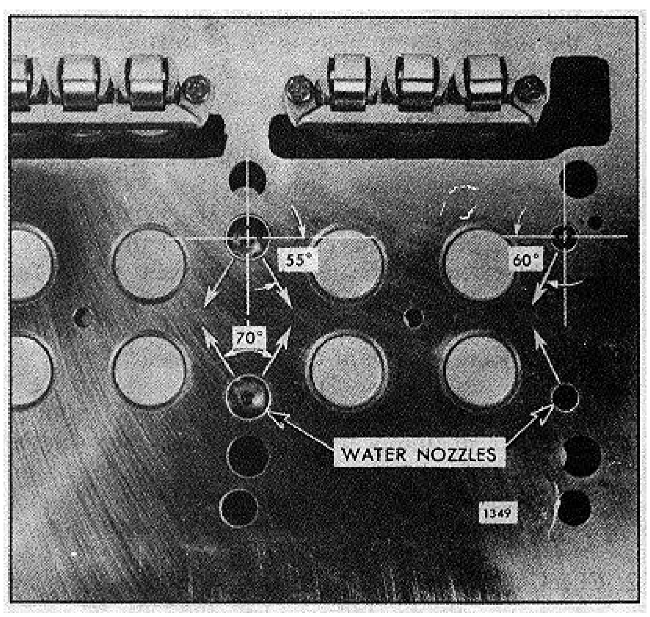


FIG. 15 - Correct Installation of Water Nozzles in Four-Valve Cylinder Head

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
6V	.0055"	.004"
8V	.008"	.00411
12V	.010"	.004"

TABLE 1

advisability of reinstalling the head on the engine or of refacing it. The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

c. If the cylinder head is to be refaced, remove the injector tubes prior to machining. Do not remove more metal from the fire deck of any cylinder head below the minimum distance of 3.536" (Fig. 13).

NOTE: When a cylinder head has been refaced, critical dimensions such as the protrusion of valve seat inserts, exhaust valves, injector tubes and injector spray tips must be checked and corrected. The push rods must also be adjusted to prevent the exhaust valves from striking the pistons after the cylinder head is reinstalled in the engine. Also, deburr the water nozzles.

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

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

5. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameters with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record and compare the readings of the followers and bores to determine the can follower-to-bore clearances. The clearance must not exceed .006" with used parts (refer to Section 1.() for specifications). If the bores are excessively scored or worn, replace the cylinder head.

6. Check the water hole nozzles to be sure they are not loose. If necessary, replace the nozzles as follows:

a. Remove the old nozzles.

b. Make sure the water inlet ports in the cylinder head are clean and free of scale. The water holes at each end of the head may be cleaned up with a 1/2" drill and the intermediate holes may be cleaned up with a 13/16" drill. Break the edges of the holes slightly.

c. Press the nozzles in place with the nozzle openings parallel to the longitudinal centerline of the *two-valve* cylinder head (Fig. 14). Install the 1/2" diameter nozzles at the ends of the cylinder head with their openings toward the center of the engine. For the positioning of the nozzles in a *four-valve* cylinder head, refer to Fig. 15. Press the nozzles flush to .0312" recessed below the surface of the cylinder head.

d. Check to make sure the nozzles fit tight. If necessary, use a wood plug or other suitable tool to expand the nozzles, or tin the outside diameter with solder to provide a tight fit. If solder is used, make sure the orifices in the nozzles are not closed with solder.

7. Replace broken or damaged studs. Apply sealant to the threads of new studs and drive them to 10-25 lb-ft (14-34 Nm) torque (water manifold cover studs) or to 25-40 lb-ft (34-54 Nm) torque (exhaust manifold studs).

8. Pilot sleeves have been added to the head mounting bolt holes at each end of the four-valve cylinder heads (on the camshaft side of current heads or exhaust side of former heads). Make sure the sleeves are flush or recessed below the fire deck of the cylinder head. Replace damaged sleeves. Pilot sleeves can be installed on early cylinder heads by reaming the end bolt holes (camshaft side of head) to .687"-.688" diameter by .750" deep and pressing the sleeves flush or slightly recessed below the fire deck. The sleeves, which act as a hollow dowel to provide a closer fit between the mounting bolts and the cylinder head, help to guide the head in place without disturbing the seals and gaskets.

9. 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, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust preventive compound is to immerse the head in a mineral spirits based solvent or fuel oil, then scrub the head and go through all of the openings with a soft bristle brush. A suitable brush for cleaning the various passages in the head can be made by attaching a 1/8" diameter brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, water nozzles, injector tubes, pilot sleeves, bridge guides, valve spring seats and the necessary plugs. In addition, studs, cover plates, gaskets, lock washers and nuts are provided to seal the water outlet openings that are not required on

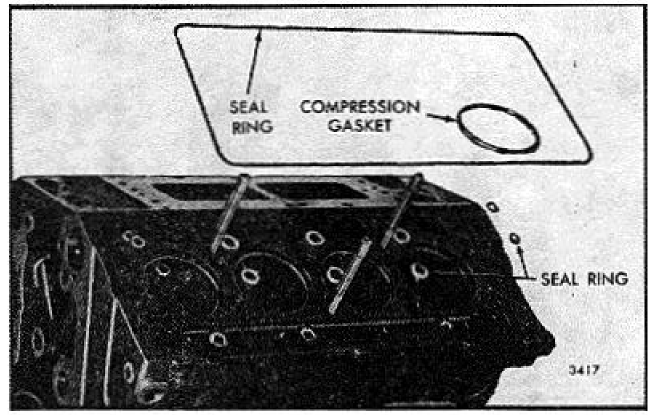


FIG. 16 - Cylinder Head Seals and Gaskets

certain engines. A length of flexible fuel hose and fittings are also included where required.

Assemble Cylinder Head

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

1. Coat the threads of the plugs with Loctite Pipe Sealant with Teflon, then install the necessary plugs and tighten them to the specified torque (Section 1.0). Drive headless plugs flush to .0625" below the surface of the cylinder head. The 3/8" socket head oil gallery plug, at each end of the head, must not protrude more than .0625", and a .2187" diameter rod placed in the vertical oil feed hole must pass the inner face of the plug. Refer to the *Cylinder Head Plugging Charts* shown as fold-outs at the end of this manual.

2. After the following parts are cleaned, inspected and replaced, if necessary, reinstall them in the old cylinder head or transfer them to the new head.

a. Exhaust valves, valve seat inserts and springs (Section 1.2.2).

b. Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets and other related parts (Section 1.2.1).

c. Place new washers on the fuel connectors. The install the connectors and tighten them to 40-45 lb-ft (54-61 Nm) torque.

d. The fuel injectors, fuel pipes, injector control tube assembly and water manifold, if used, can be installed at this time or after the cylinder head is installed on the engine.

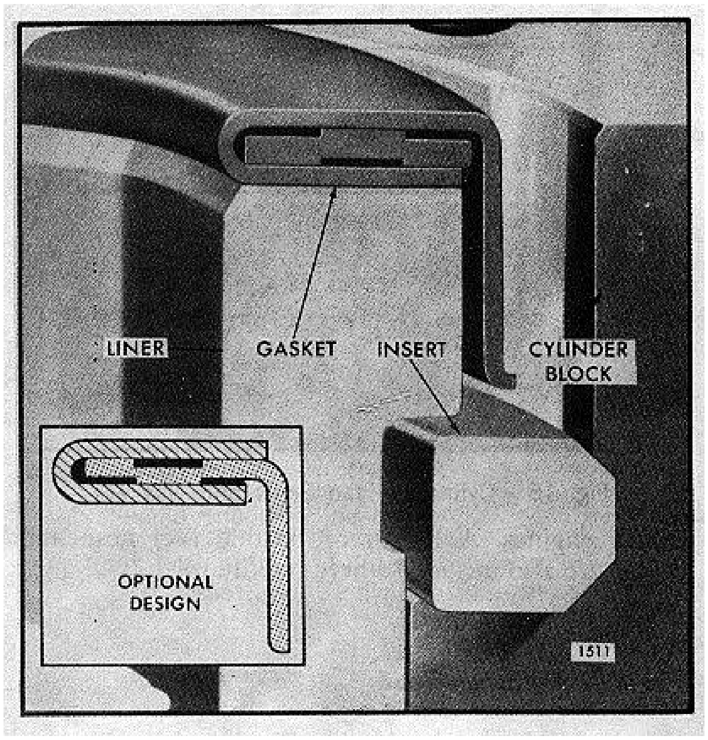


FIG. 17 Compression Gasket Mounting in Cylinder Block

Pre-Installation Inspection

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

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

2. Make sure the piston crowns are clean and free of foreign material.

3. Make sure that each push rod is threaded into its clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is rotated during engine tune-up.

4. Check the cylinder block and cylinder head gasket surfaces, counterbores and seal grooves to be sure they are clean and free of foreign material. Also check to ensure that there are no burrs or sharp edges in the counterbores.

5. 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.

NOTE: The 2.00" diameter cup plug (thermostat housing end) in a new two-valve service head for the 6V and 12V engine or the 3/4" pipe plug at the front end of the 12V four-valve service head must be removed prior to installation to prevent blocking the coolant flow out of the head. Before installing a new four- valve cylinder head, remove the 2.00)" plug from the 6V and 8V cylinder heads.

Install Cylinder Head

1. Refer to Fig. 16 and install the water and oil seal rings and compression gaskets as follows:

NOTE: Never install used gaskets or seals.

a. Place a new compression gasket on top of each cylinder liner. A new cylinder liner compression gasket with improved sealing capabilities is now being used (Fig. 17). The new gasket can be identified by GM-MC-H, GM-VG-H or GM-FP-H. The compression gasket is also color coded black, orange or white. The service gasket kits will only include a single color (black or orange). Only one color compression gaskets (seal) can be used under a single cylinder head to provide proper clamping.

NOTE: The new cylinder liner compression gasket is not interchangeable on an engine under the same cylinder head with the former compression gasket. Mixing of the former gasket with the new gasket could result in uneven loading.

b. Place new seal rings in the counterbores of the water and oil holes in the cylinder block. Silicone-composition water hole seals can be damaged if they move out of position in the cylinder block counterbore during engine rebuild. In turn, damaged seals can allow engine coolant to contaminate lube oil and cause serious engine damage. To prevent this, a spray adhesive may be used to hold seals in place if the following precautions are taken:

   1. Attach a mask or template to the cylinder block fire deck to minimize overspray.

   2. Using a high-tack, spray tube adhesive suitable for synthetic rubber seals (*3M Company Super-Tack Gasket Adhesive #8082,* or equivalent), spray a *light,* uniform coating of adhesive into the seal counterbores. Keep the adhesive off of adjacent block surfaces and wipe off any that gets on the fire deck or liner bores.

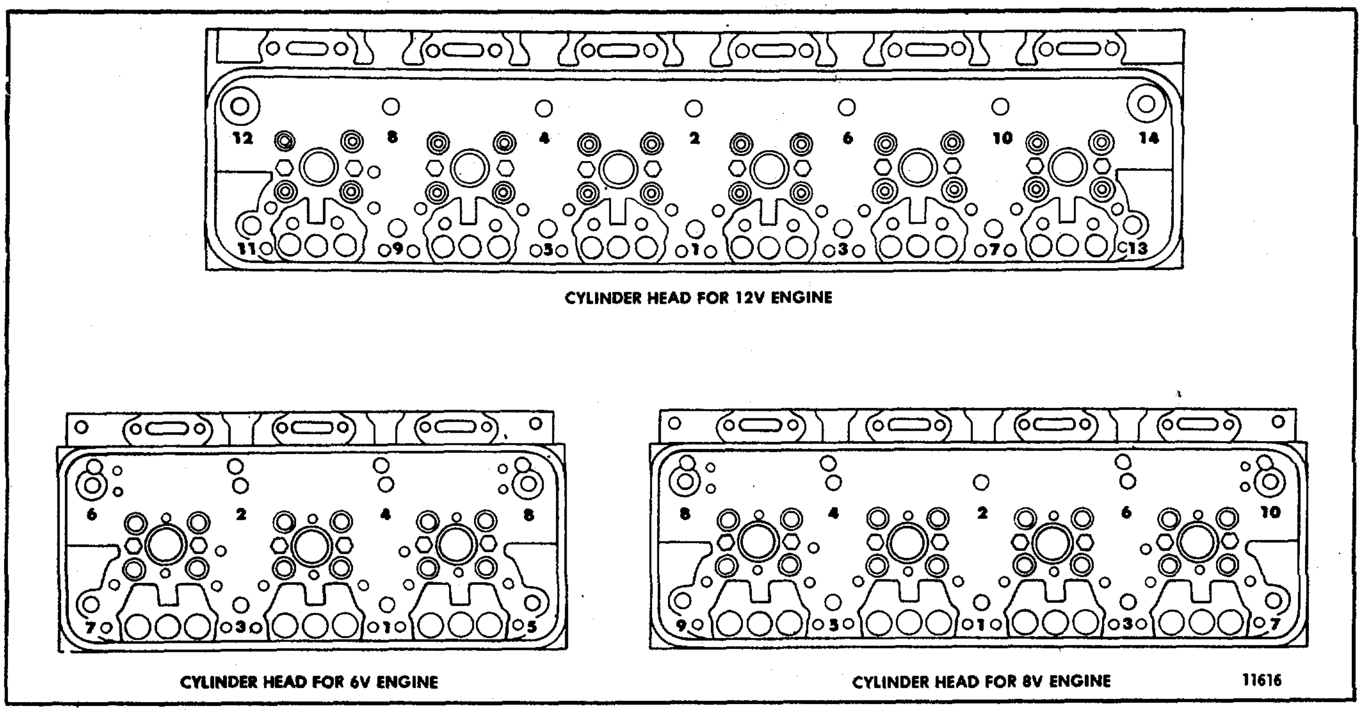


FIG. 18 - Cylinder Head Bolt Tightening Sequence

3. Allow the adhesive to dry to a high-tack consistency (stickiness) before installing the seal. This permits the evaporation of the liquid propellant used with the adhesive. Do not apply adhesive directly to the seal. The adhesive will coat the I.D. of the seal and the spray propellant may cause the seal to swell temporarily.

c. Install a new oil seal in the groove at the perimeter of the cylinder block. The seal must lay flat in the groove and must not be twisted or stretched when installed. Installing the seal strip in the groove with the colored stripe facing away from the cylinder bores can improve its sealing capabilities.

NOTE: 3M Company Super-Tack Gasket adhesive #8082 or equivalent may also be used to hold the peripheral head-to-block oil seals in place during engine rebuild.

2. To install the cylinder head on the engine without disturbing the gaskets and seals. install guide studs J 9665 (Fig. 9) in two corner bolt holes in the cylinder block.

NOTE: Current four-valve cylinder heads have piloting sleeves installed in the corner bolt holes on the camshaft side of the head (former heads had the piloting sleeves on the exhaust side). The sleeves provide more accurate alignment of the cylinder head with the block bores. *Do not install the guide studs in the bolt holes which line- up with the piloting sleeves in the head.* The guide studs are not required on early engines which include cylinder head studs in the block.

3. Attach lifting tool J 22062-01 to the cylinder head and lift the head into position above the cylinder block.

4. Make a final visual check of the compression gaskets and seals to ensure that they are in place before the cylinder head is lowered. *this is a very important check.* Gaskets and seals which are not seated properly will cause leaks and "blow-by" and result in poor engine performance and damage to the engine.

5. Wipe the bottom o(' the cylinder head clean. Then lower the head until it is about 1/2" from the surface of the cylinder block.

6. Apply a small amount of International Compound No. 2, or equivalent. to the threads and underside of the head of all cylinder head attaching bolts (to stud threads and head contact surface of stud nuts, if used). Then install a bo3t through each piloting sleeve (four-valve heads) at the corners of the head and thread them finger tight into the cylinder block. Continue to tighten these bolts (finger tight) as the head is lowered into position on the cylinder block.

NOTE: Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

7. After the head is in place, remove the guide studs and chain hoist and install the remaining bolts. running all bolts down snug tight with a speed handle (15-20 Ib-ft or 20-27 Nm torque). However, *before* tightening the bolts, loosen the lifter bracket-to-cylinder head attaching bolts, otherwise the head may be prevented from seating properly on the cylinder block. A similar condition could exist if the exhaust manifold is attached to the cylinder head. Clearance must be assured between the exhaust manifold and the bosses on the cylinder block. On some engine models, these bosses serve as a rest for the exhaust manifold after the cylinder head has been installed on the cylinder block.

8. Tighten the bolts to 175-185 lb-ft (238-251 Nm) torque in 50 lb-ft (68 Nm) increments with a torque wrench, in the sequence shown in Fig. 17. Repeat the tightening sequence at least once, because the first bolts tightened in the sequence tend to lose significant clamp load during tightening of the remaining bolts. 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. *Begin on the cam follower side of the head* to take up tension in the push rod springs. Tighten the bolts to the high side of the torque specification, but do not exceed the limit or the bolts may stretch beyond their elastic limits. Attempting to tighten the bolts in one step may result in trouble and consequent loss of' time in diagnosis and correction of difficulties, such as compression leaks, when the engine is put into operation.

NOTE: 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.

9. If the fuel injectors were not previously installed, refer to Section 2.1 or 2.1.1 and install them at this time.

10. On a four-valve cylinder head, adjust the exhaust valve bridges as outlined in Section 1.2.2.

11. Tighten the rocker arm bracket bolts to the specified torque (Section 1.0).

12. Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb-ft (16-20 Nm) torque.

NOTE: Do not bend the fuel pipes and 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 *Pressurize Fuel System -Check for Leaks* in Section 2.0).

13. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning the control tube, be sure the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10-12 lb-ft (14-16 Nm) torque.

14. After tightening the bolts, revolve the injector control tube to be sure the return spring pulls the injector racks out (no-fuel position) after they have been moved all the way in (full-fuel position). Since the injector control tube is mounted in self-aligning bearings, tapping the tube lightly will remove any bind that may exist. The injector racks *must* return to the no-fuel position freely by aid of the return spring only. *Do not bend the spring.* If necessary. replace the spring.

15. Install the fuel rods. Then slide the fuel rod cover hoses in place and tighten the clamps.

16. Connect the fuel lines.

17. Install the thermostat housing and thermostat.

18. Install the water manifold, if used.

19. Install the water bypass tube, hoses and clamps.

20 Install the thermostat housing cover, hose and clamps.

21. Install the exhaust manifold and connect the exhaust piping.

22. Install any other equipment that was previously removed.

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

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

VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the exhaust valve springs.

The rocker arms are operated by a camshaft through cam followers and short push rods extending through the cylinder head (Fig. 1).

Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to retain the cam followers in place and to align the cam follower rollers with the camshaft lobes.

A coil spring, inside of each cam follower, maintains a pre-determined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

Lubrication

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage on the camshaft side of the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms (Fig. 2).

Overflow oil from the rocker arms lubricates the exhaust valves, valve bridges and cam followers. The oil then drains from the top deck of the cylinder head through oil holes in the cam followers, into the camshaft pockets in the cylinder block and back to the oil pan.

The cam follower rollers are lubricated with oil from the cam followers, oil picked up by the camshaft lobes and by oil emitted under pressure from milled slots in the camshaft intermediate bearings.

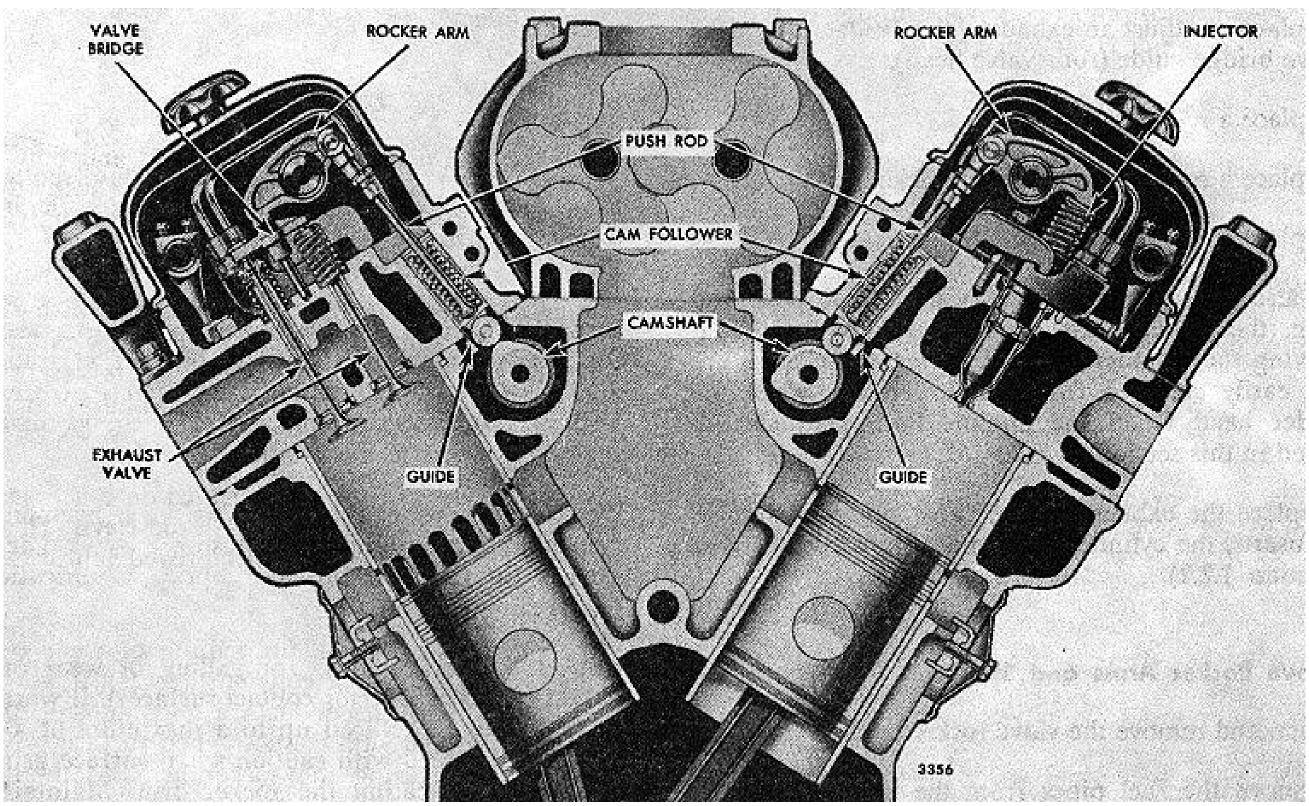


FIG. 1 Valve and Injector Operating Mechanism (Four-Valve Head)

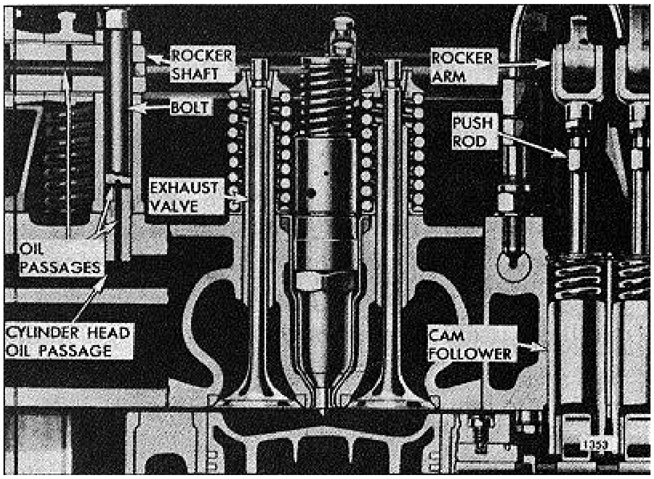


FIG. 2 - Lubrication of Valve Operating Mechanism

Service

Some service operations may be performed on the valve and injector operating mechanism without removing the cylinder head:

1. Adjust valve clearance.

2. Replace a valve spring.

3. Replace or adjust an exhaust valve bridge or replace a valve bridge guide (four-valve head).

4. Replace a rocker arm.

5. Replace a rocker arm shaft or bracket.

6. Replace a fuel injector.

It is also possible to replace a push rod, push rod spring, the spring seats or a cam follower without removing the cylinder head. However, these parts are more easily changed from the lower side when the cylinder head is off the engine. Both methods are covered in this section.

To replace the exhaust valves, valve guides and valve seat inserts, the cylinder head must be removed (refer to Section 1.2.2).

Remove Rocker Arms and Shaft

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from the injector and the fuel connectors.

NOTE: 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.

3. Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally.

NOTE: Do not bar the crankshaft in a left- hand direction of rotation with a wrench or barring tool on the crankshaft bolt, or the bolt may be loosened.

4. Remove the two bolts which secure the rocker arm shaft brackets to the cylinder head. Remove the brackets and shaft.

NOTE: When removing the rocker arm shaft, fold the three rocker arms back just far enough so the shaft can be removed. *Do not force the rocker arms all the way back with the shaft in place as this may impose a load that could bend the push rods.*

5. Loosen the lock nuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods.

NOTE: If the rocker arms and shafts from two or more cylinders are to be removed, tag them so they may be reinstalled in their original positions.

Inspection

Wash the rocker arms, shaft, brackets and bolts with clean fuel oil. Use a small wire to clean out the drilled oil passages in the rocker arms and rocker shaft bolts. Dry the parts with compressed air.

Inspect the rocker arm shaft and rocker arm bushings for wear. A maximum shaft to bushing clearance of .004" is allowable with used parts (refer to Section 1.0). Service replacement bushings must be reamed to size after installation.

The current injector rocker arm used on coach engines does not use a bushing at the push rod clevis. The bore area is "lubrited" to provide improved lubrication in this area.

Inspect the rocker arms for galling or wear on the pallets (valve or injector contact surfaces). If worn, the surface may be refaced up to a maximum of .101". However, proceed with caution when surface grinding to avoid overheating the rocker arm. Maintain the radius and finish as close to the original surface as possible. Also inspect the valve bridges (four-valve head) for wear.

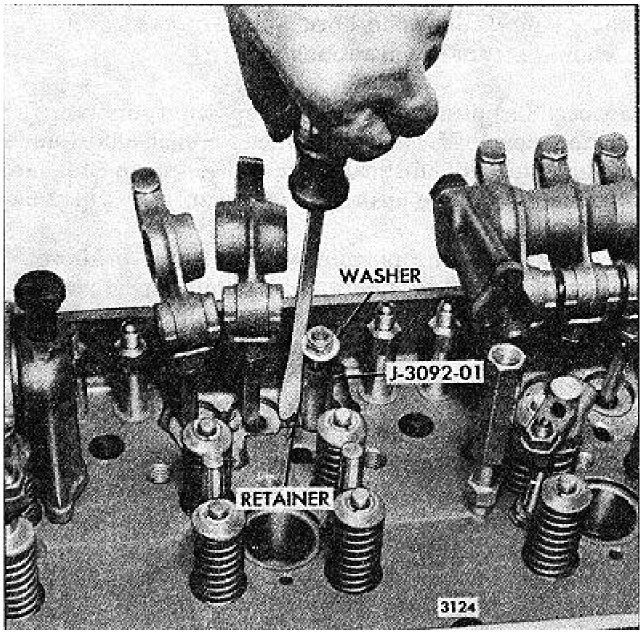


FIG. 3 - Removing Push Rod from Upper Side of Cylinder Head

Remove Cam Follower and Push Rod (with Cylinder Head on Engine)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

To remove a push rod, spring, spring seats and cam follower from the top of the cylinder head, proceed as follows:

1. Remove the rocker arm shaft and brackets as outlined under *Remove Rocker Arms and Shaft.*

2. Loosen the lock nut and unscrew the rocker arm from the push rod to be removed. Remove the lock nut.

3. Install remover J 3092-01, a flat washer and the lock nut on the push rod, with the lower end of the tool resting on the upper spring seat.

4. Thread the nut down to compress the spring.

5. Remove the spring seat retainer from the groove in the cylinder head (Fig. 3).

6. Unscrew the lock nut to release the spring. Then remove the nut, flat washer and tool from the push rod.

7. Pull the push rod, spring, spring seats and cam follower out of the cylinder head.

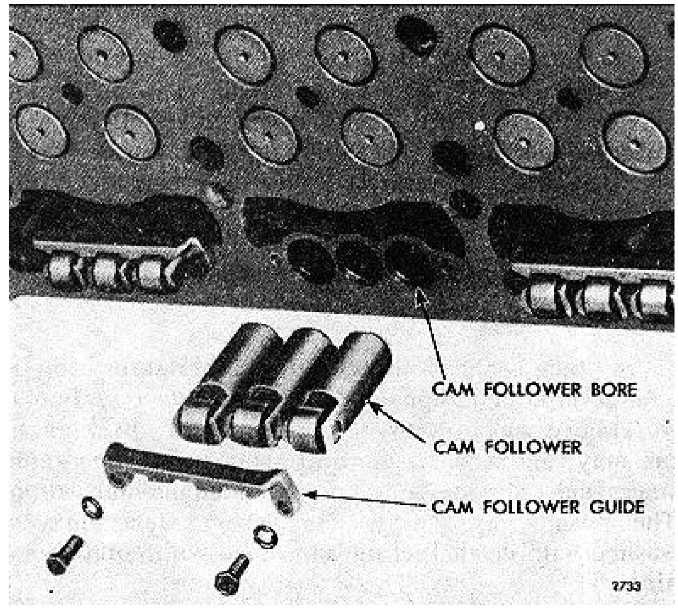


FIG. 4 - Cam Followers and Guide

Remove Cam Follower and Push Rod (Cylinder Head Removed)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

1. Rest the cylinder head on its side (Fig. 4) and remove the cam follower guide.

2. Pull the cam follower out of the cylinder head.

3. Remove the fuel pipes from the injector and the fuel connectors.

> **NOTE:** 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.

4. Loosen the push rod lock nut and unscrew the push rod from the rocker arm clevis.

5. Pull the push rod and spring assembly from the bottom of the cylinder head.

6. Remove the push rod lock nut, spring and spring seats from the push rod.

If the cylinder head is to be replaced, remove the spring retainers and install them in the new head.

Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial start-up of the engine since fuel oil does not provide adequate lubrication. The push rods, springs and spring seats may be washed with clean fuel oil and dried with compressed air.

Examine the cam follower rollers for scoring, pitting or flat spots. The rollers must turn freely on their pins. Measure the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Fig. 5. Cam followers stamped with the letter "S" on the pin, roller and follower body are equipped with an oversize pin and roller. The same clearances apply to either a standard or oversize cam follower assembly.

Examine the camshaft lobes for scoring, pitting or flat spots. Replace the camshaft if necessary.

Measure the cam follower bores in the cylinder head with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record the readings and compare the readings of the followers and bores to determine the cam follower-to-bore clearances (refer to Section 1.0 for specifications).

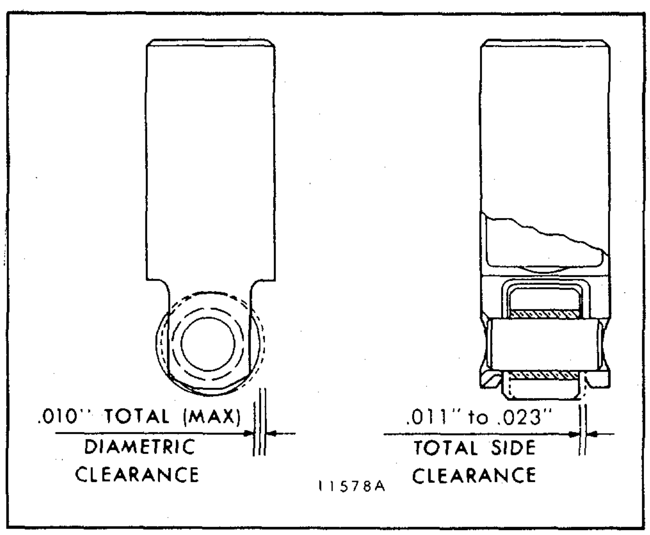


FIG. 5 Cam Roller Clearances

Inspect the push rods and spring seats for wear. The current push rods have milled wrench flats and a bright "turned" finish and the lower spring seats are serrated along the push rod contact surfaces (Fig. 6).

> **NOTE:** When replacing a push rod or lower spring seat, *do not* use a plain spring seat (Fig. 6) with a current type push rod. Any other combination of spring seat and push rod may be used.

Examine the cam follower springs for wear or damage and check the spring load. Replace a spring when a load of less than 172 lbs. (765 N) will compress it to a length of 2.125". Use spring tester J 22738-02 to check the spring load (Fig. 7).

Replace Cam Roller and Pin

To replace a cam roller and pin, proceed as follows:

> **NOTE:** Do not attempt to bore out the legs of a standard cam follower for an oversize pin.

1. Clamp fixture J 5840-01 securely in a vise as shown in Fig. 8. Then place the cam follower in the groove in the top of the fixture, with the follower pin resting on top of the corresponding size plunger in the fixture.

2. Drive the pin from the roller with a suitable drift. Exercise caution in removing the cam follower body and roller from the fixture as the roller pin is seated on a spring-loaded plunger in the fixture.

3. Before installing the new roller and pin, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil* After washing the parts, lubricate the roller and pin with Cindol 1705.

4. Position the cam follower body in the groove of the fixture, with the small plunger extending through the roller pin hole in the lower leg of the follower body.

5. Position the new cam roller in the cam follower body. When released, the plunger will extend into the roller bushing and align the roller with the cam follower body.,

6. Start the new pin in the cam follower body, then carefully tap it in until it is centered in the cam follower body.

7. Remove the cam follower from the fixture and

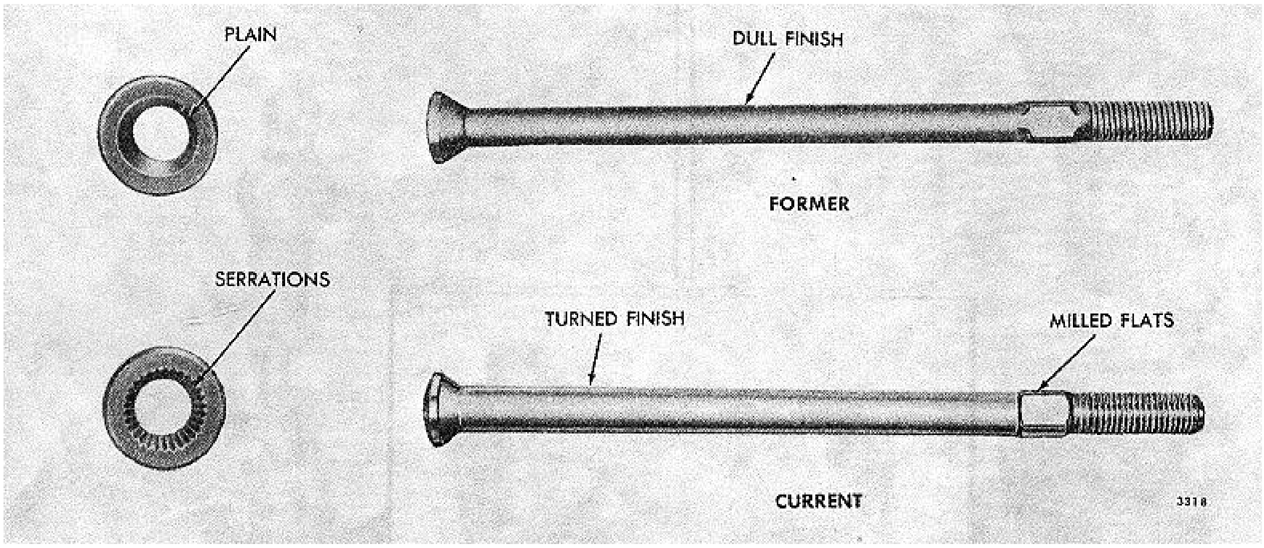


FIG. 6 - Comparison of Push Rods and Lower Spring Seats

check the side clearance (Fig. 5). The clearance must be .011" to .023 ".

Install Cam Follower and Push Rod

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

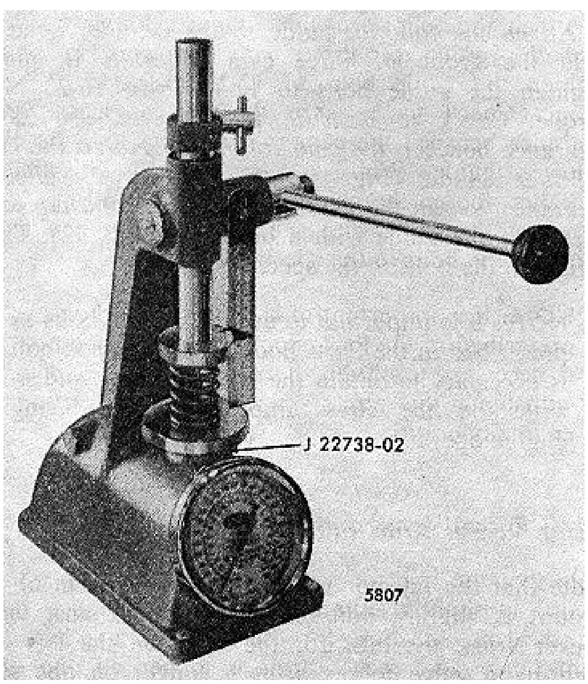


FIG. 7 - Testing Cam Follower Spring

Before cam followers are installed, immerse them in clean Cindol 1705 (heated to 100-125°F or 38-52°C) for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the cam 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 cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705, the cooling action of any air trapped in the bushing and pin area will tend to pull the lubricant into the cavity.

> **NOTE:** Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the cam followers from touching the bottom of the pail and avoid the possibility of contamination.

Install used cam followers and push rods in their original locations. Refer to Fig. 9 and proceed as follows:

CYLINDER HEAD ON ENGINE:

1. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves (Fig. 10), slide the cam follower in position in the cylinder head.

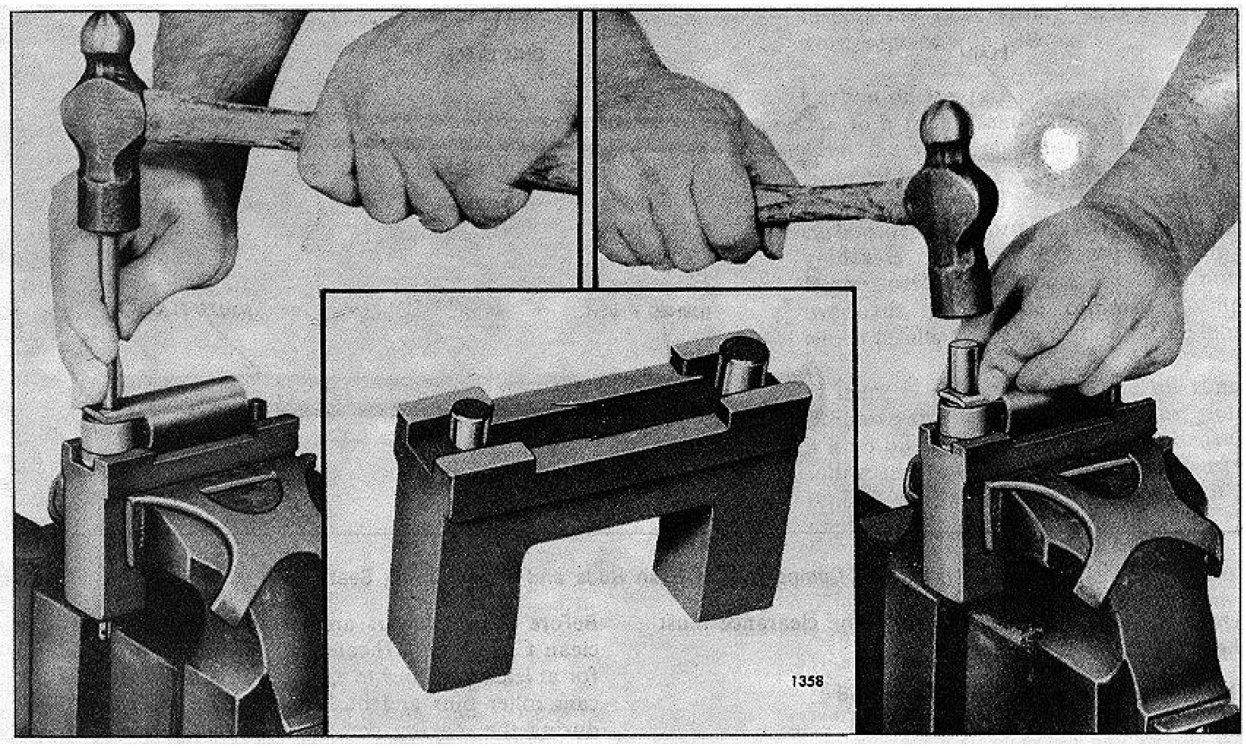


FIG. 8- Removing or Installing Cam Follower Roller and Pin

2. Assemble the *serrated* lower spring seat (Fig. 6), spring and upper spring seat on the push rod.

3. Place a flat washer over the upper spring seat and start the lock nut on the push rod. Place tool J 3092-01 on the push rod between the washer and the upper spring seat and place the push rod assembly in the cam follower. Then thread the lock nut on the push rod until the spring is compressed sufficiently to permit the spring retainer to be installed. Install the retainer with the tangs facing the notch in the cylinder head.

4. Remove the nut, flat washer and tool. Then reinstall the lock nut and thread it as far as possible on the push rod.

CYLINDER HEAD REMOVED FROM ENGINE:

Refer to Fig. 9 and install the cam follower and push rod as follows:

1. Assemble the *serrated* lower spring seat (Fig. 6), spring, upper spring seat and lock nut on the push rod.

2. With the spring retainer in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.

3. Note the oil hole in the bottom of the cam follower. With the oil hole directed away from the exhaust valves (Fig. 10), slide the cam follower in position from the bottom of the head.

4. Attach the follower guide to the cylinder head to hold the group of three cam followers in place. Tighten the guide bolts to 12-15 lb-ft (16-20 Nm) torque. Check to be sure there is at least .005" clearance between the cam follower legs and the cam follower guide (Fig. 11). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 12). Then retighten the bolts to the specified torque.

> **NOTE:** It is important to use the correct bolts as prescribed in the Parts -Book. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

Install Rocker Arms and Shaft

Note that the injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the shaft on the left and right-hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm.

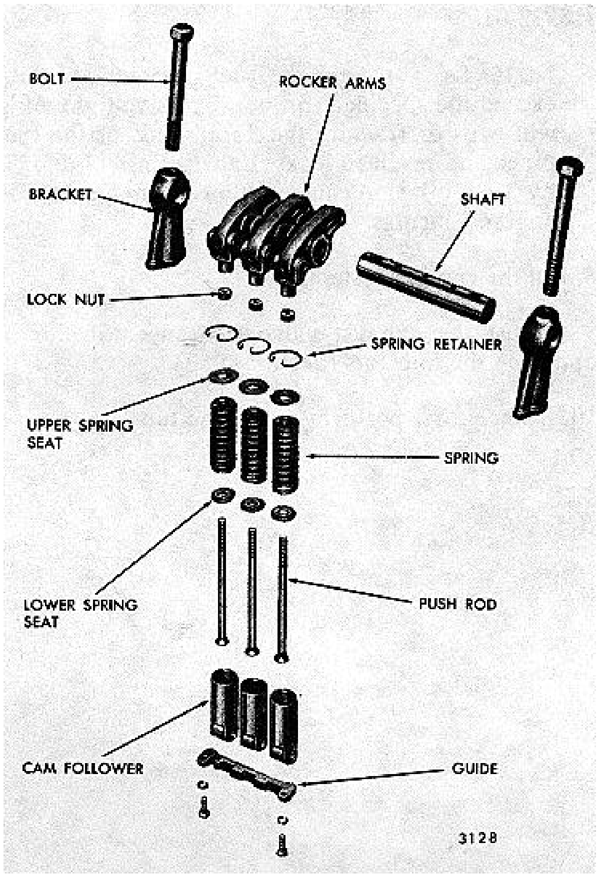


FIG. 9 Valve and Injector Operating Mechanism and Relative Location of Parts

1. Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the

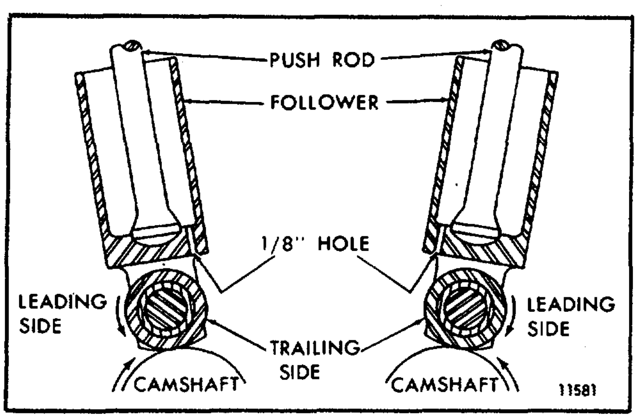


FIG. 10. - Installation of Cam Followers

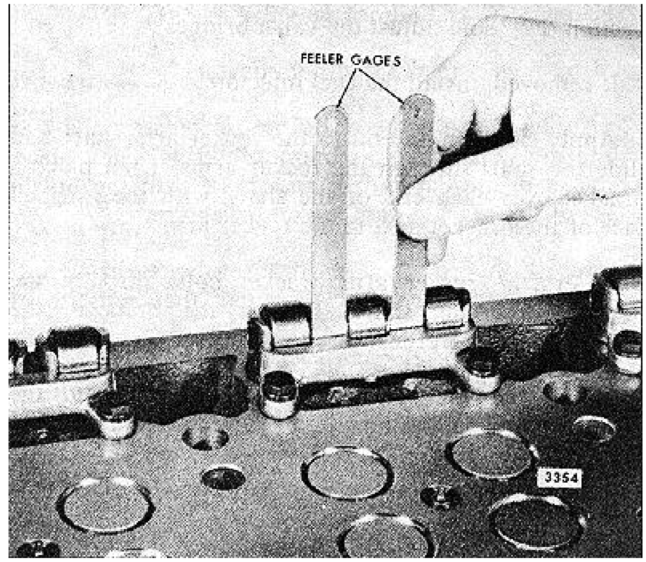


FIG. 11 Checking Cam Follower to Guide Clearance

piston when the crankshaft is turned during the valve clearance adjustment procedure.

2. If removed, install the cylinder head on the engine (refer to Section 1.2).

3. Lubricate the valve bridge guides (four-valve cylinder head) with sulphurized oil (E.P. type) and position the valve bridges in place on the guides.

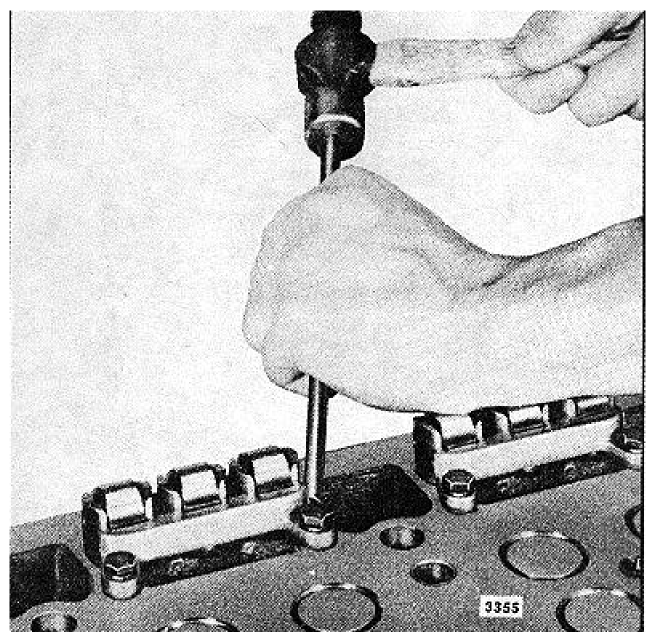


FIG. 12 - Adjusting Cam Follower Guide

Refer to *Exhaust Valve Bridge Adjustment* in Section 1.2.2 and adjust the valve bridges.

4. If removed, install the fuel injectors.

5. Apply clean engine oil to the rocker arm shaft and slide the shaft through the rocker arms. Then place a bracket over each end of the shaft, with the finished face of the bracket next to the rocker arm.

6. Insert the rocker arm bracket bolts through the brackets and the shaft. Tighten the bolts to the specified torque (refer to Section 1.0).

7. Align the fuel pipes and connect them to the injectors and fuel connectors. Tighten the fuel pipe nuts to 12-15 lb-ft (16-20 Nm) torque using socket J 8932-01.

NOTE: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubri6ating oil diluted by fuel oil can cause serious damage to the engine bearings.

8. Fill the cooling system.

9. Adjust the exhaust valve clearance (Section 14.1) and time the injectors (Section 14.2)

10. If necessary, perform an engine tune-up.

EXHAUST VALVES

Two or four exhaust valves are provided for each cylinder (Figs. I and 2), depending upon the engine model. 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 rocker arm (two-valve head) or the exhaust valve bridge (four-valve head).

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head (Fig. 3). Certain engines are equipped with exhaust valve guide oil seals.

Exhaust valve seat inserts (Fig. 3), 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 valves are ground to a 30° seating angle while the exhaust valve seat inserts are ground to a 31° seating angle.

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 valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

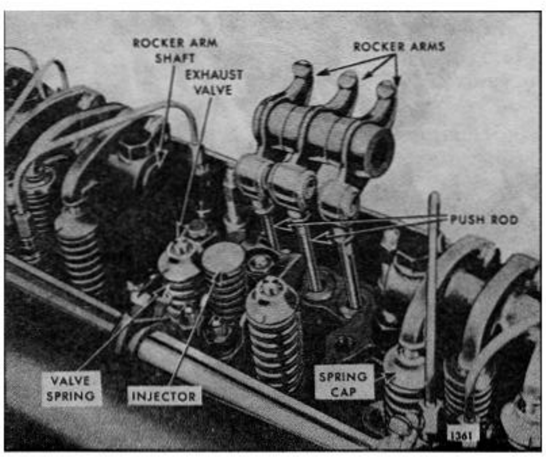


FIG. 1 Location of Exhaust Valves (Two-Valve Cylinder Head)

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.

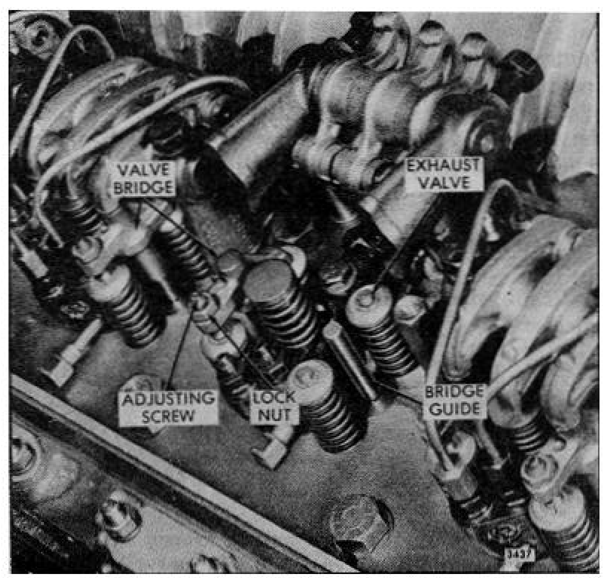


FIG. 2 Location of Exhaust Valves (Four-Valve Cylinder Head)

EXHAUST VALVES

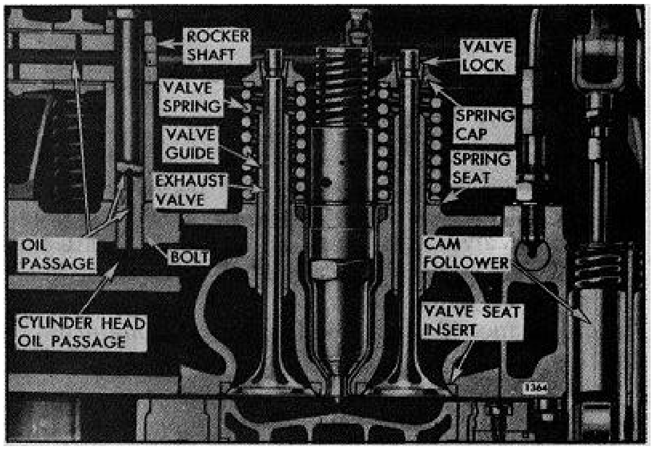


FIG. 3 Assembly of Exhaust Valves and Guides

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 and gums the valve stems, and bent or worn valve guides. Sticking valves may eventually be struck by the piston and become bent or broken.

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 from the engine, as follows:

1. Clean and remove the valve rocker cover.

2. Crank the engine over to bring the valve and injector rocker arms in line horizontally.

IMPORTANT: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt will be loosened.

NOTE: Tool J 22582 bolts to the flywheel housing in place of the engine starting motor. Gear teeth on one end of the tool mesh with the flywheel ring gear. The crankshaft can then be rotated by hand with the aid of a 3/4" drive and ratchet.

3. Disconnect and remove the fuel pipes from the injector and the fuel connectors.

NOTE: 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 brackets to the cylinder head. Then remove the brackets and shaft.

5. Remove the exhaust valve bridge (four-valve cylinder head only) and bridge spring (if used).

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 adaptor J 7455- 7 into the rocker arm bracket bolt holes in the cylinder head (Fig. 4). Then compress the valve spring and remove the two-piece tapered valve lock.

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

Remove Exhaust Valves and Valve Springs (Cylinder Head Removed)

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

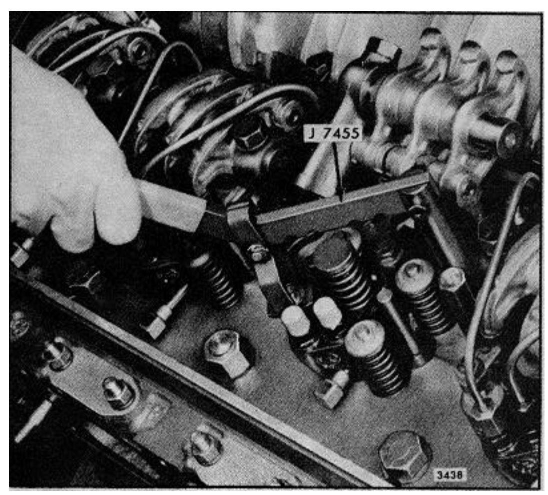


FIG. 4 - Removing Exhaust Valve Spring (Four-Valve Head Shown)

EXHAUST VALVES

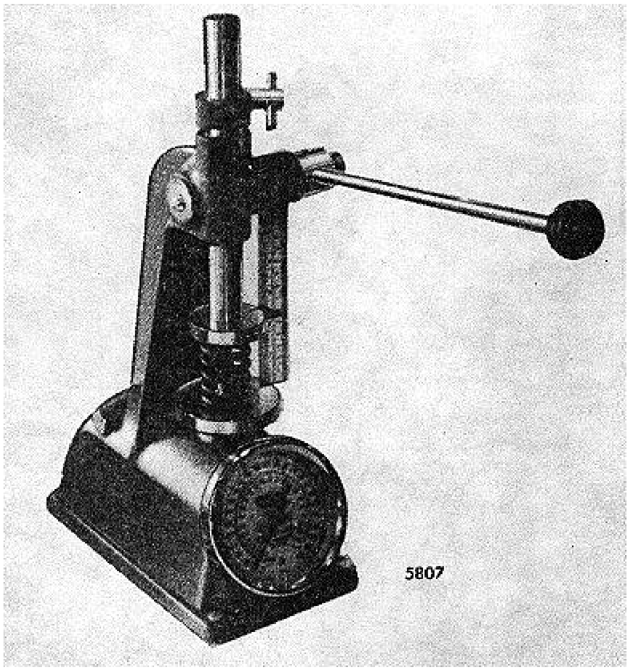


FIG. 5 Testing Exhaust Valve Spring

1. Support the cylinder head on 2" thick wood blocks to keep the cam followers clear of the bench.

2. Remove the fuel pipes from the injectors and the fuel connectors.

NOTE: 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.

3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and the shaft.

4. Remove the fuel injectors.

5. Remove the exhaust valve bridges (four-valve cylinder head) and bridge springs.

6. Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in Steps 7 and 8 above.

7. Turn the cylinder head over, using care to keep the valves from falling out of the head. 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.

8. Remove the cam followers and push rod assemblies as outlined in Section 1.2.1 under *Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).*

Inspection

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

Use spring tester J 22738-02 to check the spring load (Fig. 5). Replace a two-valve cylinder head exhaust valve spring when a load of less than 25 pounds (111 N) will compress it to 2.20" (installed length). The exhaust valve spring used on the current four-valve cylinder head has an outside, diameter of approximately .953". Replace this spring when a load of less than 25 pounds (111 N) will compress it to 1.80" (installed length). On former four-valve cylinder heads, a lighter exhaust valve spring (.859" O.D.) was used for each valve and also for the valve bridge. Replace this spring when a load of less than 79 pounds (351 N) will compress it to a length of 1.416". When replacement of either the exhaust valve spring or valve bridge spring is required, it will be necessary to use the current larger exhaust valve springs, spring seats and caps *as the valve bridge spring is no longer required.*

NOTE: When an exhaust valve spring is replaced on a four-valve head, both springs under a valve bridge should be replaced at the same time to ensure balanced valve operation.

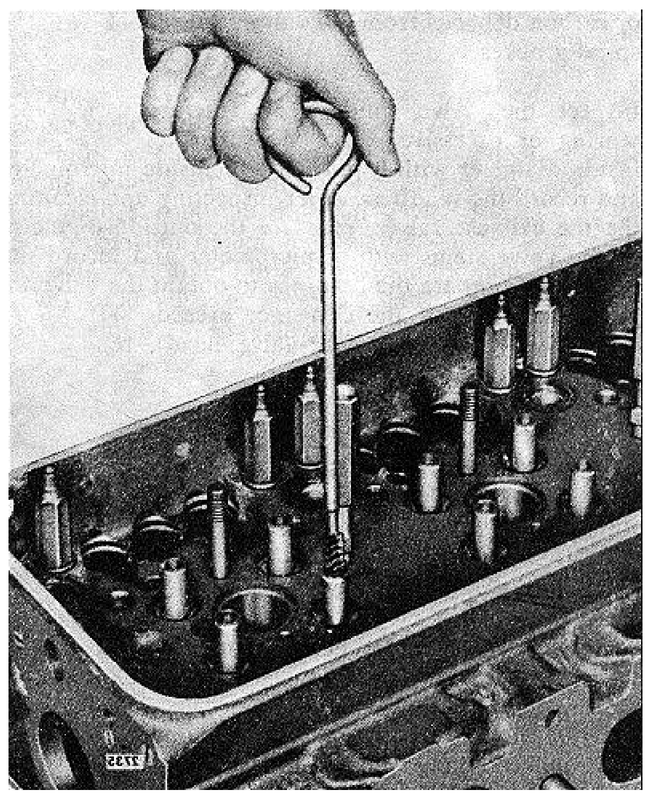


FIG. 6 - Cleaning Valve Guide

Inspect the valve spring seats and caps for wear. If worn, replace with new parts.

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.

If there is evidence of engine oil running down the exhaust valve stem into the exhaust chamber, creating a high oil consumption condition because of excessive idling and resultant low engine exhaust back pressure, replace the valve guide oil seals or, if not previously used, install valve guide oil seals.

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.
I
Clean the inside diameter of the valve guides with brush J 5437 (Fig. 6). This brush will remove all gum or carbon deposits from the valve 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 valves, measure the outside diameter of the valve stems with a micrometer and record the readings. Compare the readings to obtain the valve-to-guide clearance. If the clearance exceeds .006" (two-valve head) or .005" (four-valve head), replace the valve guides.

Replace Exhaust Valve Guide

Remove an exhaust valve guide as follows:

1. Remove and discard the oil seal, if used.

2. Support the cylinder head, bottom side up, on 3" thick wood blocks.

3. Drive the valve guide out of the cylinder head with valve guide remover J 267 (two-valve head) or J 6569 (four-valve head) as shown in Fig. 7.

Place the cylinder head right side up on the bed of an arbor press and install the valve guide (Fig. 9) as follows:

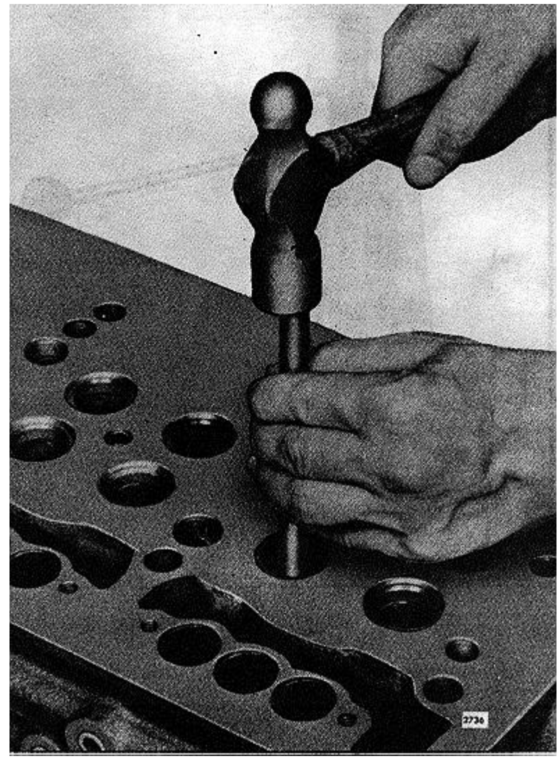


FIG. 7 Removing Exhaust Valve Guide

1 . Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to Table 1). Be sure to use the correct tool to avoid damage to the valve guide, and to locate the valve guide to the proper dimension.

When replacing the valve guides in a four-valve cylinder head, the current guide which is machined for use with a valve guide seal should be used in place of the 45° chamfered valve guide (Fig. 8). The current

Tool No.	Cylinder Head	Valve Guide	Distance of Guide Above Top of Head
J 9530	2 - Valve		1.530"
J 21520	4 - Valve	machined	.690”

TABLE 1

EXHAUST VALVES

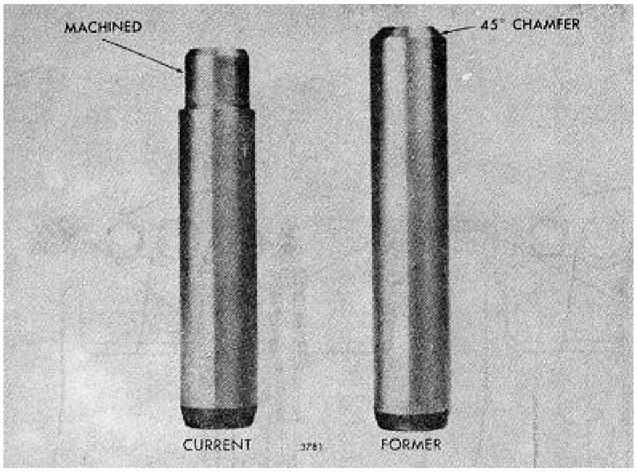


FIG. 8 - Former and Current Valve Guides

guide will facilitate field installation of valve guide seals when it is felt their use will be beneficial.

When replacing the valve guides in a two-valve cylinder head, use valve guide installer J 4144 with the former thick exhaust valve insert (.268"-.272") and use J 9530 with the current thin exhaust valve insert (.2465"-.2505") or when a valve guide oil seal is used.

2. Position the valve guide squarely in the bore in the cylinder head and press the installing tool gently to start the guide in place (Fig. 9). Then press the guide in until the tool contacts the cylinder head.

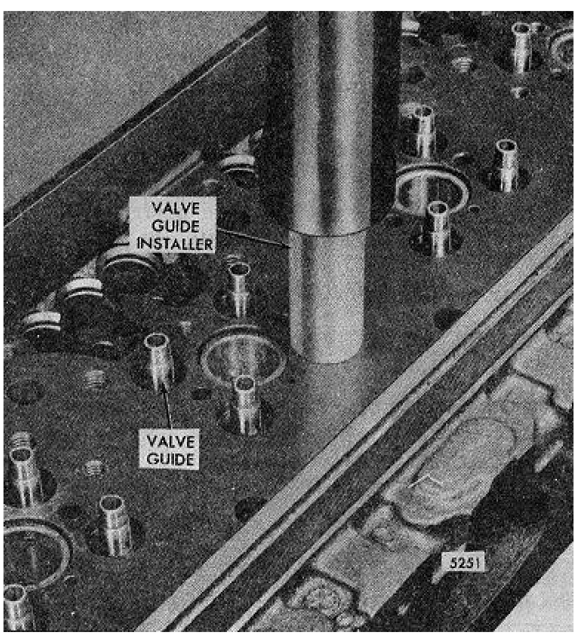


FIG. 9 - Installing Valve Guide

NOTE: Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

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

A service replacement valve guide which is .016" oversize on the outside diameter is also provided for service (two-valve cylinder head only).

3. Install a new valve guide oil seal, if used (refer to Item 5 under *Install Exhaust Valves and Springs).*

Inspect Exhaust Valve Bridge and Guide (Four-Valve Cylinder Head)

Inspect the valve bridge guide, valve bridge and adjusting screw for wear. Replace excessively worn parts.

The former threaded exhaust valve bridge guides have been replaced by press-fit bridge guides in the four-valve cylinder heads (Fig. 10). To conform with this change, current cylinder heads incorporate reamed bridge guide holes in place of the 7/16"-14 tapped holes. The former threaded bridge guide had an integral spring seat to accommodate the valve bridge spring. To permit the use of spring-loaded valve bridges on a replacement cylinder head which incorporates the press-fit guides, separate valve bridge spring seats were used.

The current press-fit valve bridge guide is hardened steel while the valve bridge is relatively soft steel. The former threaded valve bridge guide was of soft steel and was used with a hardened steel valve bridge. The soft valve bridge may be identified by the letter "S" forged on one side of the bridge.

Avoid a combination of a soft steel guide and soft steel bridge, otherwise premature wear of the bridge and guide will occur. For service requirements, a threaded valve bridge guide of hardened steel is available and is identified by 3/16" or 1/4" drill spot in the top end.

Two designs of the valve bridge are used. One has a drilled oil hole and the other has a forged oil hole in the side. The two bridges are interchangeable and can be mixed in an engine.

In addition, a new valve bridge adjusting screw with a redesigned valve contact surface replaces the former adjusting screw. The new screw may be identified by the machined (undercut) surface at the lower end of the screw. Only the new adjusting screw is available

EXHAUST VALVES

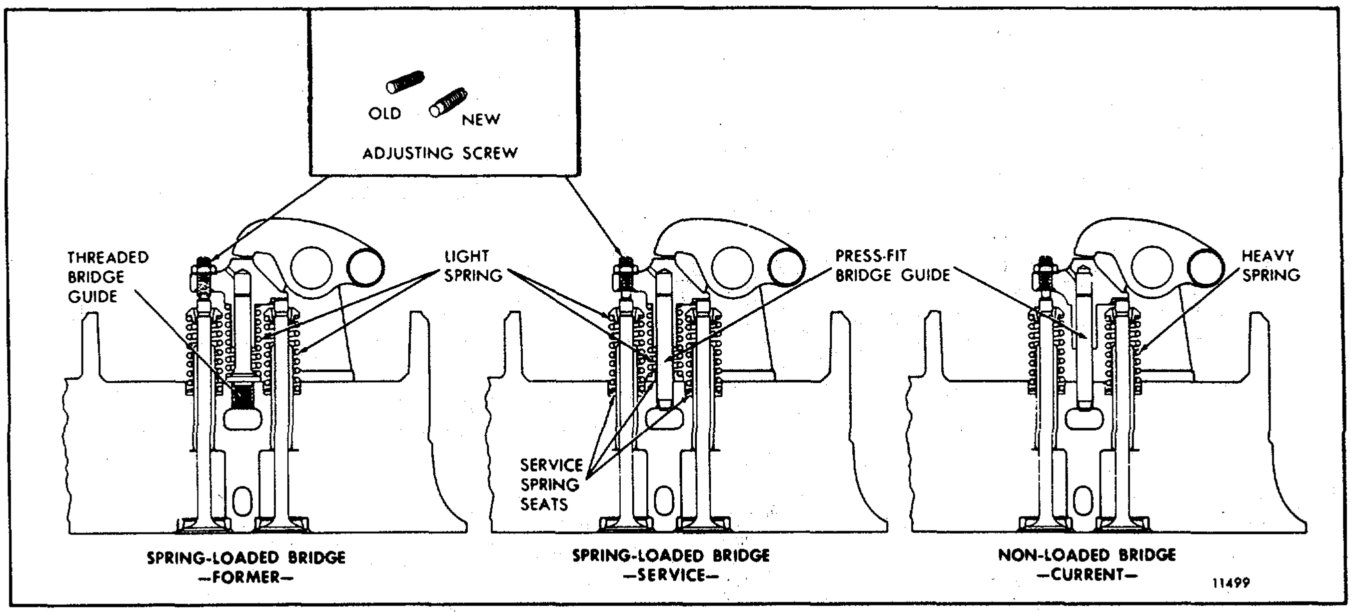


FIG. 11 - Removing Press-Fit Exhaust Valve Bridge Guide

for service. Replace the former adjusting screws at the time of an engine overhaul.

Remove Exhaust Valve Bridge Guide

Remove the valve bridge guide from a four-valve cylinder head as follows:

1. Remove the former threaded guide, identified by the hexagon section at the lower end, with socket J 6846.

2. Remove the press-fit guide (Fig. 11) with tool set J 7091-01 as follows:

a. File or grind two diametrically opposite notches 1/16" deep in the side of the guide, approximately 1-1/4" to 1-1/2" from the upper end.

b. Place spacer J 7091-3 over the guide. Then slide the guide remover J 7091-5 over the guide and align the set screws with the notches in the guide. Tighten the set screws to hold the tool securely.

c. Place spacer J 7091-4 over the guide remover. Thread the nut on the guide remover and turn it clockwise to withdraw the 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. Then tap the guide with a 1/4"- 28 bottoming tap. Thread 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 will remove the broken guide (Fig. 12).

Install Exhaust Valve Bridge Guide

Install the former threaded valve bridge guide with thin-wall socket J 6846. Lubricate the threads and nylon insert before installing the guide. Tighten the guide to 46-50 lb-ft (62-68 Nm) torque.

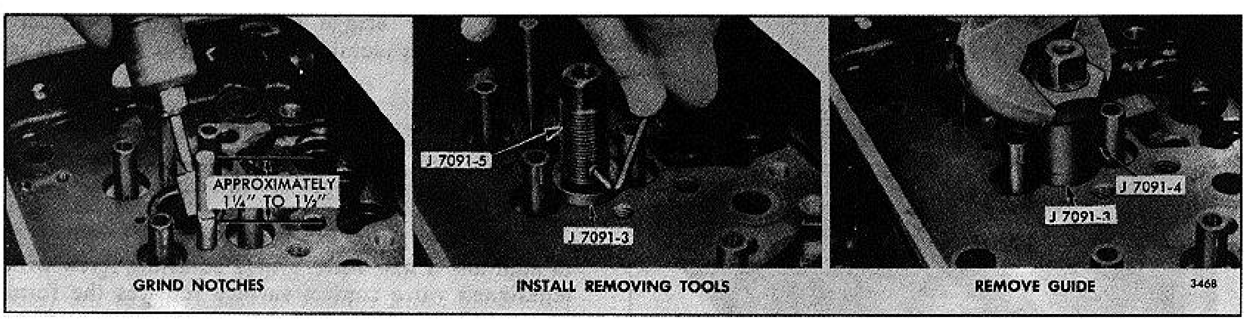


FIG..11 Removing Press Fit Exhaust Valve bridge Guide

EXHAUST VALVES

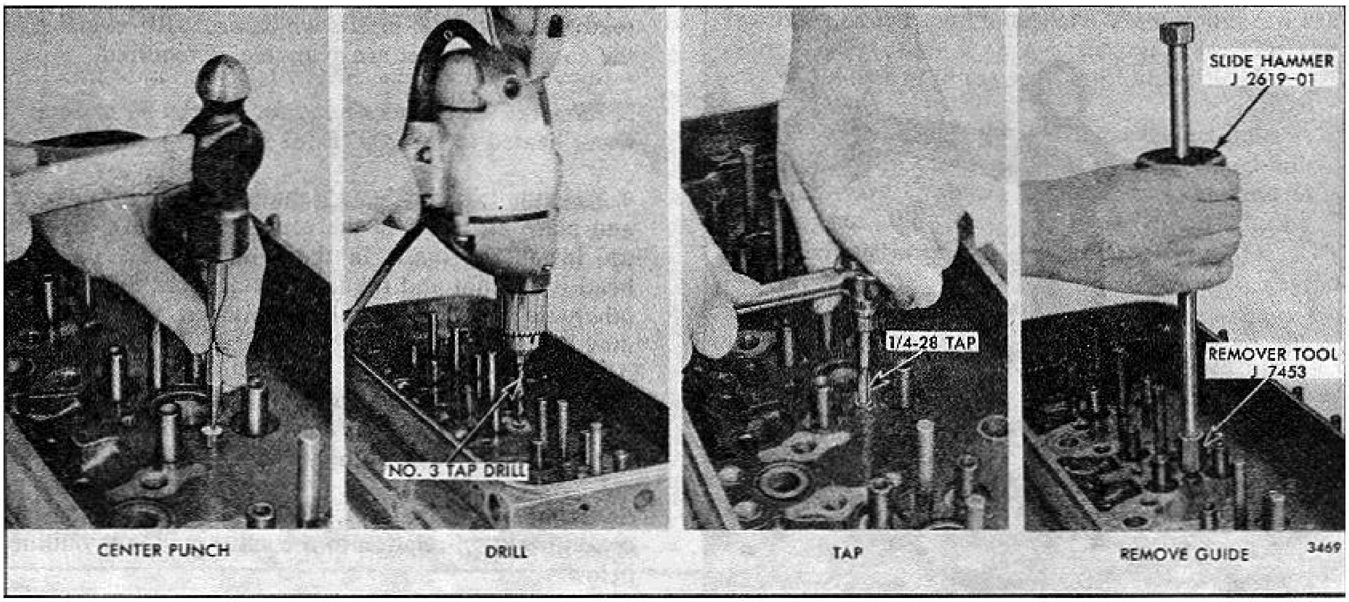


FIG. 12 Removing Broken Exhaust Valve Bridge Guide

Install the current press-fit bridge guide as follows:

1. Start the guide (undercut end first) into the cylinder head.

2. Place the installer J 7482 over the guide and drive it into place. The installer will properly position the guide to the correct height in the cylinder head (2.040”).

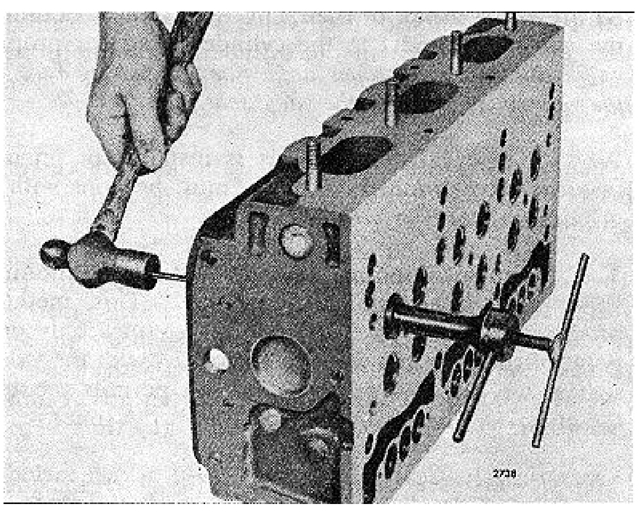


FIG. 13 - Removing Valve Seat Insert

Inspect Exhaust Valve Seat Insert

Inspect the valve seat inserts for excessive wear, pitting, cracking or an improper seat angle.

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. Place the cylinder head on its side as shown in Fig. 13.

2. Place the collet of tool J 4824-03 (two-valve head) or J 6567-02 (four-valve head) inside of the valve seat insert so that the bottom of the collet is flush with the bottom of the insert.

3. Hold the collet handle and turn the T handle to expand the collet cone until the insert is held securely by the tool.

4. Insert the drive bar of the tool through the valve guide.

5. Tap the drive bar once or twice to move the insert about I/16" away from its seat in the cylinder head.

EXHAUST VALVES

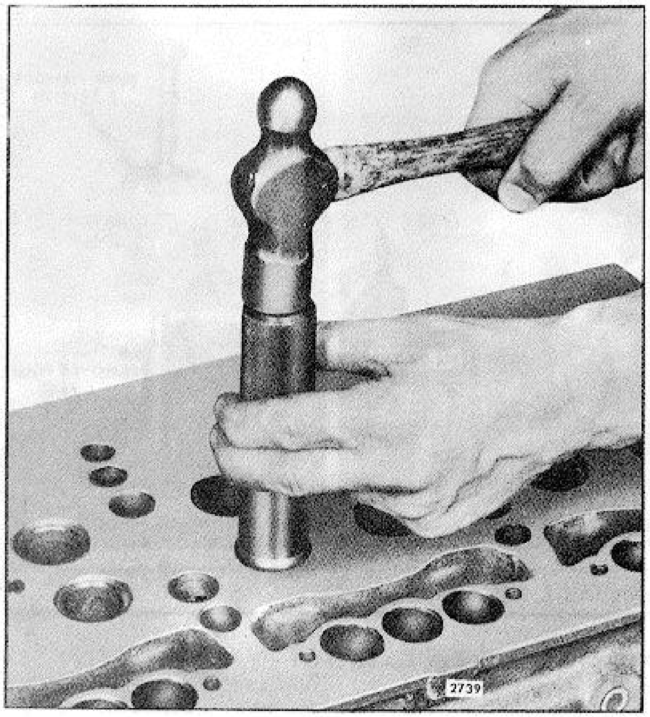


FIG. 14 Installing Valve Seat Insert

6. Turn the T handle to loosen the collet cone and move the tool into the insert slightly so the narrow flange at the bottom of the collet is below the valve seat insert.

7. Tighten the collet cone and continue to drive the insert out of the cylinder head.

> **NOTE**: In place of the above procedure, a *new* cam operated insert remover J 23479-15 and collet J 23479-9 (two-valve head) or J 23479-10 (four-valve head) can be used to remove the exhaust valve seat insert from the cylinder head.

Install Exhaust Valve Seat Insert

1. Clean the valve seat insert counterbores in the cylinder head with trichloroethylene or other suitable solvent. Also wash the valve seat inserts with the same solvent. Dry the counterbores and the inserts with compressed air.

2. Inspect the counterbores in the cylinder head for cleanliness, concentricity, flatness and cracks. The counterbores in a two-valve cylinder head have a diameter of 1.626" to 1.627" and a depth of .3705" to .3845". The counterbores in a four-valve cylinder head have a diameter of 1.260" to 1.261" and a depth of .338" to .352". The counterbores must be concentric with the valve guides within .003" total indicator reading. Valve seat inserts which are .010" oversize on the outside diameter are available, if required.

3. Immerse the cylinder head for at least 30 minutes in water heated to 180-200 ° F (82-93 ° C).

4. Rest the cylinder head, bottom side up, on a bench and place an insert in the counterbore valve seat side up. Install the insert in the cylinder head while the head is still hot and the insert is at room temperature, otherwise installation will be difficult and the parts may be damaged.

5. Drive the insert in place with installer J 1736 (two- valve head) or J 6568 (four-valve head) as shown in Fig. 14 until it seats solidly in the cylinder head.

6. Grind the valve seat inserts and check them for concentricity in relation to the valve guides as outlined below.

Recondition Exhaust Valve and Valve Seat

An exhaust valve which is to be reused may be refaced, if necessary (Fig. 15). To provide sufficient valve strength and spring tension, the edge of the valve at the valve head must not be less than .031 " in thickness and must still be within the specifications shown in Fig. 18 after refacing.

> **NOTE:** The seating area of the exhaust valve used on certain turbocharged engines is aluminized, which gives the valve seat a dull finish. *Do not remove the aluminum coating on a new valve.* However, a used valve may be refaced if necessary.

Before either a new or used valve is installed, examine the valve seat insert in the cylinder head for proper valve seating. *The proper angle for the seating face of the valve is 300 and for the valve seat insert it is 31 .*

When a new valve seat insert is installed or an old insert is reconditioned, the work must be done with a grinding wheel (Fig. 16).

The eccentric grinding method for reconditioning valve seat inserts 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 feeding the grinding wheel into the work .001 " at a time.

Eccentric valve seat grinder set J 7040, which includes the grinder, dress stand and pilot, and dial gage, is used to grind the inserts. An adaptor set which includes the grinding wheels and pilot is used with the grinder.

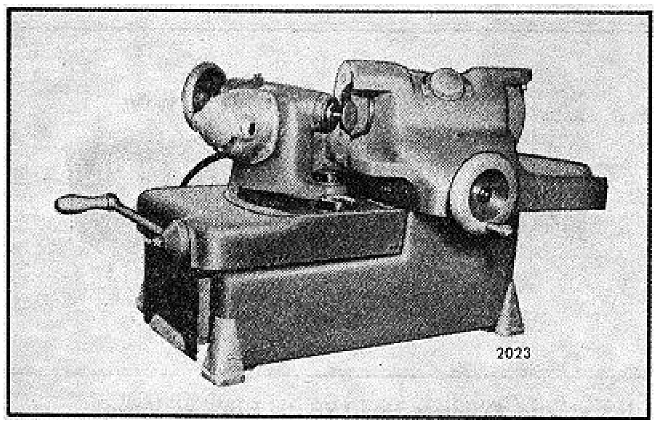


FIG. 15 Refacing Exhaust Valve

Adaptor set J 6390-02, used for the four-valve head, consists of the following:

1. Pilot, tool J 7 659-1.
2. Grinding wheel (15°), tool J 6390-2.
3. Grinding wheel (31°), tool J 6390-3.
4. Grinding wheel (60°) tool J 6390-4.

Adaptor set J 8165-8, used for the two-valve cylinder head, consists of the following:

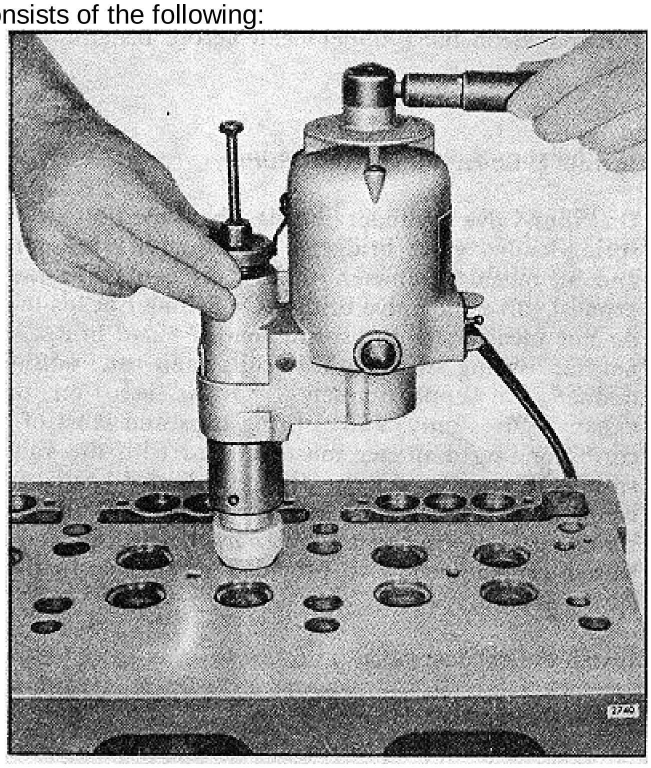


FIG. 16 Reconditioning Valve Seat Insert

1. Pilot, tool J 8165-3.
2. Grinding wheel (15°), tool J 8165-4.
3. Grinding wheel (31°), tool J 8165-5.
4. Grinding wheel (60°), tool J 8165-7.

Grind the inserts as follows:

1. First 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 the dimensions shown in Fig. 18. The 31 'face of the insert may be adjusted relative to the center of the valve face with the 15° and 60° grinding wheels.

NOTE: Do not permit the grinding wheel to contact the cylinder head when grinding the insert. When an insert has been ground to the extent that the grinding wheel will contact the cylinder head, install a new insert.

The maximum amount the exhaust valve should protrude beyond the cylinder head (when the valve is closed) and still maintain the proper piston-to-valve clearance is shown in Fig. 18. Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. If, after several grinding operations, the valve recedes beyond the specified limits, replace the valve seat insert.

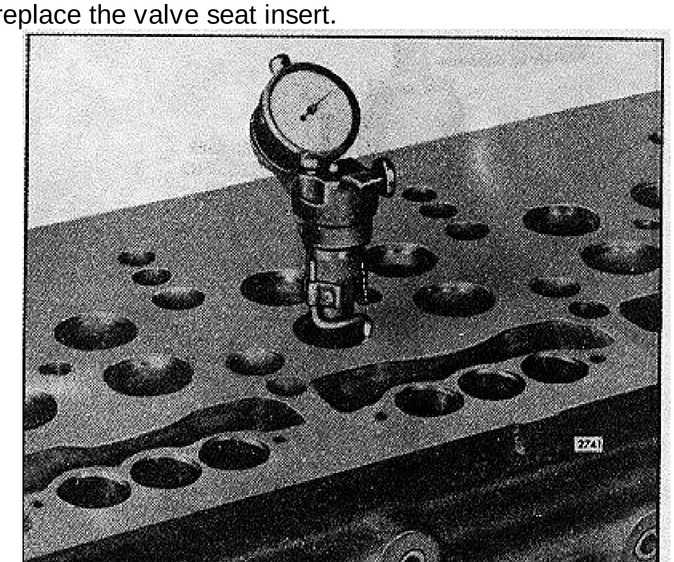


FIG. 17 Determining Concentricity of Valve Seat Insert with Dial Indicator

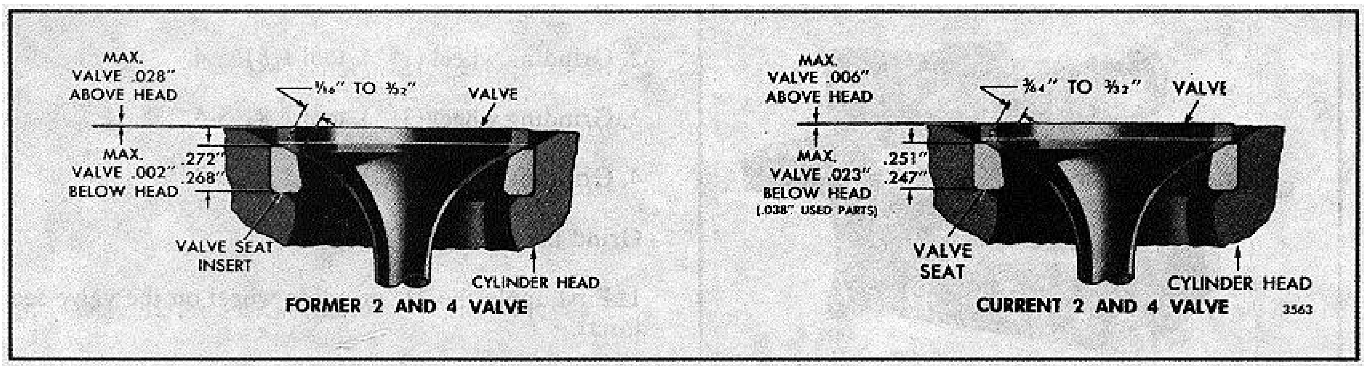


FIG. 18 - Relationship Between New Exhaust Valve, Insert and Cylinder Head (Both Exhaust Valve Seats Inserts Shown)

NOTE: Engines with 18.7:1 compression ratios must incorporate valve seat inserts that are no more than .251" thick to ensure adequate clearance between the pistons and the exhaust valves.

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Fig. 19).

4. After 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. If the runout exceeds .002", check for a bent valve guide before regrinding the insert.

After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:

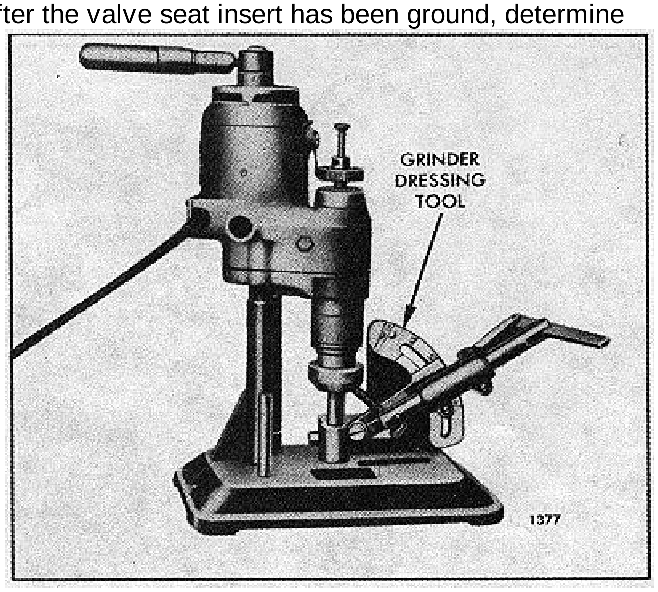


FIG. 19 - Grinding Wheel Dressing Tool of Set J 8165-1

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" the valve on the seat. *Do not rotate the valve.* This procedure will show the area of contact on the valve face. The most desirable area of contact is at the center of the valve face.

NOTE: The use of valve lapping compounds is not recommended.

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

Install Exhaust Valves and Springs

On four-valve cylinder heads that incorporate a spring-loaded valve bridge, a spring with 9-3/4 coils and an outside diameter of .859" is used with each exhaust valve and valve bridge. On cylinder heads that do not incorporate the spring-loaded valve bridge, a heavier spring with 8-3/4 coils and an outside diameter of approximately .953" is used on the exhaust valves only. Valve spring caps and seats of a corresponding diameter must be used with the valve springs. Since the current service cylinder heads are counterbored for use of the larger diameter spring, a service valve spring seat with a larger diameter and a raised center section is provided when the smaller spring is used.

Install the exhaust valves as follows:

1. Clean the valve guides.

2. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides.

IMPORTANT: If reconditioned valves are used, install them in the same relative location from which they were removed.

3. Hold the valves in place temporarily with a strip of masking tape. Then turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.

4. Install the valve spring seats.

5. Install the valve guide oil seals, if used, on the valve guides as follows:

a. Place the plastic seal installation 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 installation cap and start the seal carefully over the valve stem. Push the seal down slowly until it rests on top of the valve guide.

c. Remove the installation cap.

6. Install the valve springs and valve spring caps.

NOTE: The current four-valve cylinder head valve spring caps have a ridge for identification purposes on the upper tapered surface (Fig. 20).

7. Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 4).

8. Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring.

NOTE: If valve guide oil seals are used, compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

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

10. Check the position of the exhaust valves (Fig. 18).

Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valves are free. Then give the ends of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.

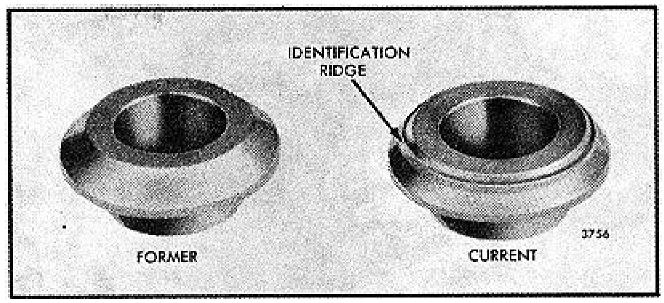


FIG. 20 - Former and Current Exhaust Valve Spring Caps (Four-Valve Heads)

11. With the exhaust valves installed in the cylinder head, use spring checking gage J 25076-01 and note the gage reading the moment the exhaust valve starts to open (Fig. 21). The minimum allowable pressure required to start to open the exhaust valve must not be less than 15 pounds (67 N) for a two-valve cylinder head or 20 pounds (89 N) for a four-valve cylinder head (two-spring design).

12. Install the injectors, rocker arms, shafts, brackets and any other parts previously removed from the cylinder head.

13. Install the cylinder head. Refer to *Pre-Installation Inspection* and *Install Cylinder Head* in Section 1.2. If the engine is equipped with a four-valve cylinder

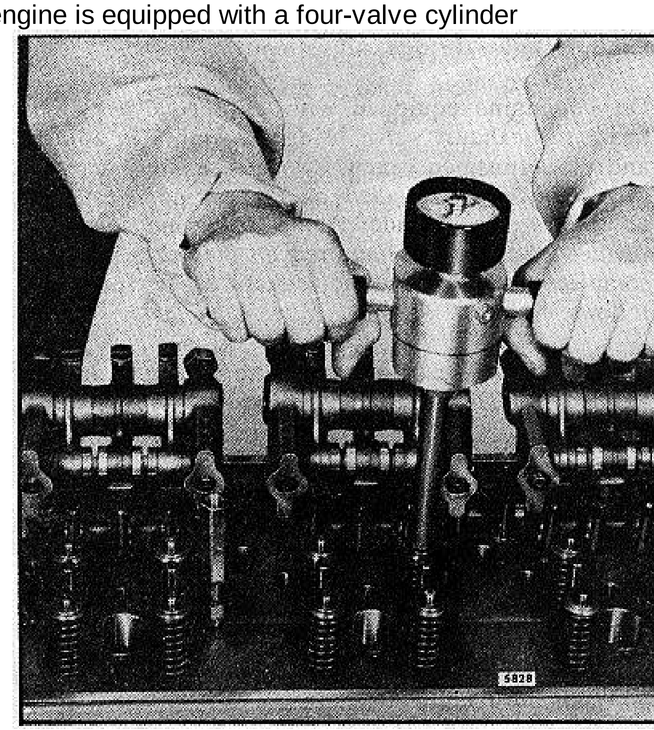


FIG. 21 - Checking Pressure Required to Open the Exhaust Valve in Cylinder Head

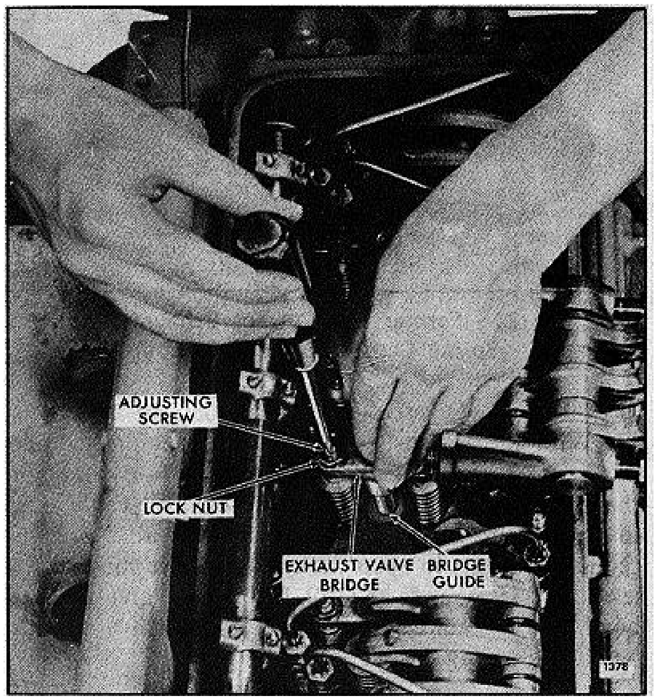


FIG. 22 Valve Bridge Adjustment (Four-Valve Cylinder Head)

head, adjust the exhaust valve bridges as outlined below.

Exhaust Valve Bridge Adjustment

On an engine equipped with a four-valve cylinder head, the exhaust valve bridge assembly 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 lock nut on the bridge adjusting screw.

> **NOTE:** Loosening or tightening the lock nut 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, without the spring (if a spring-loaded bridge is used).

3. While firmly pressing straight down on the-e 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 lock nut finger tight (Fig. 22).

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 lock nut to 20-25 lb-ft (27-34 Nm) torque.

5. Lubricate the valve bridge guide and the valve bridge with engine oil.

6. Reinstall the valve bridge in its *original* position, without the spring (if a spring-loaded bridge is used).

7. Place a .0015" feeler gage (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 with the spring in place (if a spring loaded bridge is used).

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 Section l.0. After the cylinder head is installed and the valve bridges adjusted (four-valve head), proceed' as follows:

1. Refer to Section 2.1 or 2.1.1 under *Install Injector* and install the fuel pipes.

2. Fill the cooling system.

> **NOTE:** Remove the vent plug from the thermostat housing or open the vent valve when filling the cooling system.

3. Adjust the exhaust valve clearance and time the injectors (Sections 14.1 and 14.2).

4. Start the engine and check for leaks in the fuel, cooling and lubrication systems,.

5. Perform a complete engine tune-up as outlined in Section 14.

VALVE ROCKER COVER

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head. The top of the cylinder head is sealed against oil leakage by a gasket located in the groove of the lower rail of the current die cast rocker cover or in the flanged edge of the former stamped metal rocker cover.

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

The current die cast rocker cover (Fig. 1) is held in place by 3/8 "-16 twelve-point head shoulder bolts with a steel washer and silicone isolator. The bolts have a shoulder which bottoms out against the

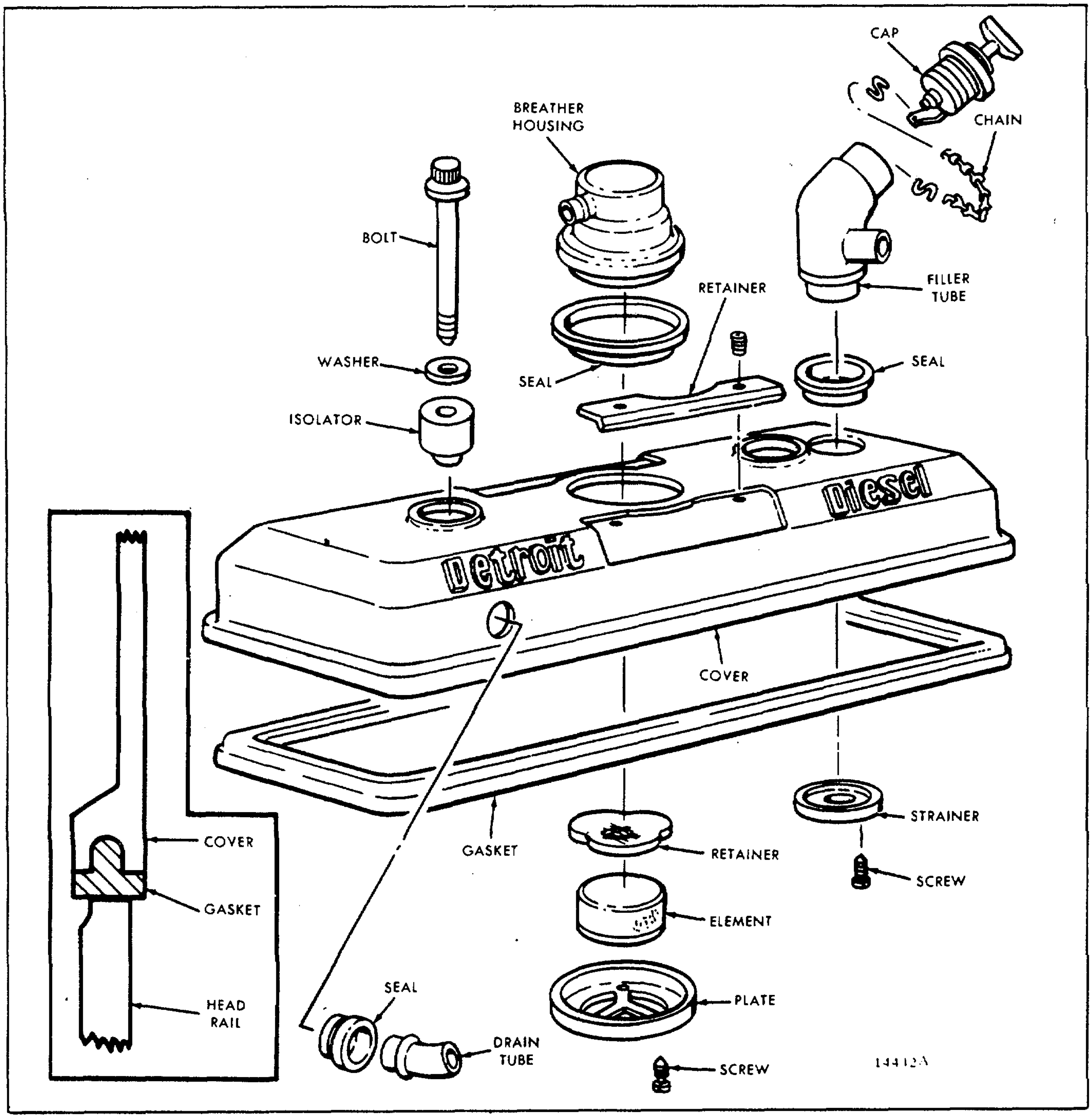


FIG. 1 - Typical Current Valve Rocker Cover Assembly

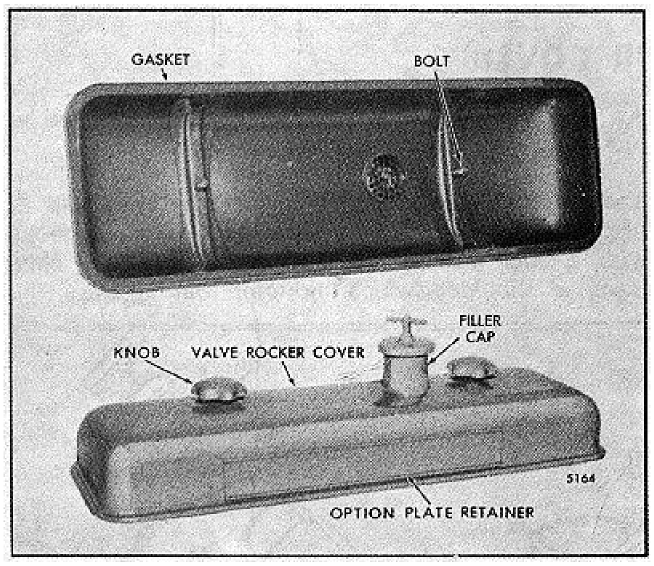


FIG. 2 Typical Former Valve Rocker Cover Assembly

cylinder head or throttle delay bracket. The isolators and gasket use low compression-set materials which provide long sealing life and minimize engine noise levels. Tighten the bolts to 15-20 lb-ft (20-27 Nm) torque. The former stamped metal rocker cover is held in place with hold-down knobs (Fig. 2).

NOTE: The shorter rocker cover bolt, which threads into the throttle delay bracket, can crack the bracket if overtightened.

IMPORTANT: The rocker cover bolt is especially designed for this purpose and must not be replaced by an ordinary bolt.

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

The former stamped metal rocker covers and the current die cast rocker covers are interchangeable. Only the current covers will be serviced. The former rocker cover gaskets, hold-down knob and studs, and components of the former ventilating system and oil filler will be available for service on early engines. When replacing a former stamped rocker cover with the new die cast aluminum rocker cover, remove the studs (adaptor) from the cylinder head. The new bolts are installed directly into the tapped holes in the cylinder head. A short (2.90" long) bolt is used when the engine is equipped with a throttle delay or fuel modulator mechanism.

The current rocker cover gasket and the current holddown bolts can only be used with the current die cast rocker cover. Do not use the former gasket and holddown knobs with the die cast cover.

Remove and Install Valve Rocker Cover

Clean the valve rocker covers and around the covers before removing them from the engine to avoid dust or dirt from entering the valve mechanism. Then loosen the bolts (current engines) or the knobs (former engines) and lift each cover straight up from the cylinder head. Use new gaskets when reinstalling the covers.

Before a die cast rocker cover is installed on a cylinder head, it is important that the silicone gasket be properly installed in its groove in the rocker cover.

1. Clean and blow out the groove in the rocker cover with compressed air. Oil in the rocker cover groove or on the silicone gasket will make it difficult to install.

2. Press the stem side of the new T shaped gasket down into the groove at the four corners of the cover first. Then press the remainder of the gasket into place in the groove (Fig. 1). Be sure the stem of the entire gasket bottoms in the groove.

NOTE: When the gasket is completely installed in the groove it should not fall out.

3. Before installing the rocker cover, lubricate the cylinder head rail and the flat surface of the gasket with a thin film of engine oil. This will keep the gasket from sticking to the cylinder head rail.

CRANKSHAFT

The crankshaft is a one-piece steel forging, heat treated to ensure strength and durability (Fig. 1). The main and connecting rod bearing journal surfaces and fillets on all current crankshafts are induction hardened.

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 cylinder block.

Two dowels and six tapped holes are provided in the rear end of the crankshaft for locating and attaching the flywheel (Fig. 1). One hole is unequally spaced so that the flywheel can be attached in only one position.

Effective with engine serial number 8VA-352893 a new crankshaft with eight (8) flywheel bolt holes in the butt end is used. The former dowel holes are now threaded the same as the other six holes, to provide for the additional two bolts.

NOTE: Do not attempt to drive dowels in a new crankshaft or serious damage could occur.

The former and new crankshafts are interchangeable in an 8V-71 engine. However, when replacing a former crankshaft with a new crankshaft include two additional flywheel attaching bolts. To allow additional socket clearance, to aid in tightening the flywheel bolts, new step-head bolts are also being used with the new 8V-71 crankshaft.

To rework an 8V-71 crankshaft with a six flywheel bolt holes into an eight flywheel bolt hole 8V-71 crankshaft refer to Section 1.0.

To standardize, the current crankshaft will no longer incorporate the two dowels in the flywheel end of the crankshaft. The former and current crankshafts are interchangeable.

CAUTION: Extreme caution should be used when removing a flywheel by either leaving one or two bolts in the flywheel, or installing two suitable guide pins to support the flywheel until a lifting tool or some other suitable safe lifting device is attached to the flywheel.

Each main bearing journal is 4-1/2 " in diameter and each connecting rod journal is 3 " 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 engine to base attaching bolts. Then, with a chain hoist and sling attached to the lifter

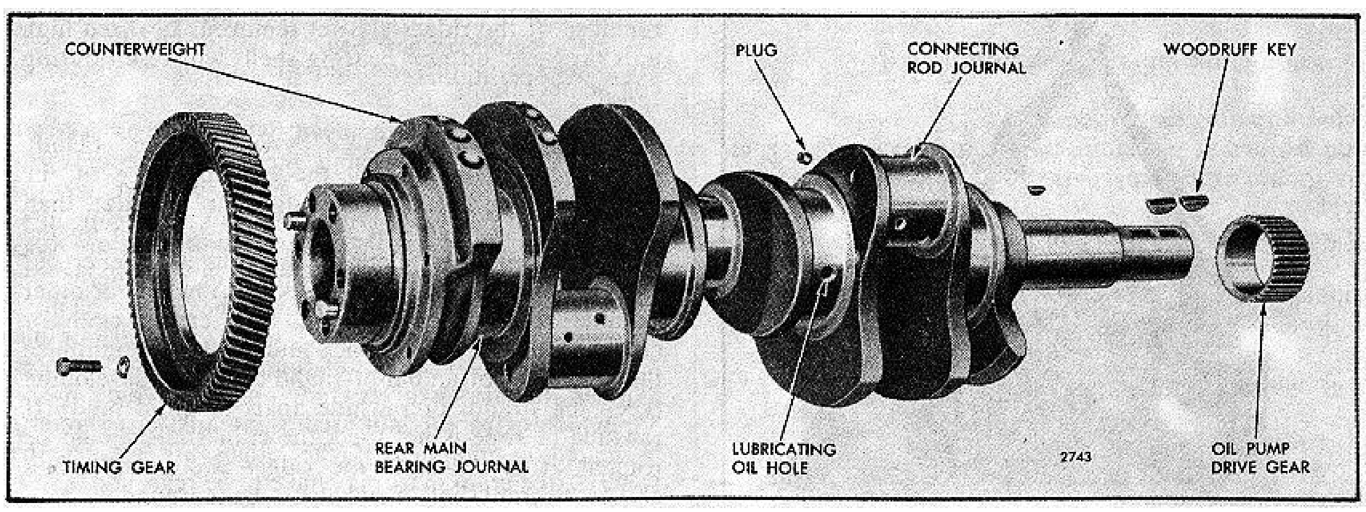


FIG. 1 - Typical 6V-71 Crankshaft

brackets or eye bolts at each end of the engine, remove the engine from the vehicle.

5. Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.

6. Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

> **CAUTION**: Be absolutely sure the engine is securely attached to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

7. Remove the oil pan.

8. Remove the lubricating oil pump, if the pump is mounted on the main bearing caps.

9. Remove the flywheel and flywheel housing.

10. Remove the crankshaft cap or pulley retaining bolt and washer at the front end of the crankshaft. Then remove the pulley, if used.

I 1. Remove the vibration damper, if used.

12. Remove the front engine support.

13. Remove the crankshaft front cover and oil pump assembly.

14. Remove the vibration damper inner cone or oil seal spacer.

15. Remove the cylinder heads.

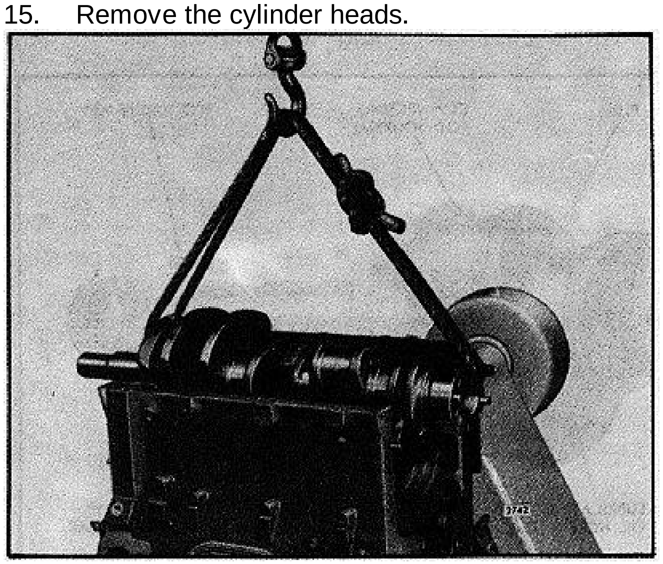


FIG. 2 Removing or installing Crankshatt

16. Remove the connecting rod bearing caps.

17. Remove the main bearing caps and stabilizers.

18. Remove the thrust washers from each side of the rear main bearing.

19. Remove the pistons, connecting rods and liners.

20. Remove the crankshaft, including the timing gear and oil pump drive gear (Fig. 2).

21. Refer to Section 1.7.5 for removal of the crankshaft timing gear.

22. Remove the oil pump drive gear and Woodruff keys from the crankshaft.

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 plug's.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment 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.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005", first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than .001", the crankshaft may have to be reground.

Carefully inspect the rear end of the crankshaft in the

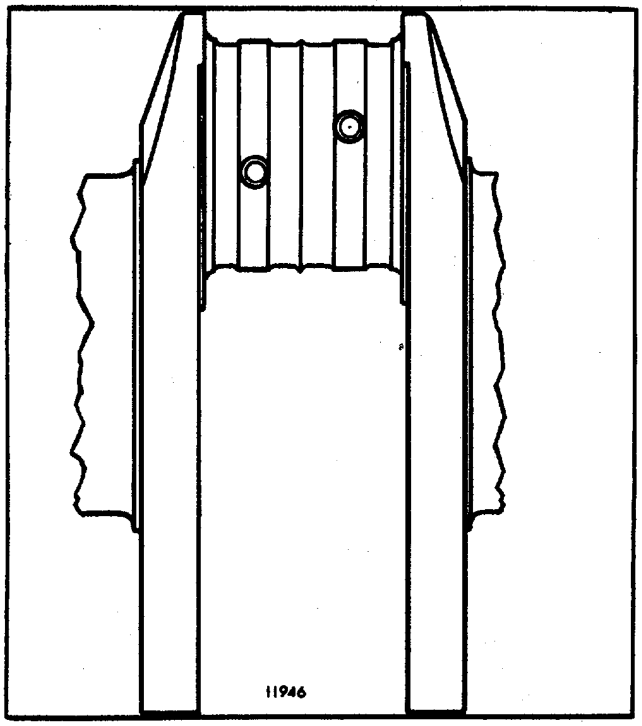


FIG. 3 - Typical Ridging of Crankshaft

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.

Slight ridges on the crankshaft oil seal contact surface may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily. the oil seal may be repositioned in the flywheel housing as outlined in Section 1.3.2.

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 oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears, if necessary.

Check the crankshaft dowel extension. The dowels must not extend more than 1/2" from the crankshaft.

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

Crankshaft Measurements

Support the crankshaft on its front and rear journals on V-blocks, in a lathe or the inverted engine block with only the front and rear upper bearing shells in place 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 .()04" total indicator reading or .002" on each journal. If the runout limit is greater than given in Table 1, the crankshaft must be replaced.

Engine	Journals	Max. Run-Out (Total indicator reading)
6V-71	On No. 2 and No. 3	.002"
8V-71	On No. 2 and No. 4	.002"
	On No. 3	.004"
12V-71	On No. 2 and No. 6	.002"
	On No. 3 and No. 5	.004"
	On No. 4	.006"

TABLE 1

Measure all of' the main and connecting rod bearing journals (Fig. 6). Measure 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 maximum connecting rod or main bearing journal-to-bearing shell clearance (with new shells) exceeds .0045" (connecting rod journal) or .0055" (main bearing journals), the crankshaft must be reground. Measurements of' the crankshaft should be accurate to the nearest .0002". Also, if the main bearing journal taper of a used crankshaft exceeds .0006" or the out-of-round is greater than .0005", the crankshaft must be reground.

Also measure the crankshaft thrust surfaces (Fig. 8).

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 de-magnetized after the test.

Florescent 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, specialty on discolored or dark surfaces, will be disclosed under the "black light".

Fluorescent Penetrate Method: This is a method which may be used on both *non-magnetic and magnetic* materials A highly fluorescent liquid penetrate is applied to the part. Then the excess penetrate is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrate 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 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

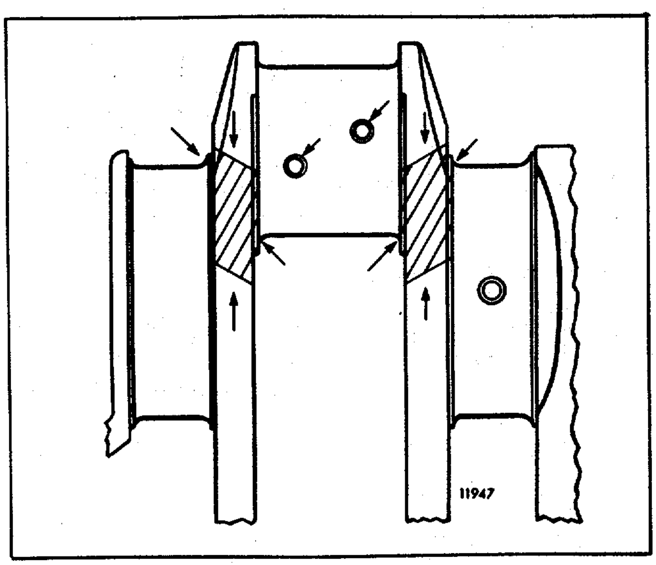


FIG. 4 - Critical Crankshaft Loading Zones

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. 4).

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. 4.

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 450 to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel 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 or the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and

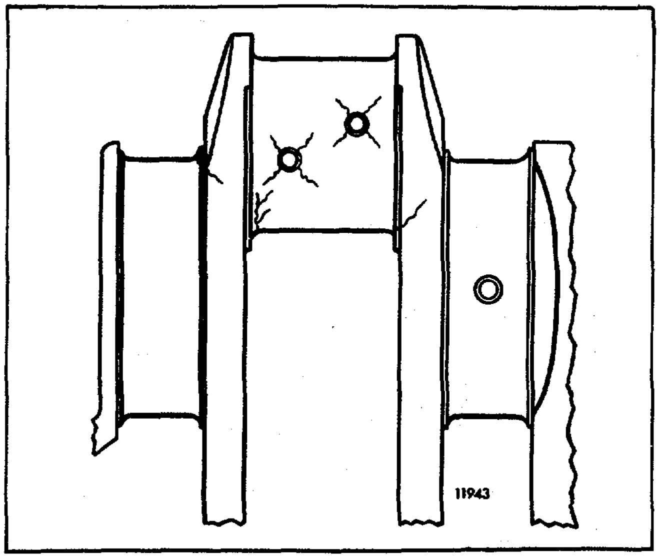


FIG. 5 - Crankshaft Fatigue Cracks

45° cracks (45 with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes as shown in Fig. 5. Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002"t, .010", .020" and .030" undersize bearings are available.

> **NOTE**: The .002" undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

If the crankshaft is to be reground, proceed as follows:

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 2 and Fig. 6 and determine the size to which the journals are to be reground.

Bearing Size	Conn. Rod Journal Dia.	Main Bearing Journal Dia.
standard	2.9985"/3.0002"	4.4985"/4.5002
.002"	2.9970"/2.9982"	4.4970"/4.4982"
.010"	*2.9885"/2.9902"	*4.4885"/4.4902"
.020"	*2.9785"/2.9802"	*4.4785"/4.4802"
.030"	*2.9685"/2.9702"	*4.4685"/4.4702"

*Dimension of reground crankshaft.

TABLE 2

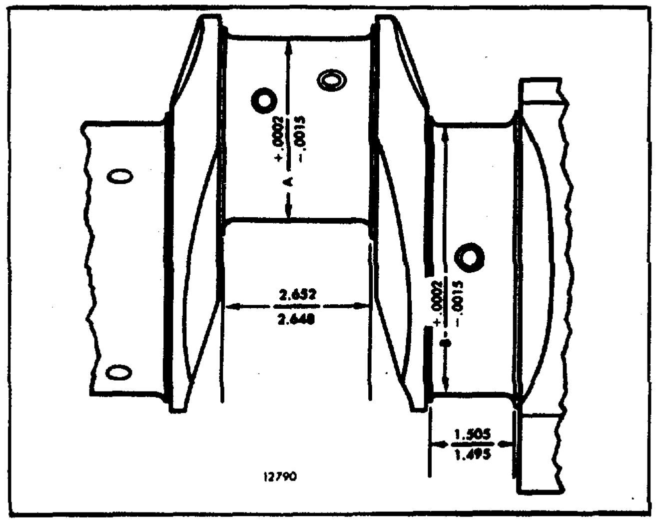


FIG. 6 - Dimensions of Crankshaft Journals

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 .100" to .130" 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.

> **NOTE:** The journals and fillets on *current* crankshafts are induction hardened and the fillets do not require rolling after regrinding.

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. Polish the ground surfaces to an 8-12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

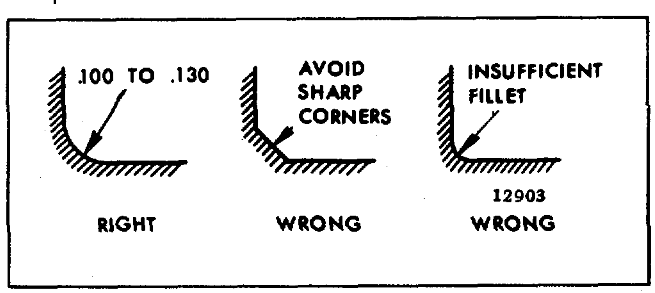


FIG. 7 - Crankshaft Journal Fillets

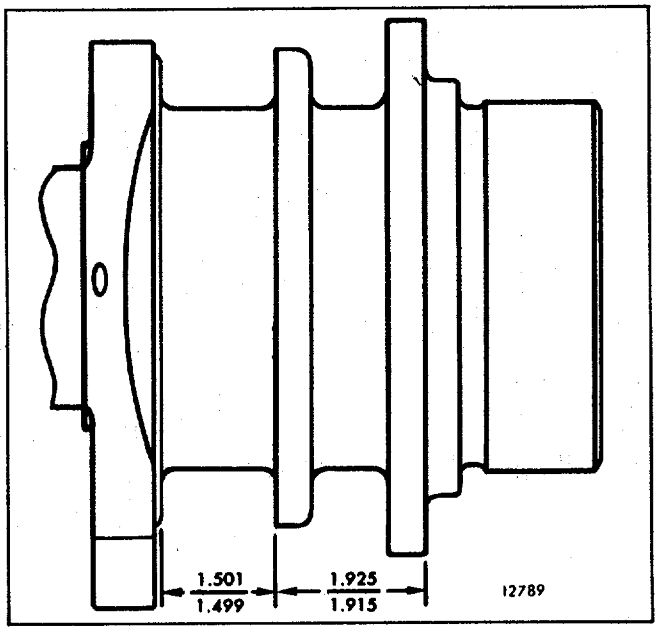


FIG. 8 - Standard Dimensions at Crankshaft Thrust Surfaces

6. If the thrust surfaces of the crankshaft are worn or grooved excessively, they must be reground and polished (Fig. 8). Care must be taken to leave a .100" to .130" radius between each thrust surface and the bearing journal.

7. Stone the edge of all oil holes in the main journal surfaces smooth to provide a radius of approximately 3/64". All other journal surfaces should be stoned smooth to provide a radius of approximately 3/32".

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

9. Demagnetize the crankshaft.

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

For additional information refer to DDA Manual 6SE453.

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 reinstall the plugs. Then install the crankshaft as follows:

1. Assemble the crankshaft timing gear (Section 1.7.5) and the oil pump drive gear (Section 4.1) on the crankshaft.

2. 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.

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

3. 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.

4. 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 washer must face toward the crankshaft thrust surfaces.*

NOTE: 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. 8 and Table 3.

Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1240"	.1270"
.010" Oversize	.1290"	.1320"

5. Install the lower 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.

6. Install the bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells* in Section 1.3.4.

NOTE: 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.

7. Check the crankshaft end play by moving the crankshaft toward the gage with a small (less than 12") pry bar (Fig. 9). 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

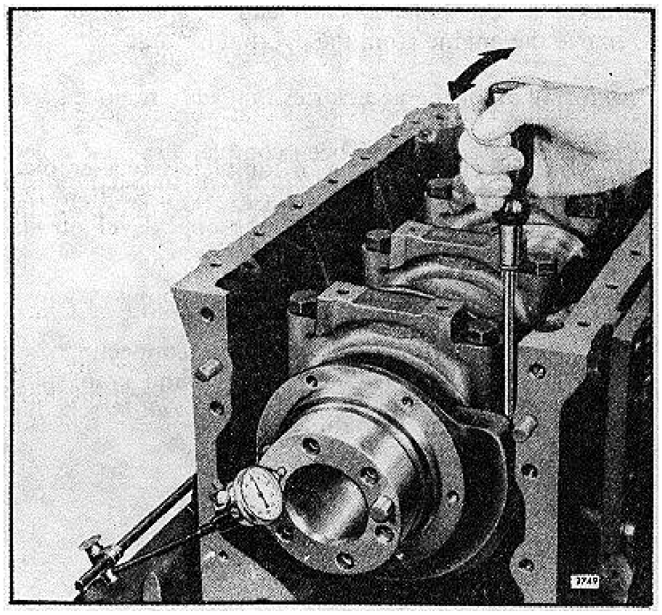


FIG. 9 - Checking Crankshaft End Play

should be .004 to .0 11 " 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.

8. Install the cylinder liner, piston and connecting rod assemblies (Section 1.6.3).

9. Install the cylinder heads (Section 1.2). 10. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4). 1 1. Install the crankshaft front cover and oil pump assembly.

> **NOTE:** Install the oil seal spacer or inner cone *after* the crankshaft front cover is in place to avoid damage to the oil seal lip.

12. Install the engine front support.

13. Install the vibration damper inner cone or oil seal spacer.

14. Install the vibration damper assembly, if used.

15. Install the crankshaft cap or pulley.

16. Install the lubricating oil pump assembly (Section 4.1).

17. Check the crankshaft for **distortion** at the rear connecting rod journal counterweights *before* and *after* installing the transmission. An improperly installed

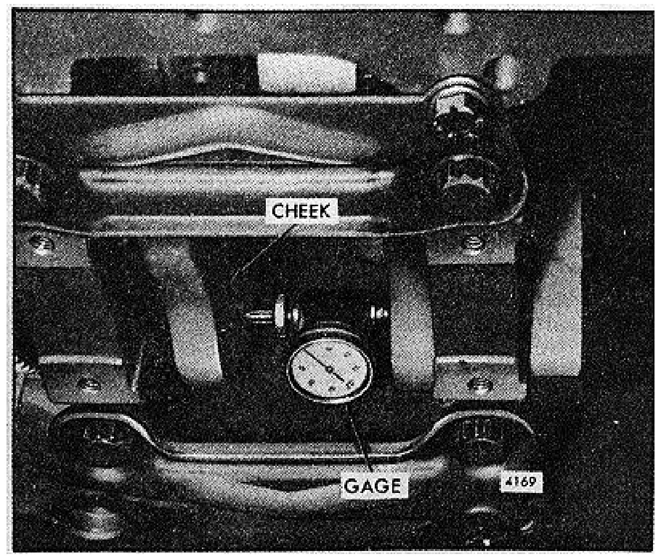


FIG. 10 - Crankshaft Distortion Measuring Gage Mounted on Crankshaft

transmission can distort the crankshaft and cause a crankshaft failure. Overtightened drive belts can also cause crankshaft distortion. See Section 15.1 for recommended belt tensions.

NOTE: While in each case one must be guided by the individual circumstances and facts that evolve, generally speaking Detroit Diesel Allison 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 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, or equivalent) in the center punch holes in the cheek of each counterweight as shown in Fig. 10.

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 .0045a total indicator reading.

NOTE: 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 transmission for improper installation and realign as necessary.

18. Affix a new gasket to the oil pan flange and install the oil pan.

19. Use a chain hoist and sling attached to the lifting bracket or eye bolts at each end of the engine and remove the engine from the overhaul stand.

20. Install all of the accessories that were removed.

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

22. Close all of the drains and fill the cooling system.

23. 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).

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.

The front oil seal (Fig. I) is pressed into the crankshaft front cover with the lip of the seal bearing against a removable spacer or vibration damper inner cone on the end of the crankshaft.

A single-lip oil seal is used at the rear end of the crankshaft on some engines. A double-lip oil seal is used in engines where there is oil on both sides of the oil seal; the lips of the seal face in opposite directions. The rear oil seal is pressed into the flywheel housing (Fig. 2).

Oil leaks indicate worn or damaged oil seals. 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 spacers. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Remove Crankshaft Oil Seals

Remove the crankshaft front cover (Section 1.3.5) and the flywheel housing (Section 1.5) and remove the oil seals as follows:

NOTE: Various crankshaft front covers are used on 12V engines. Whether the oil seal is located in a bore or counterbore in the front cover depends upon which cover is used. Note the location prior to removing the oil seal to ensure proper installation of the new seal.

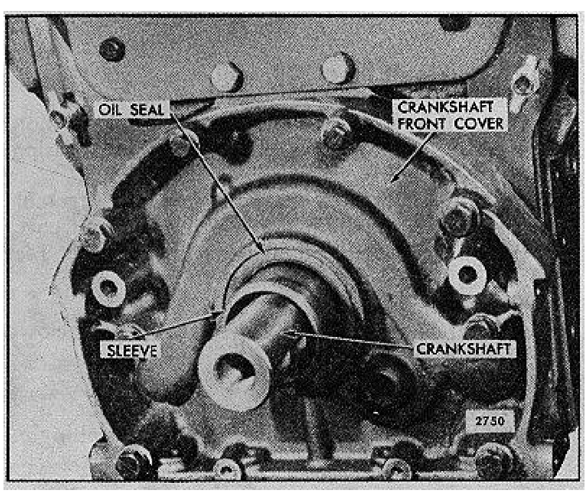


FIG. 1 Typical Crankshaft Front Oil Seal Mounting

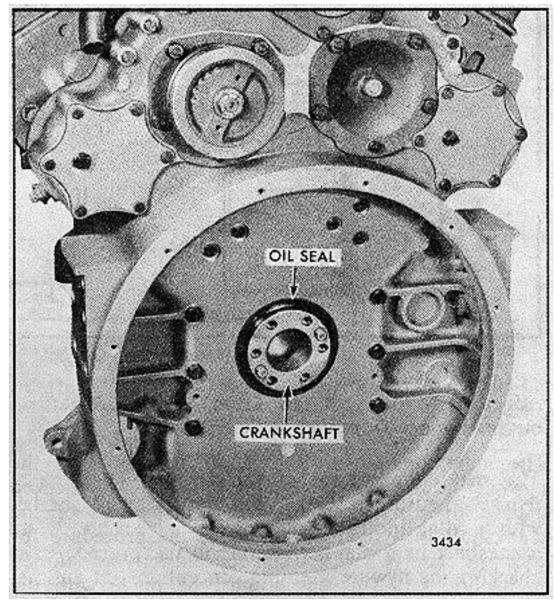


FIG. 2 - Crankshaft Rear Oil Seal Mounting

1. Support the outer face of the front cover or the rear face of the flywheel housing on wood blocks.

2. Drive the oil seal out and clean the seal bore in the front cover or flywheel housing. Discard the oil seal.

When necessary, an oil seal may be removed without removing the front cover or flywheel housing (except a front cover that is used with trunnion mounts - this cover must be removed). This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars.

Inspection

Inspect the rear end of the crankshaft for wear due to 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 damage to the seal lip when a new oil seal is installed. Slight

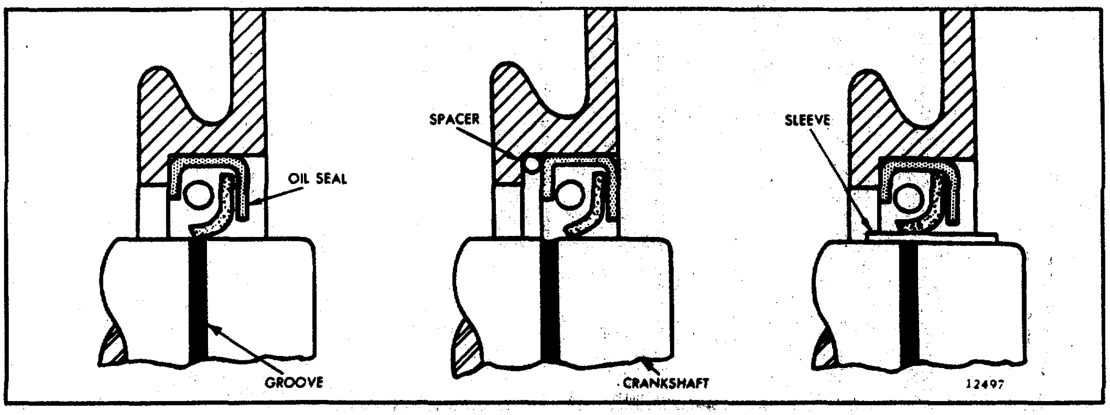


FIG. 3 - Use of Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft

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 in place on the engine and the oil seal removed.

If the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer (Fig. 3) may be installed between the counterbore in the flywheel housing and the oil seal. The spacer changes the relative position of the seal and establishes a new contact surface. However, the spacer cannot be used with a double-lip type seal since the grooves worn in the crankshaft are too close together to permit repositioning of the seal.

When the oil seal spacer can no longer be used, an oil seal sleeve (Fig. 3) may be installed on the crankshaft to provide a replaceable wear surface at the point of contact with the rear oil seal. The oil seal sleeve may be used with either the single-lip or double-lip type oil seal, and can also be used in conjunction with the seal spacer. However, an oversize oil seal must be used with the sleeve.

Install an oil seal sleeve as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.

2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.

3. Drive the sleeve squarely on the shaft with oil seat sleeve installer J 4194.

4. Wipe off any excess sealant.

5. Coat the outside diameter of the sleeve with engine oil.

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.

Oil Seals

Current oil seals are made of an oil resistant synthetic rubber which is pre-lubricated with a special lubricant. *Do not remove this lubricant.* Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surface of the casing. Do not remove this coating.

The rear oil seal may be either an open or closed back. Both types are serviced.

Install Crankshaft Front Oil Seal

1. If the oil seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing.

2. Coat the lip of the new seal with grease or vegetable shortening. Then position the seal in the front cover with the lip of the seal pointed toward the inner face of the cover.

The rear oil seal may have either an open or closed back. Both types are serviced.

> **NOTE**: The vibration damper inner cone or oil seal spacer must be removed before installing the oil seal.

3. Drive the seal into the front cover with tool J 9783.

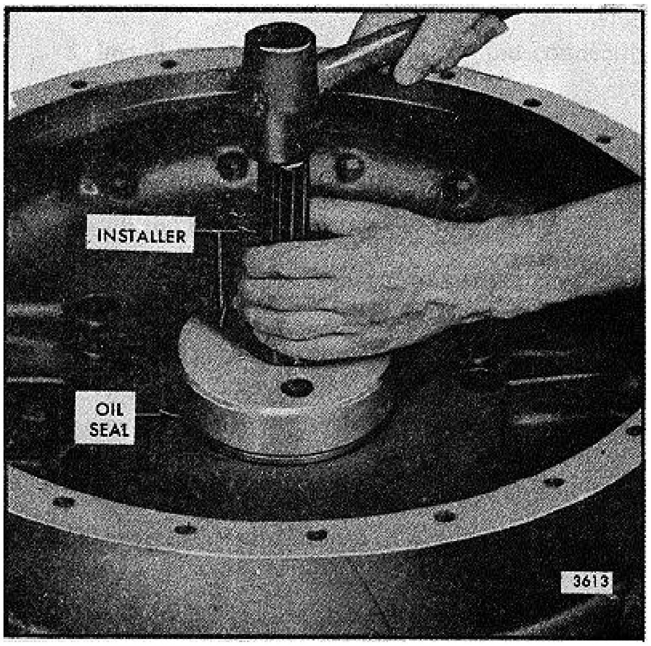


FIG. 4 - Installing Oil Seal in Flywheel Housing

The tool is designed to drive only on the outer edge of the seal casing to prevent damage to the seal.

4. Remove any excess sealant from the cover and seal.

5. Install the crankshaft front cover as outlined in Section 1.3.5.

6. Install the vibration damper inner cone or oil seal spacer after the front cover and seal assembly is in place.

Install Crankshaft Rear Oil Seal

1. Support the inner face of the flywheel housing on a flat surface.

2. Install the rear oil seal spacer, if used. Install the spacer against the shoulder in the flywheel housing oil seal bore.

3. If the new seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing. Then position the seal with the lip pointed toward the inner face (or shoulder in the counterbore) of the housing.

4. Coat the lip of the oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

5. Drive or press the seal into the housing with installer J 9727 and handle J 3154-1 (Fig. 4) until it is seated against the seal spacer (if used) or on the shoulder in the housing bore. The installer prevents damage to the seal by exerting force only on the outer edge of the seal casing.

If it is necessary to install the oil seal with the flywheel housing on the engine, place oil seal expander J 22425 (standard size seal) or expander J 4195401 with handle J 8092 (oversize seal) against the end of the crankshaft. Then, with the lip of the seal pointed toward the engine, slide the seal over the tool and on the crankshaft. Remove the seal expander and drive the seal in place with installer J 9727 and handle J 3154-1.

6. Remove any excess sealant from the flywheel housing and the seal.

7. Install the flywheel housing as outlined in Section 1.5.

> **NOTE**: If the oil seal is of the type which incorporates a brass retainer in the inner diameter of the seal, be sure the retainer is in place on the seal before installing the flywheel housing on the engine. If the retainer is left out, oil leakage will result.

CRANKSHAFT MAIN BEARINGS

The crankshaft main bearings shells are precision made and are replaceable without machining (Fig. 1). 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 bearing shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. The current TI, TA, TT and TTA engines have a through slot in each upper bearing shell which 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

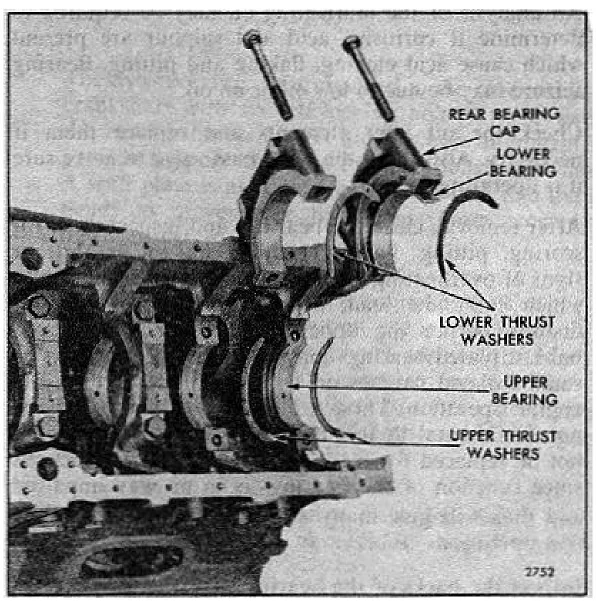


FIG. 1 - Main Bearing Shells, Bearing Caps and Crankshaft Thrust Washers

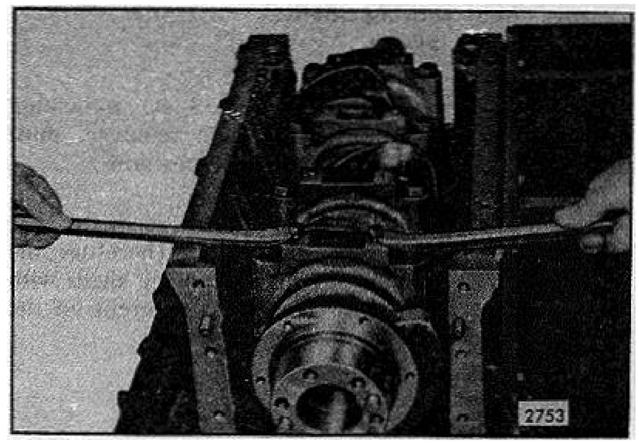


FIG. 2 - Removing Main Bearing Cap

halves of 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 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

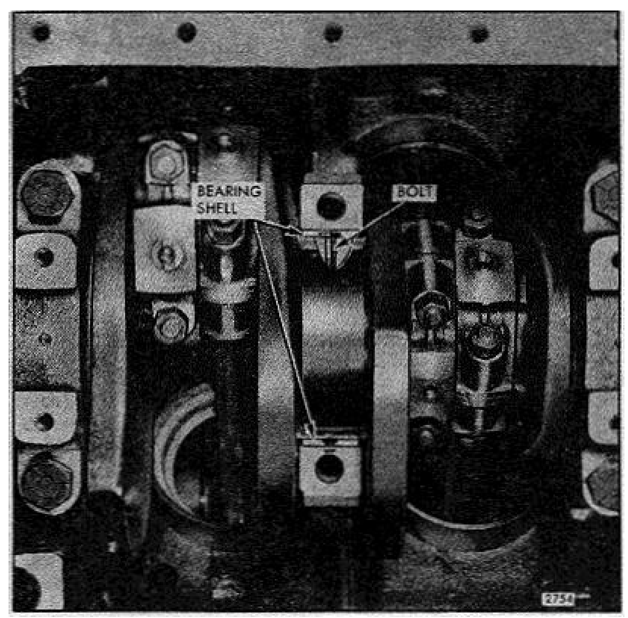


FIG. 3 - Removing Upper Main Bearing Shell (Except Rear Main)

time, as outlined below and examine the bearing shells.

Remove Main Bearing Shells (Crankshaft in Place)

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

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove 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 the oil inlet and outlet pipe assemblies.

NOTE: 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.

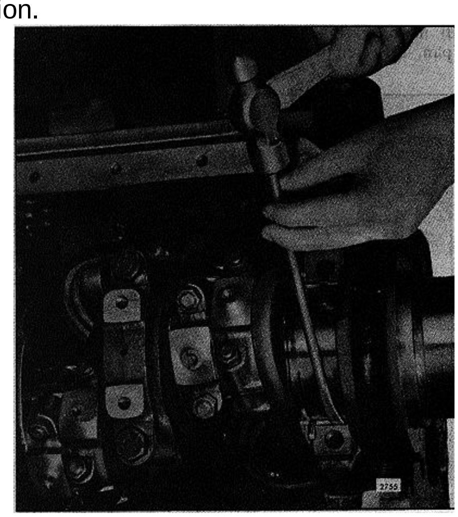


FIG. 4 - Removing Upper Rear Main Bearing Shell

3. Remove one main bearing cap stabilizer at a time, place washers (equal to the thickness of the stabilizer) on the bearing cap bolts and reinstall the bolts.

4. Remove one main bearing cap at a time (Fig. 2) and inspect the bearing shells as outlined under *Inspection.* Reinstall each bearing shell and bearing cap before removing another bearing cap:

a. To remove all except the rear main bearing shell, insert a 5/16", x I" 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 as shown in Fig. 3. The head of the bolt must not extend beyond the outside diameter of the bearing shell.

b. Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out as shown in Fig. 4.

c. 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, loss of babbitt or signs of overheating (Fig. 5). The lower bearing shells, which carry the load, will normally show signs of distress before the upper. bearing shells. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are not detrimental to this type of bearing. They should not be replaced for these minor surface imperfections since function of the bearings is in no way impaired and they will give many additional hours of trouble-free operation.

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.

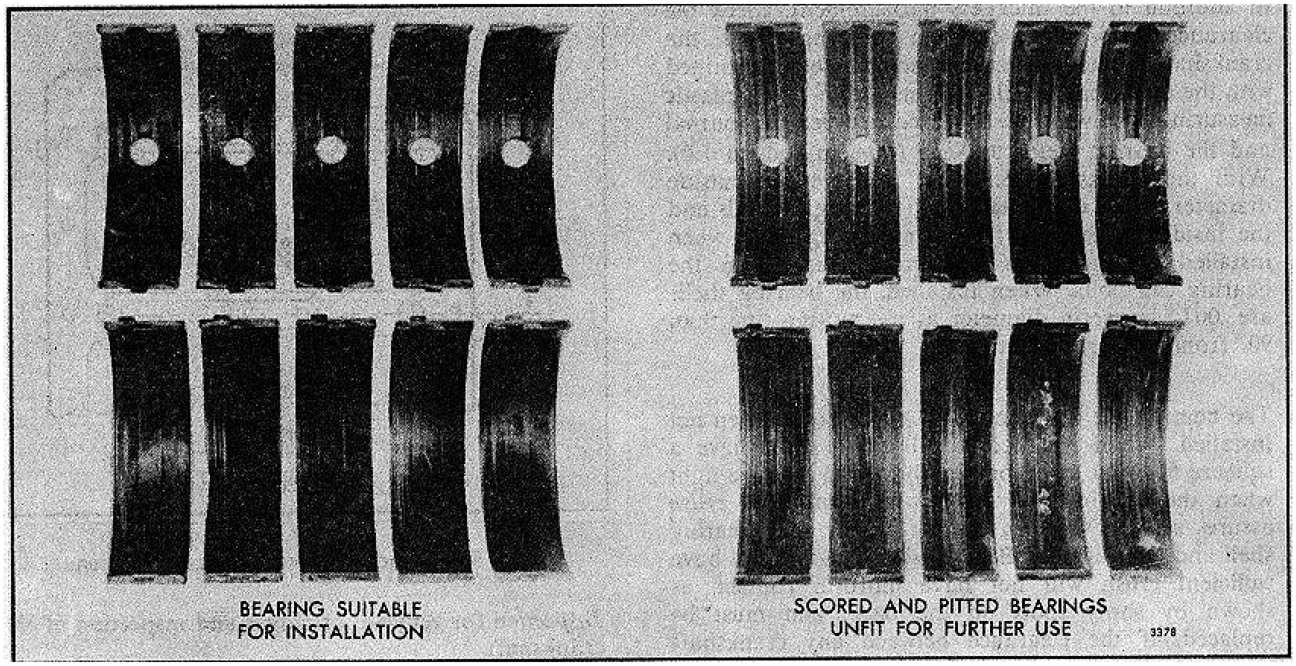


FIG. 5 - Comparison of Main Bearing Shells

Measure the thickness of the bearing shells at point "'C", 90 ° from the parting line, as shown in Figs. 6 and 7. 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 .1540 " 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 .1545 " to .1552 ". Refer to Table 1.

Bearing Size	Bearing Thickness	Minimum Thickness
standard	.1545"/.1552"	.154"
.002" Undersize	.1555"/.1562"	.155"
.010" Undersize	.1595"/.1602"	.159"
.020" Undersize	.1645"/.1652"	.164"
.030" Undersize	.1695"/.1702"	.169"

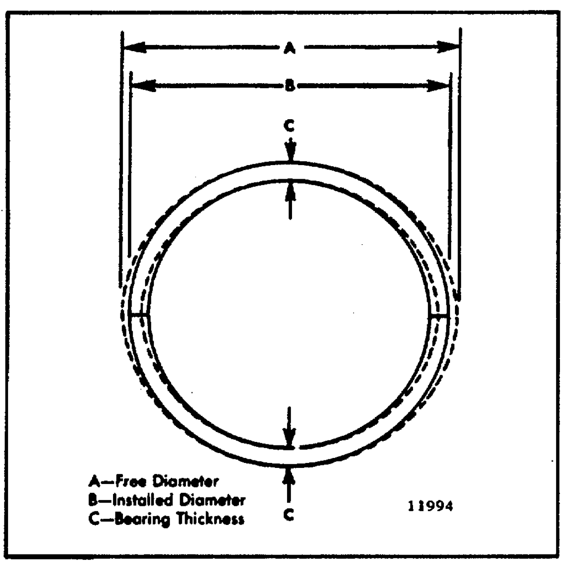


FIG. 6 - Main Bearing Measurements

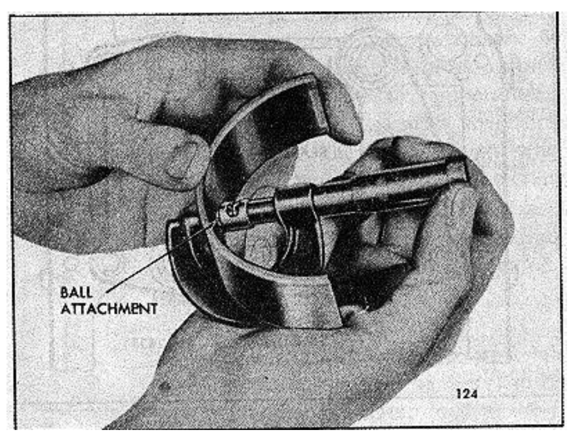


FIG. 7 - Measuring Thickness of Bearing Shell

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. 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 bearing seat. Bearing shells that do not have sufficient crush will not have uniform 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 .0060", all of the bearing shells must be discarded and replaced. This clearance is .0016 " to .0050 " 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*

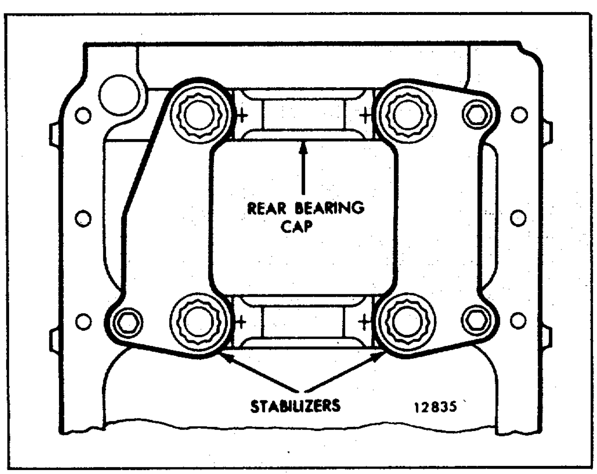


FIG. 8 - Stabilizer Mounting (12V Engine)

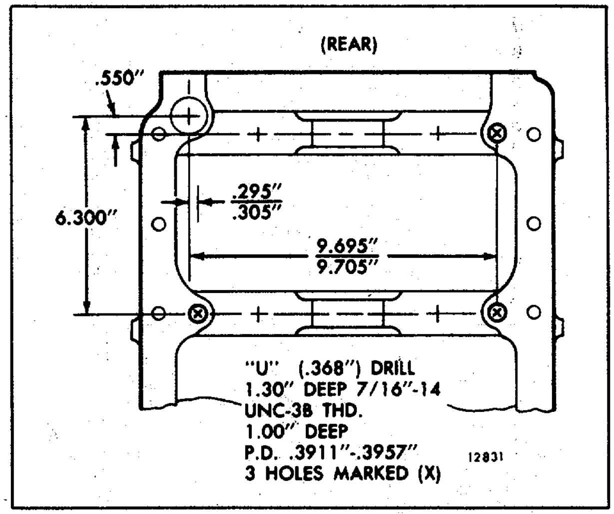


FIG. 9 - Cylinder Block Rework Instructions

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 to be used, install all new bearing shells.

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

NOTE: 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 crankshaft 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 .1 190"to .1220"thick. Thrust washers are available in .005" and .010" oversize.

Bearing cap stabilizers (Fig. 8) are used at the No. 4 and No. 5 main bearing cap positions on 8V engines and at the No. 6 and No. 7 main bearing cap positions on the 12V engines. Some engines may not be equipped with the stabilizers. It is recommended that stabilizers be added to these engines at time of overhaul. It will be necessary to modify the cylinder block by drilling and tapping three bolt holes marked "X" as shown in Fig. 9. Stabilizers can be used as templates to locate the three holes.

To improve main bearing cap clamping, a new stabilizer, main bearing cap bolt and washer are now being used in the 8V-71 engines (effective with 8VA-326189). The new stabilizers and bolts may be readily identified by a raised "71 " stamped on them.

To accept the new bolt and washer the former stabilizer can be reworked using tool J 26420. Operate the drill press at 60 rpm to provide an acceptable smooth surface on 80% of the washer seating surface of the stabilizer.

NOTE: Do not take off excessive material or the stabilizer may be weakened. Mark reworked stabilizers with a "71 R".

Only the current stabilizer can be used with the current bolt and washer. The former stabilizer can be reworked with tool J 26420 to accept the current bolt and washer. At time of overhaul it is recommended that the former stabilizer be replaced by the current stabilizer or reworked stabilizer and the current bolt and washer used.

Install Main Bearing Shells (Crankshaft in Place)

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

NOTE: Upper and lower bearing shells are serviced only in sets. Do not replace one main bearing shell alone. If one bearing shell requires replacement, install ail new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

The upper and lower main bearing shells are not alike; the upper bearing shell is grooved and drilled for lubrication -- the lower --bearing shell is not. 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.

NOTE: The main bearing caps are bored in position and stamped 1, 2, 3, etc. They must be installed in their original positions in the cylinder block.

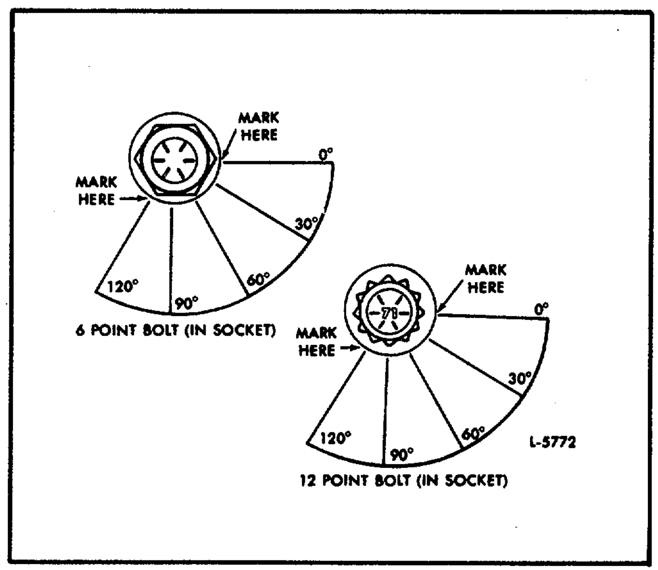


FIG. 10 - Main Bearing Cap Bolt Turn Torque Method

4. With the lower main 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 area. Install the bearing caps and draw the bolts up snug. Then rap the caps sharply with a soft hammer to seat them properly and tighten all bolts to 45-55 lb-ft (61-75 Nm) torque. Turn all bolts (except the rear main bearing bolts) an additional 10-1300 of bolt head rotation starting with the center bearing cap bolts and working alternately towards both ends of the block.

> **NOTE**: An accurate way to determine bolt head rotation is to paint or permanently scribe the sockets used with two marks 120° apart (Fig. 10). After torquing bolts to 45-55 lb-ft (61-75 Nm) put a pencil line opposite the first mark on the socket. Then rotate the bolt until the next socket mark lines up with the pencil line.

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. Turn the rear main bearing cap bolts an addition 110-130° of bolt head rotation. Tighten the 7/16"-14 stabilizer bolts to 70-75 lb-ft (95-102 Nm) torque. The current main bearing cap bolts are 6.54"-6.69" long to prevent possible bottoming.

> **NOTE**: 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.

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

6. Install the lubricating oil pump and the oil inlet and outlet pipe assemblies.

> **NOTE**: If shims were used between the pump and the bearing caps, install them in their original positions., Then check the oil pump gear clearance (Section 4.1).

7. Install the oil pan, using a new gasket.

8. 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).

9. After installing new bearing shells, operate the engine on a *run-in* schedule as outlined in Section 13.2. 1.

ENGINE FRONT COVER (Lower)

The engine front cover is mounted against the cylinder block at the lower front end of the engine (Fig. 1). It serves as a retainer for the crankshaft front oil seal. On certain 6V and 8V engines, this cover also serves as the lubricating oil pump housing. The engine is supported at the front end by engine supports attached to the front cover.

It will be necessary to remove the engine front cover to remove and install the crankshaft or when the engine is overhauled. Also, the front cover must be removed to service the lubricating oil pump on certain 6V and 8V engines. In addition, the front cover used with trunnion mounts must be removed- to replace the crankshaft front oil seal.

Remove Engine Front Cover

1. Drain the oil. Then remove the four oil pan-to-front cover attaching bolts and lock washers. Loosen all of the remaining oil pan bolts so the oil pan and gasket can be lowered approximately 1/4 " at the front end of the engine.

CAUTION: Be careful not to damage the gasket. Otherwise, it will be necessary to remove the oil pan and replace the gasket.

2. Remove the crankshaft pulley (Section 1.3.7) and vibration damper (Section 1.3.6), if used, and any other accessories that may be mounted on the front end of the crankshaft.

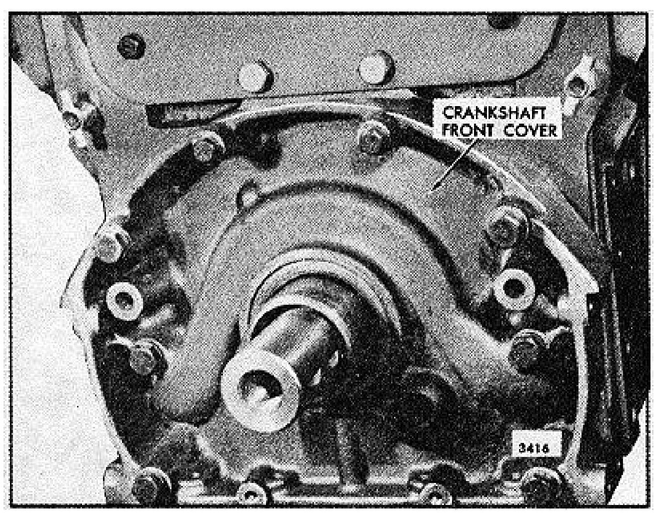


FIG. 1 - Engine Front Cover Mounting
(6V and 8V Engines)

3. Remove the vibration damper inner cone or oil seal spacer.

4. Disconnect the lubricating oil pump inlet tube at the bottom of the front cover on 6V or 8V engines.

5. Remove the cover to cylinder block attaching bolts.

6. Strike the edges of the cover alternately on each side with a soft hammer to free it from the dowels. Then pull the cover straight off the end of the crankshaft.

7. Remove the gasket from the cover or the cylinder block.

8. Replace the oil seal (Section 1.3.2).

Install Engine Front Cover

With the oil pump installed (6V and 8V engines--Section 4.1) and the oil seal installed, refer to Fig. 2 and install the front cover as follows:

1. Affix a new gasket to the inner face of the cover.

2. Coat the lip of the oil seal lightly with cup grease or vegetable shortening.

3. Install the front cover using oil seal expander J 22425 (standard size seal) or J 4195 and J 8092 (oversize seal) to pilot the oil seal over the crankshaft. Position the cover over the crankshaft and up against the cylinder block. Remove the oil seal expander.

4. Install the cover attaching bolts and lock washers and tighten the 3/8" -24 bolts to 25-30 lb-ft (34-41 Nm) torque and the 1/2" -13 bolts to 80-90 lb-ft (108-122 Nm) torque.

5. Apply engine oil to the vibration damper inner cone or oil seal spacer and slide it in place on the crankshaft.

6. Affix a new gasket to the flange on the oil pump inlet tube (6V or 8V engine) and attach the tube to the bottom of the engine cover.

7. Install the four oil pan-to-front cover attaching bolts and lock washers. Tighten all of the oil pan attaching bolts to 15-20 lb-ft (20-27 Nm) torque.

8. Install the vibration damper (Section 1.3.6), if used, the crankshaft pulley (Section 1.3.7) and any other accessories that were removed.

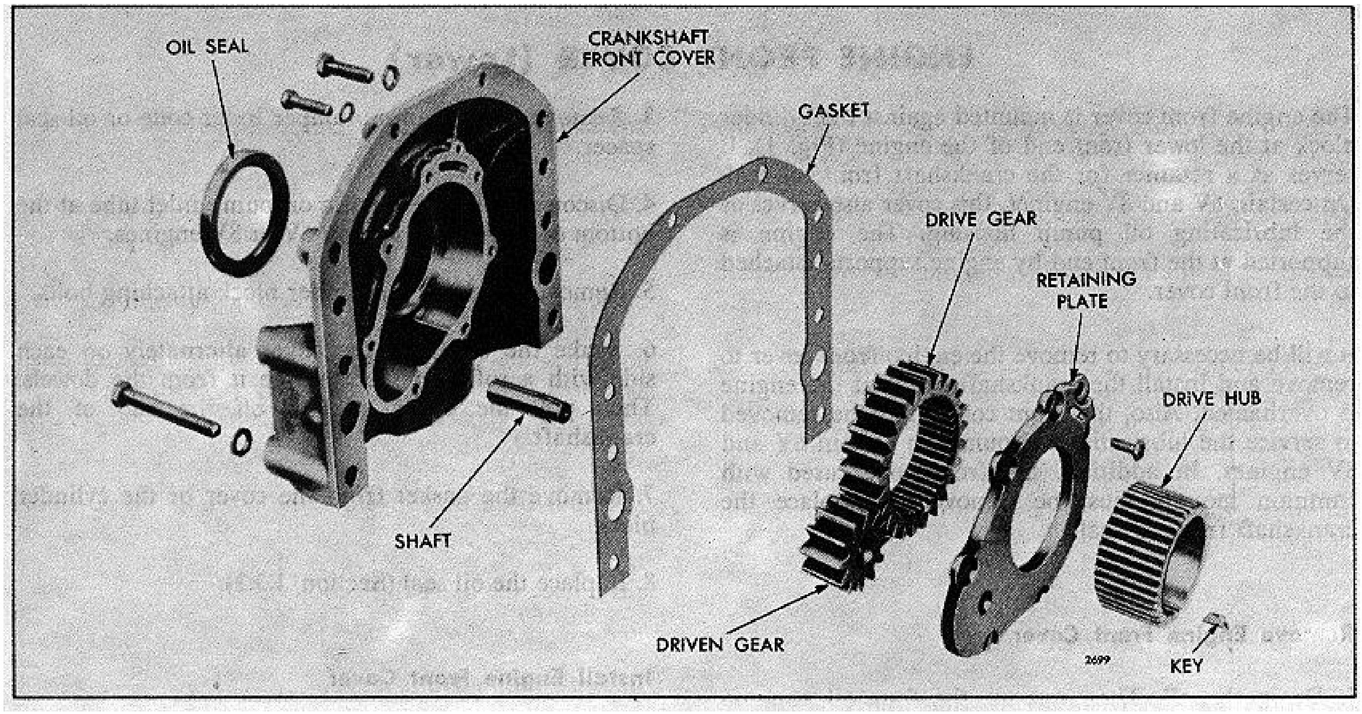


FIG. 2 - Front Cover Details and Relative Location of Parts (6V and 8V Engines)

9. Refer to *Lubricating Oil Specifications* in Section 13.3 and fill the crankcase with oil to the proper level on the dipstick.

CRANKSHAFT VIBRATION DAMPER

On 12V, a viscous type vibration damper is mounted on the front end of the crankshaft to reduce crankshaft stresses to a safe value. The new 12 " nylon coated flywheel style vibration dampers are now being used on the 12V-71 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.

A viscous type vibration damper consists of an inertia mass (flywheel) enclosed in a silicone fluid-tight outer case but separated therefrom by a thin wall of viscous liquid not responsive to temperature changes. Any movement of the inertia mass, therefore, is resisted by the friction of the fluid, which tends to dampen excessive torsional vibrations in the crankshaft.

The vibration damper must be removed whenever the crankshaft, crankshaft front oil seal, or the crankshaft front cover is removed.

The new crankshaft bolts are now lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up (crankshaft pulley, vibration damper, etc). Also the new washer (retainer) is now case hardened.

The new bolts and washer can be identified by their black color. The former bolts and washer are steel (gray) color.

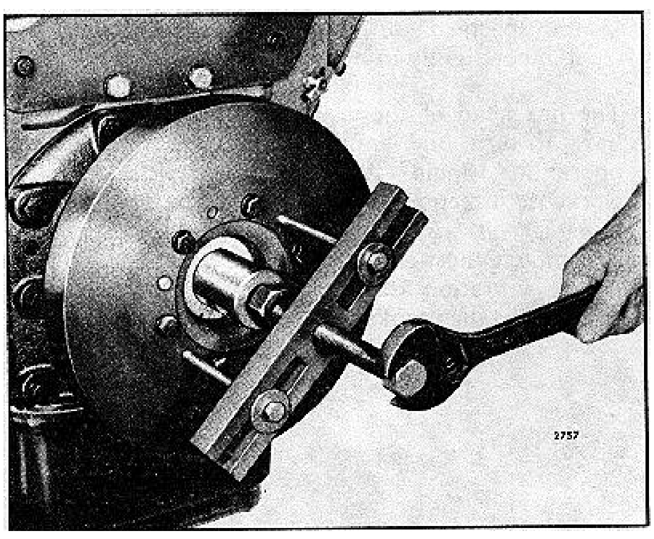


FIG. 1 - Removing Vibration Damper Outer Cone from a 12V Engine

Remove Vibration Damper From Crankshaft (12V Engine)

1. Remove the crankshaft pulley retaining bolt and washer.

2. Remove the crankshaft pulley. If required, use a suitable puller to remove the pulley.

3. Reinstall the pulley retaining bolt in the end of the crankshaft.

4. Attach puller J 24420 to the vibration damper hub. as shown in Fig. 1, with two long bolts threaded into the two 3/8 "-24 tapped holes provided in the hub. Pull the damper and hub assembly together with the outer cone, until the outer cone is loose on the crankshaft. On the rubber type vibration damper (Fig. 1), remove two damper-to-hub bolts and lock washers diametrically opposite to each other and attach the puller with two long 7/16 "-20 bolts.

5. Remove the puller from the damper hub and pull the outer cone off the crankshaft.

> **NOTE**: *Pounding with a hammer or prying with other tools must not be resorted to 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.

6. Slide the vibration damper and damper hub as an assembly off the end of the crankshaft by hand.

7. If necessary. remove the vibration damper inner cone from the crankshaft.

Inspect Vibration Damper

The viscous type damper should be inspected for dents, nicks. fluid leaks or bulges in the outer casing of the damper. Any indications of the above are sufficient causes for replacement of the damper. Due to the close clearances between the damper internal flywheel and 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.

Regardless of condition. a viscous type damper must be replaced at the time of normal periodic major engine overhaul.

After removal. clean the rubber type vibration damper in fuel oil and dry it with compressed air.

> **IMPORTANT**: Do not allow fuel oil to remain on the rubber type vibration damper too long. Dry it immediately after cleaning. otherwise damage due to action of fuel oil on rubber may result.

Inspect the rubber type damper to see that the rubber is firmly bonded to the metal parts. If the damper has been exposed to fuel oil. Lubricating oil or excessive heat. the rubber may have become loosened from the metal. In this event. discard the damper and replace it with a new one. Also check to see that the metal discs are not bent.

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 damper inner and outer cones, damper hub and end of crankshaft for galling or burrs. Slight scratches or burrs may be removed with emery cloth. If seriously damaged, the parts should be replaced and the end of the crankshaft refinished. Check the outside diameter of the inner cone for wear at the crankshaft front oil seal contact surface. If worn, the oil seal and cone should be replaced. Refer to Section 1.3.2.

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 on Crankshaft
(12V Engine)

> **IMPORTANT**: All of the parts on the front of the crankshaft must be positioned without any noticeable interference.

1. If removed, pilot the damper inner cone over the end of the crankshaft, through the oil seal and up against the oil slinger, with the tapered end of the cone pointing toward the front end of the crankshaft.

2. Slide the vibration damper and hub as an assembly over the end of the crankshaft (long end of hub facing inner cone) and up against the damper inner cone. Do not hit the damper with a hammer to position it on the crankshaft.

3. Slide the damper outer cone over the end of the crankshaft and up against the damper hub, with the tapered end of the cone pointing toward the hub.

4. Install the pulley on the crankshaft.

5. Place the washer on the crankshaft end bolt and thread the bolt into the end of the crankshaft.

> **NOTE:** If the engine was built prior to March 1977, install a new lubrite coated bolt and washer identified by their black color.

6. Tighten the crankshaft end bolt as follows:

a. Tighten the bolt to 180 lb-ft (244 Nm) torque.

b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.

c. Tighten the bolt to 300 lb-ft (407 Nm) torque and strike the bolt again.

d. Retighten the bolt to 290-310 lb-ft (393-421 Nm) torque.

> **IMPORTANT**: Do not strike the bolt after final torque has been applied.

> **NOTE:** 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.

The hex head of the crankshaft bolt may be used to bar, or 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 during the barring operation.* Otherwise serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

CRANKSHAFT PULLEY

The crankshaft pulley is keyed to the crankshaft and secured with a special washer and bolt.

The engines are equipped with either rigid type or rubber mounted type pulleys, depending on the engine application. Rubber mounted pulleys incorporate a rubber insulator between the pulley and the pulley hub, for vibration dampening, and a static clip on some engines, between the pulley and the hub, for releasing electrical charges.

The new crankshaft bolts are now lubrite coated to prevent possible damage (galling) to the bolt threads and to increase the clamp load to the front end stack up (crankshaft pulley, vibration damper, etc). Also the new washer (retainer) is now case hardened.

The new bolts and washer can be identified by their black color. The former bolts and washer are steel (gray) color.

Inspection

The condition of a rubber mounted crankshaft pulley cannot be determined by the appearance of the rubber. The only reliable method of checking for failure of the rubber bushing is to hold the crankshaft stationary and apply pressure to the pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. An unsatisfactory rubber bushing should be replaced.

Remove Crankshaft Pulley

1. Remove the pulley retaining bolt and washer and static clip, if used.

2. Remove the pulley using a suitable puller or thread the pulley retaining bolt halfway into the crankshaft and strike the bolt with a 2 to 3 pound lead hammer while prying behind the pulley with two pry bars. Keep the ends of the pry bars as close to the crankshaft as possible.

If tapped holes are provided, install the pulley bolt in the end of the crankshaft then, using puller J 4558. Remove the pulley from the crankshaft.

Install Crankshaft Pulley

1. Place the Woodruff keys in the key slots in the front end of the crankshaft, if they were removed.

2. Slide the pulley on the end of the crankshaft.

3. Place the washer and static clip, if used. on the bolt and thread the bolt into the end of the crankshaft.

4. Tighten the crankshaft end bolt as follows:

a. Tighten the bolt to 180 Ib-ft (244 Nm) torque.

b. Strike the end of the bolt a sharp blow with a 2 to 3 pound lead hammer.

c. Tighten to 300 Ib-ft (407 Nm) torque and strike the bolt again.

d. Tighten the bolt to 290-310 Ib-ft (393-421 Nm) torque.

NOTE: Do not strike the bolt after the final torque has been applied.

The hex head of the crankshaft bolt may be used to bar. or 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 during the barring operation.* Otherwise serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

FLYWHEEL

The flywheel (Fig. 1) is attached to the rear end of the crankshaft with six self-locking bolts. Two dowels in the end of the crankshaft aid flywheel alignment and provide support when the flywheel bolts are removed. A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface.

Effective with 8VA-352893 a new crankshaft with eight flywheel bolt holes in the butt end is used in the 8V-71 engines. The former dowel holes are now threaded the same as the other six holes to provide for the additional two bolts. To allow for more space between the bolt heads, new step-head bolts are also being used with the new 8V-71 crankshaft.

NOTE: Do not attempt to drive dowels in a new 8V-71 crankshaft or serious damage could occur.

To rework a six flywheel bolt hole 8V-71 crankshaft to an eight flywheel bolt hole crankshaft refer to Section 1.0.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

On some engines, a split tube type retainer (Fig. 2) is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity. Other engines use a washer type retainer.

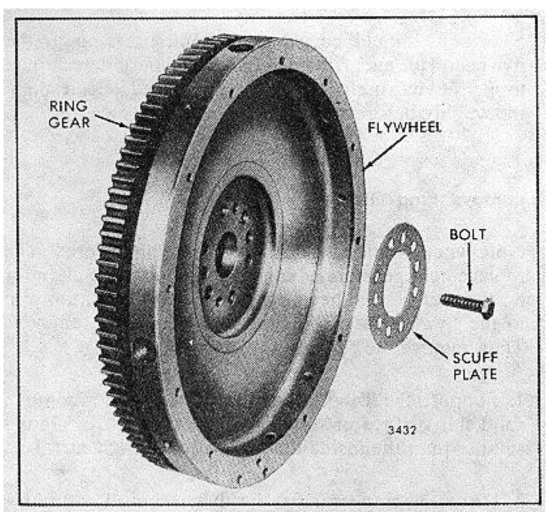


FIG. 1 - Typical Flywheel Assembly

The flywheel is machined to provide true alignment with the clutch and the center bore provides for installation of a clutch pilot bearing. The clutch is bolted to the flywheel.

An oil seal ring, which provides an oil tight connection between the crankshaft and the flywheel, is fitted into a groove on certain flywheel assemblies.

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft or flywheel housing.

Remove Flywheel (Transmission Removed)

1. Remove the six flywheel attaching bolts and scuff plate.

   a. Attach flywheel lifting tool J 6361-01 to the flywheel with two 7/16 "-14 bolts of suitable length or use lifting tool J 25026.

   b. Attach a chain hoist to the lifting tool to support the flywheel as shown in Fig. 3.

   c. Move the upper end of the lifting tool in and out

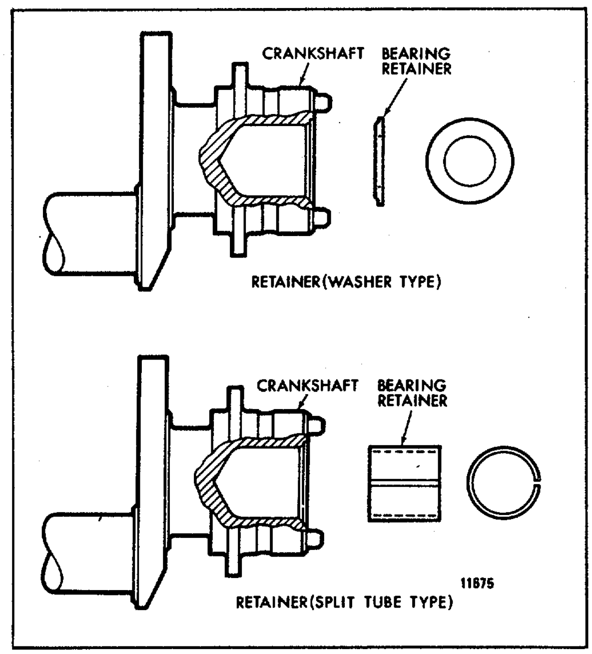


FIG. 2 - Pilot Bearing Retainers

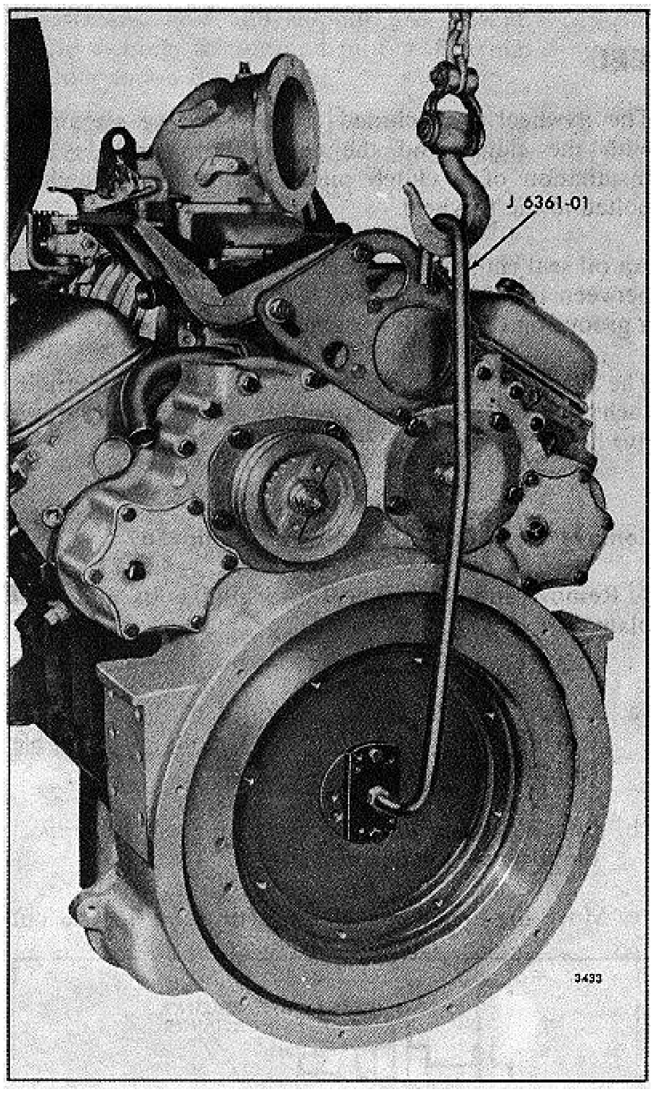


FIG. 3 Removing Flywheel

to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.

2. Remove eight flywheel attaching bolts and scuff plate.

a. Remove two flywheel bolts. Install two suitable guide pins in these holes to support the flywheel.

b. Remove the remaining flywheel attaching bolts and scuff plate.

c. Attach flywheel lifting tool J 25026, or some other suitable safe lifting device, to the flywheel.

d. Attach a chain hoist to the lifting tool to support the flywheel.

e. Remove the flywheel from the crankshaft and the flywheel housing.

3. Remove the clutch pilot bearing, if used, as outlined in Section 1.4.1.

4. Remove the washer type pilot bearing retainer, if used. It is not necessary to remove the split tube type retainer.

5. Remove the oil seal ring, if used.

Inspection

Check the clutch contact face of the flywheel for scoring, overheating or cracks. If scored, the flywheel may be refaced. However, *do not* remove more than .020 " of metal from the flywheel. Maintain all of the radii when refacing the flywheel.

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.

On crankshafts with dowels, be sure and check the dowel extension. Dowels must not extend more than 1/2 " (13 mm) from the crankshaft.

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

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed. Then remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or 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.

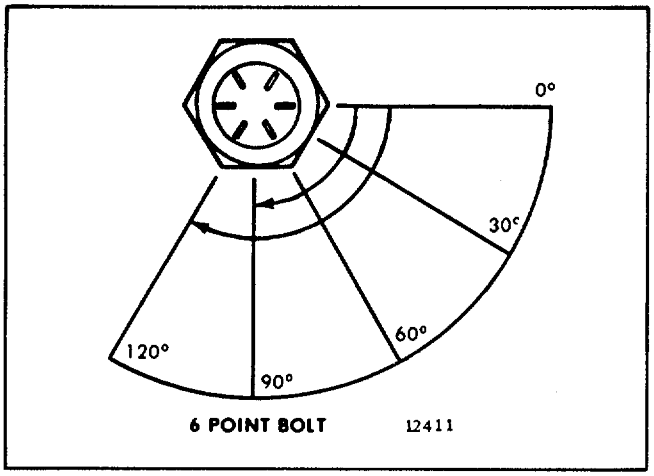


FIG. 4 Torque-Turn Limits

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.

IMPORTANT: Do not, under any circumstances, heat the gear over 400 °F (204 °C); excessive heat may destroy the original heat treatment.

NOTE: Heat indicating "crayons", which are placed on the ring gear and melt at a predetermined 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 caution.

Install Flywheel (Six bolt crankshaft and current 8V-71 eight bolt crankshaft)

1. Install a new oil seal ring (if used).

2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs). Align the flywheel bolt holes with the crankshaft bolt holes.

3. Install the clutch pilot bearing (if used).

4. Install the washer type pilot bearing retainer, if used. To install a split tube type retainer, drive the retainer in flush with the end of the crankshaft with a soft hammer.

NOTE: Do not mar the bearing contact surface of the retainer.

5. 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 studs.

6. Remove the flywheel lifting tool.

7. 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.

NOTE: International Compound must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

8. Install the remaining bolts and run them in snug.

9. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.

10. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb-ft (68 Nm) torque.

11. Turn the bolts an additional 90-120° (Fig. 4) to obtain the required clamping.

NOTE: Since the *torque-turn* method provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

IMPORTANT: 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.

2. 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.

CLUTCH PILOT BEARING

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

The clutch pilot bearing is held in place by a scuff plate, or bearing retainer, secured in place by the flywheel attaching bolts.

Lubrication

A single-shielded ball type clutch pilot bearing should be packed with an all-purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer. A double-sealed ball type clutch pilot bearing is prepacked with grease and requires no further lubrication.

Remove Clutch Pilot Bearing (Transmission Removed)

With the flywheel attached to the engine, remove the ball type clutch pilot bearing as follows:

1. Remove the six bolts attaching the flywheel to the crankshaft. Remove the bearing retainer and re-install two of the bolts to hold the flywheel in place.

2. With the clutch pilot bearing remover adaptor J 23907-2 attached to slide hammer J 23907-1, insert the fingers of the adaptor through the pilot bearing and tighten the thumb screw to expand the fingers against the inner race of the bearing.

3. Tap the slide hammer against the shoulder on the shaft and pull the bearing out of the flywheel.

With the flywheel removed from the engine, the clutch pilot bearing may be removed as follows:

1. Place the flywheel on wood supports to provide clearance for the bearing.

2. Use bearing remover J 23907-2 as outlined above, or tool J 3154-04 with suitable adaptor plates, to tap the bearing from the flywheel.

Inspection

Wipe the prepacked double-sealed bearing clean on the outside and inspect it. *Shielded bearings must not be washed;* dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Clean the other types of bearing thoroughly with clean fuel oil and dry them with compressed air.

Check the bearing for free rolling by holding the inner race and revolving the outer race *slowly* by hand. Rough spots in the bearing are sufficient cause for rejecting it.

Install Clutch Pilot Bearing

1. Lubricate the outside diameter of the bearing with clean engine oil.

2. Start the bearing in the bore of the flywheel, with the numbered side of the bearing facing away from the engine, and drive the bearing in place with bearing installer J 3154-04 and suitable adaptor plates.

3. Install the flywheel on the crankshaft (refer to Section 1.4).

FLYWHEEL HOUSING

The flywheel housing is a one-piece casting, mounted against the rear cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the transmission.

To provide additional support for the aluminum flywheel housings on 6V and 8V-71 vehicle engines, the current cylinder blocks now include two drilled waist bolt bosses. The current aluminum flywheel housings, rear end plates and gaskets have provision for the two new waist bolts. Only the current blocks will be serviced. However when a current flywheel housing or a rear end plate and gaskets replace the former parts on an early engine, disregard the waist bolt holes.

NOTE: The current aluminum flywheel housing does not have an oil drain back provision for a crankcase breather. Therefore a flywheel housing mounted breather cannot be used and it will be necessary to install a valve rocker cover mounted breather assembly.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (Section 1.3.2).

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined in Section 1.1.

2. Remove the starting motor, oil pan, flywheel and any accessories attached to the flywheel housing.

3. Remove the twelve attaching bolts located in the bell of the housing. Remove one attaching bolt located behind the small hole cover, or the crankcase breather (if used), on the right-hand side of the flywheel housing. Then remove the remaining bolts around the upper portion of the housing and the two bolts which go through the rear end plate from the front and thread into the housing.

NOTE: When removing the flywheel housing bolts, note the location of the various size bolts and washers so they may be reinstalled in their proper location.

4. To guide the flywheel housing, until it clears the end of the crankshaft, thread four pilot studs J 1927-01 into the cylinder block (Fig. 1).

5. With the flywheel housing supported by a chain hoist attached to the lifter brackets, strike the front face of the housing alternately on each side with a soft hammer to work it off the dowels and away from the cylinder block rear end plate.

Inspection

Clean the flywheel housing and inspect it for cracks or other damage.

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the end plate, otherwise runout of the pilot face and bolting flange face of the housing may be affected when the housing is installed on the engine.

The steel oil deflector used in the flywheel housing on certain former engines is no longer required and is not available for service.

Current SAE No. 2 aluminum flywheel housings have

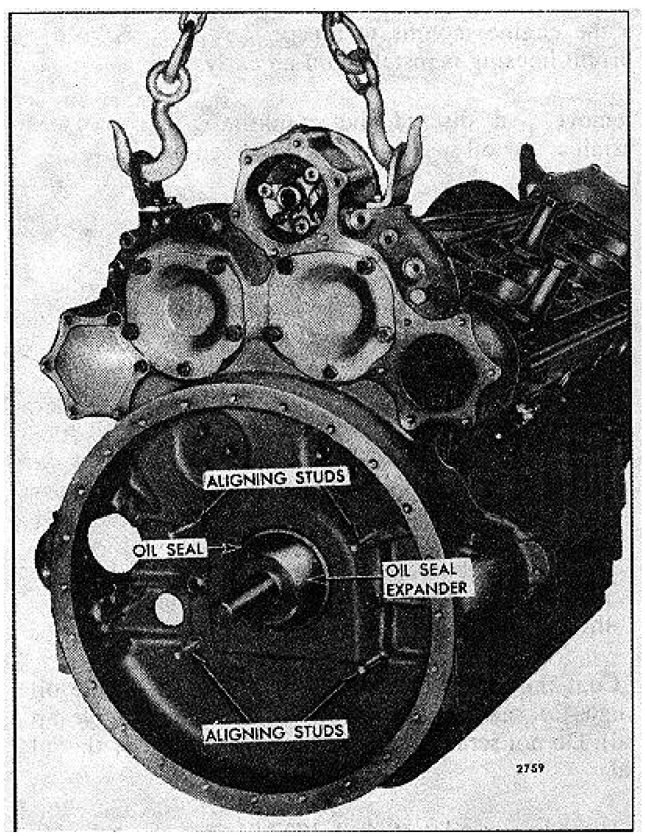


FIG. 1 - Removing or Installing Flywheel Housing

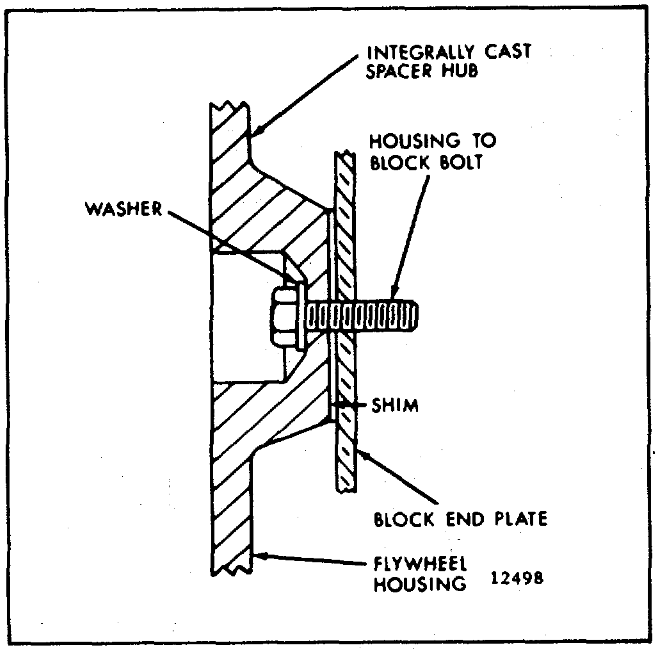


FIG. 2 - Idler Gear Hole Spacer Shim

5/8"-11 tapped holes for attaching rear engine mounts. It may be necessary to enlarge the bolt holes in the engine mounts to accept the larger bolts if a current housing is installed on an early engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined in Section 1.3.2.

Install Flywheel Housing

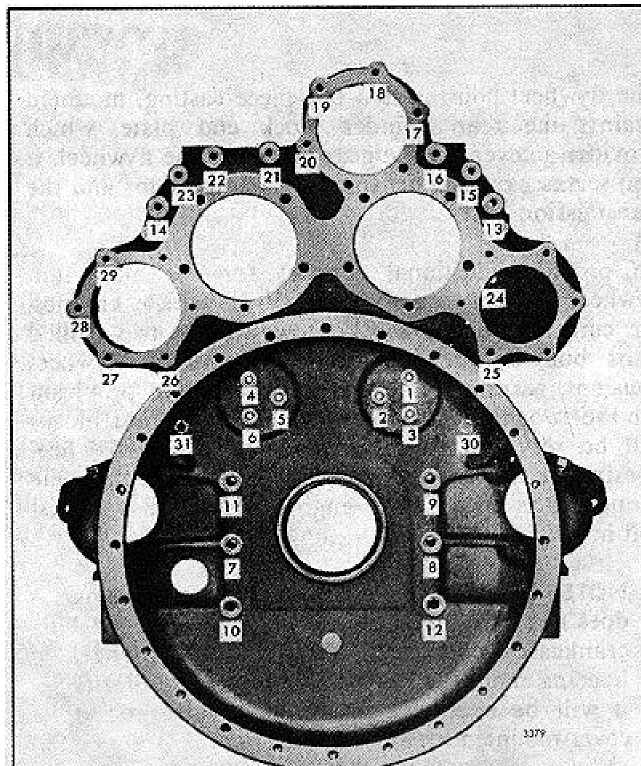
1. Lubricate the gear train teeth with clean engine oil.

2. Affix a new gasket to the flywheel housing.

NOTE: On certain flywheel housings, the idler gear hole spacer is cast integrally in the housing, opposite the idler gear (Fig. 2). As a result of this integral cast design, a shim must be installed between the flywheel housing and the cylinder block end plate. Use grease to hold the shim on the spacer during installation of the flywheel housing.

3. Coat the lip of the oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

4. Thread four pilot studs J 1927-01 into the cylinder block to guide the housing in place (Fig. 1). Use oil seal expander J 22425 (standard size seal) or expander J 4195-01 and handle J 8092 (oversize seal) on the end of the crankshaft to pilot the oil seal on the crankshaft.



Bolt Size	Location
3/8"-16x1"	1-2-3-4-5-6-30-31
3/8"-16x1 1/4"	24
3/8"-24x3 7/8"	13-14-15-16-21-22-23
1/2"-13x3 1/4"	7-8-9-10-11-12

FIG. 3 - Flywheel Housing Bolt Size and Tightening Sequence (Operation 1)

5. With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket. Remove the oil seal expander.

6. Refer to Fig. 3 and install (finger tight) six new 3/8"-16 flanged hex head bolts with a self locking sealing patch into the tapped holes of the idler gear hub and idler gear hole spacer, if used. Remove the pilot studs.

NOTE: If the idler gear hole spacer is integrally cast into the housing, be sure the shim is in place.

7. Install the six 1/2"-13 housing to block bolts with lock washers, finger tight.

8. Install the remaining flywheel housing attaching bolts and washers, finger tight.

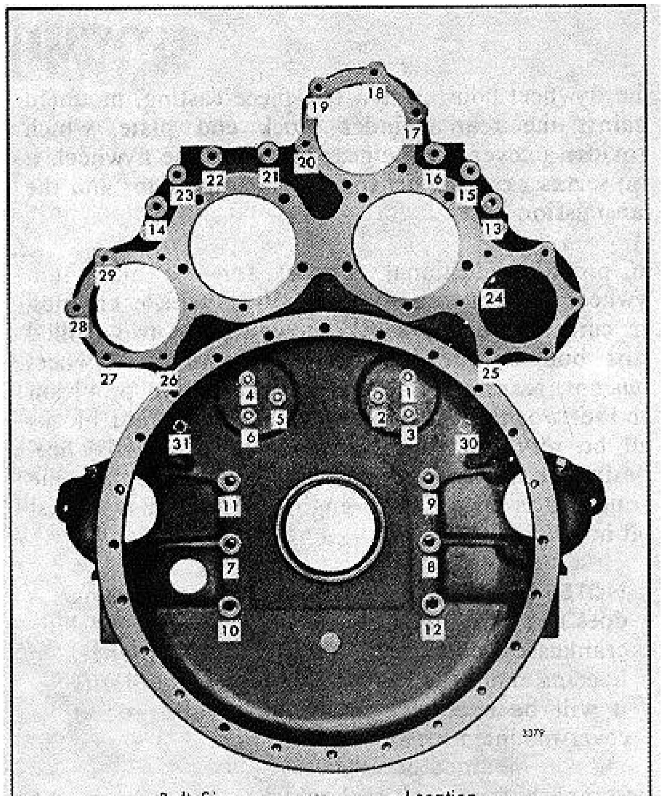


FIG. 4 - Flywheel Housing Bolt Tightening Sequence (Operation 2)

9. Refer to Fig. 3 for the bolt tightening sequence. Start at number 4 on a right-hand rotation engine or at number I on a left-hand rotation engine and, using the proper sequence, bring all bolts to within 10-15 Ib ft (14-20 Nm) of their specified torque, drawing the mating parts together evenly.

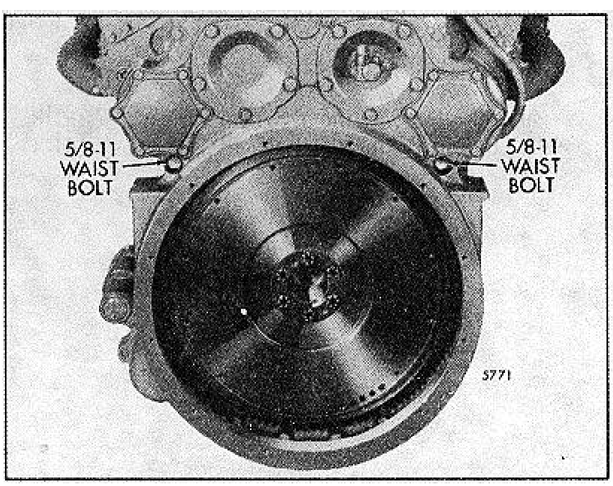


FIG. 5 - Waist Bolt Location

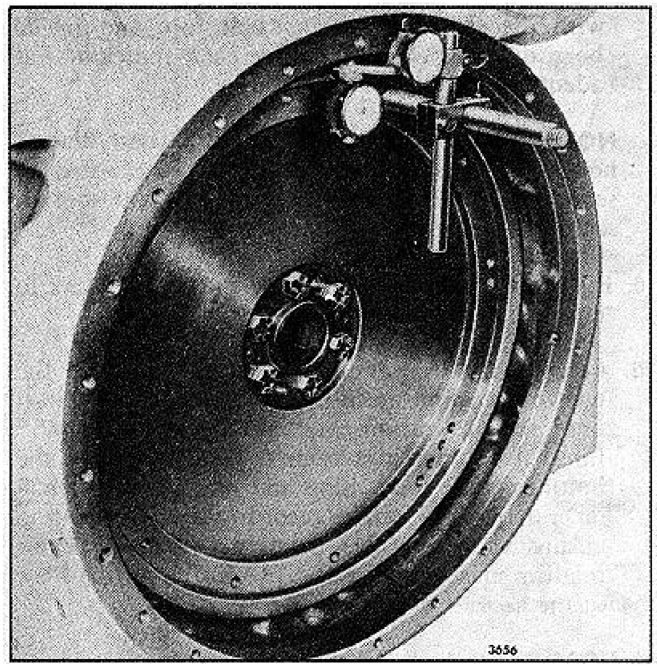


FIG. 6 - Checking Flywheel Housing Concentricity using Tool J 9737-01

NOTE: When tightening the idler gear hub bolts, turn the engine crankshaft to prevent any bind or brinelling of the idler gear bearing. The crankshaft must be rotated for the flywheel housing bell bolt tightening also.

10. Refer to Fig. 4 for the final bolt tightening sequence and, starting at number 1, tighten all of the bolts to the specified torque. Tighten the 1/2"-13 bolts to 90-100 Ib-ft (122-136 Nm) torque (cast iron housing) or 71-75 Ib-ft (96-1()2 Nm) torque (aluminum housing). Tighten the 3/8"-16 self-locking idler gear hub and spacer bolts to 40-45 Ib-ft (54-61 Nm) torque. Tighten the 3/8"-24 bolts to 25-30 Ib-ft (34-41 Nm) torque and all remaining 3/8"-16 bolts to 30-35 Ib-ft (41-47 Nm) torque. Be sure to rotate the crankshaft when tightening the idler gear hub bolts and flywheel housing bell bolts. Tighten the 5/8"-I1 flywheel housing waist bolts (Fig. 5) to 137-147 Ib-ft (186-200 Nm) torque, after tightening the other bolts in sequence.

11. Install the flywheel (Section 1.4).

12. Check the flywheel housing concentricity and bolting flange face with tool set J 9737-C as follows:

a. Refer to Fig. 6 and 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 t the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

NOTE: If the flywheel extends beyond the housing bell, the bore and face must be checked separately. Use the special adaptor in the tool set to check the housing bore.

c. Pry the crankshart 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). 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.

NOTE: On scalloped flywheel housings, position the dial indicators at the 4:30 position and rotate the crankshaft 270°.

e**.** If the runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreign material, such as old gasket material, between the end plate, flywheel housing and the new gasket (and between the end plate and the cylinder block).

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.

13. Install the oil pan.

14. Install the starting motor (Section 7.3).

NOTE: The starting motor pad bolt holes have been relocated on certain SAE No. 1 and SAE -No. 2 flywheel housings. If a current housing is installed on an early engine, the solenoid on a Sprag clutch type starting motor may have to be repositioned. Refer to Section 7.3 for the indexing procedure. It will be necessary to replace a Dyer drive type starting motor with a Sprag clutch type motor.

15. Install any accessories previously removed.

16. Install the small and large hole covers on the flywheel housing. Tighten the 3/8"-24 bolts, 7/16"a-14 bolts and 1/2"-13 bolts to 30-35 Ib-ft (41-47 Nm) torque.

NOTE. Current engines include thread inserts at the small and large hole cover stud hole positions.

17. Remove the engine from the overhaul stand and complete assembly of the engine.

Installing Flywheel Housing Small Hole Covers

An RTV (room temperature vulcanizing) sealant is now being used in place of the gasket to seal flywheel housing small hole cover ("star cover". Replace the covers as follows:

1. Clean the old gasket material and/or loose sealant from the housing and cover. It is not necessary to remove all the old sealant.

2. Apply a one-eighth inch (.125") diameter continuous, unbroken bead of sealant to the perimeter of the cover just inside the bolt holes. To provide an effective seal, this should be done not more than 10 minutes before the cover is to be secured to the flywheel housing.

NOTE: To make sure the sealant is properly applied, verify that the sealant is in the correct location by using a sample gasket as a template prior to installing the bead.

3. Attach the cover to the flywheel housing with the proper bolts and torque the bolts to 30-35 Ib-ft (41-47 Nm).

PISTON AND PISTON RINGS

TRUNK-TYPE PISTON

The trunk-type malleable iron piston (Fig. 1) is plated with a protective coating of tin which permits close fitting. reduces scuffing and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress the air into close proximity to the fuel spray.

Each piston is internally braced with fin-shaped ribs and circular struts. scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil spray to ensure better control of piston ring temperature.

The fire ring groove in the current piston is no longer induction hardened and the chrome on the wear surface on the bottom side of the piston fire ring has been eliminated. The new pistons can be identified by the part number stamped on the top of the piston.

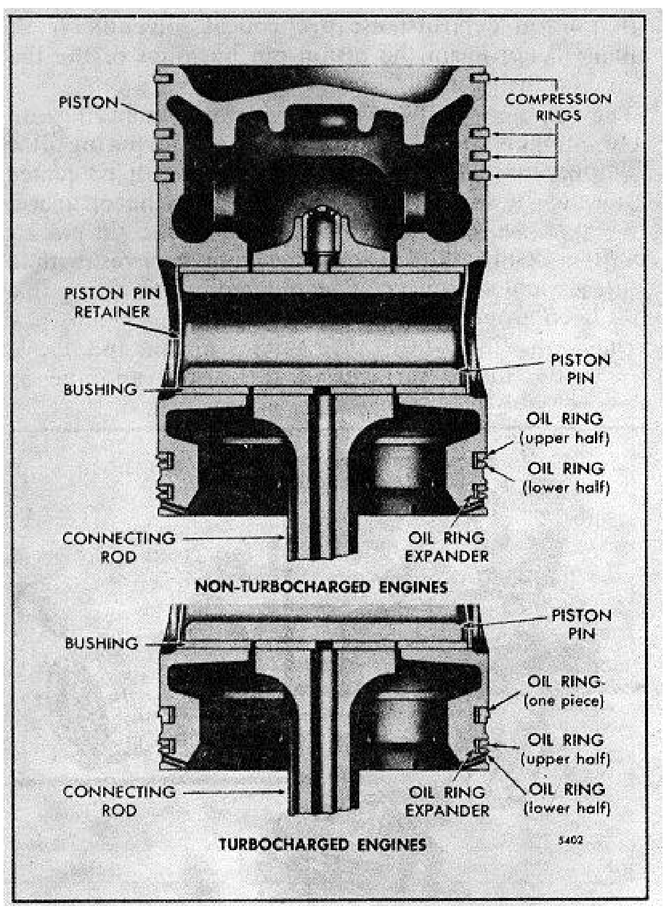


FIG. 1 Typical Piston Assembly

The piston is cooled by a spray of lubricating oil directed at the underside of the piston head from a nozzle in the top **of** the connecting rod, by fresh air from the blower to the top or the piston and indirectly by the water jacket around the cylinder.

Each piston is balanced to close limits by machining a balancing rib. provided on the inside at the bottom of the piston skirt.

Two bushings. with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened. floating piston pin. After the piston pin has been installed. the hole in the piston at each end of the pin is sealed with a steel retainer. Thus lubricating oil returning from the sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

The current turbocharged engines use a piston pin with a highly polished external surface finish and an oil hole to provide oil under pressure to the piston pin bushings. A groove on each side of the oil hole is for stress distribution (refer to Section 1.6.1).

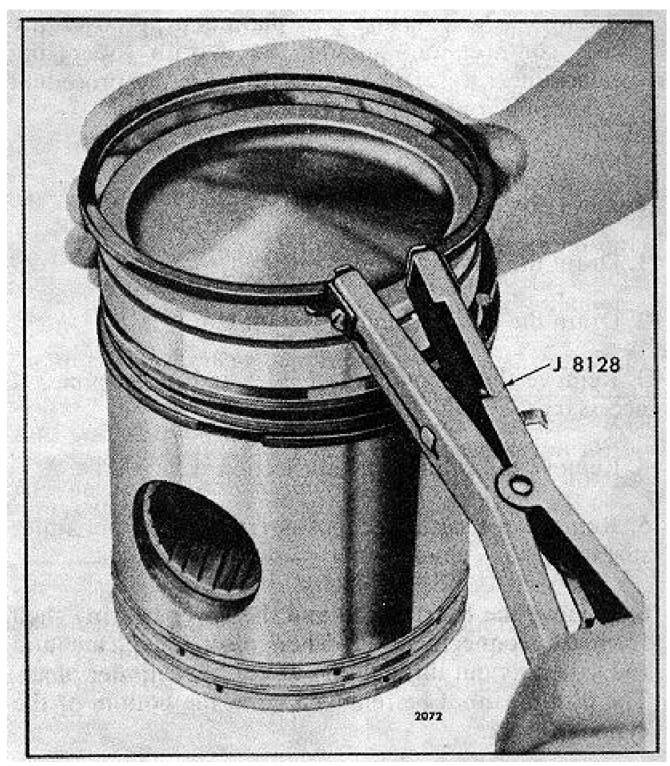


FIG. 2 Removing or installing Piston Rings

Each piston is fitted with compression rings and oil control rings (Fig. 1). Equally spaced drilled holes just below each oil control ring groove permit excess oil. scraped from the cylinder walls. to return to the crankcase.

A higher tension oil control ring expander is now being used in the upper and lower piston grooves on naturally aspirated engines. The current oil control ring expander is identified by a light blue paint strip or no paint strip. A white paint strip identifies the oil control ring expander on city coach engines. This is effective with engine serial numbers 6VA-103350. 8VA-376350 and 12VA-58709.

The *no chrome* fire rings can be identified by their black or copper oxide color. top and bottom. The prestressed fire ring has a small indentation on the top side of the ring near the gap.

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 the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.

2. Drain the oil and remove the oil pan.

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 the 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 connecting rod from the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 as shown in Fig. 2.

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 bushings.

3. Withdraw the piston pin from the piston. Then remove the connecting rod.

4. Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

Cleaning

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits, use a chemical solvent (Fig. 3) that will not harm the piston pin bushings or the tinplate on the piston.

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, use care to avoid damage to 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

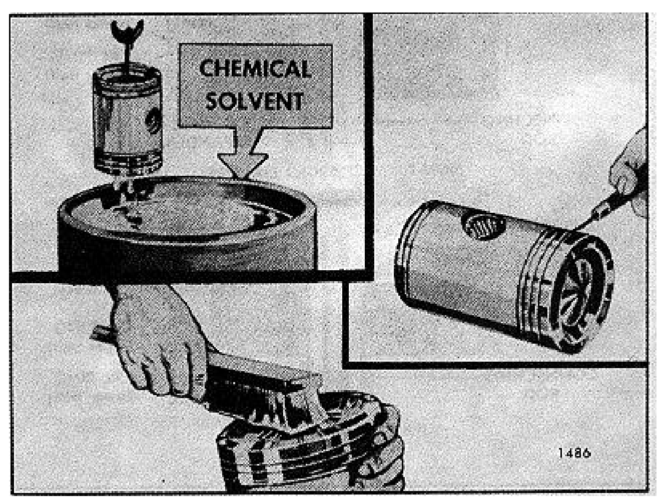


FIG. 3 - Cleaning Piston

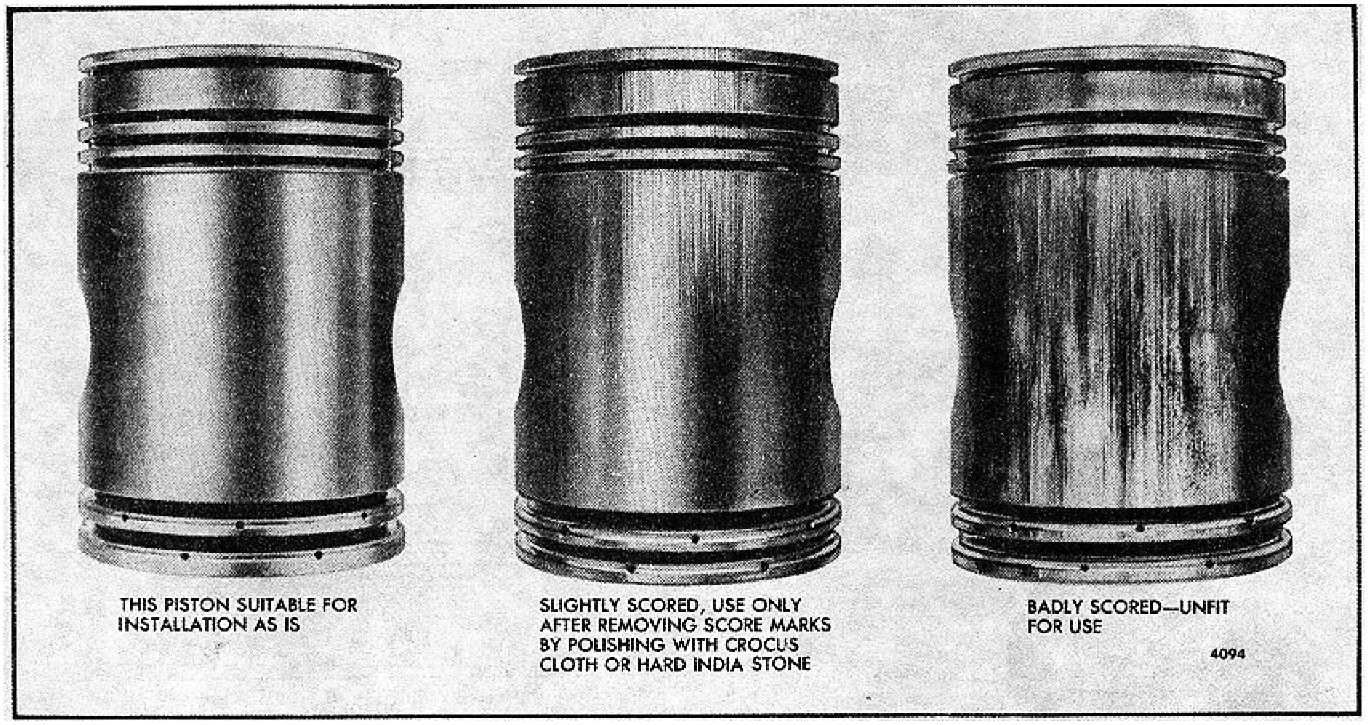


FIG. 4-Comparison of Used Pistons

drain holes in the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

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 a 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 (Fig. 4).

Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage. Replace the piston if cracks are found across the internal struts.

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 Section 1.0 for specifications).

Inspection of the connecting rod and piston pin 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).

Inspect and measure the piston pin bushings. The piston pin-to-bushing clearance with new parts is .0025 "' to .0034 ". A maximum clearance of 0.10' is allowable with worn parts. The piston pin bushings in the connecting rod are covered in Section 1.6.1.

When replacing worn parts (pistons. rings. etc.). refer to the parts catalog or microfiche to select the current parts for the particular engine being serviced. Fig. 4 - Comparison of Used Pistons

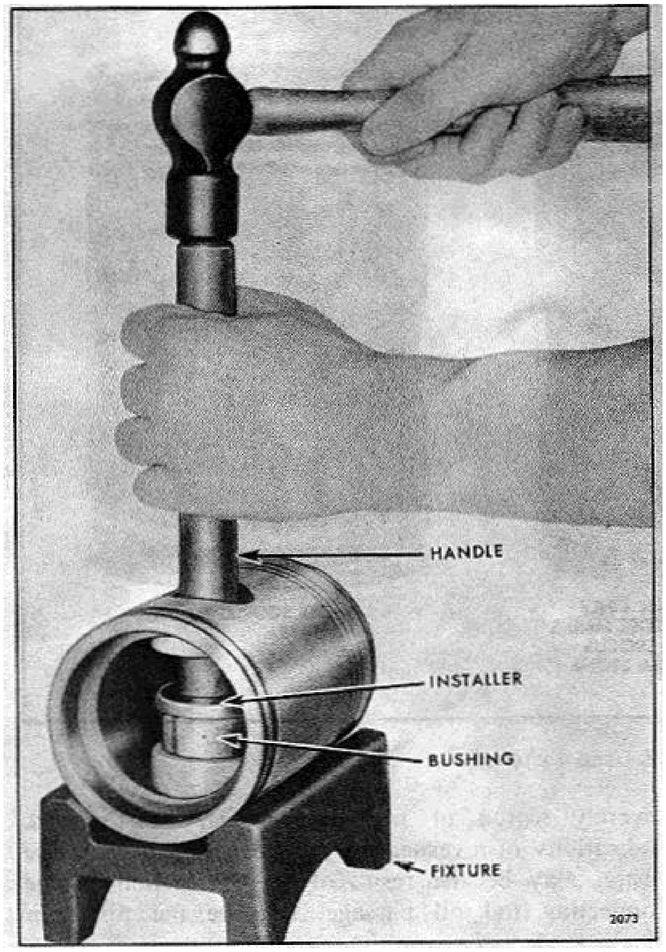


FIG. 5 Removing or Installing Piston Pin Bushings in Piston

Remove Bushings From Piston

Remove the piston pin bushings with tool set J 1513- 02 as follows:

> **NOTE**: Do not remove the bushings from the pistons used in turbocharged engines or any "N" engines because they are not serviced separately.

1 Place the piston in the holding fixture J 1513-1 so that the bushing bores are in alignment with the hole in the fixture base.

2. Drive each bushing from the piston with bushing remover J 1513-3 and handle J 1513-2 (Fig. 5).

Install Bushings in Piston

1. Place the spacer J 1513-4 in the hole in the fixture J 1513-1.

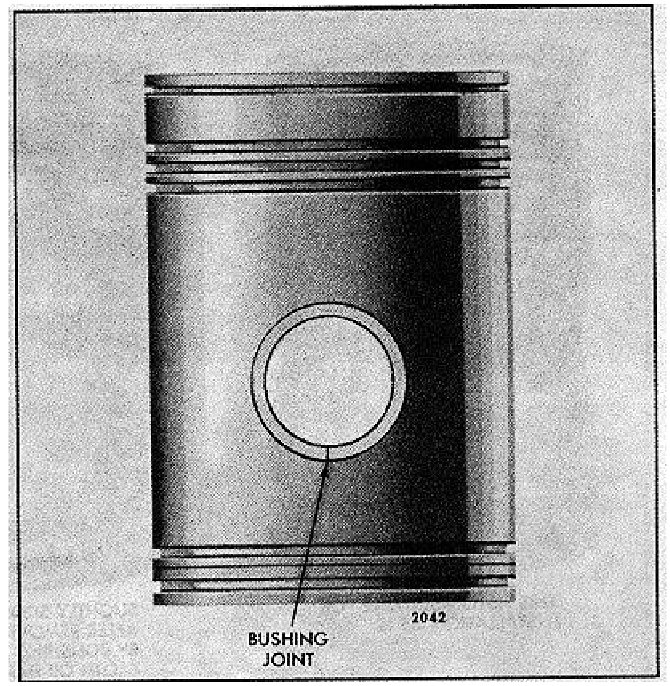


FIG. 6 - Location of Joint In Piston Pin Bushings for Piston

2. Place the piston on the fixture so that the spacer protrudes into the bushing bore.

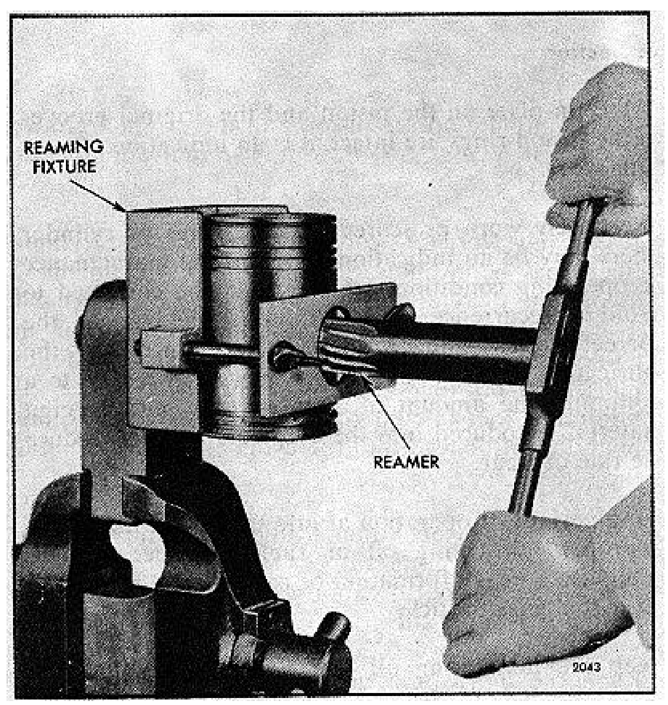


FIG. 7 - Reaming Bushings in Piston

3. Insert the installer J 1513-6 in a bushing. Then position the bushing and installer over the lower bushing bore.

   NOTE: Locate the joint in the bushing toward the bottom of the piston (Fig. 6).

4. Insert the handle J 1513-2 in the bushing installer and drive the bushing in until it bottoms on the spacer.

5. Install the second bushing in the same manner.

6. The bushings must withstand an end load of' 1800 pounds (8.007 kN) without moving after installation.

7. Ream the bushings to size, using tool set J 3071-01. as follows:

   a. Clamp the reaming fixture J 5273 in a vise (Fig. 7). Then insert the guide bushing J 3071-7 in the fixture and secure it with the set screw.

   b. Place the piston in the fixture and insert the pilot end of the reamer J 3071-6 through the clamping bar, bushings and into the guide bushing.

   c. With the piston. fixture and reamer in alignment. tighten the wing nuts securely.

   d. Ream the bushings (Fig. 7). Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

   e. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.5025 " to 1.5030 **".**

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70° F or 21° C). The taper and out-of-round must not exceed .0005 ". Refer to Section 1.0 for piston diameter specifications.

A new (long port) cylinder liner has an inside diameter of 4.2495 " to 4.2511 ". A new (short port) cylinder liner, used in non-fire ring piston engines has an inside diameter of 4.2495 " to 4.2516 ". The piston- to-liner clearance, with new parts, will vary with the particular piston and cylinder liner (refer to Section 1.0). A maximum clearance of .012 " is allowable with used parts.

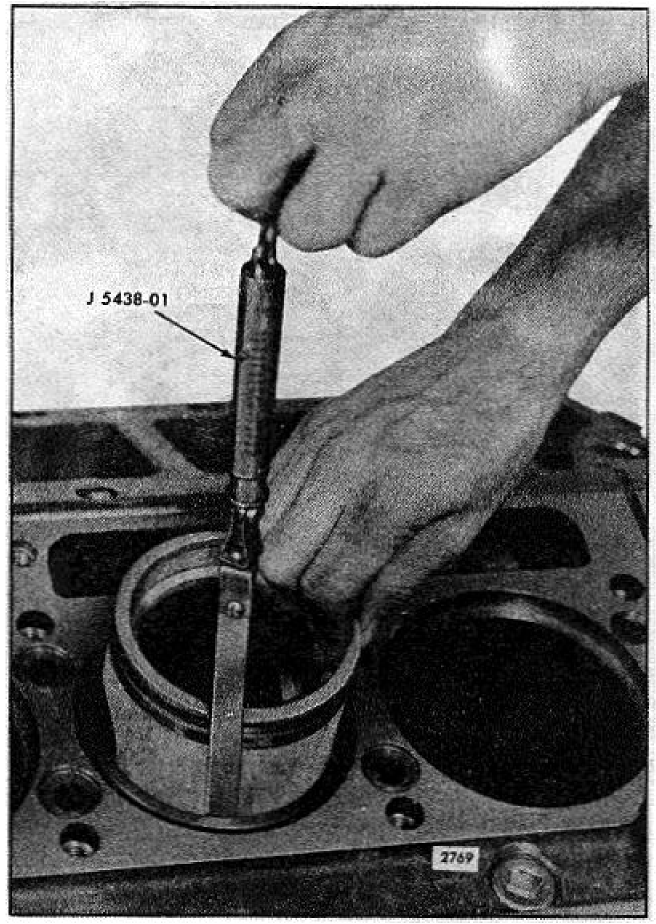


FIG. 8 - Measuring Piston-to-Liner Clearance

With the cylinder liner installed in the cylinder block. hold the piston upside down in the liner and check the clearance in four places 90 apart (Fig. 8).

Use feeler gage set J 5438401 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to with- draw the feeler gage.

Select a feeler gage with a thickness that will require a pull of six pounds (26.7 N) to remove. The clearance will be .001 " greater than the thickness of the feeler gage used, i.e., a .004 " feeler gage will indicate a clearance of .005 " when it is withdrawn with a pull of six pounds (26.7 N). The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

FIG. 9 Measuring Piston Ring Gap

Fitting Piston Rings

The current fire rings can be identified by the black oxide or copper color on the top and bottom. The pre-stressed fire ring is further identified by a small indentation on the top side of the ring near the gap.

A pre-stressed compression ring. also identified by the indentation, is also used in the ring groove immediately below the fire ring.

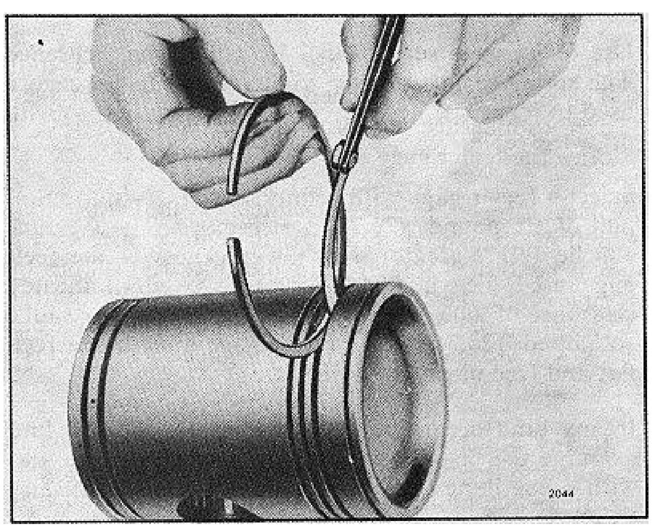


FIG. 10 Measuring Piston Ring Side Clearance

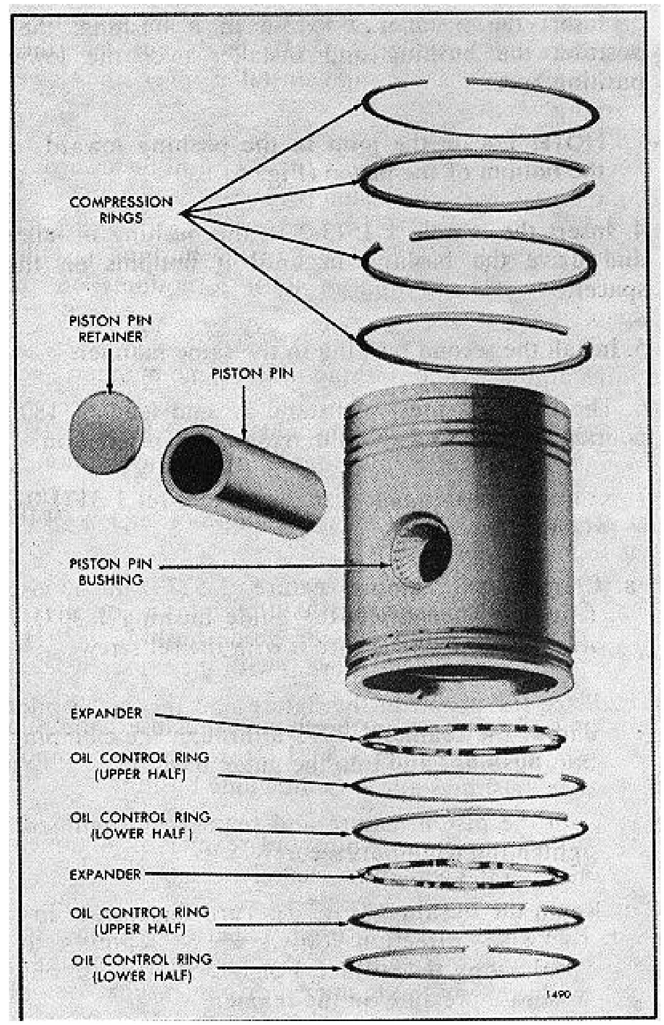


FIG. 11 Typical Piston, Piston Rings, Pin and Relative Location of Parts

A two-piece oil control ring is used in both oil ring grooves in the pistons for non-turbocharged (naturallv aspirated) engines. A one-piece oil control ring is used in the upper ring groove and it two-piece ring in the lower ring groove in the pistons for 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. Refer to the parts catalog or microfiche to select the correct piston rings for a particular engine.

Insert one ring tit a time inside of the cylinder liner and far enough down to be within the normal area of 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 as shown in Fig. 9. Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient. it may

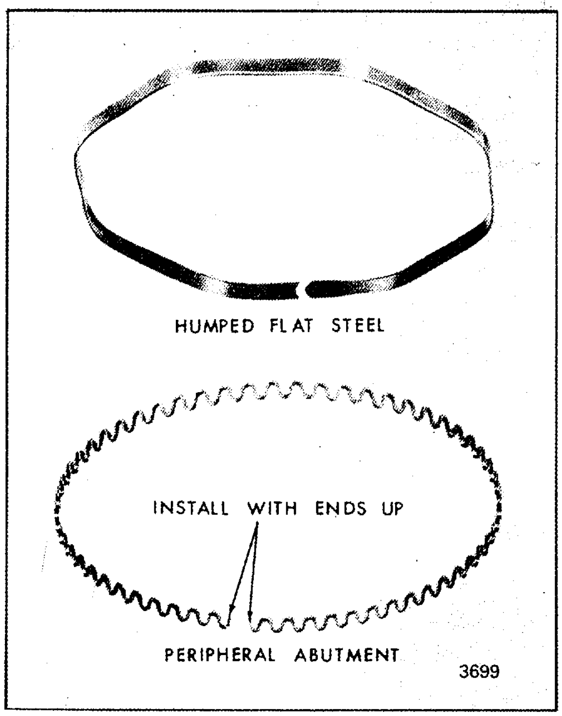


FIG. 12 Oil Control Ring Expanders

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 be approximately .015 ".

Check the ring side clearance as shown in Fig. 10. Ring side clearances are specified in Section I.0.

Install Piston Rings

Before installing the piston rings, assemble the piston and rod as outlined under *Assemble Connecting Rod to Piston* in Section 1.6.1. Then refer to Figs. I and II and install the piston rings.

NOTE: 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 8128 as shown in Fig. 2. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston.

NOTE. When installing the fire ring (top groove) and the top compression ring (second groove), be sure the oval marks are toward the top of the piston.

NOTE: Do not use fire rings with chrome in the new non-hardened fire ring groove. The new *new chrome* fire ring should not be used with the former hardened fire ring groove.

2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

The upper and lower oil control rings used on pistons f*or 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). Peripheral abutment type oil ring expanders (Fig. 12) are used on pistons for V-71N and V-71T engines. Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston.

NOTE: 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 overlap- ping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

IMPORTANT: When peripheral abutment type ring expanders (Fig. 12) are used. install them with the legs of the free ends toward the top of the piston. With the free ends pointing up, a noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped and corrective action can be taken before ring breakage occurs.

2. To install the one-piece ring (turbocharged engines), position it over the upper ring groove, using tool J 8128, 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 the scraper edges are facing down (toward the bottom or the piston).

NOTE: 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.

NOTE: The face of the top half of the upper oil control ring used on V-71N engines is chromeplated.

CROSS-HEAD TYPE PISTON

The cross-head piston (Figs. 13 and 14) is a two-piece piston consisting of a crown and skirt. A metal oil seal ring is used between the crown and skirt which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two 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. Equally spaced drain holes are located in the oil ring groove area to permit excess oil. scraped from the cylinder walls. to return to the crankcase. A lubricating oil tube and floating nut are contained inside of the piston pin. Two bolts and spacers are used to attach the connecting rod to the floating nut in the piston pin.

Internal parts of the piston are lubricated and cooled by the engine lubricating oil. Oil is pressure-fed up the drilled passage in the connecting rod. through the oil tube in 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

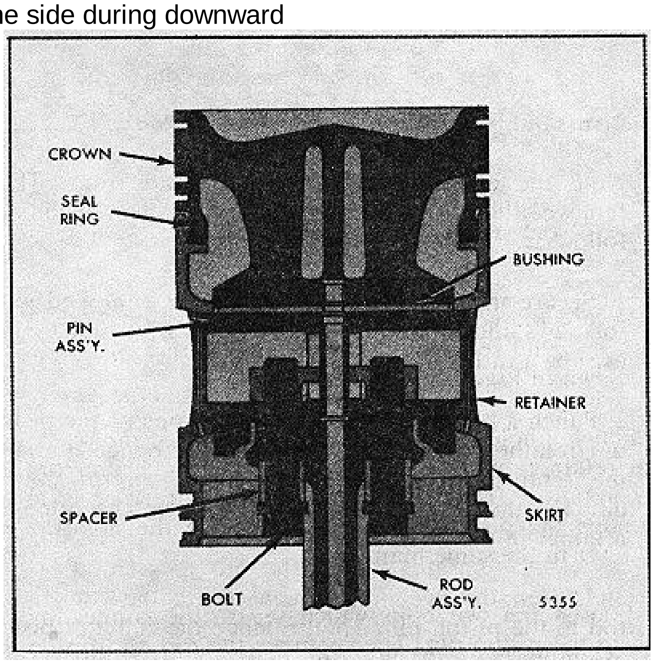


FIG. 13 - Cross-Head Piston and Connecting Rod Assembly

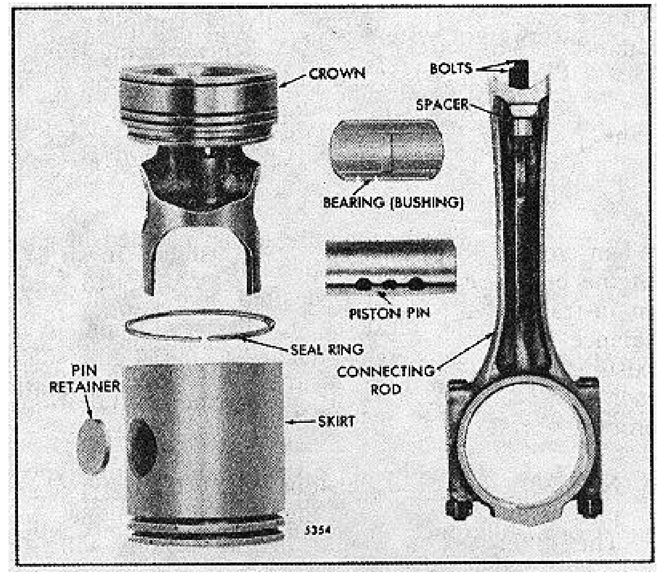


FIG. 14 - Cross-Head Piston and Connecting Rod Components

travel of the piston, the major portion of the side load is taken by the piston skirt.

The non-turbocharged (naturally aspirated) engines use an 18.7:1 compression ratio piston and the turbocharged engines use a 17:1 compression ratio piston. To aid identification of a piston, refer to Fig. 15. Fit the end of the gage between the top of the piston crown and the machined step below the third compression ring groove. A "GO" check identifies a piston used in a turbocharged engine. A space of

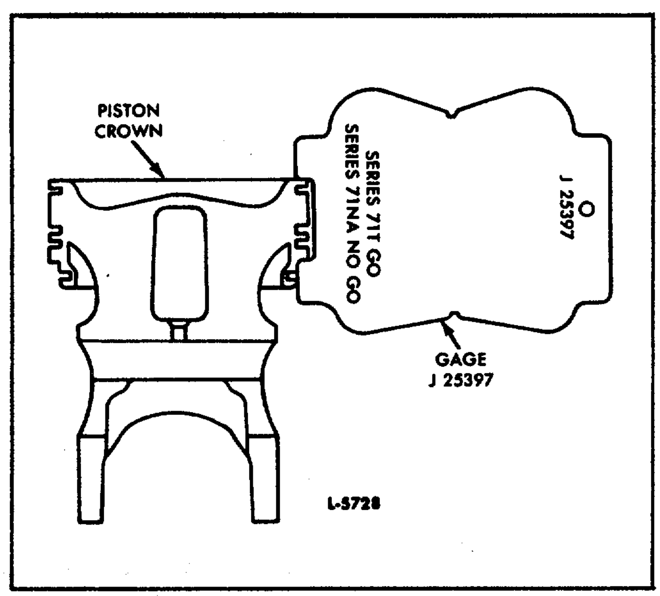


FIG. 15 - Piston Identification

approximately .030 " ("NO-GO") identifies a piston used in a natural aspirated engine.

Also in the 8V-71 engines only, a complete new balance weight system is used. When replacing trunk- type pistons with cross-head pistons in an 8V engine, a new camshaft front pulley (integral weight) on the left bank plus new bolt-on weights for the water pump drive gear and rear camshaft gears (Sections 1.7.2 and 1.7.3) must be used.

When cross-head pistons are to be installed in an 8V engine built prior to serial number 8VA-1 15016, and an in-frame overhaul is desired, a new bolt-on rear balance weight must be used in addition to the existing balance weight attached to the engine side of each rear camshaft gear. For the installation procedure, refer to Section I.O.

> **NOTE:** Cross-head pistons and trunk-type pistons must not be used together in an engine. The difference in weight of the pistons will affect engine balance.

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 the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Section 15.2 for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.
2. Drain the oil and remove the oil pan.
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 the 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.

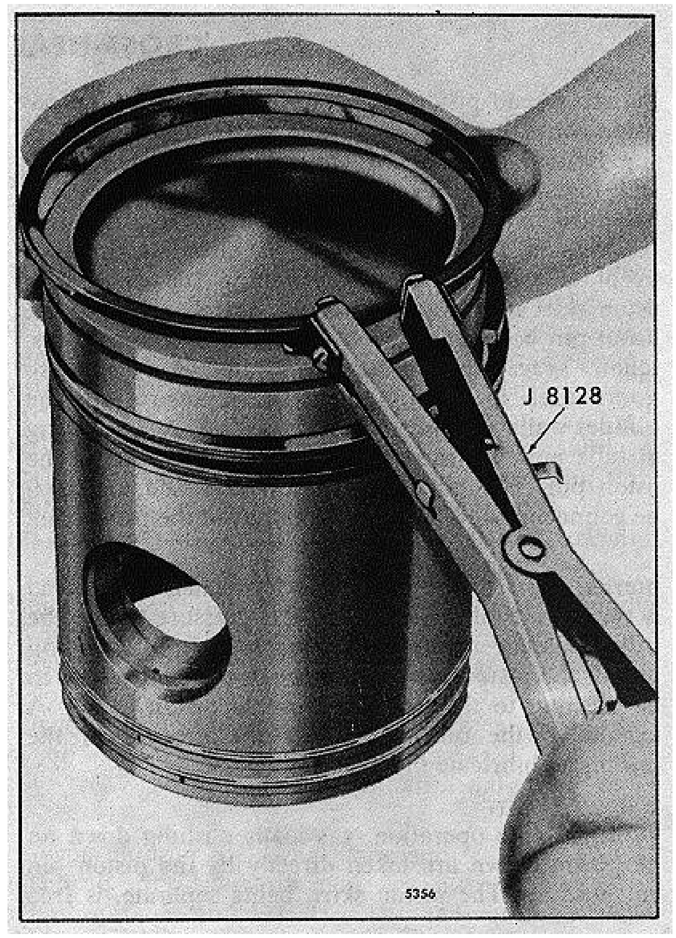


FIG. 16 - Removing or Installing Piston Rings

7. Re-assemble 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 toot J 8128 as shown in Fig. 16.

2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and prv 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 metal 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. If fuel oil does not remove the carbon deposits, use a chemical solvent that will not harm the tin-plate on the piston.

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 " - .0058 ") is recommended. Allowable air pressure is 80-100 psi (552-689 kPa).

IMPORTANT: After cleaning, do not leave glass beads in the piston crown.

NOTE: 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,

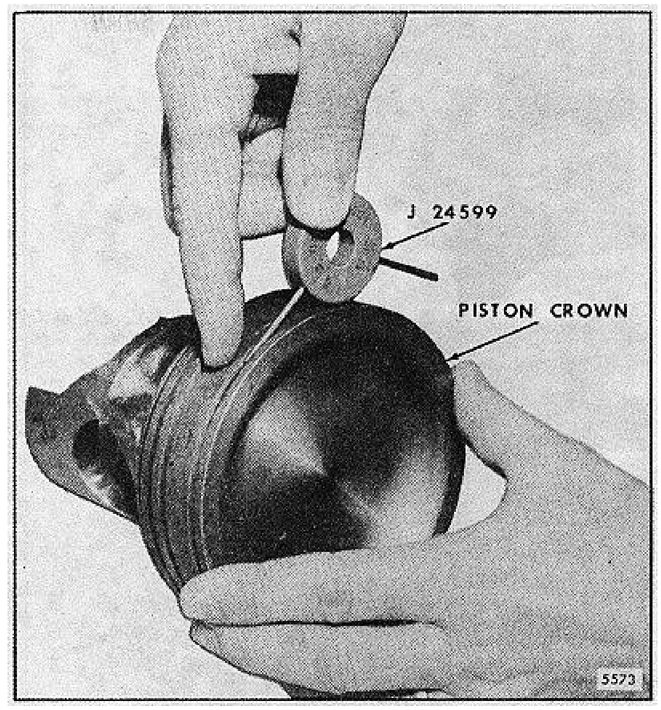


FIG. 17 - Checking Fire Ring Groove in Piston Crown

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 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.

Check the tapered fire ring groove width in the current piston crown with tool J 24599 as shown in Fig. 17. Slide the "NO-GO" wire (.106 " diameter) of the tool completely around the fire ring groove. Should the wire be below flush at any one area, the piston crown must be replaced. The "GO" wire (.100" diameter) should be flush or protrude slightly from the fire ring groove.

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 Section 1.0 for specifications).

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

FIG. 18 - Installing Seal Ring

the air cleaner, dribbling injectors, combustion blow- by and low oil pressure, (dilution of the lubricating oil).

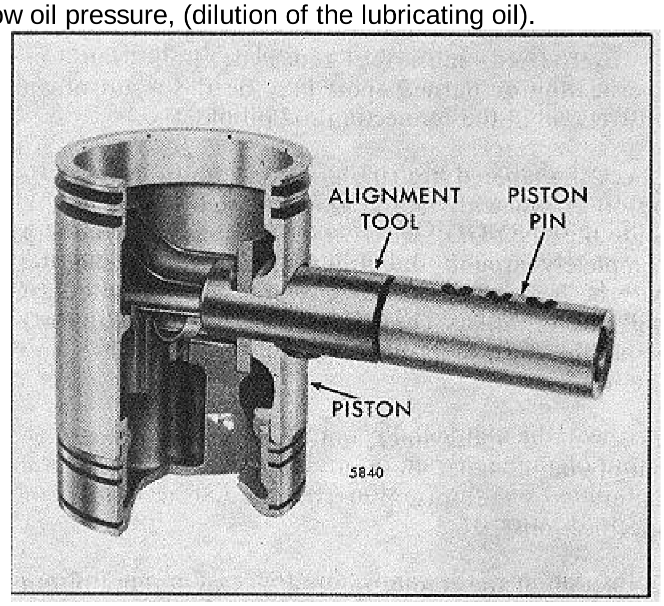


FIG. 19 Installing Piston Pin

Assemble Piston

1. Install the bearing (bushing) in the piston crown. It should slide into the piston crown without force. With new parts, there is .0005 " to .0105 " clearance between the edge of the bushing and the groove in the piston crown.

> **NOTE:** The bearing must be installed before assembling the piston skirt and crown..

2. Lubricate the metal seal ring (Fig. 18) with engine oil and install it w*ith the chamfer or counterbore directed toward the bottom of the piston.*

> **NOTE:** The current seal rings are made of cast iron and are identified by the tin-plating on the outside diameter, a black oxide finish, or a du]] cast iron color. These rings can be mixed in an engine. The former steel ring, identified by a very shiny appearance, *must not* be used for service.

3. Compress the seal ring with ring compressor J 23453 and push the skirt into position on the piston crown.

> **IMPORTANT:** 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 seal ring sticks, remove high spots or nicks in the groove with a flat file. If this does not relieve sticking, replace the piston crown.

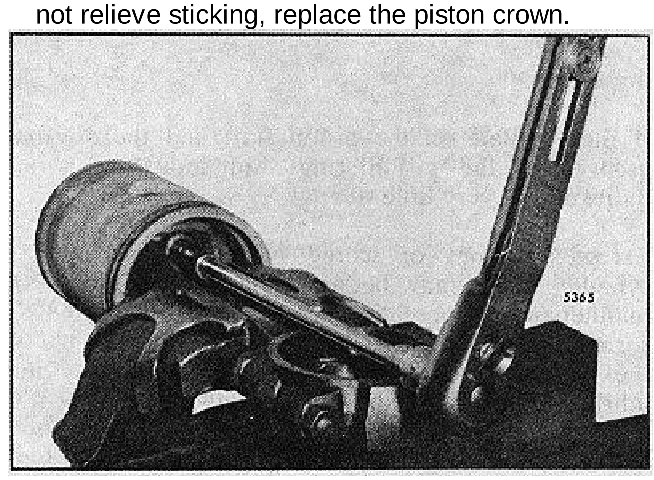


FIG. 20 -Tightening Connecting Rod to Piston Pin Bolts

4. Lubricate the piston pin with clean engine oil and install it as shown in Fig. 19.

NOTE: 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 7/16 "-20 x 2 " connecting rod to piston pin attaching bolts.

6. Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact surfaces.

7. Install and tighten the bolts finger tight. Then clamp the connecting rod in a vise and tighten the bolts to 55-60 lb-ft (75-81 Nm) torque (Fig. 20). Do not exceed this torque.

8. Place a new piston pin retainer in position. Then place the crowned end of installer J 23762 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston (Fig. 21).

9. Install the second piston pin retainer in the same manner.

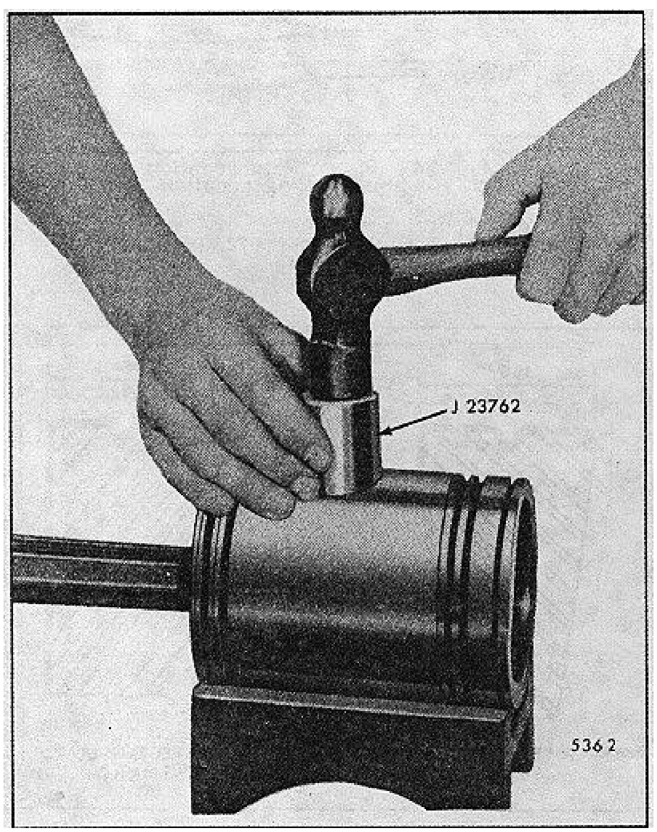


FIG. 21 - Installing Piston Pin Retainer

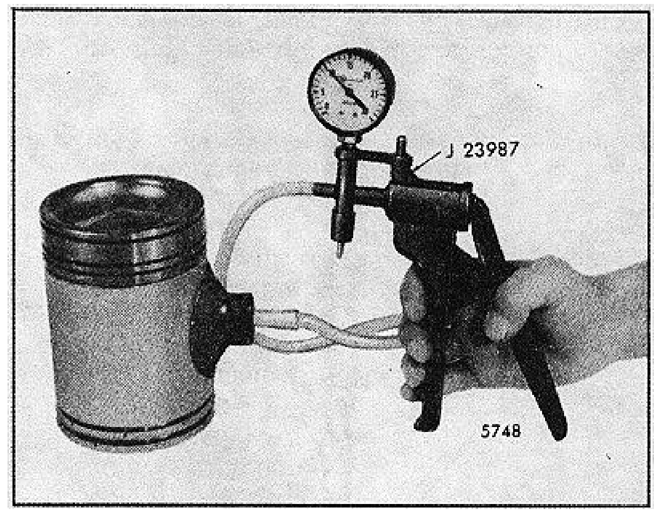


FIG. 22 - Checking Piston Pin Retainer for Proper Sealing

NOTE: 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 23987 (Fig. 22). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70° F or 21° C). Refer to Section 1.0 for specifications.

The piston-to-liner clearance, with new parts, will vary with the particular piston and cylinder liner (refer to Section 1.0). A maximum clearance of .012 " is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston skirt upside down in the liner and check the clearance in four places 90° apart (Fig. 23).

Use feeler gage set J 5438 to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

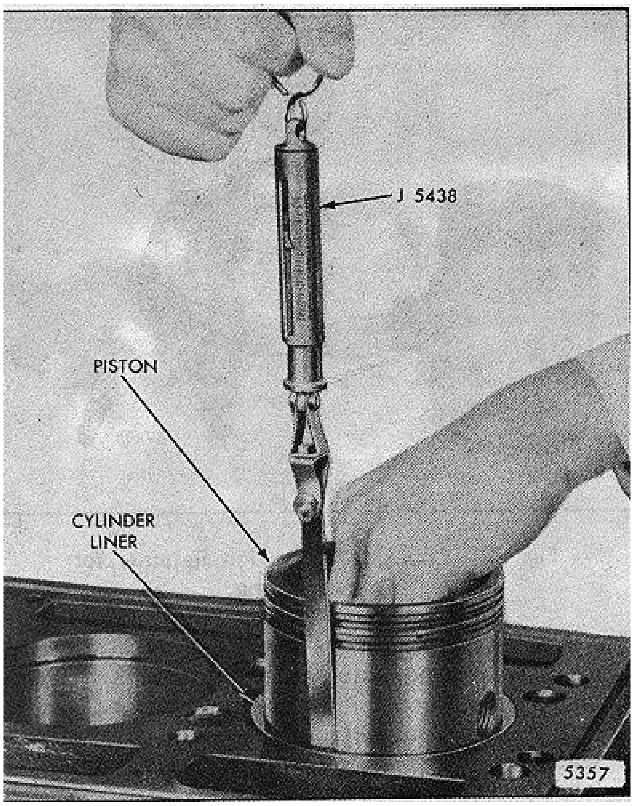


FIG. 23 - Measuring Piston-to-Liner Clearance

Select a feeler gage with t thickness that will require a pull of six pounds (26.7 N) to remove. The clearance will be .001 " greater than the thickness of the feeler gage used. i.e. a .004 " feeler gage will indicate a clearance of .005 " when it is withdrawn with a pull of' six pounds (26.7 N). The feeler gage must be perfectly flat and free of' nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring. two compression rings and two oil control rings (Fig. 24).

The top (fire) ring and the upper compression ring (second groove) are pre-stressed. Both are identified by a small indentation mark on the top side.

NOTE: The current piston crowns (18.7:1 and 17:1 compression ratio) have a tapered fire ring groove. To conform with this change, a tapered fire ring (Fig. 25) must be used. The former piston crown (17:1 compression ratio) had a rectangular fire ring groove. Only pistons with the tapered fire ring

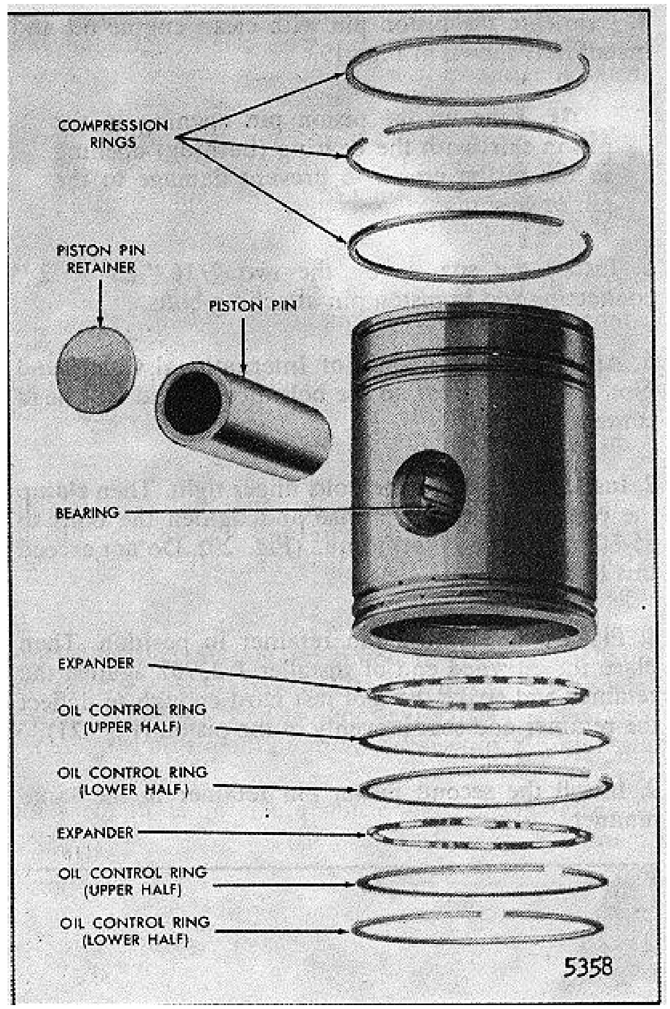


FIG. 24 Piston Ring Location

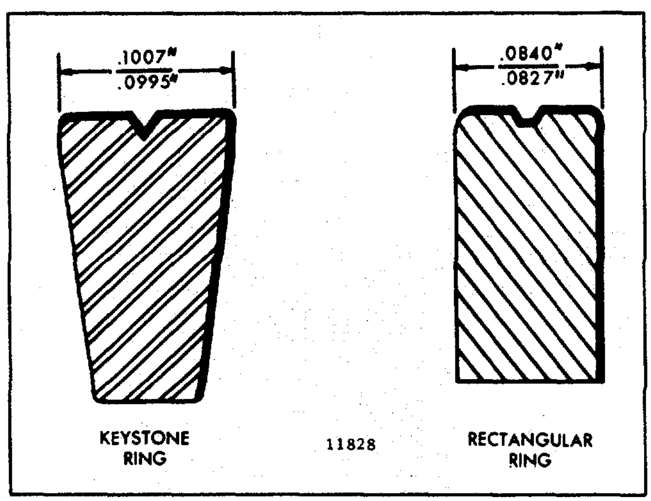


FIG. 25 - Comparison of Fire Rings

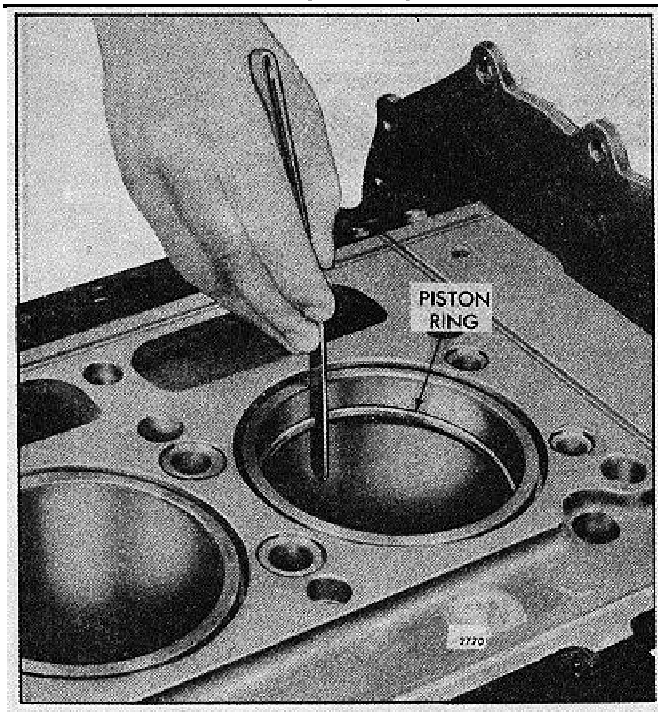


FIG. 26 - Measuring Piston Ring Gap

groove are available for service.
A two-piece oil control ring is used in both oil ring grooves in the pistons for all current 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. Refer to the parts catalog or microfiche to select the current piston rings for a particular engine

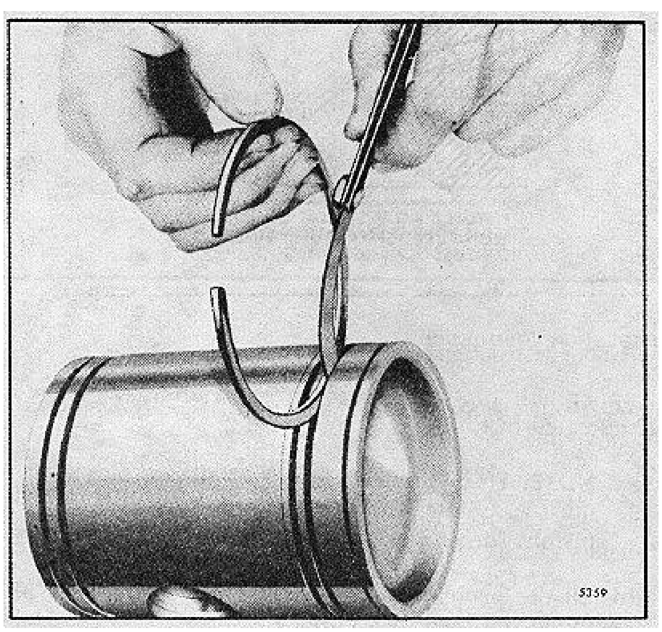


FIG. 27 Measuring Piston Ring Side Clearance

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 at feeler gage as shown in Fig. 26. Refer to Section 1.0 for ring gap specifications.

If the gap on a compression ring is insufficient, it may he 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 be approximately .015 ".

Check the ring side clearance as shown in Fig. 27. Ring side clearances are specified in Section 1.0.

Install Piston Rings

> **NOTE:** 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 8128 as shown in Fig. 16. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. Refer to Fig. 28 for ring identification and location.

2. Stagger the ring gaps around the piston.

OIL CONTROL RINGS

Refer to Fig. 28 for the type and location and install the oil rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston skirt.

> **NOTE:** 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 rings and result in high lubricating oil consumption.

IMPORTANT: When peripheral abutment type ring expanders (Fig. 12) are used, install them

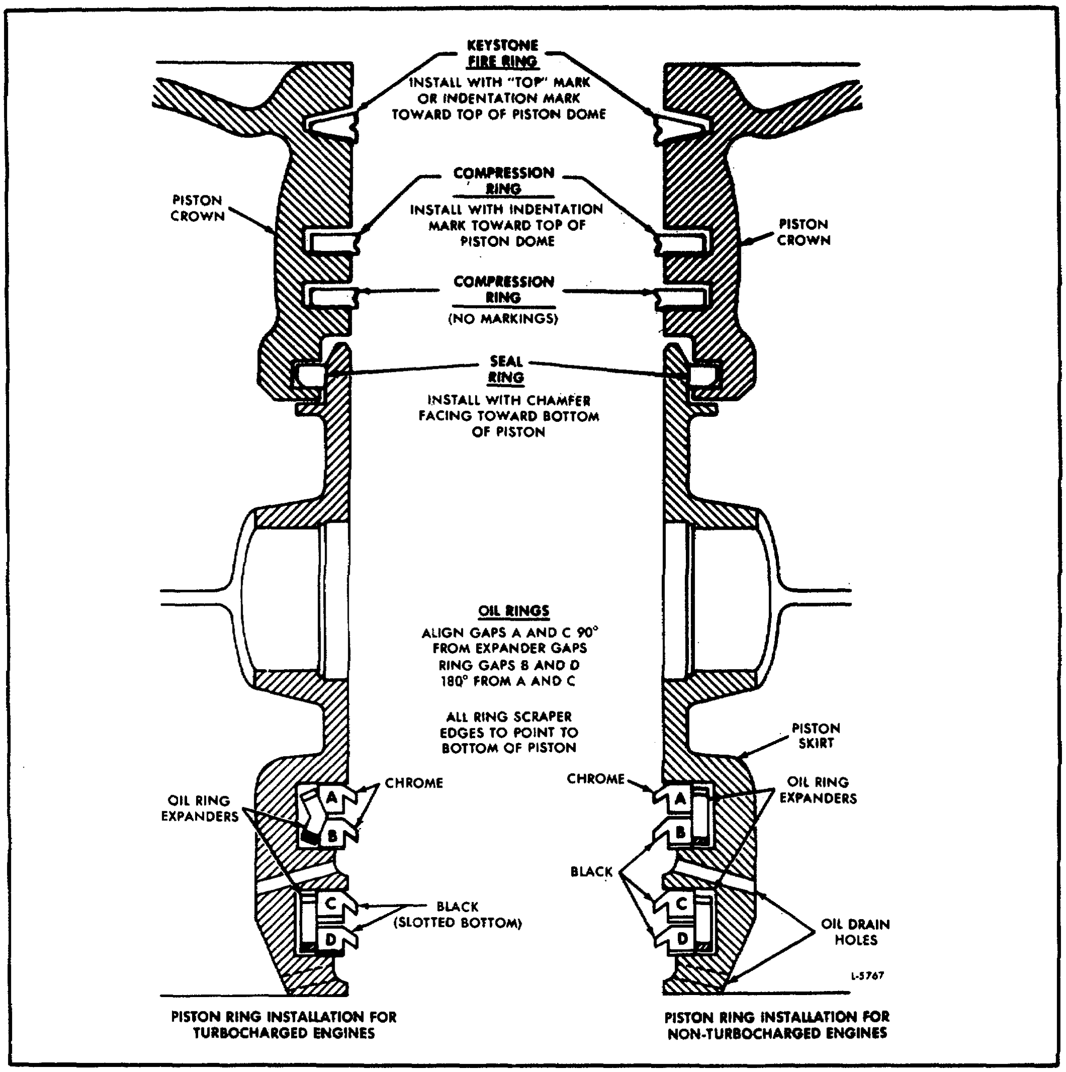


FIG. 28- Piston Ring Installation Instructions

with the legs of the free ends toward the top of the piston. With the free ends pointing up, noticeable resistance will be encountered during installation of the piston if the ends of the expander are overlapped and corrective action can be taken before ring breakage occurs.

2. Install the oil control rings by hand. Start with the upper half of' the top oil ring and align the gaps as indicated in Fig. 28.

> **NOTE:** The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

CONNECTING ROD

Trunk-Type Piston

Each connecting, rod (Figs. I and 2) is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end. The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head. An orifice is pressed into a counterbore at the lower end of the oil passage to meter the flow of oil on all V-71 engines, except turbocharged engines and early 12V two-valve engines.

A helically-grooved bushing is pressed into each side of the connecting rod at the upper end. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this cavity lubricates the piston pin bushings and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

A service connecting rod includes the bearing cap, bolts, nuts, spray nozzle, orifice and the piston pin bushings pressed in place and bored to size.

The replaceable connecting rod bearing shells are covered in Section 1.6.2.

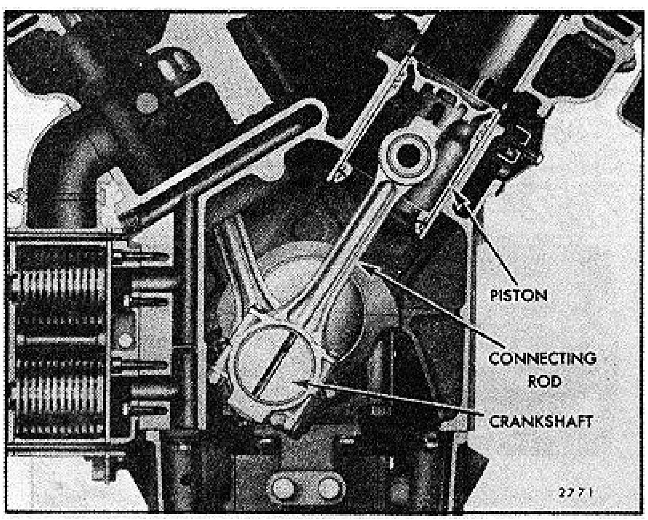


FIG. 1. Connecting Rod Mounting

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 a suitable solvent and dry them with compressed air. Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice oil passage and spray holes are not clogged.

Remove any nicks or burrs from the connecting rod bolt holes with reamer J 28460 (Fig. 4). The reamer

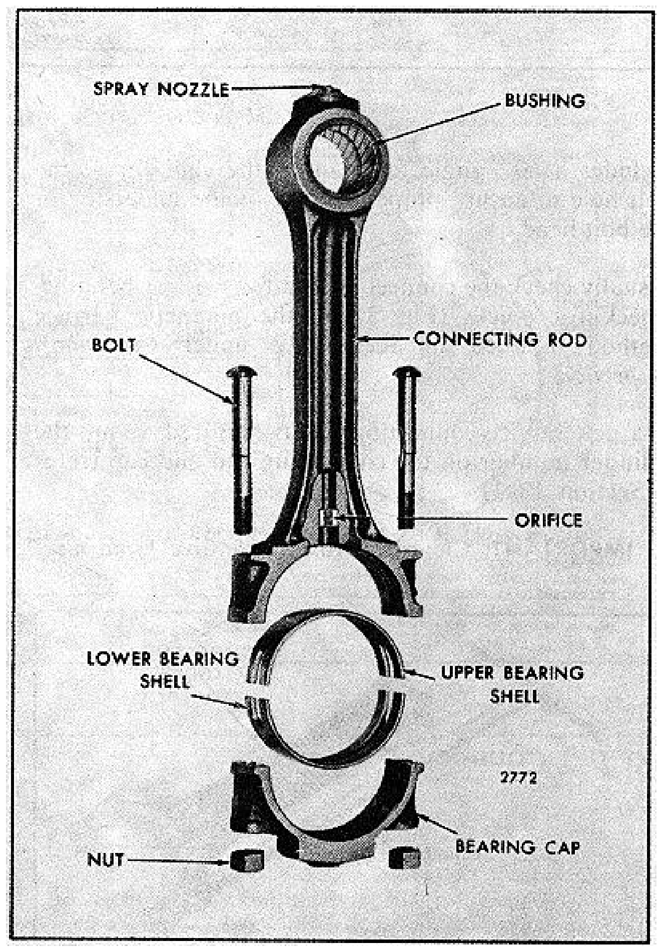


FIG. 2. Connecting Rod Details and Relative Location of Parts

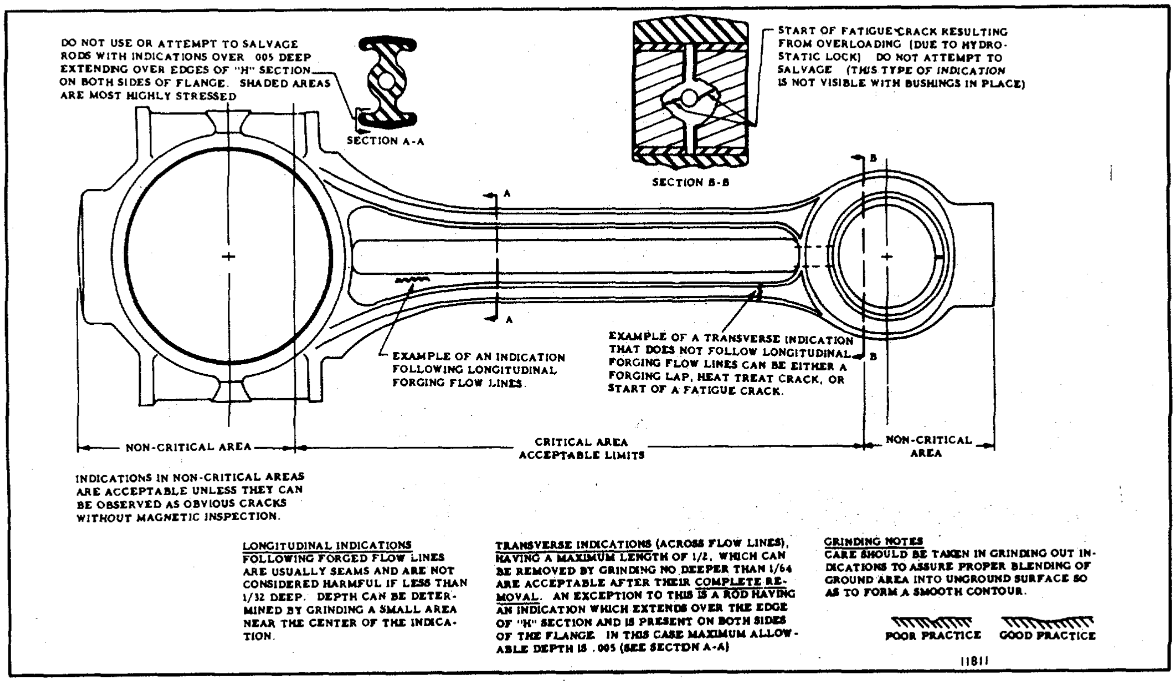


FIG. 3 - Magnetic Particle Inspection Limits for Connecting Rod

includes a 60° angle to clean-up the chamfer at the bolt hole to ensure proper seating of' the underside of' the bolt head.

Visually check the connecting rod for twist or bending. Check for cracks (Fig. 3) 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).

IMPORTANT: Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice oil passage and spray holes are not clogged. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell "crush".

NOTE: Early 12V two-valve engine connecting rods were equipped with a plug at the upper end in place of a spray nozzle. When replacement of a connecting rod in these engines is required, it is suggested that all of' the connecting rods be reworked by installing a

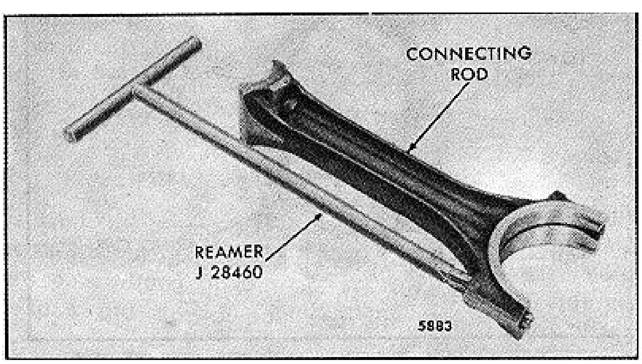


FIG. 4 - Connecting Rod Bolt Hole Reamer

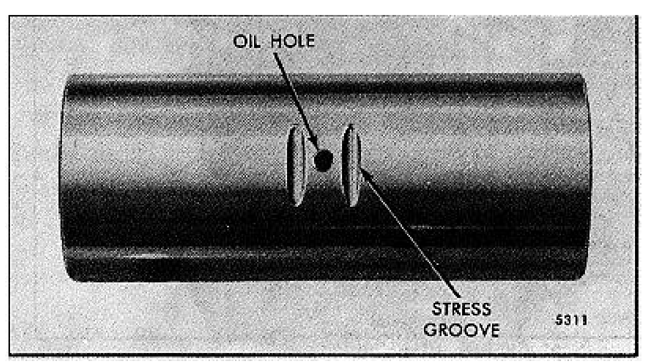


FIG. 5 Piston Pin with Oil Hole

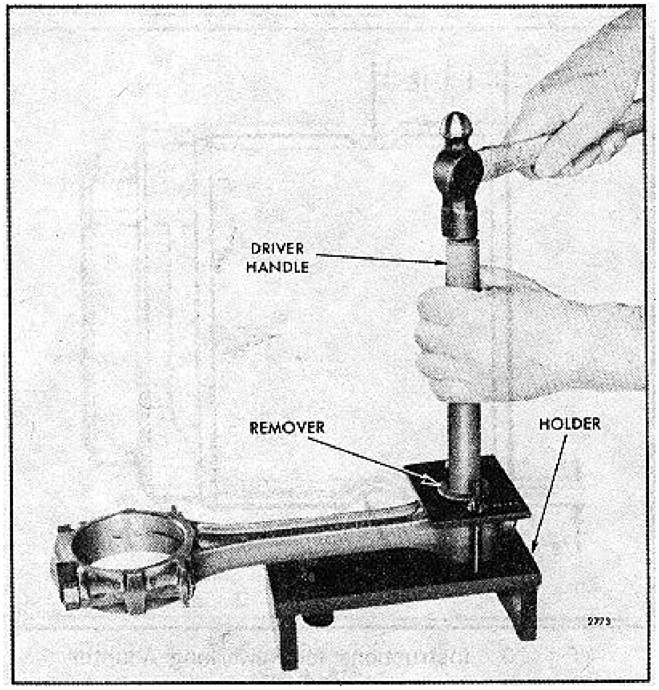


FIG. 6 - Removing or Installing Bushings

spray nozzle and orifice. *It will also be necessary to install an adequate engine cooling system (refer to Section 4.4).*

Only a plain connecting rod bolt is available for service. The scalloped bolt is not serviced. The two bolts are completely interchangeable since the use of the plain bolt in no way affects the clearance between the rod and the bearing shells, nor will it restrict oil flow around the bolt.

Check the connecting rod bushings for indications of scoring, overheating or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the supply of lubricating oil to the piston pin and spray nozzle.

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.

Since it is subjected to downward loading only free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full floating fit in the connecting rod and piston bushings, with relatively large clearances. Worn piston pin clearances up to .010 " are satisfactory.

NOTE: Current turbocharged engines use a

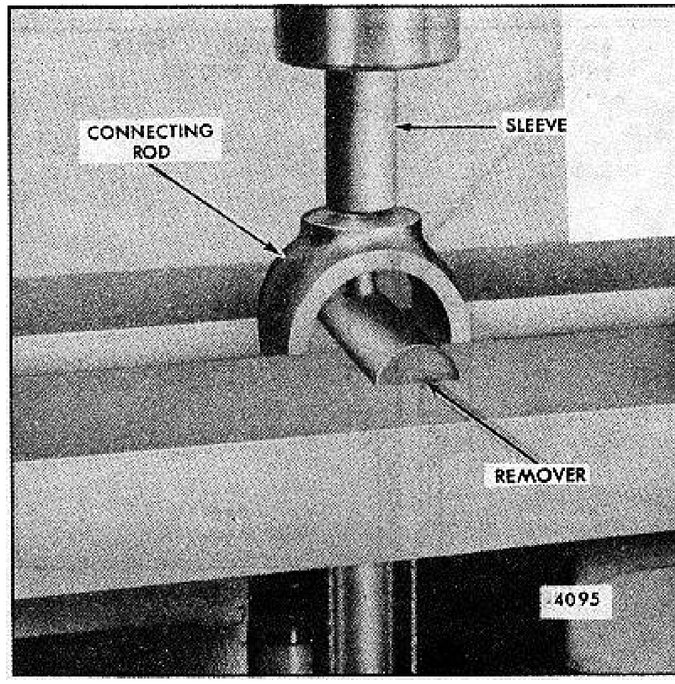


FIG. 7 Removing Spray Nozzle

piston pin which incorporates an oil hole (Fig. 5) to provide oil under pressure to the piston pin bushings. A similar piston pin is available as a service item for non-turbocharged engines.

Remove Bushings

If it is necessary to replace the connecting rod bushings. remove them as follows:

> **NOTE:** Do not remove the bushings from the connecting rods used in turbocharged engines because they are not serviced separately.

1. Clamp the upper end of' the connecting rod in holder J 7632 (Fig. 6) so that the bore in the bushings is aligned with the hole in the base of' the holder.

2. Place the bushing remover J 1513-3 in the connecting rod bushing, insert handle J 1513-2 in the remover and drive the bushings from the rod.

Replace Spray Nozzle and Orifice

The connecting rod bushings must be removed before the spray nozzle or orifice can be replaced. Replace the spray nozzle as follows:

1. Remove the connecting rod bushings (refer to NOTE).

2. Insert spray nozzle remover J 8995 through the

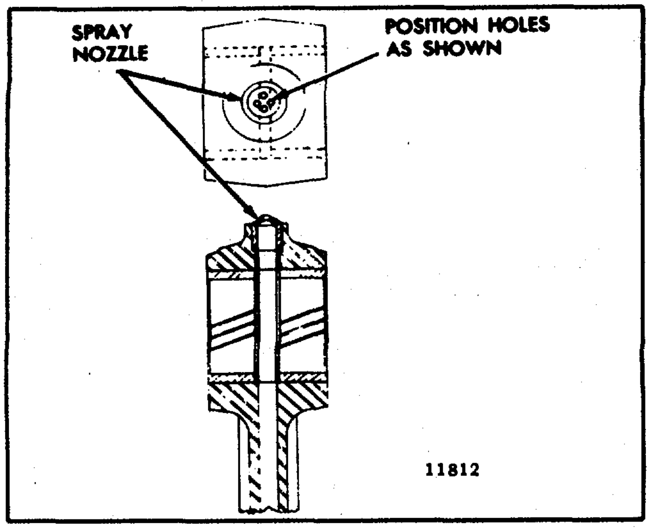


FIG. 8 Position of Spray Nozzle Holes

upper end of the connecting rod and insert the pin in the curved side of the tool in the opening in the bottom of the spray nozzle.

3. Support the connecting rod and tool in an arbor press as shown in Fig. 7.

4. Place a short sleeve directly over the spray nozzle. Then press the nozzle out of the connecting rod.

5. Remove the tool.

The steel bushing-type orifice in the lower end of the drilled passage can be replaced, if necessary, at this time. Effective with engines 6VA-254, 8VA-258 and 12VA-189 and prior to 6VA-27996, 8VA-21662 and 12VA-5655, the connecting rod assemblies included a spring pin type orifice.

FIG. 9 - Location of Bushing Joint

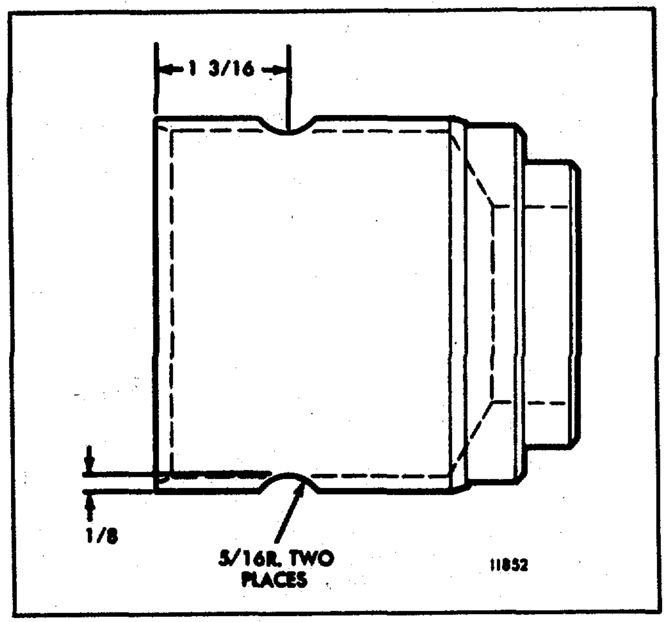


FIG. 10 Instructions for Reworking Adaptor J 1686-13

NOTE: No orifice is used in the connecting rods in 12V two-valve or turbocharged engines.

With the spray nozzle removed, insert a rod in the oil passage and drive the orifice from the lower end of the connecting rod. Install the current steel bushing-type orifice .3125 " in from the lower surface of the rod. When installing a service spring pin type orifice drive it in .200 " from the lower surface of the rod.

Install a new spray nozzle in the connecting rod as follows:

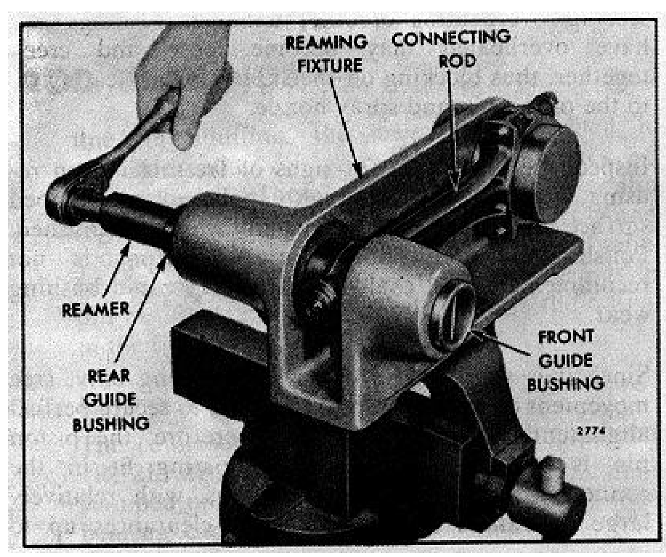


FIG. 11 - Reaming Bushings

1. Start the new spray nozzle, with the holes positioned as shown in Fig. 8, straight into the counterbore in the connecting rod.
2. Support the connecting rod in the arbor press, place a short 3/8 " I.D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.

> **NOTE**: On connecting rods equipped with a plug in place of a spray nozzle, install the plug in the same manner as outlined in Steps 1 and 2 above.

3. Install new bushings in the connecting rod.

Install Bushings

A .812 " long bushing is serviced for the connecting rod assembly used in all non-turbocharged engines. The .760 " long vapor blasted bushing used in turbocharged engines is not serviced separately. Install connecting rod bushings as follows:

1. Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings aligns with the hole in the base of the tool (Fig. 6).
2. Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Fig. 9).
3. Insert installer J 1513-6 in the bushing. then insert handle J 1513-2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.
4. Turn the connecting rod over in the holder and install the second bushing in the same manner.
5. The bushings must withstand an end load of 2000 pounds (8.9 kN) without moving after installation.
6. Ream the bushings to size, using tool set J 1686-03. as follows:
   a. Clamp reaming fixture J 1686-9 in a bench vise.
   b. Position sleeve adaptor J 1686-13 on the arbor of the fixture.

> **NOTE**: Sleeve adaptor J 1686-13. part of connecting rod reamer bushing set J 1686-03. has been revised by adding two notches. When reaming service replacement bushings in connecting rods using plain (non-scalloped) bolts, it will be necessary to use the revised adaptor or to rework the old adaptor as shown in Fig. 10. The revised adaptor may he used with either the plain or scalloped bolt.

   c. Place the crankshaft end of the connecting rod on the arbor of the fixture (Fig. 11) and tighten the connecting rod cap nuts to, 60-70(lb-ft (81-95 Nm) torque (lubrite nut) or 65-75 lb-ft (88-102 Nm) torque (plain nut).
   d. Slide the front guide bushing J 1686-11 (with the pin end facing out) in the fixture.
   e. Align the upper end of the connecting rod with the hole in the reaming fixture.
   f. Install the rear guide bushing J 1686-5 on reamer J 1686-20. then slide the reamer and bushing into the fixture.
   g. Turn the reamer in a clockwise direction only when reaming or withdrawing the reamer. For best results use only moderate pressure on the reamer.
   h. Remove the reamer and the connecting rod from the fixture blow out the chips and measure the inside diameter of the bushings. The inside diameter of the bushings must be 1.5025 " to 1.5030 ". This will provide a piston pin-to-bushing
   clearance of .0025 " to .0034 " with a new piston pin. A new piston pin has a diameter of 1.4996 to 1.5000".

Assemble Connecting Rod to Piston

Apply clean engine oil to the piston pin and bushings. Refer to Fig. 2 and assemble the connecting rod to the piston as follows:

> **NOTE**: The connecting rods used in 12V two valve and turbocharged engines do not incorporate an orifice in the lower end (crankshaft end) of the oil passage in the rods. Therefore, to be sure that the oil flow through the rods is not restricted, use non-orifice rods in these engines.

1. Place the piston in the holding fixture (Fig. 12).
2. Place a new piston pin retainer in position. Then place the crowned end of installer J 24107 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston.

> **NOTE**: Do not drive the retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.

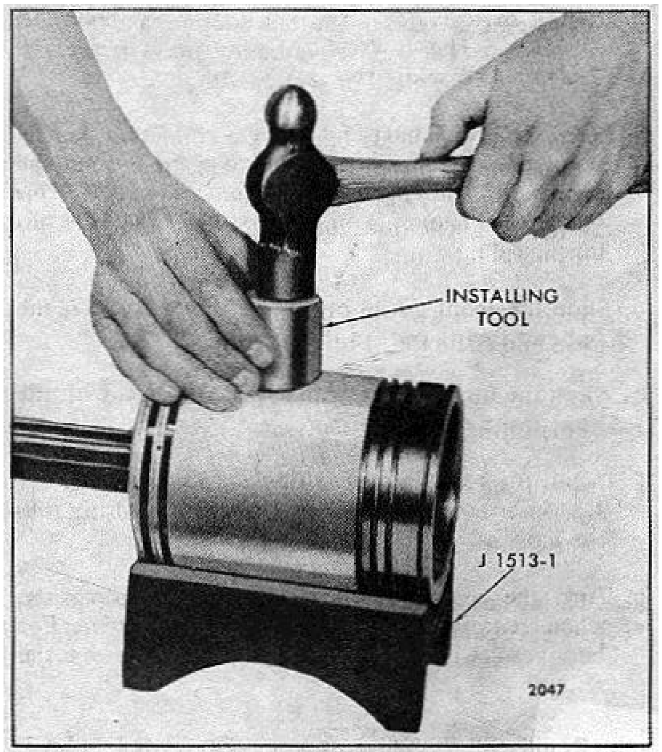


FIG. 12 Installing Piston Pin Retainer

3. Place the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then slide the piston pin in place. If the piston pin-to-bushing clearances are within the specified limits, the pin will slip into place without use of force.

4. Install the second piston pin retainer as outlined in Steps 1 and 2.

5. After the piston pin retainers have been installed, check for piston pin end clearance by cocking the connecting rod and shifting the pin in its bushings.

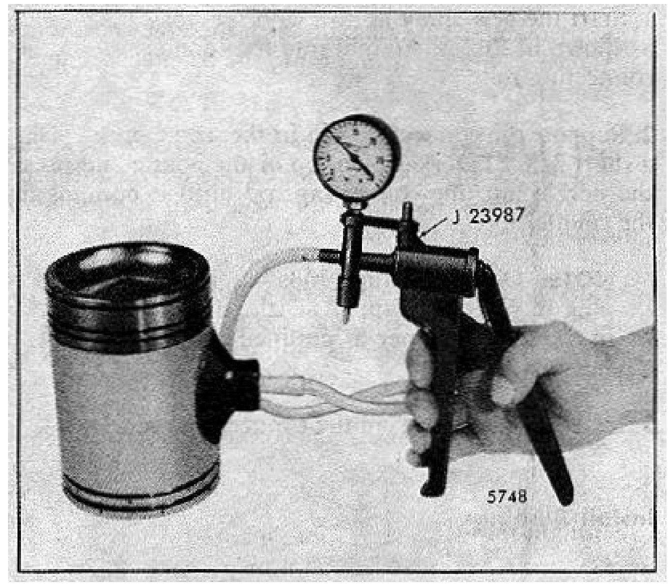


FIG. 13 - Checking Piston Pin Retainer for Proper Sealing

6. 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 bushings, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987 (Fig. 13). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of ten inches on the gage, a drop in the gage reading indicates air leakage at the retainer.

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.

CONNECTING ROD

Cross-Head Type Piston

The connecting rod (Fig. 14) 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.

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 bearing cap is secured to the connecting rod by two specially machined bolts and 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.

> **NOTE**: Only the plain connecting rod bolt is serviced. The scalloped bolt is not serviced. The two bolts are completely interchangeable since the use of the non-scalloped bolt in no way affects the clearance between the rod and the bearing shells, nor will it restrict oil flow around the bolt.

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.

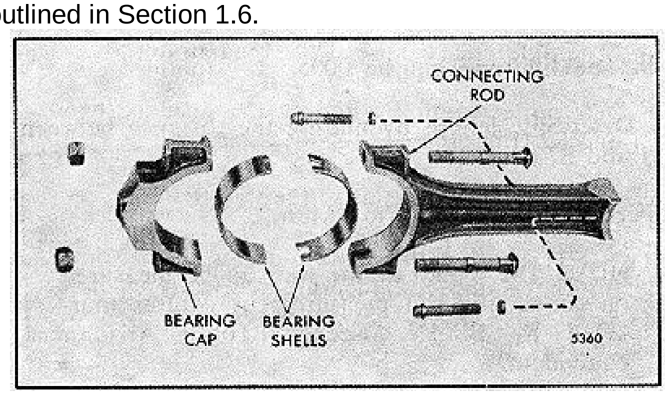


FIG. 14 - Connecting Rod Details Inspection

Clean the connecting rod and piston pin with a suitable solvent 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. 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 with the rod before reassembly.

> **NOTE**: Never use crocus cloth on the bearing side of the pin.

Connecting rods being removed from an original build 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, it should be scrapped.

In qualifying a used connecting rod from a source other than an original build engine, the following checks should be made in addition to this above.

1. Check for cracks (Fig. 14) by the magnetic particle method outlined in Section 1.3 under Crankshaft Inspection.

2. Determine bore diameter of the rod, using a dial bore gage and master ring as follows (Fig. 15).

a. Install the connecting rod clip on the connecting rod and tighten the bolt nuts to 60-70 lb ft (81-95 Nm) torque.

> **NOTE**: Do not over torque the connecting rod bolt nuts. Over torque may permanently distort the connecting rod clip.

b. Measure diameter A and B as shown ill Fig. 15.

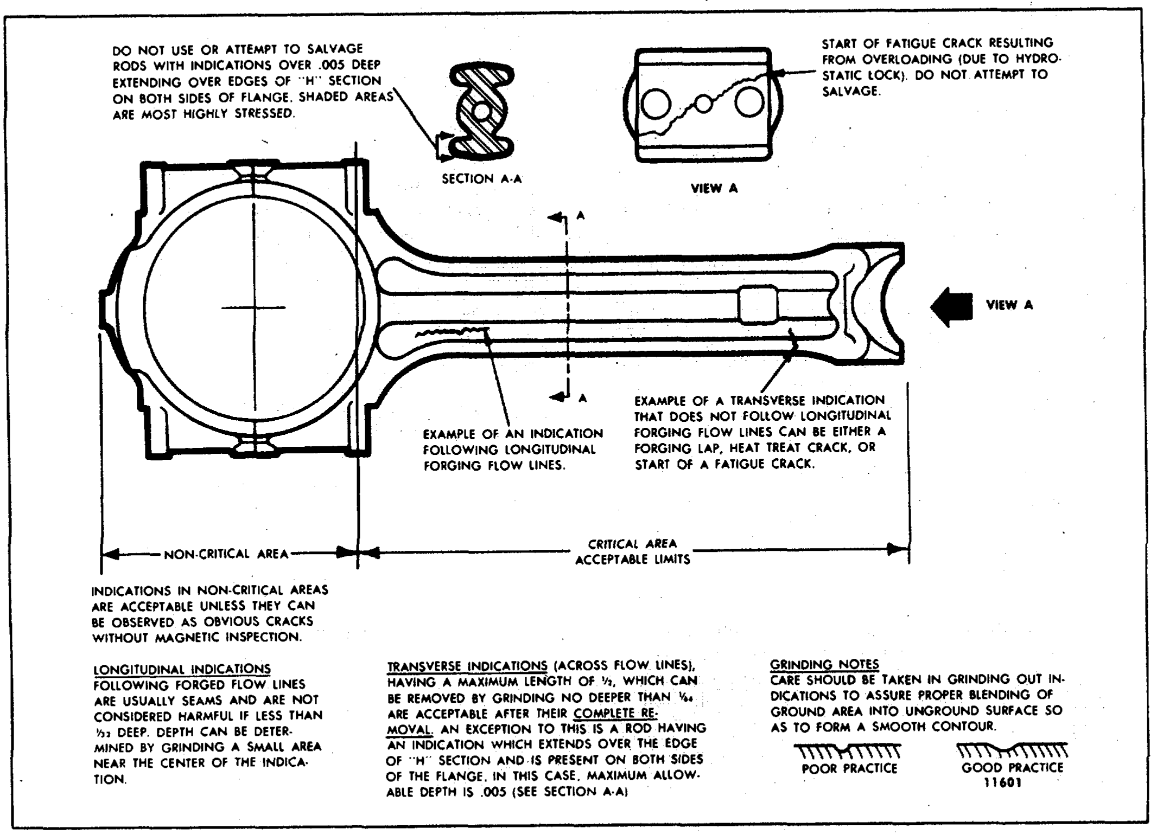


FIG. 15 Magnetic Particle Inspection Limits for Connecting Rod.

c. Obtain average of A and B to obtain size at split line.

$\frac{A + B}{2}$ = X which is the average of A + B

d. Measure C. The difference in the results of' the measurements X and C gives bore out-of-round and can be .0005 " maximum.
e. Add C with X and average to obtain average bore size.

$\frac{C + X}{2}$ = Average diameter of bore

Specifications: 3.2495 " to 3.2515 ".

IMPORTANT: If the crosshead connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.

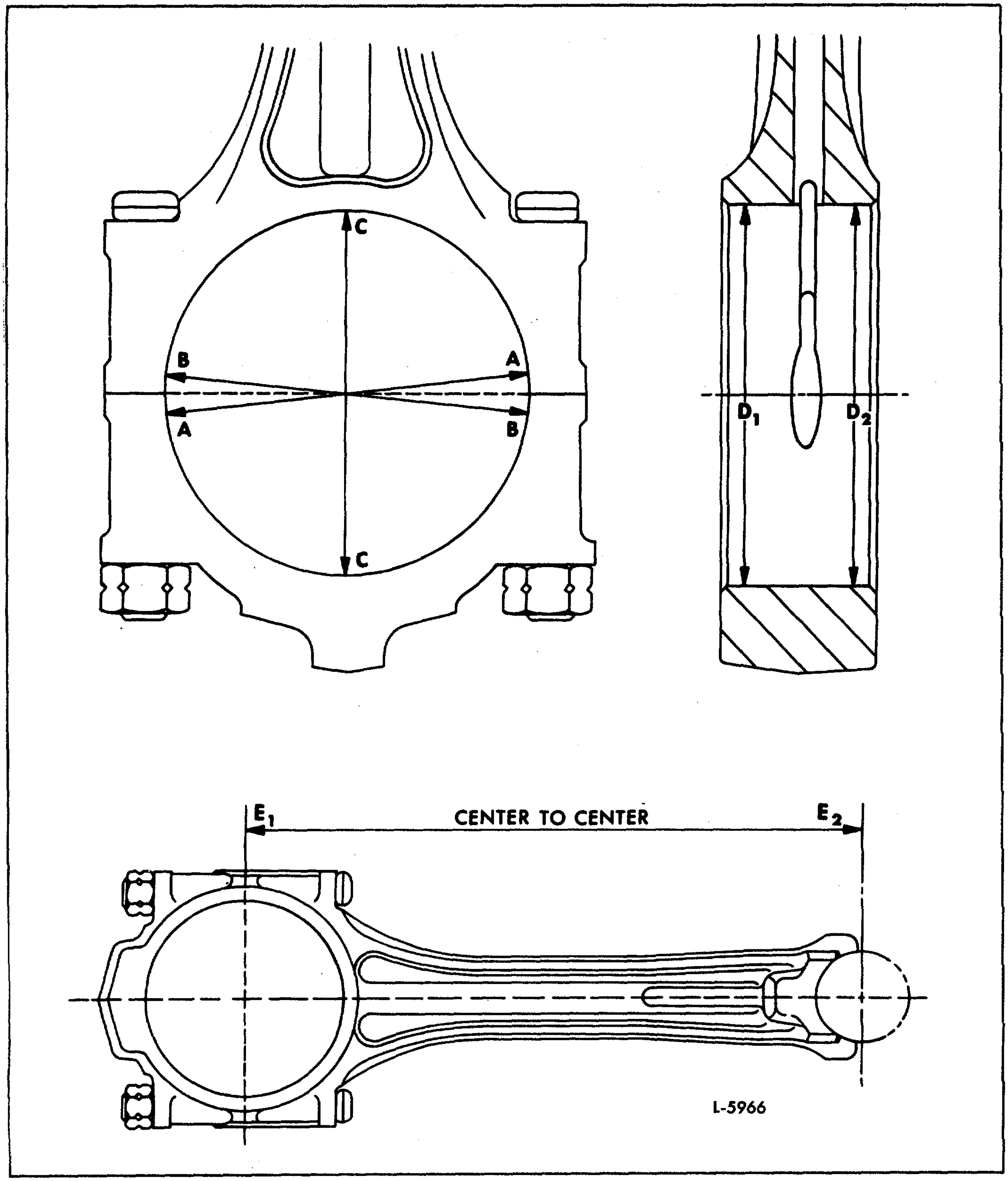
3. Determine taper as follows (Fig. 14):
   a. Subtract D1 from D2 to find the difference.
   b. The difference can be .0005 " maximum.

4. Determine length by finding the distance between E1 and E2 (Fig. 16).

Specifications: 10.121 " to 10.126".

NOTE: The length of' the rod can be measured on connecting rod measurement fixtures marketed by B. K. Sweeney, Tobin Arp or equivalent.

Remove any nicks or burrs from the connecting rod bolt holes with reamer J 28460 (Fig. 4). The reamer


C
B
A
A
B
C
D1
D2
E1
CENTER TO CENTER
E2
L-5966

includes a 60° angle to clean-up the chamfer at the bolt hole to ensure proper seating of the underside of the bolt head. If a new service connecting rod is required stamp the cylinder number on the connecting rod and cap (refer to Section 1.6.3).

> **IMPORTANT**: 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 bearing (bushing) 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 .086 " or less. A new bushing is .087 " to .088 " 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 1.4996 " to 1.5000 ". Replace the piston pin if it is worn to a diameter of 1.4980 " or less.

Assemble Connecting Rod to Piston.

Refer to *Assemble Piston* in Section 1.6 for assembly of the connecting rod to the piston.

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Fig. 1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shells

Various types of bearings have been used. Currently, multiple layer copper-lead coplated or aluminum triplated bearings are in use. These bearings have an inner surface, called the matrix, of copper-lead or aluminum. A thin deposit of babbitt is then plated onto the matrix. This babbitt overlay has excellent resistance to friction, corrosion and scoring tendencies which, combined with the material of the matrix, provides improved load carrying characteristics. These bearings are identified by the satin silver sheen of the babbitt when new and a dull gray after being in service.

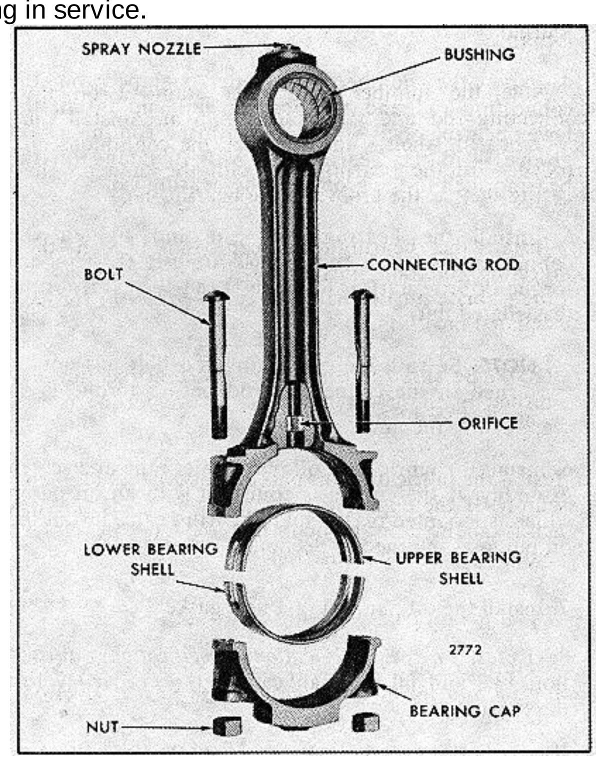


FIG. 1 - Connecting Rod and Bearing Shells

The upper and lower connecting rod bearing shells are different and are not interchangeable. Both shells are notched midway between the bearing edges for approximately 3/4 of an inch in from each parting line. In addition, the lower bearing shell has a circumferential oil groove that terminates at the notched ends. These notches maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

Remove Bearing Shells

The connecting rod bearing caps are numbered IL, 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.

Remove the connecting rod bearings as follows:

1. Drain the oil and remove the oil pan.
2. Disconnect and remove the lubricating oil pump inlet pipe and screen assembly. If the engine is equipped with an oil pump which is mounted on the main bearing caps, 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 hearing 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, cracking, loss of babbitt or signs of overheating. If any of these defects are present, the bearings must be discarded. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are NOT detrimental to this type of bearing. The bearings should not be replaced for these minor surface imperfections. The upper bearing shells, which carry the load, will normally show sign 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 bore for burrs, foreign particles, etc.

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 .1230" and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of .1240" to .1245". Refer to Table 1.

Bearing Size	*New Bearing Thickness	Minimum Worn Thickness
Standard	.1240"/.1245"	.1230"
.002" Undersize	.1250"/.1255"	.1240"
.010" Undersize	.1290"/.1295"	.1280"
.020" Undersize	.1340"/.1345"	.1330"
.030" Undersize	.1390"/.1395"	.1380"

*Thickness 90° from parting line of bearing.

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-journal clearance with used parts is .0056".

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.

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

> **NOTE**: 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.

Bearing shell sets from individual suppliers are completely interchangeable and can be mixed in an engine.

> **NOTE**: Upper and lower bearing shells are serviced only in sets. 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 to be used, install all new bearing shells.

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 and tighten the connecting rod bolt nuts to 60-70 lb-ft (81-95 Nm) torque (lubrite nut) or 65-75 lb-ft (88-102 Nm) torque (castellated nut).

> **NOTE**: Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut.

6. Install the lubricating oil pump inlet pipe and screen assembly. If the engine is equipped with an oil pump which is mounted on the main bearing caps, install the oil pump as outlined in Section 4.1.
7. Install the oil pan, using a new gasket.
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 as outlined in Section 13.2.1.

CYLINDER LINE

The replaceable type cylinder liner (Fig. I) is accurately machined and heat treated to provide a long wearing scuff-resistant surface. The flange at the top fits into a counterbore in the cylinder block and rests on a replaceable cast iron insert which permits accurate alignment of the cylinder liner.

The liner is cooled by means of a water jacket in the cylinder block and by the scavenging air introduced into the cylinder through the air inlet ports around the liner (Fig. 1). The air inlet ports 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 cleaners must be serviced regularly according to the surroundings in which the engine is operating.

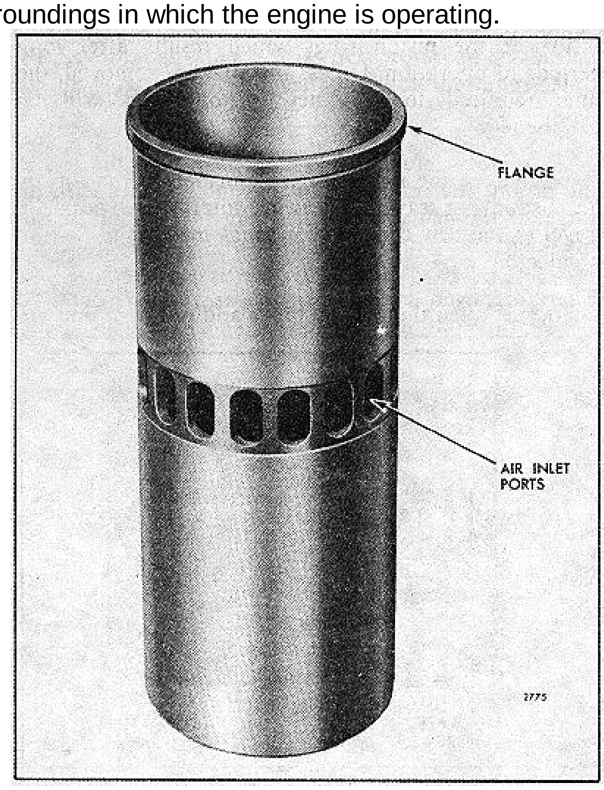


FIG. 1 - Typical Cylinder Liner

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 ring groove may collapse.

Refer to Fig. 2 and remove a cylinder liner 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 21716 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.

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.

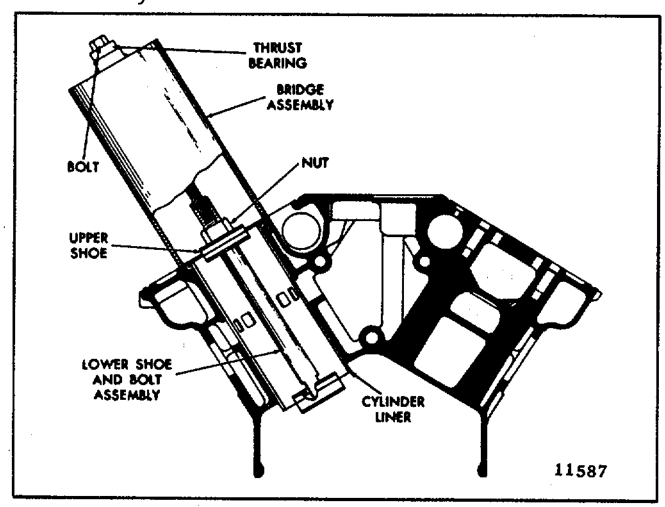


FIG. 2 - Removing Cylinder Liner

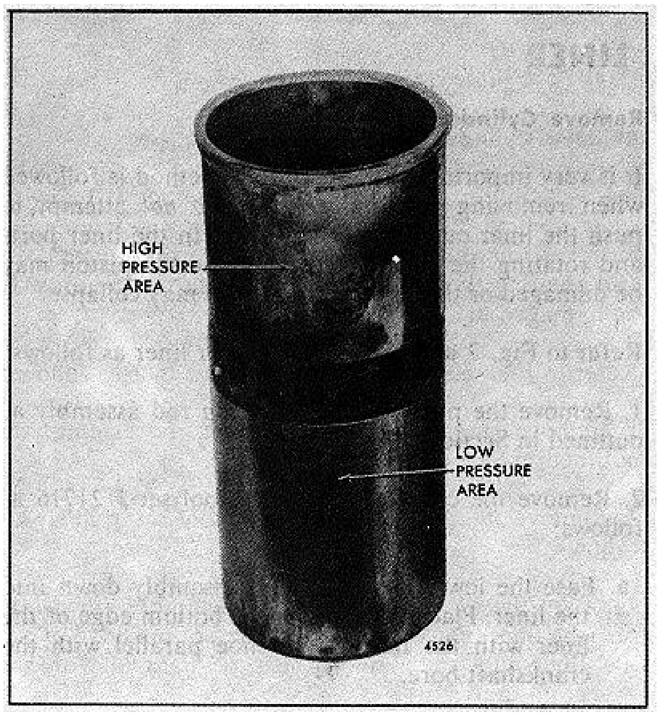


FIG. 3 - High and Low Pressure Contact Areas on Cylinder Liner

f. Turn the bolt in a clockwise direction and withdraw the liner from the block. Then remove the tool from the liner.

g. Remove the liner insert and shims (if used) from the counterbore in the block.

h. Tag the liner, insert and shims.

If tool set J 21716 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:

- Cracks
- Scoring
- Poor contact on outer surface
- Flange irregularities
- Inside diameter
- Outside diameter
- Out-of-round
- Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned-up and reused.

Excessive liner-to-block clearance or block bore distortion will reduce heat transfer from the inner to the block and to the engine coolant. Poor contact between the liner and the block bore may be indicated by stains or low pressure areas on the outer surface of the liner (Fig. 3).

Examine the outside diameter of the liner for fretting.

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.

The liner flange must be smooth and flat on both the top and bottom surfaces. Check for cracks at the flange. The liner insert must also be smooth and flat on the top and bottom surfaces. Replace the insert if there is evidence of brinelling.

A used cylinder liner must be honed for the following reasons:

NOTE: Do not modify the surface finish in a new service liner. Since the liner is properly finished at the factory, any changes will adversely affect seating the piston ring.

1. To break the glaze (Fig. 4) due to the rubbing action of the piston rings which results 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 (Fig. 5) formed at the top by the piston ring travel. 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

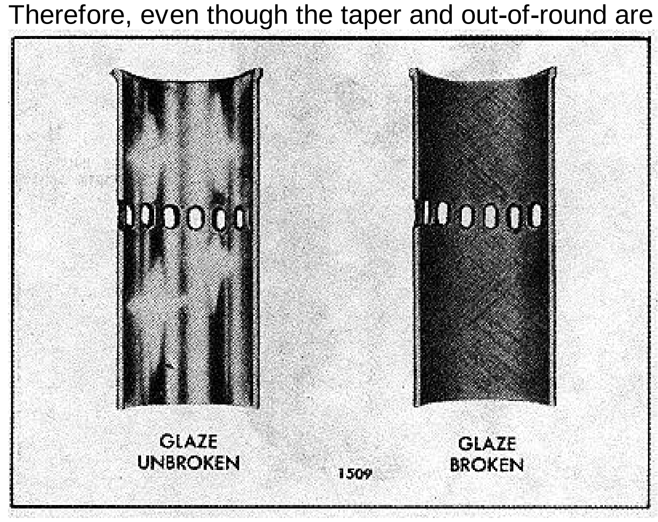


FIG. 4 Glazed Surface of Cylinder Liner

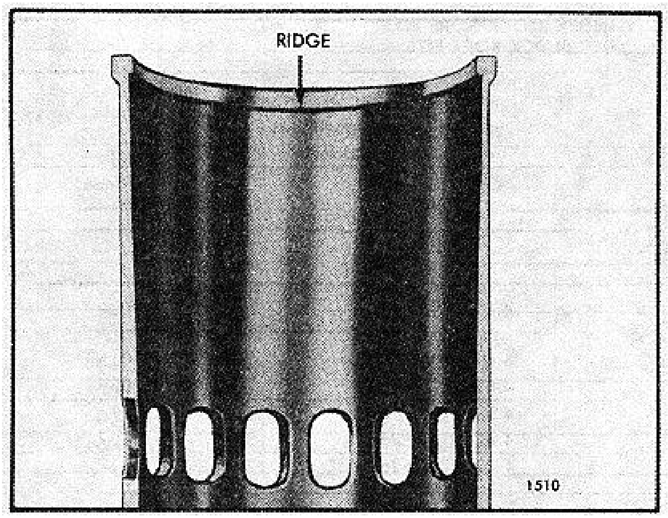


FIG. 5 Cylinder Liner Ridge Due to Wear

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.

The hone J 5902-01, equipped with 120 grit stones J 5902-14, should be worked up and down 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.

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).

Liner Measurements

Measure the block bore and the outside diameter of the liner. If the liner-to-block clearance exceeds .0025" (with used parts), it will be necessary to bore the block for an oversize liner as outlined in Section 1.1.

Install the liner in the proper bore of the cylinder block. Measure the inside diameter of the liner at the various points shown in Fig. 6. Use cylinder bore gage J 5347, which has a dial indicator calibrated in .0001,

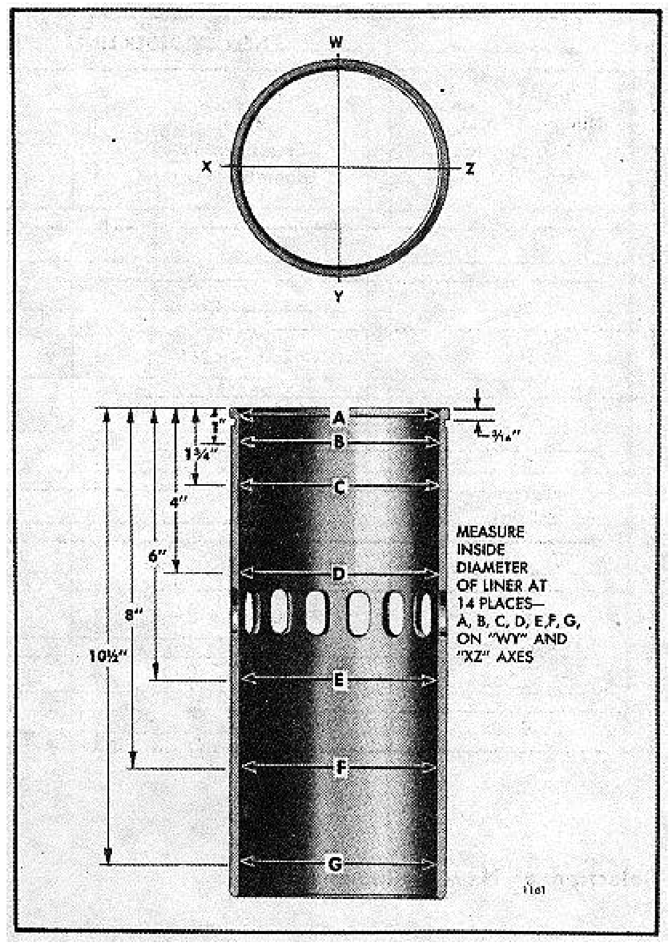


FIG. 6 Cylinder Liner I.D. Measurement Diagram

increments. Set the cylinder bore gage on zero in master ring gage J 5580-1. Also check the liner for taper and out-of-round. It is not necessary to measure the inside diameter or taper of a new liner.

> **NOTE**: Dial bore gage master setting fixture J 23059 may be used in place of the master ring gage.

The piston-liner clearance must be within the specified limits (Section 1.0). Also, the taper must not exceed .002 and the out-of-round must not exceed .0025 " on a used liner. If the out-of-round exceeds .0025 ", rotate the liner 90 ° in the block bore and recheck.

New service liners, standard and oversize, have an inside diameter of 4.2489", to 4.2511".

Cylinder liners are available in .001", .005", .010",.020, and .030", oversize on the outside diameter. When an oversize liner is installed, stamp the amount of oversize on top of the cylinder bore adjacent to the liner counterbore.

NEW CYLINDER LINER TO NEW CYLINDER BLOCK BORE FITS				
Classification Number Stamped Adjacent to Each Cyl. Bore	Cylinder Bore Classification Diameter (I.D.)	Standard Cylinder Liner Diameters and Liner-to-Block Clearances When Properly Matched		
		Liner (O.D.) Classification	Liner (O.D.) Diameter	Liner/Block Clearance
CAST IRON BLOCK				
#0	4.6256"/4.6259"	#1	4.6250"/4.6255"	.0001"/.0009"
#1	4.6260"/4.6265"	#1	4.6250"/4.6255"	.0005"/.0015"
		#2	4.6256"/4.6260"	.0000"/.0009"
#2	4.6266"/4.6270"	#2	4.6256"/4.6260"	.0006"/.0014"
		#3	4.6261"/4.6265"	.0001"/.0009"
#3	4.6271"/4.6275"	#3	4.6261"/4.6265"	.0006"/.0014"
METRIC				
#0	117.490/117.498 mm	#1	117.475/117.488 mm	.002/.023 mm
#1	117.500/117.513 mm	#1	117.475/117.488 mm	.012/.038 mm
		#2	117.490/117.500 mm	.000/.023 mm
#2	117.516/117.526 mm	#2	117.490/117.500 mm	.016/.036 mm
		#3	117.503/117.513 mm	.003/.023 mm
#3	117.528/117.539 mm	#3	117.503/117.513 mm	.015/.036 mm

TABLE 1

Selection of New Cylinder liner

The cylinder bores in a new cylinder block are classified as # 1, #2 or #3 (Table 1) designating the specific size range for each bore and the appropriate cylinder liner that may be fitted to each bore. The classification number is stamped on the fire deck of the cylinder block adjacent to each cylinder bore.

OVERSIZE SERVICE CYLINDER LINERS			
Service Liner Oversize	Liner Outside Diameter		Liner/Block Clearance Req'd After Boring Block
	inches	mm	
.001" (.0254 mm)	4.6280 4.6265	117.551 117.513	.0005"/.0015" (.013/.038 mm)
.005"	4.6315 4.6300	117.640 117.602	.0005"/.0015" (.013/.038 mm)
.010"	4.6365 4.6350	117.767 117.729	.0005"/.0015" (.013/.038 mm)
.020"	4.6465 4.6450	118.021 117.983	.0005"/.0015" (.013/.038 mm)
.030"	4.6565 4.6550	118.275 118.237	.0005"/.0015" (.013/.038 mm)

A new standard size cylinder liner is also classified as # 1, #2 or #3 as illustrated in Fig. 7 and Table 1.

Although the block bores and liners should be measured to determine the liner-to-block clearance, the selection of a liner is narrowed down to only those in the appropriate classifications or possibly a .001" oversize liner.

Before installing a liner in a used cylinder block, always lightly hone the block bore (refer to Section 1.1).

After honing the block bore, check the bore measurements to determine if a standard liner (classification # 1, #2 or #3) or possibly a .001" oversize liner can be used (refer to Tables 1 and 2). A push fit between the liner and the block is desirable. If an adequate push fit cannot be obtained, it may be necessary to bore the block to receive an oversize liner.

When it becomes necessary to install an oversize liner, the same care in selective tolerance fitting must be adhered to. However, it may be more difficult to select an oversize liner since the size range is not broken down into classifications.

In deciding whether boring is necessary or not, keep in

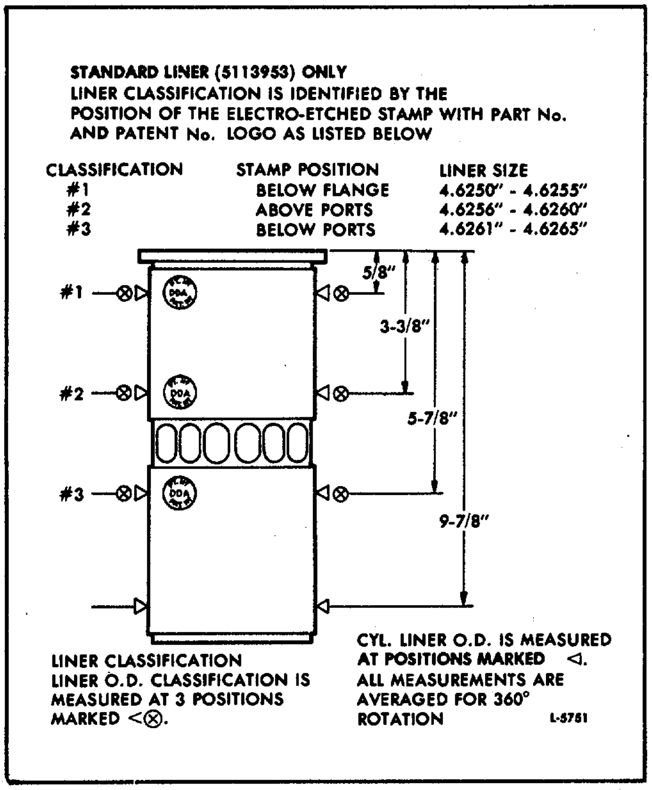


FIG. 7 - Cylinder Liner Classification

mind that each bore in a used block must not be out-of-round or tapered more than .002". If the average block bore is over 4.62851a, the cylinder block should be bored oversize.

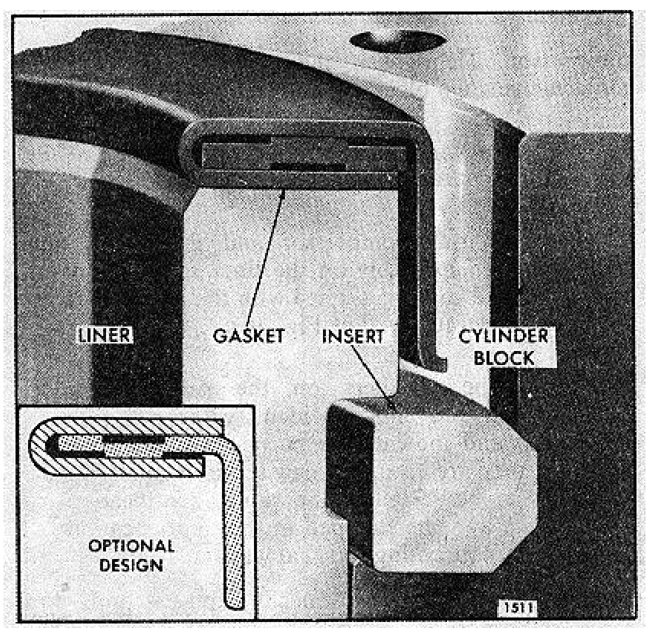


Fig. 8 - Cylinder Liner Mounting in Block

To determine what size to bore the cylinder block for an oversize liner, each service liner used must be measured on the outside diameter for size in three places (under the flange, between the flange and the ports, and above the ports). The cylinder bore size will be determined by the average liner measurement taken at the three positions.

EXAMPLE:

Service liner O.D. measures 4.6280".

O.D. size 4.6280"

plus clearance = .0005"

bore size = 4.6285"

Then, 4.6285 " + .001" boring tolerance will allow a bore size of 4.6285" to 4.6295" and a possible liner-to- block clearance of .0005" to .0015". The clearance tolerance is the dimensional difference between the liner O.D. and the block bore I.D.

Fitting Cylinder Liner in Block Bore

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean.
2. Place a standard size cylinder liner insert (.1795"-.18001, thick) in the block counterbore (Fig. 8).
3. Push the cylinder liner into the cylinder block until the liner flange rests on the insert. Do not use excessive force to install the liner. The liner should

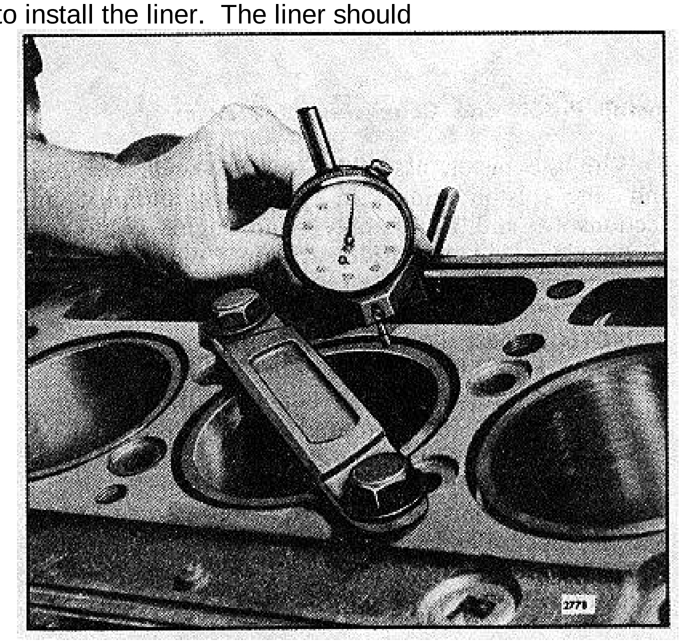


Fig. 9 - Checking Distance of Liner Flange Below Top Face of Block with Tool J 22273-01

slide smoothly in place with hand pressure. If a new liner cannot be pushed in place, light honing of the block bore may be necessary to obtain the desired fit for best heat transfer.

4. Install a cylinder liner hold-down clamp (J 21793-B) as illustrated in Fig. 9 and tighten the two bolts to 50 lb-ft (68 Nm) torque.

5. Measure the distance from the top of the liner to the top of the block with a dial indicator (Fig. 9). The liner flange must be .045" to .050" below the surface of the block. However, even though all of the liners are within these specifications, there must not be over .002" difference between any two adjacent liners when measured along the cylinder longitudinal center line.

> **NOTE**: A .002" thick shim is available for adjusting the liner height. The shim must be installed underneath the liner insert. Do not cut the shim for installation. Liner inserts which are .0015" thicker or thinner than standard are also available for service. In addition, the .004" and .008" thinner inserts which are provided for use with resurfaced cylinder blocks, can also be used to adjust the liner height.

6. 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. The matchmarks should be on the side opposite the camshaft.

7. Remove the hold-down clamp and the cylinder liner.

> **NOTE**: Do not remove the liner insert.

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 3272-03.

> **NOTE**: 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 compressor. Then push the piston down until it contacts the wood block ("Operation 1 " of Fig. 10).

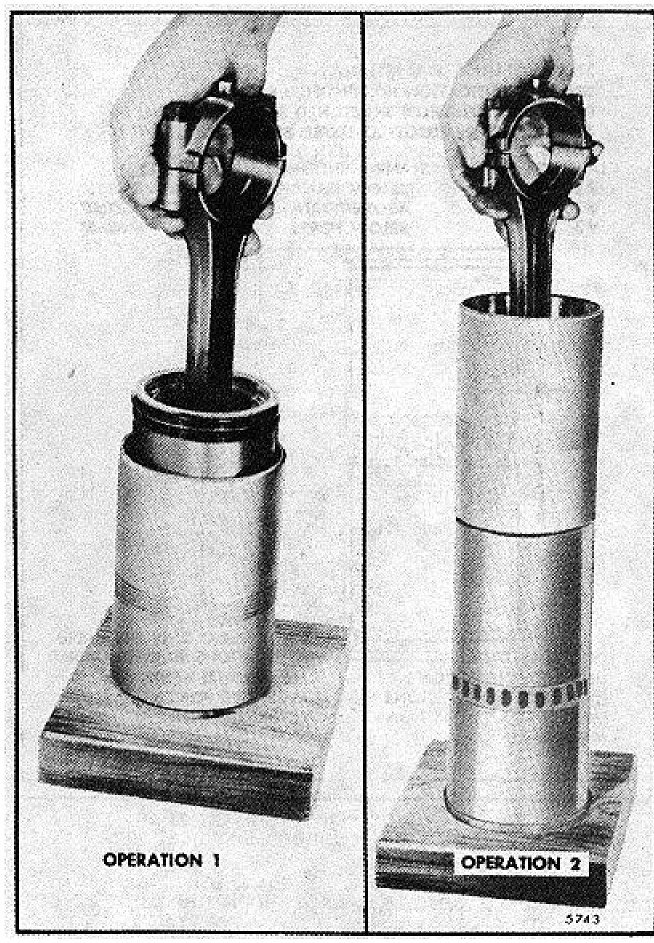


FIG. 10 - Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

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. 10).

> **NOTE**: 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.

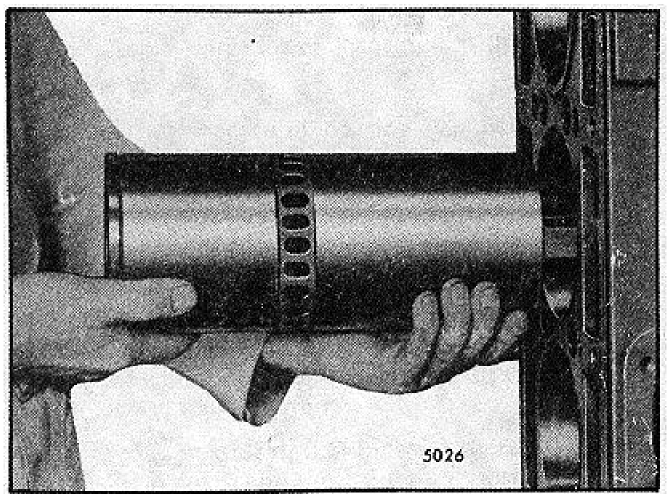


FIG. 11 - Installing Piston, Rod and Liner Assembly in Cylinder Block

> **NOTE**: Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. 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

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine as follows:

1. 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.
2. Rotate the crankshaft 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.
3. Install the upper bearing shell - the one without the continuous oil groove - in the connecting rod. Lubricate the bearing shell with clean engine oil.
4. Position the piston, rod and liner assembly in front of the cylinder block bore so that the identification number and letter on the 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 (Fig. 11) until the liner flange rests against the insert in the counterbore in the block.
5. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

> **NOTE**: 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.

6. 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 cap. Lubricate the bearing shell with clean engine oil.
7. 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. Tighten the connecting rod bolt nuts to 60-70 lb-ft (81-95 Nm) torque (notch or imbedded "0" lubrite nut) or 65-75 lb-ft (88-102 Nm) torque (castellated nut).

> **NOTE**: Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut.

8. Check the connecting rod side clearance. The clearance between each pair of connecting rods should be .008" to .016" with new parts.
9. Install the remaining liner, piston and rod assemblies in the same manner. Use hold-down clamps to hold each liner in place.
10. After all of the liners and pistons have been installed, remove the hold-down clamps.
11. Install new compression gaskets and water and oil seals as outlined in Section 1.2. Then install the cylinder head and any other parts which were removed from the engine.
12. After the engine has been completely reassembled, refer to the Lubrication Specifications in Section 13.3 and refill the crankcase to the proper level on the dipstick.
13. Close all of the drains and fill the cooling system.
14. 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

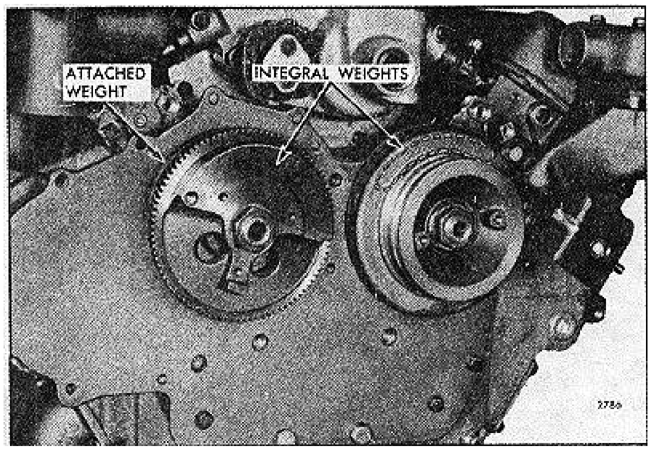


FIG.1 - Typical Front Balance Weight Mounting

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 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 canceled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the camshafts. These camshaft balance weights may be integral with the camshaft gears, the water pump drive gear or the camshaft front pulley. This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

On the camshafts, each set of 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, canceled. 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 V-71 engine. There are no secondary forces present in the V-71 engine. Consequently, the engine will operate smoothly and in balance throughout its entire speed range.

Due to the difference in the size of the camshaft balance weights used on the 6, 8 and 12V engines, it is important to have the proper set of weights on each engine.

Additional balance weights are attached to the camshaft gears and to the water pump drive gear used on the 8V,engine.

Effective with engine serial number 8VA-115016, a new camshaft front pulley (integral weight) on the left bank plus new heavier bolt-on balance weights attached to the water pump drive gear and the rear camshaft gears are used. Only the heavier weights are serviced as they are completely interchangeable with the former weights. When replacing the trunk-type pistons with cross-head type pistons in an engine, the current camshaft front pulley and heavier weights must be used.

When the cross-head pistons are to be installed in an 8V-71 engine built prior to serial number 8VA-115016, and an in-frame overhaul is desired, a new bolt-on rear balance weight must be used in addition to the existing balance weight attached to the engine side of each rear camshaft gear. Refer to Section 1.0 for the installation procedure.

On the 12V engine, the balance weight is integral with the current water pump drive gear. Prior to engine serial number 12VA-458, an additional balance weight was attached to the gear.

A camshaft torsion vibration damper is mounted to an adapter hub that is attached to the water pump drive gear on certain 12V-71 turbocharged engines.

GEAR TRAIN AND ENGINE TIMING

GEAR TRAIN

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the engine. The gear train consists of a crankshaft gear, an idler gear, two camshaft gears and a blower drive gear (Fig. I).

The crankshaft gear is bolted to the flange at the rear end of the crankshaft. The idler gear is mounted on a stationary hub on either the right-hand or left-hand side of the engine (viewed from the flywheel end), depending upon engine rotation. The camshaft gears are pressed on and keyed to their respective shafts and each is secured by a nut and gear nut retainer.

The two camshaft gears mesh with each other and run at the same speed as the crankshaft gear. Since the camshaft gears must be in time with each other, and the two as a unit in time with the crankshaft gear, timing marks (Fig. 2) have been stamped on the face of the gears to facilitate correct gear train timing. 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 timing is advanced on certain engines by aligning the "A" on the crankshaft gear with the "R" on the idler gear.

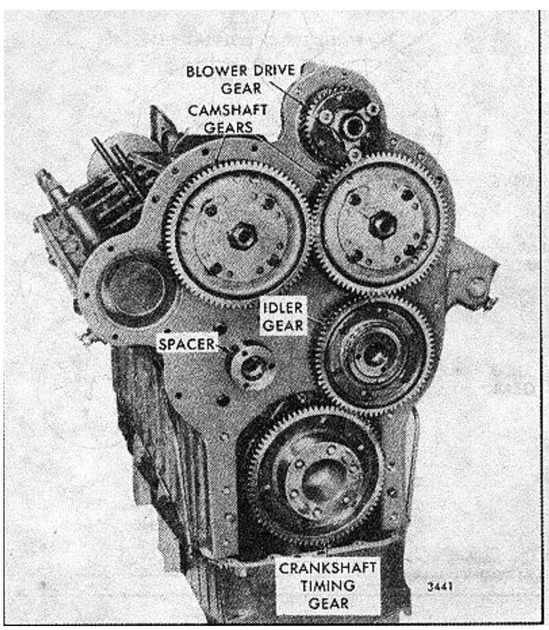


FIG.1 - Gear Train

> **NOTE:** It is advisable to line up and make a sketch indicating the position of the timing marks before removing or replacing any of the gears.

If it is impractical to determine the type of timing (standard or advanced) by rotating the gear train until the marks line up, refer to Table I as a guide.

There are no timing marks on the accessory drive gear, if used, or the blower drive gear. Therefore, it is not necessary to align these gears in any particular position during their installation.

However, as the blower drive gear and the accessory drive gear have only about half as many teeth as the camshaft gears, they turn at approximately twice the speed of the crankshaft.

The backlash between the various mating gears in the gear train should be .002 " to .008 " and should not exceed .010 " between worn gears.

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth or excessive bearing wear. Therefore, when noise develops in a gear train, the flywheel housing should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

Lubrication

The gear train is lubricated by the overflow of oil from the camshaft pockets spilling into the gear train compartment and by splash from the oil pan. A certain amount of oil also spills into the gear train compartment from both camshaft rear end bearings,

STANDARD TIMING All two valve models. All four valve models with S55, 71N5, S60, N55, N60 and N65 white tog Injectors.
ADVANCED TIMING All four valve models with brown tag N65 and N70 Injectors.

TABLE 1

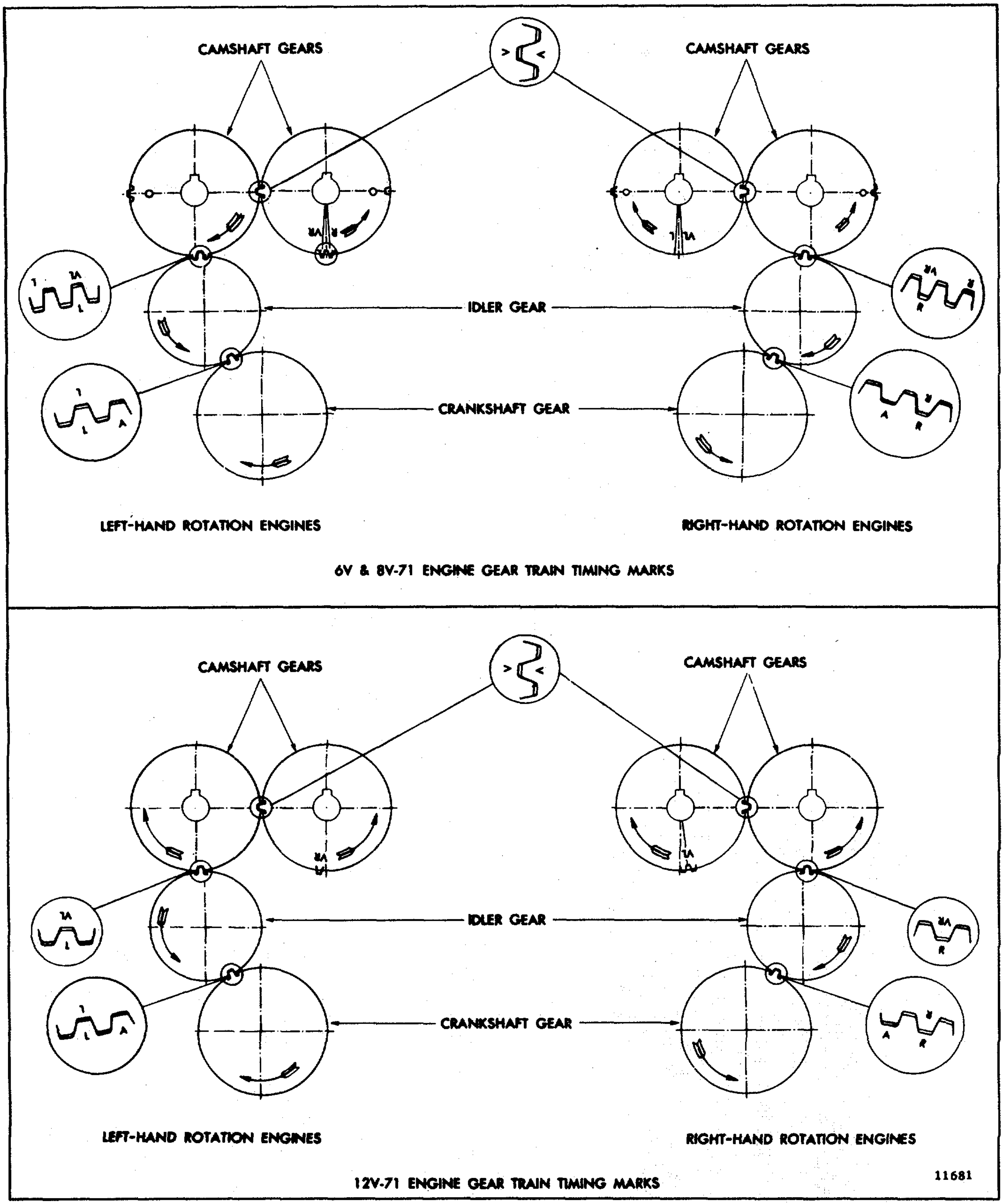


FIG.2 - Gear Train and Timing Marks

the blower drive gear bearing and the idler gear bearing. The idler gear bearing is lubricated by oil directly from the cylinder block oil gallery to the idler gear bearing hub. The blower drive gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

ENGINE TIMING

The correct relationship between the crankshaft and the two camshafts must be maintained to properly control fuel injection and the opening and closing of the exhaust valves.

The crankshaft timing gear can be mounted in only one position since one attaching bolt hole is offset. The two camshaft gears can also be mounted in only one position due to the location of the keyway in each camshaft relative to the cams. Therefore, when the engine is properly timed, the timing marks on the various gears will match as shown in Fig. 2.

An engine which is "out of time" may result in pre-ignition, 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. Clean and remove one valve rocker cover.

2. Select any cylinder for the timing check -- it is suggested that a cylinder adjacent to one of the rocker cover bolt or stud holes be chosen since the stud or bolt may be used to mount a dial indicator.

3. Remove the injector (at the cylinder selected) as outlined in Section 2.1 or 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.

5. Place the throttle in the no-fuel 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.

6. 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.

7. Mount the indicator over the injector tube. The indicator mounting may be threaded into the rocker cover stud or the tapped hole in the cylinder head. Check to be sure the indicator spindle is free in the injector tube and is free to travel at least one inch.

8. Attach a suitable pointer to the crankshaft front cover. The outer end of the pointer should extend over the top of the crankshaft pulley (or vibration damper).

9. 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.

10. Reset the dial to zero. Then turn the crankshaft until the indicator reading is .010 ".

11. Scribe a line on the crankshaft pulley (or vibration damper) in line with the end of the pointer.

12. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

13. Reset the dial to zero. Then turn the crankshaft until the indicator reading is .010 ".

14. Scribe a second line on the vibration damper (or crankshaft pulley) in line with the end of the pointer.

15. Scribe a third line half way between the first two lines. This is top dead center. Remove the indicator and rod from the engine.

> **NOTE**: If the crankshaft pulley retaining bolt has loosened, tighten it to the specified torque (Section 1.3.7).

16. Install the injector as outlined in Section 2.1 or 2.1.1. Then refer to Section 14 and adjust the valve clearance and time the injector.

Engine	* Indicator Reading		
	Correct	Retarded	Advanced 1-tooth
	Standard Timing		
6V, 8V. 12V-71	.230"	.197"	.262"
	Advanced Timing		
6V, 8V. 12V-71	.262"	.230"	.289"
	California Engines		
†8V-71 TAE	.189*	.156"	.221"

*Indicator readings shown are nominal values. The allowable tolerance is ±.005 in.

† Beginning with 1977 engines.

TABLE 2

17. Turn the crankshaft, in the direction of engine rotation, until the exhaust valves in the selected cylinder are completely open. Re-install 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.

18. Note the indicator reading and compare it with the dimensions in Table 2.

19. After completing the timing check, remove the dial indicator. Also remove the pointer from the crankshaft front cover.

20. Install the valve rocker cover.

CAMSHAFTS AND BEARINGS

The contrarotating camshafts are located near the top of the cylinder block. A left cylinder bank and a right cylinder bank camshaft is provided to actuate the exhaust valve and injector operating mechanism. The accurately ground cams ensure efficient, quiet cam follower roller action and are heat treated to provide a hard wear surface.

Both ends of each camshaft are supported by a bearing assembly which consists of a flanged housing and two bushings. In addition, intermediate two-piece bearings support the camshafts at uniform intervals throughout their length. The intermediate bearings are secured to the camshafts by lock rings, thus permitting them to be inserted in the cylinder block with the shafts. Each intermediate bearing is secured in place, after the camshafts are installed, with a lock screw threaded into a counterbored hole in the top of the cylinder block.

The camshaft gear thrust load is absorbed by two thrust washers, one on each end of the rear camshaft end bearing, on each camshaft.

A camshaft front pulley (integral weight) is attached to the front end of the left-bank camshaft and a water pump drive gear (bolt-on weight) is attached to the front end of the right-bank camshaft. A camshaft gear is attached to the rear of each camshaft.

Certain 8V engines are equipped with a camshaft torsion vibration damper that is keyed and bolted to an adapter attached to the water pump drive gear with three bolts, plain washers and lock washers.

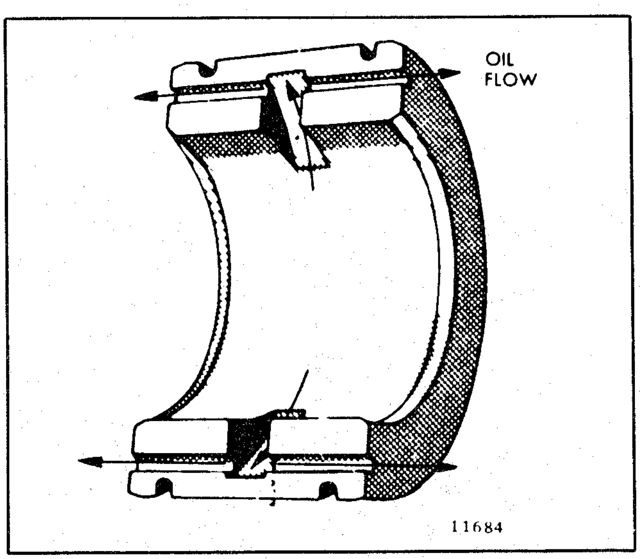


FIG.1 - Camshaft Intermediate Bearing (Lower Half)

NOTE: If an oil leak should occur at the drive plug area in the front of the left-bank camshaft, refer to Shop Notes in Section 1.0 and install a cup plug.

Lubrication

Lubricating oil is supplied under pressure to the bearings via drilled passages in the rear of the cylinder block which lead from the main oil gallery to each rear end bearing. From the rear end bearings, the oil passes through the drilled oil passages in the camshafts to the intermediate bearings and to the front end bearings.

The lower halves of the camshaft intermediate bearings are grooved along the horizontal surfaces that mate with the upper halves (Fig. I). Oil from the passage in the camshaft is forced through the milled slots in the bearing and then out the grooves to furnish additional oil to the cam follower rollers. This permits the cam pockets in the cylinder block to be filled rapidly to the operating level immediately after starting the engine.

Remove Camshafts

Whenever an engine is to be completely reconditioned or the camshafts, camshaft gears, bearings or thrust washers need replacing, remove the camshafts as follows:

1. Drain the engine cooling system.

2. Remove all of the accessories and sub-assemblies necessary to permit the engine to be mounted on an overhaul stand (refer to Section 1.1).

3. Mount the engine on the overhaul stand. Be sure the engine is securely attached to the overhaul stand before releasing the lifting sling.

4. Remove the cylinder heads (refer to Section 1.2).

5. Remove the flywheel and flywheel housing as outlined in Sections 1.4 and 1.5.

6. Remove the water pump (Section 5.1).

7. Remove the front balance weight cover.

8. Remove the bolts which secure the nut retaining plates to the camshaft gears. Then remove the plates.

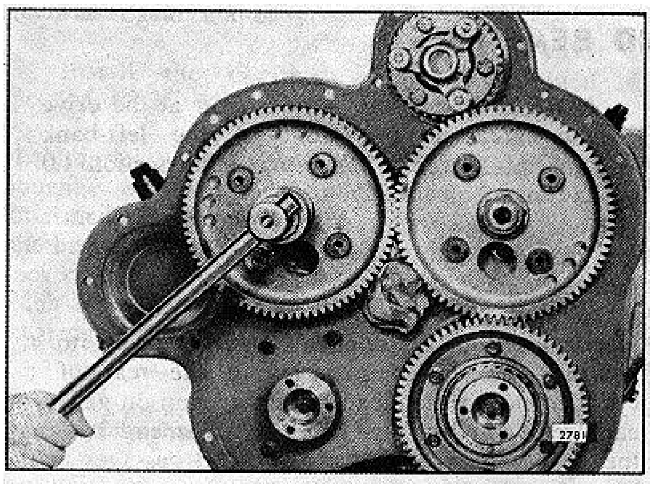


FIG.2 - Loosening Camshaft Gear Retaining Nut

9. Wedge a clean rag between the gears (Fig. 2) and remove the gear retaining nut from both ends of each camshaft. On current left-hand rotation 6V and 8V engines, remove the lock bolt and washer from the rear of the right-bank camshaft.

10. Remove the camshaft pulley, using puller J 4794-01. Use adapter J 7932 between the end of the camshaft and the puller screw to protect the end of the camshaft (Fig. 3).

11. Remove the camshaft vibration damper and adapter, if used, from the water pump drive gear.

12. Remove the water pump drive gear from the front end of the right-bank camshaft, using puller J 4870 and adapter J 7932.

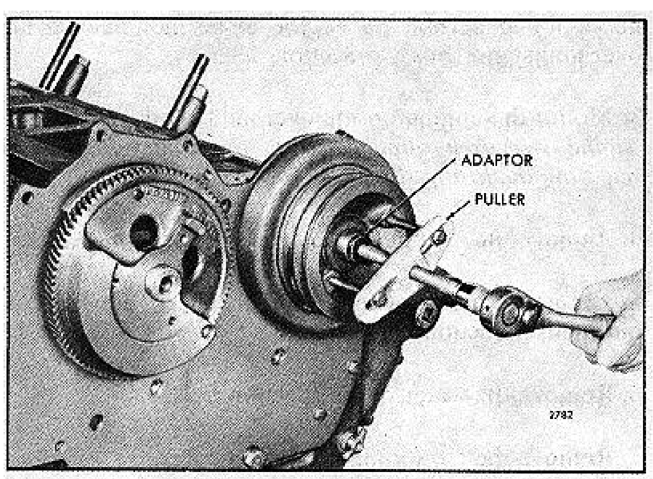


FIG.3 - Removing Camshaft Pulley

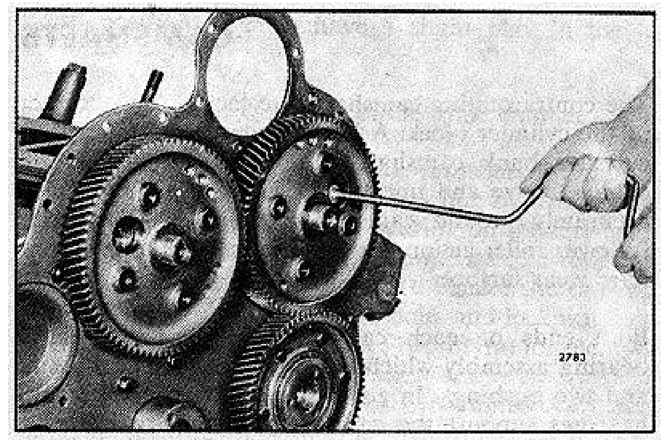


FIG.4 - Removing or Installing Camshaft End Bearing Retaining Bolts

13. Remove the woodruff key and the spacer from the front end of each camshaft.

14. Remove all of the camshaft intermediate bearing lock screws from the top of the cylinder block.

15. Rotate the camshaft gears as required to reveal the camshaft end bearing retaining bolts. Then remove the bolts (Fig. 4).

16. Withdraw each camshaft, bearing and gear assembly from the cylinder block as shown in Fig. 5.

17. Remove the camshaft front end bearing retaining

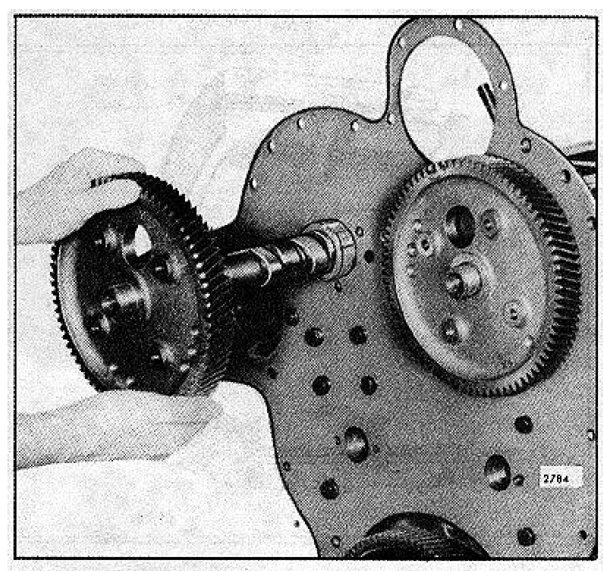


FIG.5 - Removing or Installing Camshaft

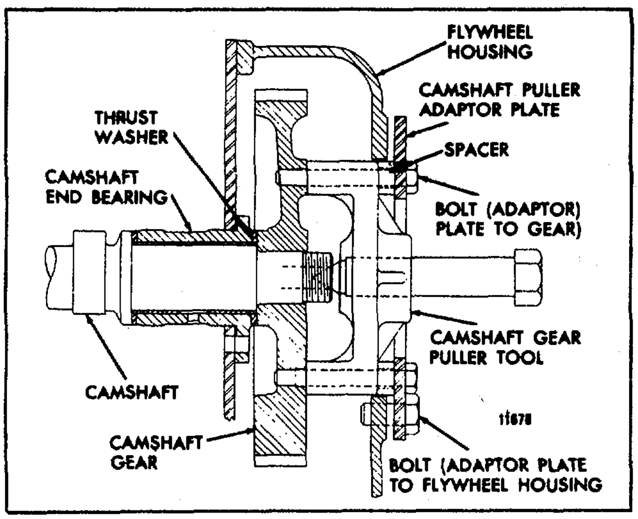


FIG.6 - Removing Camshaft with Flywheel Housing in Place

bolts. Then remove the bearings. If necessary, use a pry bar under the bearing flange.

Remove Camshaft (Flywheel Housing and Transmission in Place)

A camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission, if there is space enough to slide the shaft out through the front of the engine.

1. Drain the cooling system and remove the radiator and all attaching parts.

2. Remove the accessories and sub-assemblies with their attaching parts that are necessary to facilitate removal of the flywheel housing hole cover over the camshaft and the front balance weight cover.

3. Remove the cylinder head.

4. Remove the front balance weight cover.

5. Remove the camshaft gear nut retainer.

6. Wedge a clean rag between the camshaft gears (Fig. 2) and remove the gear retaining nut from both ends of the camshaft.

7. Remove the camshaft pulley or water pump drive gear. Then remove the woodruff key and spacer from the camshaft.

8 Remove the lock screws that secure the camshaft intermediate bearings.

9. Remove the three bolts that secure the camshaft end bearing to the front end plate.

10. Install the camshaft gear puller J 1902-01, four spacers J 6202-2 and camshaft gear puller adapter plate J 6202-1 on the camshaft gear (Fig. 6).

11. Turn the center screw of the puller clockwise to disengage the camshaft from the camshaft gear.

> **NOTE:** *Do not remove the puller or the adapter plate until the camshaft is reinstalled.* The adapter plate, secured to both the flywheel housing and the camshaft gear, will hold the gear securely in place and in alignment, which will aid in reinstallation of the camshaft.

12. Remove the front camshaft end bearing.

13. Pull the camshaft and intermediate bearings from the cylinder block.

Disassemble Camshaft

1. Remove the gear from the camshaft (Section 1.7.3).

2. Slide the rear end bearing and thrust washers off the camshaft.

3. Remove the lock rings from the camshaft intermediate bearings and remove the bearings.

4. Remove the end plugs from the camshaft, to facilitate removal of any foreign material lodged behind the plugs, as follows:

   a. Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shafts.

   b. Make- an indentation in the center of the end plug with a 31/64 " drill (carboloy tip).

   c. Punch a hole as deep as possible with a center punch to aid in breaking through the hardened surface of the plug.

   d. Then drill a hole straight through the center of the plug with a 1/4 " drill (carboloy tip).

   e. Use the 1/4" drilled hole as a guide and re-drill the plug with a 5 /16 " drill (carboloy tip).

   f. Tap the drilled hole with a 3/8" -16 tap.

   g. Thread a 3/8 "-16 adapter J 6471-2 into the plug.

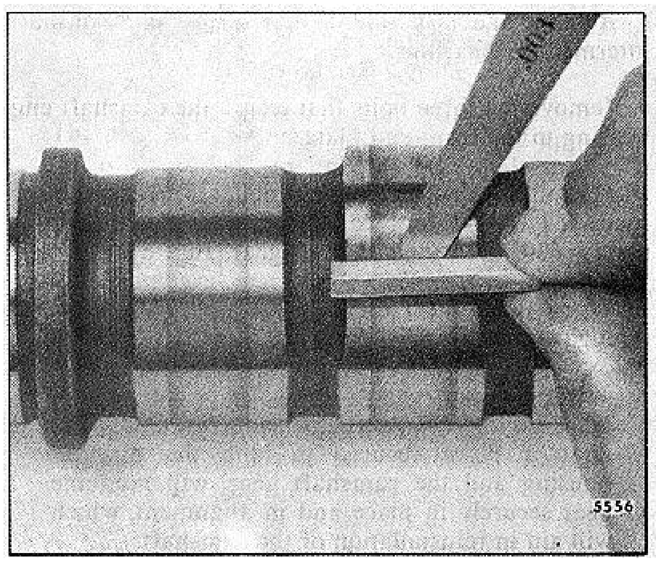


FIG.7 - Checking Cam Lobe Wear

Then attach a slide hammer J 6471-1 to the adapter and remove the plug by striking the hammer weight against the adapter handle.

h. Insert a length of 3/8" steel rod in the camshaft and drive the remaining plug out.

NOTE: If a suitable steel rod is not available, remove the remaining plug in the same manner as outlined above.

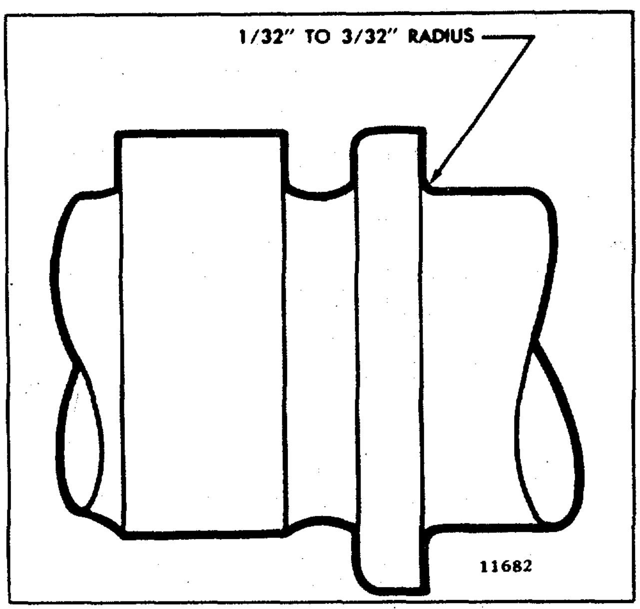


FIG.8 - Camshaft Journal Fillet

Inspection

Soak the camshaft in clean fuel oil. Then run a wire brush through the oil gallery to remove any sludge or foreign material. Clean the exterior of the camshaft and blow out the oil gallery and oil holes with compressed air. Clean the gears, bearings and related parts with fuel oil and dry them with compressed air.

Check the camshaft keyways and threads for damage.

Inspect the cams and journals for wear or scoring. Check the wear on the cam lobes as follows:

NOTE: 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 " as shown in Fig. 7.

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.

If the cam lobes are scored or worn, inspect the cam followers (refer to Section 1.2.1).

Runout at the center bearing, when mounted on the end journals, should not exceed .002 " .

Check the camshaft thrust surface for scoring or wear. The thrust surface may be smoothed with an oil stone if only slightly scratched. If the thrust surface is ground for use of an oversize thrust washer, a radius of 1/32" to 3/32" must be maintained between the thrust collar and the end bearing journal (Fig. 8). Use a fillet radius gage to measure the radius.

After the camshaft is cleaned and inspected, install new end plugs.

The current engines are equipped with low velocity, low lift injector cam lobe and long closing ramp exhaust cam lobe design camshafts. Former engines were equipped with high lift injector cam lobe camshafts. The two types of camshafts are interchangeable and only the current type, identified by the numeral "7" stamped on one end of the shaft, is serviced.

Current 6V and 8V left-hand rotation engines use a right-bank camshaft which has a 9/16" -18 tapped hole in place of the I 1 /8" -18 external thread at the rear end. The right-bank camshaft gear is secured with a 9/166"-18 lock bolt and washer. When replacing a former right-bank camshaft by the current camshaft on these engines, a new 3/4 " x 1/4 " woodruff key and the camshaft gear retaining bolt and washer are required. The current camshaft has no provision for a tachometer drive. If required, it will be necessary to relocate the tachometer drive.

NOTE: If a new service camshaft is to be installed, steam clean it to remove the rust preventive and blow out the oil passages with compressed air.

Examine both faces of each camshaft rear end bearing and thrust washer. Also check the camshaft gear hubs. Replace excessively worn or scored parts. Camshaft gear hubs that are not scored too severely may be smoothed with an oil stone.

New standard size thrust washers are .1 190 " to .1220 " thick. The clearance between the thrust washer and the camshaft thrust shoulder is .004" to .0 12 "with new parts and must not exceed .0 18 8"with used parts. Excessive clearance may be reduced by installing .005 " or .01"0 oversize thrust washers.

Inspect the bushings in the front and rear camshaft end bearings. Replace the bushings if they are worn excessively or have turned in the bearing housing. New bushings must be finish bored to a 20 R.M.S. finish after installation. The bushing must not move when a 2000 pound end load is applied. Also, the inside diameter of the bushings must be square with the rear face of the bearing housing within .00 15" total indicator reading and concentric with the outside diameter of the housing within .002" total indicator reading. The bushings must project .045 " to .055 " from each end of the rear bearing housing. The bushings in the front bearing housing must be flush with the ends of the bushing bore.

The clearance between the camshaft end journals and the camshaft end bearing bushings for 6V and 12V engines is .0025 " to .004 " and for 8V engines is .0035 " to .005 " with new parts or a maximum of .006 " with used parts. Undersize and oversize camshaft end bearings are available for service.

Inspect the spacer used at the front end of the camshaft. The outside diameter of the spacer used in the left-bank front end bearing must provide a smooth oil seal contact surface. The outside diameter is not ground and polished on the original spacer used on the right-bank camshaft in current engines. Only the polished spacer is available for service and may be used in either position.

Replace excessively scored or worn camshaft intermediate bearings. The clearance between the camshaft journals and the intermediate bearings is .0025" to .005 "with new parts or a maximum of .009 " with worn parts. Undersize and oversize camshaft intermediate bearings are available for service. Also examine the intermediate bearing lock screws and the tapped holes in the cylinder block for damaged threads.

Examine the teeth on the water pump drive gear and the camshaft gears for scoring, pitting or wear. Replace the gears, if necessary. Also examine the keyways and tapped holes in the gears and the camshaft pulley for damage.

Inspect the vibration damper, if used, for dents, nicks or bulges in the outer casing of the damper. Replace the damper, if necessary. Regardless of condition, the damper must be replaced at the time of normal overhaul.

Effective with engines 6VA-2909, 8VA-567 and 12VA-458, a front camshaft gear with 66 teeth replaced the former gear which had 92 teeth to correspond with a change in the water pump drive gear (Section 5.1). The former gear was used on the 6V, 8V and 12V engines; an external balance weight was attached to the gear used on the 8V and 12V engines.

The current front camshaft gears on the 6V and 8V engines are identical, except that an external balance weight is attached to the gear used on the 8V engine. The current front camshaft gear used on the 12V engine does not require an external balance weight.

Only the new gears are available for service. Therefore, if it is necessary to replace the former gear, a new water pump drive gear (and new front camshaft gear balance weight on the 8V engine) must also be installed. Tighten the balance weight attaching bolts to 35-39 lb-ft (27-53 Nm) torque.

Effective with engine serial number 8VA-1 15016, a new camshaft front pulley (integral weight) on the left-bank and a new bolt-on balance weight attached to the water pump drive gear are used. Only the current camshaft- front pulley (integral weight) and bolt-on weight for the water pump drive gear are serviced for either the trunk type or the cross-head type piston 8V engines. The current pulley and weight must be used with the cross-head piston engines. The rear camshaft gears are covered in Section 1.7.3.

Assemble Camshaft

Make sure the end plugs have been installed, then refer to Fig. 9 and assemble the camshaft as follows:

1. Apply grease to the steel face of each thrust washer. Then place a thrust washer against each end of the

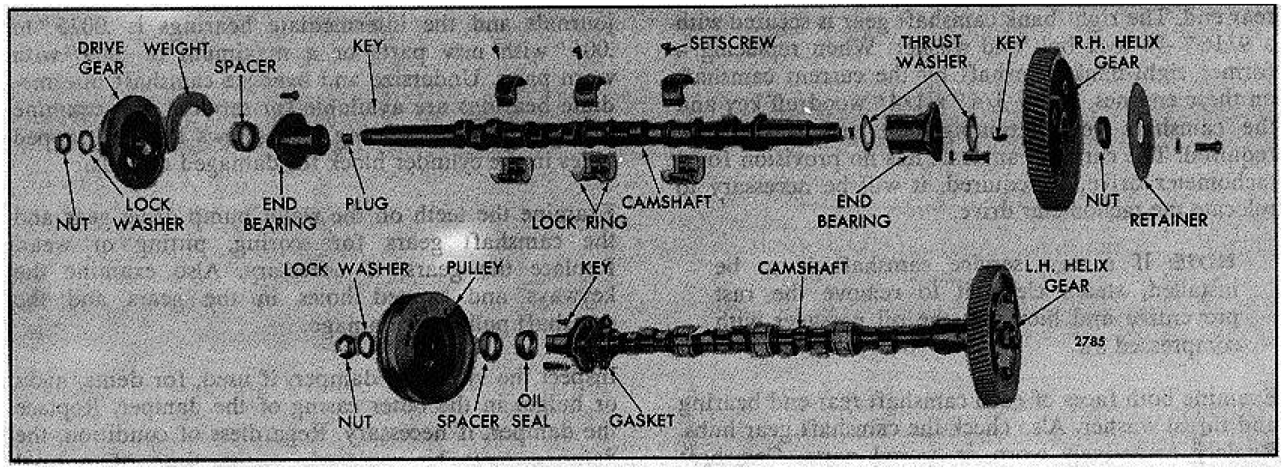


FIG.9 - Camshaft Details and Relative Location of Parts

rear camshaft end bearing. *The steel faces of the washers must face toward the bearing.*

2. Lubricate the rear camshaft bearing journal and slide the rear end bearing on the camshaft, with the bolting flange of the bearing toward the outer (camshaft gear) end of the shaft.

3. Install the camshaft gear as outlined in Section 1.7.3.

4. Lubricate the camshaft intermediate bearing journals. Then place the two halves of each intermediate bearing on a camshaft journal and lock the halves together with two lock rings. Assemble each lock ring with the gap over the upper bearing and the ends an equal distance above the split line of the bearing.

Install Camshafts

1. Refer to Fig. 5 and insert the front end of the camshaft with the right-hand helix gear through the opening on the right-bank side in the rear end plate until the first intermediate bearing enters the bore. Continue to work the camshaft and bearings into the cylinder block until the camshaft gear teeth are about to engage the teeth of the mating gear (if installed). Align the timing marks (Fig. 2, Section 1.7.1) and slide the camshaft in place.

2. Secure the rear end bearing to the cylinder block with three bolts and lock washers. Rotate the camshaft gear as necessary to install the bolts through the hole in the web of the gear (refer to Fig. 4). Tighten the bolts to 35-40 lb-ft (47-54 Nm) torque.

3. Revolve the camshaft intermediate bearing as necessary to align the locking holes in the bearings with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15-20 lb-ft (20-27 Nm) torque.

NOTE: When an intermediate bearing is locked in position, it must have a slight play in the block bore.

4. Install the other camshaft in the same manner.

5. Attach a new gasket to the camshaft front end bearing that includes the oil seal. Lubricate the bearing journal and slide the bearing on the left-bank camshaft, with the bolting flange of the bearing toward the outer end of the shaft. Secure the bearing to the cylinder block with three bolts and lock washers. Tighten the. bolts to 35-40 lb-ft (47-54 Nm) torque.

6. Install the right-bank camshaft front end bearing -- the one without the oil seal. Secure the bearing to the cylinder block with three bolts and lock washers and tighten the bolts to 35-40 lb-ft (47-54 Nm) torque.

7. Select the spacer with the polished outside diameter. Lubricate the spacer and slide it in place on the left-bank camshaft.

8. Install the other spacer on the right-bank camshaft.

9. Install a woodruff key in each camshaft.

10. Install the pulley on the front end of the left-bank camshaft and the water pump drive gear on the right-bank camshaft.

11. Attach the camshaft vibration damper- and adapter (if used) to the water pump drive gear with three bolts, plain washers and lock washers. Tighten the bolts to 30-35 lb-ft (41-47 Nm) torque.

12. Slip an internal tooth lock washer over the front end of each camshaft. Then start the gear and pulley retaining nuts on the camshafts.

NOTE: On current 6V and 8V left-hand rotation engines; a 9/16" -18 lock bolt and washer are used on the right-bank camshaft to secure the camshaft gear. Apply a small quantity of International Compound No. 2, or equivalent, to the threads and underside of the bolt head before installation.

13. Wedge a clean rag between the camshaft gears to prevent their rotation. Then tighten the nut on each end of both camshafts to 300-325 lb-ft (407-441 Nm) torque. Tighten the lock bolt to 180-190 lb-ft (244-258 Nm) torque.

14. Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque. A retainer is not used with the lock bolt.

15. Check the clearance between the thrust washer and the thrust shoulder of each camshaft. The specified clearance is .004" to .012"with new parts or a maximum of .0 1 8" with used parts.

16. Check the backlash between the mating gears. The specified backlash between new gears is .002" to .008" or a maximum of .010" between worn gears.

17. Install the flywheel housing and other parts or sub-assemblies that were removed from the engine.

Install Camshaft (Flywheel Housing and Transmission in Place)

1. Install a woodruff key in the camshaft gear end of the camshaft. Insert this end into position from the front of the engine. Push the shaft in until it slides into the rear end bearing. Use care when installing the camshaft to avoid damage to the cam lobes.

2. Align the key in the shaft with the keyway in the camshaft gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or raw hide) hammer.

NOTE: Be sure the front thrust washer on the rear end bearing is in position.

3. Revolve the camshaft intermediate bearings to align the locking holes in the bearings with the tapped holes in the top of the cylinder block. Install the lock screws and tighten them to 15-20 lb-ft (20-27 Nm) torque.

NOTE: When an intermediate bearing is locked in position, it must have a slight play in the block bore.

4. Remove the camshaft gear puller, spacers and adapter plate. Install the gear retaining nut on the shaft finger tight.

5. Install the front end bearing (using a new gasket and oil seal if the camshaft pulley is to be installed) with three bolts and lock washers. Tighten the bolts to 35-40 lb-ft (47-54 Nm) torque.

6. Install the camshaft pulley or water pump drive gear.

7. Slip an internal tooth lock washer over the front end of the camshaft. Then install the retaining nut finger tight on the front end of the camshaft.

8. With a clean rag wedged between the camshaft gears to prevent their rotation, tighten the nut on each end of the camshaft to 300-325 lb-ft (407-441 Nm) torque.

NOTE: On current 6V and 8V left-hand rotation engines, a 9/16" -18 lock bolt and washer are used on the right-bank camshaft to secure the camshaft gear to the camshaft. Apply a small quantity of International Compound No. 2, or equivalent, to the threads and underside of the bolt head before installation. The lock bolt is tightened to 180-190 lb-ft (244-258 Nm) torque. No gear nut retainer is required.

9. Install the gear nut retainer with bolts and lock washers. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque.

10. Install the accessories and sub-assemblies that were previously removed.

CAMSHAFT GEARS

The camshaft gears (Fig. 1) located at the flywheel end of the engine, mesh with each other and run at the same speed as the crankshaft. Either one of the gears may be driven by the crankshaft timing gear through an idler gear, depending upon engine rotation. Viewing the engine from the gear train end, the right-hand camshaft gear has right-hand helical teeth and the left-hand camshaft gear has left-hand helical teeth. The idler gear mates with the right-hand camshaft gear on right-hand rotation engines and the left-hand camshaft gear on left-hand rotation engines as shown in Fig. 2, Section 1.7.1.

Since the two camshaft gears must be in time with each other, timing marks are stamped on the rim of both gears. Also, since these two gears as a unit must be in time with the crankshaft, timing marks are located on the idler gear and the crankshaft gear.

Each camshaft gear on the right hand rotation engines and the right bank camshaft gear on former 6 and 8V left hand rotation engines are keyed to the shaft and held securely by a nut, nut retainer, retainer bolts and lock washers. On current 6 and 8V left hand rotation engines the right bank camshaft gear is keyed to the shaft and held securely by a lock bolt and washer (Fig. 2).

The camshaft gears used on 6V engines are identical to those used on 8V engines, except that when the gears are used on 8V engines, additional balance weights are attached to the gears. Camshaft gears used on 12V engines are not interchangeable with those used on 6V or 8V engines due to the difference in the size of the integral balance weights.

Effective with engine serial number 8VA-1203, a new balance weight (with drilled bolt holes) replaced the former balance weight (with tapped holes) on the 8V engines, The current weight is attached to the camshaft gear with two 3/8 "-24 flat head screws and nuts in place of the former bolts (Fig. 3).

The current weight must be used with the cross-head pistons. Only the current weight is serviced for either the cross-head or the trunk type pistons for 8V engines.

When cross-head pistons are to be installed in an 8V-71 engine built prior to serial number 8VA-115016, and an in-frame overhaul is desired, a new bolt-on rear balance weight must be used in addition to the existing balance weight attached to the engine side of each rear camshaft gear. For the installation procedure refer to Section 1.0.

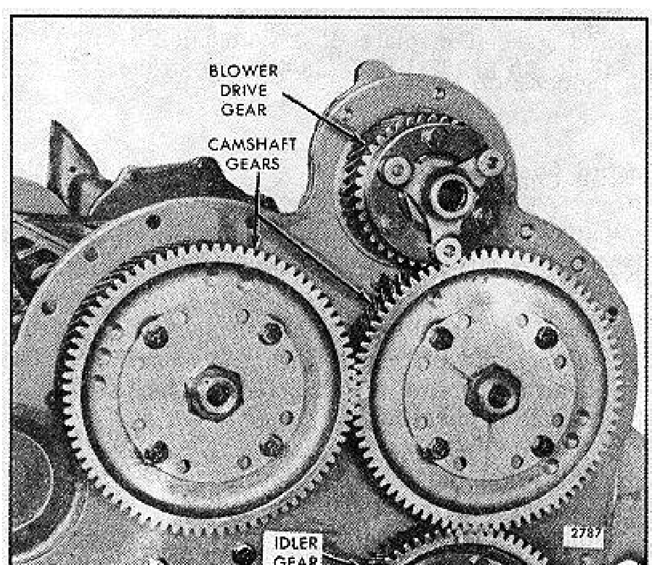


FIG.1 - Camshaft Gears Mounted on Engine

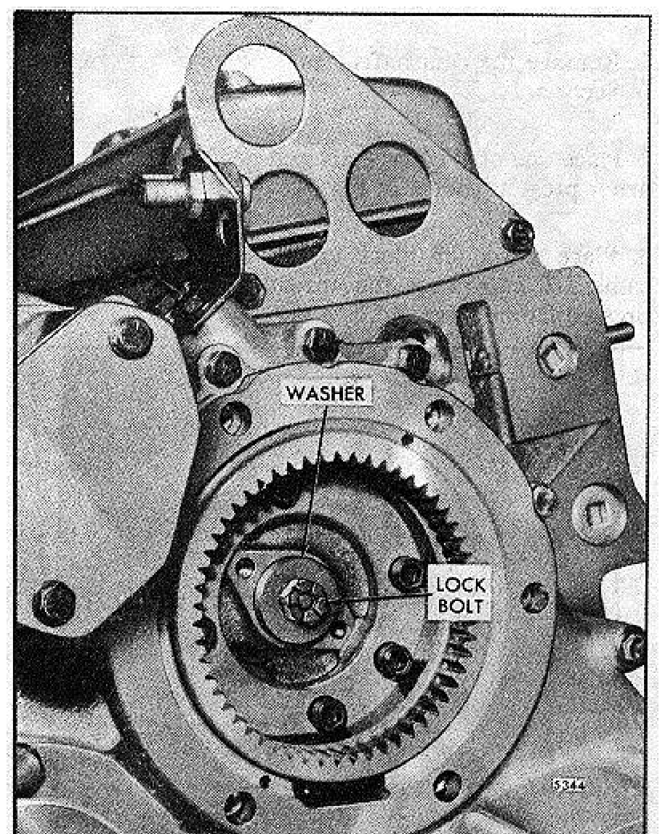


FIG.2 - Left-Hand Rotation (Right bank) Camshaft Gear Mounting

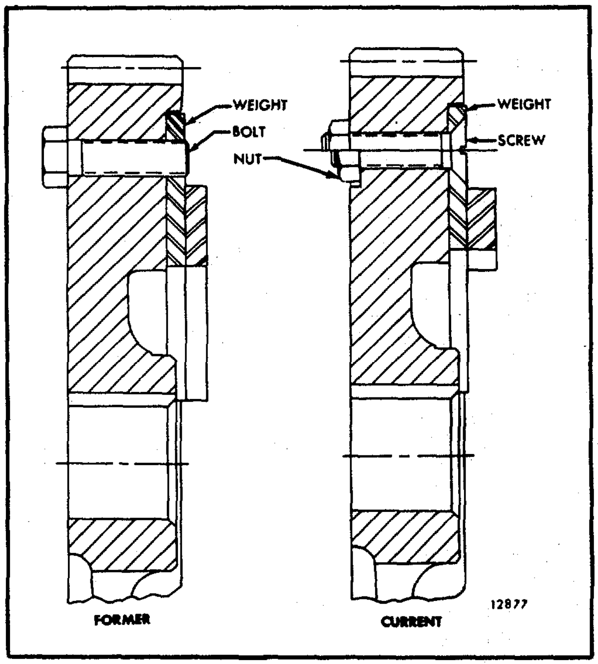


FIG.3 - Camshaft Gear Weights

Remove Camshaft Gears

1. Remove the camshafts from the, engine as outlined in Section 1.7.2.

2. Place one of the camshaft and gear assemblies in an arbor press as shown in Fig. 4.

3. Place a wooden block under the lower end of the camshaft to protect the threads when the shaft is pressed from the gear.

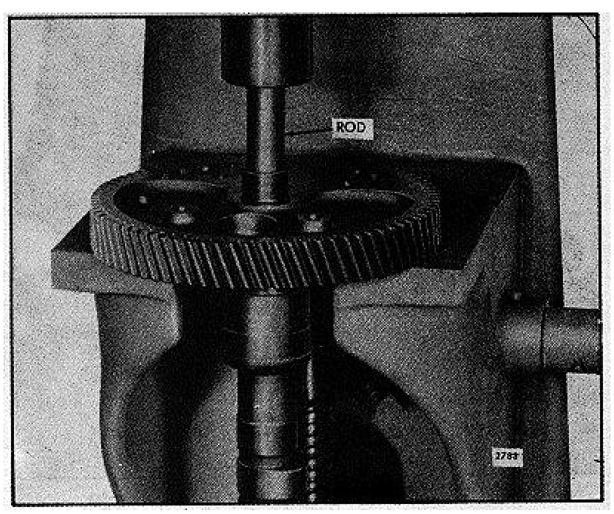


FIG.4 - Removing Camshaft Gear

4. Place a short one-inch diameter brass rod on the end of the camshaft and press the shaft out of the gear.

> **NOTE:** If an arbor press is not available, tool J 1902-01 may be used to remove the gear from the camshaft.

5. If necessary, remove the Woodruff key from the camshaft.

6. Remove the gear from the other camshaft in a similar manner.

Inspection

Clean the gears with fuel oil and dry them with compressed air. Then examine the gear teeth for scoring, pitting or wear. Replace the gears if necessary. Also check the other gears in the gear train.

If new camshaft gears are to be installed on an 8V engine, the old balance weights may be transferred to the new gears for trunk type piston engines only.

If the weights are of the former design (tapped holes), the attaching bolts must be tightened to 15-18 lb-ft (20-24 Nm) torque. However, if the current design weights (drilled holes) (Fig. 3) are used, attach the weights to the gear with flat head screws and self-locking nuts. Tighten the nuts to 25-30 lb-ft (34-41 Nm) torque. Only the current type balance weight is available for service. However, the bolt for attaching the former design weight is also available for service.

> **NOTE:** Where a plain nut is used with the screw, tighten the nut to 18-22 lb-ft (24-30 Nm) torque and stake it in place. If a slotted nut is used, tighten it to 28-32 lb-ft (38-43 Nm) torque.

Install Camshaft Gears

1. If previously removed, install the camshaft rear end bearing and thrust washers on the camshaft as follows:

   a. Apply grease to the steel face of each thrust washer and place one washer at each end of the bearing. Be sure the steel face of each washer is next to the bearing.

   b. Lubricate the bearing journal and slide the bearing and thrust washers on the camshaft, with the bolting flange of the bearing toward the outer (gear) end of the shaft.

2. Install a Woodruff key in the camshaft.

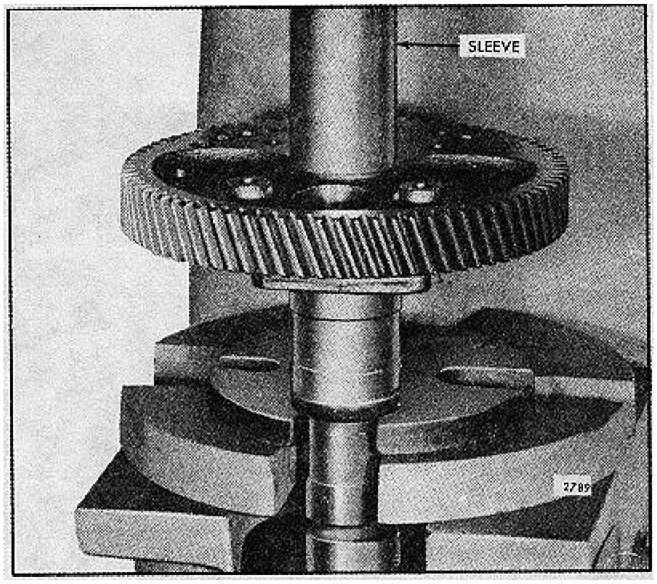


FIG. 5 - Installing Camshaft Gear

3. Start the gear over the end of the camshaft, with the key in the shaft aligned with the keyway in the gear.

4. Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and press the gear tight against the shoulder on the shaft (Fig. 5).

NOTE: If an arbor press is not available, use. tool J 1903 to install the gear on the camshaft.

5. On all right hand rotation engines and former left hand rotation engines thread the camshaft gear retaining nut on the camshaft. Tighten the nut after the camshaft is installed in the engine.

6. On the current left hand rotation engines install the 9/16 "-18 lock bolt and washer and tighten to 180-190 lb-ft (244-258 Nm) torque after the camshaft is installed in the engine.

7. Install the gear on the other camshaft in a similar manner.

8. Install the camshaft and gear assemblies in the engine as outlined in Section 1.7.2.

IDLER GEAR AND BEARING ASSEMBLY

The idler gear is mounted on a double row, tapered roller bearing, which in turn is supported on a stationary hub (Fig. 1). This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate. A dowel in the hub correctly positions the hub and prevents it from rotating.

The current idler gear bearing consists of two cups, two cones and an outer and inner spacer ring. The former idler gear bearing consists of a cup, two cones and a spacer ring.

The idler gear bearing cup(s) is a light press fit in the gear and is held in place by a retainer which is secured by six bolts. The bearing cones are pressed onto the gear hub and do not rotate. The spacer(s) separates the bearing cones.

The idler gear is pressure lubricated by oil from the cylinder block rear cross oil gallery. Oil enters an opening between the cylinder block and the idler gear hub and circulates around the idler gear hub bolt which has a smaller outside diameter than the inside diameter of the gear hub bolt hole. The oil is forced through a drilled passage in the gear hub to the roller bearing.

A left-hand helix gear is provided for right-hand rotation engines, and a right-hand helix gear is provided for left-hand rotation engines.

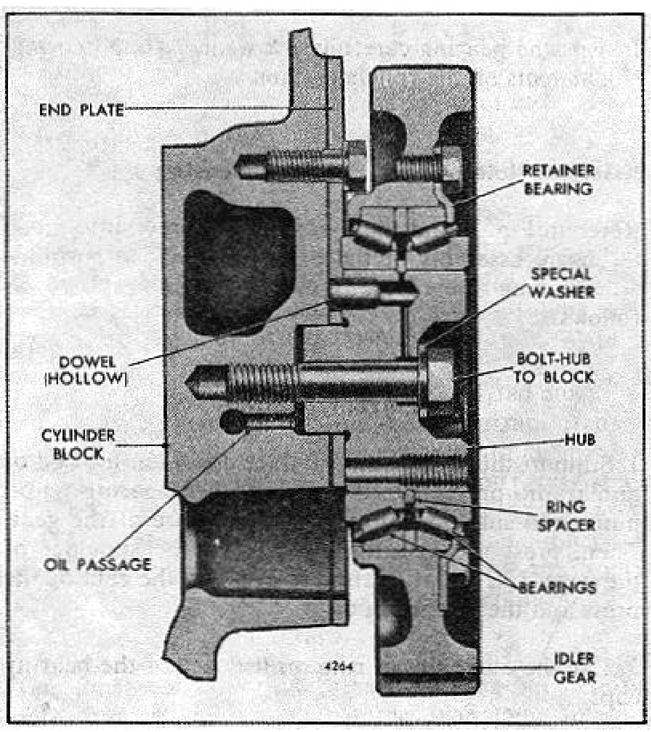


FIG. 1 Idler Gear Mounting

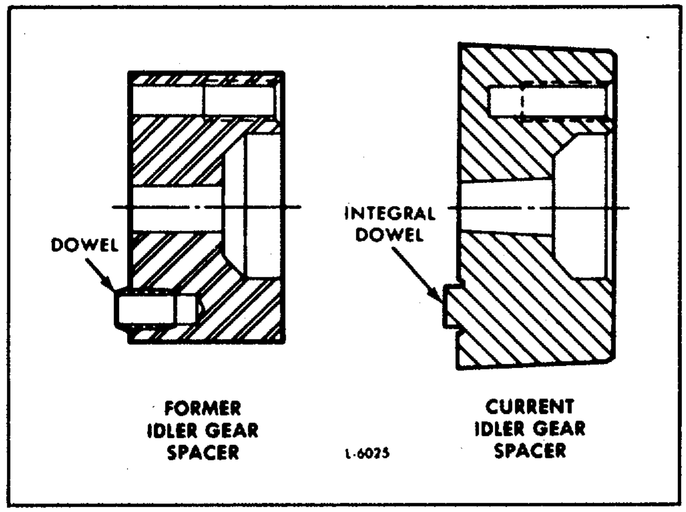


FIG. 2 Idler Gear Spacer

An idler gear hole spacer (dummy hub) is used on the side opposite the idler gear (Fig. 9).

> **NOTE:** On certain flywheel housings, the idler gear hole spacer is cast integrally in the housing, opposite the idler gear. As a result of this integral cast design, a shim must be installed between the flywheel housing and the cylinder block end plate. Use grease to hold the

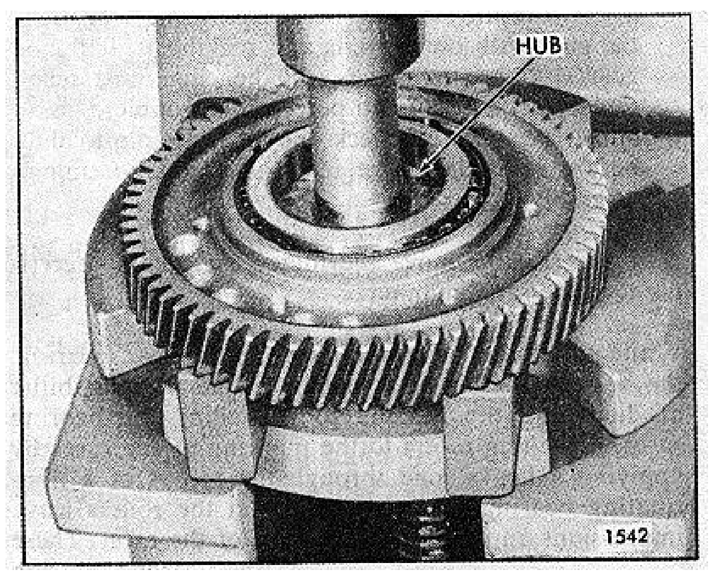


FIG. 3 Pressing Hub Out of Idler Gear Bearing

shim on the spacer during installation of the flywheel housing.

To minimize oil leakage into the flywheel housing, a new idler gear spacer (dummy hub) is now being used in those engines not equipped with an integral idler gear spacer type flywheel housing (Fig. 2).

The former and new spacers are interchangeable. Only the new spacer will be serviced. The new flanged hex head bolts with a self locking sealing patch should be used with the new spacer. They can be used with the former spacer or at the idler gear position, however, do not use a flat washer under the new flanged head bolts.

SERVICE NOTE: The service idler gear assemblies will not include the new "seal patch" bolts. The flat washer has been deleted. Also, at the time of rebuild the new bolts should be used to minimize oil leakage into the flywheel housing.

NOTE: Whenever the sealant patch bolts are removed they should be replaced with new sealant patch bolts at both the idler gear spacer and idler gear positions.

Remove and Disassemble Idler Gear, Hub and Bearing Assembly (Flywheel Housing Removed)

1. Remove the bolt and special washer which secure the idler gear hub to the cylinder block. Then, remove the gear, hub and bearing assembly from the engine.

NOTE: Before removing the idler gear assembly, check the bearing by grasping the rim of the gear with both hands and rocking it. If the gear wobbles or shakes, the bearing must be replaced. If there is no perceptible wobble, it is only necessary to check the bearing pre-load before reinstalling the idler gear and bearing assembly.

2. If necessary, remove the idler gear hole spacer (if used) in the same manner. While removing or installing an idler gear bearing, the bearing MUST be rotated to avoid the possibility of damaging the bearing by brinelling the bearing races. Brinelling refers to the marking of the races by applying a heavy load through the rollers of a non-rotating bearing in such a way that the rollers leave impressions on the contact surfaces of the races. These impressions may not be easily discerned during normal inspection. For example, a bearing may be brinelled if a load were applied to the inner race of the bearing assembly in order to force the outer race into the idler gear bore, thus transmitting the force through the bearing rollers. A brinelled bearing may have a very short life.

3. `Remove the six bolts and three bolt locks, which secure the bearing retainer to the idler gear, and remove the bearing retainer.

NOTE: The component parts of the idler gear bearing are matched; therefore, matchmark the parts during disassembly to ensure reassembly of the parts in their original positions.

4. Place the idler gear assembly in an arbor press, with the inner bearing cone supported on steel blocks as shown in Fig. 3. While rotating the idler gear to prevent brinelling of the bearing, press the hub out of the bearing.

5. Use a brass drift alternately at the four notches provided in the shoulder of the gear to tap the bearing cup(s) from the idler gear.

Inspection

Wash all of the parts thoroughly in clean fuel oil and dry them with compressed air.

Examine the gear teeth for evidence of scoring, pitting, or wear. Also, examine the idler gear hub for wear or damage. '

Inspect the bearing carefully for wear, pitting, scoring, or flat spots on the rollers or cups.

Assemble Idler Gear, Hub and Bearing

Refer to Fig. 4 and the match marks previously made to ensure assembly of the parts in the same positions from which they were removed. Then, proceed as follows:

Current Bearing

1. Support the idler gear, shoulder down, on the bed of an arbor press. Start one of the bearing cups, numbered side up, squarely into the bore of the gear. Then, press the bearing cup against the shoulder of the gear. Use a flat steel plate between the ram of the press and the bearing cup.

2. Lay the outer spacer ring on the face of the bearing cup.

3. Start the other bearing cup numbered side down, squarely into the bore of the gear. Then, press the cup

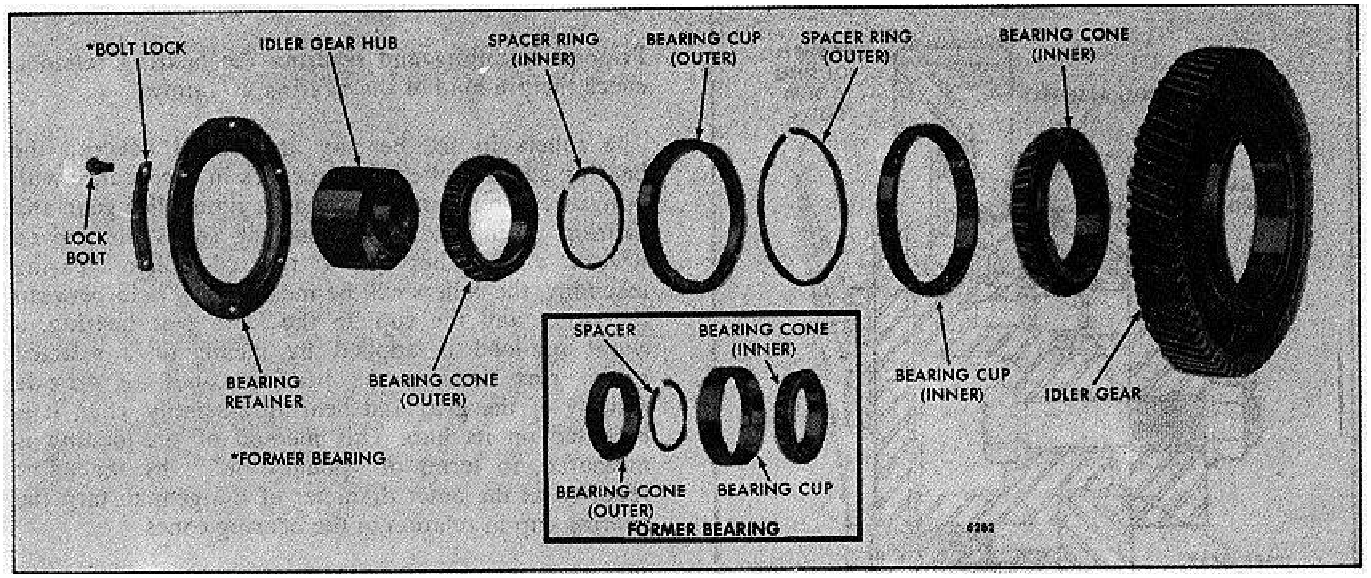


FIG. 4. - Idler Gear Details and Relative Location of Parts (Current Bearing)

tight against the spacer ring. Use a flat steel plate between the ram of the press and the bearing cup.

4. Press the inner bearing cone on to the idler gear hub, flush with the inner hub mounting face.

5. Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180° from the gap in the inner spacer ring.

6. Position the gear with both cups over the hub and inner bearing cone.

7. Press the outer idler gear bearing cone over the hub, while rotating the gear to seat the rollers properly between the cones.

NOTE: The bearing cones must be supported so as not to load the bearing rollers during this operation.

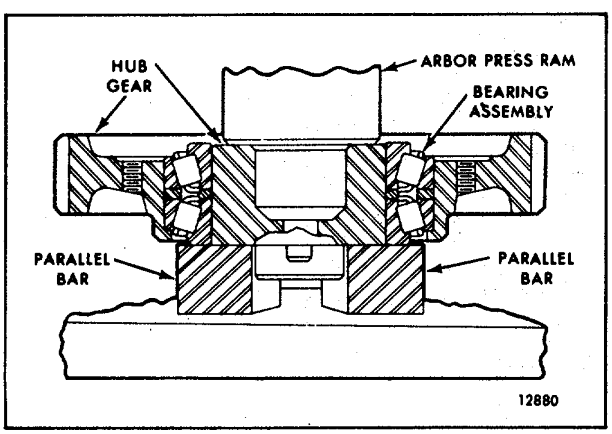


FIG. 5 - Pressing Hub into Idler Gear Bearing

Former Bearing

1. Support the idler gear, with the shoulder in the bearing bore down, in an arbor press. Place the bearing cup in position on the gear and press it tight against the shoulder in the gear, using a suitable steel plate between the bearing cup and the ram of the arbor press.

2. Support one bearing cone, numbered side down, on the bed of the arbor press (Fig. 5). Then place the idler gear and bearing cup assembly over the bearing cone.

3. Place the spacer ring on the bearing cone.

4. Place the second bearing cone, numbered side up, in the idler gear and bearing cup assembly and against the spacer ring.

5. Then, position the idler gear hub over the bearing cones so that the oil hole in the hub is 1800 from the gap in the spacer ring.

6. While rotating the gear to seat the rollers properly between the cones, press the hub into the bearing cones until the face of the hub which will be adjacent to the cylinder block end plate is flush with the face of the inner bearing cone.

NOTE: The bearing cones must be supported so as not to load the bearing rollers during this operation.

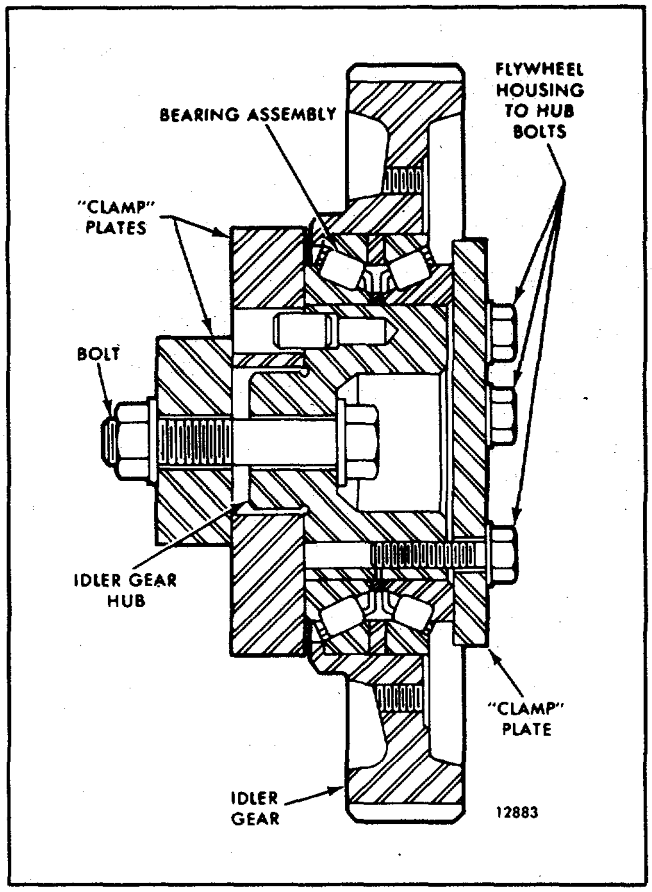


FIG. 6 - Fixture for Testing Bearing Pre-Load

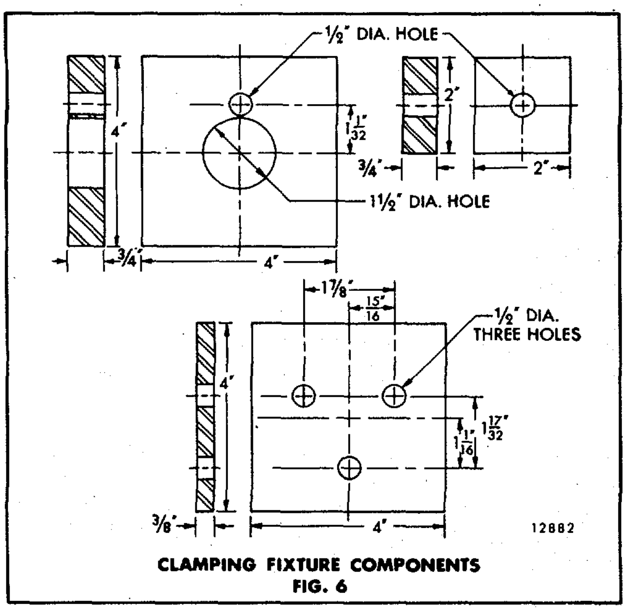


FIG. 7 - Plates for Bearing Test Fixture

Check Idler Gear Bearing Pre-Load

Prior to installing and securing the bearing retainer, check the pre-load of the bearing assembly.

The rollers in the bearing are loaded between the bearing cup 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 cup. In the idler gear bearing, a slight pre-load is applied 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 cup in relation to the bearing cones.

Check the bearing pre-load whenever the idler gear assembly is removed from the engine for service or for an engine overhaul.

The idler gear bearing 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.

If the crankshaft and camshaft gears are not mounted on the engine, the torque required to rotate the idler gear may be checked by mounting the idler gear in position on the engine, using a 4" square, 3/8" thick steel plate against the hub and cone as outlined below.

1. Mount the idler gear assembly on the engine.

2. Install the idler gear hub retaining bolt and washer and tighten the bolt to 80-90 lb-ft (108-122 Nm) torque.

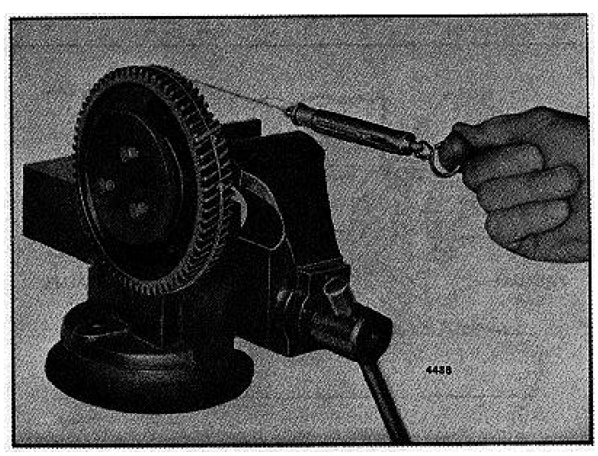


FIG. 8 - Checking idler Gear Bearing Pre-Load

3. Place the steel plate (lower plate shown in Fig. 7) against the hub and bearing. Insert three 3/8"-16 bolts through the plate and thread them into the hub. Tighten the bolts to 25-40 lb-ft (34-54 Nm) torque.

4. Tie one end of a piece of lintless 1/8" cord around a 1/8" round 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 as shown in Fig. 8. Attach the other end of the cord to a 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 1/2 lb. minimum to 4 lbs. maximum, and does not fluctuate more than 2 lbs. 11 oz., the idler gear and bearing assembly is satisfactory for use.

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture, which may be held in a vise, can be made as shown in Fig. 6. Three plates, a 1/2"-13 x 2-3/4" bolt, 1/2"-13 nut, and two 1/2" plain washers are required. The plates are made from steel stock as shown in Fig. 7. Check the pre-load on the bearings as follows:

1. Attach two of the steel plates (two upper plates shown in Fig. 7) to the idler gear hub with the 1/2"-13 bolt, washers, and nut as shown in Fig. 6. Tighten the bolt to 80-90 lb-ft (108-122 Nm) torque.

2. Attach the third plate to the idler gear hub with three 3/8"-16 bolts. Tighten the bolts to 25-40 lb-ft (34-54 Nm) torque.

3. Clamp the idler gear assembly and fixture in a vise (Fig. 8).

4. Attach a cord to the idler gear and spring scale and check the bearing pre-load as outlined in item 4 above.

If the scale reading is within the specified 1/2 to 4 lbs. specified, but fluctuates more than 2 lbs. 11l ounces, the idler gear and bearing assembly must *not* be installed on the engine. Fluctuations in scale reading may be caused by the races not being concentric to each other, damaged races or rollers, or dirt or foreign material within the bearings. In these cases, the bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed. A scale reading which exceeds the specified maximum indicates binding of the bearing rollers, or rollers improperly installed. When the scale reading is less than the specified minimum, the bearing is more likely worn and the bearing should be replaced.

After the pre-load check is completed, remove the steel plates and install the bearing retainer as follows.

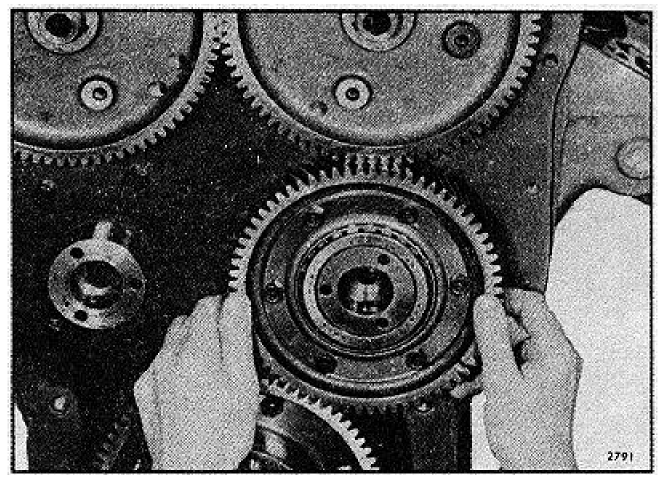


FIG. 9 - Installing Idler Gear, Hub and Bearing Assembly

1. Attach the bearing retainer to the idler gear with six bolts and three bolt locks. Tighten the bolts to 24-29 lb-ft (33-39 Nm) torque.

> **NOTE:** The current lock bolts are coated with a locking compound. *Do not use standard bolts.* With use of the lock bolts, the former bolt locks are no longer required and will not be serviced.

2. Bend the ears of each bolt lock against the flat side of the attaching bolt heads to secure the bolts.

Install Idler Gear, Hub, and Bearing Assembly

1. Position the crankshaft gear and camshaft gear so the timing marks will align with those on the idler gear (see Figs. 2 and 3 in Section 1.7.2).

2. With the timing marks in alignment, start the idler gear in mesh with the crankshaft gear and camshaft gear, and simultaneously rotate the gear so the pin in the hub registers with the hole in the end plate (Fig. 9).

3. Roll the idler gear into position and align the hollow pin with the hole in the end plate. Then, gently tap the hub until it seats against the end plate.

4. After making sure the hub is tight against the end plate, secure the idler gear assembly with the 1/2"-13 bolt and special washer. Tighten the bolt to 80-90 lb-ft (108-122 Nm) torque.

5. If previously removed, install the idler gear hole spacer (dummy hub - Fig. 8). Secure the spacer to the cylinder block with a 1/2"-13 bolt and special washer. Tighten the bolt to 80-90 lb-ft (108-122 Nm) torque.

> **NOTE:** Current V-71 engines use a new idler

gear hub and idler gear hole spacer (dummy hub) which require 1/2"-13 x 2-1/2" retaining bolts, replacing the 1/2"-13 x 2" bolts formerly used.

6. Lubricate the idler gear bearing and gear teeth liberally with clean engine oil.

7. Check the backlash between the mating gears. The backlash must be .002" to .008" between new gears and must not exceed .010" between worn gears.

8. Install the flywheel housing as outlined in Section 1.5.

CRANKSHAFT TIMING GEAR

6, 8 and 12V Engines

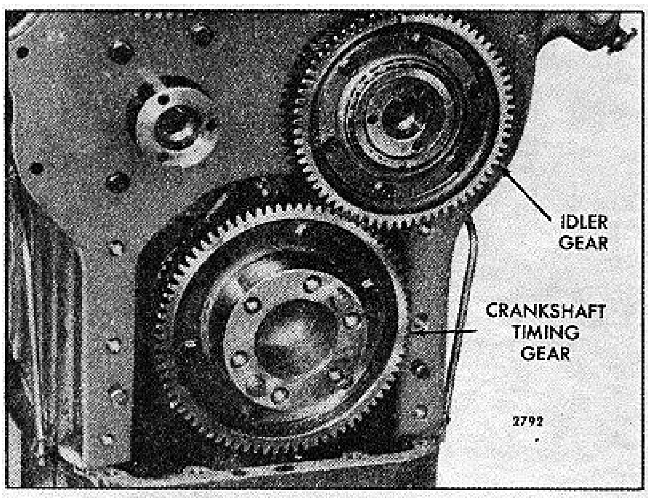


FIG. 1 - Crankshaft Timing Gear Mounting (R.H. Rotation Engine Shown)

The crankshaft timing gear (Fig. 1) is bolted to the flange at the rear end of the crankshaft and drives the camshaft gears, as well as the blower drive gear, through an idler gear. On certain 12V engines, the lubricating oil pump drive gear is attached to the crankshaft timing gear.

Since the two 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 Timing Gear (Flywheel Housing Removed)

The crankshaft gear is a press fit on the crankshaft. Remove the gear as follows:

1. 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.

2. 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.

3. Remove the six bolts which secure the gear to the crankshaft.

4. Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft. Then remove the gear with a gear puller.

Inspection

Clean the gear with fuel oil and dry it with compressed air. Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also check the other gears in the gear train.

Install Crankshaft Timing Gear

1. Position the gear (and the lubricating oil pump drive gear, if used) on the rear end of the crankshaft with the bolt holes in the gear aligned with the tapped holes in the crankshaft. One bolt hole is offset so the gear can be attached in only one position.

2. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).

> **NOTE:** When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

3. Start the six 3/8" -24 bolts through the gear and into the crankshaft. Then draw the gear tight against the shoulder on the crankshaft. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque.

4. Check the backlash with the mating gear. The backlash should be .002" to .008 " with new gears or .010" maximum with used gears.

5. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

The blower drive gear is mounted on the blower drive gear support which is attached to the cylinder block rear end plate (Fig. 1). This gear is driven at approximately twice engine speed by the right cylinder bank camshaft gear (see Table 1).

Engine	Ratio Blower to Engine Speed	No. Teeth in Blower Drive Gear
6, 8, 12 and 16V except	2.05:1	38

Table 1

Two blower drive gear and support assemblies are used on 16V engines. Since the blower drive gear and support assembly on the front of the engine incorporates a right-hand helix gear and the blower drive gear and support assembly on the rear of the engine incorporates a left-hand helix gear, they are not completely interchangeable.

The blower drive gear bearings are pressure lubricated through an external line from the blower rear end plate to the blower drive support.

The blower(s) must be removed prior to removal of the blower drive gear and support assembly.

Remove Blower Drive Gear and Support Assembly (Flywheel Housing Removed)

1. Remove blower(s) and blower drive support lubrication tube as outlined in Section 3.4 or 3.4.1.

2. Remove the two blower drive support-to-cylinder block rear end plate attaching bolts and copper washers. Then tap the assembly away from the end plate, using care not to damage the gear teeth.

3. Remove the gasket.

Disassemble Blower Drive Gear and Support Assembly

For the location and identification of the parts, refer to Fig. 2 and proceed as follows:

1. Clamp the blower drive gear support in the soft jaws of a bench vise.

2. Remove the three bolts securing the drive gear hub and flex plates to the blower drive gear.

Then, remove the two flex plates and blower drive shaft hub as an assembly from the gear. If necessary, the flex plates may be removed from the hub.

New blower drive shaft flex plates, washer head type lockpatch bolts and hub spacers are now being used on engines that incorporate the large bearing -blower. Thin hub spacers are used opposite the bolt side of the new tumbled flex plates for the front drive hub and rear turbo drive hub. The thin hub spacers have been added to protect the tumbled flex plates Only the new flex plates, bolts and thin hub spacers should be used to service V-71 engines with large bearing blowers.

> **NOTE:** The thin hub spacers are not readily accessible and some mechanics may not be aware that they are behind the flex plate. Consequently, when working on the blower hub assemblies, remove the flex plate attaching bolts carefully to avoid dropping the thin hub spacers into the gear train. If spacers are inadvertently dropped into the gear train,

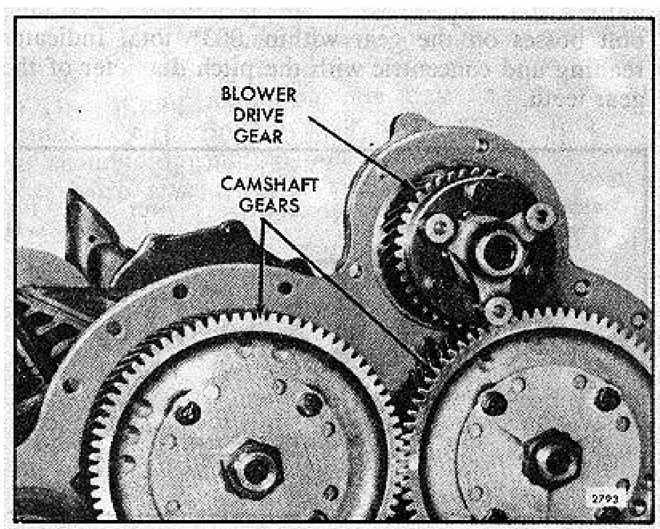


FIG. 1 - Blower Drive Gear Mounting

removal of the engine flywheel housing and/or oil pan may be required to retrieve them.

At time of rebuild or whenever the flex plates are removed, new washer head type lock patch bolts must be used. Do not attempt to reuse patch bolts.

3. Straighten the lugs on the lock washer and remove the blower drive gear thrust washer and bearing retaining nut.

4. Withdraw the lock washer, thrust washer, thrust bearings and gear from the support.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air. Make sure the oil passage in the blower drive gear support is clean. Sludge accumulations, which might restrict the oil flow, must be removed.

Replace the thrust bearings and thrust washer if they are worn excessively or scored.

Check the inside diameter of the blower drive gear bearings (bushing type and the outside diameter of the hub on the drive gear support. The clearance between the bearings and the support hub is .001" to .0025” with new parts. Replace the parts when the clearance exceeds .005” on used parts.

If new bearings are installed, the outer end of each bearing must be pressed in flush to .010" below the face of the gear. The bearings must be reamed to size (1.6260" to 1.6265" inside diameter) and to a finish of 20 microinches after installation. The bearing bores must also be square with the machined faces of the bolt bosses on the gear within .003" total indicator reading and concentric with the pitch diameter of the gear teeth.

The thrust washer retaining pin must extend approximately .080” above the threaded end of the hub.

Examine the blower drive gear teeth for scoring, pitting, or wear. If necessary, install a new gear assembly. A service replacement gear includes the bearings.

Check the serrations in the blower drive shaft hub for wear or other damage. Replace the hub, if necessary.

Assemble Blower Drive Gear and Support Assembly

For the relative location of the parts refer to Fig. 2 and assemble them as follows:

1. Clamp the blower drive support in a vise equipped with soft jaws. Then, install one of the blower drive gear thrust bearings so the tangs on the bearing register with the holes in the support.

2. Lubricate the hub of the support, the bearings in the gear, both thrust bearings and the thrust washer with clean engine oil.

3. Slide the gear on the hub, with the flat side of the gear toward the support.

4. Install the second thrust bearing on the support, with the tangs on the bearing facing away from the gear.

5. Install the thrust washer so the slots in the washer register with the tangs on the thrust bearing, and the pin in the blower drive gear support hub registers with the slot in the bore of the washer.

6. Secure the gear, thrust bearings and thrust washer with a lock washer and nut. Tighten the nut to 50-60

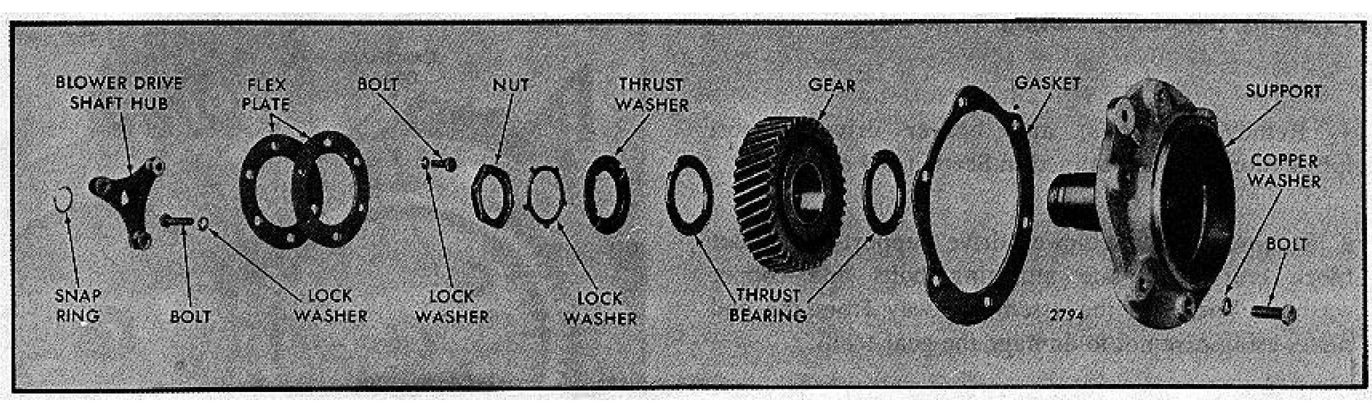


FIG. 2 - Blower Drive Gear and Support Assembly Details and Relative Location of warts

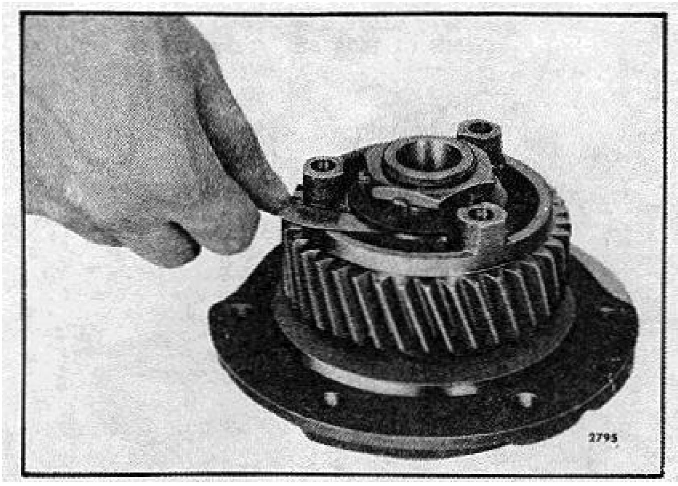


FIG. 3 - Checking Clearance Between Blower Drive Gear Support Thrust Washer and Blower Drive Gear Thrust Bearing

lb-ft (68-81 Nm) torque and bend the lugs on the lock washer against the flats on the nut.

7. Check the clearance between the blower drive gear thrust washer and thrust bearing as shown in Fig. 3. This clearance is .005”, to .010" with new parts and must not exceed .012" with used parts.

8. If the flex plates were removed, attach them to the blower drive shaft hub with three bolts and lock washers. The new drive shaft flex patches use a washer head type lock plate bolt and hub spacers. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque.

9. Attach the flex plates and hub to the blower drive gear with three bolts and lock washers. Tighten the bolts to 35-39 lb-ft (47-53 Nm) torque.

Install Blower Drive Gear and Support Assembly

1. Affix a new gasket to the blower drive gear support. Then attach the gear and support assembly to the cylinder block rear end plate with two bolts and copper washers. Tighten the bolts to 25-30 lb-ft (34-47 Nm) torque.

2. Install the flywheel housing as outlined in Section 1.5.

3. Check the backlash between the blower drive gear and the camshaft gear. All of the flywheel housing attaching bolts must first be tightened to the proper torque. The backlash must be between .002" and .008" with new gears and must not exceed .010" with worn gears.

4. Remove the four flywheel housing-to-blower drive support bolts and install the blower(s) and blower drive lubrication tube as outlined in Section 3.4 or 3.4.1. Then, reinstall the flywheel housing bolts.

ACCESSORY DRIVE

Position	Drive Ratio
1	1:1
2	1:1
*3	1.95:1, 2:1 or 2.05:1
4	2.05:1
5	Not a drive position

*Depends upon engine application

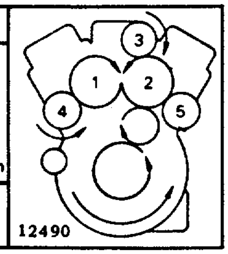


FIG. 1 - Accessory Drive Locations

Accessories such as an air compressor, hydraulic pump or battery-charging generator may be direct-driven or belt-driven from various locations on the engine.

For the possible accessory drive location and rotation of the drive at a particular position, refer to Fig. 1.

At the front of the engine, the left-bank camshaft pulley (Fig. 2) and the crankshaft pulley may be used to drive accessories. On certain applications, an accessory drive pulley (Fig. 2), which mounts on a shaft attached to the water pump drive gear, provides a drive for a high mounted battery-charging generator.

Accessories may also be driven by the blower drive gear, left-bank accessory drive gear, or either camshaft gear at the rear of the engine.

FRONT ACCESSORY DRIVE

The front accessory drive (Fig. 2) consists of a short drive shaft, which is bolted to the water pump drive gear, and a single groove pulley keyed to the shaft and secured with a bolt, lock washer and plain washer. An oil seal, pressed in the balance weight cover, prevents oil from seeping out where the shaft extends through the cover.

NOTE: Effective with 8VA370083 the engine front camshaft (drive) gear and the water pump (driven) gear are nitride hardened. The new gears can be identified by the letter "H" stamped on the gears. Also the helix angle of the gear teeth *have been reversed.* For interchangeability refer to Section 5.1.

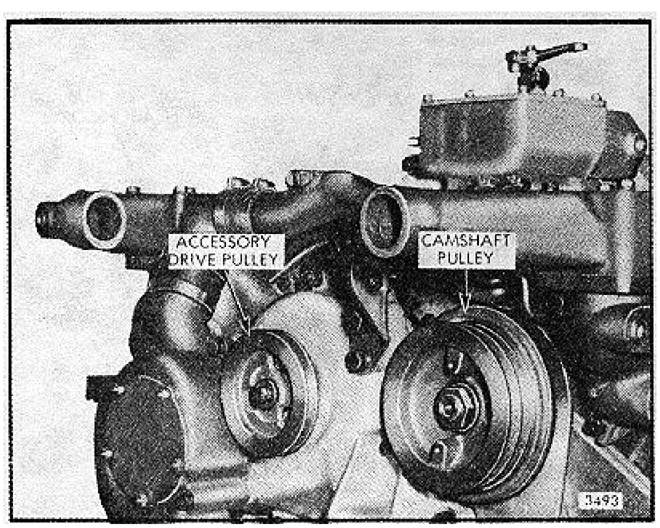


FIG. 2 - Front Mounted Accessory Drive Pulleys

Remove Front Accessory Drive

1. Loosen the generator adjusting strap and generator mounting bolts and remove the drive belt.

2. Remove any accessories necessary to provide access to the accessory drive pulley.

3. Remove the water pump (refer to Section 5. 1).

4. Remove the pulley retaining bolt, lock washer and plain washer. Then remove the pulley and the-key.

5. Remove the balance weight cover (refer to Section 1.7.8).

6. Replace the oil seal in the balance weight cover, if necessary.

7. Remove the three bolts and lock washers and withdraw the drive shaft from the water pump drive gear.

Install Front Accessory Drive

1. Attach the accessory drive shaft to the water pump drive gear with three 5/16 " -24 x 7/8 " bolts and lock washers. Tighten the bolts to 15-19 Ib-ft (20-26 Nm) torque.

2. Install the balance weight cover as outlined in Section 1.7.8.

3. Install the key in the shaft. Then install the pulley on the shaft and secure it in place with a 3/8" -16 x

7/8" bolt, lock washer and plain washer. Tighten the bolt to 25 lb-ft (34 Nm) torque.

4. Install the water pump as outlined in Section 5.1.

5. Install any accessories which were removed to provide access to the accessory drive pulley.

6. Install the drive belt and adjust the generator to provide the proper tension on the belt. Then tighten the generator adjusting strap bolt and generator mounting bolts.

NOTE: Be sure to tighten the bolt at the accessory adjusting pivot point as well as the bolt in the adjusting strap slot.

REAR ACCESSORY DRIVE (Camshaft Driven)

The camshaft driven accessory drive consists of a steel or fibre drive plate bolted to either one of the camshaft gears. On certain applications, a steel spacer is used between the steel drive plate and the camshaft gear.

A direct-driven accessory is flange-mounted on the flywheel housing and is driven by a coupling which is splined to both the accessory drive plate and a drive hub on the accessory shaft (Fig. 3).

For a belt-driven accessory, a drive shaft is used in place of the drive coupling. One end of the drive shaft is splined to the drive plate and the other end is supported by a bearing in the accessory drive retainer which is attached to the flywheel housing (Fig. 4). A drive pulley, attached to the outer end of the drive shaft, is connected by belts to the pulley on the accessory which is mounted above the flywheel housing.

On some engines, an accessory drive hub is bolted directly to the camshaft gear (Fig. 5). An oil seal retainer is bolted to the flywheel housing and the pulley is keyed and secured to the hub with a bolt, lock washer and plain washer.

On some coach engines, a step-up gear is attached to the right-bank camshaft gear with six Allen head bolts and lock washers to drive the battery-charging alternator (Fig. 6). The alternator mounting adaptor is attached to the flywheel housing. Two set screws are used to adjust and hold a clearance (maximum .002" runout) between the outer flange of the step-up gear and the alternator adaptor.

Remove Accessory Drive

Refer to Fig. 3 and remove the accessory drive 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

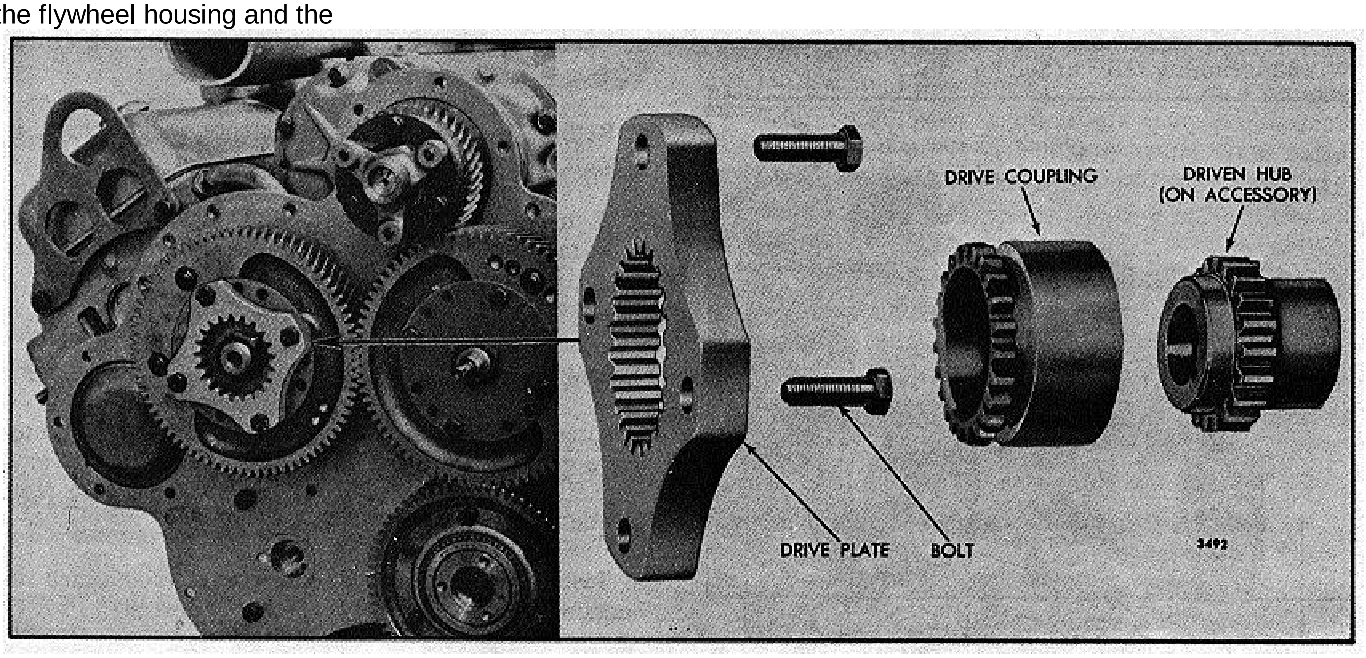


FIG. 3 - Components of Accessory Drive for Direct-Driven Accessories

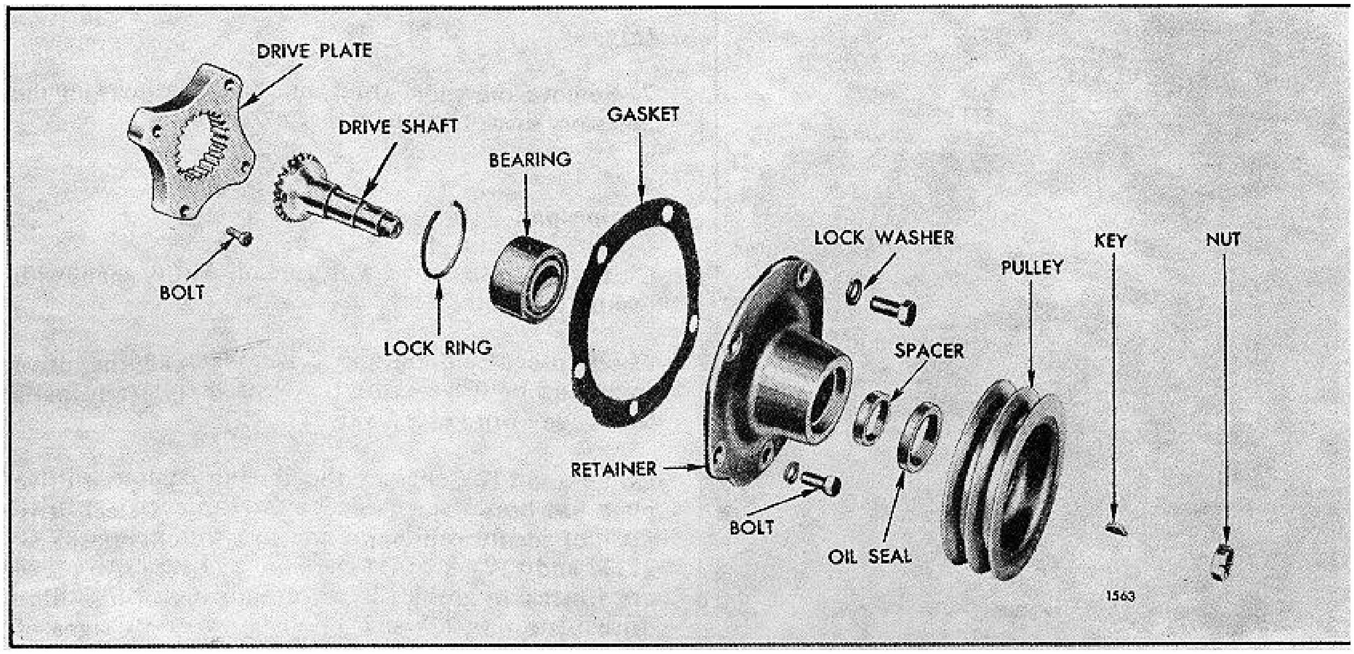


FIG. 4 - Components of Accessory Drive for Belt-Driven Accessory (Drive Plate Type)

straight out from the flywheel housing. Remove the gasket.

3. Remove the drive coupling.

4. Place a clean, lintless 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 shoulder bolts (and lock washers, if used) and withdraw the accessory drive plate (and spacer, if used).

Refer to Figs. 4 and 5 and remove the accessory drive used with a belt-driven accessory as follows:

1. Loosen the accessory mounting or adjusting bolts and remove the drive belts.

2. Remove the nut (or bolt, lock washer and plain washer) which retains the drive pulley on the accessory drive shaft.

3. Use a suitable gear puller and withdraw the pulley from the shaft. Remove the key from the shaft.

4. Remove the bolts and washers and withdraw the accessory drive retainer assembly from the flywheel housing. Remove the gasket.

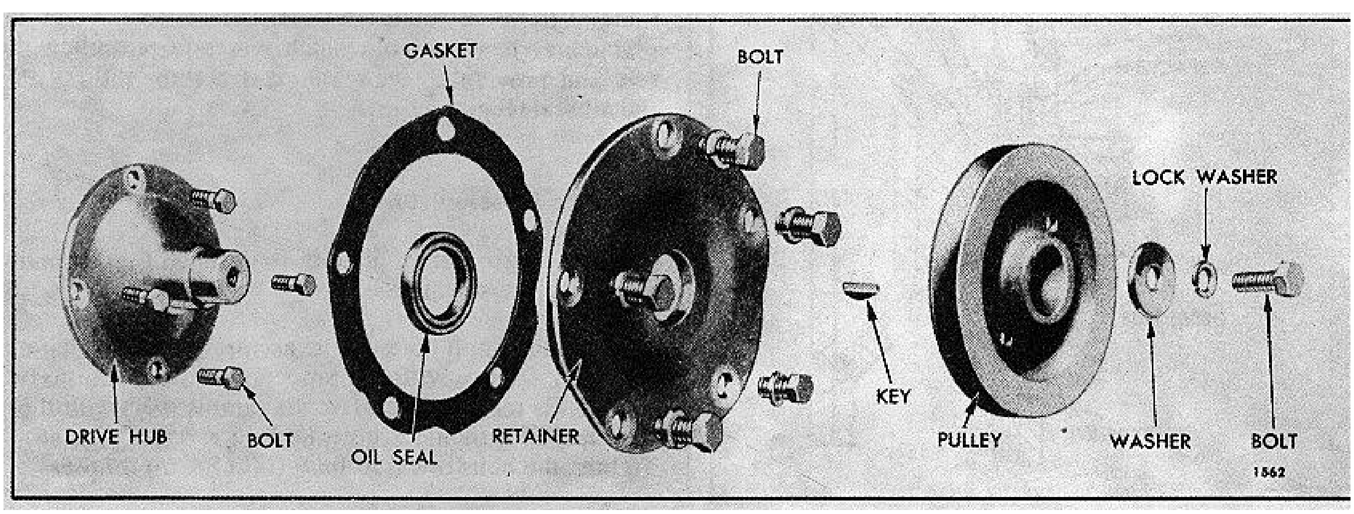


FIG.. 5 - Components of Accessory Drive for Belt-Driven Accessory (Drive Hub Type)

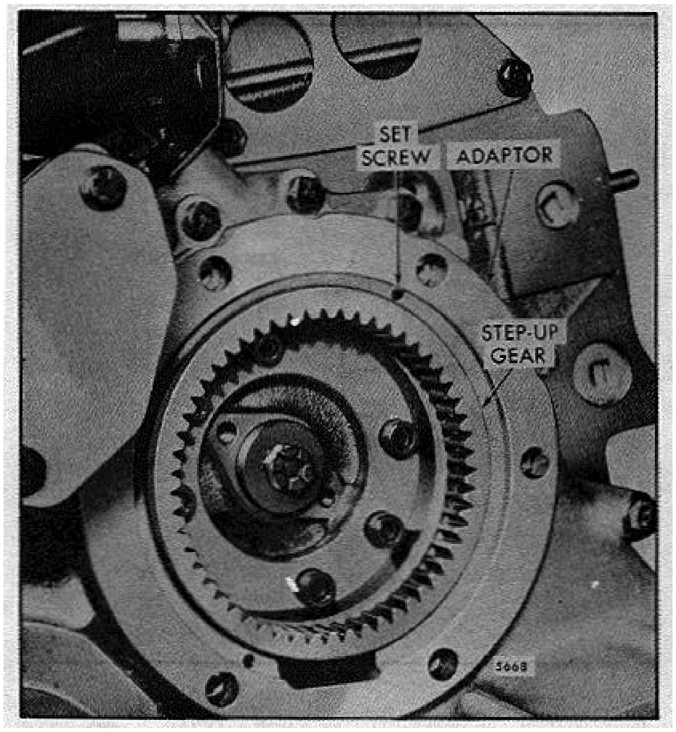


FIG.. 6 - Step-Up Gear Drive Mounting

5. Place a clean, lintless cloth in the flywheel housing opening (under the accessory drive plate or drive hub) to prevent bolts from accidentally falling into the gear train. Then remove the four shoulder bolts and withdraw the accessory drive plate (and spacer, if used), or drive hub.

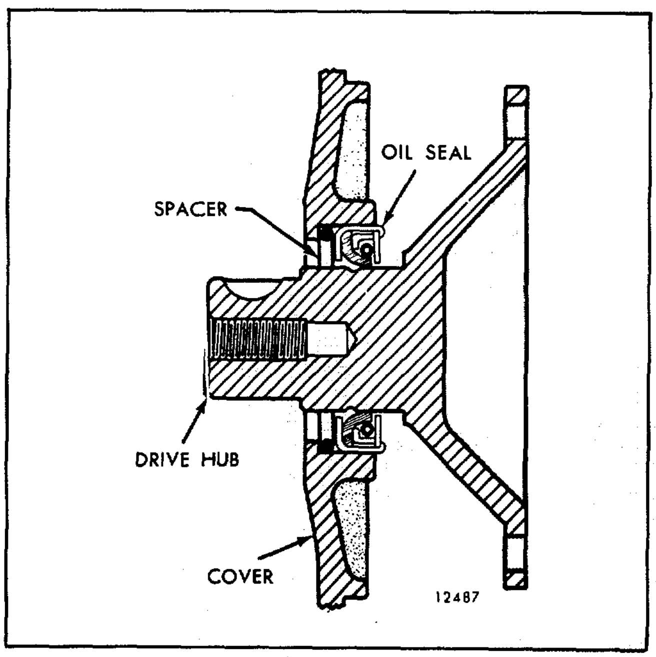


FIG.. 7 - Location of Oil Seal Spacer

6. Remove the accessory drive shaft from the retainer (Fig. 4).

7. Remove the snap ring and ball bearing from the accessory drive retainer (Fig. 4).

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

Check the teeth on the drive plate and the drive coupling or drive shaft for wear. Replace any parts which are worn excessively.

On 8V and 12V engines, the fibre air compressor drive plate has been superseded by a hardened steel drive plate of identical design effective with engines 8VA-21334 and 12VA-5741. The fibre and steel drive plates are interchangeable. If an examination of the fibre drive plate on 8V and 12V engines reveals signs of wear, the plate should be replaced with the hardened steel drive plate.

Inspect the ball bearing used to support the accessory drive shaft (Fig. 4). *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 oil seal for wear or damage. Discard the oil seal if it is worn. Also inspect the oil seal contact surface of the drive shaft (Fig. 4) for grooving. If the shaft is grooved and cannot be "cleaned-up", replace it.

If the drive hub (Fig. 5) is grooved to a point where the effectiveness of the oil seal is lost, a ring-type oil seal spacer is available which serves to reposition the seal and provide a new sealing surface for the lip of the oil seal (Fig. 7).

Install Accessory Drive

If an accessory drive plate is used, refer to Figs. 3 and 4 and proceed as follows:

1. Align the bolt holes in the accessory drive plate (and spacer, if used) with the tapped holes in the camshaft gear. Then secure the drive plate (and spacer) with the four special shoulder bolts (and lock washers, if used). Tighten the bolts to 45-50 lb-ft (61-68 Nm) torque.

2. If a gear-driven accessory is used, install the drive coupling (Fig. 3) and proceed as follows:

a. Affix a new gasket to the mounting flange on the accessory.

b. Place the accessory in position against the flywheel housing and rotate it, if necessary, to align the teeth of the driven hub with those in the drive coupling. Then secure the accessory to the flywheel housing with bolts and lock washers.

3. If a belt-driven accessory is used, refer to Fig. 4 and proceed as follows:

a. Place the accessory drive retainer on a bench, with the mounting flange side up. Lubricate the outside diameter of the bearing with oil. Then press or tap it (with the protruding face of the inner race facing toward the retainer) straight in until it contacts the shoulder in the retainer. Then install the lock ring.

b. Turn the retainer over and coat the bore with sealant. Then press a new oil seal into the bore of the retainer with the lip of the seal facing the bearing. Wipe any excess sealant from the retainer.

c. 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.

d. 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 30-35 lb-ft (41-47 Nm) torque.

e. Install the key in the shaft. Then start the pulley on the shaft and tap it into place. Install the 3/41-16 retaining nut. Tighten the nut to 120-140 lb-ft-(163-190 Nm) torque.

f. Slip the drive belts over the pulleys. Then position the accessory to provide the proper tension on the belts and secure it in place.

NOTE: Be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting strap slot.

4. If an accessory drive hub is used, refer to Fig. 5 and proceed as follows:

a. Align the bolt holes in the drive hub with the tapped holes in the camshaft gear. Then secure the drive hub to the gear with four shoulder bolts. Tighten the bolts to 45-50 lb-ft (61-68 Nm) torque.

b. Use a dial indicator to check the runout of the drive hub shaft. The runout must be within .010" total indicator reading.

c. If a new oil seal is required, coat the retainer bore with sealant and press the seal in place. The lip of the seal must face the engine when the retainer is installed.

d. Affix a new gasket to the mounting flange of the retainer. Then place the retainer against the flywheel housing and install the five attaching bolts and lock washers. Before tightening the bolts, insert tool J 21166 over the shaft and into the retainer bore to align the oil seal with the shaft. Tighten the retainer bolts to 30-35 lb-ft (41-47 Nm) torque and remove the oil seal aligning tool.

e. Install the key in the drive hub. Then start the pulley on the drive hub and tap it into place. Install the plain washer, lock washer and bolt. Tighten the bolt to 35 lb-ft (47 Nm) torque.

f. Slip the drive belt over the pulleys. Then position the accessory to provide the proper tension on the belt and secure it in place.

NOTE: Be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting strap slot.

5. If a step-up gear is used, refer to Fig. 6 and proceed as follows:

a. Affix a new gasket to the figure "8" adaptor, them position the adaptor on the flywheel housing using a feeler gage or other means of centering on the camshaft gear.

b. Install and tighten the four upper adaptor bolts. Adjust the two set screws until they are snug against the flywheel housing.

c. Place alignment gage J 29893 in the step-up gear and secure it with the gage read point at the 8 o'clock set screw position.

d. Set the dial indicator on "0".

e. Bar the engine over. The gage must travel clockwise until the read point is at the 2 o'clock position set screw (180 °).

NOTE: The barring operation should always be performed in a clockwise direction. It is very important to make certain that the crankshaft end bolt has not been loosened during the barring operation. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

f. If the dial indicator reads between the initial "0" setting and ±.02", go to step j.

g. If the dial indicator reads more than ± **.**002" from the initial setting of "0", loosen the four upper adaptor bolts. Then back off the set screws on the adaptor, and readjust them until the dial indicator reading is one-half of the total variance.

h. Repeat steps c, d, e, f and g until the proper readings are obtained or a maximum of three attempts.

i. If the proper alignment readings cannot be obtained after three attempts, change the adaptor and repeat steps a through h.

j. Remove the alignment gage.

Make sure the alternator is properly fitted to the adaptor before it is bolted in place. Improper installation of the alternator can disturb adaptor alignment and cause gear train damage.

6. If the flywheel housing small hole covers were removed, install them as outlined in Section 1.5.

REAR ACCESSORY DRIVE (Blower Drive)

Whenever an accessory is to be driven by the blower drive gear, a hub with two lugs replaces the standard hub in the blower drive assembly (Fig. 8). An accessory drive assembly consisting of a pulley, shaft, two single-row bearings, bearing spacer, driven hub and a housing is bolted to the flywheel housing. Effective with engines 6VA-29026, 8VA-22360 and 12VA-6352, the two single-row bearings and spacer were replaced by a double-row bearing, oil seal and oil seal spacer (Fig. 9).

A slotted coupling, which engages the lugs on the two hubs, provides the connection between the accessory drive and the blower drive gear.

Remove Accessory Drive

1. Loosen the generator adjusting strap and generator mounting bolts. Remove the drive belts.

2. Remove the bolts and lock washers and carefully withdraw the accessory drive assembly and the drive coupling.

3. Remove the blower drive shaft retaining ring. Then thread a No. 10-32 screw in the tapped hole and withdraw the blower drive shaft. Remove the screw used to withdraw the shaft.

4. Remove the three bolts and lock washers and withdraw the drive hub and two drive plates.

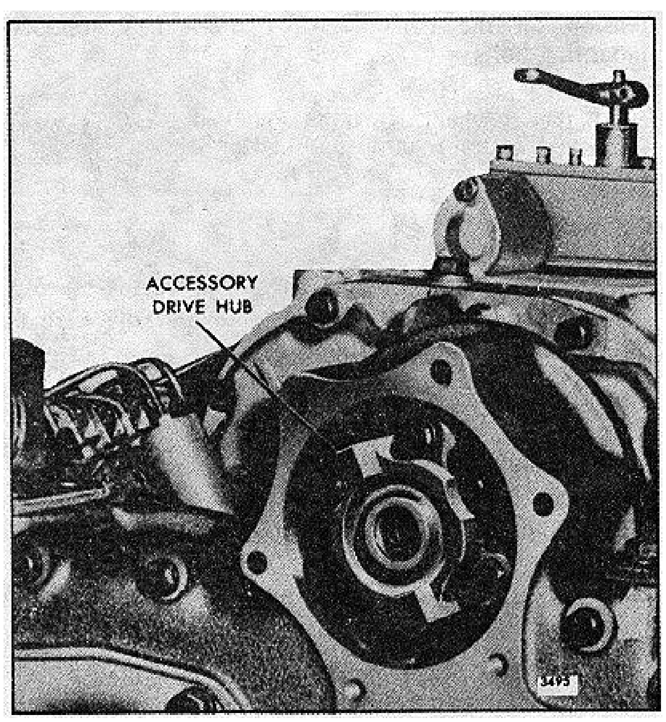


FIG.. 8 - Accessory Drive Attached to Blower Drive Gear

Disassemble Accessory Drive

1. Remove the pulley retaining nut. Then remove the pulley and the key. Remove the oil seal spacer (if used).

2. Press the shaft and hub from the bearing(s).

3. Press the shaft from the hub and remove the key from the shaft.

4. Remove the lock ring, bearing(s) and bearing spacer (if used) from the housing.

5. Press the oil seal (if used) from the housing with a suitable tool.

Inspection

Clean all of the parts, except the bearings, with fuel oil and dry them with compressed air. *Shielded type bearings cannot be washed* because of the difficulty in draining out all of the solvent.

Inspect the ball bearing (Fig. 9). 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.

Replace excessively worn or damaged parts.

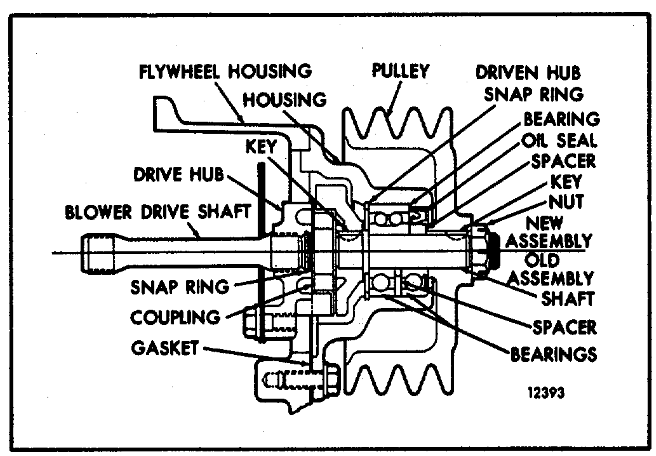


FIG.. 9 - Accessory Drive Assembly Details

Assemble Accessory Drive

1. Install a key(s) in the hub end of the shaft. Lubricate the shaft and press the hub tight against the shoulder on the shaft.

2. Install the oil seal (if used) in the housing.

3. Install the bearing(s) and spacer (if used) in the housing. Install the lock ring.

4. Use a sleeve to support the inner race of the bearing(s), lubricate the shaft and press the hub and shaft assembly in the bearing(s) and spacer (if used) until the shoulder on the shaft contacts the inner race of the bearing.

5. Install a key(s) in the pulley end of the shaft. Lubricate the shaft and press the pulley on the shaft until it contacts the inner race of the bearing or oil seal spacer (if used).

6. Install the 3/4"-16 pulley retaining nut and tighten it to 120-140 lb-ft (163-190 Nm) torque.

Install Accessory Drive

1. Install the drive hub and the two drive plates on the blower drive gear.

2. Install the blower drive shaft and secure it in place with the snap ring.

3. Place a new gasket on the mounting flange of the accessory drive housing.

4. Place the slotted drive coupling on the hub of the accessory drive assembly. Then align the slots in the coupling with the lugs on the drive hub which is attached to the blower drive gear and carefully position the accessory drive against the flywheel housing. Secure the accessory drive assembly to the flywheel housing with bolts and lock washers.

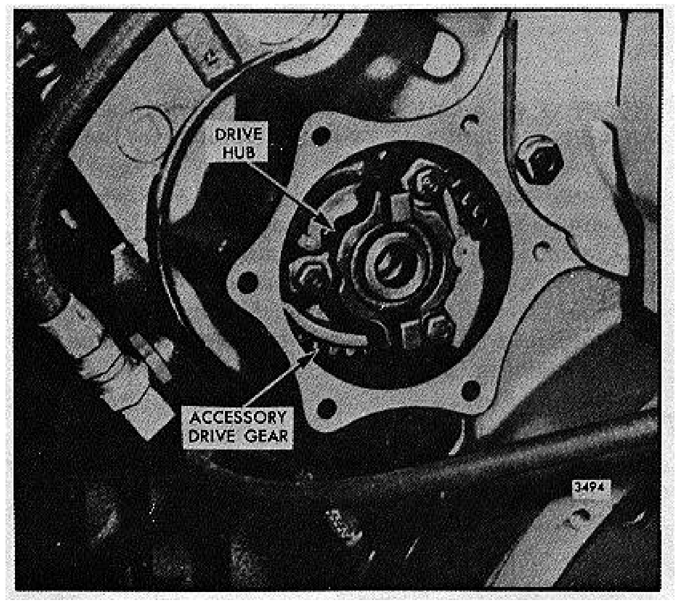


FIG.. 10 - Rear Left-Bank Accessory Drive Mounting

5. Place the drive belts over the pulleys and adjust the tension on the belts. Then tighten the accessory mounting bolts.

6. If the flywheel housing small hole covers were removed, install them as outlined in Section 1.5.

REAR LEFT-BANK ACCESSORY DRIVE

When required, an accessory drive gear is provided in the left-bank accessory pad in the flywheel housing as shown in Fig. 10. The accessory drive assembly is similar to the blower drive gear and support assembly. The accessory drive gear, mounted on a support which is attached to the cylinder block rear end plate, is driven by the left-bank camshaft gear. The bushing-type bearings in the gear are pressure lubricated through an external oil line.

Remove Accessory Drive

1. Remove the bolts and lock washers securing the hydraulic pump to the flywheel housing. Then withdraw the pump and gasket.

2. Remove the pump drive coupling.

3. Remove the three bolts and lock washers securing the accessory drive hub to the accessory drive gear. Then withdraw the drive hub.

Disassemble Accessory Drive

If further disassembly is required, the flywheel housing, gear train, accessory drive lubrication tube and cylinder block rear end plate must first be removed. Then proceed as follows:

1. Remove the two bolts and copper washers securing the accessory drive support assembly to the rear end plate. Then withdraw the support assembly and remove the gasket.

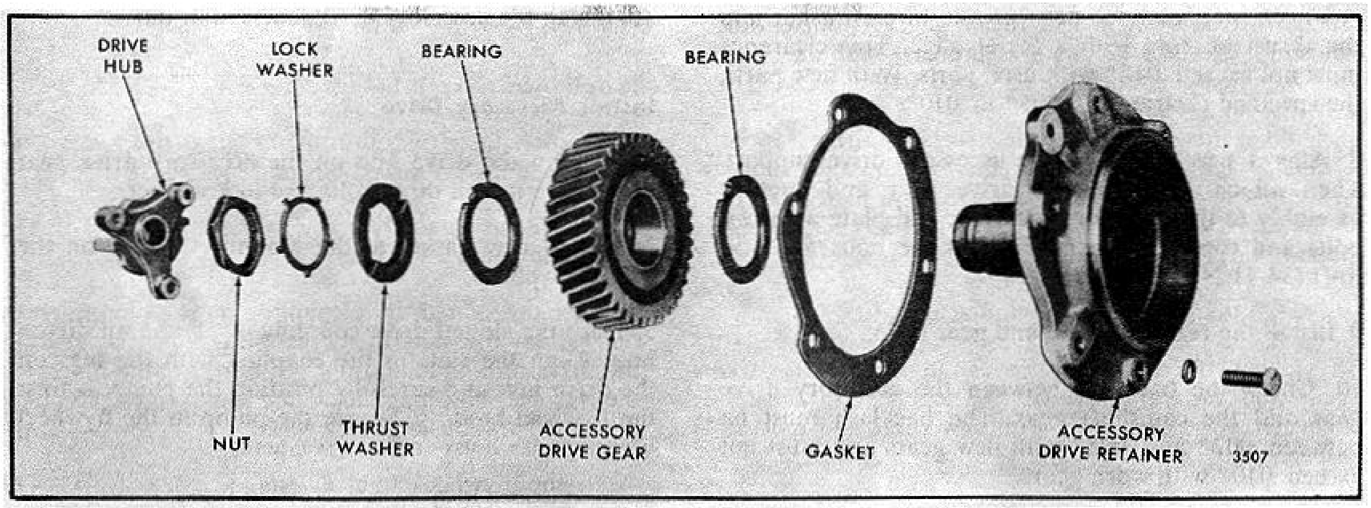


FIG.. 11 - Accessory Drive Details and Relative Location of Parts

2. Clamp the support assembly in a vise equipped with soft jaws.

3. Straighten the lugs on the lock washer and remove the gear retaining nut. Withdraw the lock washer, thrust washer, thrust bearings and accessory drive gear from the support.

Inspection

Clean the parts with fuel oil and dry them with compressed air. Make sure the oil passage in the gear support is clean.

Replace the thrust bearings and thrust washer if they are worn excessively or scored.

Check the inside diameter of the accessory drive gear bearings (bushing type) and the outside diameter of the hub on the gear support. The clearance between the bearings and the support hub is .00 1" to .0025 " with new parts. Replace the parts when the clearance exceeds .005 " on used parts.

If new bearings are installed, the outer end of each bearing must be pressed in flush to .010" below the face of the gear. The bearings must be reamed to size (1.6260" to 1.6265" inside diameter) and to a finish of 20 microinches after installation. The bearing bores must also be square with the machined faces of the bolt bosses on the gear within .003" total indicator reading and concentric with the outside diameter of the gear.

The thrust washer retaining pin must extend approximately .080" above the threaded end of the support hub.

Examine the accessory drive gear teeth for scoring, pitting or wear. If necessary, install a new gear assembly. A service replacement gear includes the bearings.

Inspect the drive and driven hubs and the drive coupling for wear. Replace severely worn parts.

Assemble Accessory Drive

Refer to Fig. 11 for the relative location of the parts and assemble them as follows:

1. Clamp the accessory drive support in a vise equipped with soft jaws. Then install one of the thrust bearings so the tangs on the bearing register with the holes in the support.

2. Lubricate the hub of the support, the bearings in the gear, both thrust bearings and the thrust washer with clean engine oil.

3. Slide the gear on the hub, with the flat side of the gear toward the support.

4. Install the second thrust bearing on the support, with the tangs on the bearing facing away from the gear.

5. Install the thrust washer so the slots in the washer register with the tangs on the thrust bearing and the pin in the support hub registers with the slot in the bore of the washer.

6. Secure the gear, thrust bearings and thrust washer with a lock washer and nut. Tighten the nut to 50-60 Ib-ft (68-81 Nm) torque and bend the lugs on the lock washer against the flats on the nut.

7. Check the clearance between the thrust washer and the thrust bearing with a feeler gage. This clearance must not exceed .012" with used parts. With new parts, the specified clearance is .005 a to .010 ".

8. Affix a new gasket to the accessory drive support. Then attach the accessory drive gear and support assembly to the cylinder block rear end plate with two bolts and copper washers. Tighten the bolts to 25-30 Ib-ft (34-41 Nm) torque.

9. Install the rear end plate and gear train.

10. Check the backlash between the accessory drive gear and the camshaft gear. The backlash must be between .002" and .008” with new gears and must not exceed .010" with worn gears.

11. Install the flywheel housing.

12. Install the accessory drive lubrication tube.

Install Accessory Drive

1. Position the drive hub on the accessory drive gear and secure it with three bolts and lock washers.

2. Affix a new gasket to the mounting flange on the hydraulic pump.

3. Place the slotted drive coupling on the pump driven hub. Align the slots in the coupling with the lugs on the drive hub and carefully position the pump against the flywheel housing. Secure the pump to the flywheel housing with bolts and lock washers.

4. If the flywheel housing small hole covers were removed, install them as outlined in Section 1.5.

BALANCE WEIGHT COVER

The balance weight cover (Fig. 1) encloses the combination balance weight and water pump drive gear on the front end of the right cylinder bank camshaft. This cover also serves as a support for the water pump.

The balance weight cover requires no servicing. However, when an engine is being completely reconditioned or the right bank camshaft, camshaft bearings or water pump drive gear need replacing, the balance weight cover must be removed.

Remove Cover

1. Drain the cooling system.

2. Remove the water pump and any other parts required to permit removal of the balance weight cover.

3. Remove the bolts, washers and lock washers which secure the balance weight cover to the front end plate and the cylinder block.

4. Since the cover is doweled to the end plate, it will be necessary to tap the ends of the cover with a soft hammer to loosen it.

5. Remove all traces of the old gasket material from the cover and the end plate.

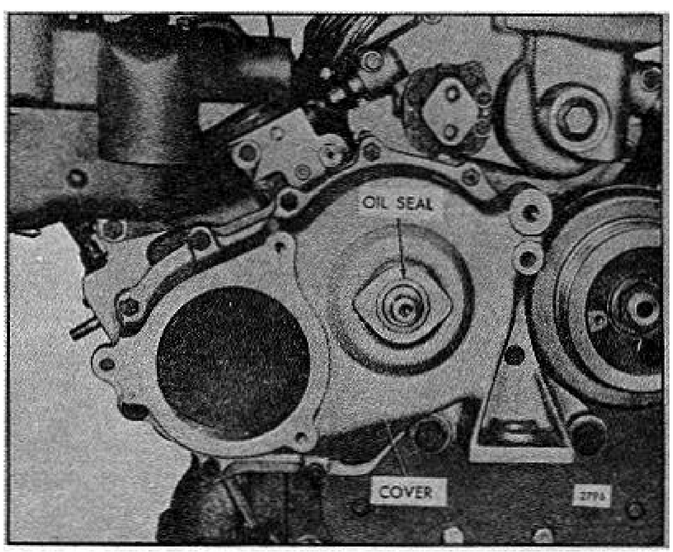


FIG.. 1 - Balance Weight Cover Mounting

Install Cover

Effective with engine serial numbers 6VA-648, 8VA-326 and 12VA-210, a new balance weight cover and cover gasket (except on model 7087-7242) replace the parts formerly used. The former and current gaskets (Fig. 2) are very similar. Since the two gaskets are not interchangeable, be sure the proper gasket is used when installing the balance weight cover.

1. Affix a new gasket to the balance weight cover.

2. An accessory drive shaft oil seal is pressed into the balance weight cover on some engines (Fig. 1). If necessary, replace the oil seal as follows:

   a. Drive the old oil seal out of the cover.

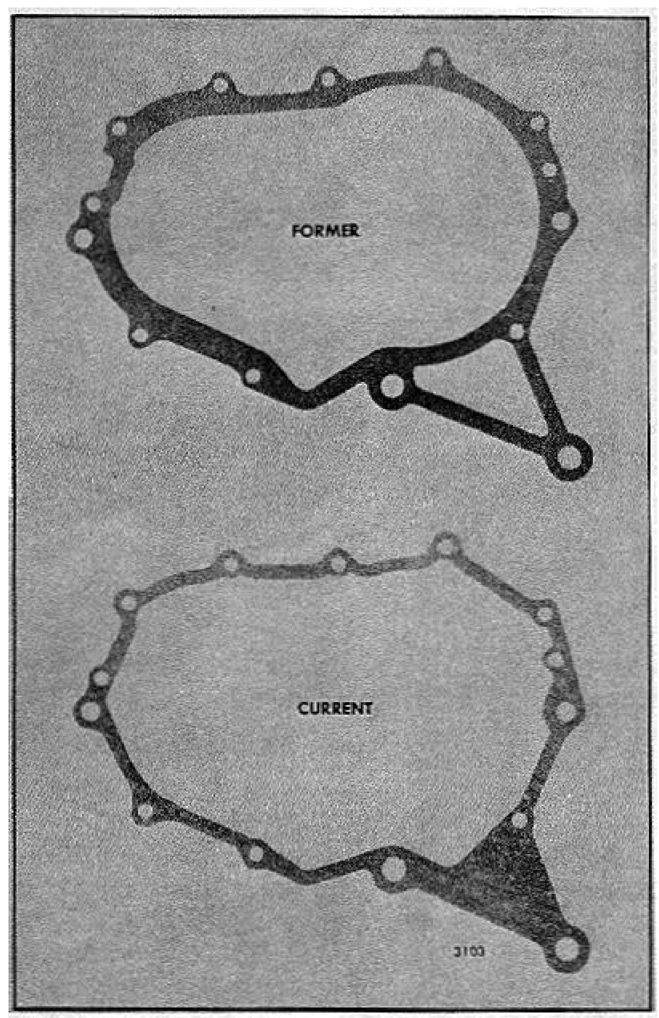


FIG.. 2 - Balance Weight Cover Gaskets

b. The new oil seal is plastic coated on the outside diameter for sealing purposes. Do not remove this coating. Position the seal with the sealing lip pointing toward the inner side of the cover.

c. Drive the seal in with installer J 9791 until it is flush with the outer surface of the cover.

d. Coat the lip of the seal with grease.

3. Install the balance weight cover on the engine and secure it with bolts, nuts, lock washers and plain washers. Tighten the 3/8"-16 bolts to 30-35 lb-ft (41-47 Nm) torque, 3/8" -24 bolts and nuts to 35-39 lb-ft (47-53 Nm) torque, 1/2" -13 bolts to 71-75 lb-ft (96-102 Nm) torque and the 5/8" 11-I bolts to 137-147 lb-ft (186-200 Nm) torque.

4. Install the water pump and any other parts that were removed.

5. Fill the cooling system.

SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

PISTON AND CYLINDER LINER USAGE (Trunk Type)

1. "N" pistons are .030 " longer than the "E" pistons and approximately .155 " longer than the special "E" piston. In addition, the fire ring turbocharged piston is .125 " longer than the non-fire ring turbocharged piston. These dimension differences dictate that pistons *cannot be mixed in an engine.* To do so would result in misfiring and a rough idle condition which could ultimately result in cylinder liner scuffing.

2. The "E" and "turbo" figure 8 cylinder liner has .900 " long ports compared to 1.055 " long ports in the oval port liner and .703 " long ports in the standard two valve figure 8 port liner. These port dimension differences *prohibit mixing of cylinder liners in an engine* which would result in a timing differential and compression ratio changes.

3. Only the oval port cylinder liners can be used with 18.7:1 compression ratio pistons. In addition, only oval port cylinder liners can be used with fire ring turbocharged pistons. The standard figure 8 port cylinder liner should be used only with the non-fire ring two valve piston.

4. Crown valve injectors can be used with the 18.7:1 pistons. *Crown valve and needle valve injectors must not be mixed in an engine.*

5. When converting to "N" pistons (see Item 1), it is important that the exhaust valve protrusion be measured carefully to assure that when fully closed the exhaust valves do not protrude more than .006 " above the cylinder head fire deck. Only the "thin" exhaust valve inserts (for two valve or four valve heads) which are .247 "-.251 " thick can be used with the "N" piston.

TEFLON WRAPPED PIPE PLUG

Pipe Plugs with a baked teflon coating are available for service. However, pipe plugs can be hand wrapped satisfactorily with teflon tape to provide a better seal and facilitate plug removal. When a teflon wrapped plug is installed, it is extremely important that the specified torque not be exceeded.

Hand wrap a pipe plug with teflon tape as follows:

1. Be sure the pipe plug is thoroughly clean and dry prior to applying the teflon tape. All dirt, grease, oil and scale must be removed.

2. Start the tape one or two threads from the small or leading edge of the plug, joining the tape together with an overlap of approximately 1/8 ".

3. Wrap the tape tightly in the same direction as you would turn a nut. The tape must conform to the configuration of the threads (be pressed into the minor diameter of the threads) without cutting or ripping the tape.

4. Hand tighten and hand torque the pipe plug and *do not exceed the specified torque. Do not use power tools.*

CAMSHAFT CUP PLUG INSTALLATION

If an oil leak occurs at the drive plug area in the front end of the camshaft, install a cup plug in the end of the camshaft rather than removing and replacing the drive plug.

> **NOTE:** It is not necessary to remove the camshaft from the engine when installing the cup plug.

Install the cup plug as follows:

1. Clean the hole in the front end of the camshaft and apply Permatex No. 1 sealant, or equivalent, to the outer diameter of the cup plug.

2. Install the plug to a depth of .180 "-.210” with tool J 24094.

CHECKING BEARING CLEARANCES

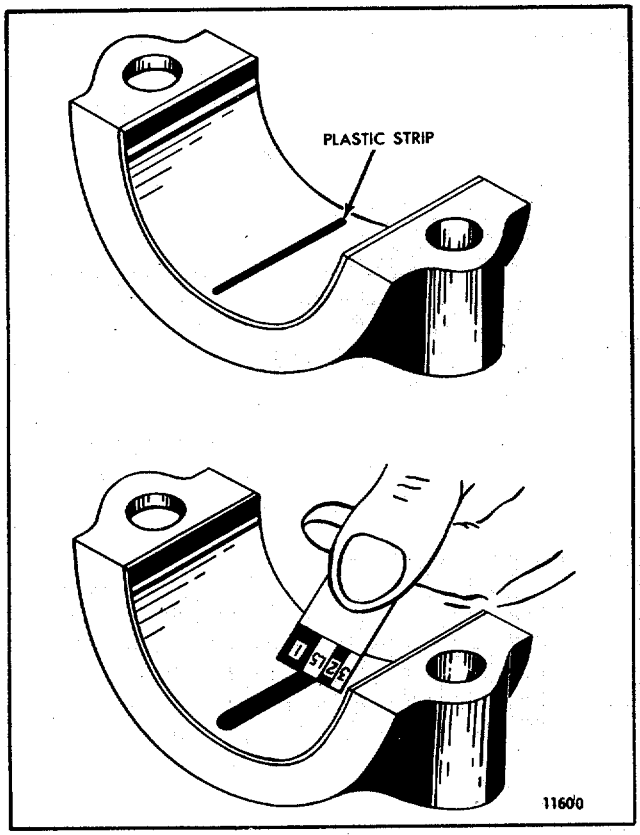


FIG.. 1 - Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

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 the crankshaft journal.

NOTE: 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, due to the weight of the crankshaft and flywheel, 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. 1).

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. 1). 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.

REPLACING CYLINFER HEAR BOLT HOLE PLUG

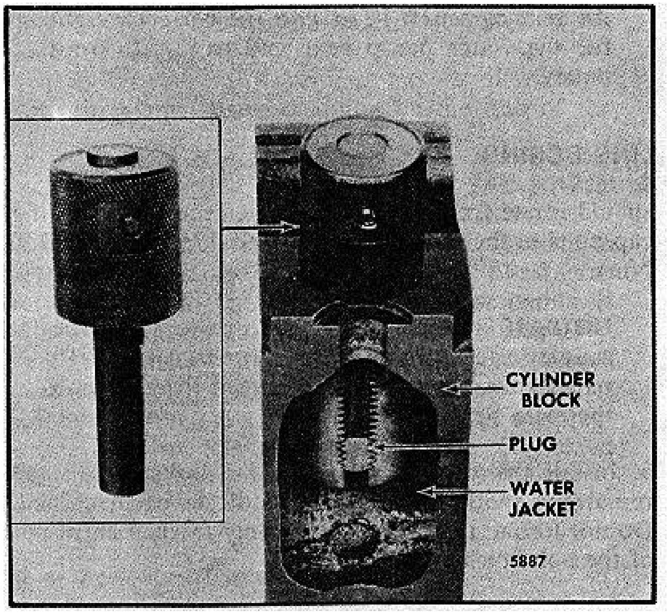


FIG.. 2 Checking Depth of Plug with Tool J 26244

The cylinder head bolt hole plugs are designed to seal the head bolt holes from the coolant passages. Tool Kit J 26620 is available for removing and installing the plugs. Replace a cylinder head bolt hole plug in the cylinder block as follows (Fig. 2):

1. Remove the old plug and clean the threads of all old sealant by running a bottom tap **(J** 25384) down the hole *(do not deepen the tapped hole).* The threads must be clean and dry before applying sealant.

2. Apply a sufficient quantity of Loctite 290 sealant or equivalent, to the threads in the block at the minimum depth of the stud plug, as well as to the plug itself. Screw in the plug until it bottoms. The ,top of the plug must be at least 2.040at below the block surface (1.920"1 on earlier cylinder blocks). Torque to 50-60 Ib-ft (68- 81 Nm).

3. If depth gage J 26244 is used, place the gage in the bolt hole and loosen the set screw (Fig. 2). If the depth gage is flush with (1.920") or below the knurled gage holder, the plug is installed and sealed at the proper depth. *Tool J 26244 is made to early cylinder block specifications of 1.920" and would automatically qualify the current V-71 cylinder block specification of* 2.040*".* Do not apply any sealant to the top of the plug after installation. Allow the sealant to set for twelve hours and pressure check for five minutes at 40 psi (276 kPa).

4. Remove excess Loctite from the bolt hole threads by running a 11/16" bottom tap until it bottoms on the plug. Run the tap in by hand. *Power equipment (impact gun, etc.) should not be used as they may cause the tap to disturb the Loctite seal.*

Inspect the bolt hole for debris before and after these operations.

INSTALLATION OF BOLT-ON REAR BALANCE WEIGHT FOR 8V-71 ENGINES

To permit an in-frame overhaul of an 8V-71 engine built prior to 8VA-115016, when installing the new cross-head pistons, a new rear balance weight is now available as a service item.

The new weight is used in conjunction with the existing balance weight attached to the engine side of each rear camshaft gear. It will only be necessary to remove the flywheel housing large hole covers to install the additional weights to the exposed face of the camshaft gears.

Install a Rear Balance Weight

1. Remove the flywheel housing large hole cover.

2. Determine the location of the existing balance weight attaching bolts and nuts. Then remove the two retainer attaching bolts and lock washers at the two positions-adjacent to them.

NOTE: Place a cloth in the opening to keep the bolts from falling into the gear train.

3. Attach the rear balance weight to the gear nut retainer with two shoulder bolts.

a. When no accessory drive disc is used, use two 3/8"-24 x .940" shoulder bolts.

b. When a .560" thick accessory drive disc is used, use two 3/8-24 x .4401, shoulder bolts.

c. When a .180" thick accessory drive disc is used, use two 3/8"-24 x 1.120" shoulder bolts.

d. Tighten the bolts to 45-50 Ib-ft (61-68 Nm) torque.

e. Remove the cloth from the opening.

4. Install the flywheel housing cover, using a new gasket.

In addition, a new thicker bolt-on weight for the water pump drive gear and a new camshaft front pulley (integral cast weight) are required for proper engine balance (refer to Section 1.7.2 and 5.1).

NOTE: Additional weights are not required on engines built effective with 8VA-1 15016 (trunk style piston) because they already incorporate the heavier production rear balance weights on the rear camshaft gears and the correct weight for the water pump gear and camshaft front pulley.

CYLINDER BLOCK LINE BORING

Tool set J 29005 is designed to repair the main bearing saddles and line bore the repaired saddles and service line bore caps in the cylinder blocks which have been damaged by spun main bearings.

Damaged main bearing saddles can be repaired by machining to accept an insert bushing. The bushing and newly fitted service line bore main bearing cap are line bored to the proper dimensions to accept standard main bearing shells.

The line bore operation is an acceptable warranty procedure.

Instructions for using the cylinder block line boring tool J 29005 are listed below:

1. Remove all the plugs and main bearing caps and clean the useable cylinder block.

NOTE: The use of this tool is dependent upon the existence of two undamaged main bearing saddles.

2. Determine which two undamaged main bearing saddles are to be used as alignment locations. These saddles should be as far apart as possible. Since the rear main bearing saddle cannot be repaired with this tool set, it *must* be one of the undamaged saddles.

In a block where the front and rear main bearing cap and saddle are serviceable, the journals in between can be repaired successively without removal of the centering rings from the front and rear positions. In the case where the only good main bearing bores are next to each other, the centering rings will have to be mounted there and marked for indexing. The closest bore will then be repaired. The rear centering ring will remain in position, but the other centering ring will be moved into the just repaired saddle so that the next damaged saddle can be repaired. The centering ring being moved should be indexed the same when moved from saddle to saddle.

3. Set the centering rings (4.8125") into the alignment saddles and install the main bearing caps. Do not tighten the bolts.

4. Slide the boring bar through the centering rings. Lubricate the ring hole during installation. The bar should rotate freely (Fig., 3). Tighten the main bearing cap bolts to the torque specified, 165-175 lb-ft (224-238 Nm).

NOTE: If the centering rings are loose in the saddle after tightening the bolts, use .001" paper shims as necessary between the ring and the main bearing cap.

5. Install the caps and tighten the bolts on all the remaining saddles, except the saddle to be machined. Do not torque the bolts. This is only to keep chips out of the bolt holes.

6. Fasten the torsion bar and the hydraulic feed unit on either end of the cylinder block. Index the flat on the feed rod into the boring bar. Snug the set screw (Fig. 4).

7. Zero the micrometer with the test block supplied (Fig. 5).

NOTE: The micrometer is .050 per revolution, not .025" as normally seen on micrometers.

8. Install the cutting tool holder on the micrometer test

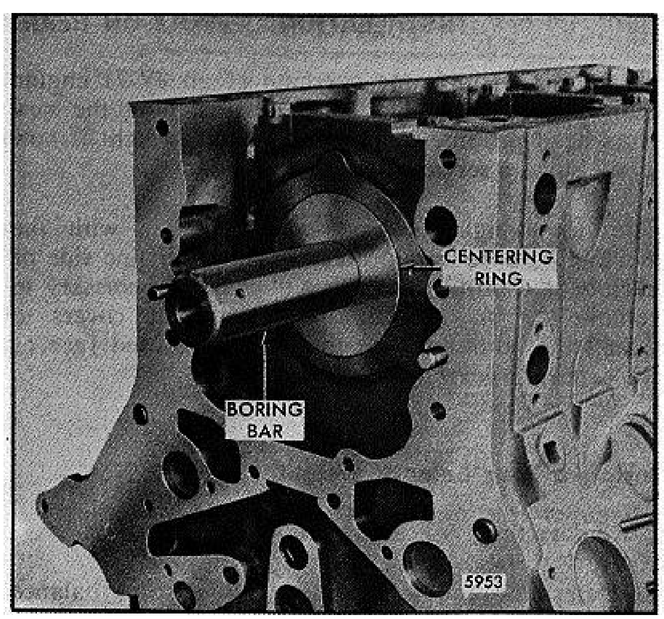


FIG.. 3 - Location of Boring Bar

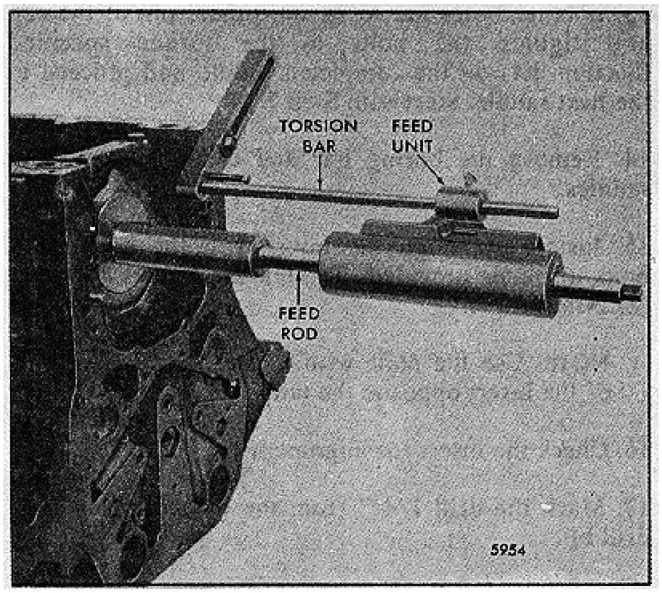


FIG. 4 Location of Feed Rod and Unit

should rotate freely (FIG. 3). Tighten the main bearing cap bolts to the torque specified, 165-175 lb-ft (224-238 Nm).

> **NOTE**: If the centering rings are loose in the saddle after tightening the bolts, use .001 " paper shims as necessary between the ring and the main bearing cap.

5. Install the caps and tighten the bolts on all the remaining saddles, except the saddle to be machined. Do not torque the bolts. This is only to keep chips out of the bolt holes.

6. Fasten the torsion bar and the hydraulic feed unit

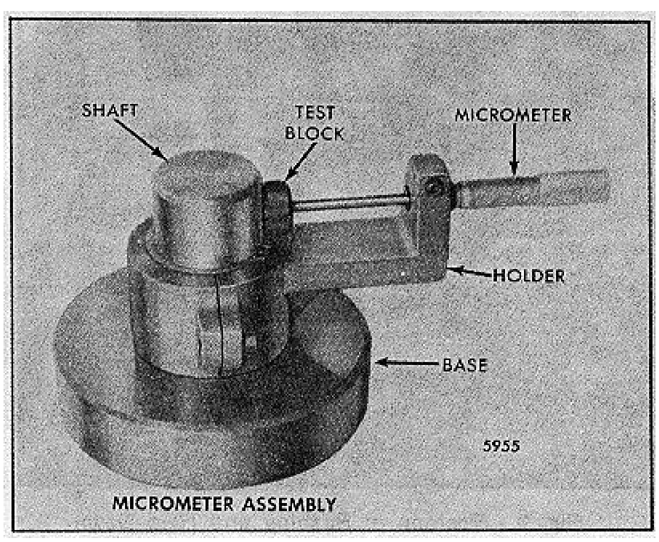


FIG. 5 Test Fixture and Micrometer

on either end of the cylinder block. Index the flat on the feed rod into the boring bar. Snug the set screw (Fig. 4).

7. Zero the micrometer with the test block supplied (Fig. 5).

> **NOTE**: The micrometer is .050 " per revolution, not .025 " as normally seen on micrometers.

8. Install the cutting tool holder on the micrometer test fixture. Use only the straight Allen wrench supplied in the kit. Set the cutting tool for the first cut of .040 (Fig. 6).

EXAMPLE:

	Block	Insert
Bore diameter	4.812"	4.712"
First cut	+.040"	+.040"
Set tool	4.852"	4.752"
Second cut	+.040"	+.040"
Set tool	4.892"	4.792"
Final cut	+.020"	+.020"
Set tool	4.912"	4.812"

> **NOTE**: The point of the cutting tool should be in the center of the micrometer barrel.

9. Install the cutting tool on the boring bar. Excessive tightening of the Allen head screws is not required.

> **NOTE**: The tool feeds away from the operator and rotates clockwise as viewed by the operator (Fig. 7). Whenever installing the cutter, be sure the sharp portion of the bit is in the cutting position.

10. Lubricate the boring bar with engine oil at the centering rings before each cut.

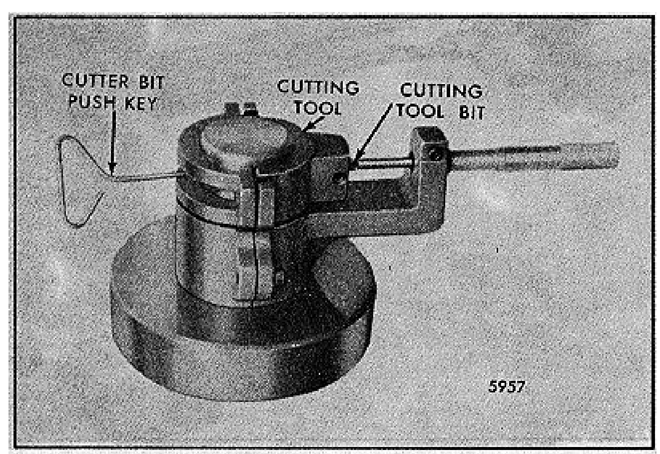


FIG. 6 Installing Cutting Tool Holder

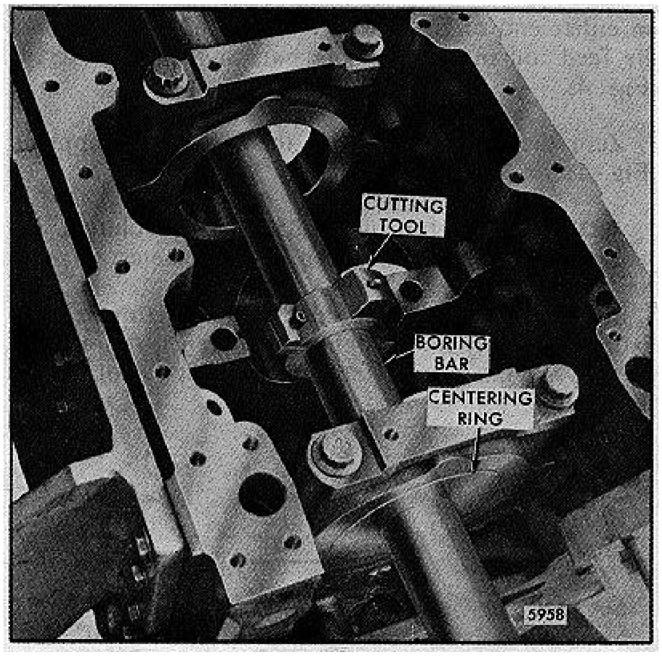


FIG. 7 Position of Cutting Tool

11. Use a 1/2 " drill motor of 300-400 RPM and install the universal drive (lubricate) into the drill chuck. Move the hydraulic feed unit lever to the "closed" position (Fig. 8).

12. Line bore the distressed saddle using the three cuts and the dimensions given in Step 8.

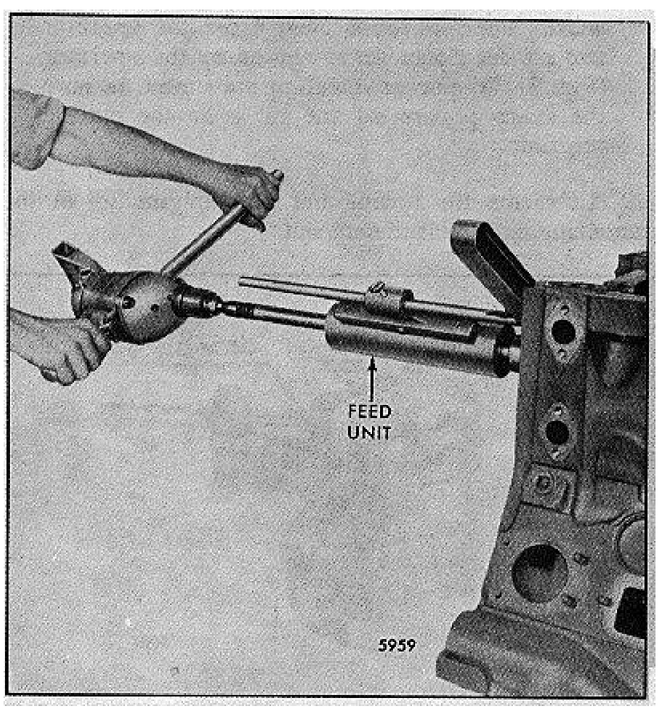


FIG. 8 Use of Hydraulic Feed Unit

13. If other bores are to be machined, install the cap and tighten the bolts to the torque specified (Section 1.1) on the completed saddle and proceed to the next saddle. Start with Step 7.

14. Remove the boring bar and clean the reworked saddles.

15. Install and align the insert with the hold down bolts to plates provided. Tighten the bolts to 20 lb-ft (27 Nm) torque.

NOTE: Use the plate with a "step" on the side of the insert opposite the tang.

16. Check the insert for alignment and fit.

17. Mark the drill 1/4 " from the end, using a 1/8 drill bit.

18. Drill the saddle through the four predrilled holes in the insert.

19. Clean the drilled holes with compressed air and install the rivets.

20. Secure the rivets with a hammer and punch. Be careful not to strike the insert directly, as the insert will distort. Two or three blows on the punch are usually sufficient to secure the rivets (Fig. 9).

NOTE: Rivets are intended for locating more than retention. The bearing and cap provide retention of the insert.

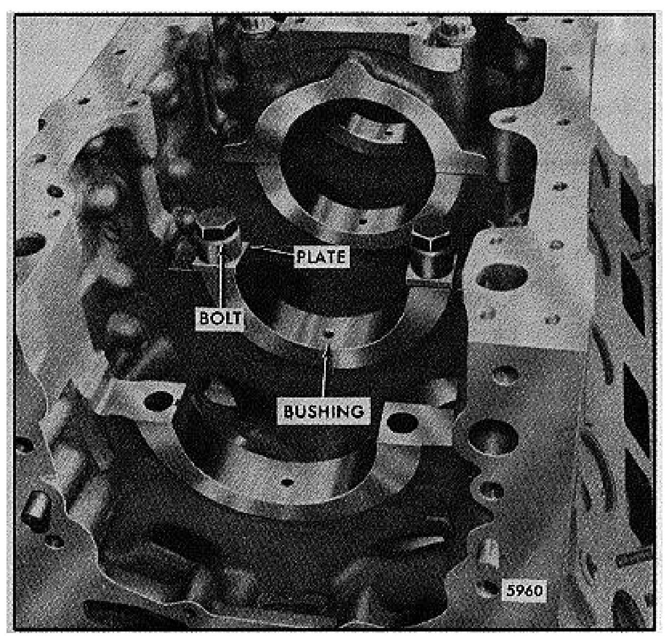


FIG. 9 Position of Bushing and Hold Down Plate

21. File off the excess rivet material (Fig. 9).

22. Remove both the insert hold downs and file the excess material on the insert flush with the saddle-cap parting surface. If the insert is loose, secure the rivets.

23. Install and tighten the bolts for the Service Line Bore cap to the torque specified (Section 1.1).

24. Line bore the cap and insert to the standard bore dimensions, using previous procedure and dimensions in step 8.

25. Remove burrs, debris and clean with spray-lube.

26. Check the finished bore with the Go-NoGo test ,-rings mounted on the boring bar. The ring should go through the reworked bore with a light drag.

NOTE: If centering rings are removed during the line boring operation, mark the ring and saddle to insure proper reinstallation alignment.

27. Clean the cylinder block, reinstall the plugs and proceed with the rebuild.

REWORKING 8V-71 CRANKSHAFT

A six flywheel bolt hole 8V-7 I crankshaft can be reworked (see Fig. 10) to an eight flywheel bolt hole crankshaft as follows:

1. Remove the two dowels by drilling and tapping, using a slide hammer.

2. Drill the reamed dowel holes 37/64 "-2.25 deep.

3. Countersink the holes 120 “-to .62 " - .65 " diameter.

4. Tap the holes using special helicoil taps.

a. Rough tap, using helicoil tool 9 FRU.

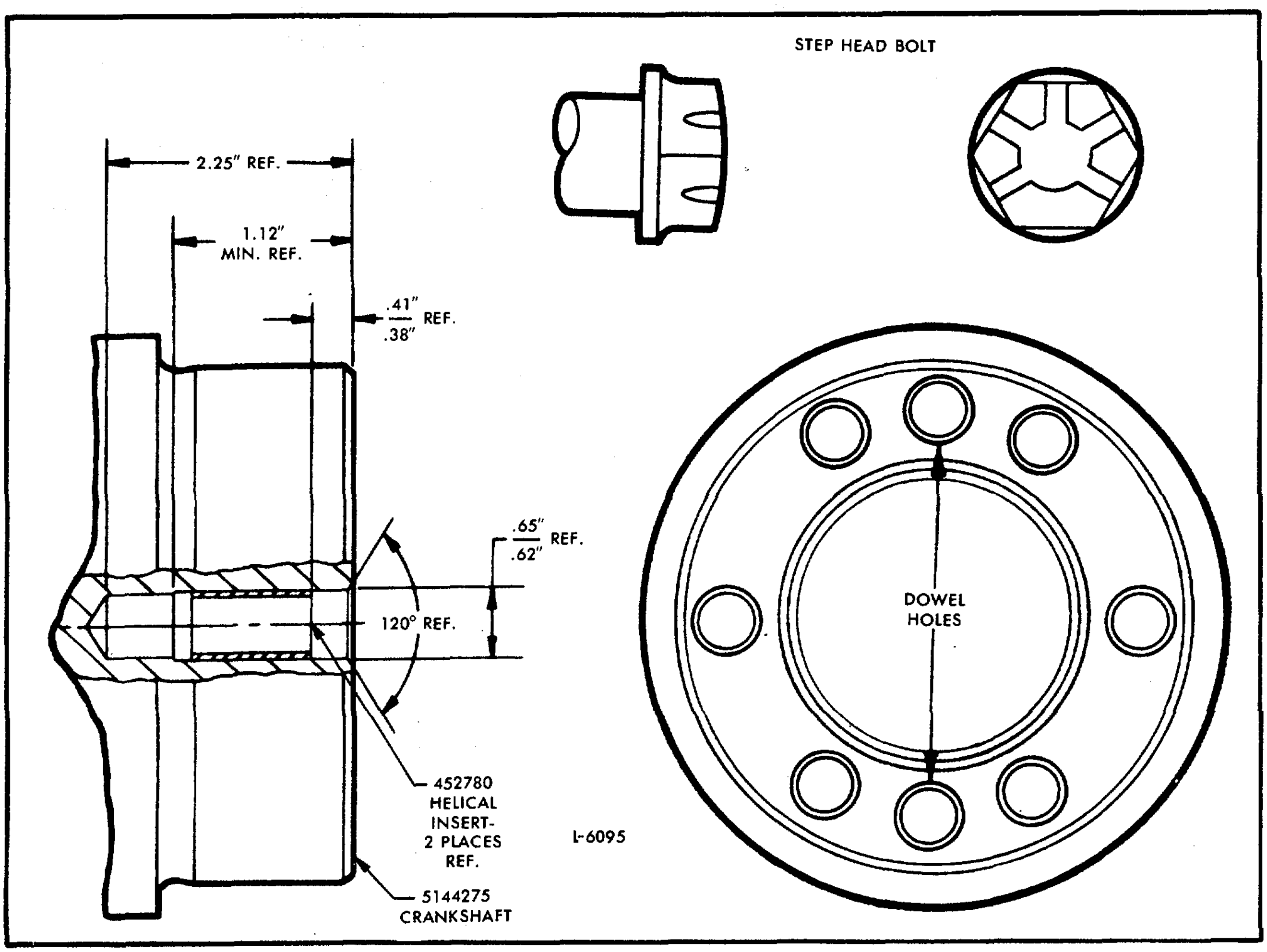


FIG. 10 Reworking 8V-71 Crankshaft to 8 Holes

b. Finish tap, using helicoil tool 42193-9 H3.

NOTE: The finished thread will have a pitch diameter of .5986 " - .6020 " and a depth of 1.62 " minimum.

5. Install a 1 1/8 " helicoil (I 191-9CN 1.125) in each hole, using helicoil driver 535-9. The helicoils must be 3/8 " - 13/32 " below the surface.

6. Break off the driving tang of the helicoil with long nose pliers by bending the tang up and down until it snaps off at the notch. Remove the tang from the hole.

MODIFICATION OF CLOSED AIR BOX DRAINS

The closed air box drain system utilized a drain tube that was routed to the crankcase via the rear dipstick holes at each side of the engine block (Fig. 11).
Engine owners wishing to modify the closed system should proceed as follows:

1. Cut the air box drain tube between the check valve and the dipstick adaptor.

2. Crimp over the remaining portion of the tube at the adaptor to prevent crankcase vapors from escaping.

3. Leave the drain tube leading from the check valve to discharge air box drainage to the atmosphere.

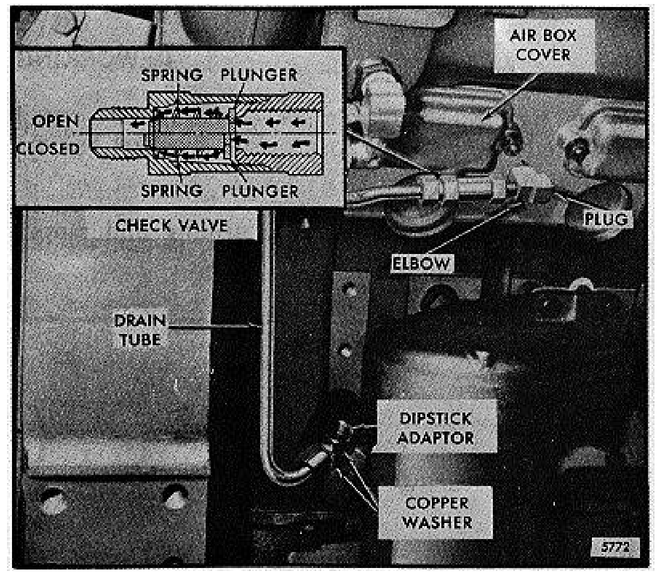
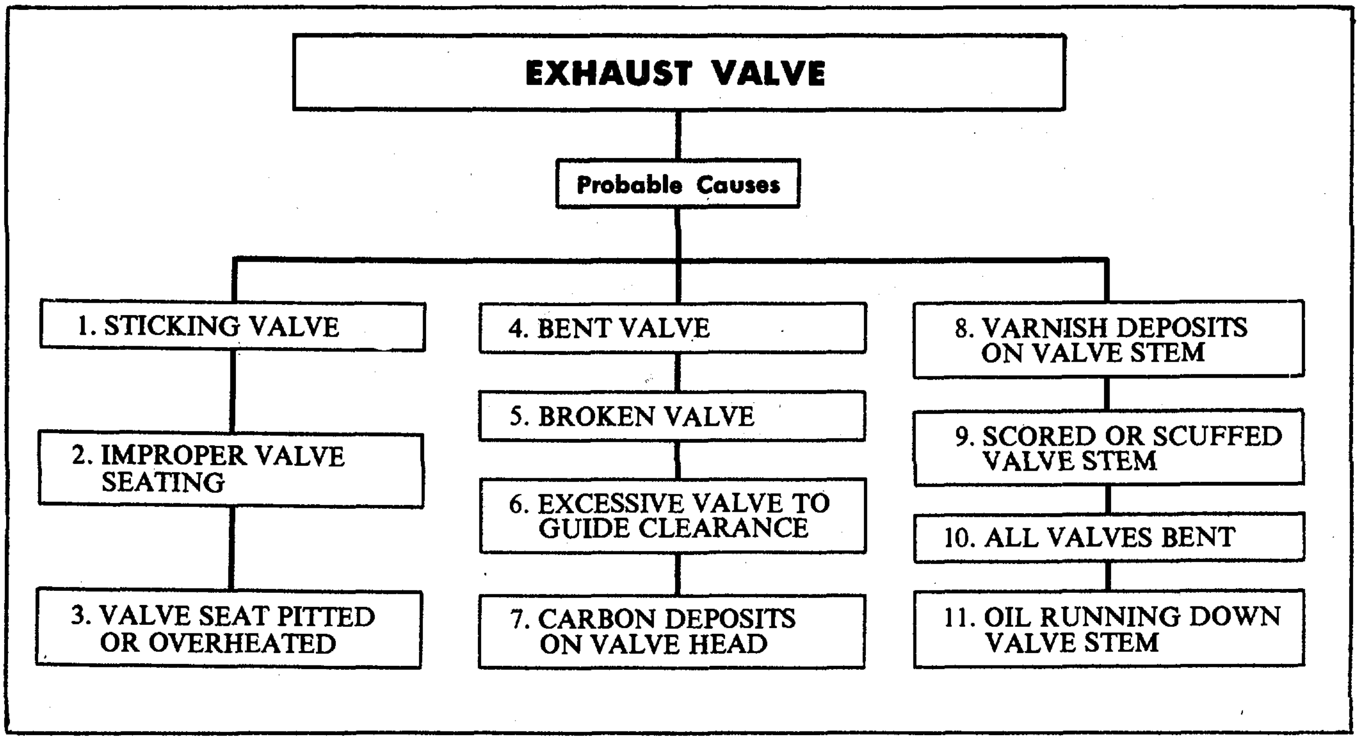


FIG. 11 - Closed Design Air Box Drain Tube and Check Valve System (6 and 8V Engines)

TROUBLE SHOOTING



SUGGESTED REMENDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (glycol) in the lubricating oil. Replace a bent guide. Clean-up 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 (four valve head) 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 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 heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean-up 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 lack of lubrication. Clean up 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.

10. Check for a gear train failure or for improper gear train timing.

11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

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 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 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	4.6256"	4.6275"	
Out-of-round		.0010"	.0020"
Taper		.0010"	.0020"
Cylinder liner counterbore:			
Diameter	5.0460"	5.0510"	
Depth	.4770"	.4795	
Main bearing bore:			
Inside diameter (vertical axis)	4.8120"	4.8130"	
Top surface of block:			
Centerline of main bearing bore to top of block	16.1840"	16.1890"	16.176"min.
Flatness--transverse (all)			.0030"
Flatness--longtudinal (6V)			.0060"
Flatness--longitudinal (8V)			.0070"
Flatness--longitudinal (12V)			.0090"
Depth of counterbores (top surface):			
Cylinder head seal strip groove	.0920"	.1070"	
Water holes (between cylinders)	.1090"	.1200"	
Combination water and oil holes	.0870"	.0980"	
Cylinder Liner			
Outside diameter	4.6250"	4.6265"	
Inside diameter	4.2489"	4.2511"	
Clearance--liner-to-block		.0020"	.0025"
Out-of-round--inside- diameter		.0020"	.0025"
Taper--inside diameter		0010"	.0020"
Depth of flange BELOW block	.0450"	0500"	.0500"
Variation in depth between adjacent liners		.0020"	.0020"
Insert thickness	.1795"	.1800"	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Trunk Type Pistons and Rings V-71 Engines			
Piston:			
Height (centerline of bushing to top):			
Two valve head engine	3.3880"	3.3930"	
Four valve head engine	3.5130"	3.5180"	
Diameter (above compression rings:			
Two valve head engine	4.2217 "	4.2247"	
Four valve head engine (60 cmm inj.)	4.2230"	4.2260"	
Four valve head engine (70 cmm inj.)	4.2190"	4.2220"	
Diameter (at skirt):			
Two valve head engine	4.2433 "	4.2455"	
Four valve head engine (60 cmm inj.)	4.2433"	4.2455"	
Four valve head engine (70 cmm inj.)	4.2428"	4.2450"	
Clearance--piston skirt-to-liner:			
Two valve head engine	.0040"	.0078"	.0120"
Four valve head engine (60 cmm inj.)	.0040"	.0078"	.0120"
Four valve head engine (70 cmm inj.)	.0045"	.0083"	.0120"
Out-of-round		.0005"	
Taper		0005"	
Compression rings:			
Gap (top-fire ring)	.0230"	.0380"	.0600"
Gap (No. 2, 3 and 4)	.0180"	.0430"	.0600"
Clearance--ring-to-groove:			
No. 1 (top, fire ring)	0040 "	.0070"	.0100"
No. 2	.0095"	.0130"	.0220"
No. 3	.0075"	.0110"	.0150"
No. 4	.0055"	.0090"	.0130"
Oil control rings:			
Gap	.0080"	.0230"	.0430"
Clearance--ring-to-groove	.0015"	.0055 "	.0080"
V-71N Engines			
Piston:			
Height (centerline of bushing to top)	3.5430"	3.5480"	
Diameter (above compression rings)	4.2225"	4.2255"	
Diameter (at skirt)	4.2428"	4.2450"	
Clearance--piston skirt-to-liner	.0045 "	.0083 "	.0120"
Out-of-round		.0005"	
Taper		0005"	
Compression rings:			
Gap (top-fire ring)	.0230"	.0380"	.0600"
Gap (No. 2, 3 and 4)	.0180"	.0430"	.0600"
Clearance--ring-to-groove:			
No. 1 (top-fire ring)	.0040"	.0070"	.0180"
No. 2	.0100"	.0130"	.0220"
No. 3 and 4	.0040"	.0070"	.0130"
Oil control rings:			
Gap ..	.0080"	.0230"	.0430"
Clearance	.0015	.0055"	.0080"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
V-71T Engines			
Piston:			
Height (centerline of bushing to top	3.5130"	3.5180"	
Diameter (above compression rings)	.4.2170"	4.2200"	
Diameter (.at skirt	4.2393"	4.2415"	
Clearance--piston skirt-to-liner	.0080"	.0118"	.0140"
Out-of-round		.0005"	
Taper		.0005"	
Compression rings:			
Gap (top ring)	.0230",	.0380"	.0600"1
Gap (No. 2, 3 and 4)	.0180"	.0430"	.0600"1
Clearance--ring-to-groove:			
Top Ring	0040"	.0070"	0100"
No. 2	0095"	.0130"	.0220"
No. 3	0075"	.0110"	.0150"
No. 4	0055"1	.0090"	.0130"
Oil control rings:			
Gap (two rings in lower groove)	.0050"	.0140"	.0340"
Gap (one ring in upper groove)	.0050"	.0140"	.0340"
Clearance (two rings in lower groove)...	.0015"	.0055"	.0080"
Clearance (one ring in upper groove)....	.0010"	.0035"	.0060"
Piston Pins (Trunk Pistons)			
Length	3.6050"	3.6200"	
Diameter-	1.4996"	1.5000"	1.4980"
Clearance--pin to piston bushing	.0025"	.0034"	.0100
Clearance--pin to conn. rod bushing	0025"	.0034"	.0100"
Clearance--end (pin-to retainer-- retainer with lock ring)	.0160"	.0640"	.0640"
Piston bushing--inside diameter	1.5025"	1.5030"	1.5050"
Connecting Rod			
Length--center-to-center of upper and lower bores	10.1240"	10.1260"	
Inside diameter (upper bushing)	1.5025"	1.5030"	1.5080"
Normal side clearance	0080"	.0160"	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Cross-Head Pistons and Rings V-71N and V-71T Engines			
Piston crown:			
Saddle-to-crown distance:			
N piston (18.7:1 compr. ratio)	2.7030"	2.7100"	
T piston (17:1 compr. ratio)	2.6730"	2.6800"	
Diameter:			
At top	4.2226"	4.2256"	
Below both compression rings	4.2391"	4.2421"	
Above and below seal ring groove	3.8850"	3.8950"	
Above and below bearing saddle	3.2360"	3.2370"	
Compression rings:			
Gap (top-fire ring)	.0230"	.0380"	.0600"
Gap (No. 2 and 3)	0180"	.0430"	.0600"
Clearance--ring-to-groove:			
*Top (Keystone fire ring)	.0010"	.0050"	.0070"
No. 2 (rectangular section)	.0100"	.0130"	.0220"
No. 3 (rectangular section)	.0040"	.0070"	.0130"
Seal ring:			
Gap (in skirt counterbore)	.0020"	.0210"	.0270"
Clearance	.0005"	.0030"	.0040"
Piston skirt:			
† Diameter	4.2428"	4.2450"	
Clearance--skirt-to-liner	.0045"	.0083"	.0120"
Seal ring bore	3.9200"	3.9240"	3.9260"
Piston pin bore	1.5000"	1.5030"	1.5040"
Oil control rings:			
Gap (two rings in lower groove)	.0080"	.0230"	.0430"
Gap (two rings in upper groove) (V-71N engine)	.0080"	.0230"	.0430"
Gap (one ring in upper groove) (V-71T engine)	.0050"	.0140,	.0340"
Gap (two rings in upper groove) (V-71T engine)	.0080"	.0230,	.0430"
Clearance (two rings in lower groove)	.0015"	.0055"	.0080"
Clearance (one ring in upper groove)	.0010"	.0035"	.0060"
Piston Pins (Cross-Head Piston)			
Length	3.6150"	3.6250"	
Diameter	1.4996",	1.500"	1.4980"
Slipper bearing (bushing):			
Thickness at center	.0870"	.0880"	.0860"
Clearance (edge of bushing to groove in piston)	.0005"	.0105"	.0120"

* Measured with Keystone fire ring flush with outside diameter of piston crown.
† Diameter above and below the piston pin may be 4.2414".

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Crankshaft			
Journal diameter--main bearing	4.4985"	4.5002"	
Journal diameter--conn. rod bearing	2.9985"	3.0002“	
Journal out-of-round		0005"	.0005"
Journal taper:			
Main bearing		0006"	.0006"
Connecting rod - full length		.0008”	
Connecting rod - half length...		.0004"	
§ Runout on journals--total indicator reading:			
6V-71 crankshaft (mounted on No. 1 and No. 4 journals):			
At No. 2 and No. 3 journals		0020”	
8V-71 crankshaft (mounted on No. 1 and No. 5 journals):			
At No. 2 and No. 4 journals		0020”	
At No. 3 journal		0040”	
12V-71 crankshaft (mounted on No. 1 and No. 7 journals):			
At No. 2 and No. 6 journals		0020"	
At No. 3 and No. 5 journals		0040”	
At No. 4 journal		0060"	
Thrust washer thickness	.1190”	.1220”	
End play (end thrust clearance)	.0040”	.0110”	.0180”
Connecting Rod Bearings			
Inside diameter (vertical axis)	3.0010”	3.0030”	
Bearing-to-journal clearance	.0008”	.0045",	.0045”a
Bearing thickness 900 from parting line	.1240”	.1245"	
Main Bearings			
Inside diameter (vertical axis)	4.5016"	4.5040”	
Bearing-to-journal clearance	.0014”	.0055”	.0055"
Bearing thickness 900 from parting line	.1545"	.1552"	
Camshaft			
Diameter (at bearing journals):			
Front and rear (6 and 12V engines)	1.4970”	1.4975"	
Front and rear (8V engines)	1.4960”	1.4965"	
Center and intermediate	1.4980”	1.4985"	
Runout at center bearing (when mounted on end bearings)		0020”	
End thrust	.0040”	.0120”	.0180”
Thrust washer thickness	.1190”	.1220”	

§ Runout tolerance given for guidance when regrinding crankshaft. When the runout on adjacent journals is in the opposite direction, the sum must not exceed .003" total indicator reading. When the runout on adjacent journals is in the same direction, the difference must not exceed .003" total indicator reading. When high spots of the 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
Camshaft Bearings			
Inside diameter:			
Front and rear	1.5010”	1.5010”	
Center and intermediate	1.5010”	1.5030”	
Clearance--bearing-to-shaft:			
Front and rear (6 and 12V engines)	.0025"	.0040"	.0060”
Front and rear (8V engines)	.0035”	.0050”	.0060”
Center and intermediate	.0025”	.0050”	.0090”
Outside diameter:			
Front and rear	2.1875”	2.1880”	
Center and intermediate	2.1840,	2.1860”	
Diameter of cylinder block bore	2.1875”a	2.1889"	
Clearance--bearings-to-block:			
Front and rear	.00054” press.	00141 loose	
Intermediate	.0015”	.0045”	
Camshaft Gears			
Inside diameter .	1.1865”	1.1875”	
Clearance--gear-to-shaft	.00159” press	.0000”	
Backlash	.0020,	.0080”	.0100"
Idler Gear			
Backlash	.0020“	.0080”	.0100”
Pre-load--Variation on pull 2 lbs. 11 o z	1/2 lb.	4 lbs.	
Crankshaft Timing Gear			
Inside diameter	5.2490f,	5.2510,	
Clearance--gear-to-shaft	.0011 press	.001" loose	
Backlash	.0020,	.0080,	.0100”
Blower Drive Gear (and Left Bank Accessory Drive Gear)			
Backlash	.0020”	.0080”	0100”
Inside diameter (support bushing)	1.6260"	1.6265"	
Hub diameter (at bearing)	1.6240”	1.6250"	
Hub-to-support bushing clearance	.0010”	.0025"	.0050”
Thrust washer thickness	2350”	.2450”	
Thrust bearing thickness	.0590”	.0610“	
End thrust	.0050”	.0100”	.0120”
Cylinder Head			
Flatness--transverse			.0040”
Flatness--longitudinal (6V engine)			.0055",
Flatness--longitudinal (8V engine)			.0080,
Flatness--longitudinal (12V engine)			.0100’
Distance between top deck and fire deck	3.5560”	3.5680”	3.5360”
Water nozzles	.0312" recess	flush	
Cam follower bores	1.0620”	1.0630”	1.0650”
Exhaust Valve Insert Counterbore:			
Diameter (2 valve)	1.6260"	1.6270”	
Diameter (4 valve)	1.2600”	1.2610”	
Depth (2 valve)	.3705”	.3845”	
Depth (4 valve)	.3380”	.3520”	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Exhaust Valve Seat Inserts			
Outside diameter (2-valve)	1.62751,	1.6285"	
Outside diameter (4-valve)	1.2615",	1.2625"	
Seat width (2-valve)	.0625"	.0937"	.0937"
Seat width (4-valve)	.0468"	.0937"	.0937"
Valve seat runout		. .0020"	.0020"
Exhaust Valves			
Stem diameter (2-valve)..	.3417"	.3425"	.3405"
Stem diameter (4-valve)	.3100"	.3105"	.3090"
Valve head-to-cylinder head:			
30° (former 2-valve and 4-valve)	.002" recess.	.028" protr.	
300 (current 2-valve and 4-valve)	.023" recess.	.006" protr.	.038" recess.
Valve Guides			
Height above cylinder head (2 valve)	1.5300"	1.5300"	
Height above cylinder head (4 valve)	.8800"	.8800"	
Height above cylinder head (4 valve-machined guide)	6900"	.6990"	
Diameter--inside (2-valve)	.34459	.34559	.3465"
Diameter--inside (4-valve)	.3125"	.31359	.3140"
Clearance--valve-to-guide (2-valve)	.0020"	.003R"	.0060"
Clearance--valve-to-guide (4 valve)	.0020"	.0035"	.0050"
Valve Bridge Guides			
Height above cylinder head (4-valve)	2.0400"	2.0400"	
Rocker Arms and Shafts			
Diameter--rocker shaft	.8735"	.8740"	
Diameter--inside (rocker arm bushing)	8750	.8760"	
Clearance--shaft-to-bushing	.0010"	.0025"	.0040"
Cam Followers			
Diameter	1.0600"	1.0610"	
Clearance--follower-to-head	.0010"	.0030"	.0060"
Rollers and pins:			
Clearance--pin-to-bushing	.0013"	.0021"	.010" Horiz.
Side clearance--roller to follower	.0110"	.0230"	.0230"

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER TORQUE Nm
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 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
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
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 SIZE	TORQUE (lb - ft)	TORQUE (Nm)
Cam follower guide bolt..	1/4 -20	12-15	16-20
Injector control shaft bracket bolt	1/4 -20	10-12	14-16
Air box cover bolt	5/16-18	8-12	11-16
Oil pan bolts (lower pan)	5/16-18	10-12	14-16
Exhaust valve bridge adjusting screw lock nut................	5/16-24	20-25	27-34
Idler gear bearing retainer bolts	5/16-24	24-29	33-39
Camshaft end bearing bolts	3/8 -16	35-40	47-54
Flywheel housing bolts..	3/8 -16	25-30	34-41
Front accessory drive pulley bolt	3/8 -16	25	34
Front end plate bolt (two bolts into water jacket plug)	3/8 -16	20-25	27-34
Idler gear hub and spacer bolts	3/8 -16	40-45	54-61
Injector clamp bolts	3/8 -16	20-25	27-34
Oil pan bolts (upper)	3/8 -16	15-20	20-27
Accessory drive disc to camshaft gear bolt	3/8 -24	45-50	61-68
Accessory drive hub to camshaft gear bolt	3/8 -24	45-50	61-68
Blower drive support bolts and nuts	3/8 -24	25-30	34-41
Balance weight-to-camshaft gear bolt............................	3/8 -24	15-18	20-24
Balance weight-to-camshaft gear lock nut	3/8 -24	25-30	34-41
Balance weight-to-camshaft gear plain nut	3/8 -24	18-22	24-30
Balance weight-to-camshaft gear slotted nut	3/8 -24	28-32	38-43
Camshaft intermediate bearing lock screw	3/8 -24	15-20	20-27
Crankshaft front cover bolts	3/8 -24	25-30	34-41
Exhaust manifold outlet flange nuts (brass)	3/8 -24	20-25	27-34
Flywheel housing bolts (threaded into plug nuts)	3/8 -24	25-30	34-41
Flywheel housing cover (small hole)	3/8 -24	30-35	41-47
Fuel pipe nuts	3/8 -24	12-15	16-20
Injector clamp nut	3/8 -24	20-25	27-34
Left bank accessory drive support bolts and nuts	3/8 -24	25-30	34-41
Water manifold cover nuts	3/8 -24	20-25	27-34
Flywheel housing “cover (large hole)	7/16-14	30-35	41-47
Generator drive bearing retaining bolt	7/16-14	30-35	41-47
Generator drive oil seal retaining bolt	7/16-14	30-35	41-47
Rear accessory drive pulley bolt	7/16-14	35	47
Stabilizer bolts	7/16-14	70-75	95-102
Connecting rod nut (castellated)	7/16-20	65-75	88-102
Connecting rod nut (Lubrite)	7/16-20	60-70	81-95
**Cross-head piston pin to conn. rod bolt	7/16-20	55-60	75-81
Exhaust manifold nuts	7/16-20	30-35	41-47
Fuel manifold connector nuts	7/16-20	30-35	41-47
#Fuel manifold connectors (Nylon insert)	7/16-20	30-35	41-47
Fuel manifold connectors (steel washer)	7/16-20	40-45	54-61

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb - ft)	TORQUE (Nm)
Cranksahft front cover bolts	1/2- 13	80-90	108-122
Flywheel housing bolts	1/2 -13	90-100	122-136
Flywheel housing cover (large hole)	1/2 -13	30-35	41-47
Generator drive bearing retaining bolt	1/2 -13	30-35	41-47
Generator drive oil seal retaining bolt	1/2 -13	30-35	41-47
Idler gear hub and dummy hub bolt	1/2 -13	80-90	108-122
@Rocker shaft bolts	1/2 -13	90-100	122-136
**Camshaft gear bolt (right-bank - 300M)	9/16-18	180-190	244-258
**Flywheel bolts (see Sect. 1.4)	9/16-18		
**Cylinder head bolts	5/8 -11	175-185	238-251
**Main bearing bolts (assembly) (see Section 1.3.4)	5/8 -11		
**Main bearing bolts (boring)	5/8 -11	165-175	224-238
**Cylinder head nuts	5/8 -18	175-185	238-251
Rear Accessory drive pulley nut (blower driven)	3/4 -16	120-140	163-190
Rear Accessory drive pulley nut (cam driven)	3/4 -16	150-170	204-231
Crankshaft end bolt ...	1-14	290-310	393-421
Camshaft nut	1 1/8 -18	300-325	407-441
Blower drive gear hub nut	17/16-16	50-60	68-81
Left bank accessory drive gear nut	1 7/16-16	50-60	68-81

*Stake nut after tightening.
@75-85 Ib-ft (102-115 Nm) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft bracket.
**Lubricate at assembly with International Compound No. 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12.8000A).

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

NPTF SIZE THREAD	TORQUE (Ib-ft)	Nm	NPTF SIZE THREAD	TORQUE (Ib-ft)	Nm
1/8	10-12	14-16	3/4	33-37	45-50
1/4	14-16	19-22	1	75-85	102-115
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

SPECIAL PLUG TORQUE SPECIFICATIONS

Oil gallery plug........... .3/8 " Dryseal PTF thread	tAssemble with max. 0.0625 " protrusion from surface
Cylinder head (side)...............................3/8-16"	Assemble flush to 0.0625 " protrusion from surface
Cylinder head (end) .... 3/4 " Dryseal PTF-SAE	Flush to 0.1250 " recessed
Cylinder head bolt hole ....5/8 "-11	§50-60 lb-ft (68-81 Nm) torque
Core hole plug (air box floor) ....1 3/4 "-16	150-180 lb-ft (204-244 Nm) torque
Core hole plug (air box floor).............2 1/2 "-16	230-270 lb-ft (312-366 Nm) torque
Oil drain plug (Nylon washer).. ....18mm	25-35 lb-ft (34-47 Nm) torque

*Apply sealing compound to plugs used without gaskets or teflon.
T After installation, a 0.2187" diameter rod inserted in oil line must pass inner face of plug.
§ Apply Locktite sealant, or equivalent, *after* plug is installed (not on threads).

STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE (lb-ft)	TORQUE (Nm)	HEIGHT
Cylinder head stud	75 min.	102 min.	4.37 "±.0312 "
Exhaust manifold stud	25-40	34-54	
Injector clamp stud..	10-25	14-34	
Water hole cover stud...	10-25	14-34	

SPRING SPECIFICATIONS

SPRING	REPLACE WHEN LOAD is LESS THAN		
	lbs.	N	HEIGHT
Cam follower (11 coils - .177 " wire)...............................	172	765	@2.1250"
Cam follower (11 1/2 coils - .162 "wire)	133	591	@2.1094"
Exhaust valve (two-valve cylinder head)........................	25	111	@2.2000"
§ Exhaust Valve and bridge guide			
(9 3/4 coils - 1.35 "wire)(former)....................................	79	351	@1.4160"
§ Exhaust Valve (8 3/4 coils - .148 "wire) (current).........	25	111	@1.8000"

§ Four-valve cylinder head

SERVICE TOOLS

TOOL NAME	TOOL NO.
Cylinder Block	
Aftercooler Water Inlet Adaptor Remover and Installer	J 25275
Block Air Box Plug (Adaptor) Installer	J 28711
Cup Plug Installer (2 112", diameter	J 24597
Cylinder Block Air Box Plugging Tool	J 29571
Cylinder Block Head Bolt Depth Gage	J 26244
Cylinder Block Head Bolt Hole Plug Tool Kit	J 26620
Cylinder Block Line Boring Tool	J 29005
Cylinder Checking Gage and Master Ring Set	J 9353
Cylinder Diameter Checking Gage	J 5347-01
Master Ring Gage for Block Bore	J 8386-01
Cylinder Hone Set (2 1/2", to 5 ¾)	J 5902-01
Dial Bore Gage Master Setting Fixture	J 23059-01
Dial Indicator Set	J227
Diesel Engine Parts Dolly	J638
Engine Overhaul Stand (6V and 8V Engines Only	J 6837-01
Engine Overhaul Stand (12V Engines)	J9389-04
Engine Overhaul Stand Adaptor (6V and 8V Engines Only)	J 8601-01
Engine Overhaul Stand Adaptor (12V Engines Only)	J 8650
Handle	J 7792
Special Plug Remover (dry cylinder block)-	J 21996-01
Special Plug Remover (water below port cylinder block).	J 23019
Cylinder Head	
Cam Follower Service Fixture	J 5840-01
Cylinder Head Guide Studs (Set of 2)	J 9665
Cylinder Head Holding Plate Set	J 3087-01
Cylinder Head Lifting Fixture	J 22062-01
Engine Barring Tool	J 22582
Feeler Gage Set (.0015", to .015")	J 3172
Feeler Stock (.0015")	J 2318
Inject Fuel Hole Brush	J815
Pressure Checking Tool	J2845
Push Rod Remover (set of 3)-	J 3092-01
Slide Hammer	J269O0
Socket	J892O0
Spring Tester	J227800
Valve Bridge Holding Fixture	J 21772
Valve Bridge Guide Remover (Broken	J 7453
Valve Bridge Guide Remover Set (Press Fit	J 7091-01
Valve Bridge Guide Installer (Press Fit	J 7482
Valve Bridge Guide Remover and Installer (Threaded - 4 Valve Head)-	J 6846
Valve Guide Cleaner	J5437
Valve Guide Installer (2-Valve Head)	J 4144
Valve Guide Installer (450 2-Valve Head)-	J 9530
Valve Guide Installer (450 4-Valve Head)-	J 9729
Valve Guide Installer (Machined 4-Valve Head)-	J 21520
Valve Guide Installer (15U 4 - Valve Head)-	.J 6570
Valve Guide Remover (2-Valve Head)-	.J 267
Valve Guide Remover (4-Valve Head)-	.J 6569
Valve Seat Dial Gage	J61652

TOOL NAME	TOOL NO.
Valve Seat Grinder	J8165-1
Valve Seat Grinder Adaptor Set (2-Valve Head)	.J 8165-8
Valve Seat Grinder Adaptor Set (4-Valve Head)	J 6390-02
Valve Seat Insert Installer (2-Valve Head)	J 1736
Valve Seat Insert Installer (4-Valve Head)	J 24357
Valve Seat Insert Remover (31° 2-Valve Head)	J 4824-03
Valve Seat Insert Remover (4-Valve Head)	J 6567-02
Valve Spring Checking Gage	J 25076-01
Valve Spring Compressor	J 7455

Crankshaft

TOOL NAME	TOOL NO.
Crankshaft Front Oil Seal Installer	J 9783
Crankshaft Oil Seal Expander	J 22425
Crankshaft Rear Oil Seal Installer	J 9727
Crankshaft Rear Oil Seal Expander - Oversize (6, 8 and 12V Front Cover)	J 4195-01
Crankshaft Rear Oil Seal Service Sleeve Installer (6, 8 and 12V)	J4194-01
Dial Indicator Set	J 5959-01
Driver Handle	J 3154-1
Driver Handle	J 8092
Engine Barring Too[	J 22582
Micrometer Ball Attachment	J 4757
Universal Bar Type Puller	J 24420
Flywheel	
Flywheel Lifting Fixture	J 25026
Flywheel Lifting Tool	J6361-01
Oil Seal Removing and Replacing Tool Set	J 3154-04
Slide Hammer Set	J 5901-01

Flywheel Housing

TOOL NAME	TOOL NO.
Drive Handle	J 8092
Flywheel Housing Aligning Studs (Set of 4)	J1927401
Flywheel Housing Concentricity Gage Set	J 9737-01
Oil Seal Expander	J 22425
Oil Seal Expander (Oversize)	J 4195-01

Piston , Connecting Rod and Cylinder Liner

TOOL NAME	TOOL NO.
Connecting Rod Bushing Reamer Set	J 1686-03
Connecting Rod Holding Fixture	J 7632
Connecting Rod Spray Nozzle Remover	J 8995
Cylinder Checking Gage and Master Ring Set	J 9353
Cylinder Hone Set (2 1/2" to 5 3/4" range)	J 5902-01
Cylinder Liner Hold-Down Clamp	J 21793-01
Cylinder Liner Remover Set	J 21716
Dial Bore Gage Setting Fixture	J 23059-01
Dial Indicator Set	J 22273
Feeler Gage Set	J 3172
Fire Ring Groove Gage (cross-head piston)	J 24599
Master Ring Gage (4.2500 “)	J 5580-1
Micrometer Ball Attachment	J 4757

TOOL NAME	TOOL NO.
Piston and Connecting Rod Bushing Installer and Remover Set	J 1513-02
Piston Bushing Reamer Set	J 3071-01
Piston Bushing Remaining Fixture	J 5273
Piston Crown Identification Gage (cross-head)	J 25397
Piston Pin Alignment Tool (Cross-Head Piston)	J 24285
Piston Pin Retainer Installer (trunk-type piston)	J 24107-01
-Piston Pin Retainer Installer (cross-head piston)	J 23762
Piston Pin Retainer Leak Detector	J 23987-01
Piston Ring Compressor	J 3272-03
Piston Ring Remover and Installer	J 8128
Piston to Liner Feeler Gage Set	J 5438-01
Seal Ring Compressor (cross-head piston)	J 23453

Camshaft

TOOL NAME	TOOL NO.
Accessory Drive Hub Oil Seal Aligning Tool	J 21166
Alternator Drive Step-Up Gear Alignment Gage	J 29893
Balance Weight Cover Oil Seal Installer	J 9791
Camshaft Cup Plug Installer	J 24094
Camshaft Gear Puller	J 1902-01
Camshaft Gear Puller Adaptor Plate Set	J 6202-01
Camshaft and Oil Pump Gear Replacer	J 1903
Dial Indicator and Attachment Set	J 5959-01
Puller Adaptor	J 7932
Slide Hammer Set	J 6471-02
Spring Scale	J 8129
Universal Bar Type Puller	J 24420

SECTION 2

FUEL SYSTEM AND GOVERNORS

CONTENTS

FUEL SYSTEM

The fuel system (Fig. I) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the-cylinder head), fuel pump, fuel strainer, fuel filter 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 and into the inlet fuel manifold, then through fuel pipes into the inlet side of each fuel injector.

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines.
injectors to the fuel return manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold in one of the cylinder heads to maintain the fuel system pressure. Refer to Section 13.2 for the size fitting required.

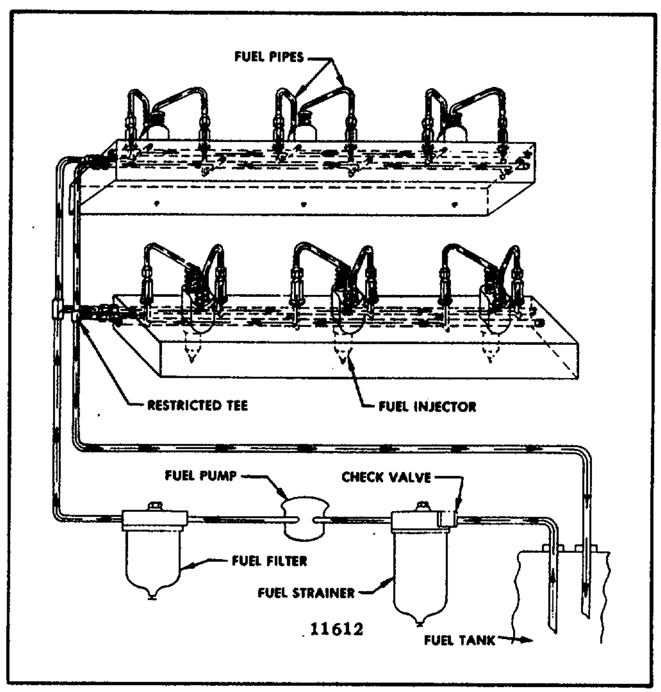


FIG. 1 - Schematic Diagram of Typical Fuel System

FUEL INJECTOR (Crown Valve)

The fuel injector (Fig. 1) 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.

The fuel injector performs four functions:

1. Creates the high fuel pressure required for efficient injection.

2. Meters and injects the exact amount of fuel required to handle the load.

3. Atomizes the fuel for mixing with the air in the combustion chamber.

4. Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small

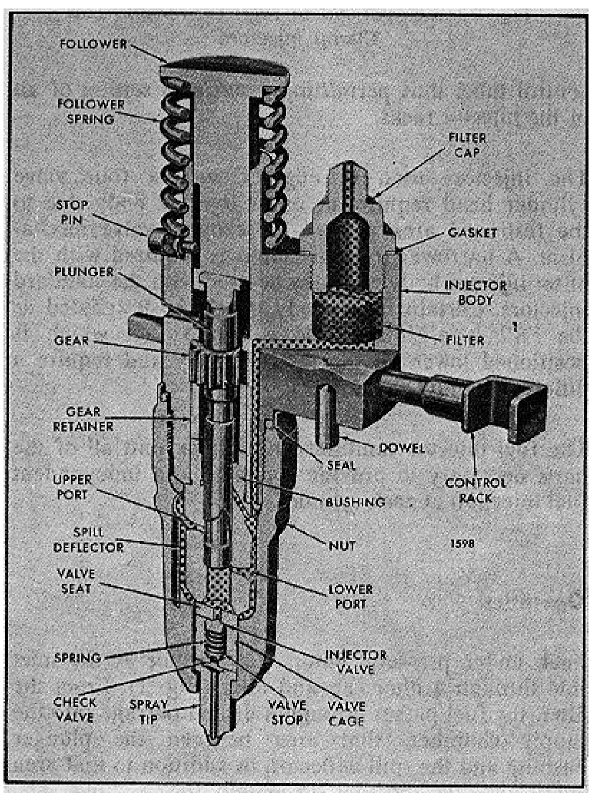


FIG. 1 - Fuel Injector Assembly

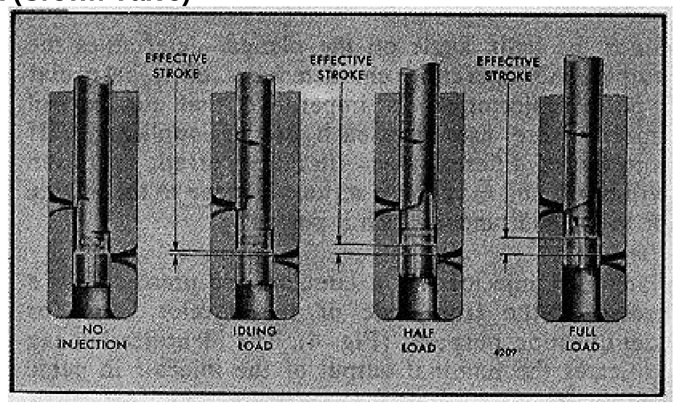


FIG. 2 - Fuel Metering from No-Load to Full-Load

quantity of accurately metered and finely atomized fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 2 illustrates the fuel metering from no-load to full-load by rotation of the plunger in the bushing.

Figure 3 illustrates the phases of injector operation by the vertical travel of the injector 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

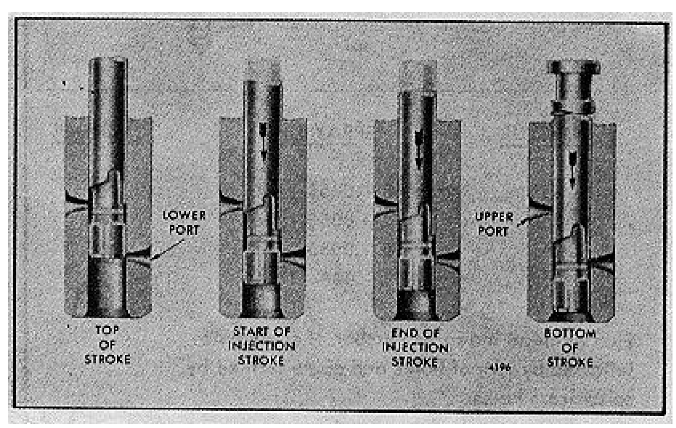


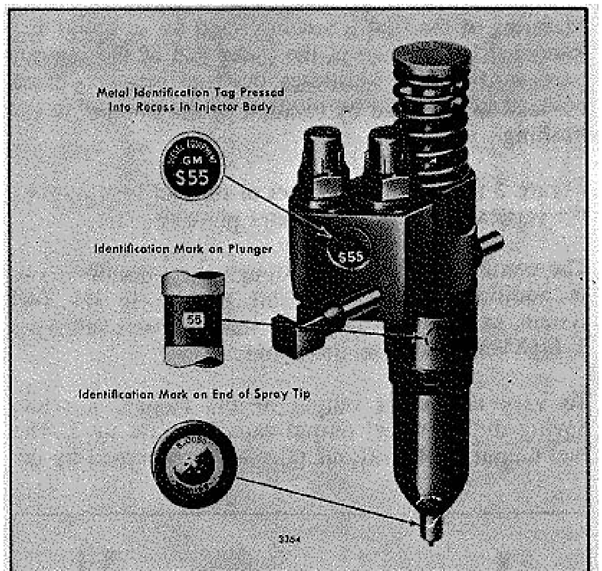
FIG. 3 - Phases of Injector Operation Through Vertical Travel of Plunger

helix angle of the plunger and the type of spray tip used. Refer to Fig. 4 for the identification of the injectors and their respective plungers and spray tips.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, 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. 4). The identification tag indicates the nominal output of the injector in cubic millimeters.

Each injector control rack (Fig. 1) 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



INJECTOR	SPRAY TIP*	PLUNGER
S55	8—.0055—165	55
S60	8—.0055—165	6H
S65	8—.0055—165	65
S70	7—.006—165H	7H

*First numeral indicates number of spray holes, followed by size of holes and angle formed by spray from holes.

FIG. 4 - Injector Identification Chart

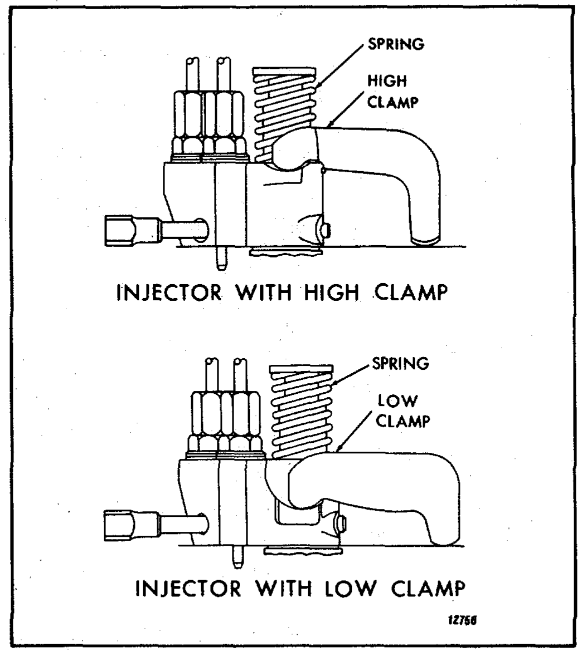


FIG. 5 - Comparison of High Clamp and Low Clamp Injectors

control tube, thus permitting a *uniform setting of all* of the injector racks.

The injectors used in engines with a four valve cylinder head require an offset injector body due to the restricted area around the exhaust valve mechanism. A narrower injector clamp is required with the offset injector body and may be used with the standard injectors. Certain offset body injectors, designated as the "S" type, incorporate a clamp seat which is positioned lower on the injector body and require a different clamp (Fig. 5).

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 pressure, enters the injector at the inlet side through a filter cap and filter (Fig. 1). 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, the bore of which is open to the fuel supply in the annular

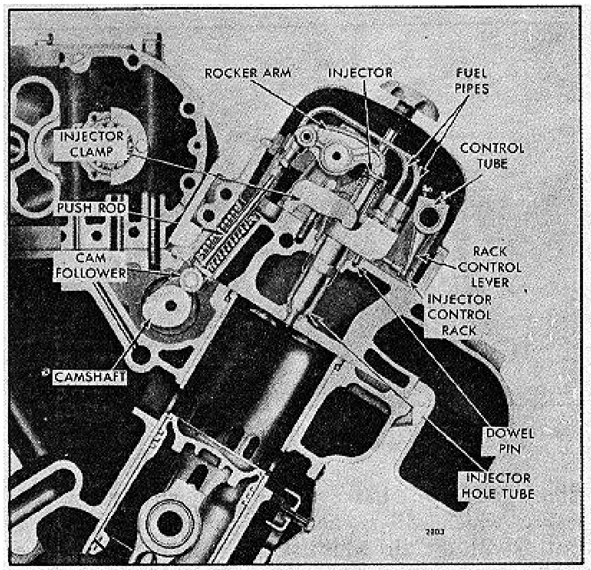


FIG. 6 - Fuel Injector Mounting

chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced 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 closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, the injector valve is lifted off of its seat and the fuel is forced through small orifices. in the spray tip and atomized into the combustion chamber.

A check valve, mounted in the spray tip, prevents air leakage from the combustion chamber into the fuel injector if 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. Figure 3 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. Figure 2 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

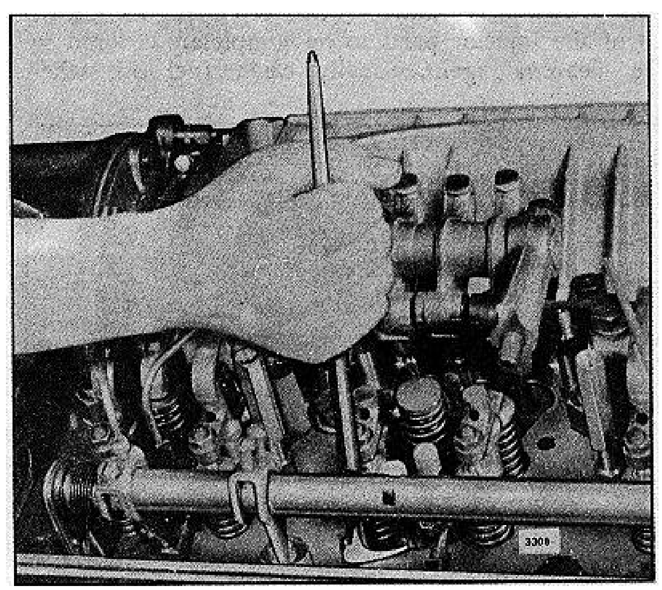


Fig. 7 Removing Injector from Cylinder Head

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 of 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 the 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 door and windows. A suitable air outlet will remove solvent fumes along with the outgoing air. Also provide a source for 110 volt alternating current electric power.

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 ell of the injector parts to be completely covered by the cleaning agent, usually clean fuel oil, when

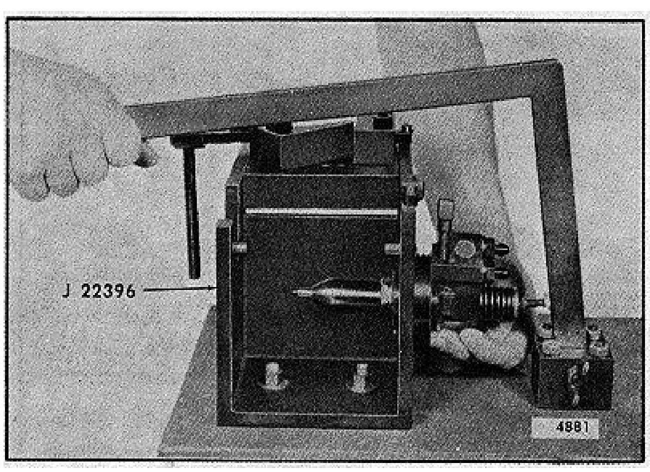


FIG. 8 - Checking Rack and Plunger For Free Movement using Tool J 22396

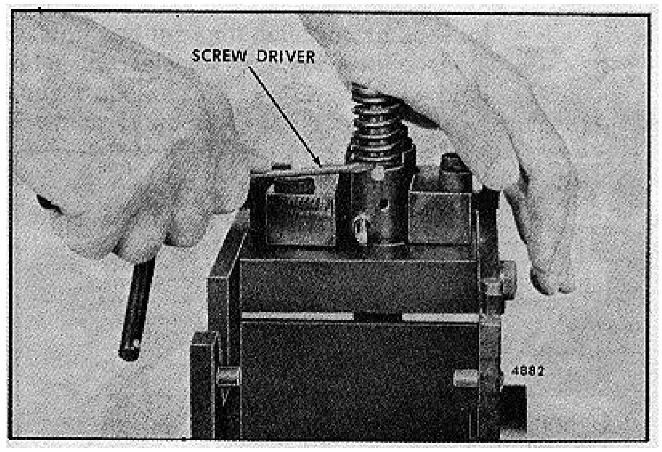


FIG. 9 - Removing Injector Follower Stop Pin

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 cleaning tissue is a good, inexpensive 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 injector. Also protect the fuel pipes and fuel connectors from 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 assembly 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.

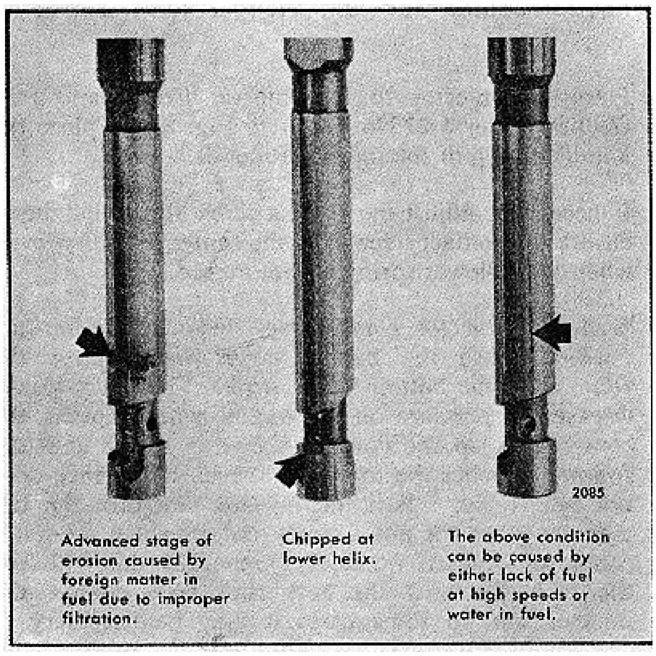


FIG. 10 Unusable Injector Plungers

NOTE: 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.

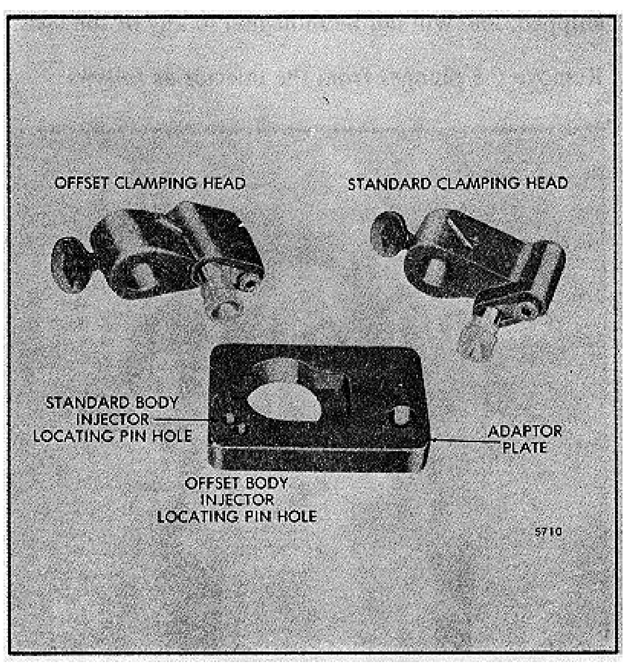


FIG. 11 - Injector Tester J 23010 Clamping Heads

Remove Injector.

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

> **NOTE:** 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. Crank the engine to bring the outer ends of the push rods of the injector and valve rocker arms in line horizontally.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws on the injector rack control lever and slide the lever away from the injector.

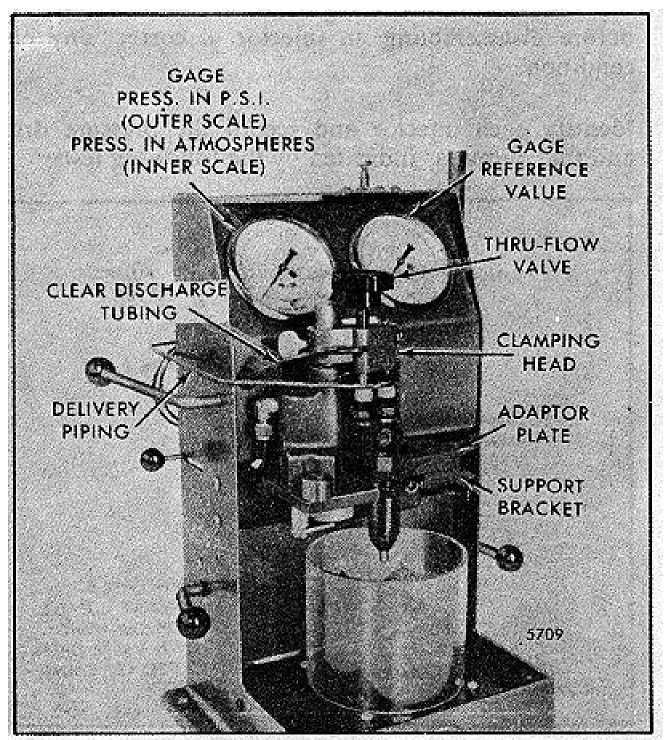


FIG. 12 Injector Installed in Tester J 23010 with Clamping Head

7. Lift the injector from its seat in the cylinder head (Fig. 7).

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean fuel oil and dry it with compressed air.

TEST INJECTOR

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.

If inspection does not reveal any external damage, then perform a series of tests to determine the condition of the injector to avoid unnecessary overhauling. Tests must be performed using injector test oil J 26400.

An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails to pass one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure drop and fuel output as indicated by the following tests:

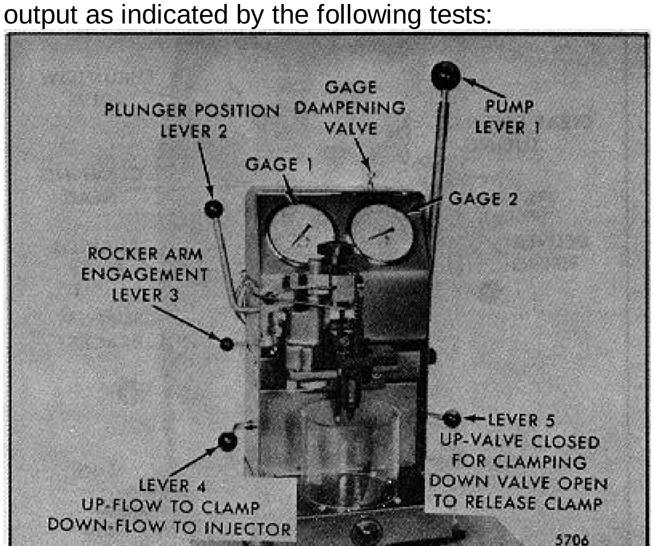


FIG. 13 Injector in Position for Testing with Tester J 23010

Injector Control Rack and Plunger Movement Tests

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center *of* the follower when the follower spring is compressed. With the injector control rack held in the no-fuel position, push the handle down and 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 as shown in Fig. 8 until the follower reaches the top of its travel. 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.

Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger' checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests.

Remove the plunger from the injector as follows:

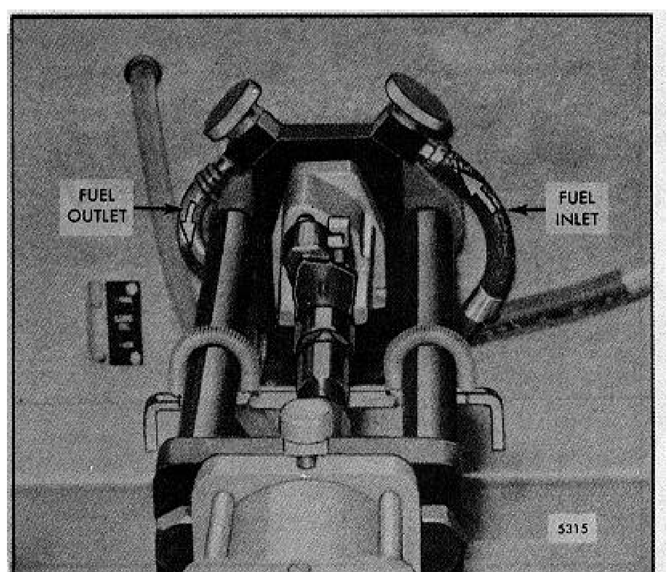


FIG. 14 - Position of Calibrator Fuel Flow Pipes

1. Support the injector, right side up, in holding fixture J 22396.

2. Compress the follower spring. Then raise the spring above the stop pin with a screw driver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.

3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.

4. Inspect the plunger. If the plunger is chipped (Fig. 10), replace the plunger and bushing assembly.

5. Reinstall the plunger, follower and spring.

Installing Fuel Injector in Tester J 23010

1. Select the proper clamping head (Fig. 11). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 12).

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.

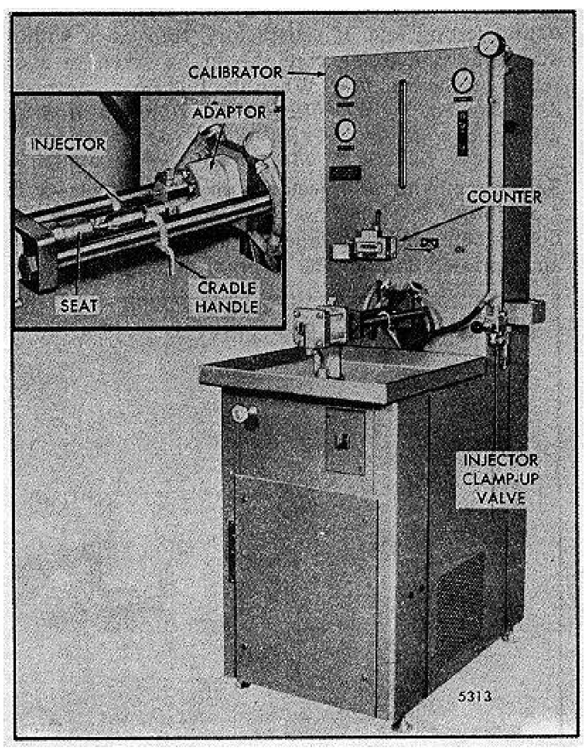


FIG. 15 - Injector in Calibrator J 22410

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 injector.

5. Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 11).

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. 13 and position the tester levers as follows:

Lever 2 up and to the rear

Lever 3 in the rear detent position

Lever 4 up (horizontal)

Lever 5 up (horizontal)

2. Align the clamping head nylon seals over the injector filter caps (Fig. 12).

3. Back off the Thru-Flow valve about half-way to allow the self-aligning nylon seals to seat properly during the clamping operation.

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.

> **NOTE:** The Thru-Flow valve should still turn freely. If it does not, turn the valve counter-clockwise until it rotates freely and reapply clamping pressure.

> **NOTE:** 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.

Injector Valve Opening and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the injector valve opens and fuel injection begins.

1. Clamp the injector properly and purge the air from the system.

2. Close the Thru-Flow valve to allow pressure to build in gage 1 (do not overtighten or the nylon seal will be damaged).

3. With the fuel rack in the full-fuel position, operate pump lever I rapidly until the valve opening pressure of 450 to 850 psi (3 100 to 5 857 kPa) is reached and the spray pattern occurs. Note if all spray tip holes are open by the pattern of the spray produced.

Injector High Pressure Test

This test checks for leaks at the filter cap gaskets, body plugs and nut seal ring.

1. Clamp the injector properly and purge the air from the system.

2. Close the Thru-Flow valve, but do not overtighten.

NOTE: Be sure lever 4 is in the *down* position before operating pump lever 1.

3. Move lever 2 to the forward, horizontal position.

4. Operate pump lever 1 to build up to 1600-2000 psi-(11 024-13 780 kPa) on gage 1 and check for leakage at the filter cap gaskets, body plugs and nut seal ring.

Injector Pressure Holding Test

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 and purge the air from the system.

2. Close The Thru-Flow valve, but do not overtighten.

3. Move lever 2 to the rear, horizontal position.

4. Operate pump lever 1 until gage I reads approximately 500 psi (3 445 kPa).

5. Move lever 4 to the up position.

6. Time the pressure drop between 450 to 250 psi (3 100 to 1 723 kPa). If the pressure drop occurs in less than 15 seconds, leakage is excessive.

Refer to the *Trouble Shooting Charts* in Section 2.0 if the fuel injector does not pass any of the preceding tests.

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 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.

Fuel Output Test

Perform the injector fuel output test in calibrator J 22410.

When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine, note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the braided fuel

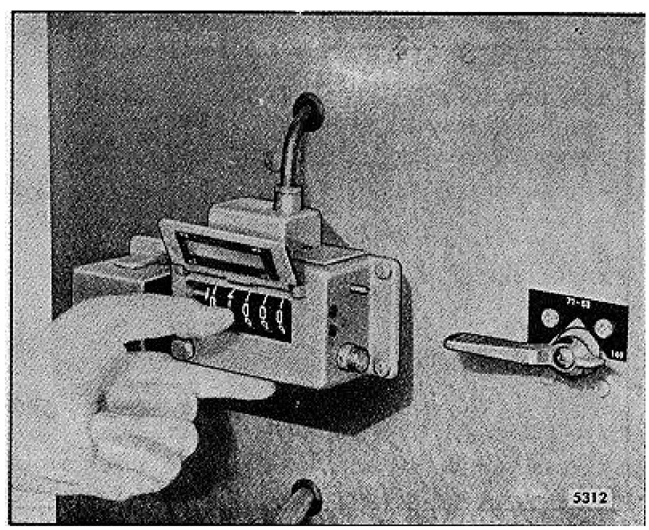


FIG. 15 Setting Calibrator Stroke Counter

Injector	Calibrator J 22410	
	Min.	Max.
S55	55	59
S60	59	63
S65	64	68
S70	71	75

FIG. 17 Fuel Output Check Chart

inlet tube and the plastic fuel outlet tube on the calibrator (Fig. 14) depends on the adaptor being used and the direction of fuel flow through the injector.

Calibrator J 22410

To check the fuel output. operate the injector in calibrator J 22410 (Fig. 15) as follows:

> **NOTE:** Place the cam shift index wheel and fuel flow]ever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95-105°° F (35-40 C).

1. Place the proper injector adaptor between the tie

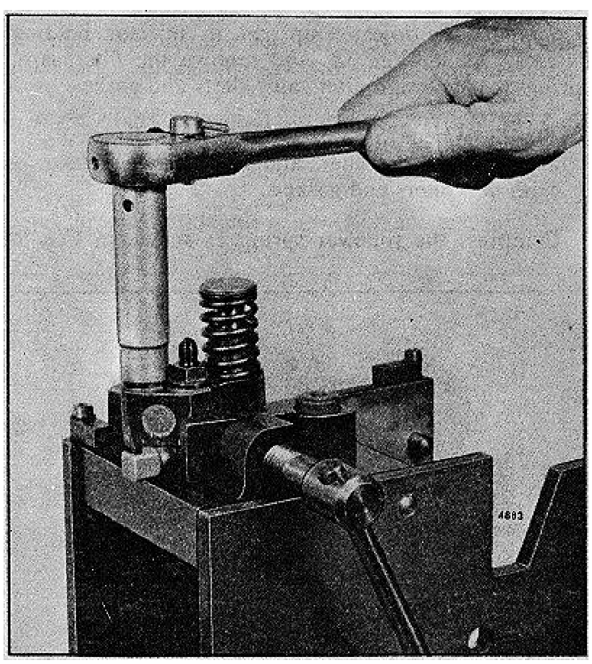


FIG. 18. Removing or Installing Filter Cap

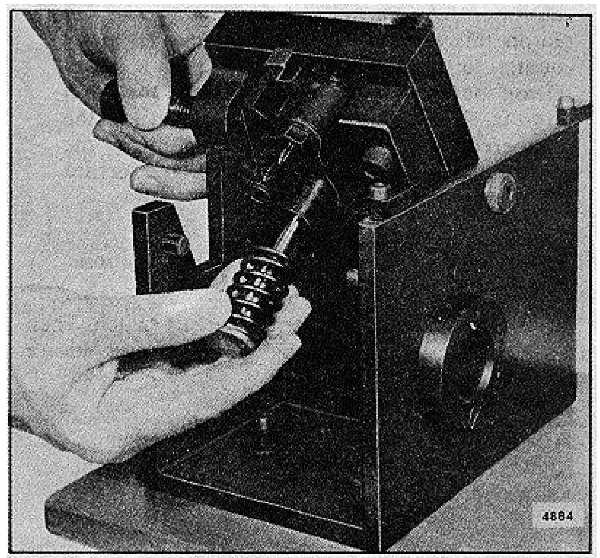


FIG. 19 Removing or Installing Plunger Follower, Plunger and Spring

rods and engage it with the fuel block locating pin. Then slide the adaptor forward and up against the fuel block face.

2. Place the injector seat J 22410-226 into the permanent seat (cradle handle in vertical position). Clamp the injector into position by operating the air valve.

> **NOTE:** Make sure the counter (Fig. 16) on the

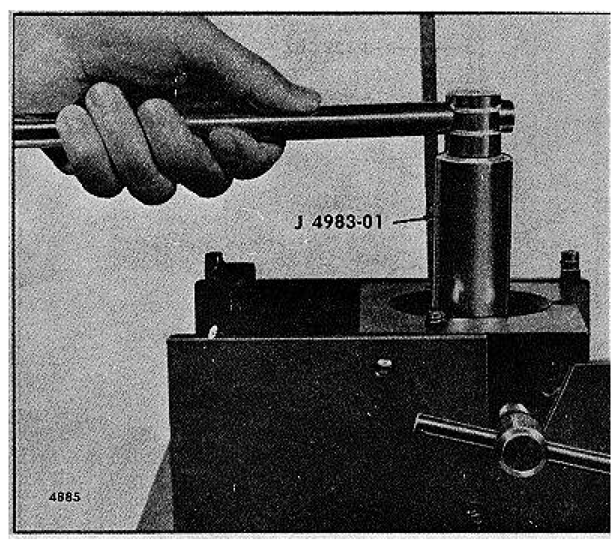


FIG. 20 - Removing Injector Nut using Tool J 4983-01

calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to l000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

3. Pull the injector rack out to the no-fuel position.

4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

NOTE: The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

5. 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.

6. After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.

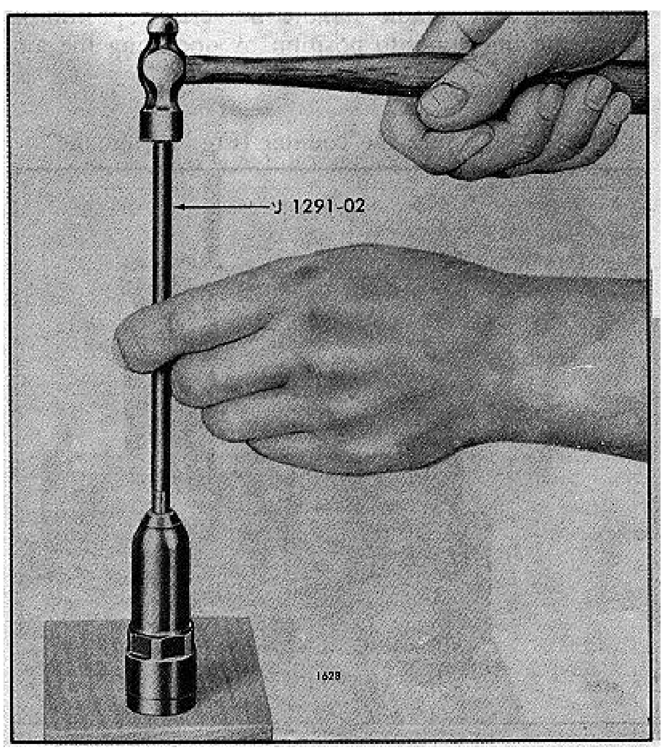


FIG. 21 Removing Spray Tip from Injector Nut using Tool J 1291-02

7. Shut the calibrator off (the calibrator will stop in less time at full-fuel).

8. Observe the vial reading and refer to Fig. 17 to determine whether the injector fuel output fa11s within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to Trouble Shooting Chart 3 and Shop Notes in section 2.0 for the cause and remedy.

NOTE: Refer to Section 2.0 for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 18) and remove the filter caps, springs (early design filter cap), filters and gaskets.

NOTE: Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets.

2. Compress the follower spring as shown in Fig. 9.

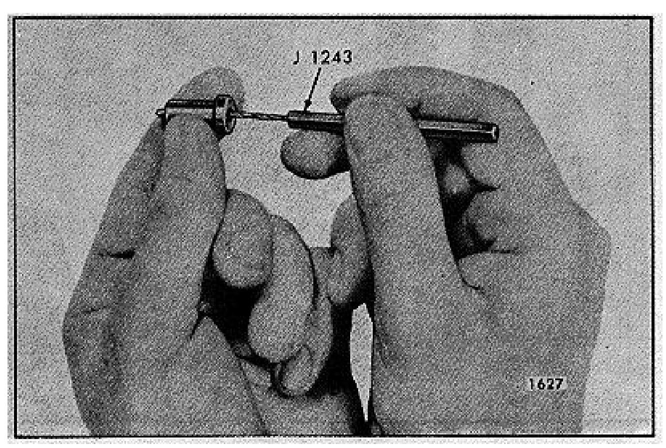


FIG. 22 - Cleaning Injector Spray Tip using Tool J 1243

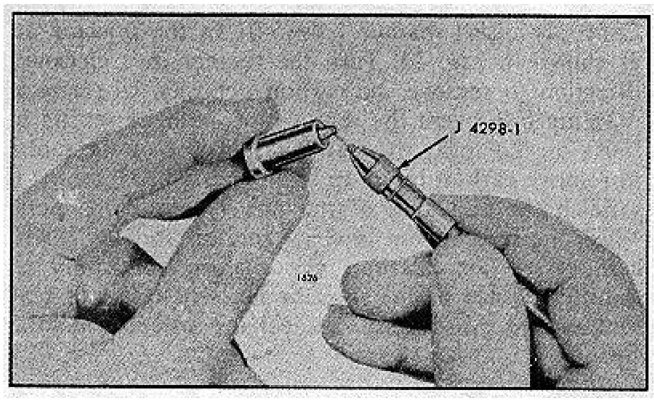


FIG. 23 Cleaning Spray Tip Orifices using Tool J 4298-1

Then raise the spring above the stop pin with a screw driver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to Fig. 19 and remove the plunger follower, plunger and spring as an assembly.

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (Fig. 20).

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.

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 as shown in Fig. 2 1.

6. Refer to Fig. 31 and remove the spill deflector and the seal ring from the injector nut.

7. Remove the plunger bushing, gear retainer and gear from the injector body.

8. Withdraw the injector control rack from the injector body.

Clean Injector Parts

Since most injector difficulties 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.

Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. Do not use waste or rags for cleaning purposes. Clean out all of the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation. Methyl Ethyl Ketone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 1243 (Fig. 22). Turn the reamer in a clockwise direction to remove the carbon deposits. Wash the spray tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1, using the proper size spray tip cleaning wire (Fig. 23). Use wire J 21459 to clean .005" diameter holes, wire J 21460 to clean .0055" diameter holes and J-21461 wire to clean .006" diameter holes.

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.

The exterior surface of an injector spray tip may be

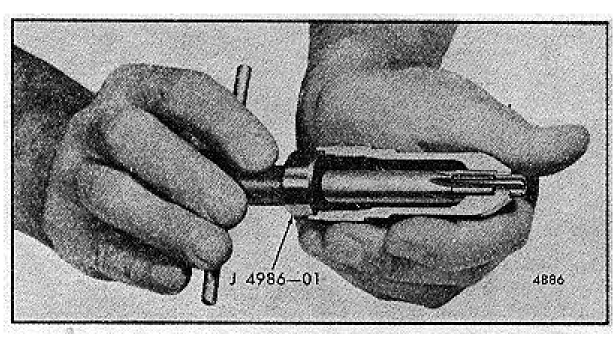


FIG. 24 - Cleaning Injector Nut Spray Tip Seat using Tool J 4986-01

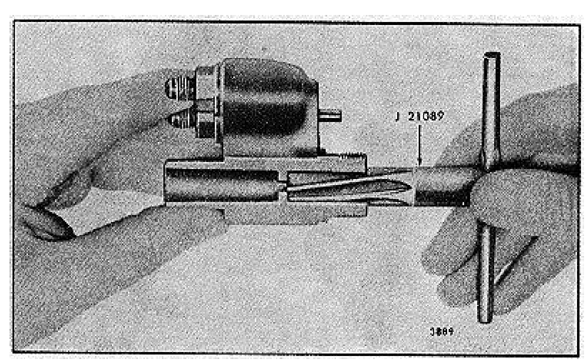


FIG. 25 - Cleaning Injector Body Ring using Tool J 21089

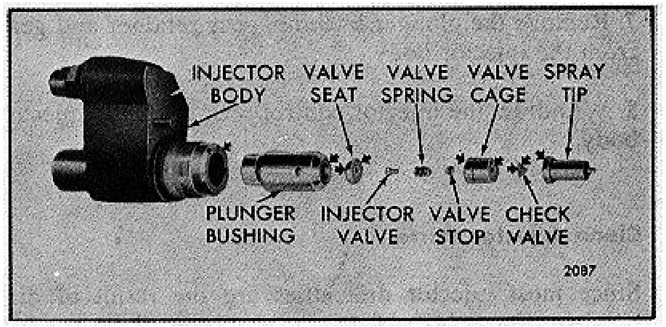


FIG. 26 Sealing Surfaces Which May Require Lapping

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 spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTE: Do not buff 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. This cleans the spray tip orifice area and will not plug the orifices.

Wash the spray tip in clean fuel oil 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.

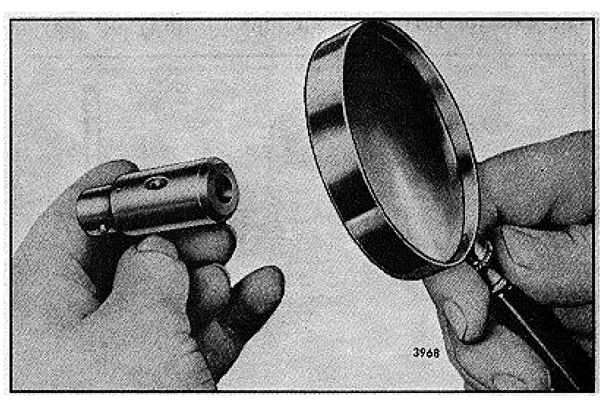


FIG. 27 Examining Sealing Surface with a Magnifying Glass

Carefully insert reamer J 4986-01 in the injector nut as shown in Fig. 24. Turn the reamer in a clockwise direction to remove the carbon deposits. Use care in reaming to prevent the removal of metal or setting up burrs on the spray tip seat. The purpose of the tool is to remove carbon build-up only, and is NOT meant to refinish the end area of the nut by removing metal. Wash the injector nut in clean fuel 6il and dry it with compressed air. Carbon deposits on the spray tip seating surface of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

Carefully insert reamer J 21089 in the injector body (Fig. 25). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean fuel oil 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 and bushing together as they are mated parts.*

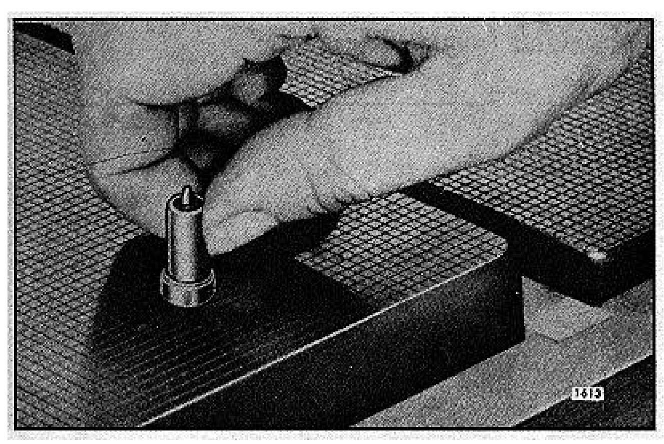


FIG. 28 Lapping Spray Tip on Lapping Blocks J 22090

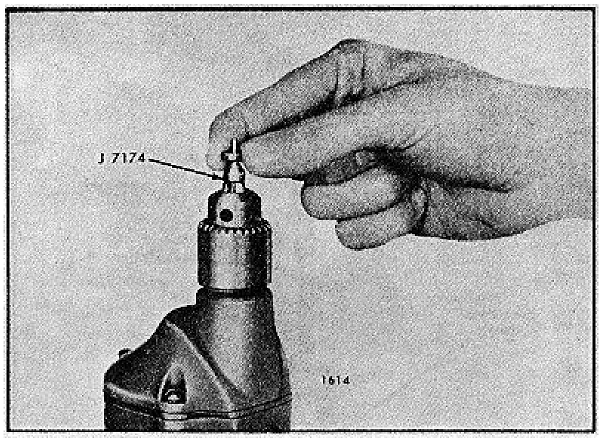


FIG. 29 Lapping Edge of Hole in Valve Seat using Tool J 7174

After washing, submerge the parts in a clean receptacle containing clean fuel oil. Keep the parts of each injector assembly together.

Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace damaged or worn parts.

Inspect the injector follower and pin for wear. Refer to Section 2.0.

Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone.

Inspect the follower spring for visual defects. Then check the spring with tester J 22738-02.

The current injector follower spring (.142" diameter wire) has a free length of approximately 1.504" and should be replaced when a load of less than 70 lbs. will compress it to 1.028". Formerly, a spring (.1201, diameter wire) with a free length of approximately 1.668" was employed and it should be replaced when a load of less than 48 lbs. will compress it to 1.028".

It is recommended that at the time of overhaul, all injectors in an engine be converted to the current spring (.142" diameter wire) which will provide improved cam roller to shaft follow. However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

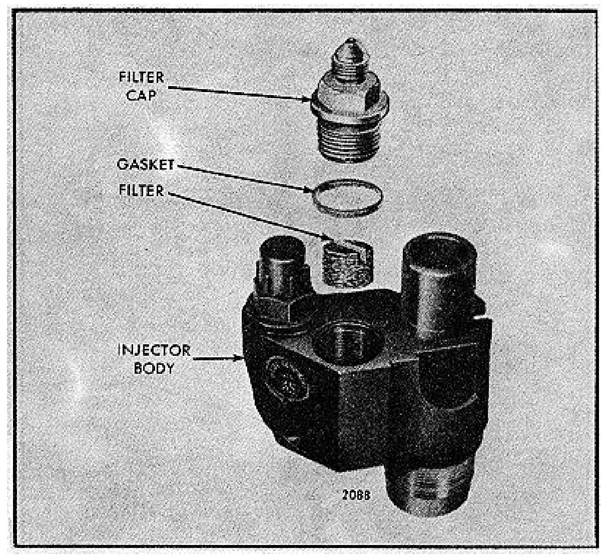


FIG. 30 Details of Injector Filters and Caps and Their Relative Location

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Injector Bushing Inspectalite J 21471 can be used to check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement. *Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts*. Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

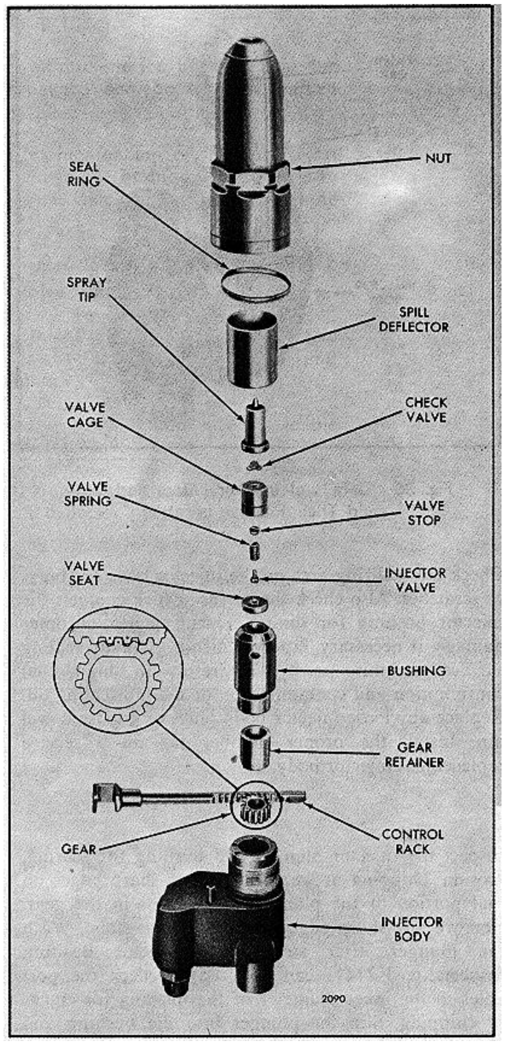


FIG. 31 Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

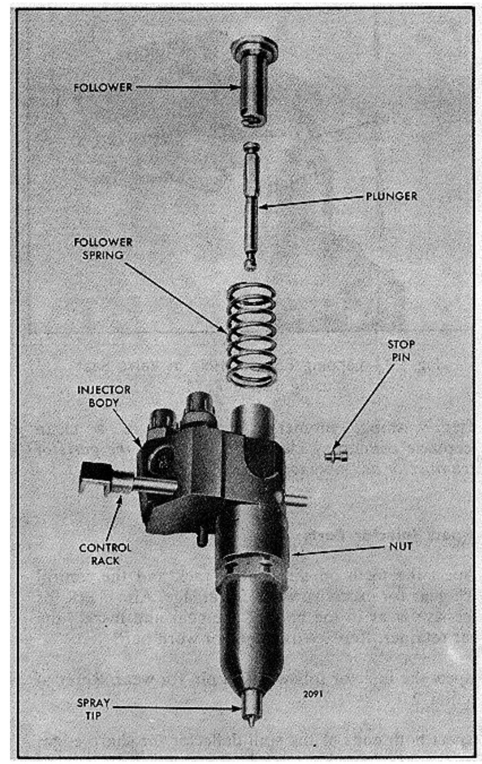


FIG. 32 - Injector Plunger, Follower and Relative Location of Parts

Examine the spray tip seating surface of the injector nut for nicks, burrs or brinelling. Reseat the surface or replace the nut if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the spray tip and valve parts indicated in Fig. 26. Examine the sealing surfaces with a magnifying glass as shown in Fig. 27 for even the s]ightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts. Check the minimum thickness of the lapped parts as noted in the chart.

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163"-.145"
Check Valve	.022"
Valve Spring Cage	.602"

MINIMUM THICKNESS (Used Parts)

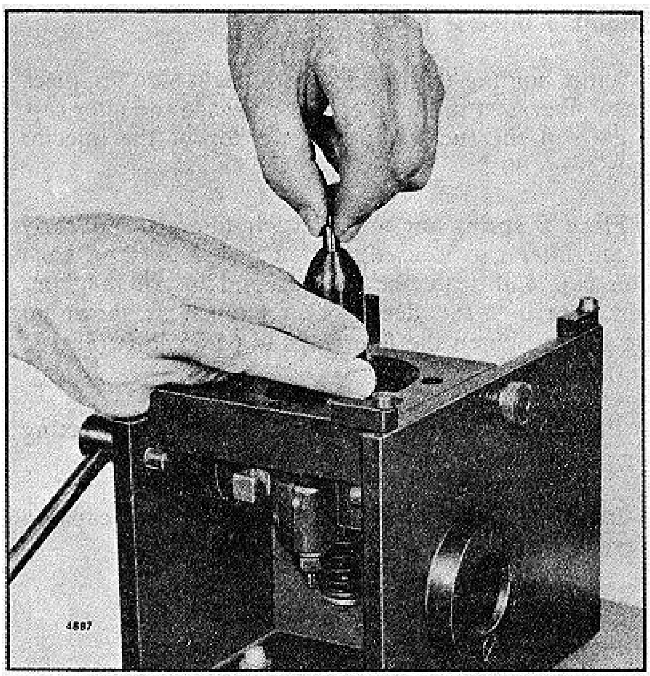


FIG. 33 Tightening Injector Nut by Hand

Before reinstalling used valve parts in an injector, lap all of the sealing surfaces indicated in Fig. 26, except the injector valve (crown valve). It is also good practice to lightly lap new valve parts, except the injector valve (crown valve), which may become burred or nicked during handling.

Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 26 and the chart as follows:

l. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

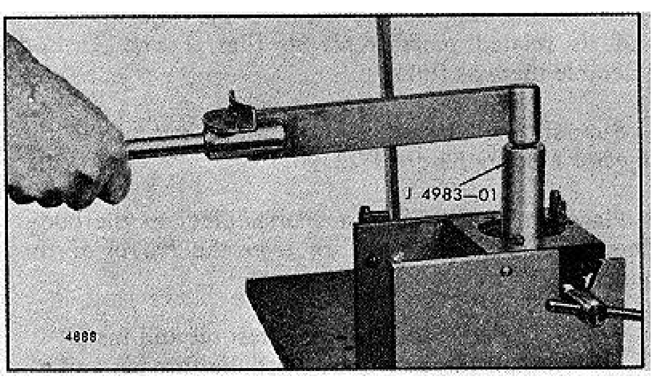


FIG. 34 Tightening injector Nut with Torque Wrench using Tool J 4983-01

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 as shown in Fig. 28 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 (refer to the chart on minimum thickness).

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. Examine the edge of the hole in the crown valve seat under a magnifying glass. If the edge of the hole shows small irregularities, lap the hole with tool J 7174. Since only the edge of this hole contacts the valve, it must be a true circle and present an unbroken surface.

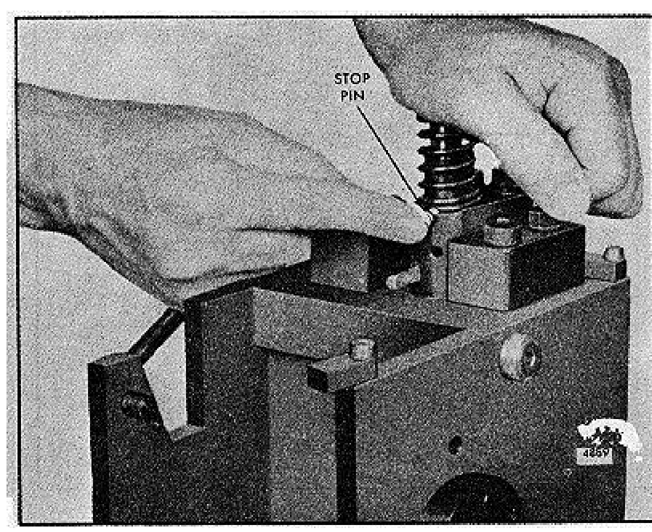


FIG. 35 - Installing Injector Follower Stop Pin

Mount tool J 7174 in a drill motor (Fig. 29) and place a small amount of lapping powder and oil mixture on the tool. Place the valve seat over the pilot of the tool and start the drill motor. Touch the valve seat lightly against the rotating lapping tool to produce a uniform seat at the hole. After lapping the edge of the hole in this manner, flat lap the face of the seat lightly. Then clean and examine the width of the chamfer produced at the edge of the hole. The specified width is .002" to .005 ". A width in excess of these limits, due to excessive lapping, will lower the valve opening pressure of the injector.

9. Wash all of the lapped parts in clean fuel oil and dry them with compressed air.

ASSEMBLE INJECTOR

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean. Study Figs. 30 through 32 for the proper relative position of the injector parts, then proceed as follows:

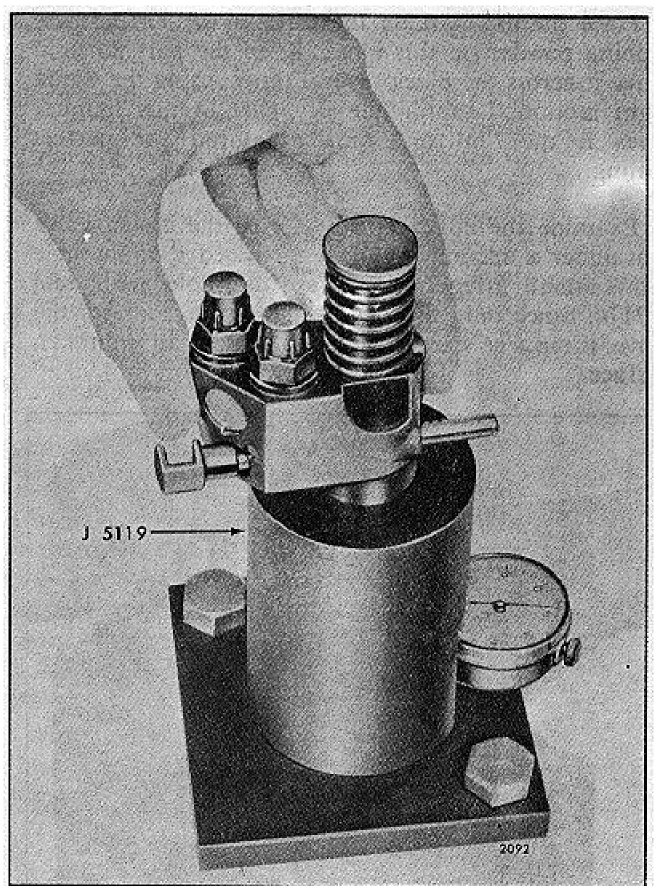


FIG. 36 Checking Injector Spray lip Concentricity using Tool J 5119

Assemble Injector Filters

1. While holding the injector body right side up, place a new filter, slot in the filter up or toward the filter cap, in each of the fuel cavities in the top of the injector body (Fig. 30).

2. Place a spring on top of each filter (if an early design filter cap is used) and a new gasket on each filter cap. Lubricate the threads and install the filter caps. Use a 9/16" deep socket wrench as shown in Fig. 18 to tighten the filter caps to 65-75 lb-ft (88-102 Nm) torque.

3. Purge the filters after installation by directing compressed air or fuel through the filter caps. 4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

Assemble Rack and Gears

Refer to Fig. 31 and note the drill spot marks on the control rack and gear. Then proceed as follows:

l. Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack.

3. Place the gear retainer on top of the gear. Next align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

Assemble Injector Valve and Related Parts

After having lapped and cleaned the injector valve and its related parts, refer to Figs. 1 and 32 and assemble them as follows:

1. Support the injector body, bottom end up, in the injector holding fixture J 22396.

2. Place a new seal ring on the shoulder of the body. Then slide the spill deflector over the barrel of the bushing.

> **NOTE**: 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.

3. Place the valve seat on the end of the bushing. Then insert the stem of the valve in one end of the valve spring and the valve stop in the other end. Lower the valve cage over this assembly so that the valve stop seats in the cage. Place the valve cage assembly on the valve seat.

4. Locate the check valve centrally on the cage and place the spray tip over the check valve and against the valve cage.

5. 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 (Fig. 33). 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.

6. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 55-65 lb-ft (75-88 Nm) torque (Fig. 34).

> **NOTE:** 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.

Assemble Plunger and Follower

1. Refer to Fig. 32 and slide the head of the plunger into the follower.

2. Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in. Then place the follower spring on the injector body.

3. Refer to Fig. 35 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next align the flat side of the plunger with the slot in the follower. Then 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.

Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in the concentricity gage J 5119 as shown in Fig. 36 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 .0081", remove the injector from the gage. Then loosen the injector nut, center the spray tip and tighten the nut to 55-65 lb-ft (75-88 Nm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under *Test Injector.* The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, assemble and test the injector again.

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 5286-9, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head 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 runs out of the outlet filter cap. Install the injector in the engine as follows:

1. Refer to Fig. 6 and insert the injector into the injector tube with the dowel in the injector body registering with the locating hole in the cylinder head.

2. Slide the 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 20-25 lb-ft (27-34 Nm) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

> **NOTE:** Check the injector control rack for free

movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0.

NOTE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridges are not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridges before, during and after tightening the rocker shaft bolts.

5. Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb-ft (16-20 Nm) torque.

IMPORTANT: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end pf the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Pressurize Fuel System - Check for Leaks* in Section 2.0).

NOTE: 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. Reinstall the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 and refill the crankcase to the proper level with the recommended grade of oil.

6. 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 levers.

FUEL INJECTOR (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.

The fuel injector performs four functions:

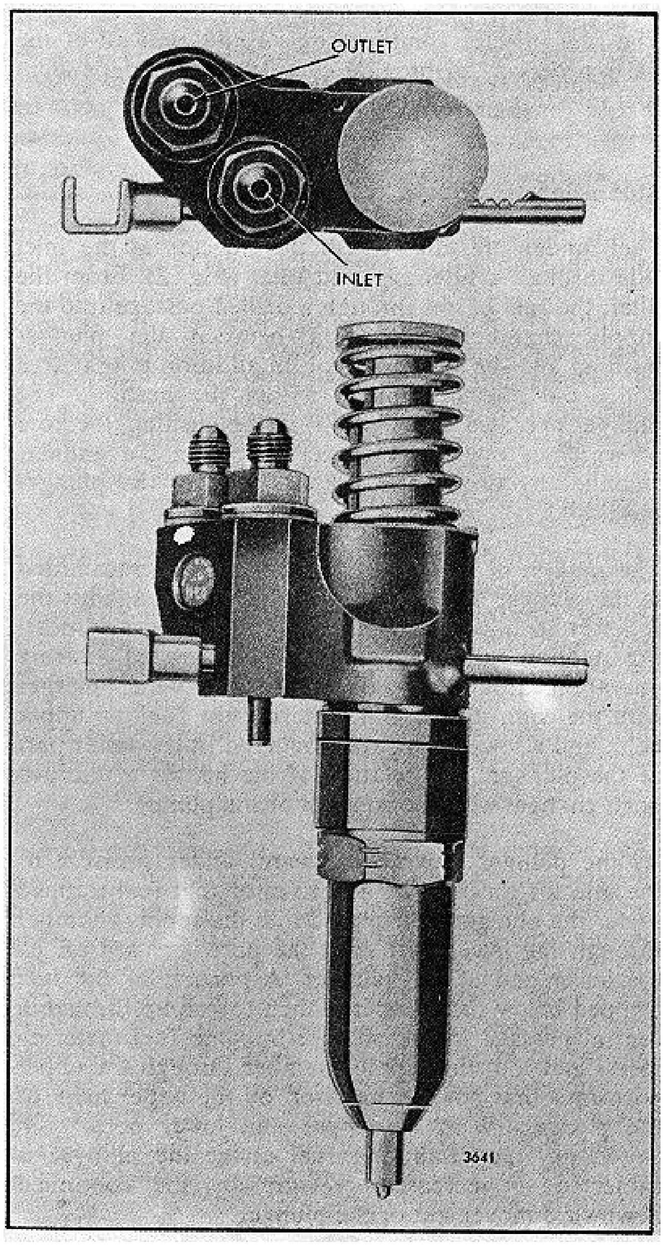


FIG. 1 Fuel Injector Assembly

1. Creates the high fuel pressure required for efficient injection.

2. Meters and injects the exact amount of fuel required to handle the load.

3. Atomizes the fuel for mixing with the air in the combustion chamber.

4. Permits continuous fuel flow.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder.

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 3 illustrates the fuel metering from no-load to full-load by rotation of the plunger in the bushing.

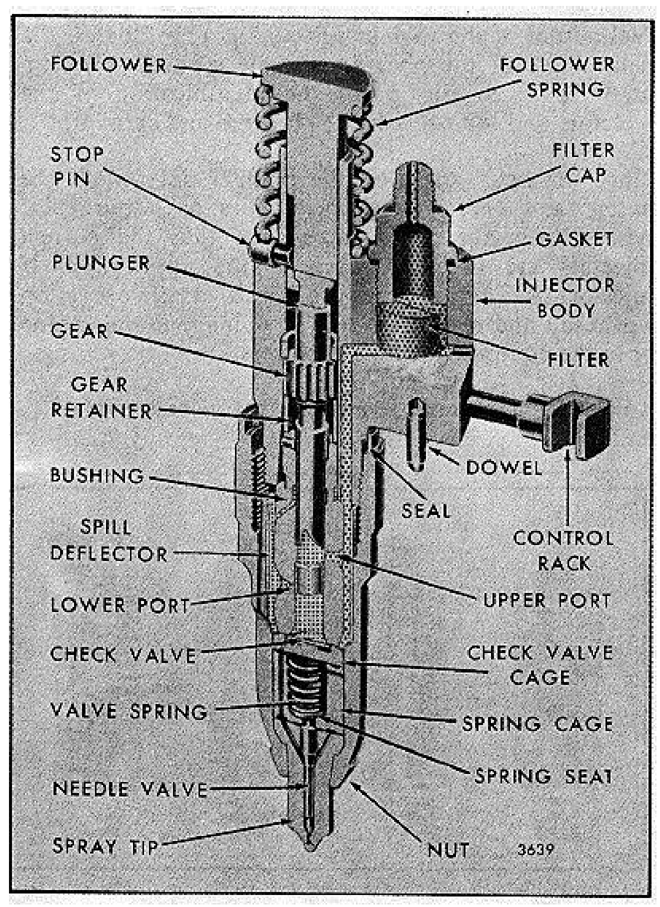


FIG. 2 - Cutaway View of Fuel Injector

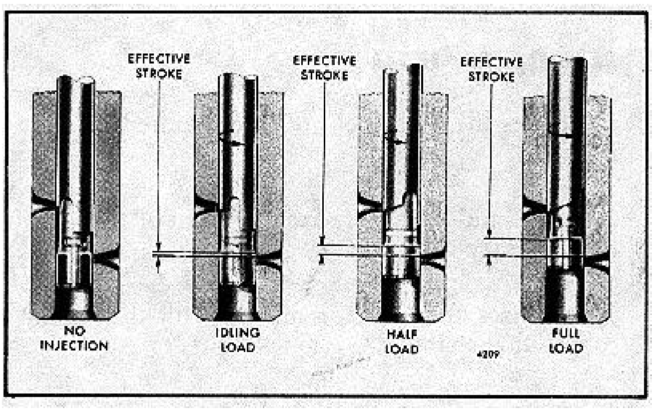


FIG. 3 - Fuel Metering from No-Load to Full Load

Figure 4 illustrates the phases of injector operation by the vertical travel of the injector 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 helix angle of the plunger and the type of spray tip used. Refer to Fig. 5 for the identification of the injectors and their respective plungers and spray tips.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

NOTE: Do not intermix the needle valve

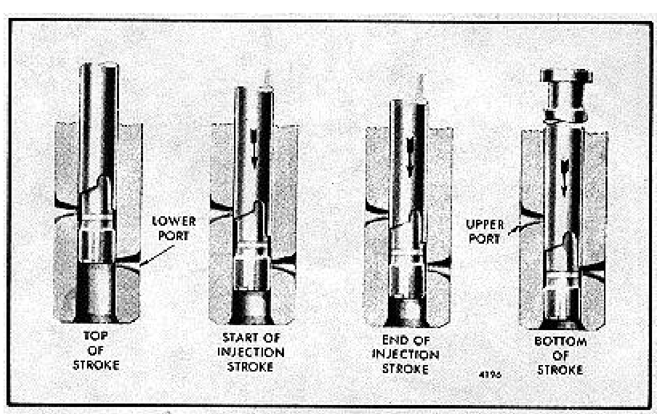


FIG. 4 - Phases of Injector Operation Through Vertical Travel of Plunger

injectors with other types of injectors in an engine.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 5). The identification tag indicates the nominal output of the injector in cubic millimeters.

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 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.

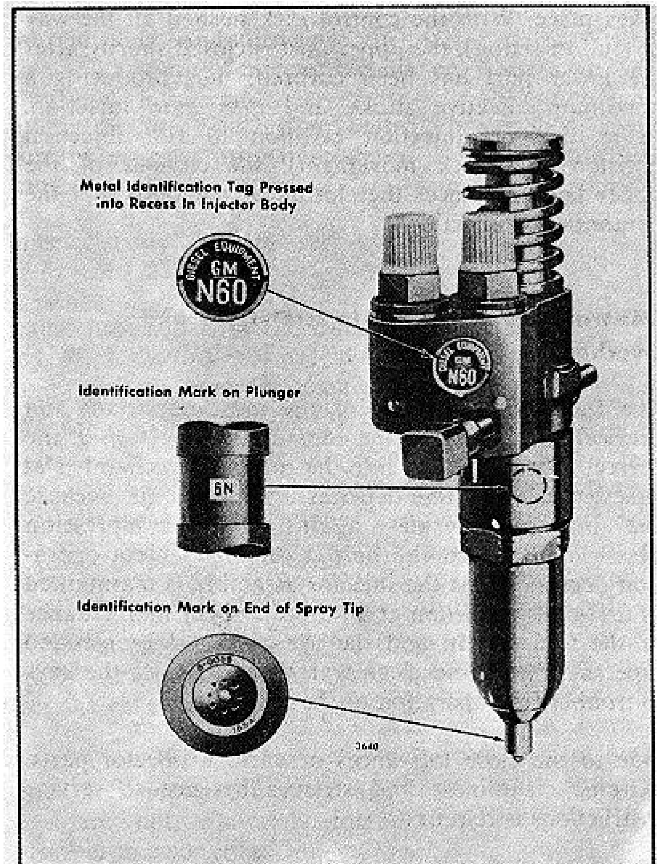
Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (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, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced 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 closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel 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, non-return check valve. The fuel in the check valve



INJECTOR	SPRAY TIP*	PLUNGER
71N5	8-0055-165A	5N
N55	8-0055-165A	55N
N60	8-0055-165A	6N
N65 (brown tag)	8-006-165A	N65
N70	7-006-165	7N
N75	7-006-165	75N
71C5	8-0055-165A	5C
C55	8-0055-165A	55C
C60	8-0055-165A	6C
C65	7-006-165A	65C
C70	7-006-165	7C
B55	8-006-162	45C
B60	8-006-162	5C
865	8-006-165A	65B
7185	8-006-162	4C
B55E	8-006-162	B55E
7B5E	8-006-162	7B5E

*First numeral indicates number of spray holes, followed by size of holes and angle formed by spray from holes.

FIG. 5 - Injector Identification Chart

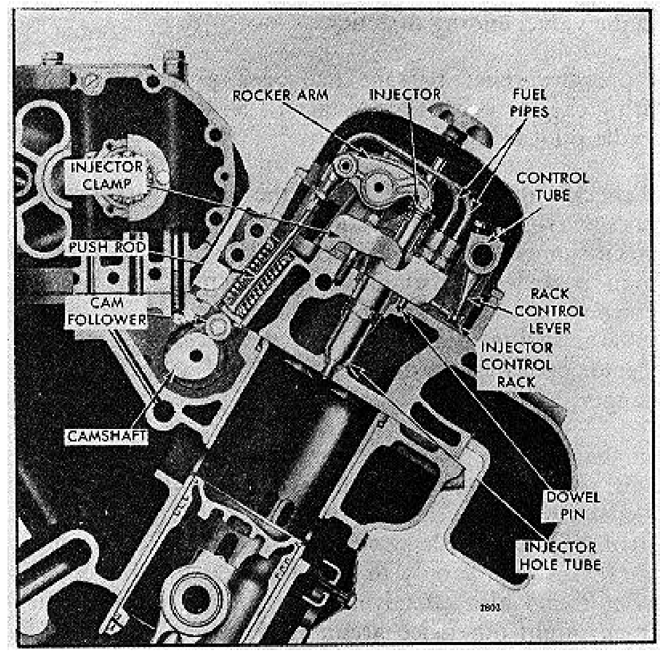


FIG. 6 Fuel Injector Mounting

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

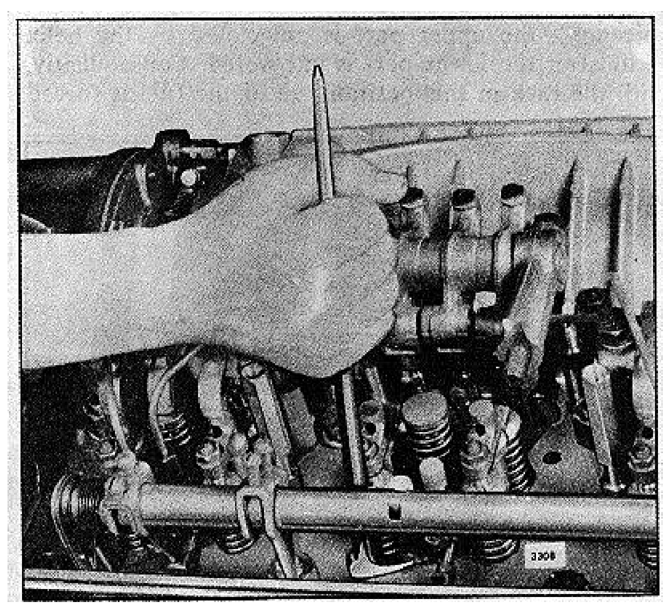


FIG. 7 - Removing Injector from Cylinder Head

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. Figure 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. Figure 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 of 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. Also provide a source for 110 volt alternating current electric power.

Provide the injector repair room with a supply of

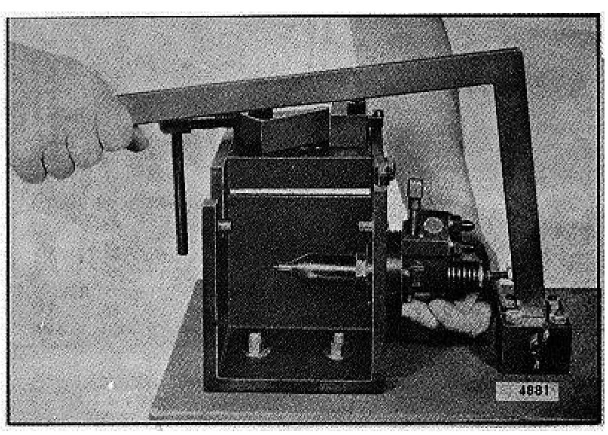


FIG. 8 - Checking Rack and Plunger for Free Movement using Tool J 22396

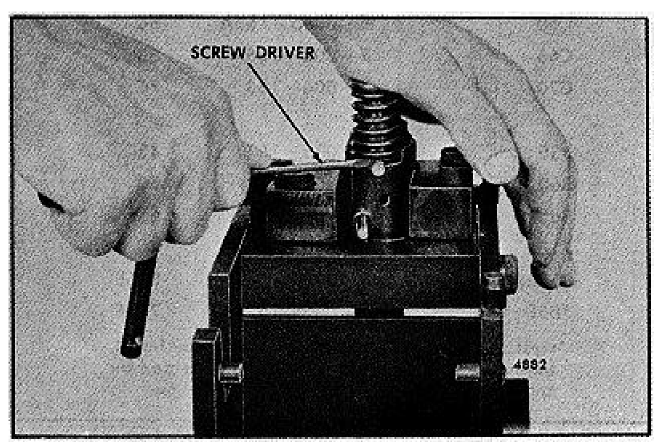


FIG. 9 Removing Injector Follower Stop Pin

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 agent, usually clean fuel oil, 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 cleaning tissue is a good, inexpensive 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. Also protect the fuel pipes and fuel connectors from 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 assembly of an injector.

> **NOTE:** In the offset injector, a filter is used in the inlet side only. No filter is required on the outlet side (Fig. 34).

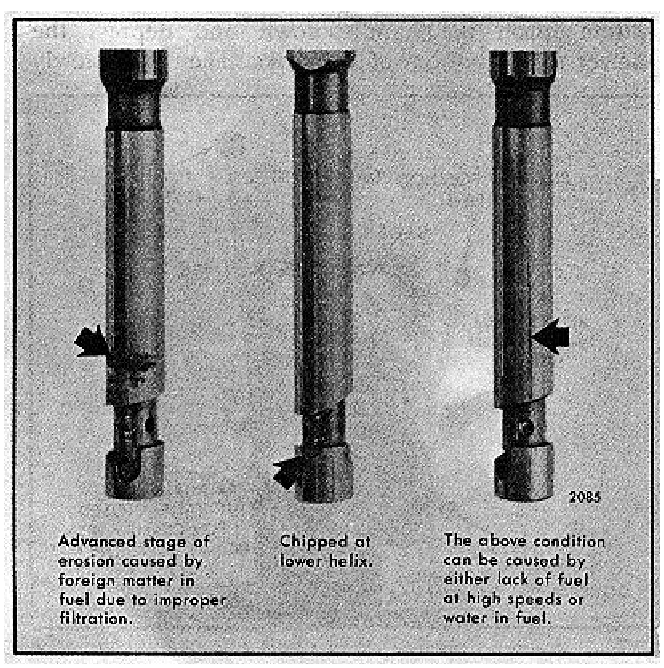


FIG. 10 Unusable Injector Plungers

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.

> **NOTE:** 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.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

> **NOTE:** 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.

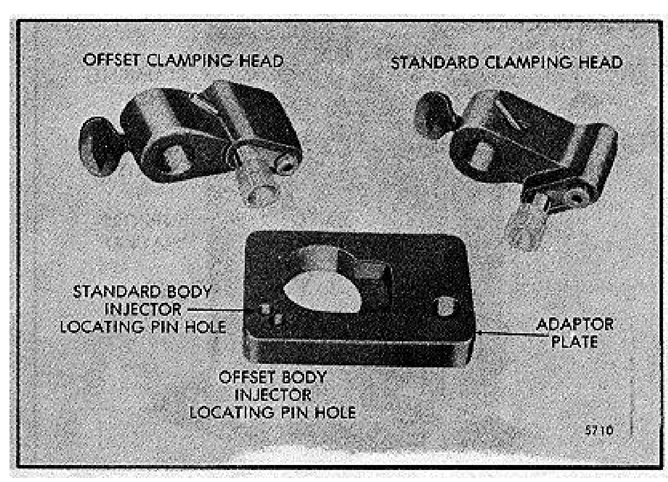


FIG. 11 Injector Tester J 23010 Clamping Heads

3. Crank the engine to bring the outer ends of the push rods of the injector and valve rocker arms in line horizontally.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws (certain engines have only one adjusting screw and lock nut) on the injector rack control lever and slide the lever away from the injector.

7. Lift the injector from its seat in the cylinder head.

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean fuel oil and dry it with compressed air.

TEST INJECTOR

CAUTION: The fuel spray from an injector can penetrate the skin. Fuel oil which enters the blood stream can cause a serious infection.

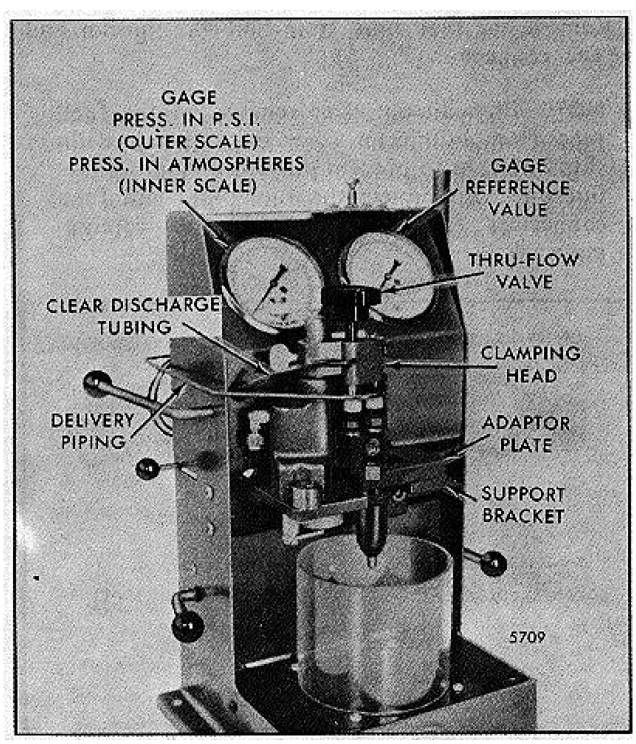


FIG. 12 -Injector Installed in Tester J 23010 with Clamping Head

Therefore, follow instructions and use the proper equipment to test an injector.

If inspection does not reveal any external damage, then perform a series of tests to determine the condition of the injector to avoid unnecessary overhauling. Tests must be performed using injector test oil J 26400.

An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails to pass one or more of the, tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure drop and fuel output as indicated by the following tests:

Injector Control Rack and Plunger Movement Test

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.

With the injector control rack held in the no-fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly

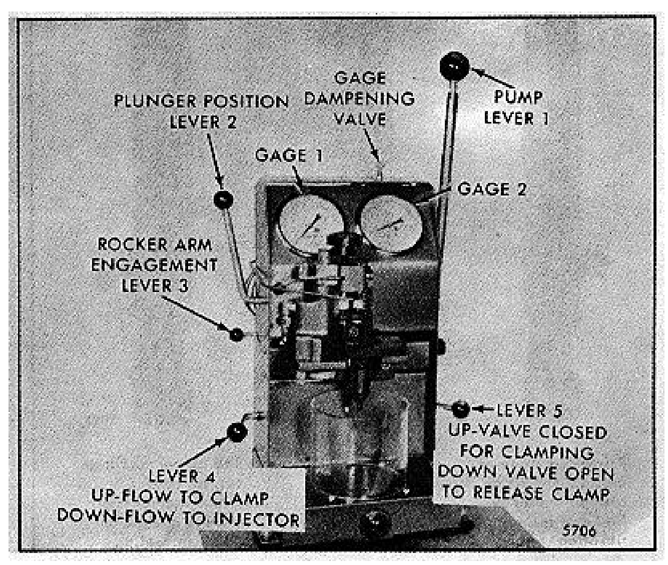


FIG. 13 Injector In Position for testing with Tester J 23010

release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the follower reaches the top of its travel. 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.

Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix, if chipped, that will not be indicated in any of the tests. Remove the plunger from the injector as follows:

1. Support the injector, right side up, in holding fixture J 22396.
2. Compress the follower spring. Then raise the spring above the stop pin with a screw driver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.
3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.
4. Inspect the plunger. If the plunger is chipped (Fig. 10), replace the plunger and bushing assembly.
5. Reinstall the plunger, follower and spring.

Installing Fuel Injector in Tester J 23010

1. Select the proper clamping head (Fig. 1l). Position it on the clamping post and tighten the thumb screw into the lower detent position (Fig. 12).
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.
5. Mount the injector through the large hole and insert the injector pin in the proper locating pin hole (Fig. 11).
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. 13 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 nylon seals over the injector filter caps (Fig. 12).
3. Back off the Thru-Flow valve about half-way to allow the self-aligning nylon seals to seat properly during the clamping operation.
4. Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever evenly to move the clamping head *down* to seal the filter caps.

NOTE: The Thru-Flow valve should still turn freely. If it does not, turn the valve counter clockwise until it rotates freely and reapply clamping pressure.

NOTE: Excessive force on lever 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 I 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.

Injector Valve Opening and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the injector valve opens and fuel injection begins.

1. Clamp the injector properly and purge the air from the system.

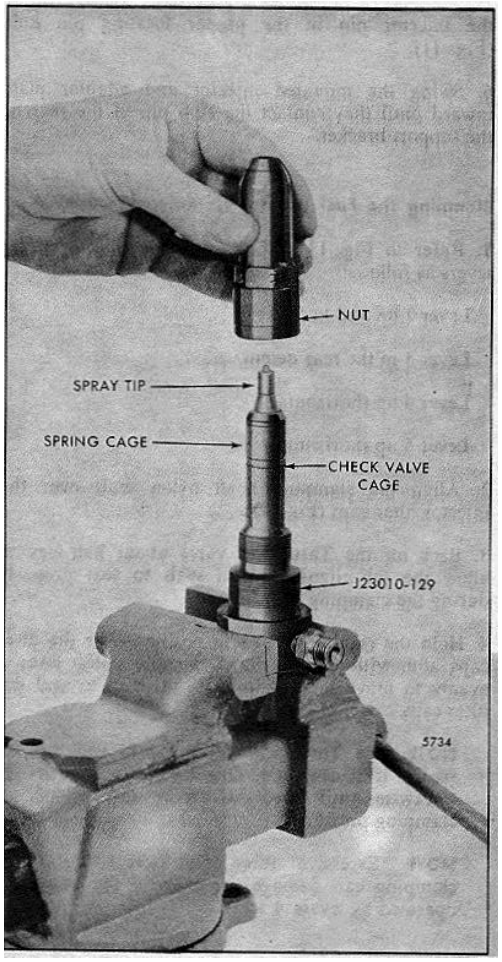


FIG. 14 Assembling Injector Valve Parts on Tip Tester Adaptor J 23010-129

2. Move lever 4 *down.*
3. Position the injector rack in the full-fuel position.
4. Place pump lever I in the vertical position.
5. Move lever 3 to the forward detent position.
6. The injector follower should be depressed rapidly (at 40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray pattern 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.

The highest pressure reference number shown on gage 2 will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector. Reference values for Series 71 injectors, except the N-90, 7B5E, B55E and B65 are from 127 minimum to 146 maximum. Reference values for the N-90, 7B5E, B5SE and B65 are from 138 minimum to 162 maximum.

> **NOTE:** The reference value obtained when pop testing the needle valve injectors is to be used as a trouble shooting 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 tester J 23010 and tip test adaptor J 23010-129 or auxiliary tester J 22640.

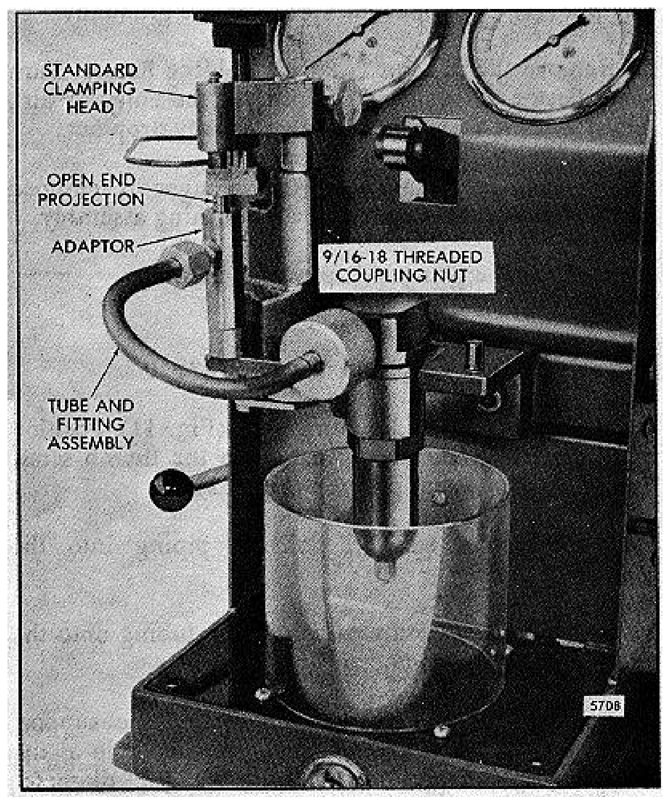


FIG. 15 Adaptor and Tube Assembly on Injector Tester J 23010

Injector High Pressure Test

This test checks for leaks at the filter cap gaskets, body plugs and nut seal ring.

1. Clamp the injector properly and purge the air from the system.
2. Close the Thru-Flow valve, but do not overtighten.

NOTE: Make sure lever 4 is in the *down* position before operating pump lever 1.

3. Operate pump lever 1 to build up to 1600 to 2000 psi (11 024 to 13 780 kPa) on gage 1. Check for leakage at the injector filter cap gaskets, body plugs and injector nut seal ring.

Injector Pressure Holding Test

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 and purge the air from the system.
2. Close the Thru-Flow valve, but do not overtighten.
3. Move lever 2 to the rear, horizontal position.
4. Operate pump lever 1 until gage 1 reads approximately 700 psi (4 823 kPa).
5. Move lever 4 to the *up* position.
6. Time the pressure drop between 450 to 250 psi (3 100 to 1 723 kPa). If the pressure drop occurs in less than 15 seconds, leakage is excessive.

Refer to the *Trouble Shooting Charts* in Section 2.0 if the fuel injector does not pass any of the preceding tests.

If the fuel injector passes all of the above tests, proceed with the *Fuel Output Test.*

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.

Needle Valve Tip Test (Using J 23010 Tester and Tip-Test Adaptor)

Assemble injector parts on tip test adaptor as follows:

1. Clamp the flat sides of the tip test adaptor J 23010-129 firmly in a vise and assemble the cleaned injector parts including the check valve cage, spring, spring seat, spring cage and spray tip assembly.
2. Carefully pilot the injector nut over the spray tip and valve parts and thread it onto the adaptor (Fig. 14).
3. Tighten the injector nut.
4. Mount the adaptor and assembled injector parts in the support bracket (adaptor plate, not needed). Refer to Fig. 15.
5. Install the offset clamping head on the clamping post (on J 23010 testers without serial numbers, use the upper detent position and on J 23010 testers numbered 1051 and higher, use the lower detent position).
6. Select the (larger) 9/16"-18 threaded coupling nut J 23010-20 and thread it on tubing J 23010-75.
Install the tubing and fitting to adaptor J 23010-167.
7. Connect the tubing to tip test adaptor J 23010-129 by threading the coupling nut on the tip test adaptor.

Installing Adaptor and Tube Assembly on Tester J 23010

1. Position the adaptor and tubing assembly with the solid projecting end located in the hole on the left side of the support bracket.
2. Swing the clamping head over the adaptor and clamp it with the oil supply outlet aligned over the open projecting end of the adaptor (Fig. 15).

NOTE: Use the fuel injector clamping procedure to clamp adaptor J 23010-167 in the injector tester.

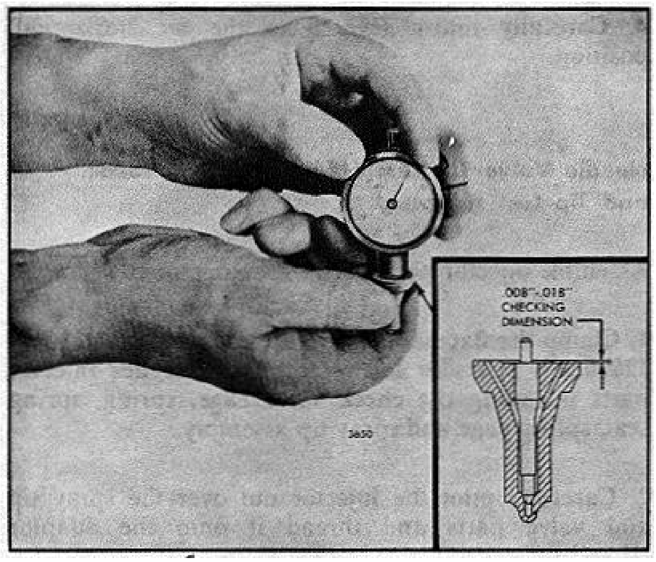


FIG. 16 - Checking Needle Valve Lift using Tool J 9462-02

Spray Tip Test

1. Move]ever 4 *down* and operate pump lever 1 rapidly with smooth even strokes (40 strokes per minute) simulating the action of the tip functioning in the engine (Fig. 13).
2. Note the pressure at which the needle valve opens on gage 1. The valve should open between 2200 and 3200 psi (15 158 and 22 048 kPa). The opening and closing action should be sharp and produce a normal, finely atomized spray pattern.

If the valve opening pressure is below 2200 psi (15 158 kPa) and/or atomization is poor, the cause is usually a weak valve spring or a poor needle valve seat.

If the valve opening pressure is within 2200-3200 psi (15 158-22 048 kPa), proceed to check for spray tip leakage as follows:

a. Actuate pump lever 1 several tines 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.

Needle Valve Lift Test

To measure the needle valve lift, use tool J 9462-01 (Fig. 16) as follows:

1. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

2. 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.

3. 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 .008" to .018". If it exceeds .018", the tip assembly must be replaced. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.

4. 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.

5. Reassemble the injector as outlined under *Assemble Injector* and check the injector output with calibrator J 22410.

Needle Valve Tip Test (Using Auxiliary Tester J 22640)

1. Connect the pipe from auxiliary tester J 22640 to the rear of the J 23010 tester at the connection located near the bottom of the tester (Fig.17).

2. Assernble cleaned injector parts, including the check valve cage, spring, spring seat, spring cage and spray tip assembly, on the auxiliary tester J 22640 (Fig. 18).

3. Carefully pilot the injector nut over the spray tip and valve parts and thread it on the auxiliary tester.

4. Tighten the injector nut.

5. Open the valve on the auxiliary tester and place lever 4 in the up (horizontal)-position.

6. Install the shield on the auxiliary tester and operate pump lever I until the needle valve has opened several times to purge the air from the system.

7. Operate pump lever 1 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 3200 psi (15 158 and 22 048 kPa). The beginning and ending of delivery should be sharp and the test oil should be finely atomized spray. If the valve opening pressure is below 2200 psi (15 158 kPa) and /or

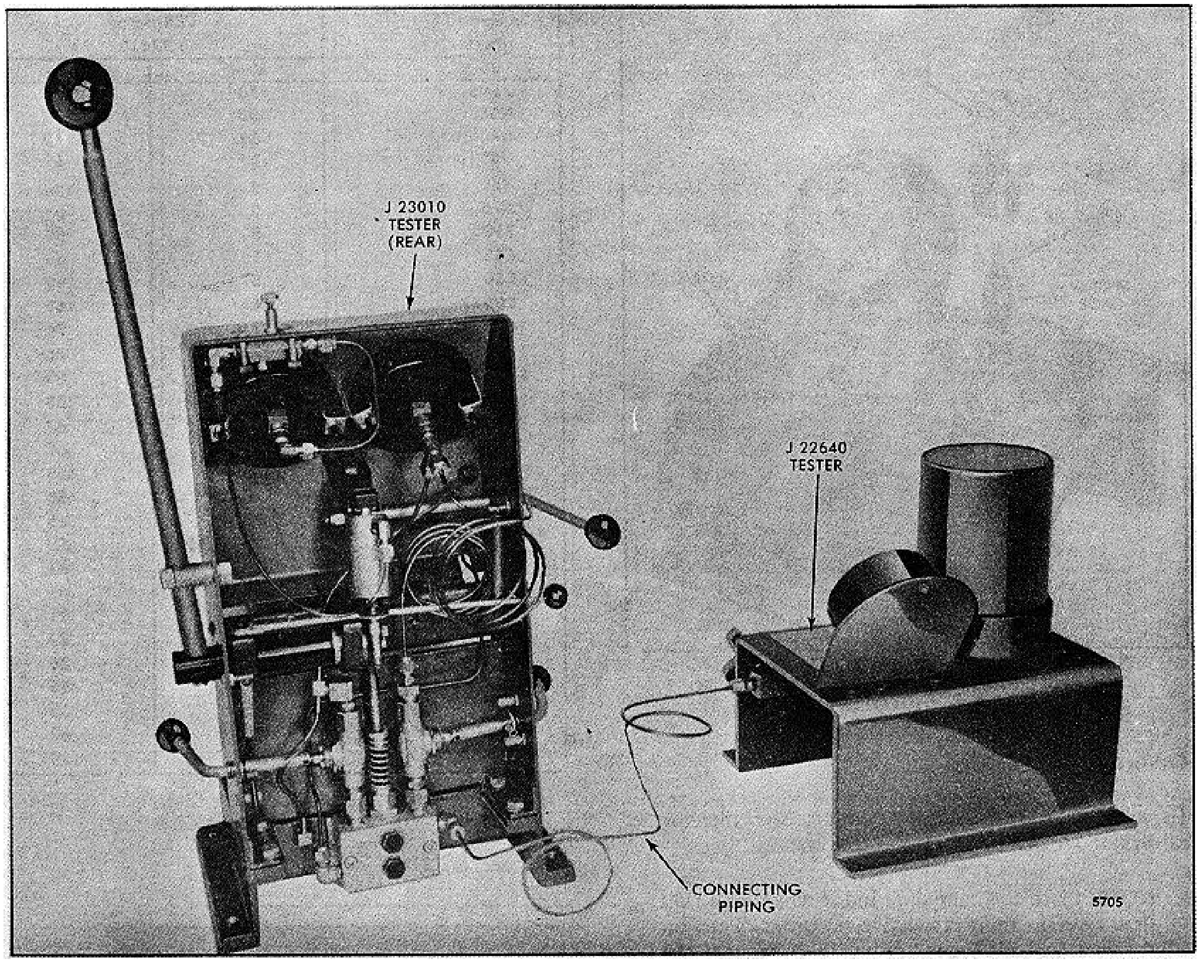


FIG. 17 Injector Needle Valve Tester J 23010 with Auxiliary Tester J 22640

atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within 2200-3200 psi (15 158-22 048 kPa), proceed to check for spray tip leakage as follows:

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.

Perform the needle valve lift test.

Fuel Output Test

Perform the injector fuel output test in calibratorJ 22410.

When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine, note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the calibrator (Fig. 20) depends on the adaptor being used and the direction of fuel flow through the injector.

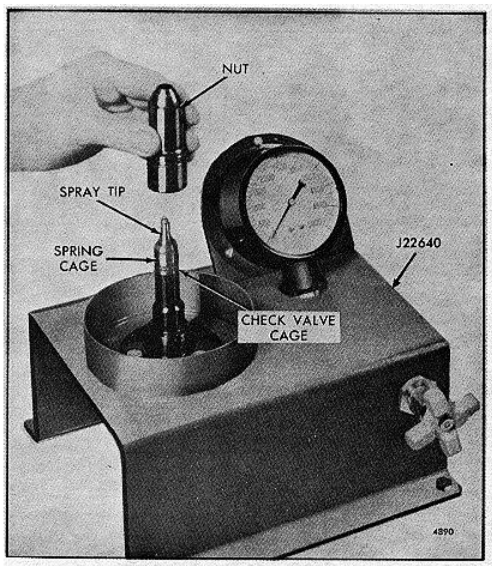


FIG. 18 - Installing Injector Valve Parts on Auxiliary Tester J 22640

Calibrator J 22410

To check the fuel output, operate the injector in calibrator J 22410 (Fig. 21) as follows:

> **NOTE:** Place the cam shift index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95-105° F (35-40° C).

1. 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.
2. Place the injector seat J 22410-226 into the permanent seat (cradle handle in vertical position). Clamp the injector into position by operating the air valve.

> **NOTE:** Make sure the counter (Fig. 22) on the calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

Injector	Calibrator J 22410	
	Min.	Max.
71N5	50	55
N55	53	58
N60	57	62
N65 (brown tag)	64	69
N70	71	76
N75	75	80
71C5	50	55
C55	53	58
C60	57	62
C65	64	69
C70	71	76
7C70	71	76
7C75	75	80
B55	53	58
B60	57	62
B65	64	69
71B5	50	55
B55E	53	58
7B5E	50	55
7A50	53	58
7A55	56	61
7A60	60	65
7A65	66	71
7A70	72	77
7A75	75	80
7E50	50	55
7E55	53	58
7E60	57	62
7E65	63	68

FIG. 19 Fuel Output Chart

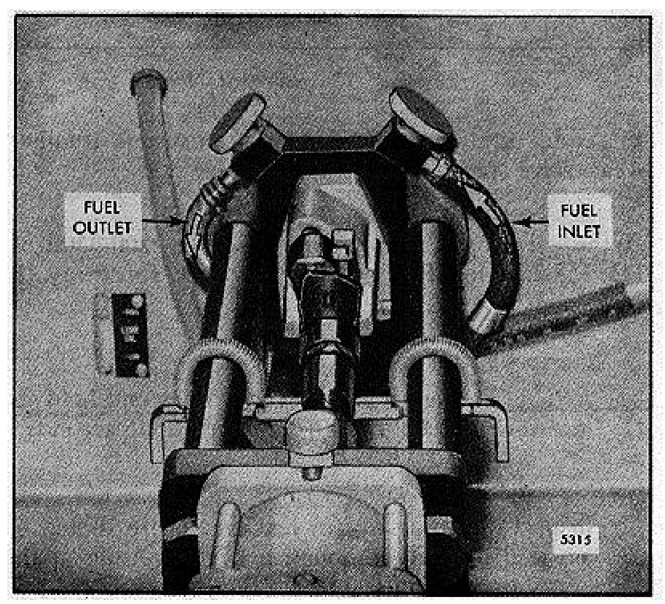


FIG 20. Position of Calibrator Fuel Flow Pipes

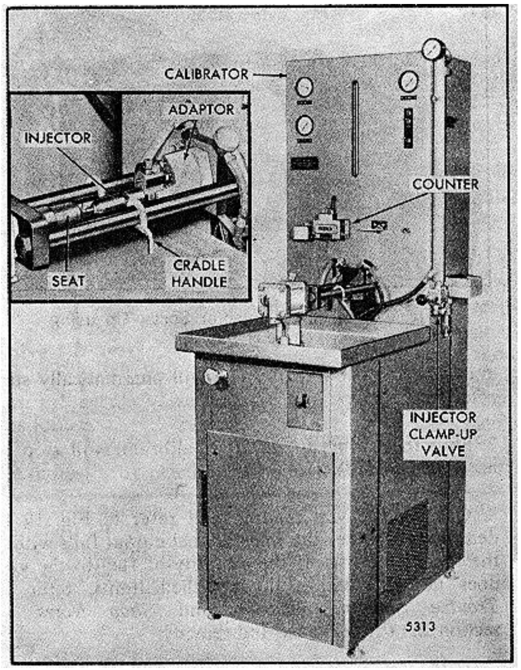
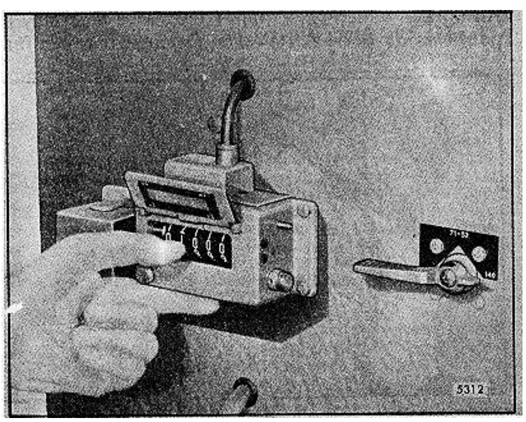


FIG. 21 Injector in Calibrator J 22410

3. Pull the injector rack out to the no-fuel position.
4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.



. FIG. 22 Setting Calibrator Stroke Counter

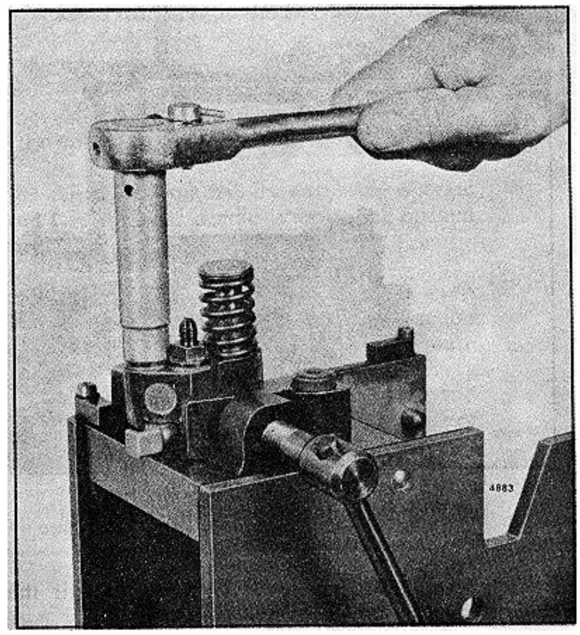


FIG. 23 Removing or Installing FIlter tap

NOTE: The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

5. After the calibrator has started, set the injector rack into the full-fuel position. Allow the injector to operate

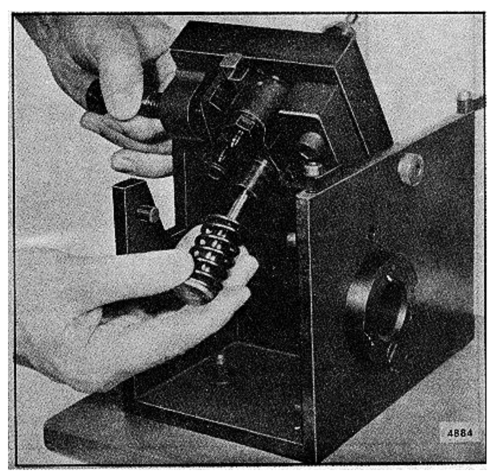


FIG. 24 - Removing or Installing Plunger Follower, Plunger and Spring

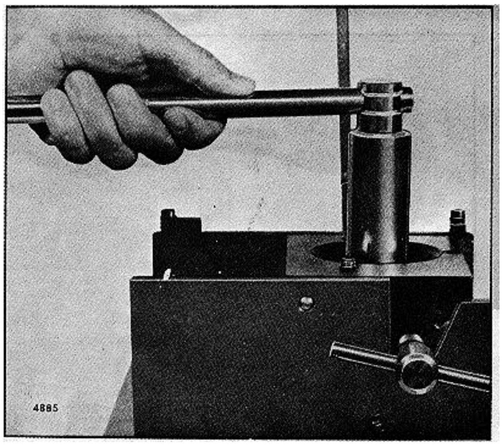


FIG. 25 - Removing Injector Nut using Tool J 4983-01

for approximately 30 seconds to purge the air that may be in the system.

6. After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the

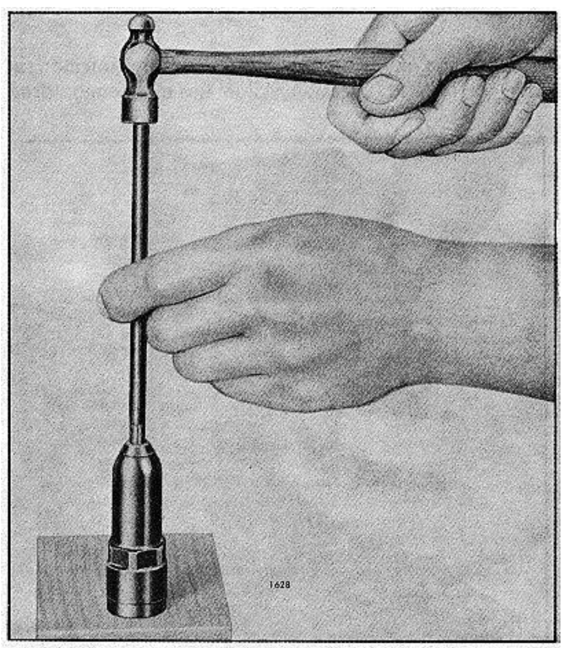


FIG. 26 - Removing Spray Tip from Injector Nut using Tool J 129102

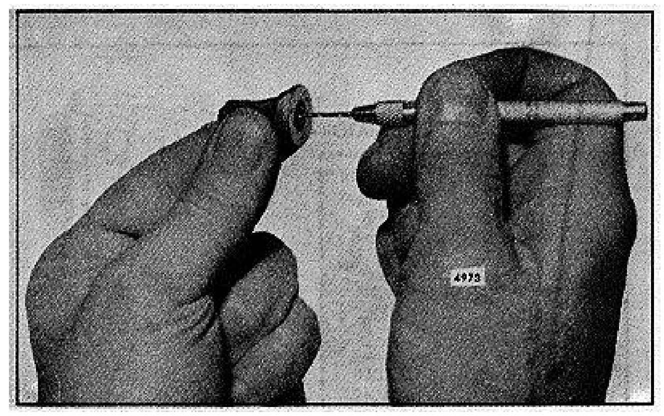


FIG. 27 Cleaning Injector Spray Tip using J 24838

vial. The fuel flow to the vial will automatically stop after 1000 strokes.

7. Shut the calibrator off (the calibrator will stop in less time at full-fuel).

8. Observe the vial reading and refer to Fig. 19 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 *Trouble Shooting Chart* 6 and *Shop Notes* in section 2.0 for the cause and remedy.

> **NOTE**: Refer to Section 2.0 for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

An injector which passes all of the above tests may be put back into service. However, an injector which fails

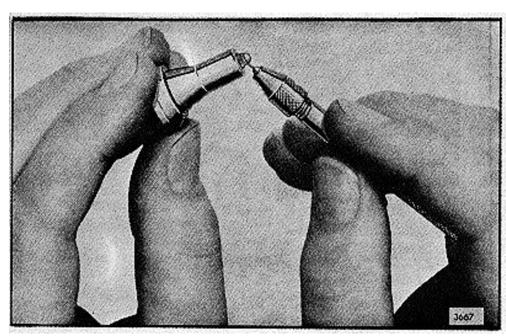


FIG. 28 - Cleaning Spray Tip Orifices using Tool J 4298-1

to pass one or more of the tests must be rebuilt and checked on the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

Disassemble Injector

If required, disassemble an injector as follows:

1. Support the injector upright in injector holding fixture J 22396 (Fig. 23) and remove the filter caps, gaskets and filters.

> **NOTE:** Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. *In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 34).*

2. Compress the follower spring as shown in Fig. 11. Then raise the spring above the stop pin with a screw driver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to Fig. 24 and remove the plunger follower, plunger and spring as an assembly.

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (Fig. 25).

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.

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

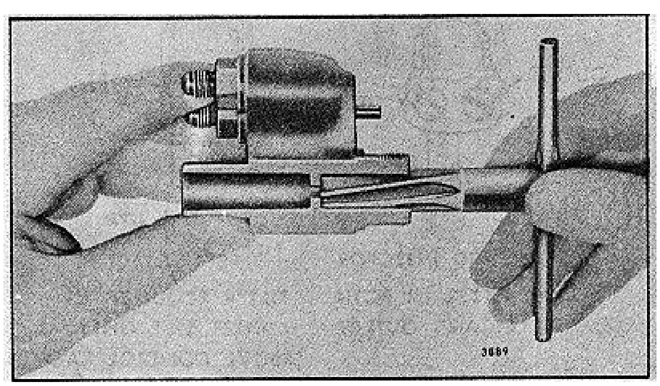


FIG. 29 Cleaning Injector Body Ring using Tool J 21089

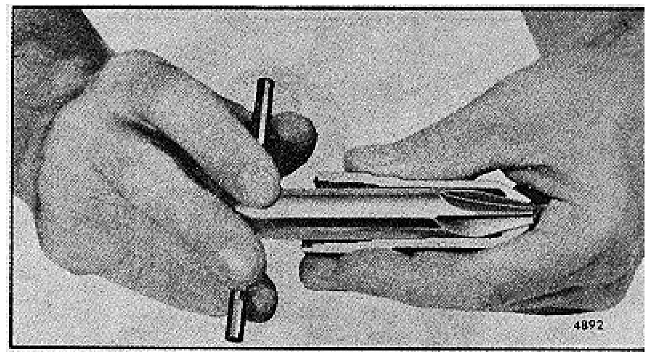


FIG. 30 - Cleaning Injector Nut Spray Tip Seat using Tool J 9418-5

tip down through the nut, using tool J 1291-02 as shown in Fig. 26.

6. Refer to Fig. 36 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 difficulties 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.

Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. *Do not use waste or rags for cleaning purposes.* Clean out all of the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15

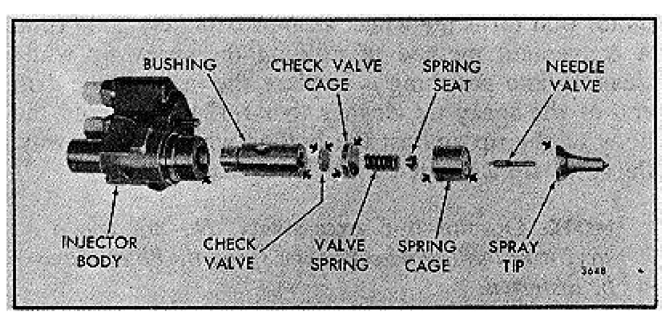


FIG. 31 - Sealing Surfaces which may Require Lapping

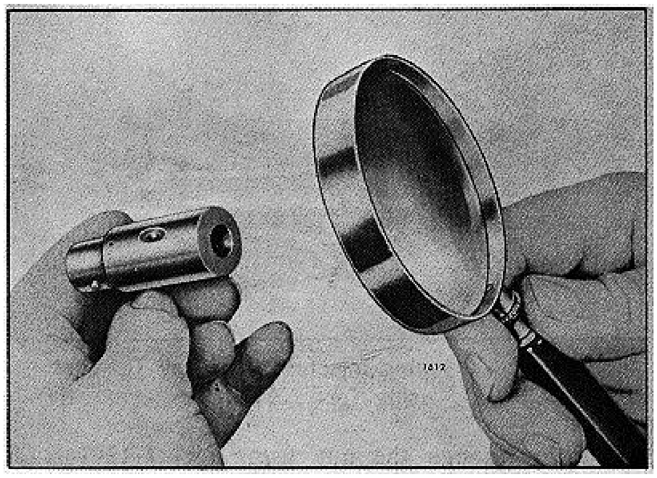


FIG. 32 - Examining Sealing Surface with a Magnifying Glass

minutes in a suitable solution prior to the external cleaning and buffing operation. Methyl Ethyl Ketone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 9464-01 (Fig. 27).

NOTE: Care must be exercised when inserting the carbon remover J 9464-01 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1 and the proper size spray tip cleaning wire. Use wire J 21460 to clean .0055" diameter holes and wire J 21461 to clean .006" diameter holes (Fig. 218).

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 I/8" from 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 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTE: Do not buff 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. This cleans the spray tip orifice area and will not plug the orifices.

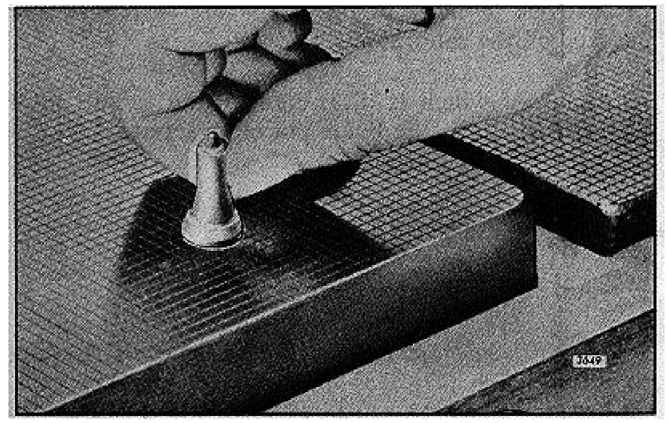


FIG. 33 - Lapping Spray Tip on Lapping Blocks J 22090

Wash the spray tip in clean fuel oil 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 reamer J 21089 in the injector body (Fig. 29). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

Carefully insert a .375" diameter straight fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.

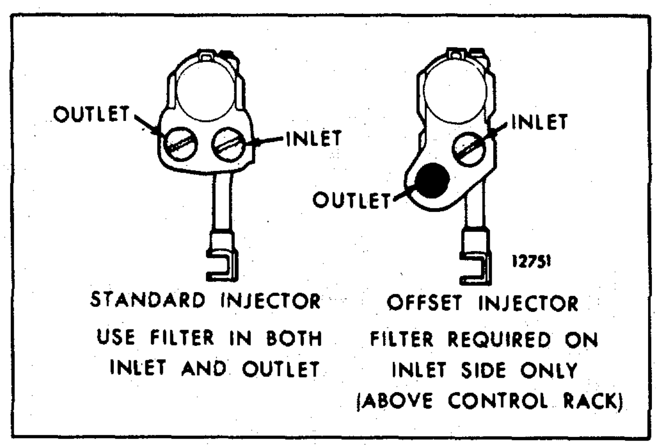


FIG. 34 - Location of Filter in Injector Body

Remove the carbon deposits from the lower inside diameter taper of the injector nut with carbon remover J 9418-5 (Fig. 30). Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut. Carefully insert carbon remover J 9418-1 in the injector nut. Turn it clockwise to remove the carbon deposits on the flat spray tip seat.

Wash the injector nut in clean fuel oil 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 fuel oil 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 and bushing together as they are mated parts.*

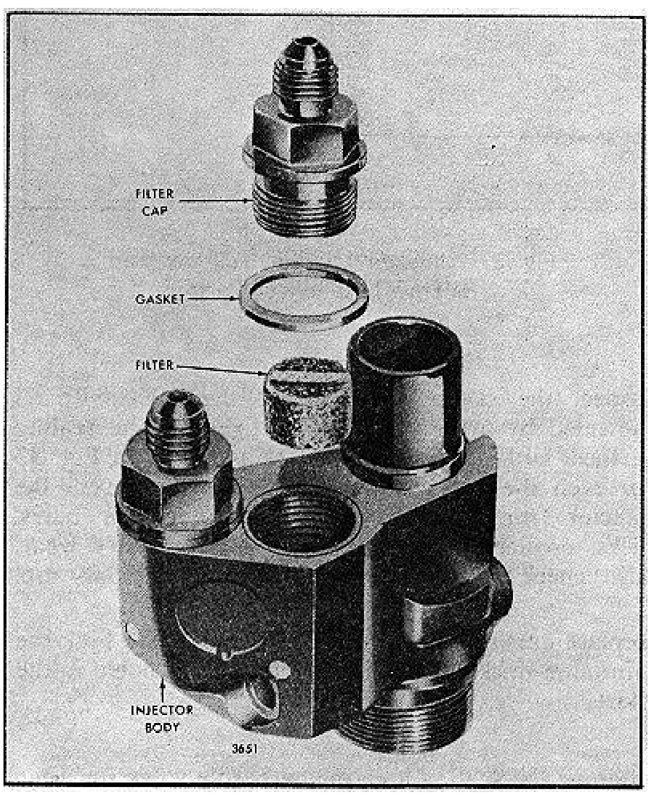


FIG. 35 -Details of Injector Filters and Caps and Their Relative Location

After washing, submerge the parts in a clean receptacle containing clean fuel oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace damaged or worn parts. Inspect the injector follower and pin for wear. Refer to Section 2.0.

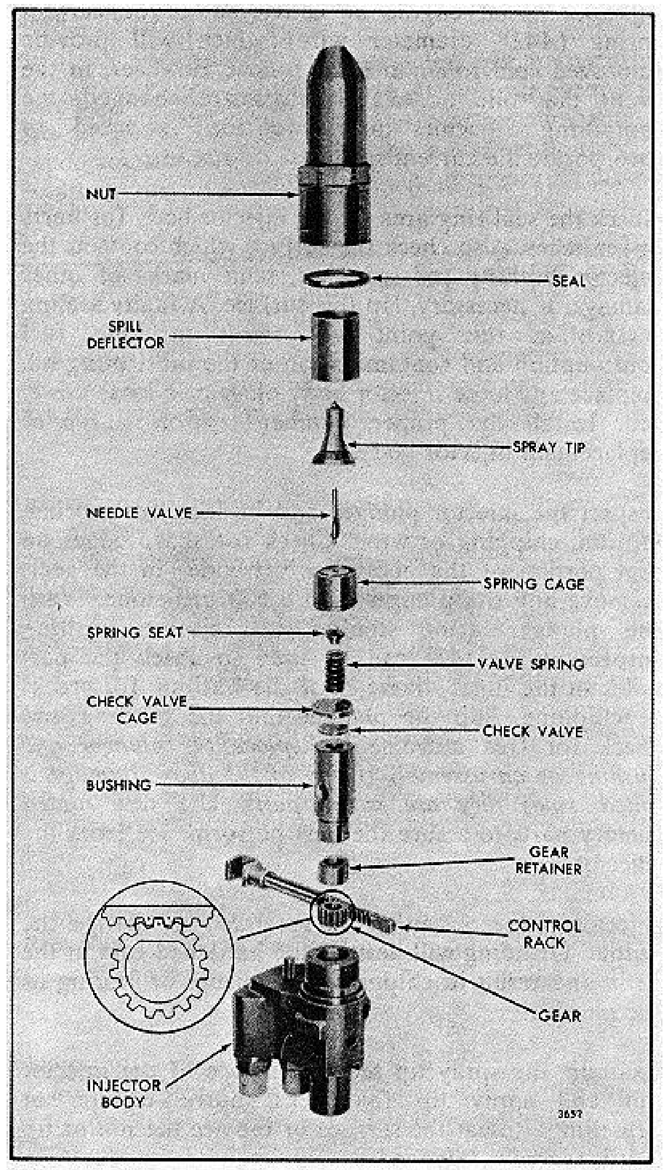


FIG. 36 Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500 grit stone.

Inspect the follower spring for visual defects. Then check the spring with spring tester J 22738-02.

The current injector follower spring (.142" diameter wire) has a free length of approximately 1.504" and should be replaced when a load of less than 70 lbs. Will compress it to 1.028".

It is recommended that at the time of overhaul, all injectors in an engine be converted to the current spring (.142" diameter wire) which will provide improved cam roller to shaft follow. However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bushing for scoring, erosion, chipping or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500 grit stone. Wash the plunger after stoning it. Injector Bushing Inspectalite J 21471 can be used to check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the, plunger into the bushing and check for free movement. *Replace the plunger and bushing as an assembly if any of the above damage is noted, since they are mated parts.* Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion or brinelling. Reseat the surface or replace the nut or tip if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

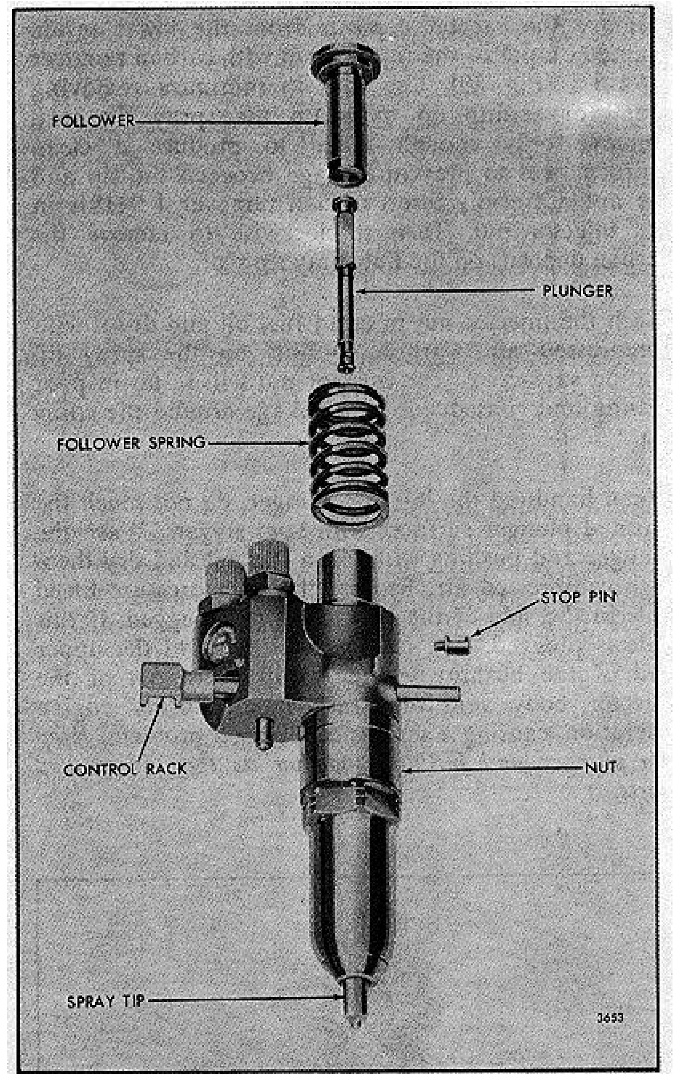


FIG. 37 Injector Plunger, Follower and Relative Location of Parts

Inspect the sealing surfaces of the injector parts indicated by arrows in Fig. 31. Examine the sealing surfaces with a magnifying glass as shown in Fig. 32 for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping and excessive wear. Also check for enlarged orifices in the spray tip.

Replace damaged or excessively worn parts. Check the minimum thickness of the lapped parts as noted in the chart.

Examine the seating area of the needle valve for wear or damage. Also examine the needle quill and its contact point with the valve spring seat. Replace damaged or excessively worn parts.

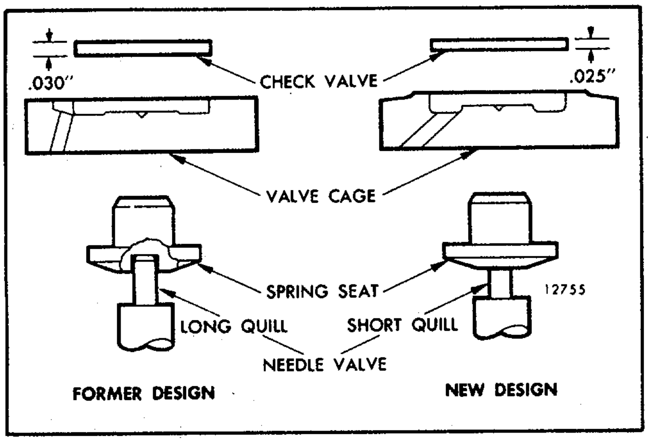


FIG. 38 - Comparison of Former and New Design Injector Parts

Examine the needle valve seat area in the spray tip for foreign material. The smallest particle of such material can prevent the needle valve from seating properly. Polish the seat area with polishing stick J 22964. Coat only the tapered end of the stick with polishing compound J 23038 and insert it directly into the center of the spray tip until it bottoms. Rotate the stick 6 to 12 times, applying a light pressure with the thumb and forefinger.

NOTE: Be sure that no compound is accidentally placed on the lapped surfaces located higher up in the spray tip. The slightest lapping action on these surfaces can alter the near-perfect fit between the needle valve and tip.

Before reinstalling used injector parts, lap all of the sealing surfaces indicated by the arrows in Fig. 31. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

NOTE: The sealing surface of current spray tips is precision lapped by a new process which leaves the surface with a dull satin-like finish; the lapped surface on former spray tips was bright and shinny (Fig. 39). It is not recommended to lap the surface of the *new* current spray tip.

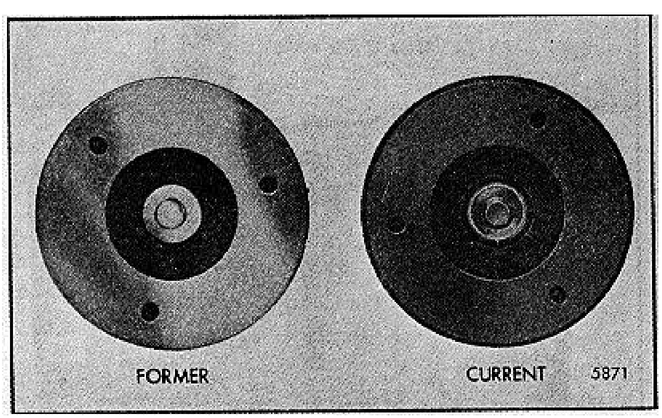


FIG. 39 Spray Tip Sealing Surface Identification

Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 31 and Table 1 as follows:

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163"-.165"
Check Valve	.022"
Valve Spring Cage	.602"

TABLE 1 - Minimum Thickness (Used Parts)

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 as shown in Fig. 33 and, using a figure eight motion, move it back and forth across the block. Do not press

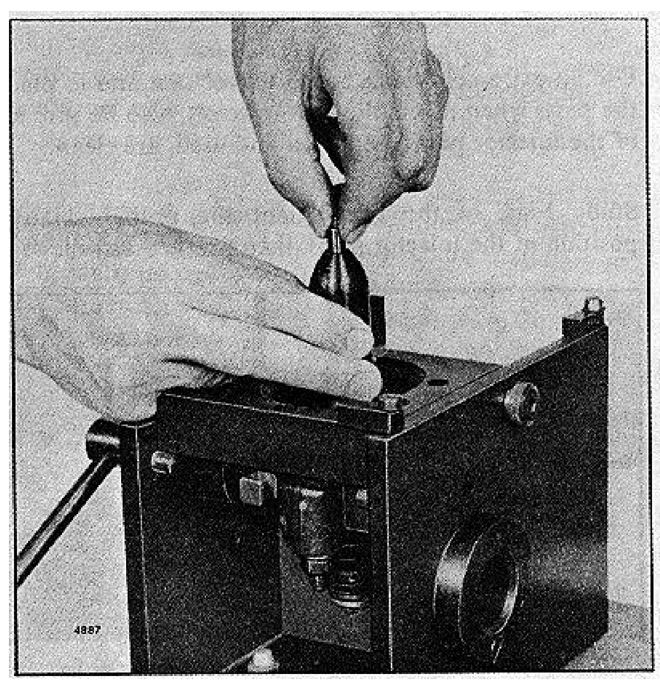


FIG. 40 - Tightening Injector Nut By Hand

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* (refer to Table 1).

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 fuel oil and dry them with compressed air.

ASSEMBLE INJECTOR

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean.

Study Figs. 34 through 37 for the proper relative position of the injector parts, then proceed as follows:

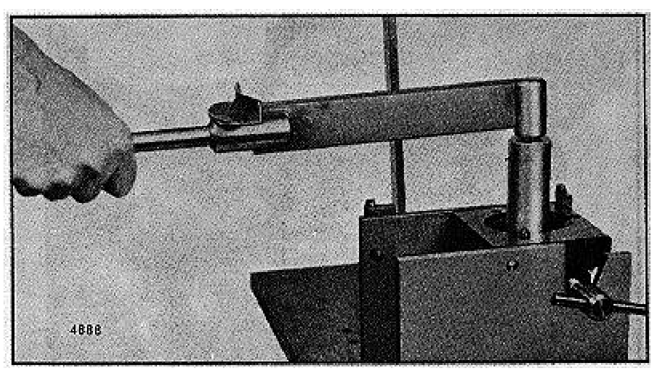


FIG. 41 - Tightening Injector Nut With Torque Wrench using Tool J 4983-01

Assemble Injector Filters

Always use new filters and gaskets when reassembling an injector.

1. Insert a new filter, dimple end down, slotted end up, in each of the fuel cavities in the top of the injector body (Fig. 35).

> **NOTE:** Install a new filter in the inlet side (located over the injector rack) in a fuel injector with an offset body. No filter is required in the outlet side of the offset body injector (Fig. 34).

2. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps lb 65-75 lb-ft (88-102 Nm) torque with a 9/16" deep socket (Fig. 23).

3. Purge the filters after installation by directing compressed air or fuel through the filter caps.

4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

Assemble Rack and Gears

Refer to Fig. 36 and note the drill spot marks on the control rack and gear. Then proceed as follows:

1. Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 36).

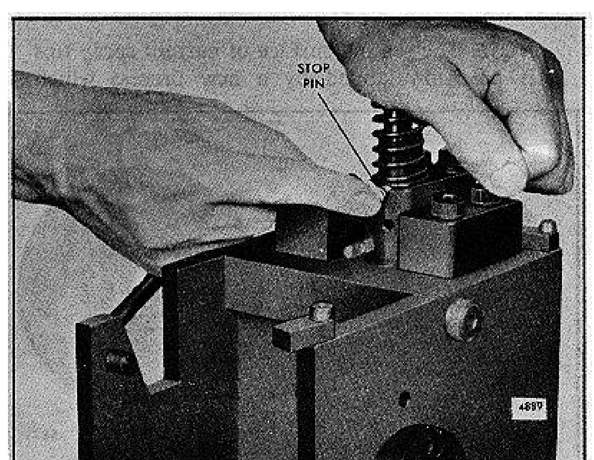


FIG. 42 - Installing Injector Follower Stop Pin

3. Place the gear retainer on top of the gear.

4. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

Assemble Spray Tip, Spring Cage and Check Valve Assemblies

Refer to Fig. 36 and assemble the parts as follows:

1. Support the injector body, bottom end up, in injector holding fixture J 22396.

2. Place a new seal ring on the shoulder of the body.

NOTE: 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.

A new injector nut seal ring protector (J 29197) is now available to install the seal ring. Use the following procedure when installing the seal ring with the new protector:

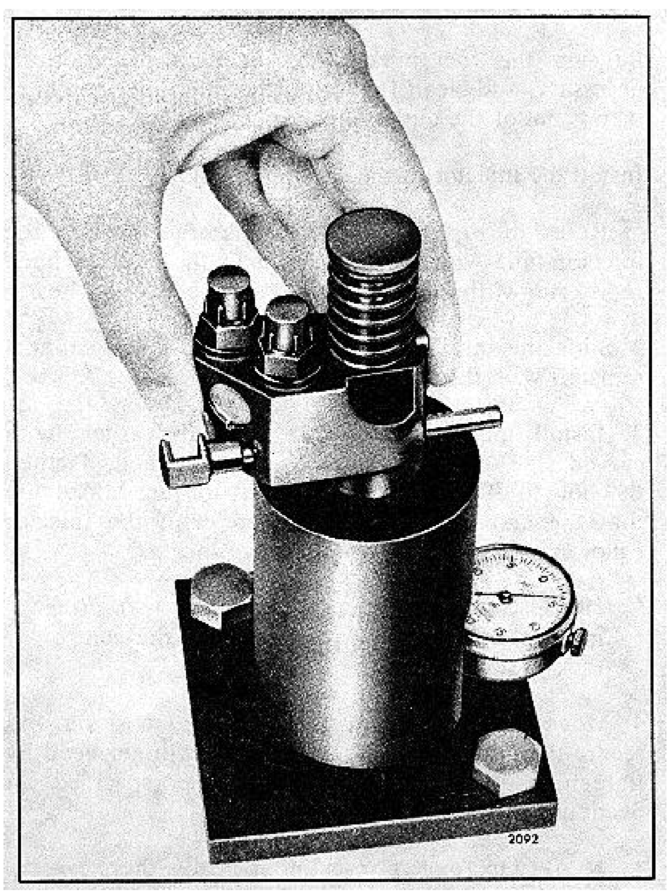


FIG. 43 Checking Injector Spray Tip Concentricity using Tool J 5119

a. Place the new seal ring and protector in a container with a small amount of injector test oil.

NOTE: Lubrication of the seal ring and protector is important to assure proper installation of the seal ring.

b. Support the injector body, bottom end up, in injector holding fixture J 22396.

c. Place the lubricated protector over the threads of the injector body. Place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

d. Remove the protector.

3. Install the spill deflector over the barrel of the bushing.

4. Place the check valve (without the .010" hole) centrally on the top of the bushing. Then place the check valve cage over the check valve and against the bushing.

NOTE: The former and new check valve and check valve cage are not separately interchangeable in a former injector (Fig. 38).

5. Insert the spring seat in the valve spring, then insert the assembly into the spring cage, spring seat first.

NOTE: Install a new spring seat (Fig. 38) in a former injector if a new design spray tip assembly is used.

6. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

NOTE: When installing a new spray tip assembly in a former injector, a new valve spring seat must also be installed. The current needle valve has a shorter quill.

7. Insert the needle valve, tapered end down, inside of the spray tip (Fig. 2). Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

8. 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 (Fig. 40). 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.

9. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 lb-ft (102-1*15* Nm) torque (Fig. 41).

> **NOTE:** 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.

10. 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 which may allow assembly on the body without extruding the seal and forcing it out of the body-nut crevice.

Assemble Plunger and Follower

1. Refer to Fig. 37 and slide the head of the plunger into the follower.

2. Invert the injector in the assembly fixture (filter cap end up) and push the rack all the way in. Then place the follower spring on the injector body.

3. Refer to Fig. 42 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next align the flat side of the plunger with the slot in the follower. Then 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 Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in the concentricity gage J 5119 as shown in Fig. 43 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 75-85 lb-ft (102-115 Nm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under *Test Injector.*

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble and test the injector again.

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 5286-9, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head 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 runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to Fig. 6 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 20-25 lb-ft (27-34 Nm) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

> **NOTE:** Check the injector control *rack* for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the *rocker arm brackets to the cylinder head by* tightening the bolts to the torque specified in Section 2.0.

> **NOTE:** On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the

rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridge before, during and after tightening the rocker shaft bolts.

5. Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-0l to tighten the connections to 12-*l5* lb-ft (16-20 Nm) torque.

IMPORTANT: 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 *Pressurize Fuel System - Check for Leaks* in Section 2.0).

NOTE: 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 filter 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. Re-install the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 and refill the crankcase to the proper level with the recommended grade of oil.

6. 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 the top with a neoprene ring and upset into a flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

Effective with engine serial numbers 6VA-99654, 8VA-362195 and 12VA-54414 a new Fluoroelastomer (Viton) seal ring is being used.

> **NOTE:** Do not use methoxy propanol based antifreeze in the cooling system of any Detroit Diesel engine built after the above engine serial numbers, or engines where the new (Viton) seal ring has been installed.

Repair Leaking Injector Tube

To enable the repair of a leaking fuel injector hole tube at the seal ring, without removing the cylinder head from the cylinder block, a new injector hole tube swaging tool J 28611 is now available.

Before removing the fuel injector, pressurize the cooling system at the radiator to verify the injector tube seal ring leak. Then with the fuel injector removed, insert the swaging tool into the fuel injector hole tube. The tool is tapered and flanged to prevent damage to the cylinder head or injector tube. Hit the top of the tool moderately with a one pound hammer two or three blows seating the tool. This will cause the top edge of the injector hole tube to expand, thus

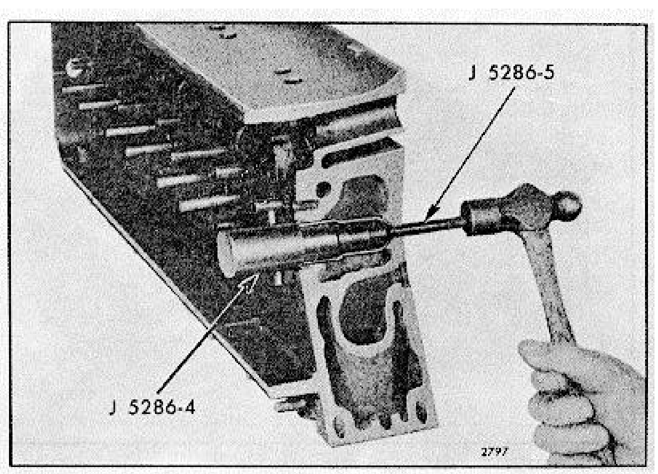


FIG. 1 Removing Injector lube

increasing the crush on the injector tube seal ring and seal the leak. Install the fuel injector and again pressurize the cooling system to verify the leak has been stopped.

This tool was designed mainly for use on engines built between July, 1973 and August, 1977 with fuel injector hole tube seal rings that may be pressure sensitive and, if so, could take a heat set. The result being a coolant leak at the seal ring. The use of the swaging tool, as stated above will restore tension to the seal ring.

Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22525 as follows:

1. Remove, disassemble and clean the cylinder head as outlined in Section 1.2.

2. Place the injector tube installer J 5286-4 in the injector tube. Insert the pilot J 5286-5 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.

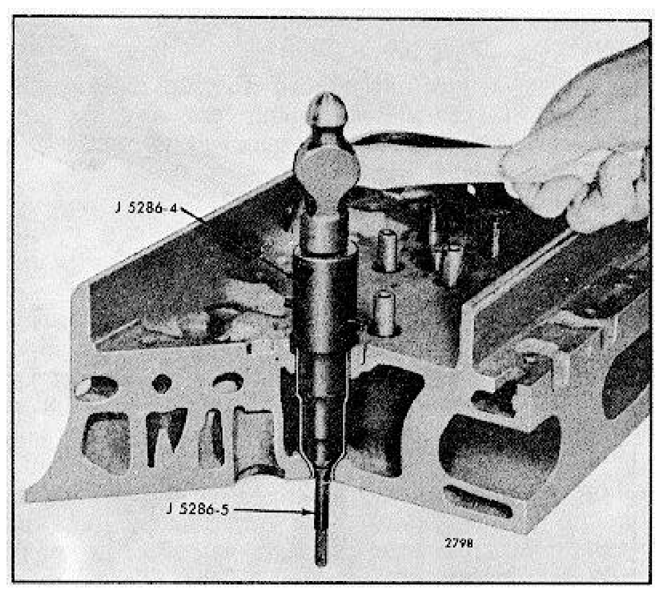


FIG. 2 Installing Injector Tube

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 5286-4 in the injector tube. Then insert the pilot J 5286-5 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 into the injector bore and drive it in place as shown in Fig. 2. Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

4. With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

   a. Turn the cylinder head bottom side up, remove the pilot- J 5286-5 and thread the upsetting die J 5286-6 into the tapped end of the installer J 5286-4 (Fig. 3).

   b. Then, using a socket and torque wrench, apply approximately 30 Ib-ft (41 Nm) torque on the upsetting die.

   c. Remove the installing tools and ream the injector tube as outlined below.

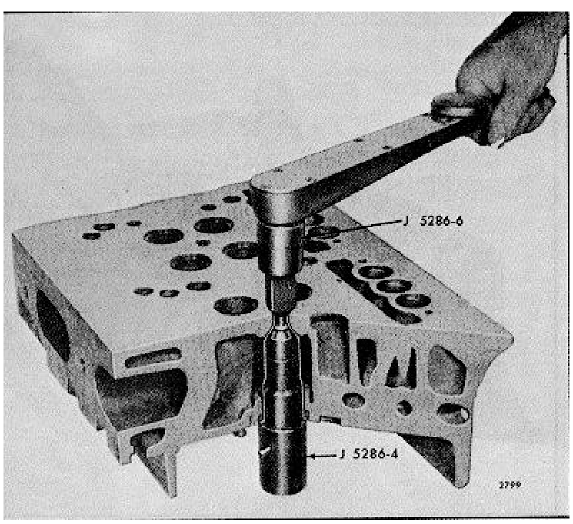


FIG. 3 Upsetting Injector Tube

Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations: First, *hand reamed,* as 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; and third, *hand reamed,* as shown in Fig. 5, 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.

> **NOTE:** 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 22525-1 in the injector tube.

   b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 4). Clean out all of the chips.

2. Remove excess stock:

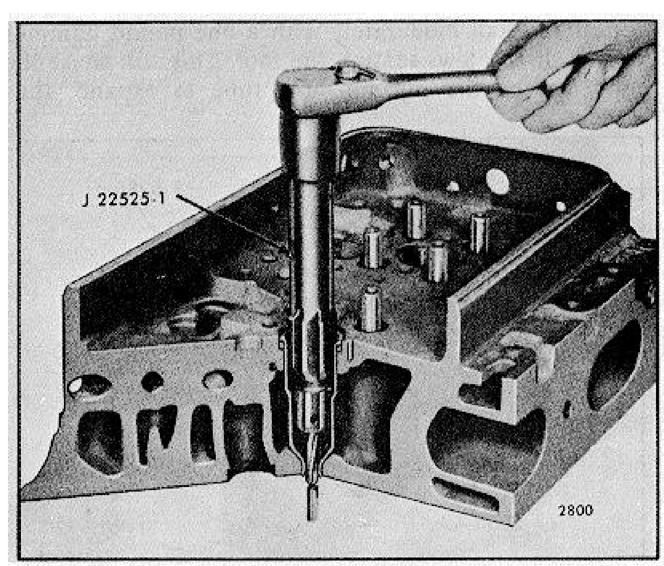


FIG. 4 Reaming Injector Tube for Injector Body Nut and Spray Tip

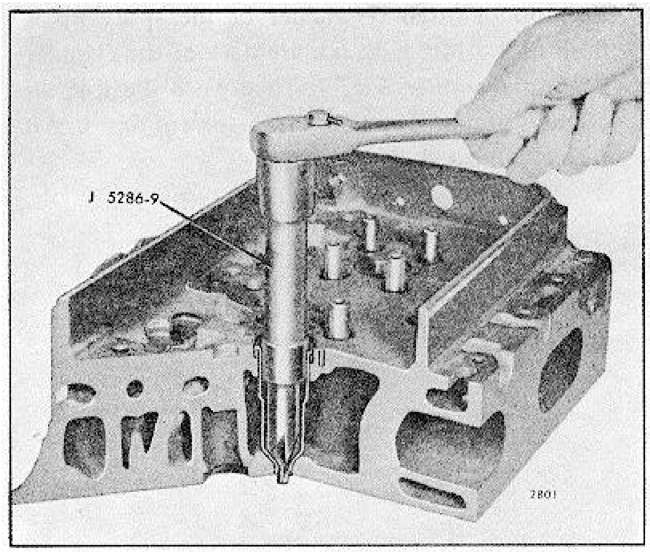


FIG. 5 - Reaming Injector Tube for Injector Nut

a. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286-8 into the small hole of the injector tube.

b. Place a few drops *of* cutting oil on the tool. Then, using a socket and a speed handle, 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.

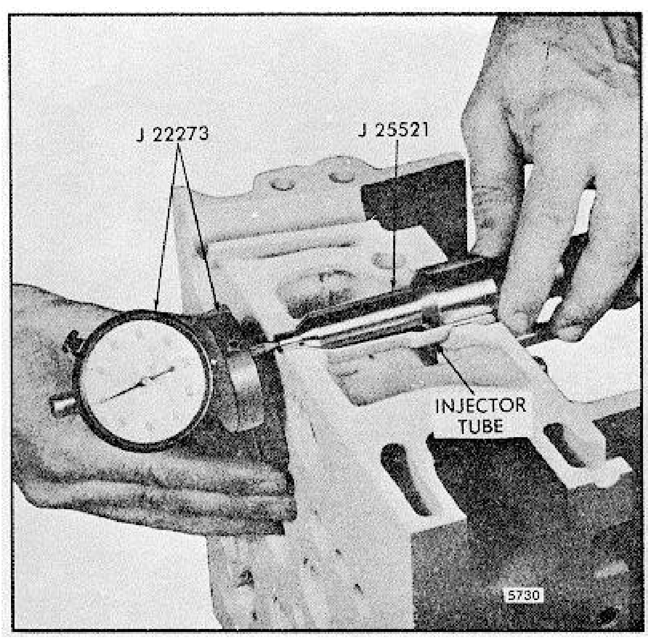


FIG. 6 - Measuring Relationship of Bevel Seat of Injector Tube to Fire Deck of Cylinder Head.

3. Ream the bevel seat in the injector tube:

*The tapered lower end of the injector tu*be *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 seat of the tube, refer to Fig. 6.

Install gage J 25521 in the injector tube. Zero the sled gage dial indicator J 22273 to the fire deck. Gage J 25521 should be flush to ±.014 " with the fire deck of the cylinder head (Fig.7).

NOTE: Any fire deck resurfacing work must be done prior to final injector tube seat gauging. Refer to Section 1.2 for resurfacing instructions.

With the first reaming operation completed and the injector tube spot-faced, wash the interior of the injector tube with clean solvent and dry it with compressed air. Then perform the second reaming operation as follows:

a. Place a few drops of cutting oil on the bevel seat o*f the* tube. Carefully *lower the reamer J 5286-9* into the injector 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.

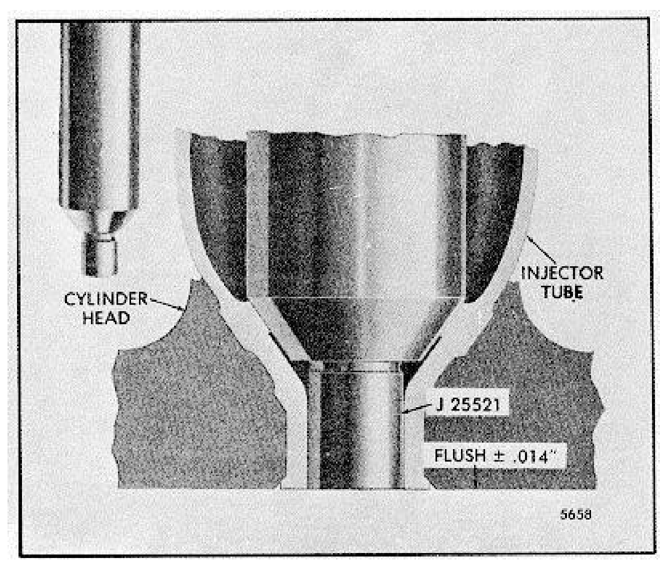


FIG. 7 - Measuring Relationship of Gage to Fire Deck of Cylinder Head

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 gage J 25521, continue the reaming operation until the shoulder of the spray tip is flush to ± .014" with the fire deck of the cylinder head as shown in Fig. 7. Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

FUEL PUMP

The positive displacement gear-type fuel pump (Fig. 1) transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system- and cools the 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 attached to the governor housing with three nylon patch bolts which prevents the oil in the governor housing from seeping out around the bolt threads. The pump is driven off the end of the right-hand helix blower rotor by means of a drive coupling fork attached to the end of the pump drive shaft and mating with a drive disc attached to the blower rotor as shown in Fig. 2. The fuel pump is a left-hand rotating pump. Regardless of engine rotation, the pump will always rotate in a left-hand rotation.

Certain engine applications use a high-capacity fuel pump with 3/8" wide gears to increase fuel flow and reduce fuel spill temperature. The high-capacity fuel pump and the standard fuel pump with 1/4" wide gears may not be completely interchangeable; therefore, when replacing a standard pump with a high-capacity pump, the appropriate fuel lines and connections must be used.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal-to-metal

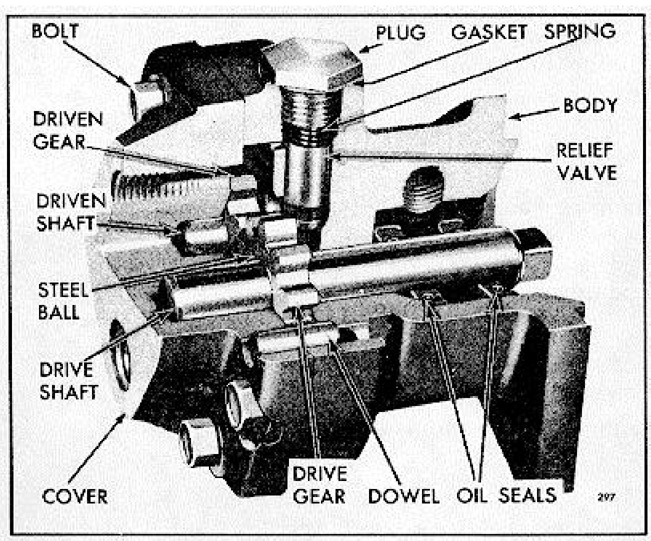


FIG. 1. - Typical Fuel Pump Assembly

contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. 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" 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 "B" 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 governor housing (Fig. 1). 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.

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shutdown. 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. 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. However, if leakage exceeds one drop per minute, replace the seals.

Effective with engines built November, 1979; a higher temperature material lip type seal is now being used in the fuel pumps. The new fuel pump seal is made of polyacrylate material, whereas the former seal is made of nitrile. The new fuel pumps (with the polyacrylate seals) will have the seals installed the same as the high lift fuel pumps, with the lips of the seals facing in the

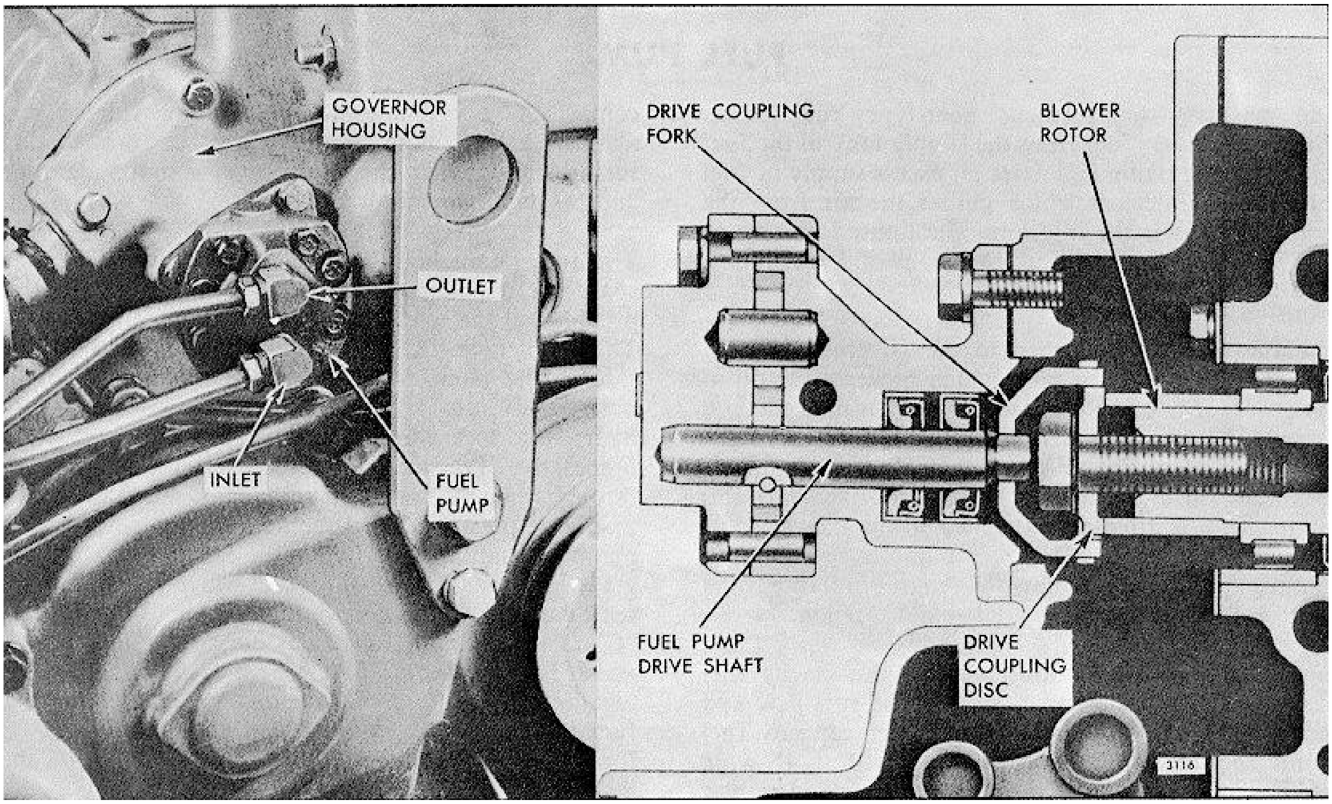


FIG. 2 - Typical Fuel Pump Mounting and Drive

opposite direction of each other (Fig. 4). The former fuel pumps have the nitrile seals installed with both seal lips facing the mounting flange end of the pump. Both the polyacrylate and nitrile seals are interchange- able in a fuel pump. Only the polyacrylate seals and fuel pumps with polyacrylate seals will be serviced.

The drive and driven gears are a line-to-line to .001 press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft (Fig. 2).

A 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 65 psi (448 kPa).

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 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 when the discharge pressure reaches approximately 65 to 75 psi (448-517 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. Remove the three pump attaching bolts and withdraw the pump from the governor housing.

3. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

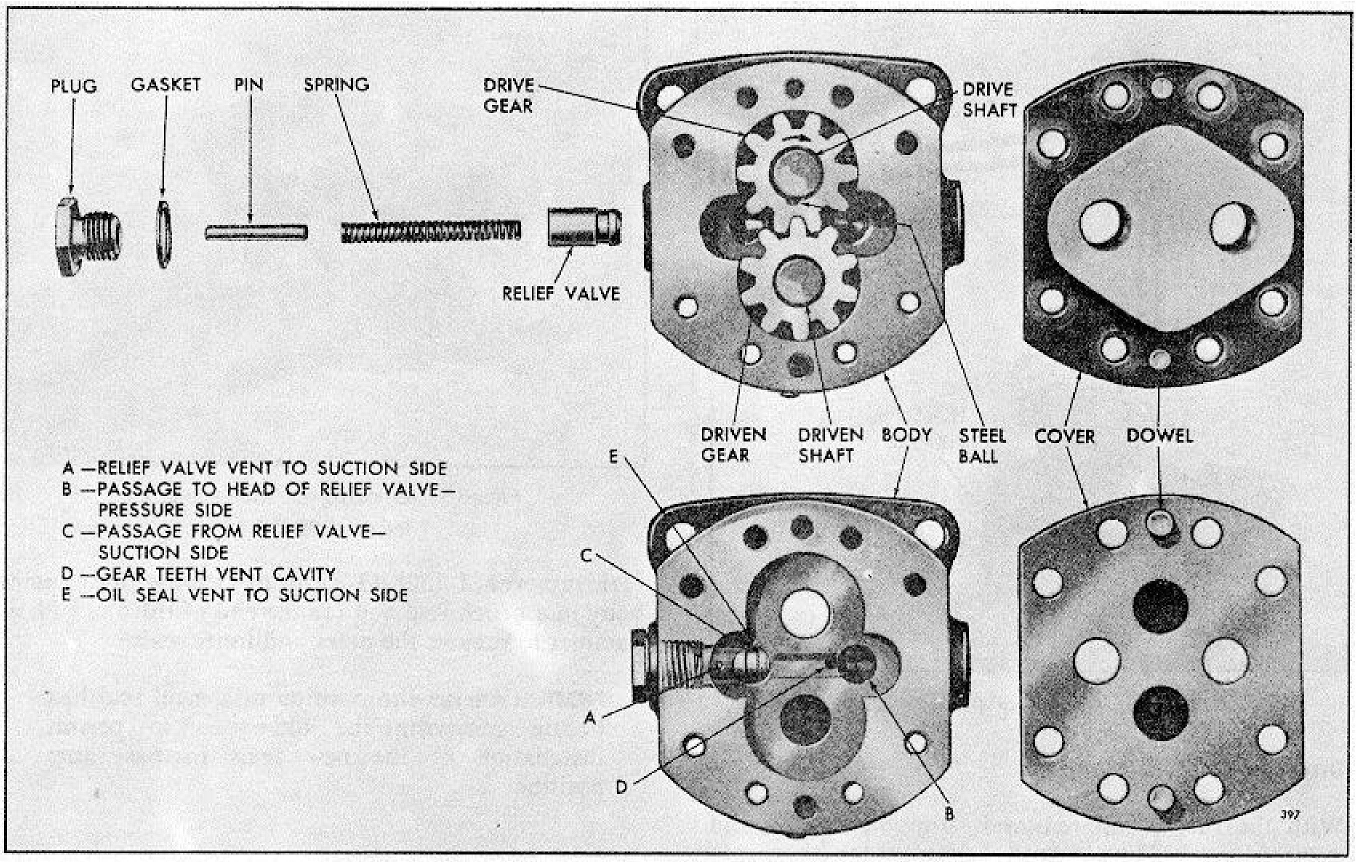


FIG. 3 - Fuel Pump Valving and Rotation

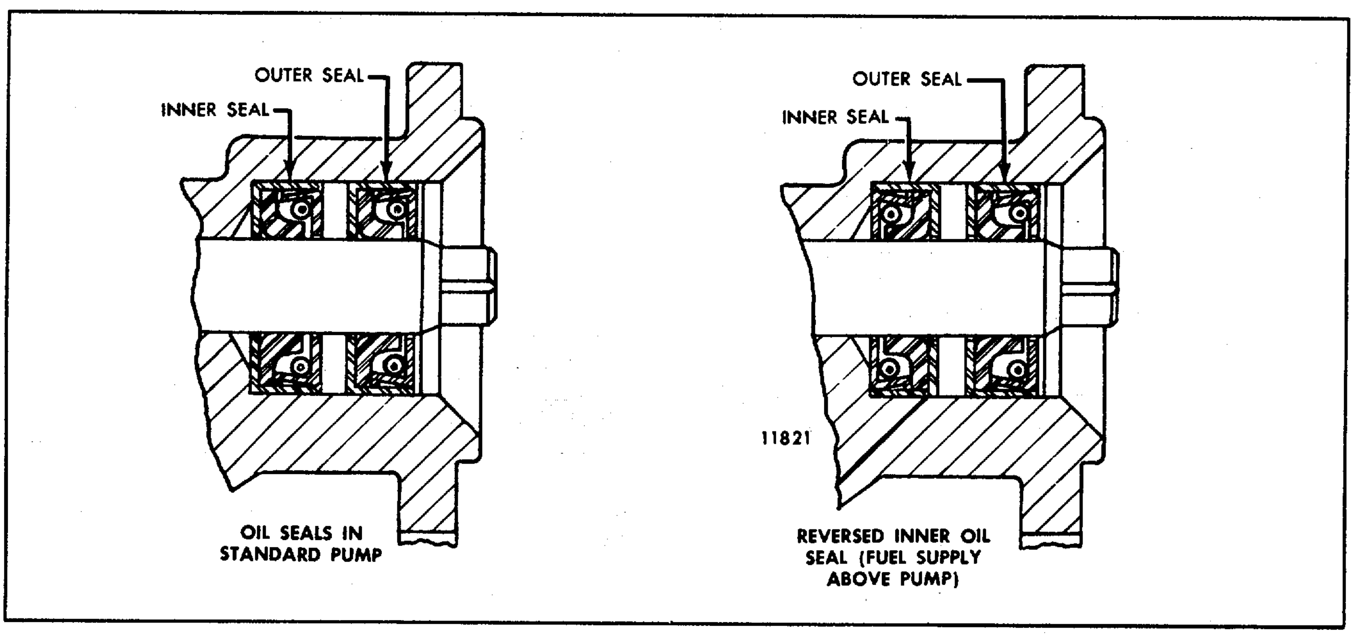


FIG. 4 Fuel Pump Oil Seal Arrangements

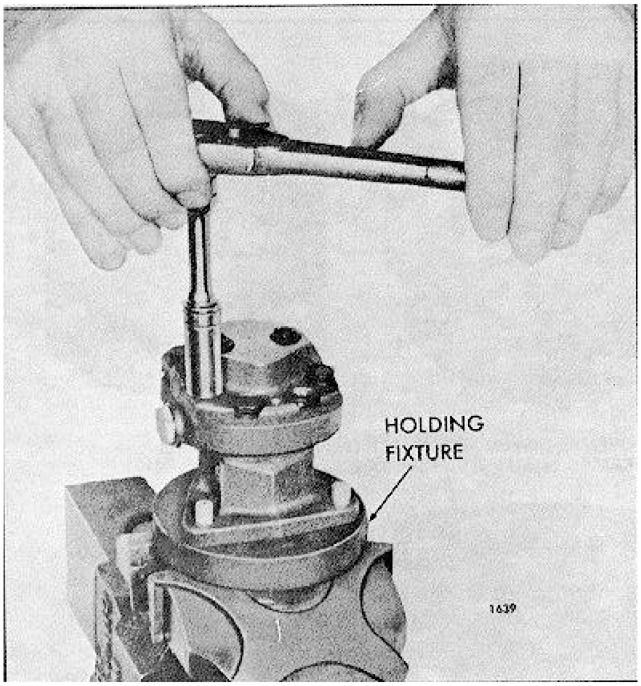


FIG. 5 Removing Pump Cover

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 as shown in Fig. 5, refer to Figs. 1 and 7 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.

2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.

3. 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.

4. 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.

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

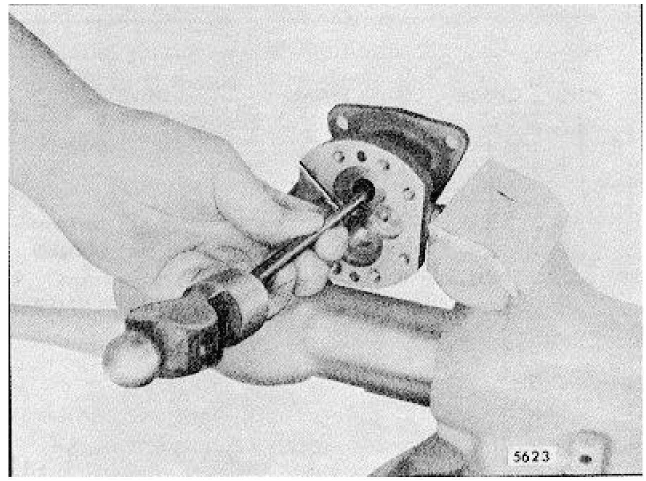


FIG. 6 - Removing Oil Seals using Tool J 1508- 13

seal remover J 1508-13 (Fig. 6). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals.

NOTE: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position.

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the *gear.*

Inspect the drive and driven shafts for scoring or wear. Replace the shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

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 valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Current standard fuel *pumps* (with 1/4" wide gears) incorporate a 1/8" shorter pump body with three

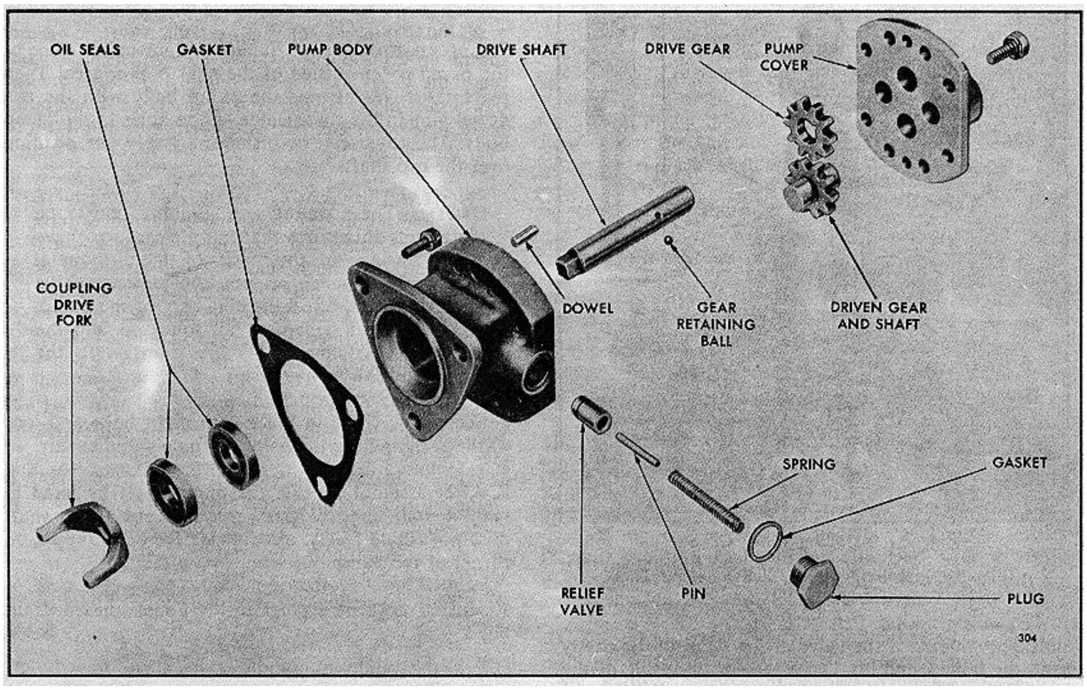


FIG. 7. Fuel Pump Details and Relative Location of Parts

drain holes, a 1/8" shorter drive shaft and a cover with a 3/8" inlet opening. When replacing a former pump, a 3/8" x 1/4" reducing bushing is required for the inlet opening and the unused drain holes must be plugged.

NOTE: Current four-valve head 12V engines use a .1065" restricted elbow in the fuel return line with a high-capacity fuel pump (3/8" wide gears). Former engines used an .080" restricted elbow and a standard fuel pump (1/4" wide gears). If a high-capacity pump is installed on an early 12V engine, be sure to install a .1065" restricted fitting in the fuel return line.

Assemble Fuel Pump

Refer to Figs. 1, 3 and 7 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:

NOTE: The inboard seal facing "IN" requires greater care at assembly or service to prevent seal lip damage.

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 toward the shoulder on the tool.

b. With the pump body supported on wood blocks (Fig. 8), 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.

c. Place the shorter end of the adaptor J 1508-9 over the pilot and against the shoulder of the installer handle. 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 (Fig. 9) 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

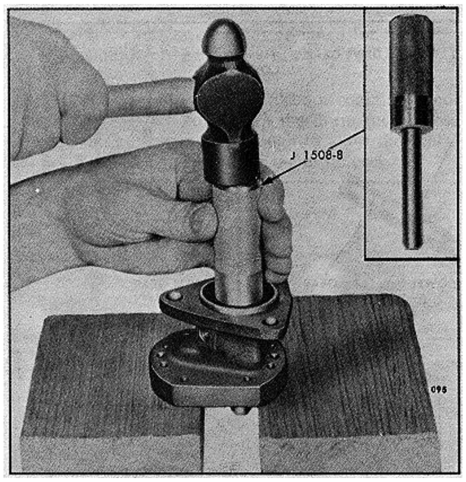


FIG. 7 Installing Inner Oil Seal

FIG. 8 Installing Inner Oil Seal using Tool J 1508-8

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 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 1/2"-20 plug to 18-22 lb-ft (24-30 Nm) torque.

3. 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.

4. Lubricate the pump 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 as shown in Fig. 10.

5. Place the driven shaft and gear assembly in the pump body.

NOTE: The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used. The slot must face toward the pump cover.

6. Lubricate the gears and shafts with clean engine oil.

7. 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 cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

NOTE: 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.

8. Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.

9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.

10. Install 1/8" pipe plugs in the upper unused drain holes.

11. If the pump is not to be installed immediately, place plastic shipping plugs in the inlet and outlet

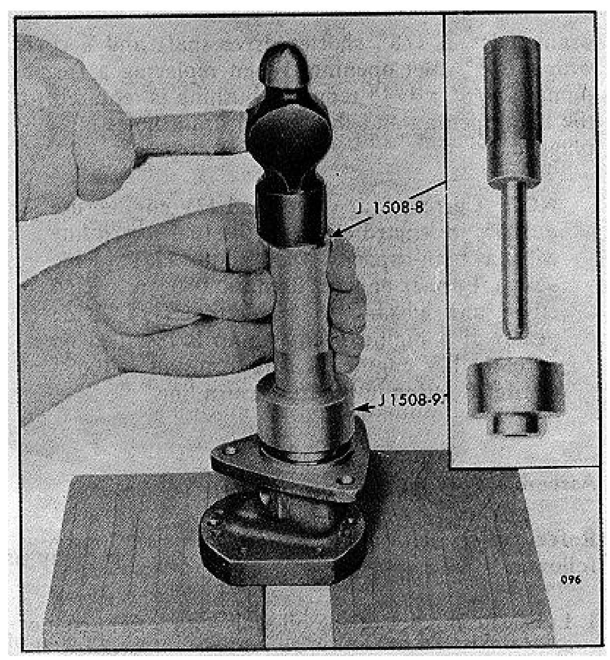


FIG. 9 - Installing Outer Oil Seal using Tools J 1508-8 and J 1508-9

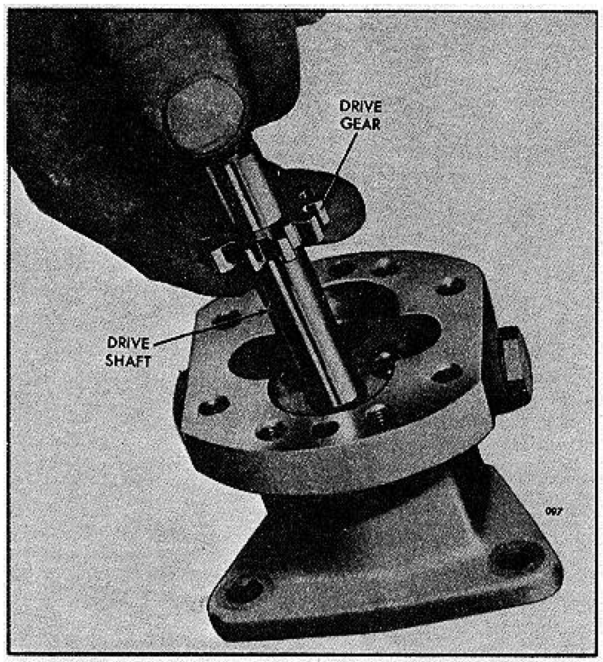


FIG. 9 - Installing Drive Shaft and Gear Assembly

FIG. 10 Installing Drive Shaft and Gear Assembly

openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

The pump must always be installed with the inlet opening in the pump cover (marked "L.H. IN") next to the balance weight cover on 6V, 8V and 12V engines. Refer to Fig. 2 and note that the fuel pump is bolted to the governor housing and is driven by the drive coupling fork and the drive disc which is attached to the blower rotor. Install the pump as follows:

1. Affix a new gasket to the pump body mounting flange. Then place the drive coupling fork on the square end of the drive shaft.

2. Place the fuel pump against the governor housing, being certain that the drive coupling fork registers with the slots in the drive disc.

3. Secure the pump to the governor housing with three nylon patch bolts.

NOTE: To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

4. If removed, install the fuel inlet and outlet elbows in the pump cover.

5. Connect the inlet and outlet fuel lines to the fuel pump elbows.

6. If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine using tool J 5956. This will prevent the possibility of pump seizure upon initial starting.

FUEL STRAINER AND FUEL FILTER

(Bolt-On Type)

A fuel strainer (primary) and fuel filter (secondary), Fig. 1, are used to remove impurities from the fuel. 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 (Fig. 2) can remove particles as small as 10 microns.

NOTE: 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 quickly clog the fuel filter and cause damage to the fuel pump and the fuel injectors.

The fuel strainer and fuel filter are essentially the same in construction and operation, and they will be treated as one in this section. The filter and strainer, illustrated in Figs. 3 and 4, consist basically of a shell, a cover, and a replaceable filtering element. The assembly is made oil tight by a shell gasket, a cover nut or bolt, and a cover nut or bolt gasket. The central stud is a permanent part of the shell and, when the unit is assembled, extends up through the cover where the nut or bolt holds the assembly together.

A filter element sets over the central stud inside the shell and is centered in the shell by the stud.

The former and current cover assemblies are visibly different by a cast letter "P" (primary) that has been added to the top of the strainer cover and the letter "S" (secondary) that has been added to the top of the filter cover.

Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the inlet passage in the cover and into the shell surrounding the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where dirt particles are removed. Clean fuel flows to the interior of the filter element, up through the central passage in the cover and into the outlet passage, then to the fuel inlet manifold in the cylinder head.

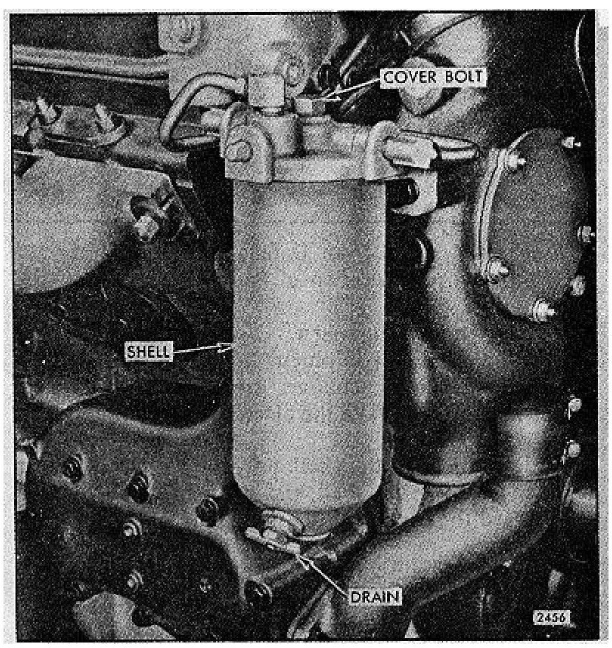


FIG. 1 Typical Mounting of Fuel Filter

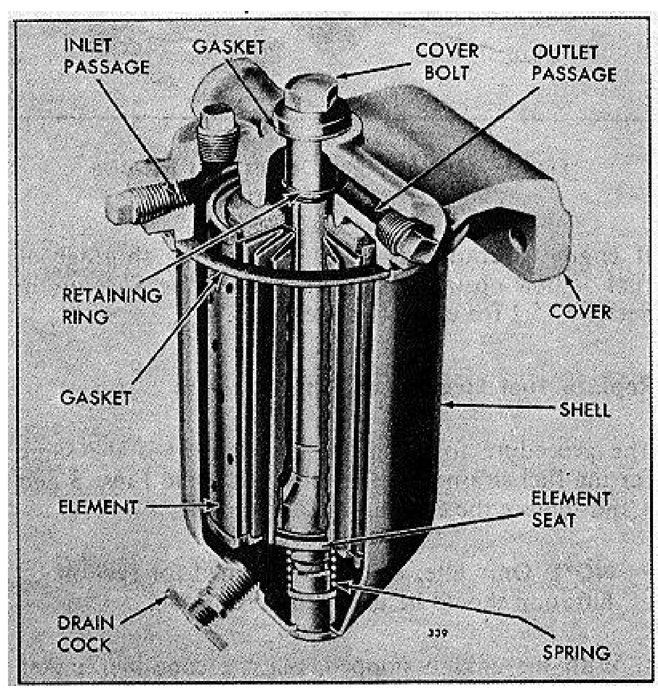


FIG. 2 Fuel Filter Assembly

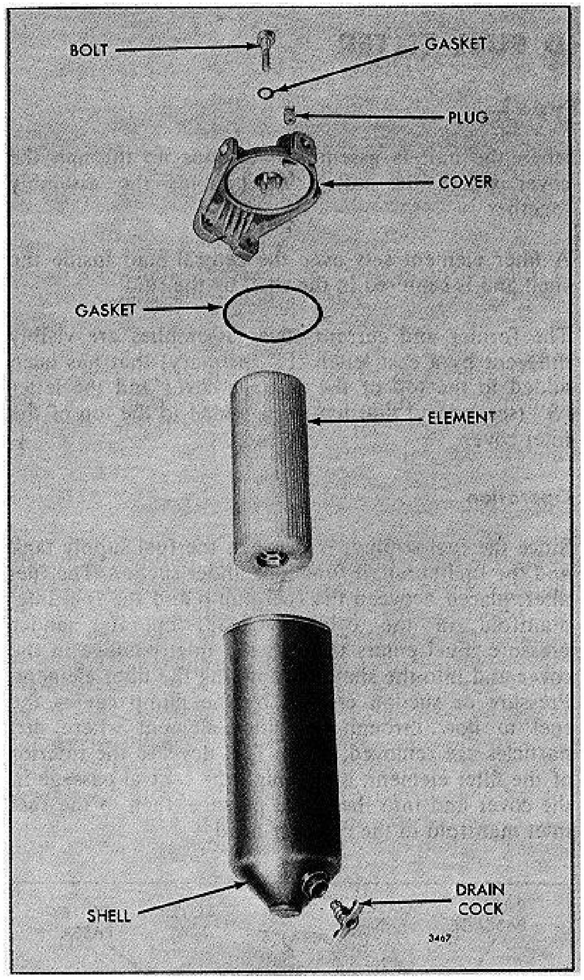


FIG. 3 Fuel Strainer Details and Relative Location of Parts

If engine operation is erratic, indicating shortage of fuel or flow obstructions, refer to *Trouble Shooting* in Section 15.2 for corrective measures.

Replace Fuel Strainer or Filter Element

The procedure for replacing an element is the same for the fuel strainer or fuel filter. Refer to Figs. 3 and 4 and replace the element as follows:

NOTE: 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.

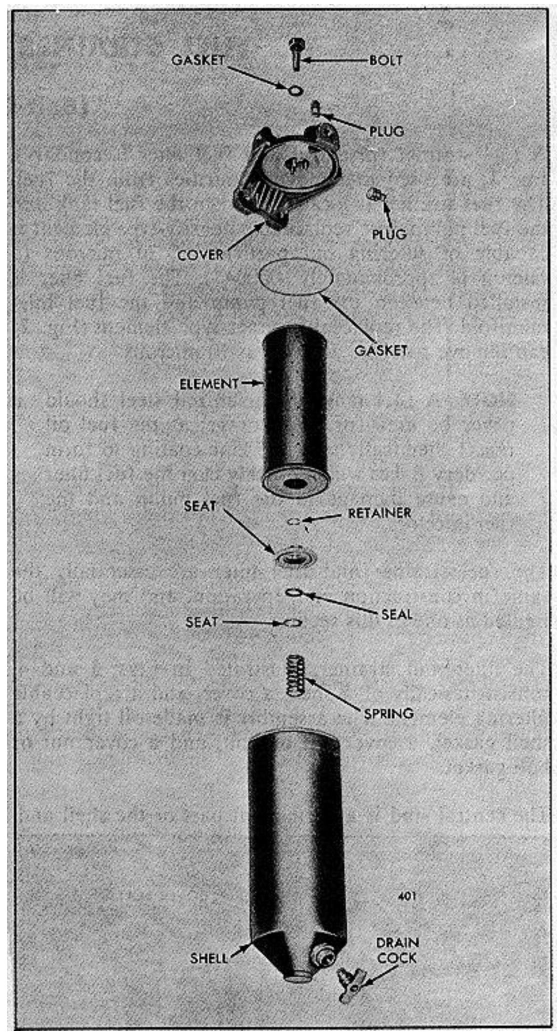


FIG. 4 Fuel Filter Details and Relative Location of Parts

NOTE: 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. Also remove and discard the cover nut retaining ring, if used.

3. Remove and discard the filter element and shell gasket, the cover nut or bolt gasket, and, if used, the cover bolt snap ring.

NOTE: Current strainers and filters do not incorporate the cover bolt snap ring. This was eliminated to facilitate replacement of the bolt gasket with each element replacement.

4. Wash the shell thoroughly with clean -fuel oil and dry it with compressed air.

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.

NOTE: The element seat, spring, washer and seal can not 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. The strainer element also includes both the former and current bolt gaskets.

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.

NOTE: 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. Place a new shell gasket in the recess of the shell; also place a new gasket on the cover nut or bolt.

8. Place the shell and element in position under the cover. Then thread the cover bolt (or nut) in the center stud.

9. With the shell and the gasket properly positioned, tighten the cover bolt or nut 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.

FUEL STRAINER AND FUEL FILTER

(Spin-On Type)

A spin-on type fuel strainer and fuel filter (Fig. 5) is used on certain engines. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly (Fig. 6). No separate springs or seats are required to support the filters.

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No drain cocks are provided on the spin-on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and inverting the filter. Refill the filter with clean fuel oil before reinstalling it.

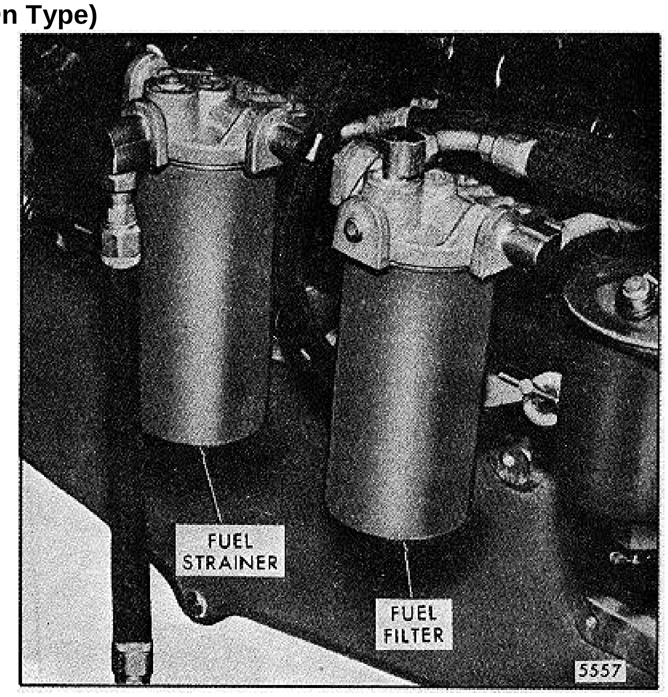


FIG. 5 Typical Spin-On Filter Mounting

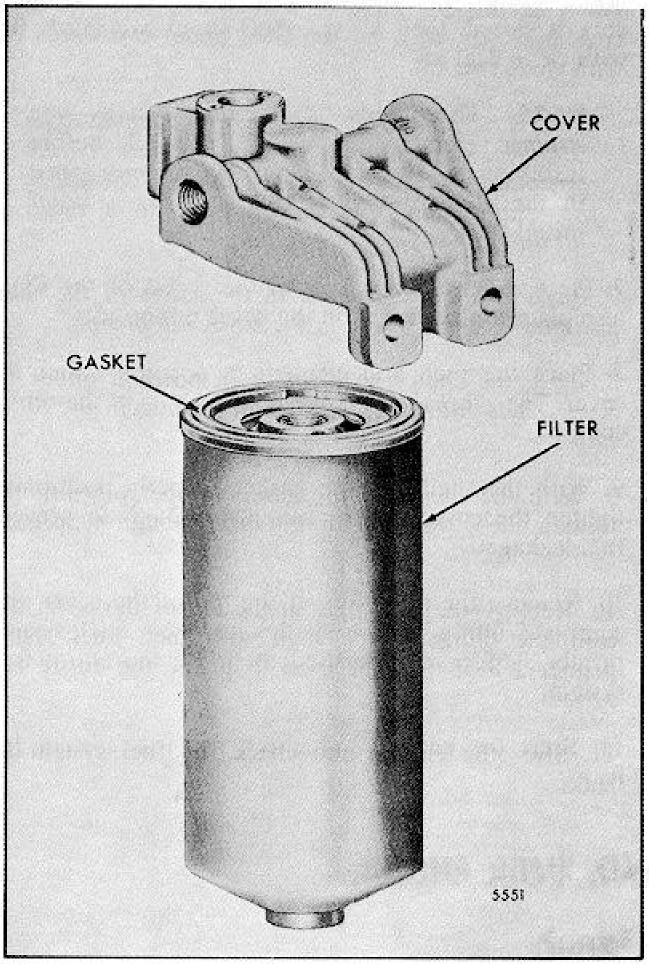


FIG. 6 - Spin-On Filter Details

Filter Replacement

A 1" diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter (or strainer) and discard it.

2. Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new filter assembly and tighten it to one-half of a turn beyond gasket contact.

4. Start the engine and check for leaks.

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 an automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the driver, 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 number, type, idle speed range and drive ratio. 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 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 or 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 clamp bolt to 20-25 lb-ft 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 or 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 governors used on the V-71 engines perform the following two functions:

1. Controls the engine idling speed.

2. Limits the maximum operating speed of the engine.

The limiting speed governors illustrated in Fig. 1 are double-weight type. Double-weight dual range governors (Fig. 2) are also provided for certain 6, 8 and 12V engine applications.

NOTE: A new double weight limiting speed governor is now being used to improve the performance of certain V-71 engines. The new double weight limiting speed governor includes the lighter weight Fuel Squeezer engine weight system. These new double weight governors can replace the former single weight governors in cases where performance problems are being encountered.

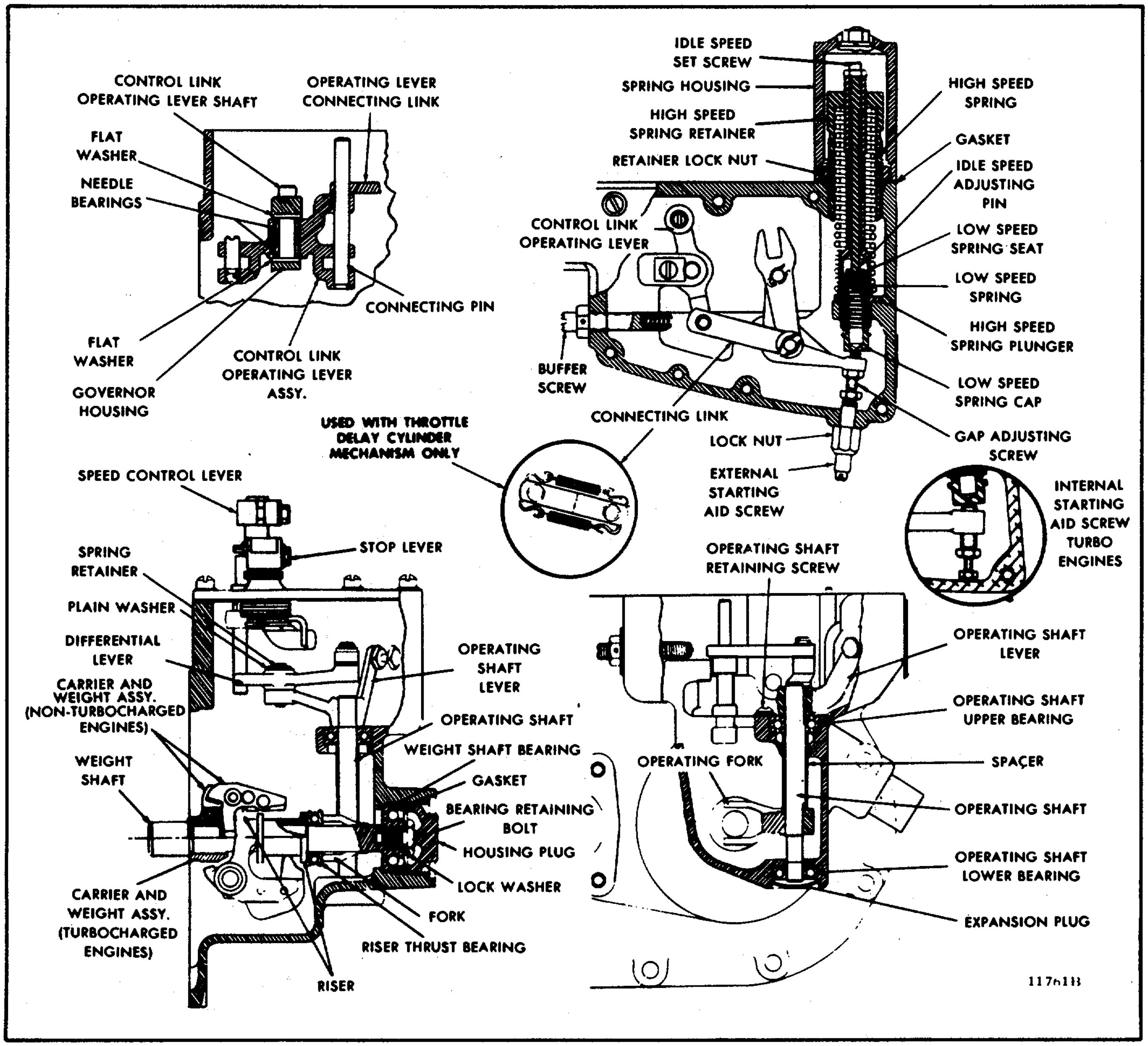


FIG. 1 - Cross Sections of Double Weight Limiting Speed Mechanical Governor

A tamper-resistant double-weight limiting speed governor is provided for highway vehicle engines (refer to Section 2.0).

The limiting speed governor illustrated in Fig. 3 is a single weight type and is utilized on 6, 8 and 12V-71 engine applications, except for Fuel Squeezers and certain coach applications that require low idle speed control (below 500 rpm.

Each governor has an identification plate located on the governor housing, containing the governor assembly number, type and idle speed range. On 6, 8 and 12V engines, the governor is mounted on the front end of the blower. The governor is driven by a blower rotor.

The governor consists of two subassemblies.'

1. Control housing cover.

2. Control and weight housing.

To provide additional design features, a new die cast governor cover with serrated shafts and three bosses is now being used (Fig. .4). This is effective with mechanical governors dated December, 1978. Two bosses are drilled for the limiting speed governors, one for the throttle shaft and one for the shutdown shaft.

> **NOTE:** If a customer furnished mounting bracket is attached to the new cover, it may be necessary to rework the old bracket to clear the unused cast bosses (one for limiting speed governors).

The new die cast governor cover assemblies include a 3/8" diameter serrated shutdown shaft for limiting

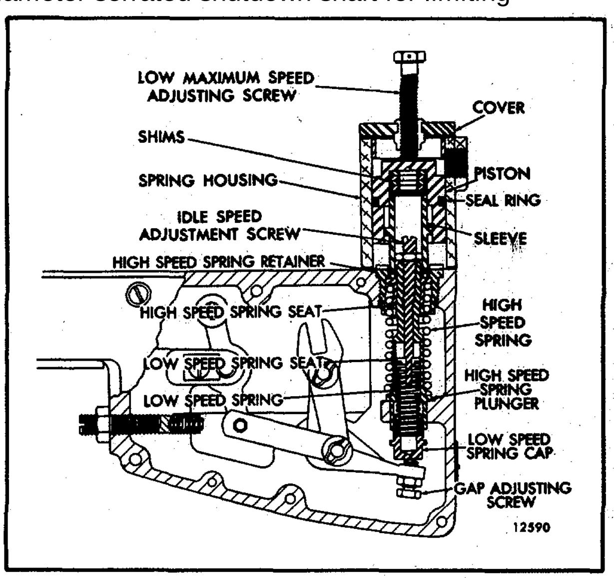


FIG. 2 Cross Section of Dual Range Governor Spring Assembly

speed governors. This assures positive clamping between the serrated levers and the shafts to prevent any slippage. Four serrations -are eliminated on the shutdown shafts to permit certain customers to design a mating 'ever with missing serrations, which will provide a fixed position for particular requirements. Levers are not provided with missing serrations.

To reduce governor speed control lever shaft assembly stop pin wear and prolong bushing and "0" ring seal life, a yieldable speed control lever is available. This newly designed yieldable speed control lever cannot be used with the former stamped cover assemblies; however, a service yieldable speed control lever is available for use with the stamped cover.

The former and new cover and shaft assemblies are interchangeable on a governor.

> **NOTE:** When only a former cover needs replacing, it will be necessary to replace the cover and shaft assembly. Only the new cover is serviced separately. The former control shafts and levers will continue to be serviced for, the former governors.

Operation (Standard Double Weight Governor) - Fig. 1

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.

To limit fuel input during engine start-up, when the speed control lever is in its idle speed position, the turbocharged engines use a starting aid screw. With governors dated June, 1974 or later, the starting aid screw is externally mounted- in the front of the governor housing. It has a domed end and cannot be removed from the outside of the housing (Fig. 1). When the screw is not required, as in naturally aspirated engines, back it out as far as possible to make it ineffective. Turbocharged engine governors dated prior to June, 1974 include an internal starting aid screw threaded into the low-speed gap adjusting screw.

The centrifugal force of the revolving governor low and high-speed weights (Fig. 1) is converted into linear motion which is transmitted through the riser and the 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

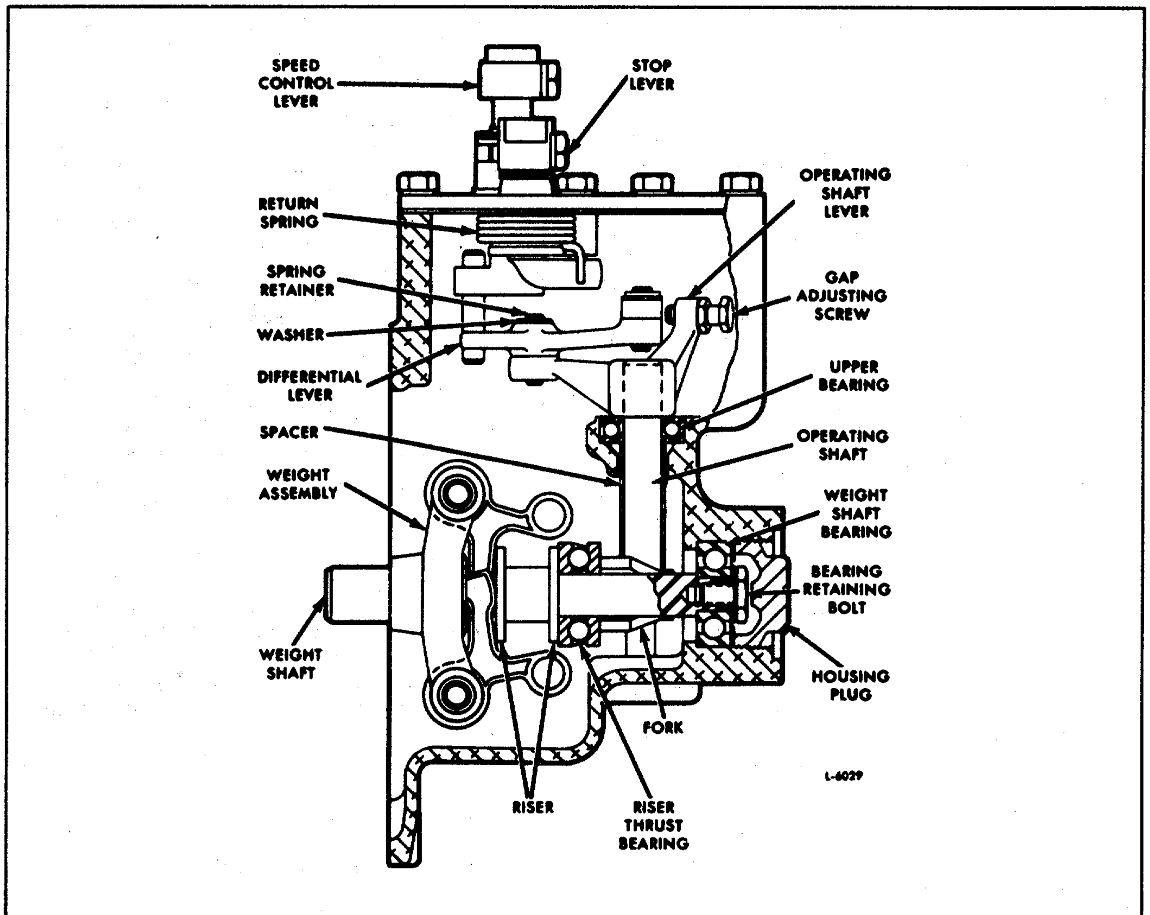


FIG. 3 - Cross Section of Single Weight Limiting Speed Mechanical Governor

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 this force can overcome the high-speed spring and the governor again takes control of the engine, limiting the maximum engine speed.

Fuel rods are connected to the differential lever and injector control tube levers through the control link operating lever and connecting link. This arrangement provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the force exerted by the governor low-speed spring. When the governor speed control lever is placed in the idle speed position, the engine will operate at the 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. Refer to Section 14.3 for the idle speed adjustment.

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 nut will increase or decrease the tension on the high-speed spring. Refer to Section 14.3 for the maximum no-load speed adjustment.

Operation (Double Weight Dual High-Speed Range Governor) - Fig. 2

The mechanical double-weight limiting speed dual range governor has been designed for use in applications that require a high maximum speed part of the time and a low maximum speed the remainder of the time.

This governor in vehicle application, due to its dual speed feature, permits a high engine speed in the lower gear ratios for maximum vehicle acceleration while providing a conservative vehicle speed in the higher gears. The valve for controlling the high and low-speed ranges of the governor is usually connected to the transmission. Thus, the shifting of the transmission from the lower gears to high gear will automatically shift the governor from its high maximum speed range to the low maximum speed range.

The two speed operation is accomplished by the use of air or oil pressure behind a piston to increase the tension on the governor high-speed spring (Fig. 2). On current engines the spring assembly has been revised to include a shorter sleeve and a longer idle speed adjustment set screw. The new sleeve (1.64") and the new set screw (5/16"-24 x 2") must be used together in the spring assembly. Do not mix with the former sleeve (1.84") and set screw (5/16"-24 x 1 l/2').

The removal of air pressure from behind the piston permits the governor high-speed spring to force the piston against the low maximum speed adjusting screw that retains enough tension in the governor high-speed spring to operate the engine at the desired lower speed.

A seal ring is used to prevent leakage of air pressure past the piston assembly. The cylinder is lubricated at the time the piston assembly is installed by spreading an all purpose grease throughout the cylinder bore.

Operation (High-Idle Speed Governor)

The high-idle speed double-weight governor with an idle speed range of 500-800 rpm is used on 12V-71 engines, equipped with Allison Series DP8000, CT, CLT, CBT, CLBT, VCLT, VCBLT, 5000 and 6000 transmissions. The high idle speed increases lubrication to the transmission components during long periods of idle and assures immediate response by the transmission after operating at low speed.

Since the transmission input oil pump volume output is directly related to engine speed, a 650 minimum rpm idle speed in neutral range is required to provide adequate oil flow in the above transmissions at idle. The oil is regulated to precharge the torque converter assembly, range clutches, lubrication system and other areas to assure immediate and prompt initial vehicle performance.

Operation (Single-Weight Governor) - Fig. 3

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. One end of 'the 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 governor control lever.

In the low speed range, the centrifugal force transmitted operates against the low-speed spring. As the engine speed is increased, the centrifugal force compresses the low-speed spring until the spring cap is tight against the high-speed plunger. This removes the low-speed spring from operation and the governor is then in the intermediate speed range. In this range, the centrifugal force is operating against the high-speed spring and thus the engine speed is manually controlled.

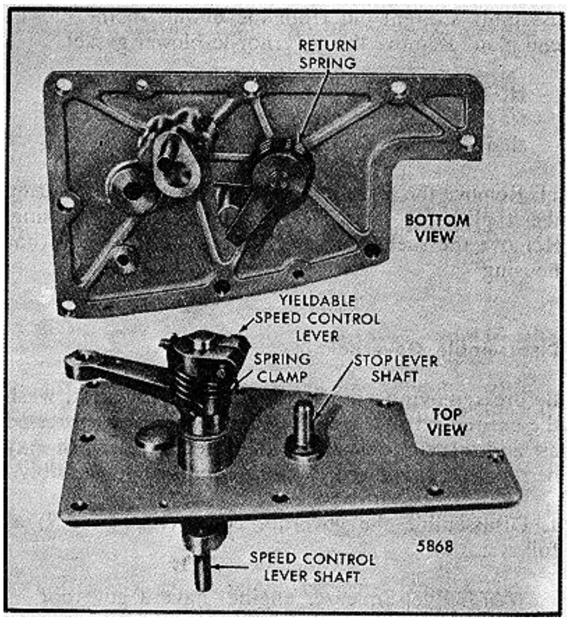


FIG. 4 Die Cast Governor Covers

As the engine speed is increased to a point where the centrifugal force overcomes the pre-load of the high-speed spring, the governor will move the injector racks out to that position required for maximum no-load speed.

A fuel rod, connected to the differential]ever and the injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out tension on the low-speed spring.

Adjustment of the engine idle speed is accomplished by changing the tension of the low-speed spring by means of the idle adjusting screw. Refer to Section 14.3 for the idle speed adjustment.

The maximum no-load speed is determined by the centrifugal force required to balance out the tension on the 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 nut will increase or decrease the tension on the high-speed spring. Refer to Section 14.3 for the maximum no-load speed adjustment.

Lubrication

The governor is lubricated by a spray of lubricating oil from 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 From Engine

Governor operation should be checked as outlined in Section 2.7 before the governor is removed from the engine. If, after performing these checks, the governor fails to control the engine properly, it should be removed and reconditioned.

1. Open the drain cocks and drain the engine cooling system.

2. Remove any accessories attached to the cylinder head, governor or front end of the engine that interfere with removal of the governor assembly.

3. Disconnect the control linkage from the speed control and stop levers (Fig. 5).

4. Remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.

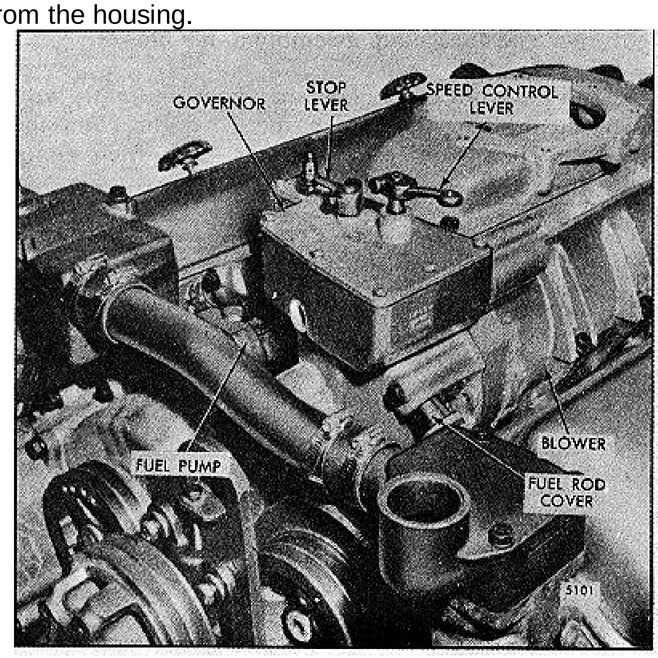


FIG. 5 Limiting Speed Mechanical Governor Mounting

5. Remove the fuel rods from the control link operating lever assembly (Fig. l or 3) and the injector control tube levers as follows:

a. Remove the valve rocker covers from the cylinder heads.

b. Remove the right-bank fuel rod by removing the screw type pin, in the control link operating lever, and the clevis pin in the control tube lever and withdraw the fuel rod from the governor.

c. Remove the left-bank fuel rod by removing the clevis pin in the control tube lever and lift the connecting pin up out of the control link operating lever approximately three-quarters of an inch. Then withdraw the fuel rod from the governor.

6. Loosen the hose clamps at each end of the water bypass tube. Slide the hoses and clamps onto the bypass tube and remove the tube from the engine.

7. Disconnect and remove the fuel oil lines attached to the fuel pump and the crossover fuel oil line attached to each cylinder head.

8. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.

9. Note the location of the two copper, one plain and eight lock washers on the governor-to-blower bolts before removing them. Then remove the ten bolts and washers |(two inside and eight outside) securing the governor and fuel pump assembly to the blower.

10. Tap the sides of the governor housing lightly with a plastic hammer to loosen the governor from the blower Then pull the governor and fuel pump

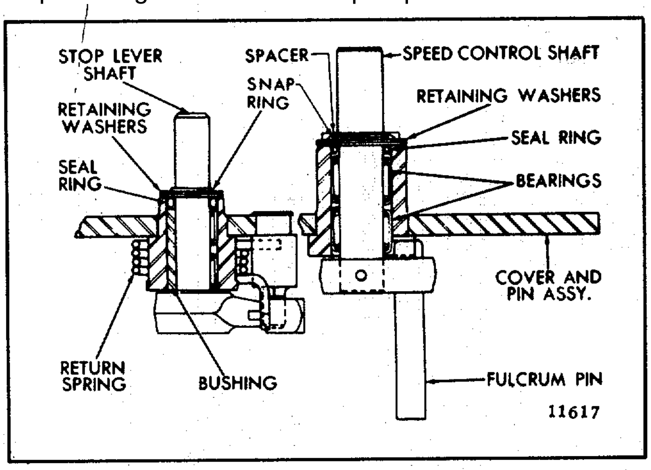


Fig. 6 - Cross Section of Current Governor Cover (other than Fuel Squeezer Engines)

assembly straight out from the dowels in the blower end plate. Remove the governor-to-blower gasket.

NOTE: The fuel pump drive coupling fork may stay on either the fuel pump or the blower rotor shaft. Remove the drive coupling fork.

11. Remove the three bolt and seal assemblies securing the fuel pump assembly to the governor housing. Remove the fuel pump and gasket from the governor 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 (Fig. 6 or 7) as follows:

NOTE: Fuel Squeezer engines have a governor cover with an extended hub and a longer speed control shaft (3.30" long). The cover also incorporates two hardened steel roll pins in the speed control shaft hub (Fig. 7). Only this cover should be used on a fuel squeezer engine.

a. Remove the lubrication fitting from the speed control shaft, if used.

b. Loosen the speed control lever retaining bolt and lift the control lever from the speed control shaft.

c. Remove the spacer (if used), snap ring and two seal ring retaining washers, and seal ring from the speed control shaft. Withdraw the shaft from the cover.

d. Loosen the bolt securing the stop lever to the stop - lever shaft and remove the stop lever.

e. Remove the snap ring, two seal ring retaining washers and seal ring from the stop lever shaft. Withdraw the lever shaft and the lever shaft return spring from the cover.

f. Wash the cover assembly thoroughly in clean fuel oil and inspect the needle bearings and bushings for wear or damage. If the bearings and bushings are satisfactory for further use, removal is unnecessary.

g. If needle bearing removal is necessary, place the inner face of the cover over the opening on the bed of an arbor press. Place remover J 21967-01 on the top of the bearing and press both bearings out of the cover as shown in Fig. 8.

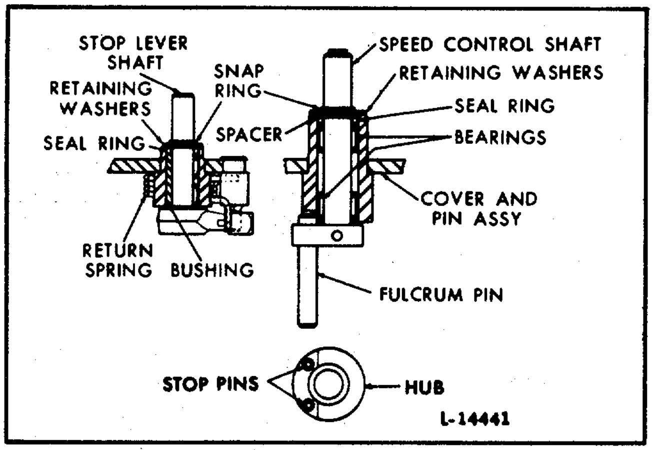


FIG. 7 Cross Section of Governor Cover (Fuel Squeezer Engines)

h. Remove the bushing or bearings from the stop lever shaft opening using remover J 8985 as shown in Fig. 9.

2. Disassemble the former design governor cover (Fig. 9) as follows:

a. Remove the lubrication fitting from the throttle shaft, if used.

b. Loosen the governor speed control lever retaining bolt and lift the control lever from the speed control lever shaft.

c. Remove the tapered pin from the spacer. Lift the speed control lever, spacer and seal ring retainer

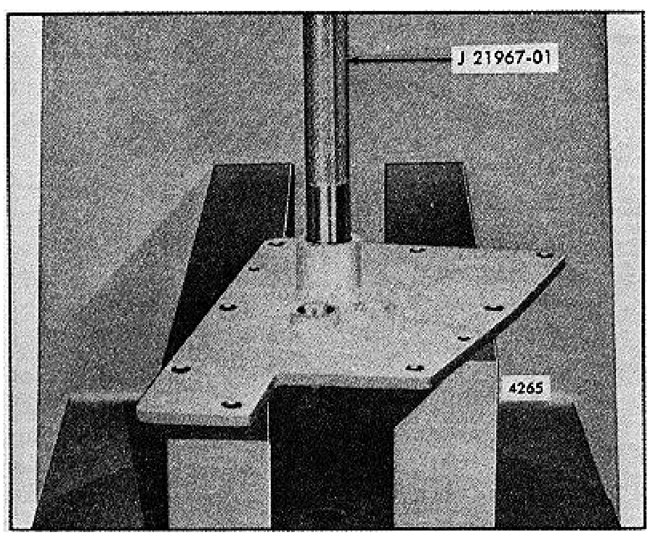


FIG. 8 - Removing Speed Control Shaft Bearing from Governor Cover using Tool J 21967-01

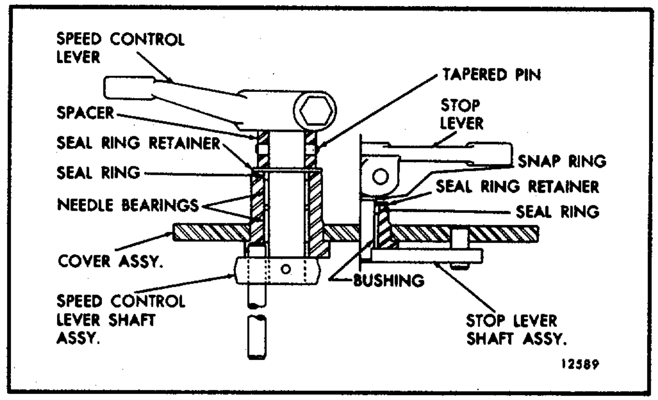


FIG. 9 - Cross Section of Former Design Governor Cover (other than Fuel Squeezer Engines)

from the speed control shaft. Withdraw the shaft from the cover.

d. Remove the seal ring from the governor cover.

e. Loosen the bolt securing the stop lever on the stop lever shaft and remove the stop lever.

f. Remove the snap ring from the shaft and the seal ring retainer (two flat washers).

g. Slide the shaft from the cover and remove the seal ring from the cover.

h. At this stage of disassembly, wash the cover assembly thoroughly in clean fuel oil and inspect the needle bearings and bushing for wear or damage. If the bearings and bushing are satisfactory for further use, removal is unnecessary.

i. If needle bearing removal is necessary, place the

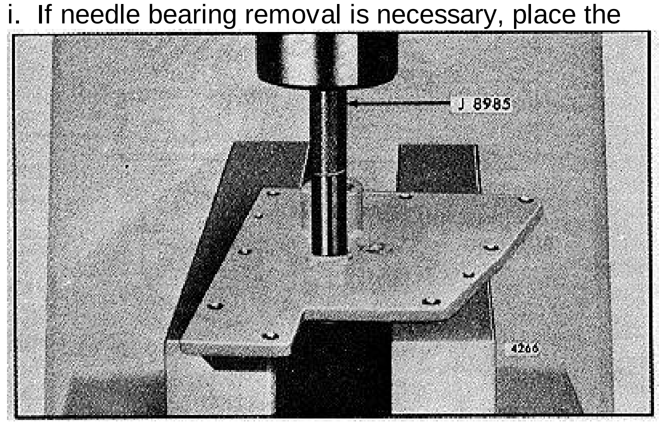


FIG. 10 - Removing Stop Lever Shaft Bearing or Bushings from Governor Cover using Tool J 8985

inner face of the cover over the opening on the bed of an arbor press. Place remover J 21967-01 on the top of the bearing and press both bearings out of the cover as shown in Fig. 8.

j. If necessary, remove the bushing from the stop lever shaft opening using remover J 8985 as shown in Fig. 10.

3. Refer to Figs. I and 22 and disassemble the high and low-speed springs, plunger and adjusting screw (except dual range governor):

a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

b. Remove the two bolts and lock washers securing the high-speed spring retainer housing to the governor housing and withdraw the retainer housing and gasket.

c. Loosen the high-speed spring retainer lock nut (Fig. l) with a spanner wrench. Then remove the high-speed spring retainer, idle speed adjusting screw, high-speed spring, spring plunger, low-speed spring, spring seat and spring cap as an assembly.

d. For Fuel Squeezer engines refer to Fig. 23 and loosen the set screw in the Belleville spring retainer nut. Then remove the retainer nut, two flat washers and two Belleville washers from the high-speed spring plunger.

e. Remove the low-speed spring cap, spring and spring. seat from the high-speed spring plunger. Depress the high-speed spring by hand and remove the idle speed adjusting screw lock nut. Remove the high-speed spring retainer, high- speed spring, and idle speed adjusting screw from the high-speed spring plunger.

4. Refer to Figs. 2 and, 23 and disassemble the high and low-speed springs, plunger and adjusting screws of the dual range governor as follows:

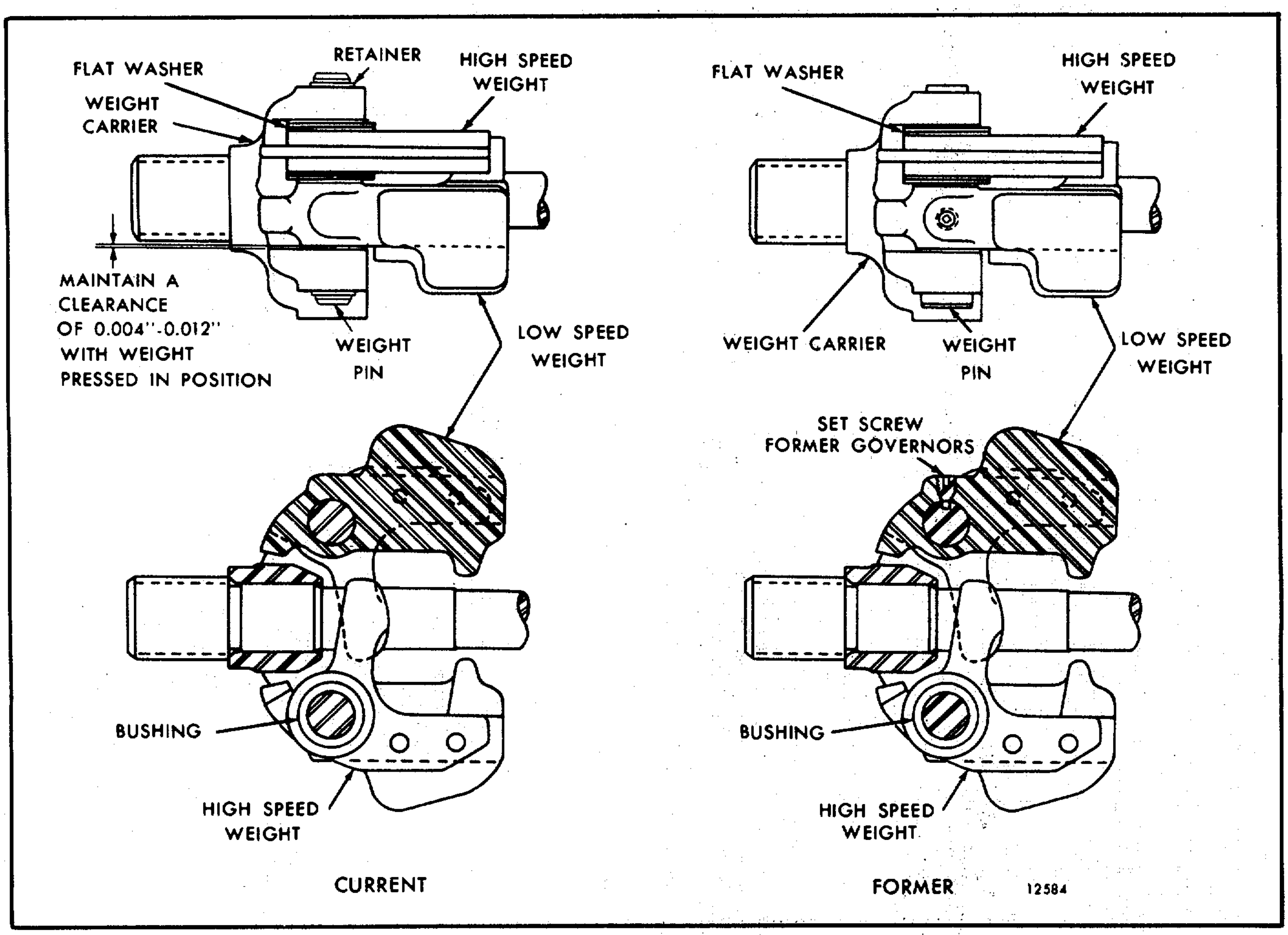


FIG. 11 Cross Section of Governor Double Weight Assemblies (Former and Current)

a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

b. Remove the two bolts and lock washers securing the high-speed retainer housing and piston assembly to the governor housing and withdraw the retainer housing, piston, shims and sleeve as an assembly from the governor housing (Fig. 2).

NOTE: Current governors have a blocking ring in the spring housing to prevent removal of the seal from the rear end (cover end) of the spring housing, thus preventing seal ring damage.

c. Remove the sleeve, shims, cover, cover gasket, piston and seal ring assembly from the high-speed spring retainer housing. Remove the retainer housing gasket.

d. Remove the high-speed spring retainer with tool J 5345-5 and withdraw the retainer, idle speed adjusting screw, high-speed spring, spring plunger, low-speed spring, spring seat and spring cap as an assembly from the housing.

e. Remove the low-speed spring cap, spring and spring seat from the high-speed spring plunger. Depress the high-speed spring by hand and remove the idle speed adjusting screw lock nut. Remove the high-speed spring seat, high-speed spring and idle speed adjusting screw from the high-speed spring plunger.

5. Remove the governor weights and shaft assembly (double and single weight governors) from the governor housing as follows:

a. Clamp the flange of the governor housing in a vise equipped with soft jaws.

b. Remove the governor weight housing plug and gasket (Fig. I or 3).

c. Bend the tang on the lock washer away from the head of the bolt. Then, while holding the weight carrier from turning, remove the bearing retaining bolt, flat washer and lock washer.

d. Thread a 5/16"-24 x 3" bolt into the bearing retaining bolt hole. Support the governor housing on the bed of an arbor press and press the governor weight shaft from the bearing as shown in Fig. 14.

e. Slide the governor riser thrust bearing and riser from the weight shaft.

NOTE: The thrust bearing is specially designed to absorb thrust load; therefore, looseness

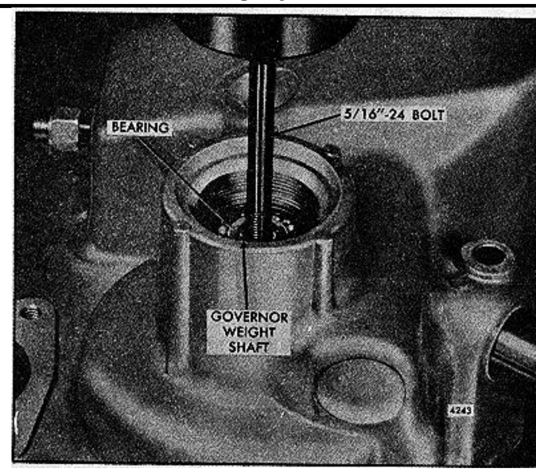


FIG. 12 Removing Governor Weight Shaft Assembly from Governor Housing

between the mating parts does not indicate excessive wear.

f. Remove the weight shaft bearing from the governor housing. If necessary, use a small brass rod and hammer to tap the bearing out of the housing.

6. Remove the governor weights from the carrier and shaft assembly on **non-turbocharged** engines as follows:

a. Matchmark the low and high-speed weights and carrier with paint or a center punch for identification.

b. Remove the retaining rings from the weight pins. Then drive the pins out of the carrier and the weights by tapping on the grooved end of the pins. Remove the governor weights.

7. Disassemble the governor weight and shaft assembly on **turbocharged engines** as follows:

a. Matchmark the low and high-speed weights and carrier with paint or a center punch for identification; also note the position of the flat washer at the side of the high-speed weight so the parts can be replaced in their original positions (Fig. II).

b. If removal of the weights from the carrier is necessary on current double weight governors, refer to Fig. 11 and remove the retainer 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

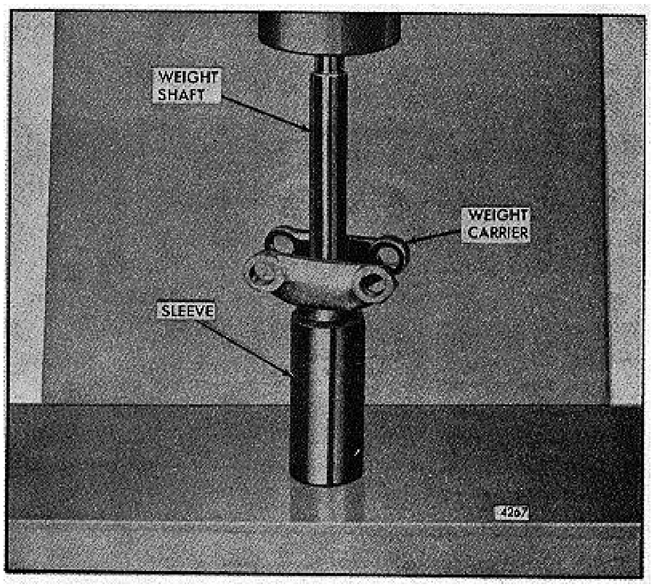


FIG. 13 Removing Governor Weight Shaft from Weight Carrier

the low-speed weight with a 3/32" allen wrench. Then remove the weight pin and weight from the carrier.

c. Remove the second pair of weights in the carrier in the same manner as described above.

d. If removal of the weight carrier from the weight shaft is necessary, support the shaft, weight carrier and sleeve on the bed of an arbor press as shown in Fig. 13 and press the shaft out of the weight carrier.

e. Position the high-speed governor weight on a, sleeve on the bed of the arbor press and press the

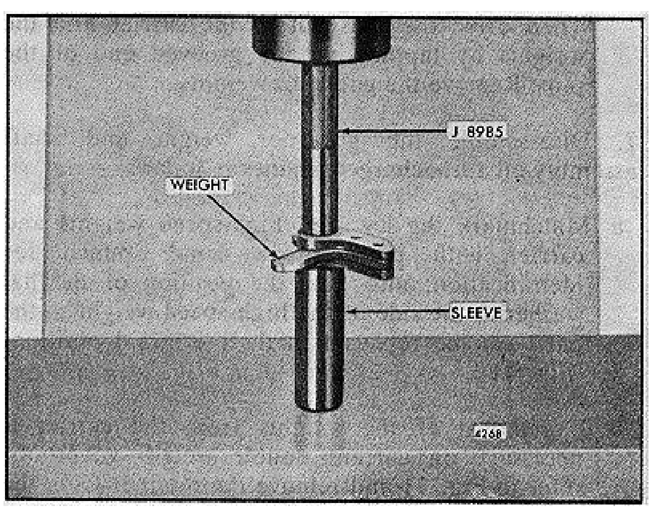


FIG. 14 - Removing governor Weight Bearings using Tool J 8985

bearing from the weight, using replacer J 8985 as shown in Fig. 14.

8.. Remove the governor linkage and operating shaft from the governor housing as follows:

a. Remove the spring retainer and plain washer securing the connecting link to the differential lever and remove the connecting link.

b. Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever and remove the differential lever.

NOTE: Remove the low-speed gap adjusting screw, also the internal starting aid screw (early turbocharged engines), from the operating shaft lever, if necessary.

c. Remove the screw, lock washer and lock clip securing the control link operating lever shaft in the housing. Lift the shaft out of the housing and remove the operating lever and two flat washers at each side of the operating lever.

NOTE: Be sure not to lose the two flat washers located between the top and bottom of the lever assembly and the governor housing.

d. Remove the expansion plug from the bottom of the governor housing (Fig. I or 3).

e. Remove the operating shaft upper bearing

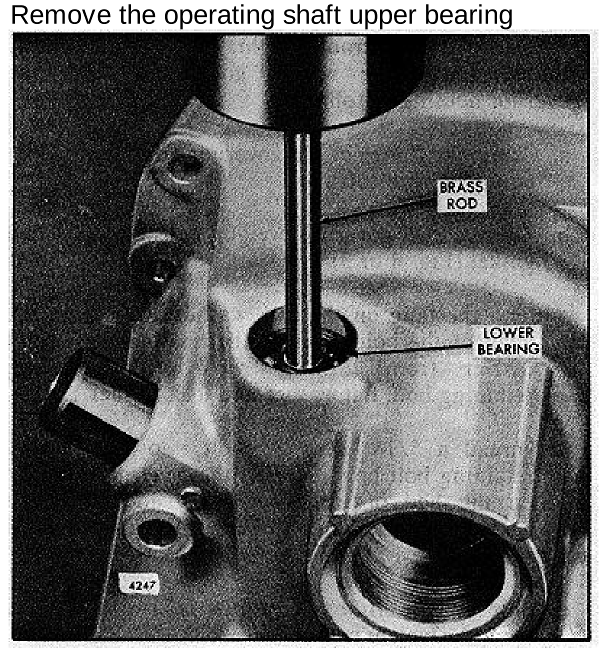


FIG. 15 - Removing Operating Shaft from Operating Shaft Lower Bearing

retainer screw, lock washer and flat washer securing the bearing in the governor housing.

f. Support the governor housing bottom side up on the bed of an arbor press, with the two dowel pins in the top of the housing between the two steel supports. Place a small brass rod on the end of the operating shaft and press the shaft out of the bearing (Fig. 15).

g. With the housing still supported on the bed of the press, place a 9/16" open end wrench under the operating fork as shown in Fig. 16. Place a brass rod on the end of the shaft and press the fork off of the operating shaft. Remove the shaft, operating lever and bearing as an assembly from the housing.

h. Remove the operating shaft lower bearing from the bottom of the governor housing.

i. On the current governor, slide the governor operating shaft spacer from the shaft.

j. Place a short 9/16" inside diameter sleeve over the end of the operating shaft and rest it against the inner race of the bearing on the current operating shaft, or the flat washer under the bearing on the former operating shaft.

k. Support the operating shaft, lever, bearing and sleeve on a large washer or plate, with a 5/8" hole, on the bed of an arbor press as shown in Fig. 17. Place a small brass rod on the end of the shaft and press the operating shaft out of the operating lever and bearing. Catch the shaft by

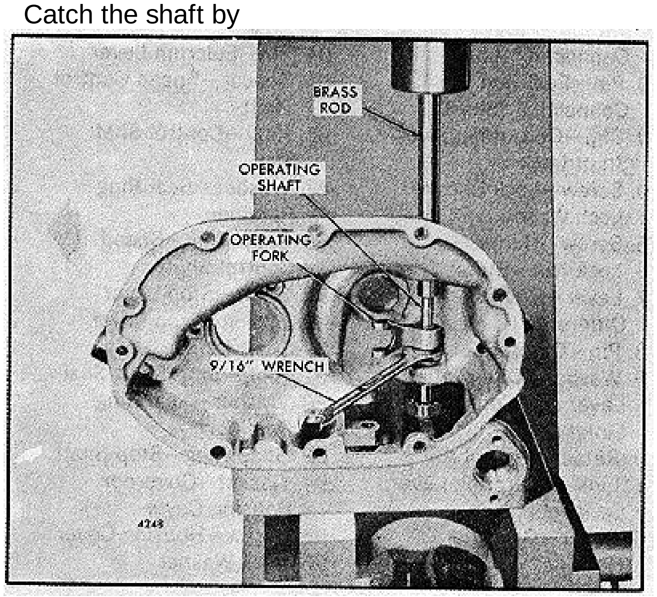


FIG. 16 Removing Operating Fork, Shaft and Lever Assembly from Governor Housing

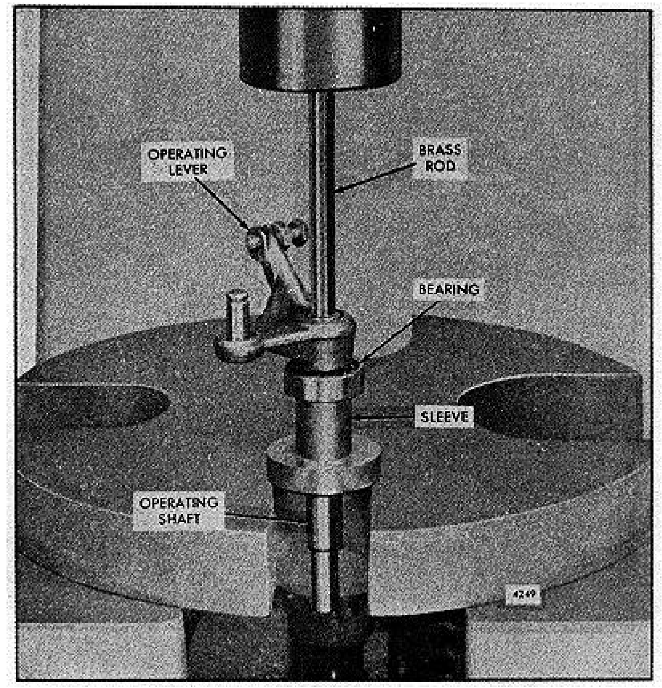


FIG. 17 - Removing Operating Lever and Upper Bearing from Operating Shaft

hand when pressed from the lever and bearing to prevent it from falling and being damaged.

NOTE: Be sure that the bearing inner race is resting on the sleeve or the bearing may be damaged.

l. Wash the control link operating lever (containing the bearings) thoroughly in clean fuel oil and inspect the needle bearings for wear or damage. If the bearings are satisfactory for further use, removal is unnecessary.

m. If removal of the needle bearing is necessary, support the control link operating lever on a sleeve and rest the sleeve on the bed of an arbor press. Place tool J 8985 on top of the bearing and press both bearings out of the lever as shown in Fig. 18.

9. Remove the buffer screw from the governor housing.

10. Remove the external starting aid screw (governors dated June, 1974 or later) from the governor housing, if necessary.

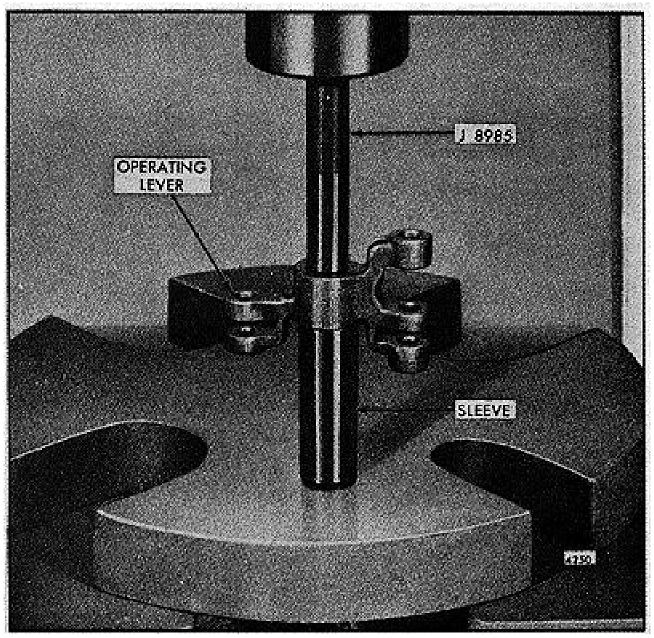


FIG. 18 Removing Operating Lever Needle Bearings

Inspection

Wash all of the governor parts in clean fuel oil and dry them with compressed air.

Examine the bearings for any indications of corrosion or pitting. Lubricate each bearing with light engine oil. Then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

Examine the riser thrust bearing for excessive wear, flat spots or corrosion.

Examine the weight carrier pins and bushings in the weights for wear.

Examine the control link operating lever shaft and needle bearings for wear or damage.

If'-the speed control and stop lever shafts are worn excessively due to worn or damaged needle bearings and bushing, replace the shafts, needle bearings and bushing in the cover.

Inspect the spring seats, plunger, adjusting screws, lock nuts, pins, seal rings and any other parts in the governor housing for wear or defects that might affect governor operation.

When replacing a limiting speed governor housing (with or without a starting aid screw), only the current governor housing assembly with the external starting aid screw is serviced.

2. Housing–Governor
3. Gasket–Housing to Blower
4. Bolt–Housing to Blower
5. Lock Washer
8. Shaft–Governor Operating
9. Lever–Operating Shaft
10. Pin–Shaft Lever
11. Bearing–Operating Shaft (Upper)
13. Fork Operating Shaft
14. Bearing–Operating Shaft (Lower)
15. Plug–Expansion
16. Screw–Bearing Retaining
17. Lock Washer
18. Flat Washer
19. Screw–Gap Adjusting
20. Lock Nut
21. Spacer–Operating Shaft
25. Carrier–Governor Weight
26. Weight–Low Speed
27. Weight–High Speed
29. Pin–Weight
30. Flat Washer
31. Screw–Weight Pin Set
32. Carrier–Governor Weight
34. Weight
35. Pin–Weight
36. Retainer–Weight Pin
37. Shaft–Weight Carrier
38. Lock Nut
39. Screw–Gap Adjusting
40. Shaft–Weight Carrier
41. Riser–Governor
42. Bearing–Riser Thrust
43. Bearing-Weight Carrier Shaft End
44. Bolt–Bearing Retainer
45. Lock Washer–Special
46. Flat Washer
47. Plug–Governor Housing
48. Gasket–Housing Plug
50. Screw–Starting Aid
51. Lock Nut
53. Lever–Control Link Operating
54. Bearing–Operating Lever
55. Shaft–Operating Lever
56. Washer–Operating Lever Shim
57. Pin–Fuel Rod Connecting (Long)
58. Pin–Fuel Rod Connecting (Short)
59. Clip–Operating Lever Shaft Lock
60. Screw–Lock Clip
61. Lock Washer
65. Screw–Buffer
66. Lock Nut–Buffer Screw
67. Lever–Governor Differential
68. Pin–Differential Lever
69. Washer–Differential Lever and Connecting Link Flat
70. Retainer–Spring
71. Link–Operating Lever Connecting
80. Cover–Governor Housing
81. Bearing–Speed Control Shaft
82. Bushing–Stop Lever Shaft
83. Shaft–Speed Control Lever
84. Pin–Fulcrum Lever
85. Spacer–Speed Control Shaft
86. Ring–Control Shaft Seal
87. Washer–Seal Ring Retainer
88. Snap Ring–Speed Control Shaft
89. Shaft–Stop Lever
90. Spring–Stop Lever Shaft Return
91. Ring–Stop Shaft Seal
92. Washer–Seal Ring Retainer
93. Snap Ring–Stop Shaft
94. Gasket–Governor Housing Cover
95. Screw–Housing Cover
96. Lock Washer

FIG. 19 Limiting Double Weight Speed Governor Details and Relative Location of Parts

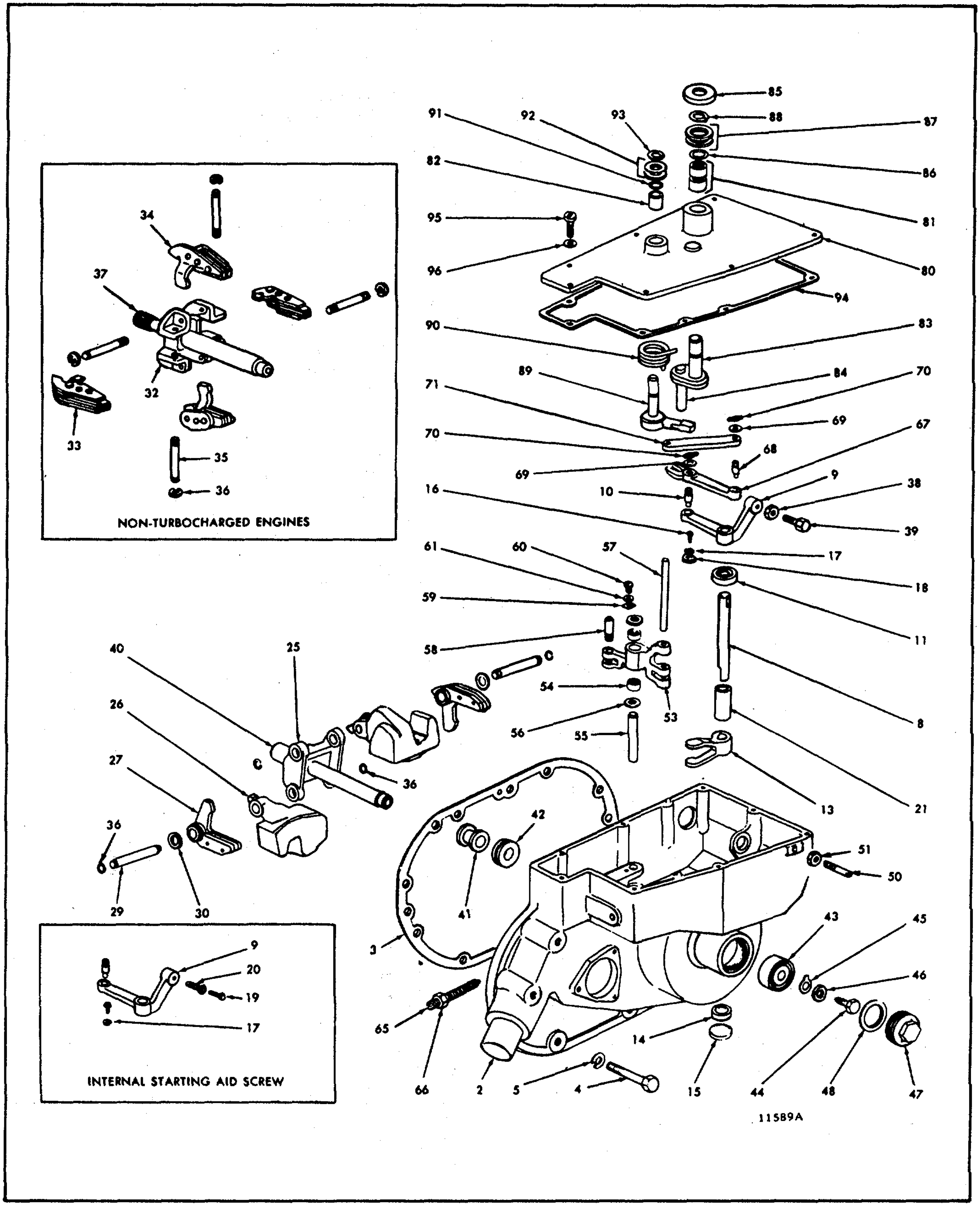


FIG. 19 - Limiting Speed Double Weight Governor Details and Relative Location of Parts

NOTE: If the external starting aid screw is not required, back it out as far as possible to make it ineffective.

If the governor is equipped with an internal starting aid screw, remove the gap adjusting screw and the starting aid screw from the operating shaft lever and replace them with the current gap adjusting screw and nut. Then perform an engine tune-up (Section 14).

Replace all of the parts that are worn or damaged.

Assemble Governor

With all of the governor parts cleaned and inspected and the necessary new parts on hand, the governor may be assembled.

Refer to Figs. 1 and 19 (double weight) and Fig. 3 (single weight) for the location of the various parts and assemble the governor as follows:

1. If removed, install the external starting aid screw (governor dated June, 1974 or later) in the governor housing.
2. install the operating shaft and governor linkage in the governor housing as follows:

a. Lubricate the inside diameter of the governor operating shaft upper bearing with engine oil. Start the bearing, numbered side up, straight on the large end of the operating shaft. Support the bearing and operating shaft on a 9/16" inside diameter sleeve on the bed of an arbor press, with the inner race of the bearing resting on the sleeve, then press the shaft into the bearing until 1/4 of the shaft protrudes through the bearing.

On the former governor operating shaft, place the upper bearing (flat) washer on the end of the shaft. Install the bearing, numbered side up, on the shaft and press it tight against the bearing washer.

b. Lubricate the inside diameter of the governor operating shaft lever with engine oil. Start the lever, pivot pin in the operating lever facing up, straight on the operating shaft with the flat on the shaft registering with the flat surface in the lever. Support the operating lever, bearing and shaft on the bed of an arbor press with a steel support directly under the center of the lever, then press the operating shaft through the bearing and lever until the end of the shaft contacts the steel support.

NOTE: The upper end of the shaft must be flush with the top surface of the lever.

On the former governor operating shaft, install the governor operating lever on the shaft and press it tight against the inner race of the bearing.

c. On the current governor operating shaft, place the operating shaft spacer over the lower end of the shaft and slide it against the upper bearing inner race.

d. Insert the end of the governor operating shaft, bearing, spacer and lever assembly through the upper bearing bore in the governor housing with the lever positioned as shown in Fig. 1 or 3.

NOTE: If removed, install the low-speed gap adjusting screw and lock nut in the operating shaft lever and thread the starting aid screw (early turbocharger engines) in the gap adjusting screw (Fig. 1 or 3). Both screws (turbocharged engines) have a nylon locking patch on the threads in lieu of the lock nut.

e. Lubricate the inside diameter of the governor operating shaft fork with engine oil, then place the operating fork over the lower end of the shaft with the finished cam surfaces on the fork fingers facing the rear of the governor housing and the flat on the shaft registering with the flat surface in the fork.

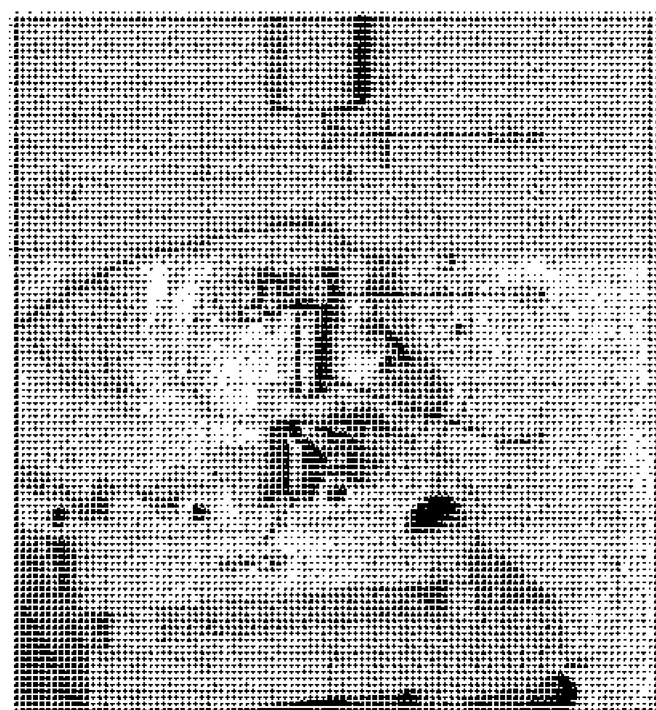


FIG. 20 Installing Governor Operating Shaft Fork

f. Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support as shown in Fig. 20. Place a 7/16" inside diameter sleeve over the end of the shaft and against the fork, then press the fork tight against the shaft spacer on the shaft.

On the former governor operating shaft, press the operating fork tight against the shoulder on the shaft.

g. Lubricate the governor operating shaft lower bearing with engine oil. Start the bearing, numbered side up, straight in the governor housing and over the end of the operating shaft.

h. Support the governor housing and operating shaft assembly on the bed of an arbor press with the upper end of the operating shaft resting on a steel support as shown in Fig. 20. Place a 7/16" inside diameter sleeve on the inner race of the bearing and press the bearing on the shaft until it seats on the shoulder in the housing.

i. Install the governor operating shaft upper bearing retaining flat washer, lock washer and screw in the governor housing (Fig. 1 or 3).

j. Apply a thin coat of good quality sealant around the edge of a new expansion plug. Place the plug, concave side up, in the opening in the housing next to the lower operating shaft bearing. Tap the center of the plug with a hammer to secure the plug in the housing.

k. Place the differential]ever over the pivot pin in the operating lever, pin in the lever up, and secure it in place with a plain washer and spring retainer.

l. If removed, place the control link operating lever on the bed of an arbor press with a steel support under the bearing bore. Lubricate the bearing with engine oil and start the bearing, numbered end up, straight into the bore of the lever. Insert the pilot end of installer J 8985 in the bearing and press the bearing into the lever until it is flush with the top surface of the lever. Reverse the lever on the press and install the second bearing in the same manner.

m. Lubricate the control link operating lever needle bearings with Shell Alvania No. 2 grease, or equivalent. Place the operating lever in position between the two bosses inside the governor housing. Insert a flat washer on each side of the lever (Fig. 1 or 3). Then install the operating lever shaft with the slot (in the side at one end of the shaft) up.

n. Align the slot in the operating lever shaft with the lock clip screw hole in the boss next to the shaft. Install the lock clip, lock washer and screw and tighten it securely.

o. Place one end of the connecting link over the differential lever pin and secure it in place with a washer and spring retainer (Fig. 1 or 3). Place the opposite end of the connecting link on top of the control link operating lever and install the connecting pin.

p. If removed, thread the lock nut on the buffer screw and thread the buffer screw into the governor housing.

3. Assemble the governor double weights on the carrier and shaft assembly on **non-turbocharged** engines(Fig. 19) as follows:

a. Position the low-speed weights, identified by the short cam arm, on opposite sides of the weight carrier. Note the matchmarks placed on the weight carrier and weights at the time of disassembly.

b. Drive the weight pins in place and install the retaining rings. To install a weight pin correctly, push the grooved end through the smaller hole in the carrier and through the weight. Then drive the knurled end in just enough so the retaining ring can be installed on the pin.

c. Install the high-speed weights on the carrier in the same manner.

d. Lubricate the weight shaft with clean engine oil.

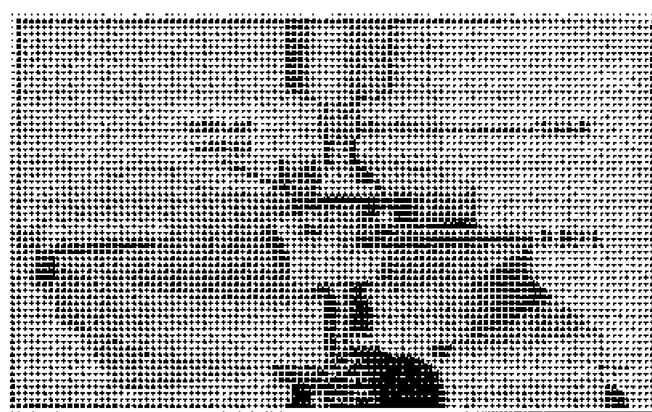


FIG. 20 installing Governor Operating Shaft Fork

4. Assemble the governor double weight and shaft assembly on **turbocharged engines** (Fig. 19) as follows:

If the governor weight carrier assembly was removed from the weight shaft, the low and high-speed weights must be removed from the carrier before attempting to install the carrier on the shaft.

a. Support the weight carrier (rear face up) on a sleeve and a steel support (with a 1" hole) over an opening in the bed of an arbor press as shown in Fig. 21.

b. Lubricate the weight shaft with engine oil. Then insert the non-splined end of the shaft through the carrier, sleeve and hole in the steel support. Press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

c. Refer to Fig. 11 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 the high-speed weight and its bushing.

d. 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.

NOTE: To maintain this clearance, insert a .004"-.012" shim between the low-speed weight and the carrier while pressing the pin into position.

e. Remove the shim and install the second weight pin retainer.

f. Install the second pair of weights in the carrier in the same manner as described above.

5. Assemble the (former) governor weight and shaft assembly as follows:

If the governor weight carrier assembly was removed from the weight shaft, the low and high-speed weights must be removed from the carrier before attempting to install the carrier on the shaft.

a. Support the weight carrier (rear face up) on a sleeve and a steel support (with a 1 ″ hole) over an opening in the bed of an arbor press as shown in Fig. 21.

b. Lubricate the weight shaft with engine oil. Then insert the non-splined end of the shaft through the carrier, sleeve and hole in the steel support. Press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

c. Refer to Fig. 11 and start a weight pin through the opening in the low-speed weight side of the carrier. Note the matchmarks placed on the weight carrier and weights at the time of disassembly. Then place the low-speed weight on the pin and slide the pin through the weight.

d. Place the high-speed weight on the pin and slide the pin just through the high-speed weight. Place a flat washer between the high-speed weight and the carrier, then push the pin through the washer and into the carrier.

e. Align the indentation in the pin with the Allen set screw hole in the low-speed weight. Apply a sealant such as Loctite grade C, CV or equivalent op the threads of each set screw. Insert the Allen set screw and tighten it to 20 **lb-in** (2.26 Nm) minimum. Be sure and stake the edge of the set screw hole in two places to secure the screw.

NOTE: Before applying the sealant to a new set

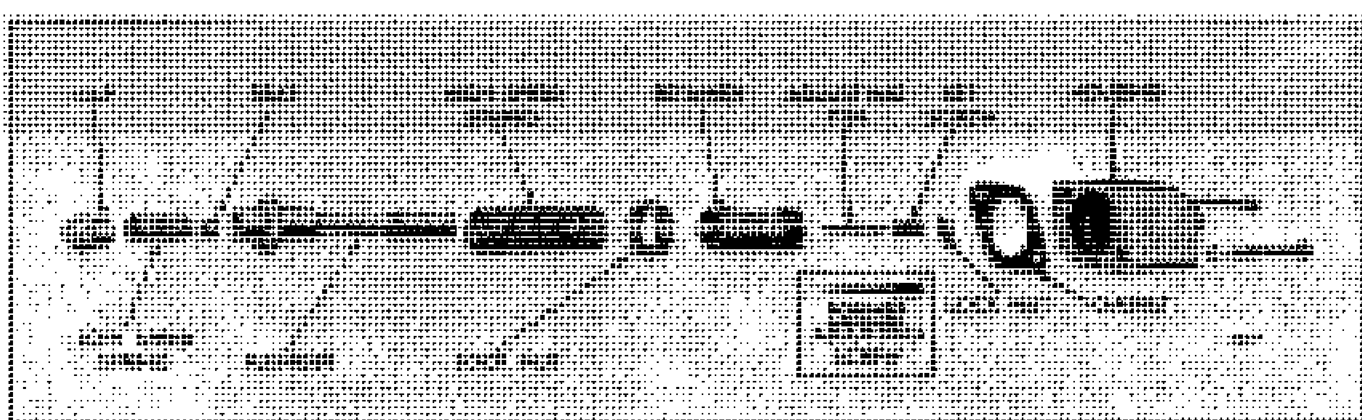


FIG. 22 - High and Low-Speed Springs and Plunger Details and Relative Location of Parts (other than Fuel Squeezer Engines)

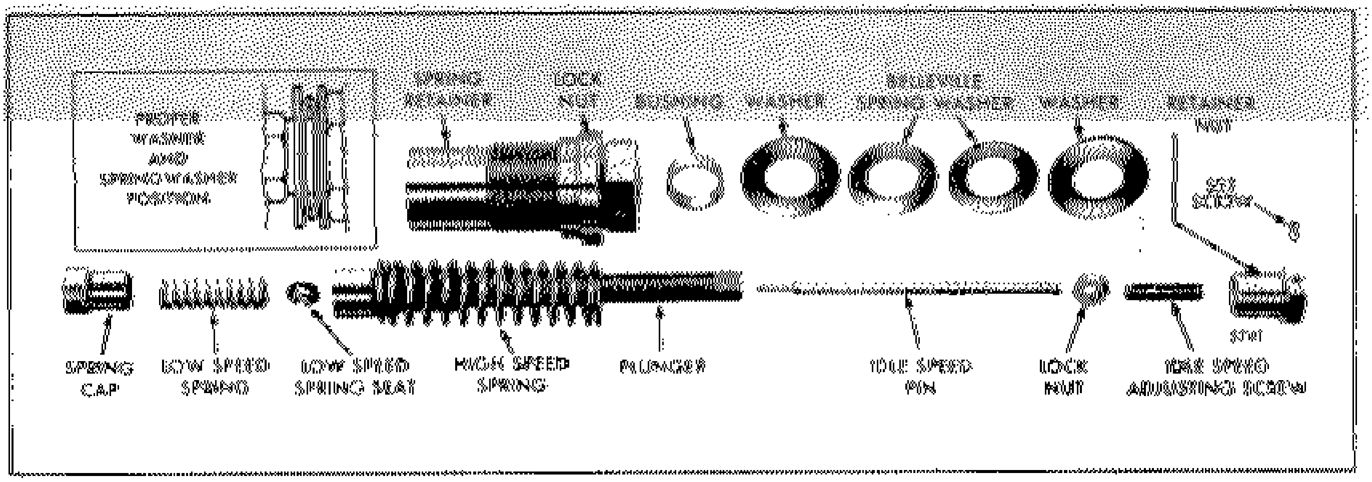


FIG. 23 - High and Low-Speed Springs, and Plunger Details (Fuel Squeezer Engines)

screw, immerse the set screw in Loctite Primer T, or equivalent.

f. Install the second pair of weights in the carrier in the same manner as described above.

6. Assemble the governor-single weights as follows (Fig. 3):

a. Install the retainer in the groove of the weight pin. Place a flat washer over the pin and against the lock ring.
b. Start the pin through the opening in the weight carrier. Place a second washer over the pin and against the projecting arm of the weight carrier.
c. Position the governor weight between the projecting arms of the weight carrier. Push the pin through the governor weight.
d. Place the third flat washer over the pin and against the weight.
e. Then push the pin completely through the weight carrier and place the fourth flat washer over the pin and against the projecting arm of the weight carrier. Install a second lock ring in the groove of the weight carrier pin.
f. Install the second governor weight in a similar manner.

7. Install the governor weight and shaft assembly in the governor housing as follows:

a. Slide the governor riser on the weight shaft and against the fingers of the high-speed weight.
b. Place the governor riser thrust bearing over the

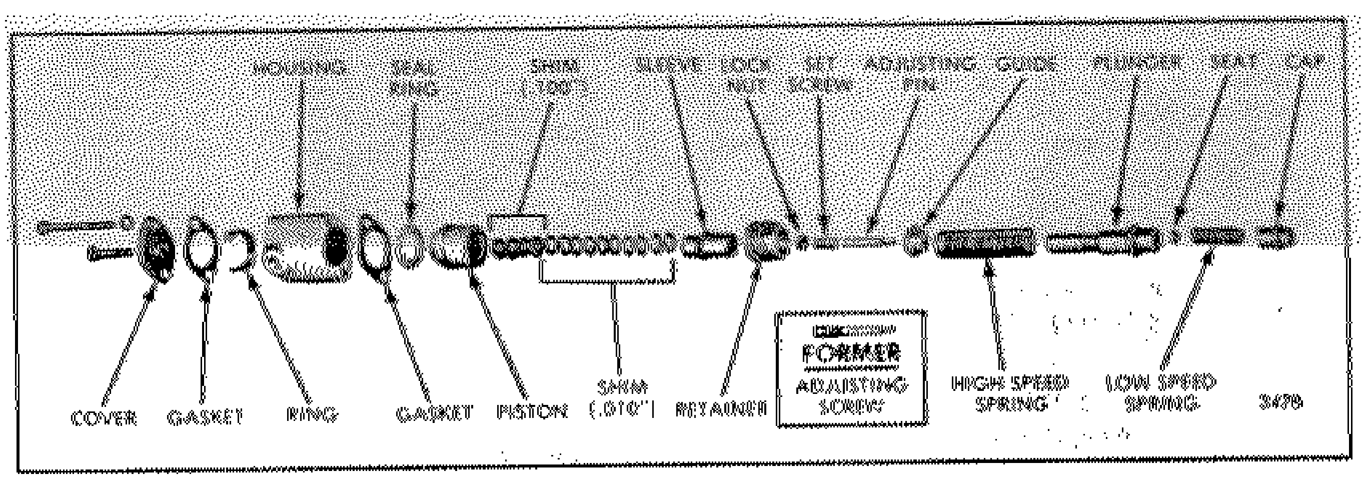


FIG. 24 - High and Low-Speed Springs, Plunger and Piston Details and Relative Location of Parts (Dual Range)

weight shaft with the bearing race having the smaller inside diameter against the riser. Incorrect installation of the bearing will result in erratic operation of the governor.

c. Insert the weight carrier and shaft assembly in the governor housing. Then support the splined end of the shaft and the governor housing on the bed of an arbor press with the upper end of the shaft under the ram of the press.

d. Place the weight shaft bearing in the governor housing (numbered side up) and start it straight on the end of the weight carrier shaft. Place a sleeve with a 1/2" inside diameter on top of the bearing inner race and press the bearing into the housing and against the shoulder on the shaft.

NOTE: The former bearing used on the 6, 8 and 12V engines had thrust capacity in one direction only. Be sure to install the bearing so the thrust shoulder is toward the governor weights. Otherwise, the force exerted by the weights will pull the inner race and ball assembly away from the outer race and result in damage to the bearing and erratic governor operation.

e. Place the special lock washer on the end of the weight carrier shaft with the tang on the inner diameter of the washer in the notch in the end of the shaft.

f. Place the flat washer on the bearing retainer bolt and thread the bolt into the shaft. Clamp the splined end of the weight carrier shaft in the soft jaws of a bench vise and tighten the bearing retainer bolt to 15-19 Ib-ft (20-26 Nm) torque. Bend the tang on the lock washer against the head of the bolt.

g. Place a gasket against the weight shaft bearing. Apply a sealant such as Loctite grade H, HV or HVW, or equivalent, on the threads of the governor housing and the plug and thread the plug into the housing. Tighten the plug to 45 Ib-ft (61 Nm) torque.

NOTE: Rotate the governor weight assembly to see that there is no bind. If bind exists, remove the housing plug and check to see if the weight shaft bearing is fully seated in the governor housing.

8. Refer to Figs. 1 and 22 and assemble the high and low-speed springs, plunger and adjusting screw (except dual range governor):

a. If removed, thread the retainer lock nut on the high-speed spring retainer approximately 1-1/2". Place the high-speed spring on the high-speed spring plunger with the close wound coils inside the spring retainer and the spring against the shoulder of the plunger.

b. Insert the high-speed spring and plunger assemble) in the high-speed spring retainer. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2". Then thread the lock nut on the idle speed adjusting screw.

c. Place the low-speed spring in the low-speed sprine cap and the small end of the low-speed sprint seat in the opposite end of the spring.

d. Insert the low-speed spring seat, spring and cap assembly into the high-speed spring plunger and over the idle speed adjusting screw.

e. For Fuel Squeezer engines, install the bushing in (he end of the high-speed spring retainer (ii removed) and align the two flat washers and two Belleville spring washers as shown in Fig. 23 Then install the set screw in the Belleville spring-retainer nut and thread the retainer nut onto the high-speed plunger.

f. Affix a new high-speed spring retainer housing gasket to the governor housing.

g. Insert the spring, plunger and retainer assemble) into the opening in the governor housing and thread the retainer into the housing approximately one inch.

h. Install the high-speed spring retainer housing after the governor assembly has been installed or

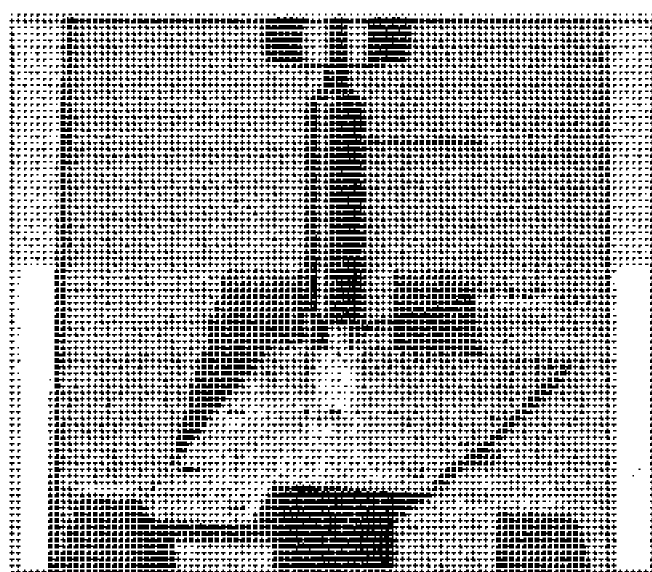


FIG. 25 - Installing Bushing in Governor Cover using Tool J 21068

the engine and the governor adjustment procedures performed as outlined in Section 14.3 or Section 14.3.5 (Fuel Squeezer Engines)

9. Refer to Figs. 2 and 24 and assemble the high and low-speed springs, plunger and adjusting screws (dual range governor):

a. Thread the idle speed adjusting screw into the threaded end of the high-speed spring plunger approximately 1/2".

b. Place the high-speed spring guide in the end of the high-speed spring. Next, place the high-speed spring and guide over the end of the idle speed adjusting screw and plunger. Then thread the lock nut on the idle speed adjusting screw and against the spring guide.

c. Place the low-speed spring in the low-speed spring cap and the small end of the low-speed spring seat in the opposite end of the spring.

d. Insert the low-speed spring seat, spring and cap assembly into the high-speed spring plunger and over the idle speed adjusting screw.

e. Place the high-speed spring retainer over the high-speed spring guide. Then insert the springs, plunger and retainer assembly into the opening in the governor housing and thread the retainer into the housing. Tighten the retainer in the housing with tool J 5345-5.

f. If removed, install the piston blocking ring in the outer end of the high-speed spring retainer housing with the ring gap straddling the threaded hole and flush with the outside face of the housing.

g. Place the piston seal ring in the groove in the speed adjusting piston.

h. Apply a thin coat of grease on the inside diameter of the retainer housing. Then insert the solid end of the speed adjusting piston in the retainer housing.

i. Install the four thick and the ten thin high-speed spring shims down inside the speed adjusting piston. Then insert the small end of the piston sleeve inside the piston and against the shims.

j. Affix a new high-speed spring retainer housing gasket to the governor housing.

k. If removed, thread the low maximum speed adjusting screw into the high-speed spring retainer housing cover approximately one inch.

Then affix a new gasket to the inside face of the cover.

1. Attach the high-speed spring retainer housing with piston, shims, sleeve and cover to the governor housing with two bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

10. Assemble the former design governor cover (Fig. 9) as follows:

a. If the speed control lever shaft needle bearings (Fig. 9) were removed from the cover, place the cover, inner face down, on two steel supports on the bed of an arbor press. Lubricate the outside diameter of a bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

b. Place the correct end of the bearing installer J 21068 in the bearing as shown in Fig. 26. Then press the bearing into the bore until the stop on the installer contacts the cover boss.

NOTE: Installer J 21068 has a pilot on each end; one end is for the speed control lever shaft upper bearing and the other end is for the stop lever shaft bushing or upper bearing.

c. Reverse the cover (inner face up) on the bed of the arbor press. Lubricate the outside diameter of the lower bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

d. Place the bearing installer J 21068 in the bearing

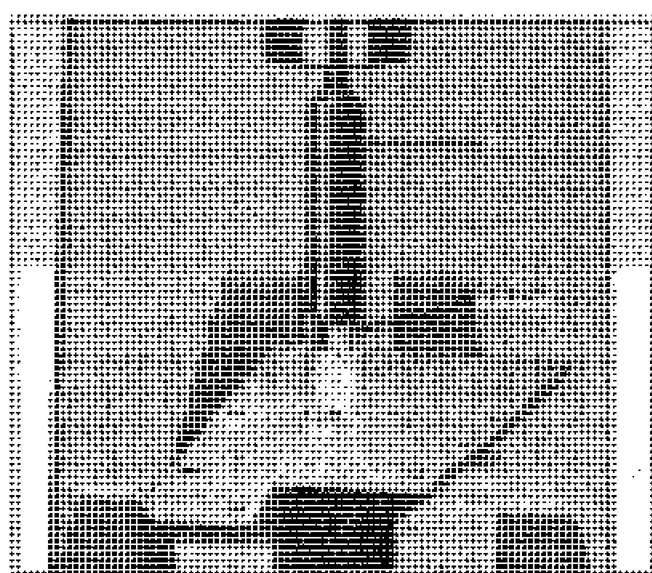


FIG. 26 Installing Bearings in Governor Cover using Tool J 21068

and press the bearing in the bore until it is flush with the face of the boss.

e. If the stop lever shaft bushing (Fig. 9) was removed from the cover, install the bushing in the cover boss in the same manner as described in Steps a and b above. Use the small pilot end of the installer J 21068 to install the bushing.

f. Lubricate the stop lever shaft with engine oil, then insert the shaft, from the inner face side, through the bushing with the lever on the lower end of the shaft on the right-hand side of the pin in the cover (as viewed from the blower end of the governor).

g. Place the seal ring over the shaft and push it into the bearing bore and against the bushing. Place the two seal ring retaining washers on the shaft and against the cover boss. Then install the snap ring in the groove in the shaft.

h. Install the stop lever on the shaft and secure it in place with the retaining bolt and lock washer.

i. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then insert the speed control lever shaft, from the inner face side, through the bearings.

j. Place the seal ring over the shaft and push it into the bearing bore and against the upper bearing.
Place the seal ring retaining washer on the shaft and against the cover boss.

k. Place the speed control lever spacer on the speed control shaft and against the seal ring retaining washer with the pin holes in the spacer and shaft in alignment. Install the tapered pin in the hole in the spacer, then support the cover and spacer assembly on a steel block and drive the pin into place.

l. Install the speed control lever on the shaft and secure it in place with the retaining bolt and lock washer.

m. Install the lubrication fitting in the speed control lever shaft, if used.

11. Assemble the current design governor cover (Fig. 6) or Fuel Squeezer engine cover (Fig. 7) as follows:

a. If the speed control lever shaft needle bearings (Fig. 6 or 7) were removed from the cover, place the cover, inner face down, on two steel supports on the bed of an arbor press. Lubricate the outside diameter of a bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

b. Place the correct end of the bearing installer J 21068 in the bearing as shown in Fig. 26. Then press the bearing into the bore until the stop on the installer contacts the cover boss.

NOTE: Installer J 21068 has a pilot on each end; one end is for the speed control shaft upper bearing and the other is for the stop shaft bushing or upper bearing.

c. Reverse the governor cover, inner face up, on the bed of the arbor press. Lubricate the outside diameter of the lower bearing with engine oil and start the bearing, numbered end up, straight in the bore in the cover boss.

d. Place the bearing installer J 21068 in the bearing and press the bearing in the bore until it is flush with the face of the boss.

e. On a governor cover equipped with stop lever shaft needle bearings, install the needle bearings in the same manner as described in Steps a, b, c and d above. Use the small pilot end of installer J 21068 to install the bearings.

f. On a governor equipped with a stop lever shaft bushing, install the bushing in the cover in the same manner as described in Steps a and b above. Use the small pilot end of installer J 21068 to install the bushing.

g. Lubricate the stop lever shaft needle bearings or bushing with Shell Alvania No. 2 grease, or equivalent.

h. Place the stop lever shaft return spring over the boss on the inner face of the cover as shown in Fig. 6 or 7. Insert the shaft part way through the bearings or bushing and hook the end of the return spring over the end of the lever, then push the shaft up in the cover. Position the end of the lever on the right side of the stop pin (Fig. 6 or 7).

NOTE: New seal rings made of a Viton material are being used for the speed control lever shaft and for the stop lever shaft.

i. Place the seal ring over the shaft and push it-into the bearing bore and against the bearing or bushing. Place the two seal ring retainer washers on the shaft and against the cover boss, then install the snap ring in the groove in the shaft.

j. Install the stop lever on the shaft and secure it in place with the retaining bolt and lock washer.

k. Lubricate the speed control shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Then insert the speed control shaft through the bearings.

l. Place the seal ring over the shaft and push it into the bearing bore and against the bearing. Place the two seal ring retainer washers on the shaft and against the cover boss. Then install the snap ring in the groove in the shaft.

m. Install the spacer on the speed control shaft (slip fit) against the retaining washers and over the snap ring.

NOTE: Prior to September, 1970, a spacer was not used. When assembling a governor housing cover on an engine built prior to September, 1970, include either a .440" thick spacer or a .078" thick spacer, depending on the model application.

n. Install the speed control lever on the shaft and secure it in place with the retaining bolt and lock washer. Be sure the lever, contacts the spacer.

o. Install the lubrication fitting in the speed control shaft, if used.

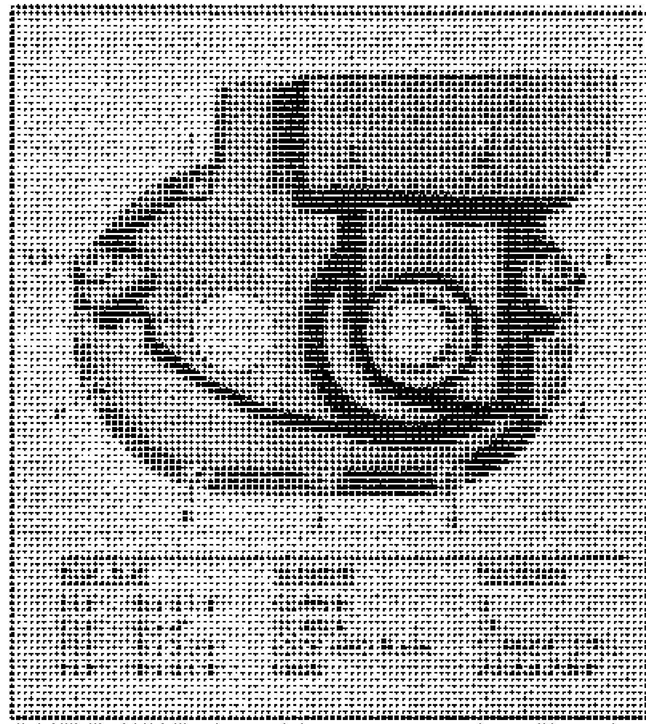


FIG. 27 Location and Size of Governor Retaining Bolts

Install Governor on Engine

1. Affix a new gasket to the bolting flange of the fuel pump. Place the fuel pump against the governor housing in its original position and secure **it** in place with the three bolt and seal assemblies. Tighten the bolts to 13-17 Ib-ft (18-23 Nm) torque.

2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing.

3. Affix a new gasket to the forward face of the blower end plate.

4. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines in the blower rotor.

5. Push the governor straight in over the dowels in the blower end plate and against the gasket.

6. Refer to Fig. 27 for the location and install the bolts, lock washers, copper washers and plain washer securing the governor to the blower. Tighten the bolts to 13-17 Ib-ft (18-23 Nm) torque.

7. Slide each fuel rod cover tube hose down on the cover tubes attached to the cylinder heads and tighten the hose clamps.

8. Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

9. Place the water bypass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Then tighten the hose clamps.

10. Install the fuel rods between the cylinder heads and the governor as follows:

a. Insert the lower end of the left-bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

b. Raise the connecting pin up in the control link operating lever (Fig. 1). Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

d. Insert the lower end of the right-bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

e. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

11. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the speed control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover.'

12. Install the eight governor cover attaching screws and lock washers. Tighten the screws securely.

NOTE: The short cover attaching screw, with the drilled head, goes in the corner hole next to the high-speed spring retainer housing.

13. Install all of the accessories that were removed from the cylinder head, governor or the front end of the engine.

14. Connect the control linkage to the speed control and stop levers.

15. Close the drain cocks and fill the cooling system.

16. Perform the governor and injector rack control adjustment as outlined in Section 14.3.

LIMITING SPEED MECHANICAL GOVERNOR

(Variable Low-Speed)

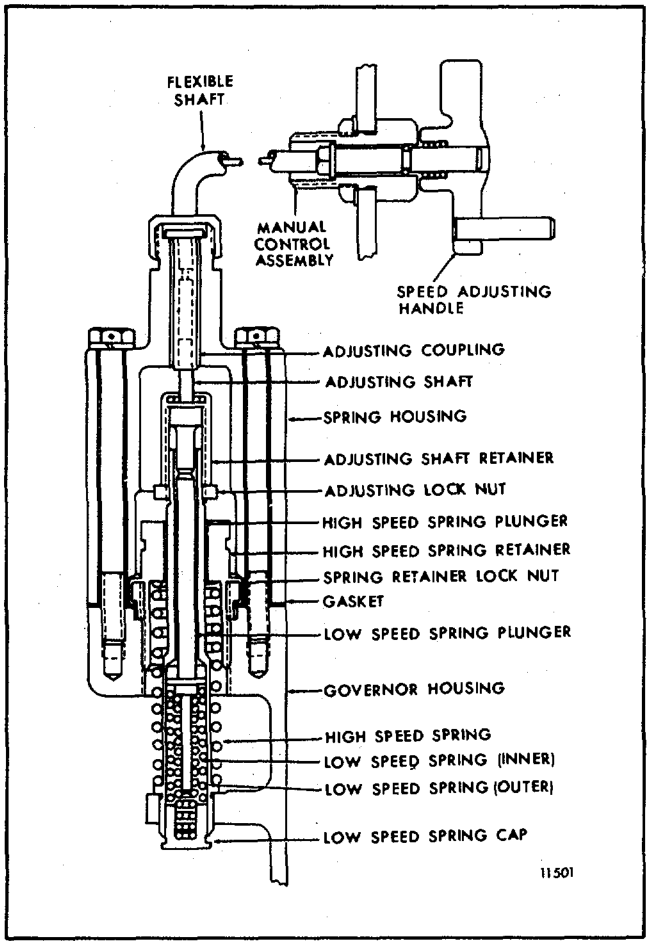


FIG. 1 - Cable Operated Governor Spring Housing and Components

The variable low-speed limiting speed mechanical governor is used on highway vehicle engines where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain and liquids) and a high idle speed range is desired during auxiliary operation.

The current governor is a single-weight type and provides an idle speed range of 500 to 1800 rpm. The former governor was a double-weight type and provided an idle speed range of 450 to 1300 rpm.

The governor is mounted on the front end of the blower and is driven by one of the blower rotors.

Governor identification is provided by a name plate attached to the governor housing. The letters V.L.S.L.S. stamped on the name plate denote a variable low-speed limiting speed mechanical governor.

Operation

During highway operation, the governor functions as a limiting speed governor, controlling the engine idling speed and limiting the maximum operating speed. At the unloading area, the throttle is left in the idle speed position and the speed adjusting handle, on the cable operated governor (Fig. 1), is turned to the speed required within the above range to operate the auxiliary equipment. For the air operated governor (Fig. 3), the engine speed is changed to the speed required by increasing or decreasing the air supply pressure to the governor. The governor then function as a variable speed governor, maintaining a constant speed when the load is constantly changing, during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned back to the stop, then turned ahead about one-quarter of a turn. The air operated governor's air supply pressure must be vented before resuming highway operations.

Lubrication

The governor is lubricated in the same manner as the limiting speed mechanical governor (Section 2.7. 1).

Check Governor Operation

Governor difficulties should be checked out in the same manner as outlined in Section 2.7. If, after making the checks, the governor fails to control the engine or auxiliary equipment properly, it should be removed and reconditioned.

Remove Governor

1. Disconnect the manual control flexible shaft from the governor spring housing.

2. Remove the governor following the same procedures outlined in Section 2.7.1.

Disassemble Governor

The variable low-speed limiting speed governor is similar to the limiting speed governor with the exception of the spring housing and its components. Therefore, disassemble the governor as outlined in Section 2.7.1, then disassemble the spring housing and its components (Fig. 1) as follows:

1. Clamp the flange of the governor housing in a vise equipped with soft jaws.

2. Remove the two bolts and lock washers securing the spring housing to the governor housing and withdraw the spring housing and gasket.

3. Remove the adjusting coupling from the adjusting shaft.

4. Hold the adjusting lock nut with a wrench and back off the retainer and adjusting shaft.

5. Unscrew the adjusting shaft from the retainer.

6. Unscrew the idle speed adjusting lock nut from the end of the high-speed spring plunger.

7. Unscrew the high-speed spring retainer lock nut and remove the high-speed spring retainer, plunger and spring along with the low-speed spring plunger, inner and outer springs and low-speed spring cap as an assembly from the governor housing.

8. Remove the high-speed spring retainer and spacer assembly and spring from the high-speed spring plunger. Remove the low-speed spring cap from the opposite end of the high-speed spring plunger and remove the low-speed spring plunger along with the inner and outer low-speed springs.

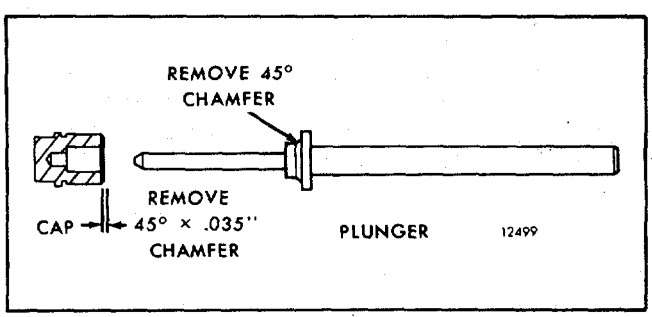


FIG. 2 - Rework Former Plunger and Cap

NOTE: The high-speed spring retainer on early engines did not include a spacer. If the shaft sticks in the retainer, replace it with the current retainer and spacer assembly.

Inspect Governor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air, then inspect them as outlined in Section 2.7.1.

Assemble Governor

NOTE: During assembly, lubricate all spring housing components and needle bearing assemblies with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

Assemble the governor as outlined in Section 2.7.1, then assemble the spring housing and components (Fig. 1).

To assure a 500 rpm idle speed for certain on highway vehicle engines, the spring seat chamfer has been removed from the low-speed spring plunger and cap. The internal chamfer has been removed from both ends of the coil of the outer low-speed spring. A high idle condition could be the result if an unchamfered spring did not seat properly due to the chamfer on the former plunger and cap. To correct this condition, install a current (modified) plunger and cap, or remove the 45° chamfer from the spring seat area of the plunger and also the 45 ° x .035 " chamfer on the cap (shaded area, Fig. 2).

NOTE: A chamfered spring should not be used with an unchamfered plunger and cap, because a severe wear condition will result.

1. Thread the spring retainer lock nut on the high-speed spring retainer approximately 1-1/2 ".

2. Place the high-speed spring on the high-speed spring plunger.

3. Insert the high-speed spring and plunger assembly in the high-speed spring retainer.

4. Insert the low-speed spring plunger into the high-speed spring plunger.

5. Place the inner and outer springs in the lower end of the high-speed spring plunger, over the low-speed spring plunger.

6. Install the low-speed spring cap over the end of the inner low-speed spring and into the end of the high--speed spring plunger and install the assembly in the governor housing.

NOTE: Place the spring housing gasket in position before installing the assembly.

7. Thread the idle speed adjusting lock nut on the threaded end of the high-speed spring plunger approximately 1/2 ".

8. Screw the adjusting shaft into the adjusting shaft retainer all the way in as shown in Fig. 1.

9. Install the adjusting retainer and shaft onto the high-speed spring plunger. Turn down the adjusting retainer against the idle speed adjusting lock nut.

10. Install the adjusting coupling and spring housing after the governor adjustments (Section 14.3.3) have been performed.

Install Governor

Install the governor as outlined in Section 2.7.1, then connect the manual control flexible shaft to the governor spring housing (Fig. 1).

Adjust the governor as outlined in Section 14.3.3.

Remove Governor From Engine

1. Disconnect the air controls from the governor spring housing.

2. Remove the governor following the same procedures outlined in Section 2.7. 1.

Disassemble Governor

The air operated variable low-speed limiting speed governor is similar to the limiting speed governor with the exception of the spring housing and its components. Therefore, disassemble the governor as outlined in Section 2.7.1, then disassemble the spring housing and its components (Fig. 3) as follows:

1. Clamp the flange of the governor housing in a vise equipped with soft jaws.

2. Remove the two bolts and lock washers securing the spring housing to the governor housing and withdraw the spring housing and gasket. Discard the gasket.

3. Loosen the 5/16 "-24 idle speed jam nut and remove the idle speed adjusting screw, seal ring and nut as an assembly. Discard the seal ring.

4. Hold the 1/2 "-20 jam nut on the high-speed spring plunger with a wrench and unscrew the air cylinder cap, retainer ring, pin, piston, air cylinder and seal ring as an assembly from the end of the high-speed spring plunger.

   a. Disengage the retainer ring from the air cylinder and remove the air cap and piston from the air cylinder.

   b. Remove the seal ring from the piston. Discard the seal ring.

5. Unscrew the high-speed spring retainer lock nut and remove the high-speed spring retainer, plunger and spring along with the low-speed spring plunger, inner and outer springs and low-speed spring cap as an assembly from the governor housing.

6. Remove the high-speed spring retainer and spacer assembly and spring from the high-speed spring plunger. Remove the low-speed spring cap from the opposite end of the high-speed spring plunger and remove the low-speed spring plunger along with the inner and outer low-speed springs.

Inspect Governor Parts

Wash all of the parts in clean fuel oil and dry them with compressed air, then inspect them as outlined in Section 2.7.1.

Assemble Governor

NOTE: During assembly, lubricate all spring housing components with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

Assemble the governor as outlined in Section 2.7.1,

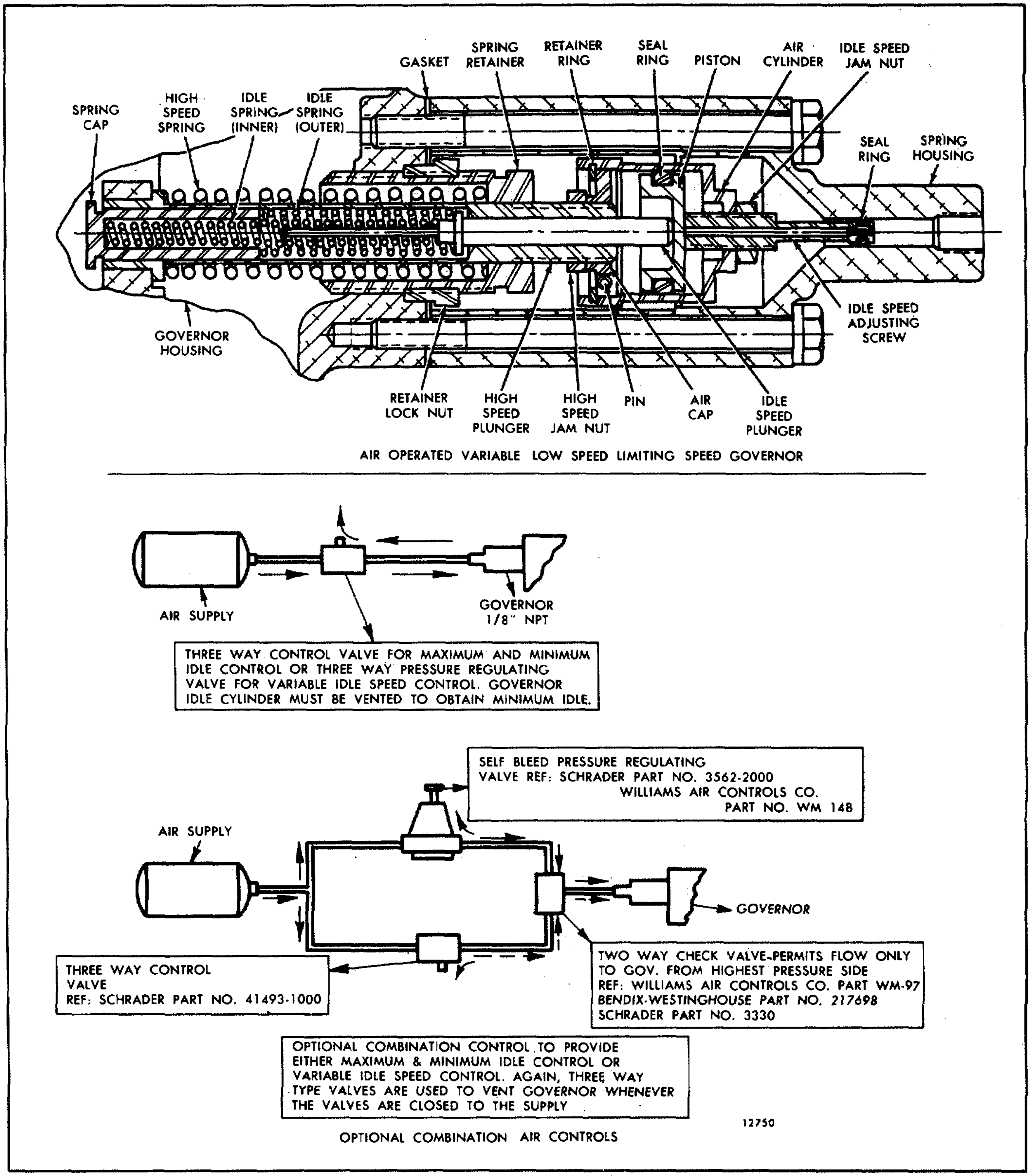


FIG. 3 - Air Operated Variable Low Speed Limiting Speed Governor and Sir Controls

then assemble the spring housing and components as follows (Fig. 3):

1. Thread the spring retainer lock nut on the high-speed spring retainer approximately 1-1/2 ".

2. Place the high-speed spring on the high-speed spring plunger.

3. Insert the high-speed spring and plunger assembly in the high-speed spring retainer.

4. Insert the low-speed spring plunger into the high-speed spring plunger.

5. Place the inner and outer springs in the lower end of the high-speed spring plunger, over the low-speed spring plunger.

6. Install the low-speed spring cap over the end of the inner low-speed spring and into the end of the high-speed spring plunger and install the assembly in the governor housing.

NOTE: Place the new spring housing gasket in position before installing the assembly.

7. If removed, thread the 1/2 "-20 high-speed spring jam nut on the threaded end of the plunger approximately 1/2 ".

8. Place a new seal ring on the piston and assemble the piston and air cap in the air cylinder. Secure them in the air cylinder with the retainer ring.

9. Screw the air cylinder assembly on the high-speed spring plunger and against the high-speed spring plunger and jam nut.

10. Place a new seal ring on the idle speed adjusting screw and install the adjusting screw and jam nut in the air cylinder.

11. Install the spring housing after the governor adjustments (Section 14.3.3) have been performed.

NOTE: Be sure and lubricate the bore of the spring housing with grease as stated in the above note.

Install Governor

Install the governor as outlined in Section 2.7.1, then connect the air controls to the governor spring housing (Fig. 3).

Adjust the governor as outlined in Section 14.3.3.

LIMITING SPEED MECHANICAL GOVERNOR
Fast Idle Cylinder

The limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover (Fig. 1). An engine shutdown air cylinder, if used, is also mounted on the governor cover.

For operation and adjustment of the fast idle air cylinder, refer to Section 14.3.4.

Lubrication

The governor is lubricated in the same manner as the limiting speed governor (Section 2.7.1).

Check Governor Operation

Governor difficulties should be checked in the manner outlined in Section 2.7. If, after making the checks, the governor fails to control the engine or auxiliary equipment properly, it should be removed and reconditioned.

Remove Governor

1. Release any air in the system and disconnect the air hoses from the air cylinders.

2. Remove the governor by following the procedure outlined in Section 2.7.1.

Disassemble Governor

1. Disassemble the governor as outlined in Section 2.7.1.

2. Refer to Fig. 2 and disassemble the fast idle cylinder as follows:

a. Pull the plunger out of the buffer spring and cylinder.

b. Clamp the air cylinder in a vise equipped with soft jaws.

c. Apply pressure on the end of the air inlet plug and remove the plug retaining ring from the groove in the air cylinder.

d. Pull the air inlet plug and seal ring assembly from

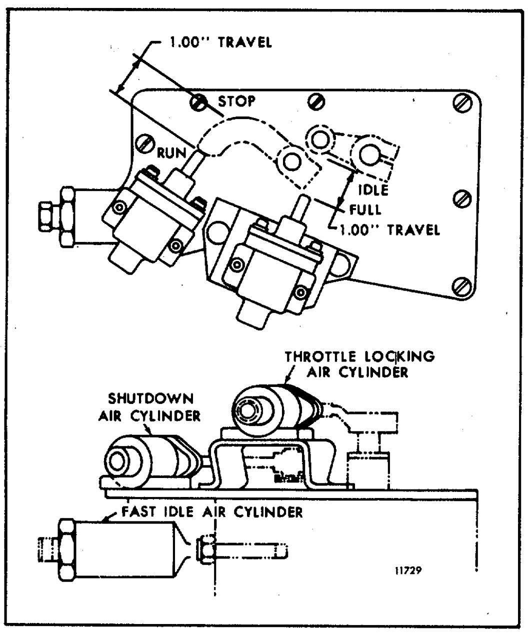


FIG. 1 - Governor with Fast Idle Cylinder

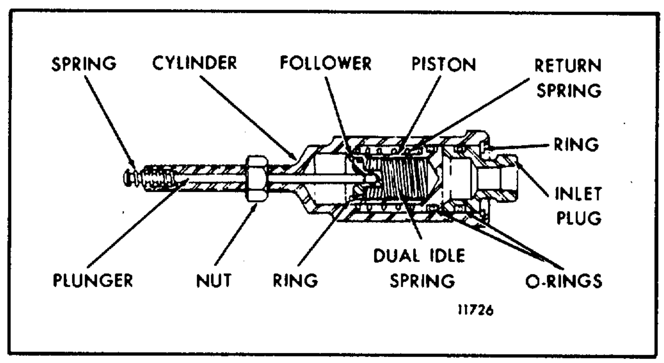


FIG. 2 - Fast Idle Air Cylinder

the air cylinder. Remove the seal ring from the groove in the plug.

e. Insert a 3/32"diameter steel rod in the plunger opening in the air cylinder and push the piston, seal ring, dual idle spring and spring follower out of the air cylinder as an assembly. Then remove the air cylinder spring from the cylinder.

f. Remove the seal ring from the groove in the piston. Apply pressure on the spring follower and remove the follower retaining ring from the groove in the piston. Remove the follower and spring.

Inspection

Wash all of the governor components in clean fuel oil and dry them with compressed air. Then inspect them as outlined in Section 2.7.1.

Examine the fast idle air cylinder components for wear or any defects. Replace worn or damaged parts.

Assemble Governor

1. Assemble the governor as outlined in Section 2.7.1.

2. Assemble the fast idle cylinder as follows:

a. Refer to Fig. 2 and insert the dual idle spring inside of the fast idle air cylinder. Place the spring follower, with the small diameter end down, inside of the spring. Apply pressure on the spring follower and compress the spring enough to expose the retaining groove. Then install the retaining ring in the groove.

b. Install a new seal ring in the groove in the piston. Then install the air cylinder spring over the small diameter end of the piston.

c. Lubricate the seal ring on the piston with engine oil. Then insert the piston and spring assembly, with the small diameter end of the piston first, straight into the air cylinder spring seats on the shoulder in the cylinder.

d. Install a new seal ring in the groove of the air cylinder air inlet plug.

e. Lubricate the seal ring with engine oil. Then insert the air inlet plug straight into the air cylinder and against the piston.

f. Clamp the air cylinder in a vise equipped with soft jaws. Apply pressure on the end of the air inlet plug and compress the spring enough to expose the retaining ring groove. Then install the retaining ring.

g. If removed, thread the lock nut on the air cylinder. Then insert the plunger through the buffer spring and into the air cylinder.

3. Install the fast idle air cylinder assembly in the governor housing buffer screw hole.

Install Governor

1. Install the governor on the engine as outlined in Section 2.7. 1.

2. Install the throttle locking and engine shutdown air cylinders.

3. Connect the air hoses to the air cylinders.

4. Adjust the governor as outlined in Section 14.3.4.

LIMITING SPEED MECHANICAL GOVERNOR
(Variable High Speed)

The air operated variable high speed limiting speed mechanical governor is provided for highway vehicle applications where the same engine powers both the vehicle and auxiliary equipment, for unloading bulk products (such as cement, grain or liquids) and where a variable speed range is desired during auxiliary constant speed operation.

Operation

The idle speed range for these governors is the same as for the standard limiting speed governors. The normal no-load speed range is the same as for the standard limiting speed governor. A variable high speed limiting governor will control engine RPM from any normal no-load speed down to near idle speed. Also, in addition to the high speed control kit, a regulated air supply and an air cylinder to move the throttle to the wide open throttle position is required.

Install Control Housing

Without disturbing the engine tune-up, install a high speed control housing assembly (Fig. l) on a standard limiting speed governor having a long spring pack, as follows:

1. Loosen the two bolts and copper washers and remove the spring retainer housing.
2. Remove the idle speed adjustment screw and replace it with the longer high speed control idle speed screw and reset the idle speed RPM to the previous setting.

NOTE: If the governor has the former one piece idle speed screw, replace it with the current idle speed pin and long screw.

The engine tune-up procedure for the high speed control governor is the same as stated in Section 14.3 except the idle speed adjustment is made, using the longer idle speed screw.

3. Assemble the high speed control housing as follows:
   a. Install the small ring in the spring housing and the large seal ring on the piston.
   b. Lubricate the piston and inside of housing with engine oil. Install the piston in the housing, bottoming the piston on its stop.
4. Slide the housing and piston assembly over the spring retainer and idle speed screw.
5. Ins*tall* the idle screw self-locking nut and make the following adjustments:
   a. Place a .010" feeler gage between the VHS housing gasket and the main governor housing.
   b. Adjust the elastic stop nut, while holding the idle screw stationary, until a slight drag is felt on the shim (Fig. 2). This adjustment is made easily with Tool J 28598-A.
   c. Remove the shim.
6. Install the gasket and either flat or tamper-resistant

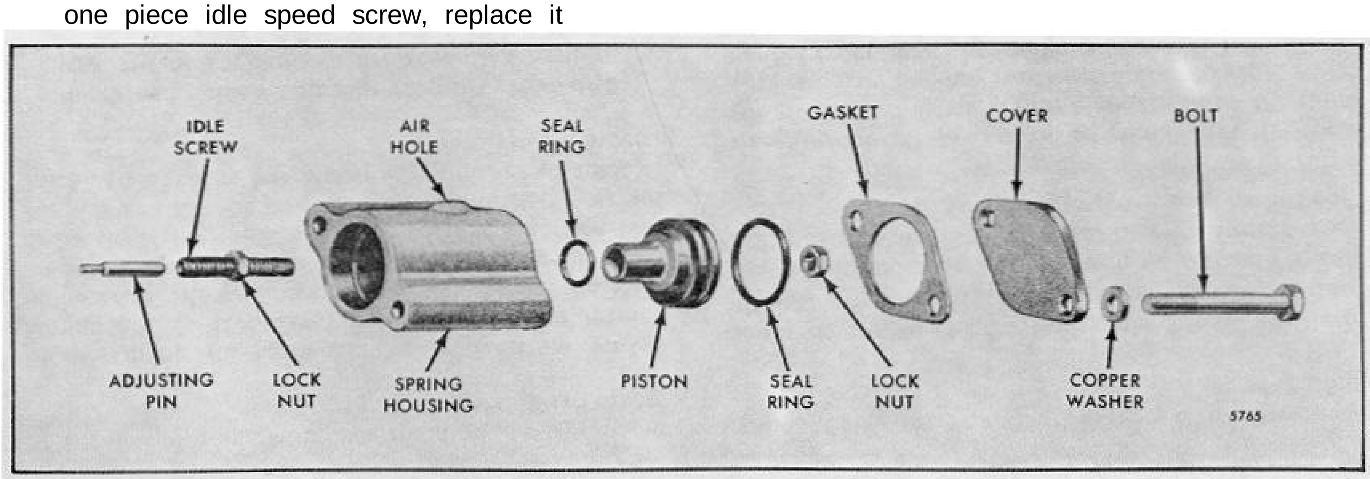


FIG. 1 - Air Operated Variable High Speed Limiting Speed Mechanical Governor Components

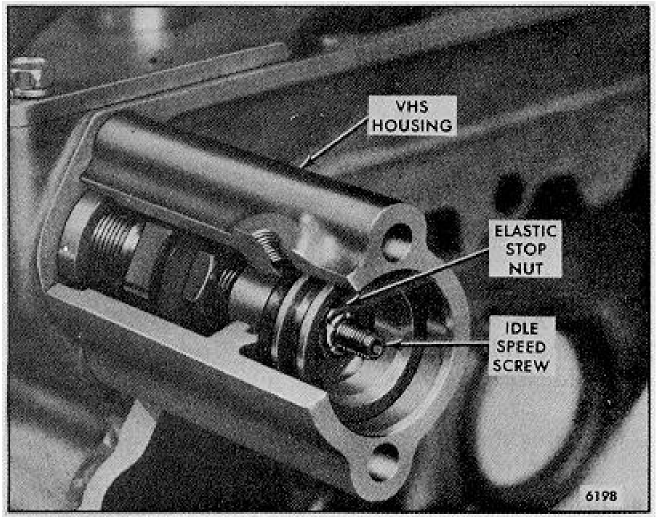
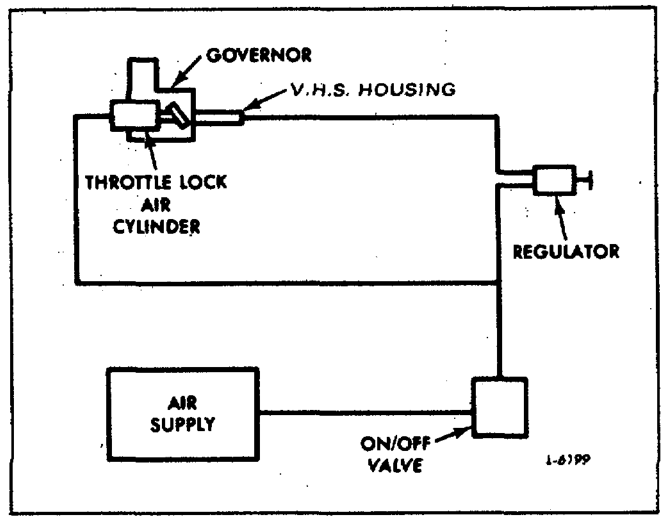


FIG. 2 - Adjust Elastic Stop Nut using Toot J 28598-A

cover with two copper washers and two 5/16" bolts. Tighten the bolts.

Install the air cylinder (throttle lock) on the governor cover so that it does not interfere with the throttle linkage when no air pressure is applied and moves the speed control lever to the wide *open throttle position* when full air pressure is applied (Fig. 3).

Supply air should only be taken from the accessory air supply. At no time should supply air be taken from the service brake system. However all air supply components should be plumbed and mounted in compliance with the recommendations for the air Fig. 3 - Schematic Drawing of Limiting Speed Mechanical Governor (Variable High Speed) brake system. Both air cylinders must be vented to insure rapid disengagement.



Before starting an engine after an engine speed control adjustment or alter removal of the engine governor cover and lever assembly, the serviceman must determine that the injector racks move to the no fuel position when the governor stop lever is placed in the stop position. Engine over-speed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

CAUTION: An over-speeding engine can result in engine damage which could cause personal injury.

FUEL INJECTOR CONTROL TUBE

The fuel injector control tube assemblies (Fig. l) are mounted on the left and right bank cylinder heads of a V-71 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 cylinder head.

The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no-fuel position. 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.

Certain engines use spring-loaded injector control tube assemblies (Fig. 2), similar to the above except they have a yield spring at each injector rack control lever and only one screw and lock nut to keep each injector rack properly positioned. This enables an engine to be brought to a lesser fuel position if there is an inoperative fuel injector rack, whereas with the non-spring loaded two screw injector control tube this could not be done. The above also permits the use of an air inlet housing with no emergency air shut-off valve as is required in some applications.

NOTE: 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 shut-off 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" 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 shutdown lever to the no-fuel position. With the two screw design injector control tube and lever assembly, emergency engine shutdown is accomplished by tripping the air shut-off valve in the air inlet housing.

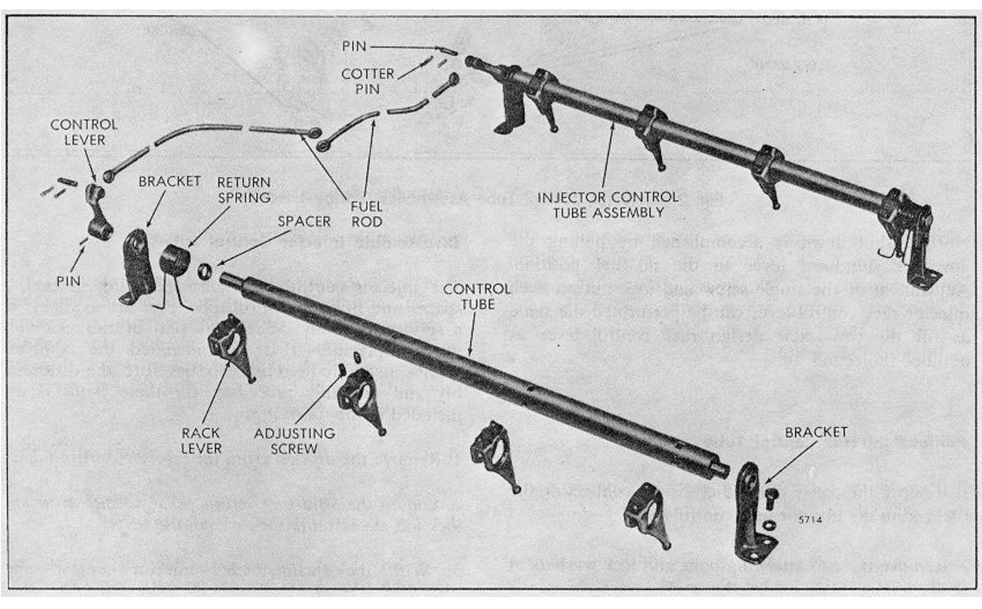


FIG. 1 - Injector Control Tube Assemblies (Non-Spring Loaded)

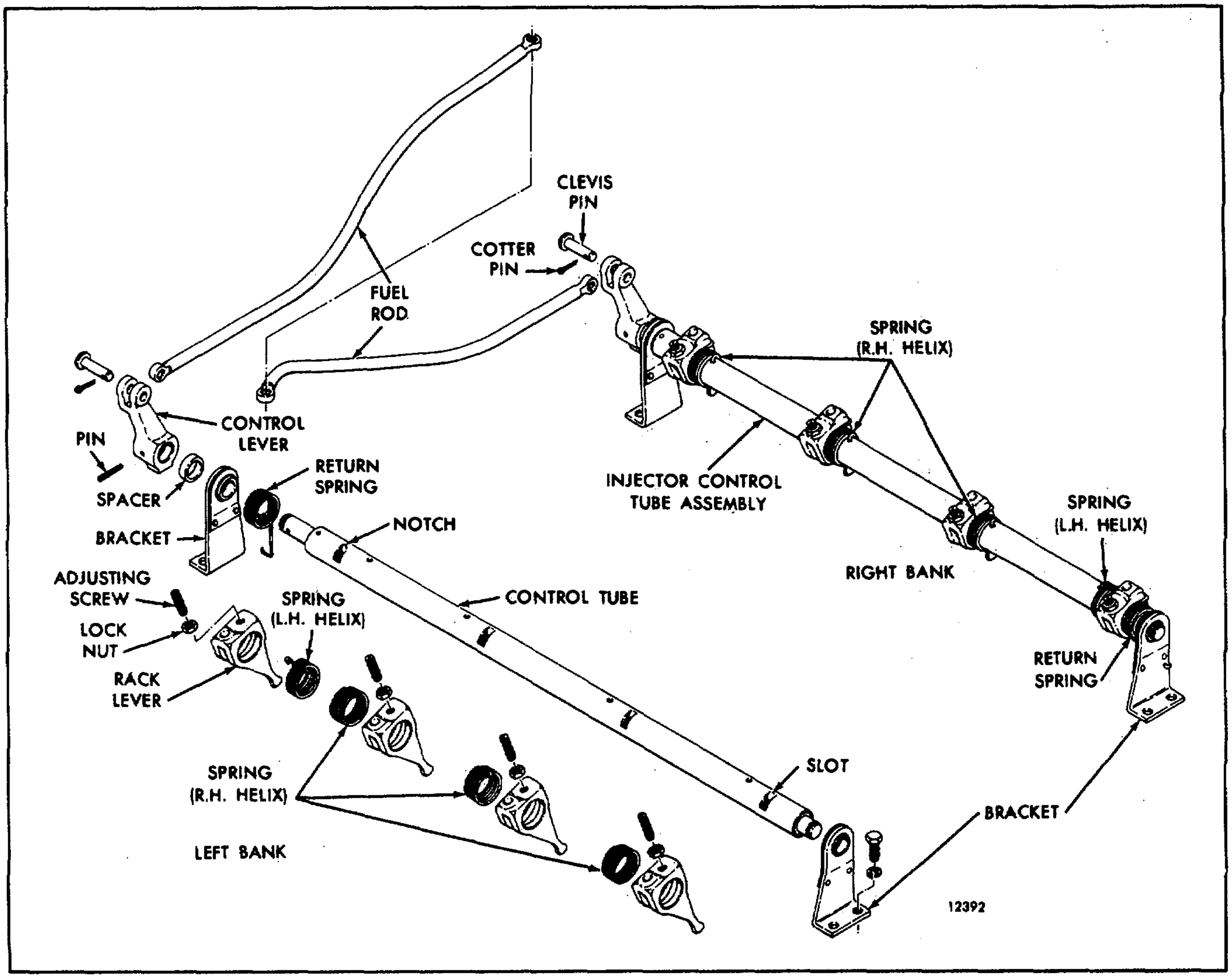


FIG. - Injector Control Tube Assemblies (Spring-Loaded)

Normal shut down is accomplished by pulling the governor shutdown lever to the no-fuel position. Adjustment of the single screw and lock nut on each injector rack control lever can be performed the same as for the two screw design rack control lever as 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 the control tube assembly from the cylinder head.

Disassemble Injector **Control Tube**

The injector control tube, one mounting bracket, a spacer and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for these items is not included in the following:

1. Remove the bracket from the injector control tube.
2. Loosen the adjusting screws or adjusting screw and lock nut at each injector rack control lever.
3. With the spring-loaded injector control tube, disconnect the yield springs at each rack lever, then roll the yield springs out of the slots and notch of *the* control tube.

4. Disconnect the return spring from the bracket and front or rear rack lever.
5. Then remove the yield springs and/or return spring and rack levers from the control tube.

Inspection

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

Examine the control tube, control lever, control tube rack control levers and brackets for excessive wear, cracks or damage and replace them if necessary. The bearing in the bracket is not serviced separately.

Examine the yield springs and/or return spring and replace them if worn or fractured.

Assemble Injector Control Tube

With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. l or 2 and assemble as follows:

LEFT BANK CYLINDER HEAD

1. Install the return spring on the control tube and against the front bracket
2. On the two screw design injector control tube, install the rack control levers on the control tube, with the levers facing the rear bracket position, and turn the adjusting screws in far enough to position the levers on the control tube.
3. On the one screw and lock nut design injector control tube, install a rack control lever, with the lever facing the rear bracket position, and the odd (L. H. helix) yield spring. Then install the R. H. helix yield springs and rack control levers with the levers facing the rear bracket.
4. On the one screw and lock nut design injector control tube, attach the curled end of the yield springs to the rack control levers and roll the yield springs into the notch (odd spring) and slots (R. H. helix springs) in the control tube. Then turn the adjusting screws and lock nuts into the slots far enough to position the levers on the control tube.
5. On both designs, attach the curled end of the control tube return spring to the rack control lever and the extended end of the spring behind the front bracket.
6. On both designs, install the rear bracket on the end of the injector control tube.

RIGHT BANK CYLINDER HEAD

1. On the two screw design injector control tube, install the rack control levers on the control tube, with the levers' facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.
2. On the one screw and lock nut design injector control tube, install the rack control levers, with the levers facing the front bracket position and the R. H. helix yield springs. Then install the odd (L. H. helik) yield spring and rack control lever, with the lever facing the front bracket position.
3. Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R. H. helix yield springs) in the control tube. Then turn the adjusting screws and lock nuts into the notch and slots far enough to position the levers on the control tube.
4. On both designs, install the control tube return spring and rear bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the rear bracket.

Install Injector Control Tube

1. Engage the injector rack control levers with the injector control racks and place the brackets over the mounting holes on the cylinder head.
2. Install the two 1/4" -20 x 5/8" bolts and lock washers at each bracket to attach the injector control tube assembly to the cylinder head. Tighten the bolts to 10-12 lb-ft (14-16 Nm) torque.
3. Check the control tube to be sure it is free in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.
4. Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.
5. Refer to Section 14 and position the injector rack control levers.

NOTE: -Be sure the injector rack control levers can be placed in a no-fuel position before re- starting the engine.

CAUTION: Loss of shut down control could result in a -runaway engine which could cause personal injury.

SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

INJECTOR CALIBRATOR READINGS

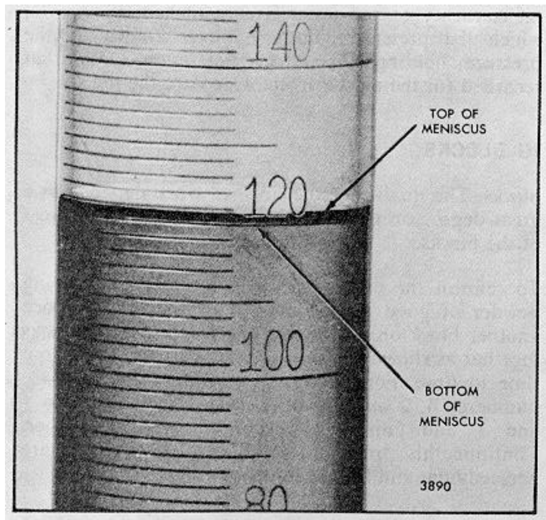


FIG. 1- Checking Fuel Output

Several factors affect the injector calibrator output readings. The four major items are:

1**. Operator Errors:** If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of I or 2 points with result. Refer to Fig. 1.

2**. Air InLines:** This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.

3. **Counter Improperly Set:** The counter should be set to divert the injector output at 1,000 strokes. This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 100 strokes (if properly set) although the counter may overrun several digits.

4**. Test Oil:** A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner if required.

In addition, other malfunctions such as a slipping drive belt, low level of test oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions.

CHECKING INJECTOR TESTER

The injector tester (J 9787 or J 23010) should be checked monthly to be sure that it is operating properly. The following check can be made very quickly using test block J 9787-49.

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. Otherwise, the pump check valve must be removed, lapped and cleaned or replaced (J 9787). The pump check valve must be replaced on tester J 23010.

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 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.

REFINISH LAPPING BLOCKS

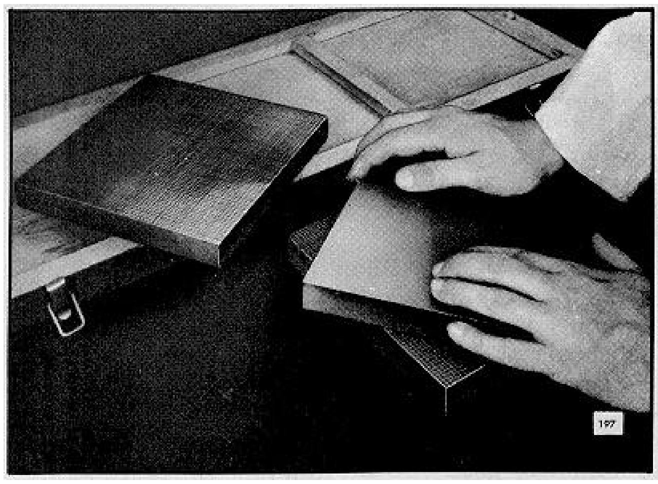


FIG. 2 - Refinishing Lapping Blocks

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished 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 s shown in Fig. 2. Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2 and 3, work 1 and 2 together, then I 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 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 trichloroethyl- *ene and scrubbing* with a b*ri*stle *brush.*

When not in use, protect the lapping blocks against damage and dust by storing them in a close fitting wooden container.

EFFECT OF PREIGNITION 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 recurrernce of the problem. Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective *b*lower *oil seals,* high *crankcase pressure,* plugged *air* box drains, ineffective oil control rings or dilution of the lubricating oil.

INJECTOR TIMING

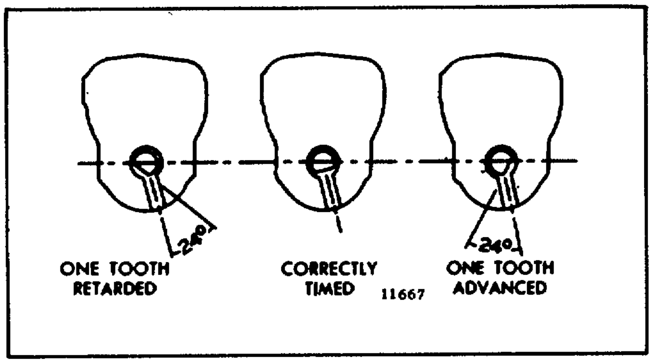


FIG. 3 - Injector Rack-to-Gear Timing

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. 3) and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack-to-gear timing.

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.

INJECTOR PLUNGERS

The fuel output and the operating characteristics of an injector are, to a great extent, determined BY the type .of plunger us(l. Three types of plungers are illustrated. in Fig. 4. The beginning of the injection period is. controlled by the upper helix angle. The lower helix .angle retards or advances the end of the injection. period. Therefore, it is imperative that the correct .plunger is installed whenever an injector is over hauled.. If injectors with different type plungers (and spray. tips) are mixed in an engine, erratic operation will. result and may cause serious damage to the engine or .to the equipment which it powers. .Injector plungers cannot be reworked to change the. output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

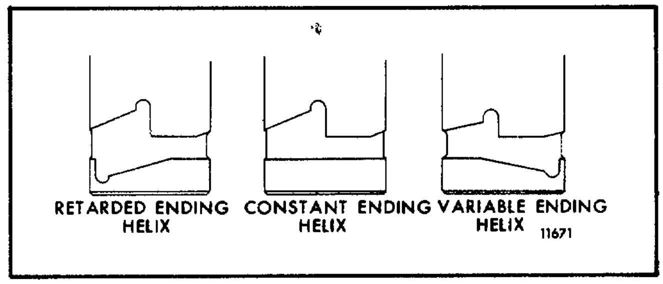


FIG. 4 - Types of Injector Plungers

MASTER INJECTOR CALIBRATING KIT

Use Master Injector Calibrating Kit J 26298 to determine the accuracy of the injector calibrator.. With the test fluid temperature at 100 ° F ± 11 (38 °C ± 1 °) 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 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% 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.

REFINISHING INJECTOR FOLLOWER FACE

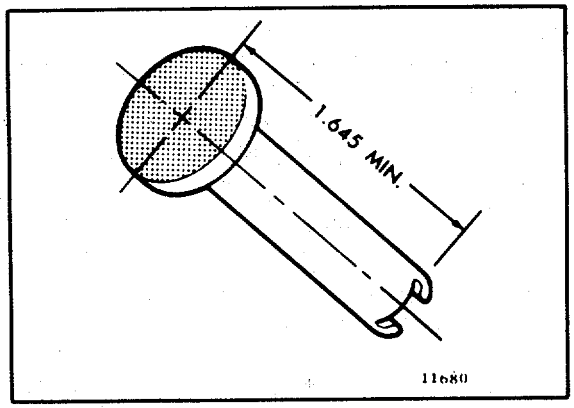


FIG. 5 - Injector Follower

When refinishing the face of an injector follower, it is extremely important that the distance between the follower face and the plunger slot is not less than 1.645" minimum as shown in Fig. 5. If this distance is less than specified, the height of the injector follower in relation to the injector body will be altered and proper injector timing cannot be realized.

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 15 to 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 2()-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- 8() 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 (see note).

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 10 to 2() 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.

> **NOTE:** 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 spillage of fuel during leak detection testing further dilutes the lube oil. so the flinal step in maintenance of this type should include lube oil and lube oil filter changes.

TAMPER RESISTANT GOVERNOR FOR HIGHWAY VEHICLE ENGINES

A tamper-resistant double-weight limiting speed governor is provided for highway vehicle engines.

This governor incorporates an adaptable high-speed spring housing to make unauthorized speed setting changes extremely difficult. The new governor spring housing has one inch of additional metal resembling two bosses cast on the bolt head of the housing (Figs. 6 and 7). These bosses are counterbored to accept the two bolts which hold the spring housing on the governor housing and to allow for the installation of' plugs over the bolt heads. The plugs are secured in the counterbores by tapered pins which, when driven in place, cannot be removed when the governor is mounted on the blower.

In order to remove the pins to get to the spring housing retainer bolts, the complete governor must be removed from the blower. The governor is not tamper-resistant as furnished on an engine by the factory. The spring housing retainer bolts are removable to permit governor adjustments that may be necessary before. the engine is placed in service following delivery. To make the governor tamper-resistant after initial engine start-up, 2 plugs, 2 tapered pins and the gap adjusting screw and spring cover must be added to the governor as follows:

1. Disassemble the governor spring housing and spring assemblies as follows:

a. Remove the two bolts and washers securing the high-speed spring *housing* to the governor housing and withdraw the housing.

b. Loosen the high-speed spring retainer locknut with a spanner wrench. Then remove the high-speed spring retainer, idle speed adjusting pin and set screw, high-speed spring, spring plunger, low- speed spring, spring seat and spring cap as an assembly. Remove the gasket.

2. Remove the governor housing cover and lever assembly. Remove and discard the spring housing bolt retainer which should be lying loose in the governor housing.

3. Refer to Figs. 6 and 7 and ins*tall* the gap *adjusting* pin and set screw and spring cover and spring assemblies in the governor housing as follows:

a. Place the gap adjusting screw and spring cover in the governor housing with the threaded bolt hole up and in position to receive the low and high- speed springs and plunger assembly.

b. Insert the high-speed spring and plunger assembly in the high-speed spring retainer. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2". Then thread the locknut on the idle speed adjusting screw.

c. Insert the low-speed spring seat, spring and cap assembly into the high-speed spring plunger and over the idle speed adjusting screw.

d. Affix a new spring housing gasket to the governor housing.

e. Insert the springs, plunger and retainer as an assembly into the opening in the governor and through the center of the gap adjusting screw and spring cover. The inner diameter of the cover should pilot on the outer diameter of the retainer. Thread the retainer into the housing approximately one inch.

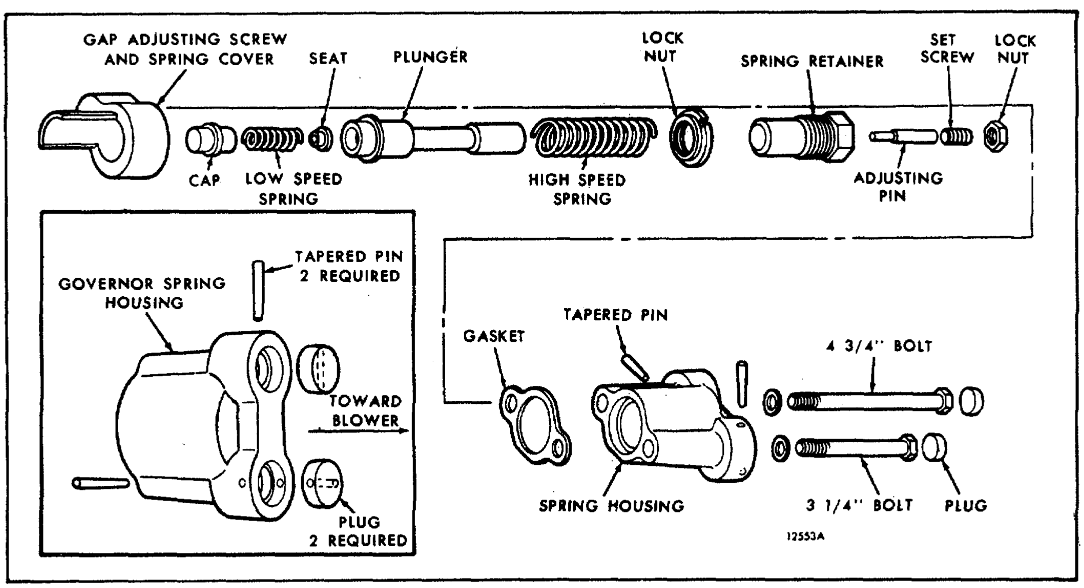


FIG. 6 - Tamper-Resistant Governor Components (Former)

4. Perform the governor adjustments outlined in Section 14.3. Install the governor spring housing as follows:

a. Position the spring housing on the governor housing.

NOTE: On vehicles using a frontal air system, it will be necessary to remove material from the air cleaner adaptor boss to provide clearance for the governor spring housing.

b. Insert the 4 3/4" bolt with copper washer through the top bolt hole in the spring housing and thread it into the threaded hole in the gap adjustment screw and spring cover.

c. Thread the 3 1/4" bolt with lock washer into the bottom hole in the spring and governor housings.

d. Tighten each bolt to 13-17 lb-ft (18-24 Nm) torque.

5. Refer to Fig. 6 and install the tamper-resistant plugs and pins in the counterbores of the spring housing as follows:

a. Install the top plug with the drilled passage in the vertical position and the larger opening up.

b. Install the bottom plug with the drilled passage horizontal and the larger opening away from the blower.

c. Drive the tapered pins, small end first, into the drilled passages in the top and side of the spring housing until the pin is below flush and firmly in place.

Most limiting speed governors on engines already in service can be converted to the tamper-resistant setup as follows:

1. Disassemble the governor spring housing and spring assemblies as outlined under Step 1, Items a and b above.

2. Remove the governor housing cover and lever assembly. Drill out the 5/16"-18 tapped hole in the governor housing at the spring housing top retaining bolt position to 11/32" diameter.

NOTE: Remove all drilled particles from the inside of the governor housing following the drilling operation.

3. Refer to the inset in Fig. 6 and install the new gap screw and spring cover and the high and low-speed spring assemblies, replacing the former retainer with the new longer retainer in the governor housing as outlined under Step 3, Items a through e above.

4. Perform the governor adjustments outlined in Section 14.3. Replace the former spring housing with the new spring housing and install the new housing and governor housing cover on the governor housing as outlined under Step 4, Items a through d above.

5. Refer to Fig. 6 or 7 and install the tamper-resistant plugs and pins in the counterbores of the spring housing as outlined under Step 5, Item a through c above.

NOTE: If the spring housing of a tamper- resistant governor is removed for any reason, the gap adjusting screw and spring cover will fall into the governor housing. Therefore, it is important to remove the governor cover and lever assembly and check to make sure that the gap adjusting screw and spring cover is secured by the 5/16"-18 x 4 3/4" bolt after the spring housing is installed.

GOVERNOR HOUSING REPAIR KIT

A governor housing repair kit is available to recondition limiting and variable speed mechanical governor housings. Kit PT-7150 allows service technicians to accurately ream out worn governor operating lever shaft holes and sleeve the holes in the housings with brass repair bushings. Complete instructions are included with the kit.

MODIFICATION OF GOVERNOR HOUSING TO ACCEPT CURRENT TAMPER-RESISTANT GAP

ADJUSTING SCREW AND SPRING COVER

A former governor housing can be reworked to accept the new tamper-resistant gap adjusting screw and spring cover. Kent-Moore Master Thread Repair Kit J 26520 can be used.

With this procedure, two threaded inserts are installed in the governor housing, one from the inside and one from the outside. This will allow the new retaining screw to be installed on the inside of the governor housing and the new spring housing upper 3-1 /4" bolt to be installed from the outside (Fig. 7).

1. Remove the governor cover, high-speed spring housing and spring pack.
2. Apply a thick coat of grease to the inside of the housing. Fit an oil soaked rag through the spring pack hole, using the grease as a seal between the housing and the rag.
3. Drill the upper high-speed housing bolt hole to 13/ 32 " and tap the hole with a 7/16"-14 tap.
4. Remove the rag, making sure all of the chips are out of the housing. Then wipe the grease from the housing.
5. Thread a 5/16"-18 insert by hand from each side until the lock tabs bottom. Then used the 5/16" tab driver to drive the lock tabs in until flush. This will lock the insert in place. On the inside insert, use the same driver and a brass rod.

NOTE: The inserts and tab tools can be part of J 26520 master thread repair kit. The 5/1611-18 insert kit is J 26520-312 containing 20 inserts. The tab tool is J 26520-31 1.

The: inside of the governor housing cast boss, where the drill breaks through, may need to be filed flat. This is to prevent the gap adjusting screw and spring cover from tilting out of position when the retaining screw is tighten.

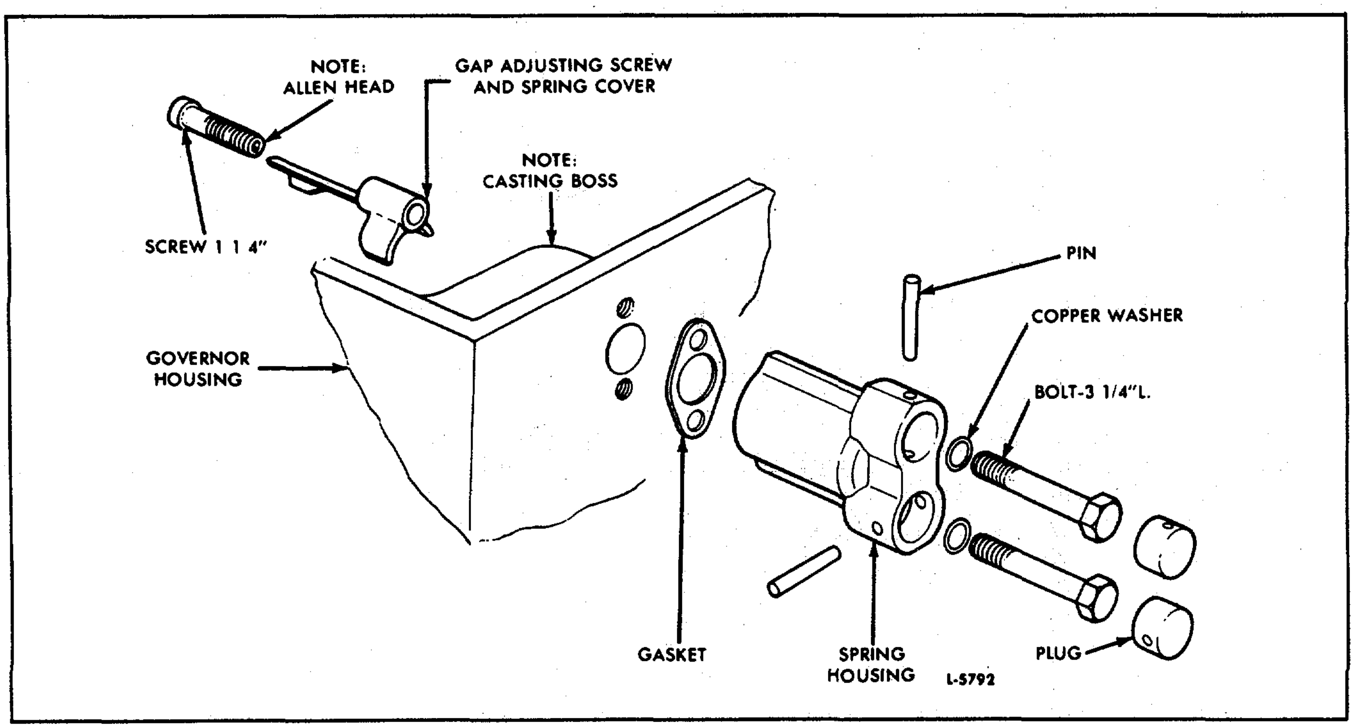


FIG. 7 - Tamper-Resistant Governor Components (Current)

REWORK GOVERNOR HOUSING

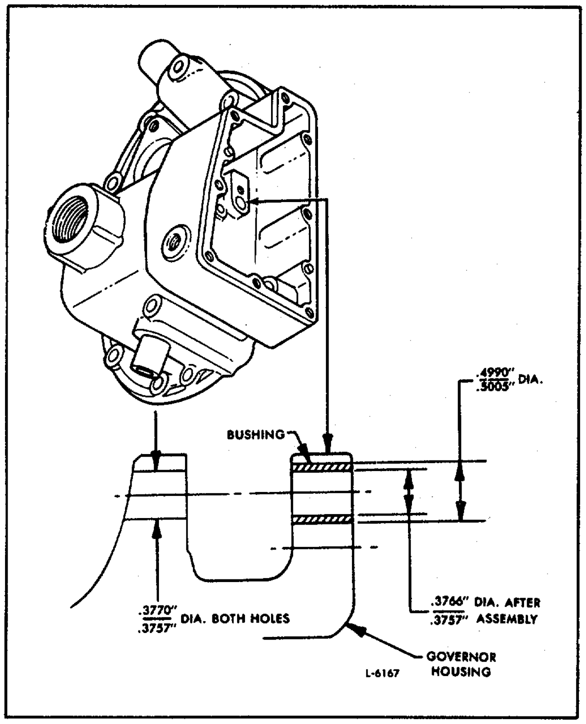


FIG. 8 Reworking Governor Housing

The V-71 engine mechanical governor housing can be reworked when wear occurs at the boss that holds either the upper or lower end of the operating lever shaft.

Repair can be made by adding a bushing to the worn boss as follows:

1. Refer to the drawing and bore out the hole so that the repair bushing fits tight (.4990"-.5005" diameter).

2. Shorten the bushing to a length of .380".

3. Press the bushing in the hold flush to .010" below the surface of the housing boss.

4. Ream the bushing to .3757"-.3766" diameter, using a 3/8" reamer.

> **NOTE:** After assembly of the governor, check for shaft freeness.

Careful workmanship is a must when making this repair to maintain proper geometry and fit within the governor.

TROUBLE SHOOTING

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 fuel 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 (Fig. 9).
2. Start and run the engine at 1200 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 1200 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

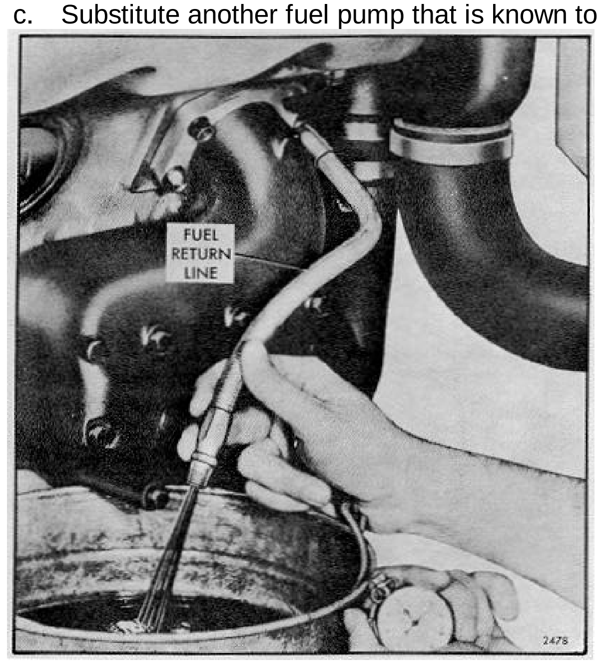


FIG. *9* Measuring Fuel -Flow

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 connection is air 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 and may be checked as follows:

1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screw driver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.

2. Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.

3. 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.

AIR-OPERATED VARIABLE HIGH SPEED GOVERNORS

The most common condition is that the minimum rpm is too high. This is especially true on kit installations to an unknown governor. The most frequent causes are these:

1. Lack of enough air pressure to completely overcome the high speed spring preload.

V-71 engines require 70 psi (483 kPa) or more. This air pressure is required at the governor after the regulator. The regulator must have an operating range of 0-120 psi (0-827 kPa).

2. An interaction between the idle circuit and the high speed circuit.

Many Detroit Diesel Allison governors were designed to idle as low as 350 rpm. If these older design governors are being modified, a low minimum control with the VHS cannot be obtained, especially if a high normal idle is used. All engines supplied by Detroit Diesel Allison with the VHS feature installed as original equipment have a compatible governor which

GOVERNORS W/TYPICAL HEAVY WEIGHT IDLE CIRCUIT

NORMAL IDLE OF	500	550	600	650	750
Minimum Control w/Blue Stripe Idle Spring	700	900	1100	1375	1500
w/Green or Yellow Stripe Idle Spring	1100	1225	1400	NA	NA

will allow control from no-load to within l00 rpm of idle The following chart shows the minimum control speed f the heavy weight governors with various idle speeds and idle springs.

NOTE: Minimum certified idle values should not e violated.
Single weight governors capable of accepting the VHS re also capable of reducing the minimum rpm to within l00 rpm of idle.

3. Idle screw protrudes beyond VHS position. or elastic top nut is not tight.
Determine if the idle screw or piston hits the VHS cover.

If idle screw hits the VHS cover, raise the idle until the crew is flush with the end of the piston. In certain cases the idle screw may have to be shortened to meet he criteria of being flush and acquire the desired idle speed.

If the piston hits first, the elastic stop nut is not properly adjusted. Readjust, making sure that the piston is bottomed, then proceed to adjust the elastic stop nut (See Section 2.7.1.5).

4. Engine overshoot.
This usually relates to the non-synchronized engagement of the throttle lock and the regulated air supply to the VHS housing. A variable orifice (needle valve type) in one of the air supply lines will provide capability for synchronization as follows
In cases of *overshoot,* the variable orifice is installed in the supply line to the throttle lock.
In case of *undershoot,* the variable orifice is installed in the regulated air pressure line to the VHS housing.

5. Lowered idle or no-load.

Usually caused by air from the air supply leaking into or being trapped in the VHS housing. Any pressure in Recheck the air plumbing.

6. Lack of normal power.

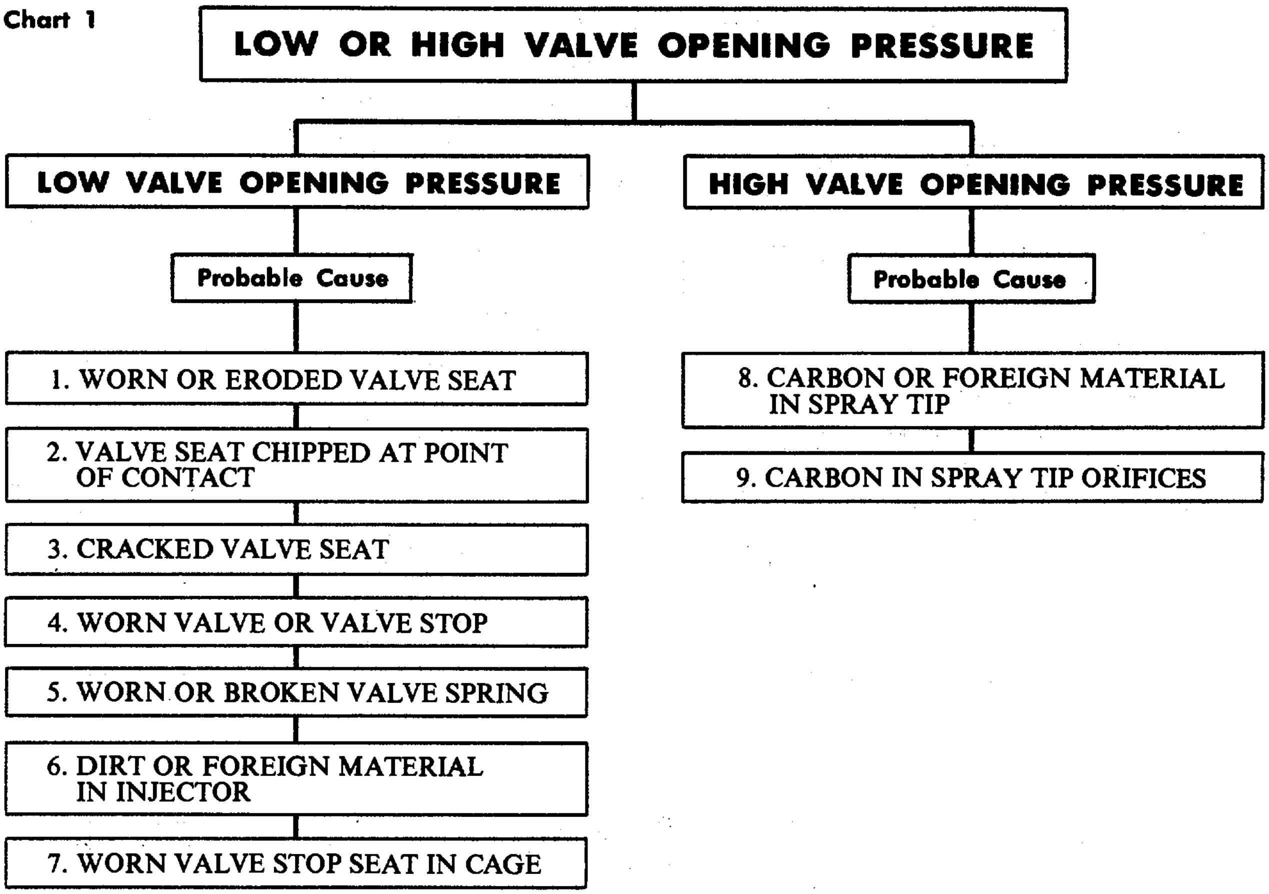
The elastic stop nut is screwed in too tight, pulling the high speed plunger off its seat. This will cause low power but no change in the no-load rpm. Readjust the elastic stop-nut.

7. No-load increased.

Interference of the piston and idle screw. Check to be sure that the screw is free as it protrudes through the piston.

TROUBLE SHOOTING CHARTS (Crown Valve Injectors)

Chart 1



SUGGESTED REMEDY

1. A worn or eroded valve seat may be lapped, but not excessively as this would reduce thickness of the part causing a deviation from the valve stack-up dimension.

2. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the I.D. of the hole. Mount tool J 7174 in a drill motor and place the valve seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve opening pressure.

3. Replace the valve seat.

4. Replace the valve or valve stop.

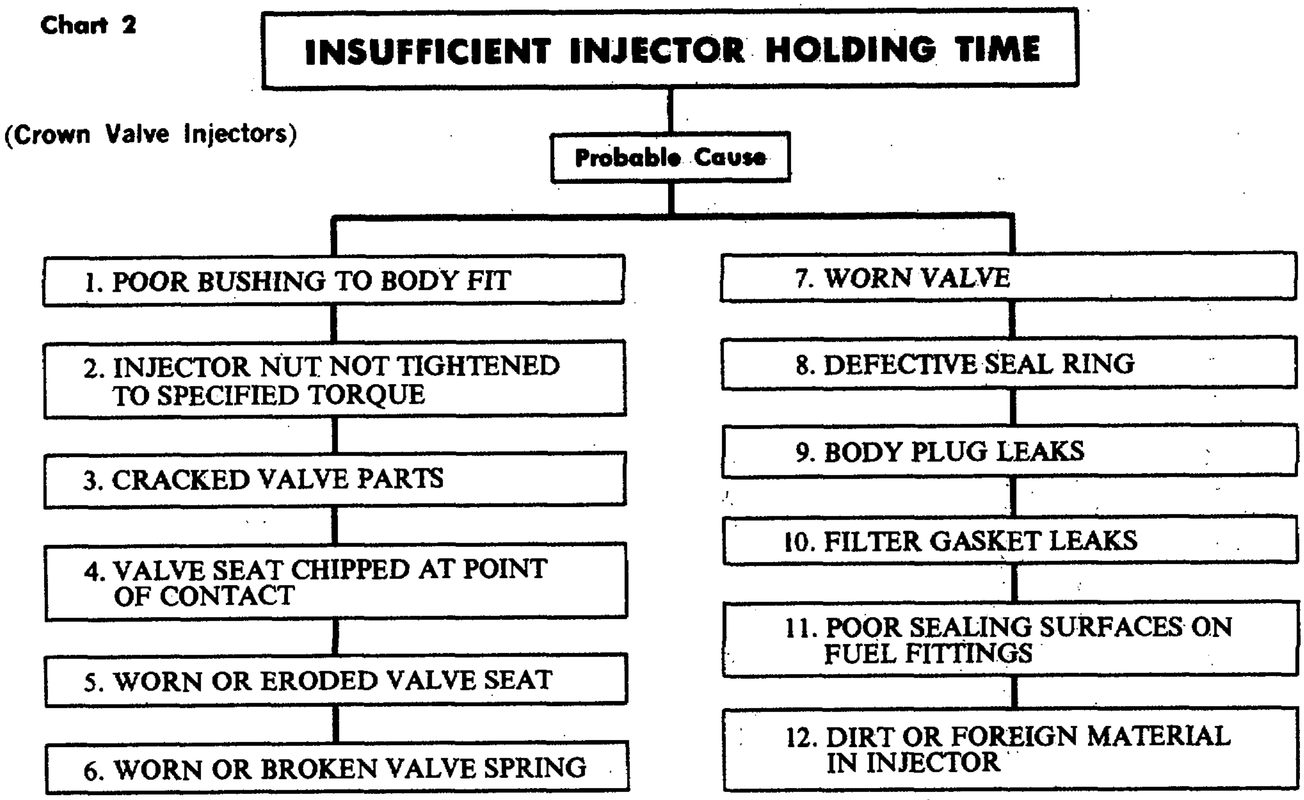
5. Replace the spring. Check the valve cage and valve stop for wear; replace them if necessary.

6. Disassemble and clean the injector.

7. Replace the valve cage.

8. Carbon in the tip should be removed with tip reamer J 1243 which is especially designed and ground for this purpose.

9. Check the size of the spray tip orifices. Then, using tool J 4298-l with the proper size wire, clean the orifices.



SUGGESTED REMEDY

1. Lap the injector body.

2. Tighten the nut to 55 to 65 lb-ft (75-88 Nm) torque. Do not exceed the specified torque.

3. Replace the valve parts.

4. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the I.D. of the hole. Mount tool J 7174 in a drill motor and place the valve seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact- after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve opening pressure.

5. A worn or eroded valve seat may be lapped, but not excessively as this would reduce the thickness of the part causing a deviation from the valve stack-up dimension.

6. Replace the spring. Check the valve cage and valve stop *for* wear; replace them if necessary.

7. Replace the valve.

8. Replace the seal ring.

9. Install new body plugs.

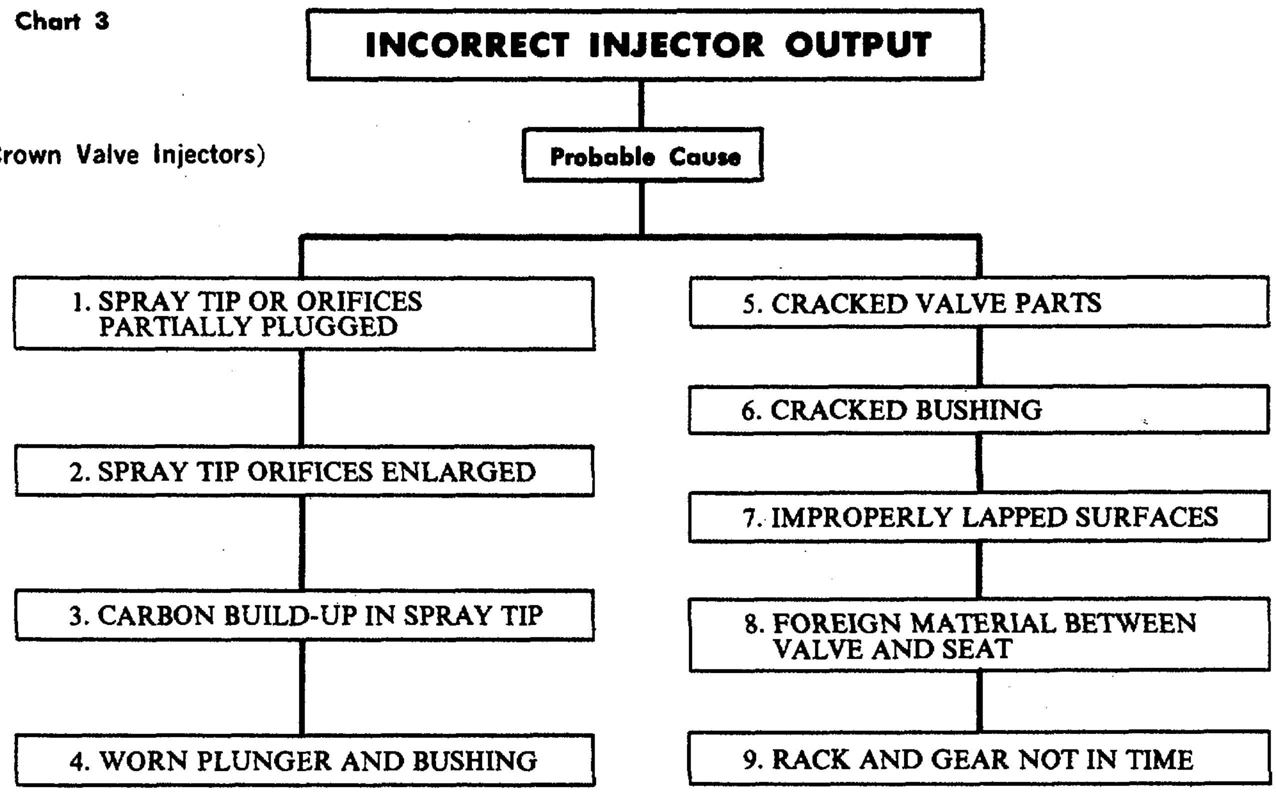
10. Replace the filter gaskets and tighten the filter caps to 65 -to 75 lb-ft (88-102 Nm) torque.

11. Clean up the sealing surfaces or replace the filter caps, if necessary.

12. Disassemble the injector and clean all of the parts.

Chart 3

(Crown Valve Injectors)



SUGGESTED REMEDY

1. Clean the orifices with tool J 4298-l, using the proper size wire.

2. Replace the spray tip.

3. Clean the injector tip with tool J 1243.

4. After the possibility of an incorrect or faulty tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and using with a new assembly.

NOTE: 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 cracked parts.

6. Replace the plunger and bushing assembly.

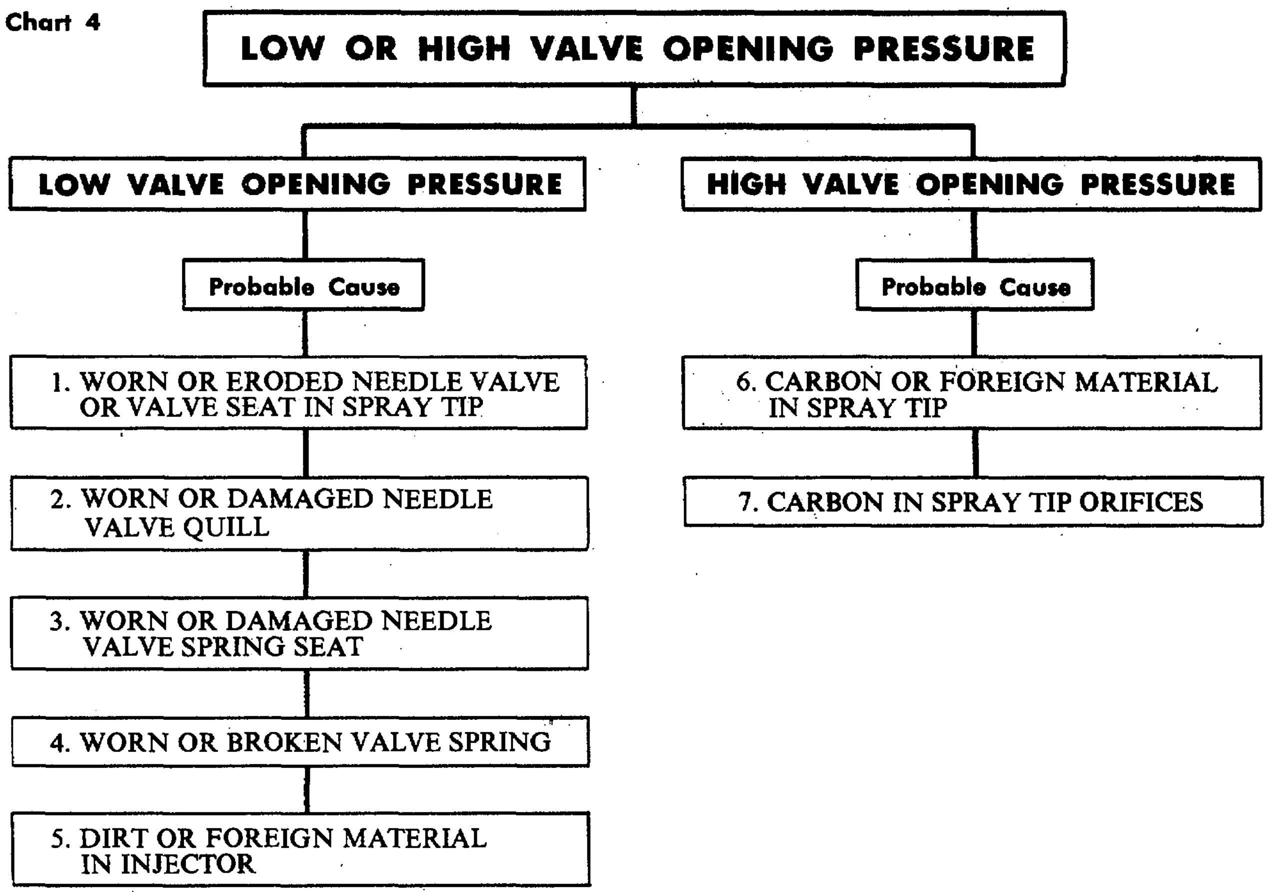
7. Lap the sealing surfaces.

8. Disassemble the injector and clean all of the parts.

9. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth of the rack.

TROUBLE SHOOTING CHARTS (Needle Valve Injectors)

Chart 4

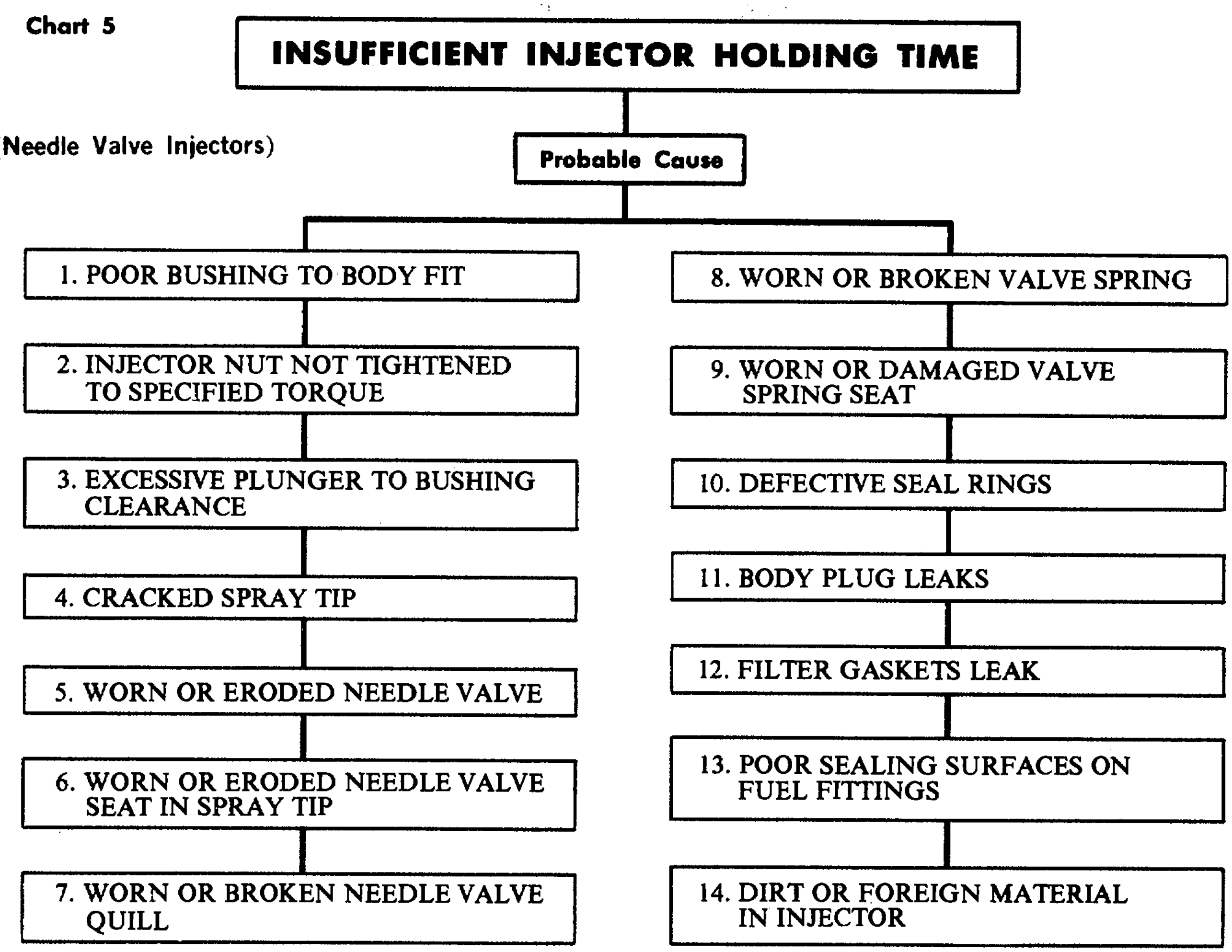


SUGGESTED REMEDY

1. Replace the needle valve and spray tip assembly.
2. Replace the needle valve and spray 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 tip reamer J 24838 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.

Chart 5

(Needle Valve Injectors)



SUGGESTED REMEDY

1. Lap the injector body.

2. Tighten the injector nut to 75-85 lb-ft (102-115 Nm) 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.

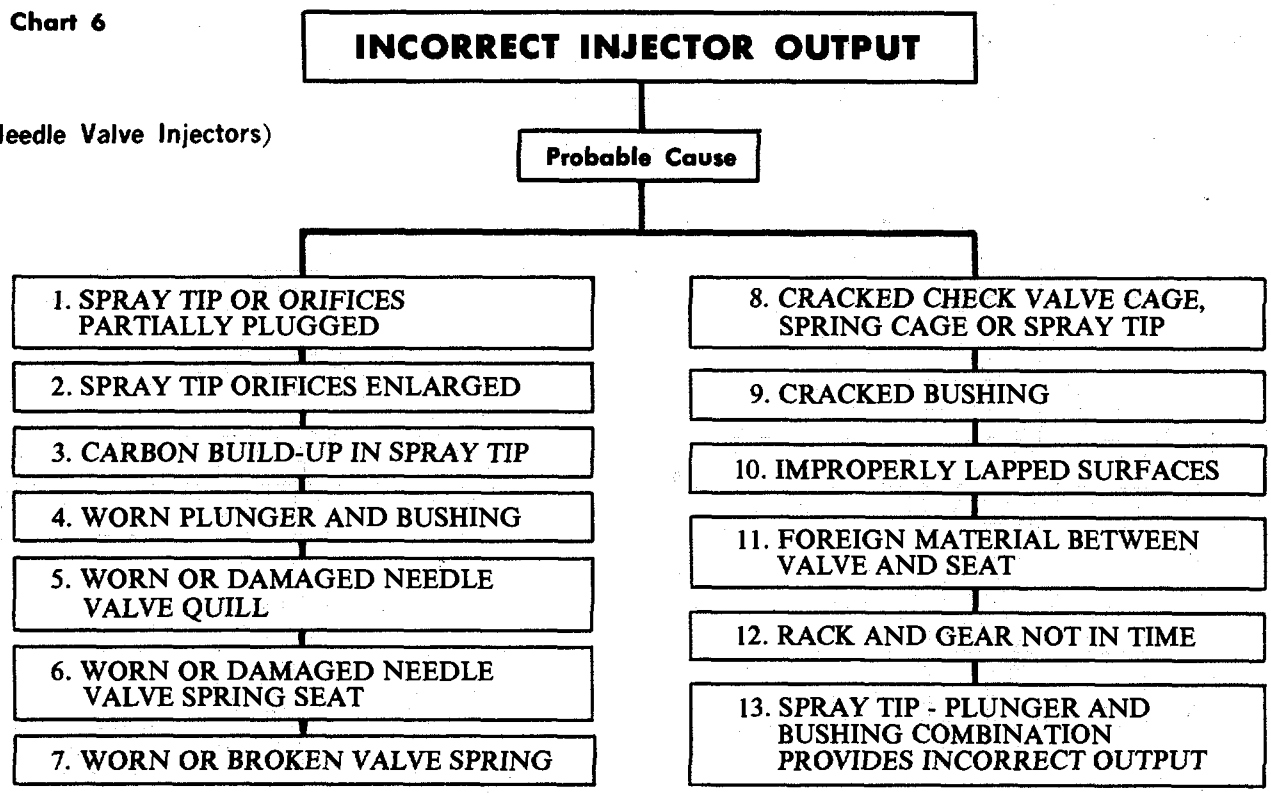
12. Replace the filter cap gaskets and tighten the filter caps to 65-75 lb-ft (88-102 Nm) torque.

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.

Chart 6

(Needle Valve Injectors)



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 with tool J 1243.

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.

> **NOTE**: 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)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	Nm
1/4 -20	5- 7	7- 9	1/4 -20	7-9	10-12
1/4 -28	6- 8	8-11	1/4 -28	810	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	1/220	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 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
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
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

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE lb-ft	TORQUE Nm
Governor Weight Shaft Bearing Retaining Bolt	5/16-24	15-19	20-26
Air Inlet Housing Adaptor-to-Blower Housing Bolt	3/8 -16	16-20	22-27
Air Inlet Housing-to-Adaptor Bolts	3/8 -16	16-20	22-27
Injector Clamp Bolt	3/8 -16	20-25	27-34
Fuel Pipe Nut	3/8 -24	12-15	16-20
Blower End Plate-to-Cylinder Block Bolts	7/16-14	40-45	54-61
*Rocker Arm Bracket Bolts	1/2 -13	90-100	122-136
Injector Filter Cap	5/8 -24	65-75	88-102
Injector Nut (crown valve)	15/16-24	55-65	75-88
Injector Nut (needle valve)	15/16-24	75-85	102-115

*75-85 lb-ft (102-115 Nm) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft brackets.

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR	
Auxiliary injector tester ("N" injectors)	J 22640
Fuel pipe socket	J8932-01
Fuel system primer	J5956
Injector body reamer	J21089
Injector body thread reconditioning set	J 22690
Injector calibrator	J 22410
Injector nut seal ring installer	J 29197
Injector service set (includes *tools)	J1241-07
Injector service set ("N" injectors - includes §tools)	J 23435-02
*Deburring tool	J7174
§*Fuel hole brush	J8152
§ *Injector, nut and seat carbon remover set	J 9418
§*Injector nut socket wrench	J 4983-01
§*Injector spray tip driver	J 1291-02
*Injector tip cleaner	J 1243
§ 'Pin vise	J4298-1
§*Rack hole brush	J 8150
§*Spray tip carbon remover	J 24838
*Spray tip seat remover	J 4986-01
*Spray tip wire (.005")	J 21459-01
§*Spray tip wire (.0055")	J 21460-01
§*Spray tip wire (.006")	J 21461-01
§*Wire sharpening stone	J 8170
*Injector test oil	J 26400
Injector tester	J9787
Injector tester	J 23010
Injector tester modification package (J 23010 only)	J 23010-194
Injector tip concentricity gage	J 5119
Injector vise and rack freeness tester	J22396
Injector vise jaws (offset body)	J 8912
Injector vise jaws (standard body)	J1261
Lapping Block set	J 22090
Polishing compound ("N" injectors)	J 23038
Polishing stick set ("N" injectors)	J 22964
Spray tip flow gage	J 25600
Spray tip gage ("N" injectors)	J 9462-02
Spring tester	J22738-02
Wire brush (brass)	J 7944
INJECTOR TUBE	
Cylinder head holding plates	J 3087-01
Injector tube service tool set	J 22525
Injector tube service tool set (for power equipment)	J 22515
Injector tube swaging tool	J 28611

*Available in 5, 15, 30 and 55 gallons.

TOOL NAME	TOOL NO.
FUEL PUMP	
Fuel pump tool set	J1508-03
Fuel pump wrench	J4242
Fuel system primer	J5956
MECHANICAL GOVERNOR	
Adjustable spanner wrench	J 5345-5
Control ink operating lever bearing remover/installer	J 8985
Governor cover bearing installer	J 21068
Governor cover bearing remover/installer	J 21967-01
Master thread repair kit	J 26520

SECTION 3

AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

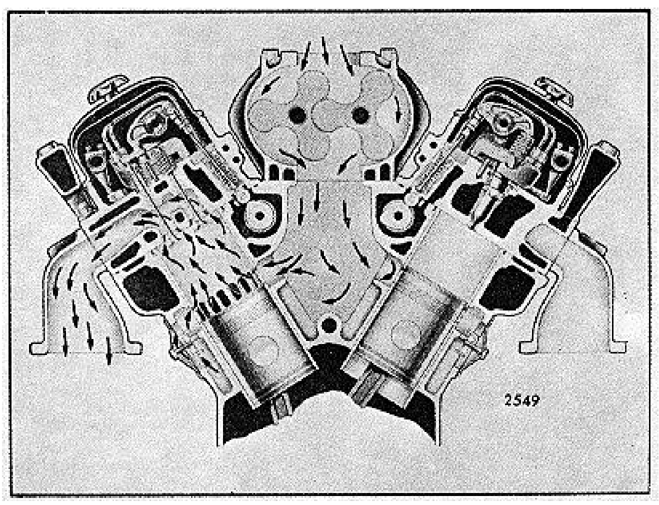


FIG. 1 - Air Flow Through Blower and Engine

In the scavenging process employed in the V-7 1 engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, therefore, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Fig. 1. The continuous discharge of fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners.

The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

AIR CLEANER

Oil Bath Type

The oil bath type air cleaners used on the V-71 engines are designed to remove foreign matter from the air, pass the required volume of air for proper combustion and scavenging, and maintain their efficiency for a reasonable period of time before requiring service.

The importance of keeping dust and grit-laden air out of an engine cannot be over-emphasized since clean air is so essential to satisfactory engine operation and long engine life. The air cleaner must be able to remove fine materials such as dust and blown sand as well as coarse materials such as chaff, sawdust or lint from the air. It must also have a reservoir capacity large enough to retain the material separated from the air to permit operation for a reasonable period before cleaning and servicing are required.

Dust and dirt entering an engine will cause rapid wear of piston rings, cylinder liners, pistons and the exhaust valve mechanism with a resultant loss of power and high lubricating oil consumption. Also, dust and dirt which is allowed to build-up in the air cleaner passages will eventually restrict the air supply to the engine and result in heavy carbon deposits on pistons and valves due to incomplete combustion.

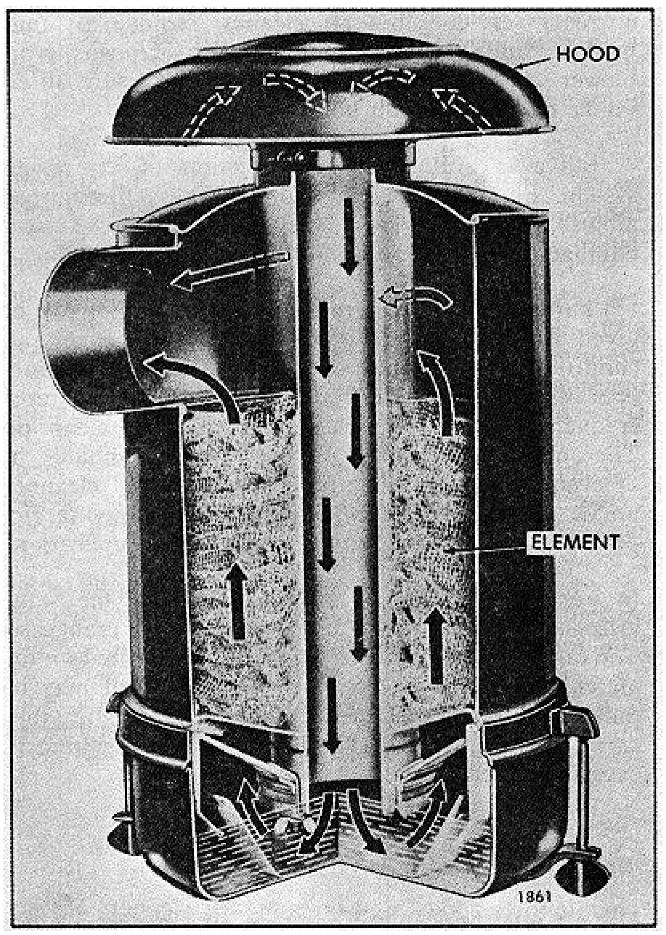


FIG. 1 - Typical Oil Bath Air Cleaner

Oil Bath Type Air Cleaner

In the oil bath air cleaners the air is drawn through the air inlet hood and down through the center tube (Fig. l). At the bottom of the tube, the direction of air flow is reversed and oil is picked up from the oil reservoir cup. The oil laden air is carried up into the separator screen where the oil which contains the dirt particles is separated from the air by collecting on the separator screen.

A low pressure area is created toward the center of the air cleaner as the air passes a cylindrical opening formed by the outer perimeter of the central tube and the inner diameter of the separator screen (Fig. 2). This low pressure is caused by the difference in air current velocity across the opening. The low pressure area, plus the effect of gravity and the inverted cone shape of the separator screen, causes the oil and dirt mixture to drain to the center of the cleaner cup. This oil is again picked up by the incoming air causing a looping cycle of the oil; however, as the oil is carried toward another cycle, some of the oil will overflow the edge of the cup carrying the dirt with it. The dirt will

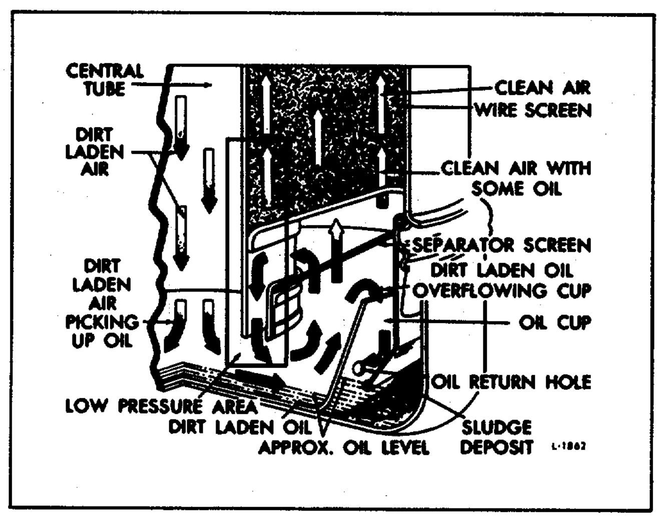


FIG. 2 - Air Flow Through Oil Bath Air Cleaner

be deposited in the outer area surrounding the cup. Oil will then flow back into the cup through a small hole located in the side of the cup. Above the separator screen, the cleaner is filled with a wire screen element which will remove any oil which passes through the separator screen. This oil will also drain to the center and back into the oil cup. The clean air then leaves the cleaner through a tube at the side and enters the blower through the air inlet housing.

An air inlet hood must be used with the air cleaner. The inlet hood normally requires cleaning more frequently than the main air cleaner. The air inlet hood serves only to prevent rain, rags, paper, leaves, etc., from entering the air cleaner. Air enters the hood through a heavy screen which forms the lower portion of the hood, and the air flow is reversed in the hood and pulled downward into the air cleaner. The hood is mounted on the air cleaner inlet tube and is held in place by a clamp. The openings in the hood should be kept clear to prevent excessive restriction to air flow.

Air Cleaner Mounting

Air cleaner mountings vary in accordance with the air cleaner installation and the engine units on which they are employed. The air cleaners are mounted on brackets attached to the flywheel housing and the cleaner outlet is connected to the air inlet housing by means of a hose and clamp.

Air Cleaner Maintenance

Although air cleaners are highly efficient, this efficiency depends upon proper maintenance and periodic servicing. If the cleaners are not properly maintained, the oil sump will become filled with sludge and the screens or elements will not remove dust properly. This will result in dust and dirty oil entering the engine and also increase the restriction to air flow through the cleaner.

Should dust in the air supply enter the engine, it would be carried directly into the cylinders and, due to its abrasive properties, cause premature wear of moving parts, which would materially shorten engine life. Should the air flow through the cleaner be restricted, it would eventually be impossible for the engine to burn all of the fuel injected into its cylinders and carbon formation would progress at a greatly increased rate.

The efficiency of the air cleaner may be offset by leaks in the duct work, loose hose connections or damaged gaskets which permit dust-laden air to completely bypass the cleaner and enter the engine directly.

The following maintenance procedure will assure efficient air cleaner operation:

1. Keep air cleaner tight on air intake to engine.

2. Keep air cleaner properly assembled so joints are strictly oil and air tight.

3. In case of damage to the air cleaner, intake or connections, repair at once.

4. In dusty areas, inspect the air cleaner frequently for dirt deposits in the oil bath or thickened oil.

Thoroughly clean the oil bath cleaner often enough to prevent oil from becoming excessively thick with sludge, and be sure to use the proper kind and quantity of oil. Keep the oil at the level mark in the cup. When replacing the cup, be sure it fits snugly to form a tight joint.

5. Where rubber hose from cleaner to blower is employed, remove hose connections and cement them in place. Use new hose and clamps,. if necessary, to obtain an air-tight connection.

6. After servicing the air cleaner, remove air inlet housing and clean accumulated dirt deposits from blower screen and air inlet housing. Make sure all air intake passages and air box are kept clean.

7. Make careful periodic inspection of entire air system. Enough dust-laden air will pass through an almost invisible crack to eventually cause serious damage to an engine.

No hard fast rule for servicing any air cleaner can be given since it depends upon the type of cleaner, air conditions and type of application. A cleaner operating in severe dust conditions will require more frequent service than a cleaner operating in clean air. The most satisfactory service period should be determined by frequently inspecting the cleaners, under normal operation, then setting the service period to best suit the requirements of the application.

In air cleaners having an oil bath, use the same viscosity oil as that being used in the engine crankcase. The oil level should not be above that indicated on the air cleaner sump. If too much oil is used, it may be pulled through the element and into the engine, thus carrying dirt into the cylinders and also resulting in excessive speed.

Air Cleaner Service

The air inlet hoods used on some air cleaners are not intended to do any cleaning. However, some dirt will collect on the heavy screens and in the hood itself.

Therefore, it will be necessary to remove the hood occasionally for cleaning.

The oil sump should be checked for dirt accumulation. Loosen the wing nuts and pull the side rod assemblies away from their forked retaining brackets to remove the oil cup(s). Empty the oil from the cup(s) and clean with fuel oil to remove all sediment.

A tray type screen is used on some air cleaners. A lip on the tray fits over the edge of the oil cup of the cleaner. One rubber seal ring fits over the lower edge of the cleaner body to form an air tight seal between the cleaner body and tray. Another seal ring fits around the tray and forms an air and oil seal between the tray and the oil cup.

The efficiency of the tray type oil bath air cleaner will be greatly reduced unless the fibrous material caught in the tray is removed. It is extremely important that the tray be cleaned regularly and properly.

If a tray is plugged with lint or dirt wash the tray in a solvent and blow out with compressed air (Fig. 3). An even pattern of light should be visible through the screens when a clean tray is held up to the light (Fig. 3). It may be necessary, as a last resort, to burn off the lint. Extreme care must be taken not to melt the galvanized coating in the tray screens. Some trays have equally spaced holes in the retaining baffle. Check to make sure that they are clean and open.

Check for dirt accumulation in the air cleaner center tube. Remove dirt by passing a lintless cloth through the center tube. Some tubes have a restricted portion at the lower end and care must be exercised not to damage this end.

At some regular period of engine service, remove the entire air cleaner from the engine and clean the fixed element. This can be done by passing a large quantity of clean solvent through the air outlet and down into the fixed element. When clean, allow the element to dry thoroughly before installing the cleaner on the engine. If the fixed elements require too frequent cleaning, it is advisable to relocate the air intake to provide a cleaner air supply.

When all of the components have been cleaned, the cleaner is ready for assembly. The removable screen or tray should be installed. Replace the rubber seal rings if necessary. The oil cup(s) should be filled with clean engine oil of the same viscosity and grade as used in the engine crankcase. Fill the cup(s) to the indicated oil level and install on the cleaner. Care should be exercised that all gaskets and joints are tight. All connections from the cleaner to the engine should be checked for air leaks to prevent any air bypassing the air cleaners.

If it is found that unfiltered air is being admitted into the engine through the duct work of an air cleaner installation, the following procedure may be used for finding air leaks in an air duct system. The air cleaning system does not have to be dismantled. Thus effecting a saving in time.

To make this check, it is necessary that suitable plugs be provided to block the air cleaner system inlet and outlet. The air cleaner inlet plug should contain a

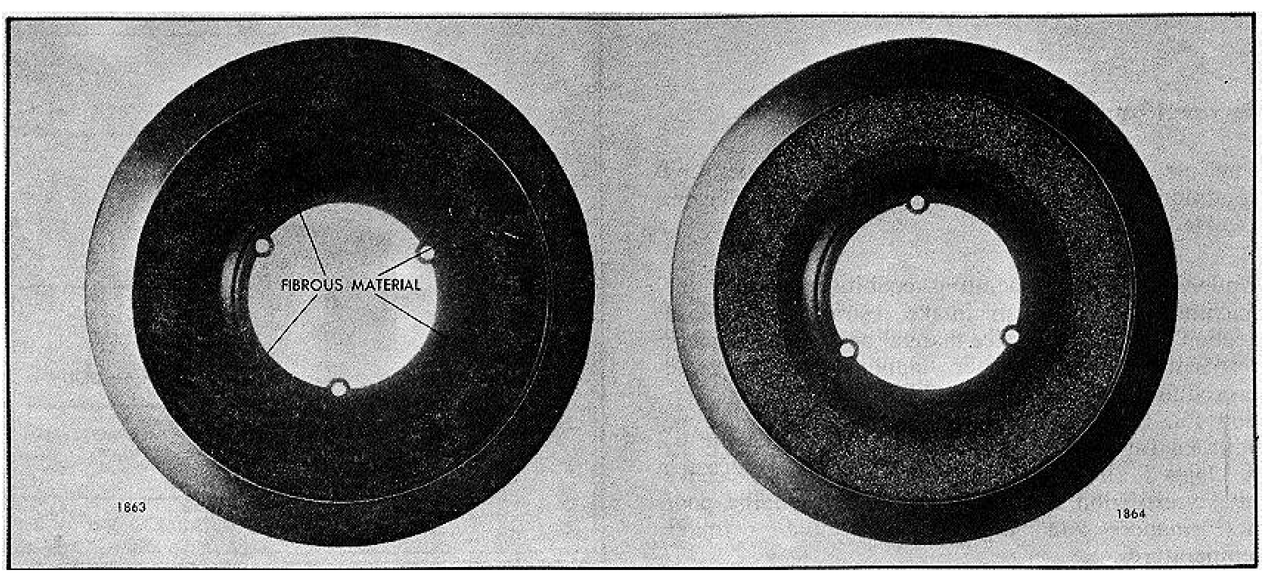


FIG. 3 - Comparison of Air Cleaner Trays

suitable air connection and shutoff valve to maintain two pounds pressure (14 kPa) in the air duct system. The outlet plug need only be of sufficient size to form a completely air-tight seal at the out]et end of the system. Then check the system as follows:

1. Remove the air inlet hood.

2. Insert the plug (with the fitting for the air hose) in the air cleaner inlet to form an air-tight seal.

3. Insert the other plug in the outlet end of the system to form an air-tight seal.

4. Attach an air hose to the plug in the air cleaner inlet and regulate pressure *not* to exceed 2 psi (14 kPa).

5. Brush a soap-suds solution on all air duct connections. Any opening which would allow dust to enter the engine can then be detected by the escaping air causing bubbles in the soap-suds solution. All leaks thus discovered should be remedied to ensure an air-tight system.

6. Remove the plugs and install the air inlet hood.

TWO-STAGE DRY TYPE AIR CLEANER

The Donaldson dry type air cleaners shown in Figs. 4 and 5 are designed to provide highly efficient air filtration under all operating conditions. The cleaners have a replaceable impregnated paper filter element that can be cleaned.

The fins on the element give high speed rotation to the intake air, which separates a large portion of the dust from the air by centrifugal action. The plastic fins, the element and the gasket make up a single replaceable element assembly.

The dust is swept through a space in the side of the baffle and collects in the lower portion of the body or dust cup. The dust remaining in the precleaned air is removed by the element.

The dry type cleaner *cannot be used* where the atmosphere contains oil vapors, or fumes from the breather can be picked up by the air cleaner.

Service (Dry Type)

The air cleaner should be serviced as operating conditions warrant. See Section 15.1 for element change intervals.

Under no engine operating conditions should the maximum allowable air intake restriction shown in Section 13.2 of the service manual be exceeded. Check restriction with a water manometer using the procedure outlined under "final run-in" in Section 13.2.1. In addition, inlet restriction should be adjusted for high altitude conditions (see TABLE 1). A clogged air cleaner element will cause excessive intake restriction, reduce air supply to the engine, poor performance and higher valve and cylinder temperatures.

Disassemble the cleaner as shown in Fig. 4 as follows:

1. Loosen the cover bolt and remove the cover and bolt as an assembly.

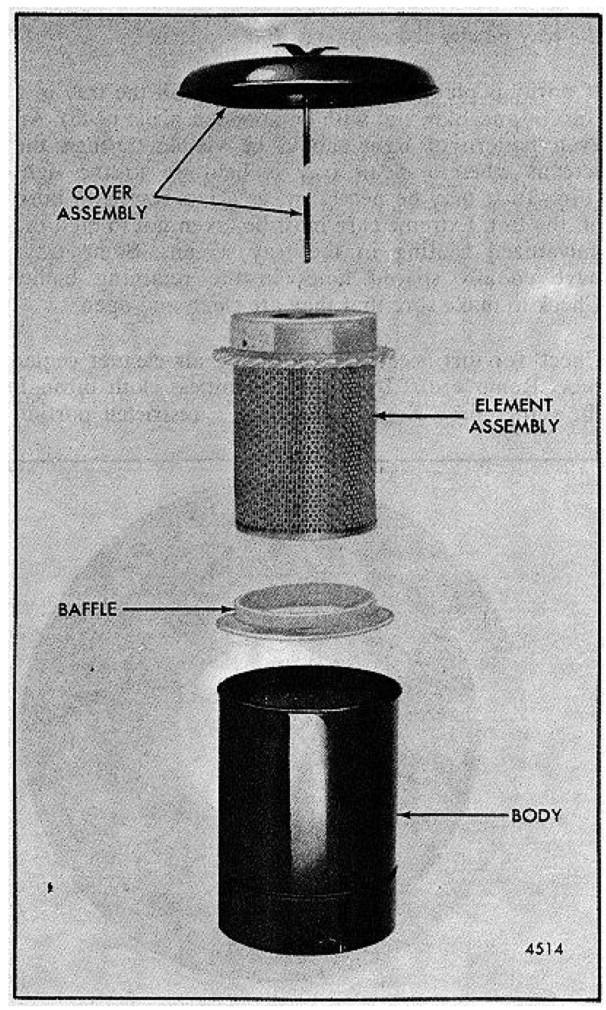


FIG. 4 - Dry Type Air Cleaner

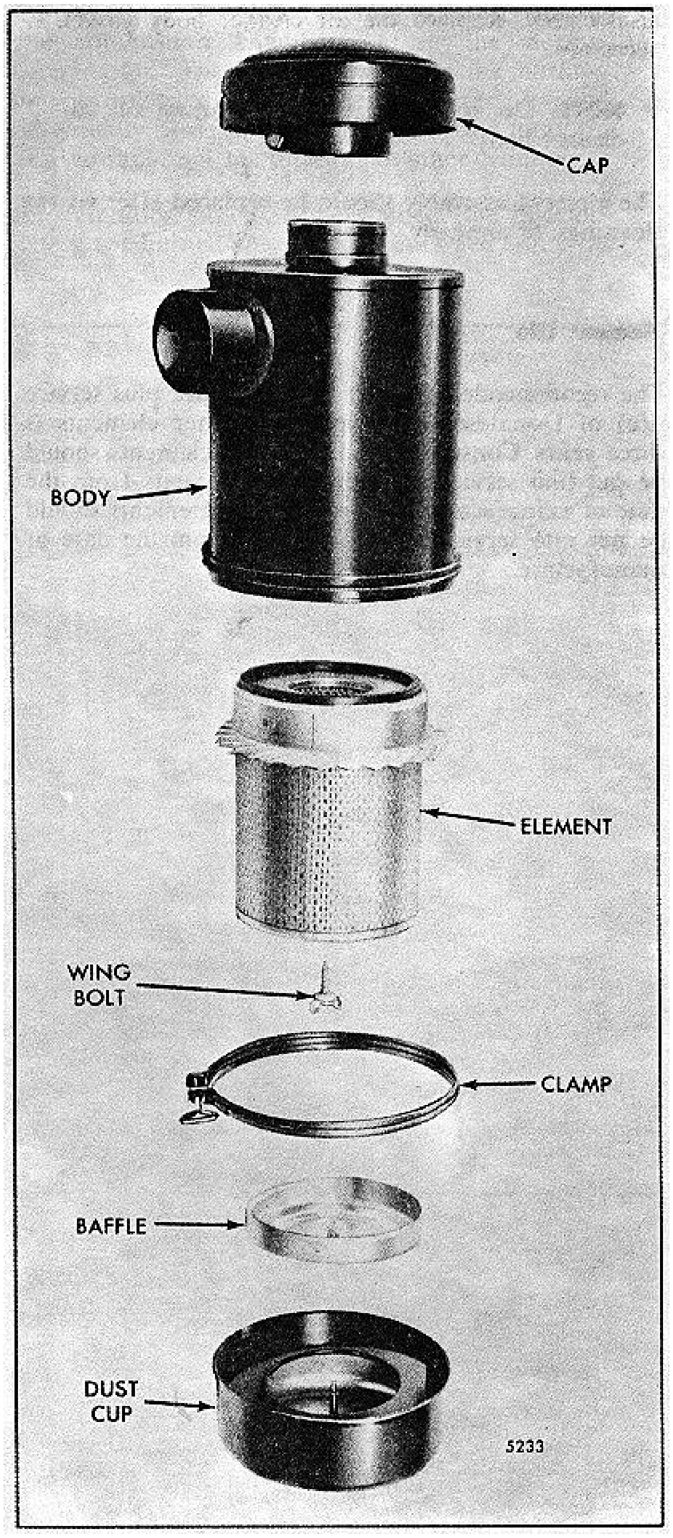


FIG. 5 - Dry Type Air Cleaner (Heavy Duty)

2. Remove (he element assembly and baffle from the cleaner body.

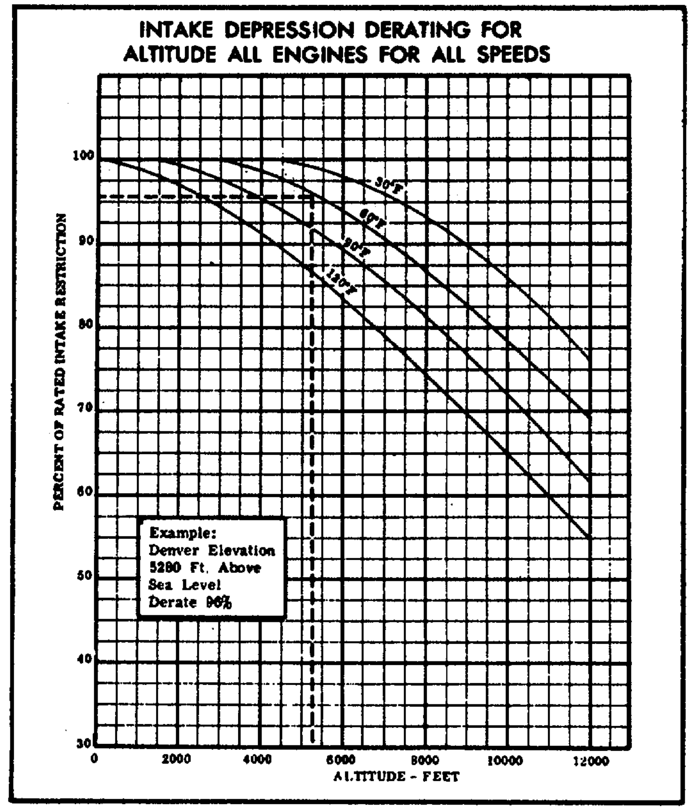


TABLE 1

3. Remove the dust and clean the cleaner body thoroughly.

Disassemble the cleaner in Fig. 5 as follows:

1. Loosen the dust cup clamp and remove the dust cup.

2. Loosen the wing bolt in the dust cup and remove the baffle from the dust cup.

3. Remove the wing bolt from the cleaner body and remove the element assembly.

4. Remove the dust and thoroughly clean the cleaner body, dust cup and baffle.

The paper pleated element assembly can be cleaned as follows:

NOTE: The pre-cleaning fins are not removable.

1. The element can be dry cleaned by directing clean air up and down the pleats on the clean air side of the element. Air pressure at the nozzle of the air hose must not exceed 100 psi (689 kPa). Maintain a reasonable distance between the nozzle and the element.

2. Donaldson advises that elements used in on highway applications should not be washed or reused. The reason for this is that on-highway trucks operate in an environment contaminated by a mixture of fine dust and exhaust carbon. To better enable dry type air cleaners to handle this type of contaminant, most on highway truck air cleaners contain special chemically treated elements. Washing can remove the chemical treatment and shorten element life. Consequently, on highway air cleaner elements should not be washed and reused.

3. Inspect the cleaned element with a light bulb after each cleaning. Thin spots, pin holes, or the slightest rupture will admit sufficient air borne dirt to render the element unfit for further use and cause rapid failure of the piston rings. Replace the 'element assembly if necessary.

4. Inspect the gasket on the end of the element. If the gasket is damaged or missing, replace the element.

Reassemble the air cleaner in reverse order of disassembly. Replace the air cleaner body gasket, if necessary.

NOTE: Do not use oil in the bottom of the cleaner body.

The element assembly should be replaced after six (6) cleanings, or annually.

Element Life

The recommended product life (shelf life plus service life) of Donaldson dry type air cleaner elements is three years. Consequently, Donaldson elements should be put into service no later than two years from the date of manufacture. Farr air cleaner elements should be put into service within one year from the date of manufacture.

AIR SHUTDOWN HOUSING

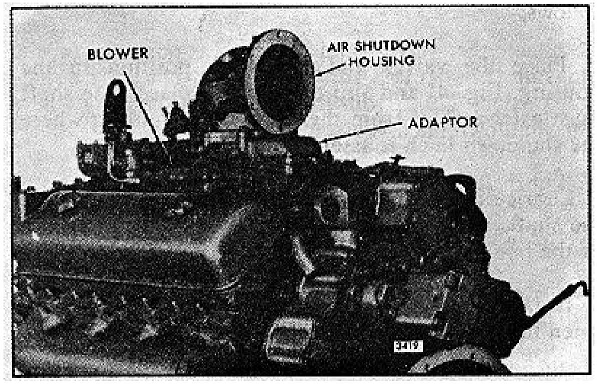


FIG. 1 Typical Air Shutdown Housing Mounting

The air shutdown housing is mounted on the blower as illustrated in Fig. 1 and 2. A valve mounted inside of the housing may be closed to shut off the air supply and stop the engine when abnormal operating conditions require an emergency shut down.

With the 12V-71 turbocharged intercooled engines, the air shutdown housings are mounted on the intercoolers, which are mounted on the blowers. Long mounting studs with nuts are used to secure the air shutdown housings and intercoolers (Section 3.5.2) to the blowers.

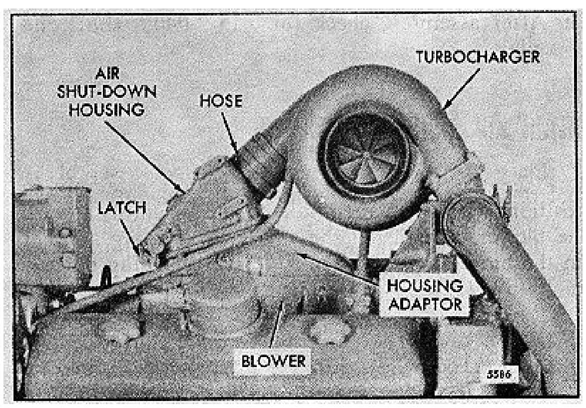


FIG. 2 Typical Air shutdown Housing Mounting (Turbocharged Engine)

Remove Air Shutdown Housing

1. Disconnect and remove the air ducts between the air cleaner and the air shutdown housing.

2. Disconnect the control wire from the air shut-off cam pin handle.

3. Remove the six bolts and lock washers which attach the housing to the adaptor. Then remove the housing and gasket.

4. Remove the bolts and washer which attach the housing adaptor to the blower. Then remove the adaptor and the blower screen.

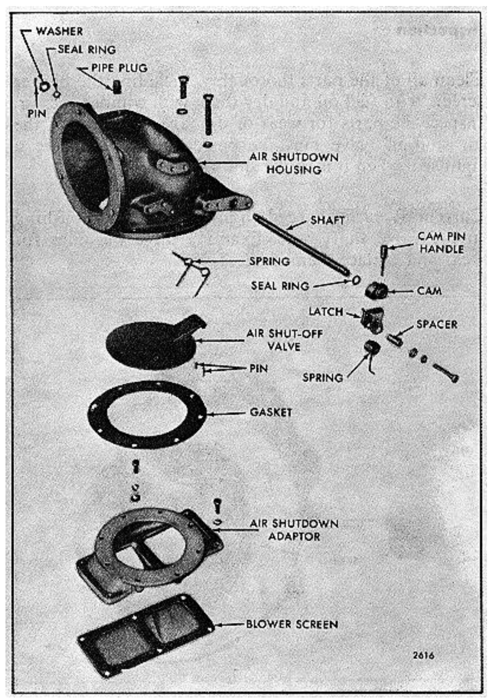


FIG. 3 - Air Shutdown Housing Details and Relative Location of Parts

Disassemble Air Shutdown Housing

1. Remove the pin from the end of the air shut-off valve shaft. Then remove the washer or spacer from the shaft and the seal ring from the housing.

2. Remove the two pins that secure the air shut-off valve to the shaft.

3. Remove the bolt, lock washer and plain washer which attach the latch to the housing. Then remove the latch, latch spring and spacer.

4. Note the position of the air shut-off valve spring and valve (Fig. 4), then withdraw the shaft from the housing to release the valve and spring. Remove the valve and spring and the seal ring from the housing.

5. Remove the cam pin handle and withdraw the cam from the shaft.

Inspection

Clean all of the parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air. Inspect the parts for wear or damage. The face of the air shut-off valve must be perfectly flat to assure a tight seal when it is in the shut-off position.

Current 8V turbocharged engines use a nylon bushing in the valve shaft bore. Examine these bushings for wear and replace them if necessary.

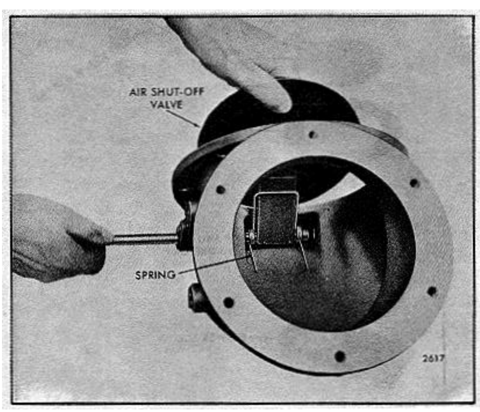


FIG. 4 Installing Air Shut-Off Valve Spring and Valve

Assemble Air Shutdown Assembly

The holes for the cam pin handle and the retaining pins must be drilled, using a 1/8 " diameter drill, at the time a new service shaft or shut-off valves are assembled. The valves must be in the same plane within .030 " when in the stop position (flush with the housing face). Refer to Figs. 3 and 4 and proceed as follows:

1. Place the valves and spring in position in the housing (Fig. 4) and slip the shaft in place. The shaft must extend .70 " from the side of the housing where the shutdown latch is assembled.

2. Lubricate and install a new seal ring at each end of the shaft. Be sure the seal is seated in the counterbore of the housing.

3. Install the cam and cam pin handle on the shaft. Then install the pin which retains the cam to the shaft.

4. Install a washer or spacer and retaining pin at the other end of the shaft.

5. Assemble the spacer, spring and latch to the shutdown housing with the 1/4 "-20 bolt, lock washer and plain washer.

   a. Align the notch on the-cam with the notch on the latch and lock the cam in this position.

   b. Install the pins in the valves to retain them to the shaft with the cam release latch set and the valves in the run position.

   c. Level the valves in the shut-off position.

   d. Adjust the cam so the valves contact the housing when the cam release latch is set.

   e. After assembly, check for .015 "-040 " shaft end play.

Install Air Shutdown Housing

1. Place the blower screen and gasket assembly in position, with the screen side of the assembly toward the blower, and install the shutdown housing adaptor on the blower. Tighten the 3/8 ″-16 attaching bolts to 16-20' Ib-ft (22-27 Nm) torque.

IMPORTANT: The current blower screen gasket consists of wire mesh secured between two sheets of gasket material. The former screen was imbedded in one sheet of gasket material and was installed with the screen side toward the blower.

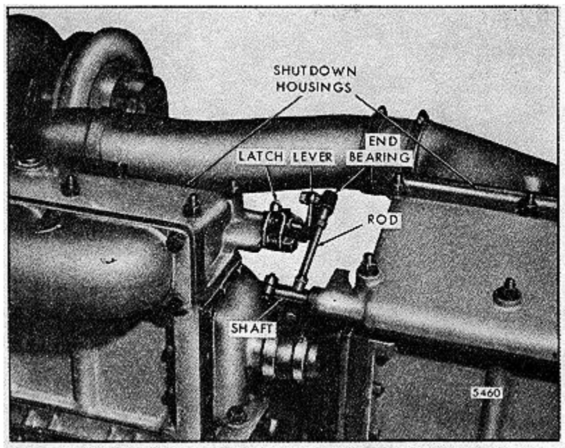


FIG. 5 Dual Air Shutdown Housing Mounting

When a striker plate and gasket are used, install them between the blower screen and gasket assembly and the air shutdown housing.

2. Place a new gasket on the adaptor. Mount the air shutdown housing on the adaptor and secure it with 3/8 "-16 bolts and lock washers. Tighten the bolts to 16-20 Ib-ft (22-27 Nm) torque.

3. Install the air ducts from the air cleaner to the air shutdown housing. Use a new gasket at the housing. Be sure all connections are air tight.

4. When dual air shutdown housings (Fig. 5) have been installed, position the crossover shaft and manual shutdown [ever between the housings.

> **NOTE:** Before securing the couplings, close the valves in both of the shutdown housings and center the couplings on both housing shafts with the aid of new cotter pins. Tighten the bolts in the coupling to 21-26 Ib-ft (28-35 Nm) torque.

5. Reset the air shut-off valves to the run position.

6. Start and run the engine at idle speed and no load. Trip the air shutdown. If the engine does not stop, check it for air leakage between valves and. the strike plates. If necessary, reposition the valves.

7. After this test has been satisfactorily performed, pin the couplings to the shafts with two roll pins for each coupling.

BLOWER (Small Bearing)

The small bearing (2.047 " O.D.) blower used on 6, 8 and 12V naturally aspirated engines has either a 2.05:1 or a 2:1 ratio blower-to-engine speed. The turbo- charged engines employ a 1.95:1 ratio blower. For the large bearing blower refer to Section 3.4.1.

The blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in a housing bolted to the top deck of the cylinder block, between the two banks of cylinders. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form (Fig. 1).

Two timing gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance; therefore, as the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip type oil seals are installed in the blower end plates of naturally aspirated engine blowers. Metal ring-type oil seals are incorporated in the blower used on turbocharged engines (inset in Fig. 1). Each ring-type oil seal consists of a carrier pressed on the rotor shaft, a collar pressed into the end plate and a seal ring contained in a groove of the carrier. The outside diameter of the seal ring rides against the collar to prevent leakage of air or oil.

Each rotor is supported in the doweled end plates of the blower housing by a roller bearing at the front end and a double-row pre-loaded radial and thrust ball bearing at the gear end.

The right-hand helix rotor of the blower is driven at approximately twice engine speed by the blower drive shaft (Table 1). The blower drive shaft is splined at one end to a flexible drive hub attached to the blower drive gear and at the other end to a flexible coupling

Blower	Ratio Blower to Engine Speed	No. Teeth in Blower Drive Gear
6, 8 and 12V	2.05:1	38
6, 8 and 12V Turbocharged	1.95:1	40

TABLE 1

attached to the right-hand helix blower timing gear. The mating left-hand helix timing gear drives the left- hand helix rotor.

The flexible coupling, formed by an elliptical cam driven by two bundles of leaf springs which ride on four semi-cylindrical supports, is attached to the blower right-hand helix timing gear and prevents the transfer of torque fluctuations to the blower.

The basic blower parts for the 6 and 8 cylinder engines are identical and interchangeable with the exception of the housing and rotors which differ in length. Two 6V blowers, coupled together by a sprocket and chain drive, are mounted in tandem on the top deck of the 12-cylinder engines.

The blower rotors are timed by the two rotor gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance between the rotor lobes will not be maintained. A change in rotor timing is obtained by the use of shims between the gears and the bearings.

Normal gear wear causes a decrease of rotor-to-rotor clearance between the leading edge of the right-hand helix (drive) rotor and the trailing edge of the left- hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be corrected by adjustment, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds .004”, replace the gears.

Lubrication

The blower bearings, timing gears, governor drive and fuel pump drive are pressure lubricated by oil passages in the top deck of the cylinder block which lead from the main oil galleries to an oil passage in each blower end plate (Fig. 2).

A cup shaped oil strainer has been incorporated in the vertical oil passage at the bottom of each blower end plate to remove any foreign material in the lubricating oil (Fig. 2).

The oil flows upward in the end plate and leaves through a small orifice just above the centerline of the end plate. The oil is ejected from this orifice against the timing gears at the rear and the governor weights at the front of the blower and is then carried by splash to the bearings. Oil which collects at the bottom of

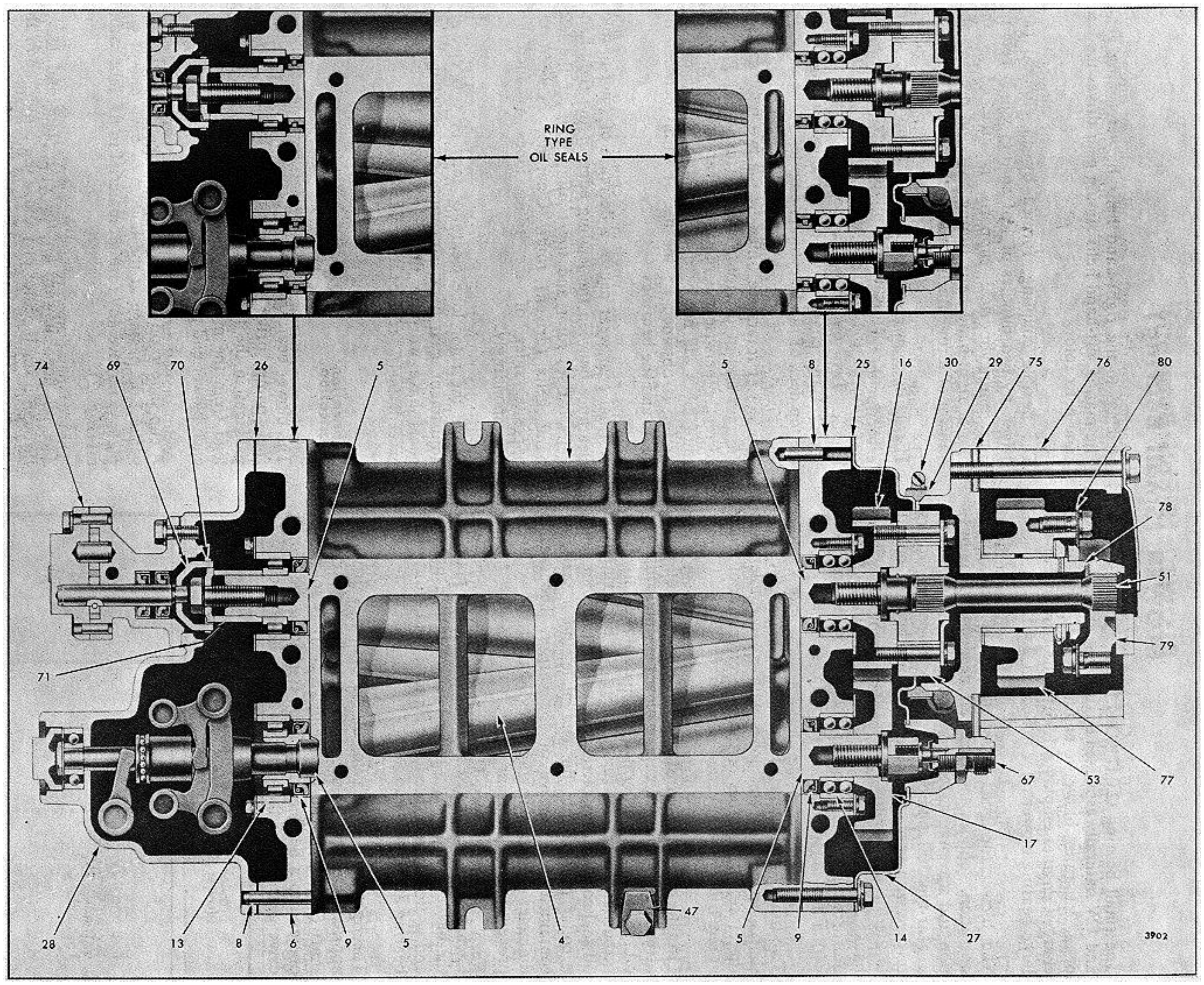


FIG. 1 Blower (Small Bearing) and Drive Assembly and Accessories Attached to Blower

2. Housing--Blower	25. Gasket--Rear End Plate Cover	51. Shaft--Blower Drive	75. Plate--Cylinder Block Rear End
4. Rotor Assy. --Blower	26. Gasket--Front End Plate Cover	53. Coupling Assy-Blower Drive	76. Housing--Flywheel
5. Shaft.-Rotor	27 Cover--Rear End Plate	67. Fitting--Tachometer Drive Adaptor	77. Gear--Blower Drive
6. Plate--Blower End	28. Housing--Governor (Front End Plate Cover)	69. Fork--Fuel Pump Drive	78. Support--Blower Drive
8. Pin-- Dowel	. 29. Seal--Rear End Plate Cover	70. Disc--Fuel Pump Drive	79. Coupling--Blower Drive Flexible
9. Seal--Oil	30. Clamp--Rear End Plate Cover Seal	71. Spacer- Fuel Pump Drive	80. Plate.-Blower Drive Flexible Coupling
13. Bearing--Front (Roller)	47. Lug Mounting Bolt	74. Pump Assy.--Fuel	81. Collar--Blower End Plate
14. Bearing--Rear (Ball)			82. Carrier--Seal Ring
16. Gear--Rotor Drive			83. Ring Seal (Piston Type)
17. Gear--Rotor Driven			

FIG. 1 Blower (Small Bearings) and Drive Assembly and Accessories Attached to Blower

each end plate overflows into two drain passages which lead back to the crankcase via oil passages in the cylinder block.

The orifice size in both the front and rear current end plate is .078 ". Prior to this change the orifice size was .042 ". When overhauling a small bearing blower or installing a new basic blower built prior to May, 1976 it is recommended that the orifice in both end plates be enlarged to the .078 " dimension (5/64 " drill).

NOTE: The blower end plate for the till coach engine continue to have the .042 " orifice. The tilt of the coach engine retains oil and with the larger orifice the additional oil could cause flooding of the left bank cylinder head.

To further increase lubricating oil flow to the bearings, struts were added to the front and rear end plates (including tilt coach engines) to provide a dam in the area above the bearings (Fig. 2). This was effective with 6VA98085, 8VA361352 and 12VA53309 engines. Also the current bearing retainers have a larger diameter to help form the dam and include scallops which allow oil to flow unrestricted out of the orifice in the end plate.

The blower drive support bearings receive oil under pressure from a tube which connects the oil passage in the rear end plate to passages in the blower drive support. Excess oil drains back to the crankcase by way of the gear train.

Inspection

The blower may be inspected for any of the following conditions without being removed from the engine. However, the air inlet housing, air shutdown housing and adaptor must first be removed.

CAUTION: When inspecting a blower on an engine with the engine running, keep fingers and clothing away from moving parts of the blower and run the engine at low speeds only.

1. Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and "dress" the parts to eliminate interference. or replace the rotors if they are badly scored.

2. Leaky oil seals are usually manifest by the presence of oil on the blower rotors or inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals toward the inlet of the blower is indicative of leaking seals.

3. A worn blower drive, resulting in a rattling noise inside the blower, may be detected by grasping the right-hand helix rotor firmly and attempting to rotate it. The rotors may move from 3/8" to 5/8 ", measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4 ". If the rotors cannot be moved as directed above, or if the rotors move too freely, the flexible blower drive coupling should be inspected and replaced if necessary. The drive coupling is attached to the right- hand helix blower timing gear.

4. Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates or between the rotors and the housing. Generally, a combination of these conditions exists. Worn or damaged bearings will cause rubbing between mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing or the end plates. This condition will usually show up at the end where the bearings have failed.

5. Excessive backlash between the blower timing gears

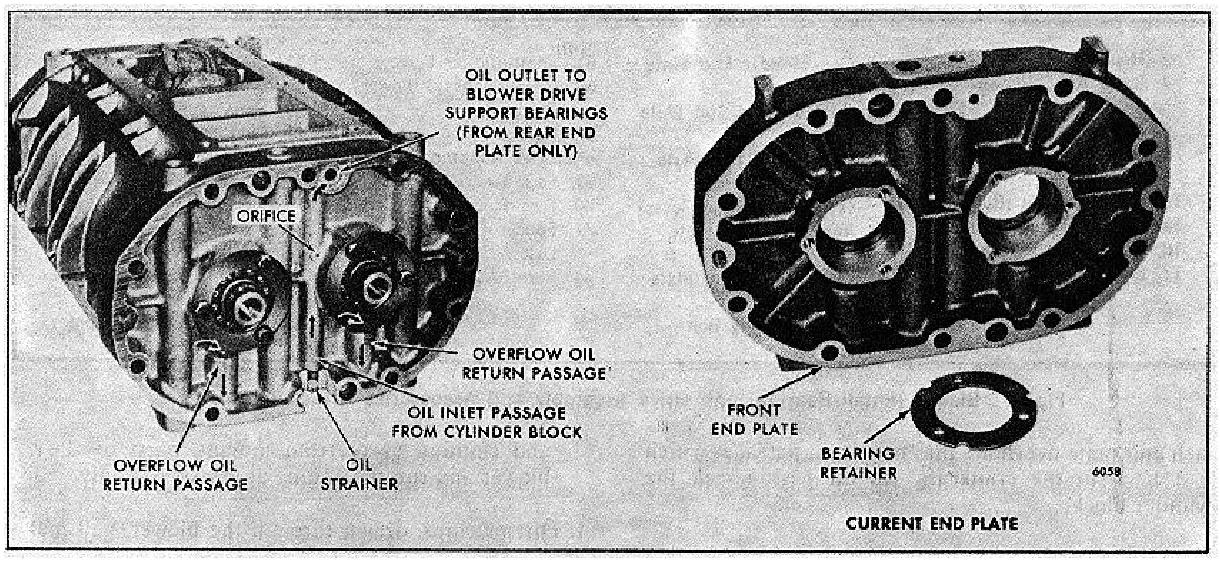


FIG. 2 Blower Lubrication

usually results in the rotor lobes rubbing throughout their entire length. This usually is on the trailing (close clearance) side.

6. Inspect the blower inlet screen periodically, as noted in Section 15.1, for an accumulation of dirt which, after prolonged operation, may affect the air flow. Servicing of the screen consists of thoroughly washing it in fuel oil and cleaning with a stiff brush until the screen is free of all dirt deposits. If broken wires are found in the blower screen, replace the screen.

7. Check the lubricating oil connection between the blower and the blower drive support for excessive oil leakage. If oil leakage exists, retighten or replace the fittings. When oil leakage occurs on engines built prior to engine serial numbers 6VA-55818. 8VA-108713 and 12VA-20733, it is suggested the current dry seal connector be installed in the blower instead of the former "O" ring seal, spacer and retaining plate. The current 6V and 12V engines use an adaptor with the dry seal connector. The current 8V engines continue to use the same blower drive support tube and fittings with the dry seal connector.

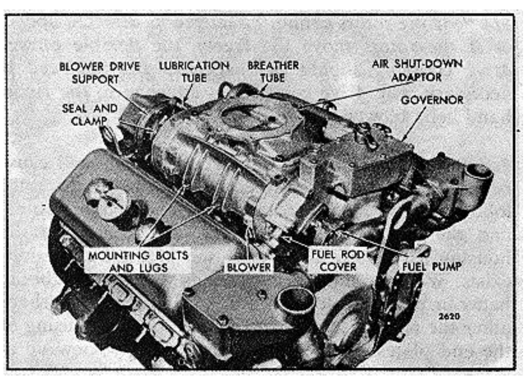


FIG. 3 Typical Blower Mounting (Single Blower)

A former blower rear end plate can be reworked to incorporate the dry seal connector. Refer to Section 3.0.

To correct any of the conditions cited in Items 1 through 6, the blower must be removed from the engine and either repaired *or* replaced.

Remove Blower from Engine

The engine governor components are assembled in a combination governor housing and blower front end plate cover. The fuel pump is also attached to the front end of the blower. Therefore, when removing the blower assembly from the engine, the governor and fuel pump will also be removed at the same time. Refer to Figs. 3, 4 and 5 and proceed as follows:

1. Loosen the hose clamps and slide the air inlet housing hoses back to disconnect the housing from the air cleaners.

On engines equipped with turbochargers, disconnect and remove the air inlet and outlet tubes from the turbochargers.

2. Remove the six bolts, lock washers and plain washers securing the air inlet housing to the air shutdown housing. Remove the air inlet housing and gasket.

3. Disconnect the cable assembly from the air shut-off cam pin handle.

4. Remove the six bolts, lock washers and plain washers securing the air shutdown housing to the air inlet adaptor. Remove the shutdown housing and gasket.

5. Remove the bolts and washers securing the air inlet adaptor to the blower. Remove the adaptor and the blower screen.

6. Loosen the oil pressure line fitting from the rear of the blower to blower drive support and slide the fitting back on the tube.

7. Loosen the hose clamp on the blower drive support-to-blower seal. On 12V engines, loosen the clamp securing the seal between the front and rear blowers.

8. Disconnect the tachometer drive cable. if used, from the adaptor at the rear of the blower.

9. Remove the flywheel housing cover at the blower drive support.

10. Remove the snap ring and withdraw the blower drive shaft from the blower.

11. Open the drain cocks and drain the engine cooling system

12. Loosen the hose clamps and slide the hoses back on the by-pass tube between the thermostat housings. Remove the by-pass tube.

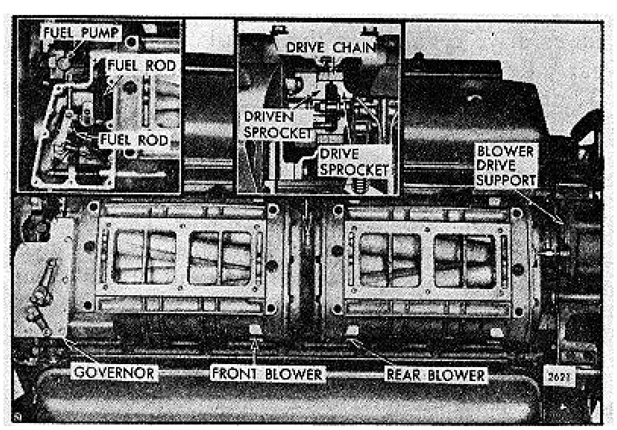


FIG. 4 - Typical Blower Mounting (Tandem Blower 12V Engine)

13. Remove the fuel inlet and outlet lines to the fuel pump. Also remove the fuel return crossover tube between the cylinder heads.

14. Remove or disconnect the breather pipe at the top of the cylinder block.

15. Remove the front engine lifter bracket if necessary.

16. Disconnect the throttle control rods from the governor.

17. Clean and remove the rocker cover from each cylinder head.

18. Remove the eight governor cover screws and lock washers and remove the governor cover.

19. Disconnect the fuel rods from both injector control tube levers and the governor and remove the fuel rods.

20. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.

21. Remove the bolt and washer through the top of each end plate which secures the blower to the cylinder block.

22. Remove the blower-to-block bolts and retaining washers on each side of the blower.

23. Disconnect and remove any tubing or accessories which may interfere with removal of the blower.

24. Thread eyebolts in the diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts as shown in Fig. 6.

25. Lift the blower up slightly and move it forward to detach the blower from the seal at the drive end. Then lift the blower up and away from the engine. Remove the blower gasket.

On 12V engines. the front blower must be removed first. Move the front blower forward slightly to disengage the drive chain from the sprockets. Then lift the blower away from the engine. Move the rear blower forward to detach the seal at the rear of the blower. then lift the rear blower away from the engine. Remove the blower gaskets.

With the blower. fuel pump and governor assembly removed from the engine. cover the air inlet -inlet outlet openings of the blower housing and install the governor cover. Wash the exterior of' the blower and governor housing with clean fuel oil and dry them with compressed air.

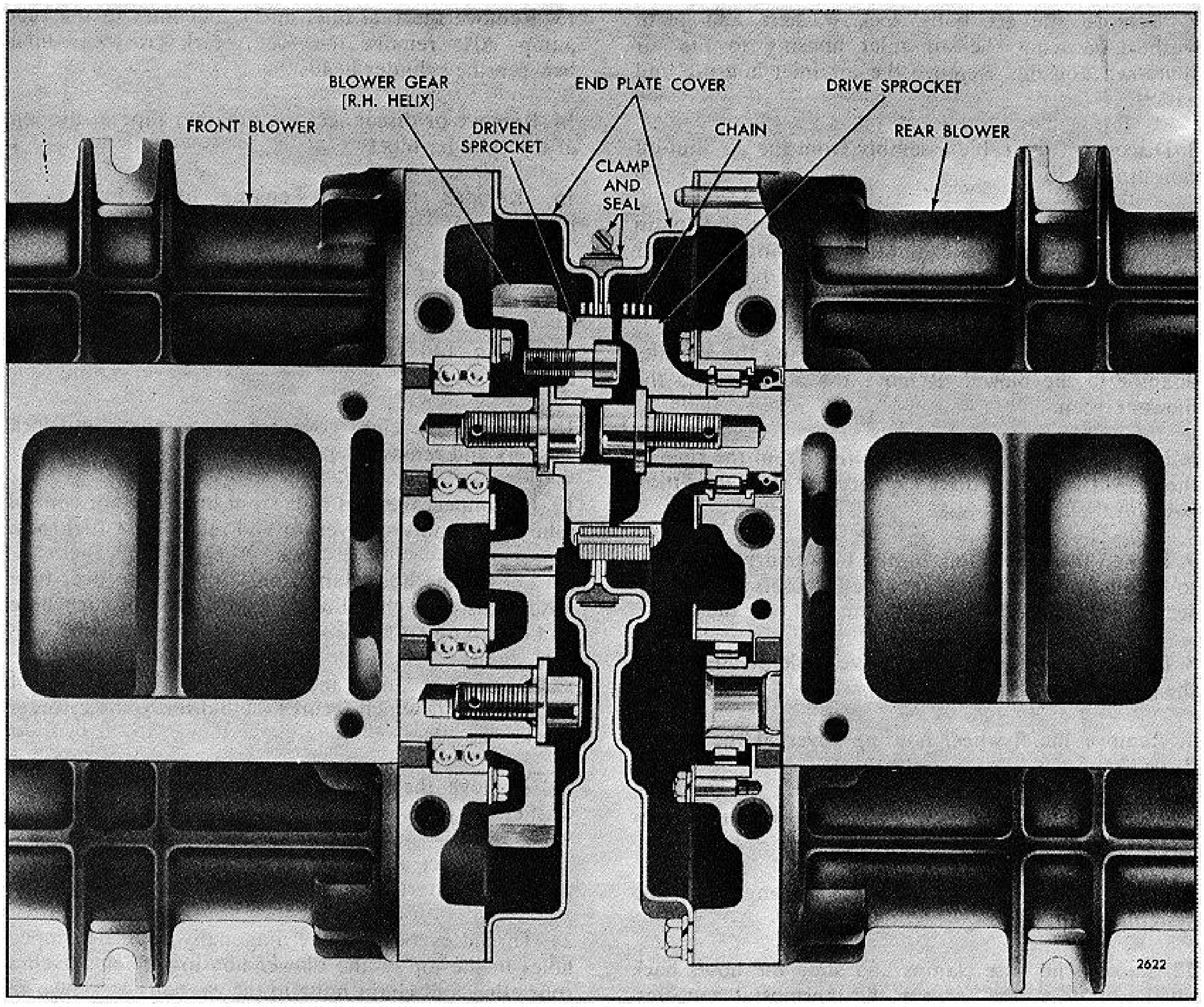


FIG. 5 Method of Coupling Tandem Blower Together (12V Engine)

Remove Blower Rear End Plate Cover

Remove the blower rear end plate cover, blower drive coupling, governor and fuel pump assembly from the blower as follows:

1. Remove the two bolts and lock washers securing the lubricating oil tube seal ring retaining plate to the blower rear end plate cover. Then remove the plate. Oil tube, seal ring washer and seal ring from the blower end plate and cover.

2. Remove the remaining bolts, lock washers and special washers securing the end plate cover to the end plate. Remove the cover and gasket from the end plate.

3. Remove the six bolts and lock washers securing the blower drive coupling to the right-hand blower rotor gear. Remove the retainer and drive coupling assembly from the gear.

4. Note the location of the two copper washers. One plain washer and eight lock washers on the governor-to-blower bolts before removing them. Then remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.

5. Tap the sides of the governor housing slightly with a plastic hammer to loosen the governor from the blower. Then pull the governor and fuel pump assembly from the dowels in the blower end plate. Remove the fuel pump drive coupling fork and the governor housing gasket.

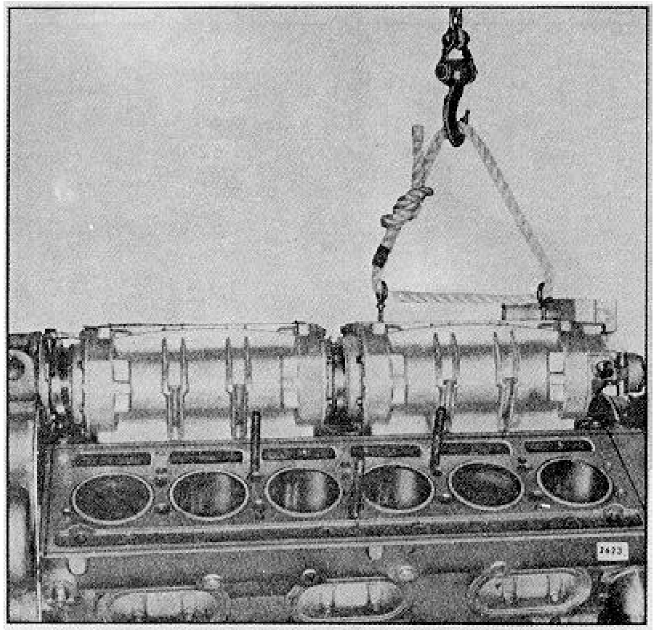


FIG. 6 - Removing Blower from Engine (12V Engine)

6. On a 12V engine, remove the drive chain, rear end plate cover and gasket of the front blower. Then remove the three bolts securing the driven sprocket to the timing gear. Remove the sprocket. Remove the front end plate cover and gasket on the rear blower. Then remove the Allen head bolt and washer and remove the drive sprocket.

Disassemble Blower

With the blower rear end plate cover, blower drive coupling and governor assembly removed from the blower, refer to Figs. 1and 13 and disassemble the blower as follows:

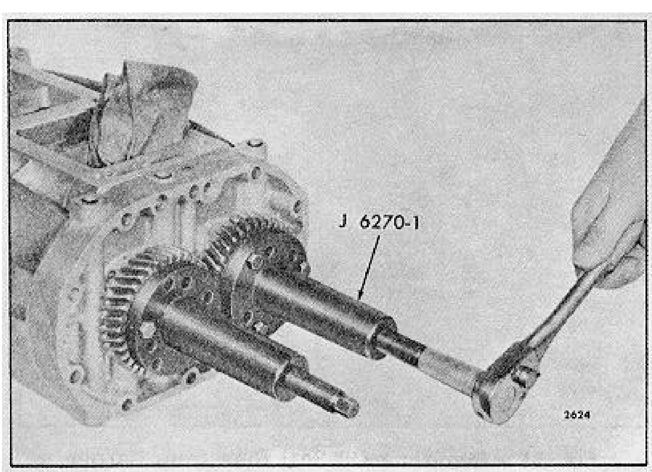


FIG. 7 - Removing Blower Gears

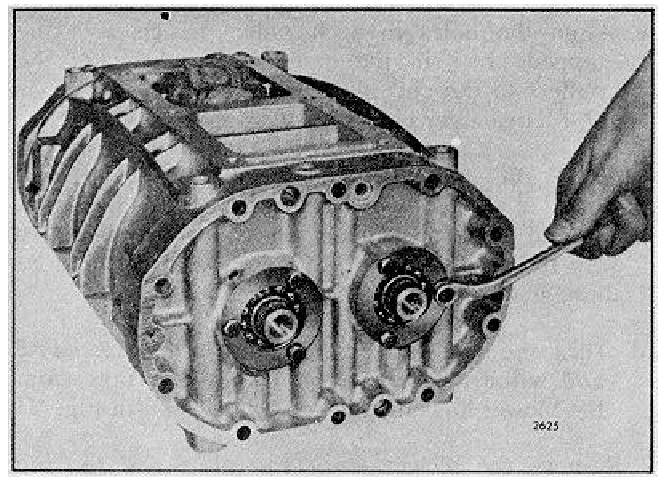


FIG. 8 - Removing Blower Bearing Retainers

1. Place a clean folded cloth between the rotors. Then remove the Allen head bolts and spacers securing the timing gears to the blower rotor shafts.

2. Remove the timing gears with pullers J 6270-1 (Fig. 7). Both gears must be pulled at the same time as follows:

   a. Back out the center screws of both pullers and place the flanges against the gear faces. Aligning the flange holes with the tapped holes in the gears. Secure the pullers to the gears with 5/16"- 24 x 1-1/2" bolts (two bolts on the L.H. helix gear and three bolts on the R.H. helix gear).

   b. Turn the two puller screws uniformly clockwise and withdraw the gears from the rotor shafts as shown in Fig. 7.

3. Remove the shims from the rotor shafts, after the gears have been removed, and note the number and thickness of shims on each rotor shaft to ensure identical replacement when assembling the blower.

4. Remove the bolts and lock washers securing the rotor shaft bearing retainers to the front and rear end plates. Remove the retainers (Fig. 8).

5. Remove the blower rear end plate and bearing assembly from the blower housing and rotors with the two pullers J 6270-1 as follows:

   a. Remove the two fillister head screws securing the rear end plate to the blower housing and loosen the two fillister head screws securing the front end plate to the housing approximately three turns.

   b. Back out the center screws of the pullers far enough to permit the flange of each puller to lay flat on the face of the end plate.

c. Align the holes in each puller flange with the tapped holes in the end plate and secure the pullers to the end plate with six 1/4 "-20 x 1-1/4 " or longer bolts.

NOTE: Be sure that the 1/4 "-20 bolts are threaded all the way into the tapped holes in the end plate to provide maximum anchorage for the pullers and to eliminate possible damage to the end plate.

d. Turn the two puller screws uniformly clockwise and withdraw the end plate and bearings from the blower housing and rotors as shown in Fig. 9.

6. Remove the blower front end plate and bearing assembly in the same manner as described in Step 5 above.

7. Withdraw the blower rotors from the housing.

8. Remove the bearings and *lip type* oil seals from the blower end plates as follows:

a. Support the outer face of the end plate on wood blocks on the bed of an arbor press.

b. Place the long end of the oil seal remover and installer J 6270-3 down through the oil seal and

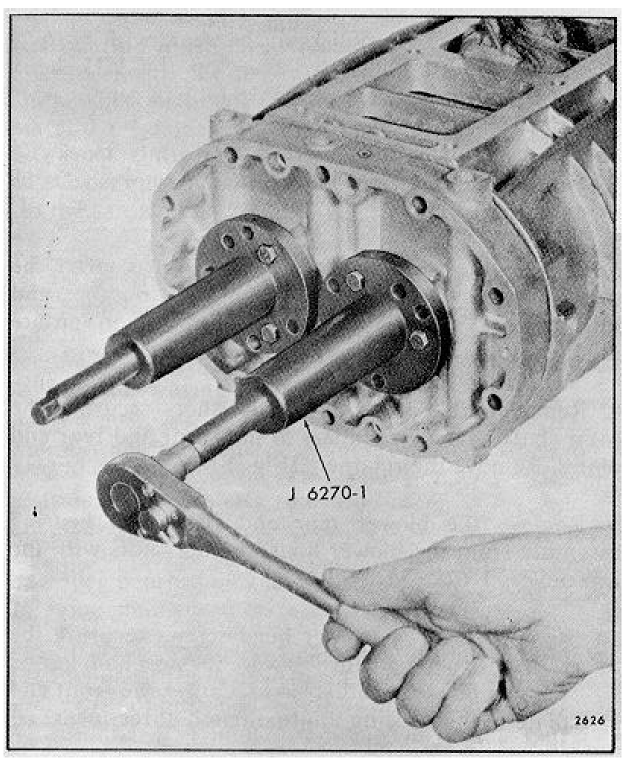


FIG. 9 - Removing Blower End Plate and Bearings from Housing and Rotors

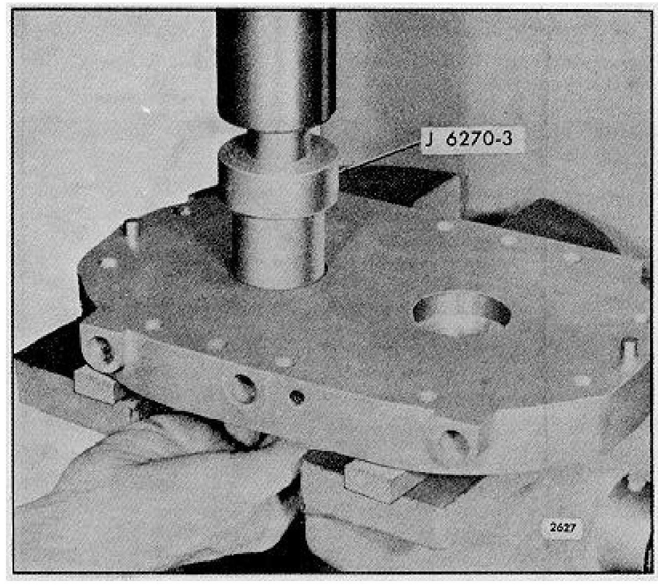


FIG. 10 - Removing Oil Seal (or Oil Seal Ring Collar) and Bearing from End Plate

into the bearing, with the opposite end of the remover under the ram of the press (Fig. 10). Then press the bearing and oil seal out of the end plate. Discard the oil seal.

c. Remove the remaining bearings and oil seals from the end plates in the same manner.

9. Remove the bearings and r*ing-type* oil seals, carriers and collars from the turbocharged engine blower rotor shafts and end plates as follows:

a. Clamp one lobe of the rotor in a bench vise

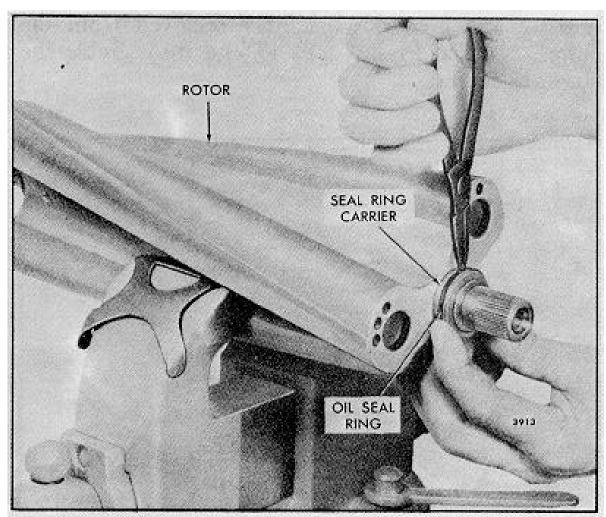


FIG. 11 - Removing Oil Seal Ring from Carrier (Turbocharged Engine Blowers)

equipped with soft jaws (Fig. 11). Tighten the vise just enough to hold the rotor stationary.

b. Remove the oil seal ring from the seal ring carrier on each blower rotor shaft with a pair of snap ring pliers as shown in Fig. 11.

NOTE: To avoid breakage or distortion, do not spread or twist the ring any more than necessary to remove it.

c. Refer to Fig. 12 and place the seal ring carrier remover adaptor J 6270-2 over the carrier. Make sure the adaptor is seated in the groove of the carrier.

d. Back out the center screw of puller J 6270-1 far enough to permit the puller flange to lay flat against the adaptor J 6270-2.

e. Place the puller over the end of the rotor shaft and against the adaptor on the oil seal ring carrier. Align the holes in the puller flange with the tapped holes in the adaptor, then secure the puller to the adaptor with two bolts.

f. Turn the puller screw clockwise and pull the oil seal ring carrier from the rotor shaft (Fig. 12).

g. Remove the remaining oil seal ring carriers from the rotor shafts in the same manner.

h. Refer to Fig. 10 and support the outer face of the blower end plate on wood blocks on the bed of an arbor press.

i. Place the long end of the oil seal remover and installer J 6270-3 down through the oil seal ring collar and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 10). Then press the bearing and oil seal ring collar out of the end plate.

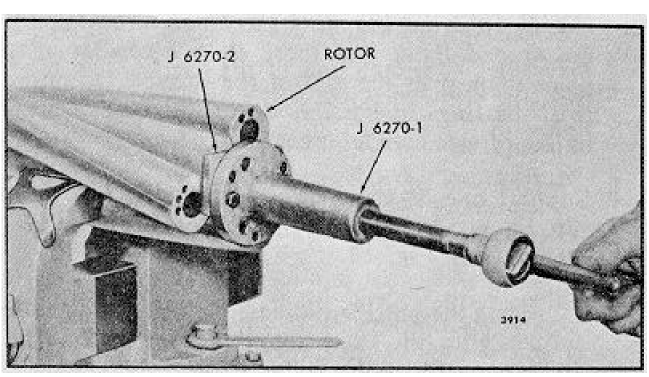


FIG. 12 - Removing Oil Seal Ring Carrier from Blower Rotor Shaft (Turbocharged Engine Blowers)

j. Remove the remaining bearings and oil seal ring collars from the end plates in the same manner.

Inspection

Wash all of the blower parts in clean fuel oil and dry them with compressed air.

Examine the bearings for any indications of corrosion or pitting. Lubricate each ball bearing with light engine oil. Then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

The double-row ball bearings are pre-loaded and have no end play. A new bearing will seem to have considerable resistance to motion when revolved by hand.

Check the oil seal rings, carriers and collars for wear and scoring. If worn excessively, they must be replaced. The current oil seal rings are chrome flashed and the carriers are liquid nitrided. When replacement of an oil seal ring or carrier is necessary, both parts must be replaced together.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. Rotors must be smooth for satisfactory operation of the blower. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs or peening. Also inspect the bearing and oil seal contact surfaces of the shafts for wear and scoring.

Inspect the inside surface of the blower housing for burrs and scoring. The inside surface must be smooth for efficient operation of the blower. If the inside surface of. the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing for flatness and burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

NOTE: Be careful not to remove metal at the joint face between the end plates and the housing. Air or oil leaks could develop after assembly.

Examine the serrations in the blower timing gears for wear and peening; also check the gear teeth for wear, chipping or damage. If the gears are worn to the point where the backlash between the gear teeth exceeds

.004", or damaged sufficiently to require replacement, both gears must be replaced as a set.

Check the blower drive shaft serrations for wear or peening. Replace the shaft if it is bent, cracked or has excessive spline wear.

Inspect the blower drive coupling springs (pack) and the cam for wear.

Replace all worn or excessively damaged blower parts.

Clean the oil strainer in the vertical oil passage at the bottom of each blower end plate and blow out all oil passages with compressed air.

Assemble Blower

Several precautions are given below to assure proper assembly of the rotors and gears for correct blower timing.

1. The lobes on the *driving* blower rotor and the teeth on its gear form a right-hand helix while the lobes and teeth of the *driven* rotor and gear form a left-hand helix. Hence, a rotor with right-hand helix lobes must be used with the gear having right-hand helix teeth and vice versa.

NOTE: New rotors with a different helix angle have been incorporated in the 8V engine blowers. The former and new rotors must not be mixed in a blower assembly. The proper clearances cannot be obtained in a mix of the former and new rotors.

2. One serration is omitted on the drive end of each blower rotor shaft and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serrations in alignment.

3. The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 25.

With these precautions in mind, proceed with the blower assembly, referring to Figs. 13 through 25 as directed in the text:

1. Install new *lip type* oil seals as follows:

   a. Support the blower end plate, finished surface facing up, on wood blocks on the bed of an arbor press.

   NOTE: If oversize oil seals are being used in the blower end plates, use installer J 6270-28 to install the oversize oil seal spacers on the rotor shafts.

   b. Start the oil seal straight into the bore in the end plate with the sealing edge facing down (toward the bearing bore).

   c. Place the short end of oil seal remover and installer J 6270-3 in the oil seal and under the ram of the press'(Fig. 14). Then press the oil seal into the end plate until the shoulder on the installer contacts the end plate.

   NOTE: A step under the shoulder of the installer will position the oil seal approximately *.005 "'* below the finished face of the end plate. This is within the .002 " to .008 " specified.

   d. Install the remaining oil seals in the end plates in the same manner.

2. Install the *ring-type* oil seal, carriers and collars on the rotor shafts and in the end plates as follows:

   a. Support one of the rotor assemblies on wood blocks on the bed of an arbor press as shown in Fig. 16.

   b. Lubricate the inside diameter of the oil seal ring' carrier with engine oil. Then start the carrier straight over the end of the rotor shaft with the chamfered inside diameter end facing the rotor.

   c. Place the oil seal ring carrier installer J 6270-13 over the end of the rotor shaft and against the carrier with the end of the installer under the ram of the press. Then press the carrier down tight against the rotor.

   d. Install the remaining oil seal ring carriers on the rotor shafts in the same manner.

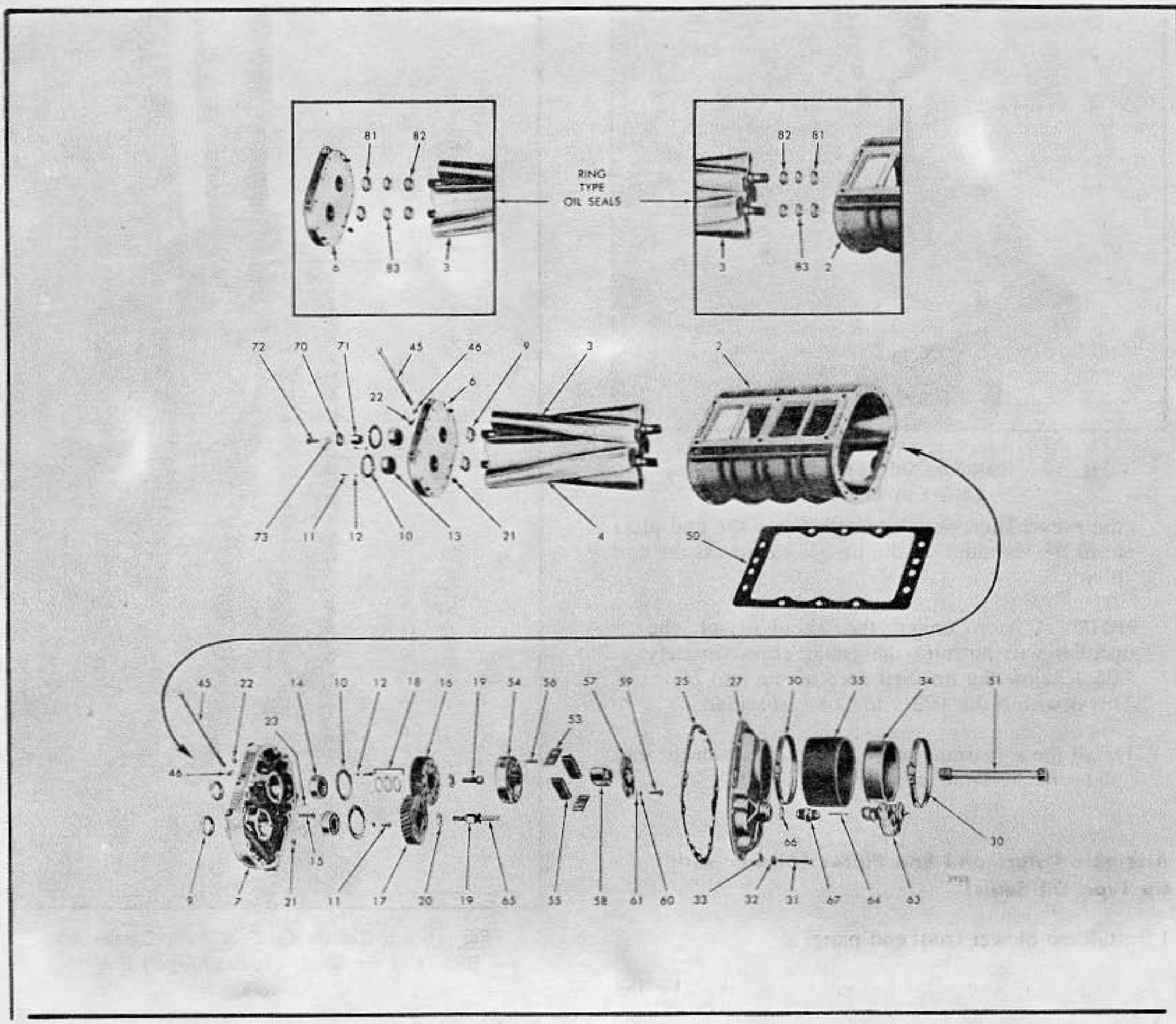
   e. Install an oil seal ring in the ring groove of each carrier with a pair of snap ring pliers in the same manner as shown in Fig. 11.

   NOTE: To avoid breaking the oil seal rings. Do pot spread them any more than necessary to place them over the end of the carrier. Do not twist the rings or possible distortion may result in loss of side contact area.

   f. Support one of the blower end plates, inner face up, on wood blocks on the bed of an arbor press as shown in Fig. 14.

   g. Lubricate the outside diameter of a seal ring collar with engine oil. Then start the chamfered outside diameter end of the collar straight into the bore in the end plate.

   h. Place the oil seal ring collar installer J 6270-3 on top of the seal ring collar and under the ram of



2. Housing--Blower
3. Rotor Assy.--R.H. Helix
4. Rotor Assy.--L.H. Helix
6. Plate--Blower Front End
7. Plate--Blower Rear End
9. Seal--Oil
10. Retainer--Blower Bearing
11. Bolt--Retainer
12. Lock Washer
13. Bearing--Blower Rotor Front (Roller)
14. Bearing--Blower Rotor Rear (Ball)
15. Screw--Fillister Head
16. Gear--R.H. Helix Rotor
17. Gear--L.H. Helix Rotor
18. Shim--Blower Gear
19. Bolt--Blower Gear
20. Spacer
21. Strainer--End Plate Oil Passage
22. Plug--Oil Passage
23. Orifice--Oil Passage
25. Gasket--Rear End Plate Cover
27. Cover--Rear End Plate
30. Clamp--Hose
31. Bolt--Cover
32. Lock Washer
33. Washer--Special Flat
34. Cover--Blower Drive (Steel)
35. Hose--Blower Drive Cover
45. Bolt--Blower Mounting
46. Lock Washer
50. Gasket
51. Shaft--Blower Drive
53. Seat--Coupling Spring End
54. Support--Blower Drive Coupling
55. Spring (Pack)--Blower Drive Coupling
56. Seat--Coupling Spring
57. Retainer--Coupling Spring
58. Cam--Drive Coupling
59. Bolt--Retainer
60. Lock Washer
61. Plain Washer
63. Adaptor--Tachometer Drive
64. Key--Tachometer Drive
65. Shaft--Tachometer Drive
66. Seal--Tachometer Drive
67. Fitting--Tachometer Drive Adaptor
70. Disc--Fuel Pump Drive
71. Spacer--Fuel Pump Drive Disc
72. Bolt--Drive Disc
73. Lock Washer
81. Collar--Blower End Plate
82. Carrier--Seal Ring
83. Ring--Seal (Piston Type)

FIG. 13 - Blower (Small Bearing) Details and Relative Location of Parts

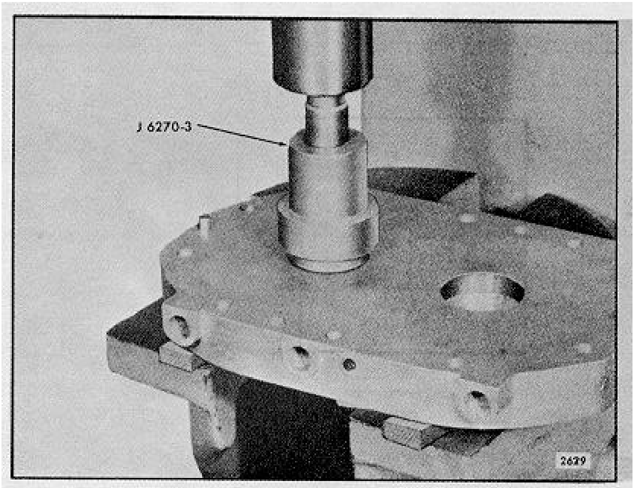


FIG. 14 - Installing Oil Seal (or Oil Seal Ring Collar) in End Plate

the press. Then press the collar into the end plate until the shoulder on the installer contacts the end plate.

NOTE: A step under the shoulder of the installer will position the collar approximately .005" below the finished face of the end plate. This is within the .002" to .008" specified.

i. Install the remaining oil seal ring collars in the end plates in the same manner.

Assemble Rotors and End Plates (Blower with Lip Type Oil Seals)

1. Install the blower front end plate.

The top of the end plate is readily identified by the three bolt holes and one oil hole, whereas the bottom

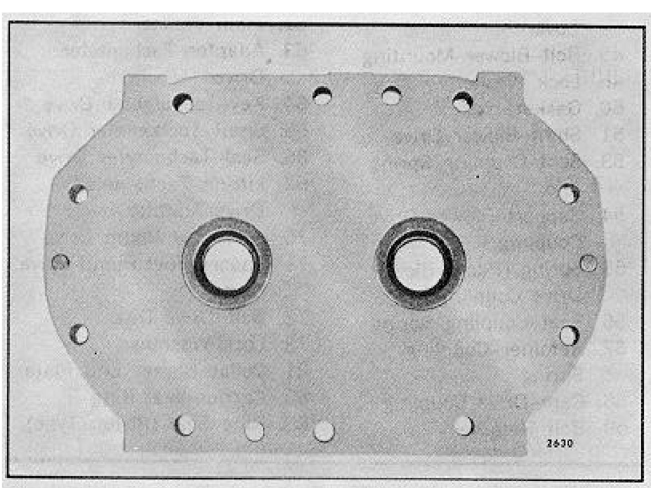


FIG. 15 - Location of Oil Seals in End Plate

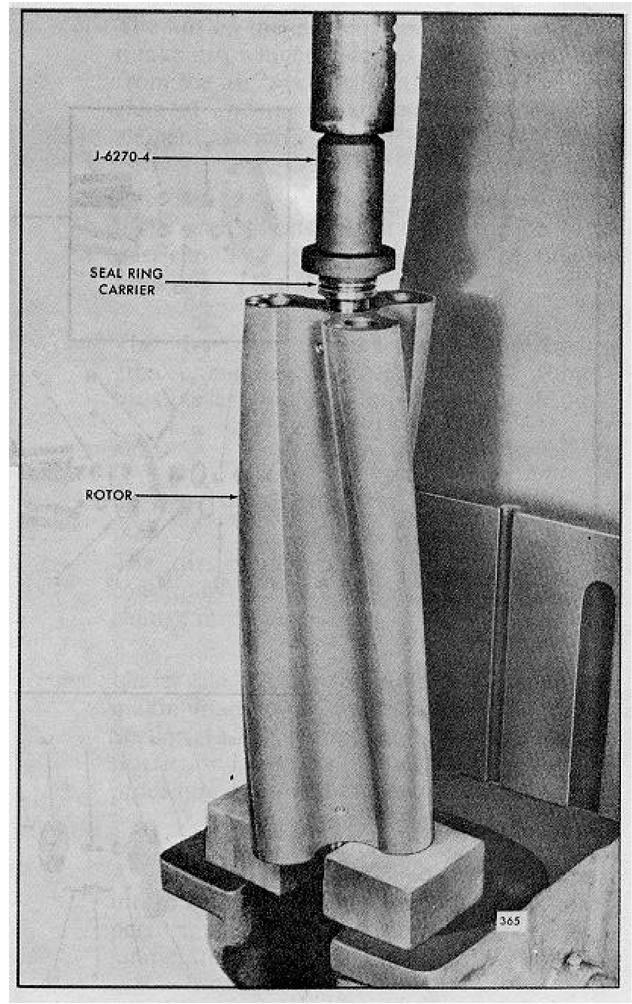


FIG. 16 - Installing Oil Seal Ring Carrier on Blower Rotor Shaft (Turbocharged Engine Blowers)

side of the end plate has three bolt holes and three oil holes. Also the dowel pins extend on both sides of the front end plate.

IMPORTANT: The horizontal oil passage in the top front face of the front end plate that intersects the vertical oil passage is plugged. Do not install this end plate on the rear end of the blower housing.

The front end plate should be attached to the front end of the blower housing first. The rear end plate is attached to the blower housing after the rotors are in place. Attach the front end plate to the blower housing as follows:

a. If removed, press a new oil strainer into the vertical oil passage at the bottom side of the plate from flush to .015” below the bottom surface (Fig. 2). Then install the pipe plug in the vertical oil passage at the top of the end plate.

b. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

c. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

NOTE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

d. Place the blower housing on a bench with the top side of the housing up and the front end of the housing facing the outside of the bench.

e. Apply a light coating of Permatex FORM-A-GASKET NO.2 or an equivalent sealant to the mating surfaces of both the end plate and blower housing. Then position the end plate in front of the blower housing with the top side of the end plate facing up. Start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing. Note that no gasket is used between the end plate and the housing. Therefore, the mating surfaces should be perfectly flat and smooth, however, caution must be used so that no sealant protrudes into the housing. Also, the sealant must not prevent the end plate from laying flat against the housing.

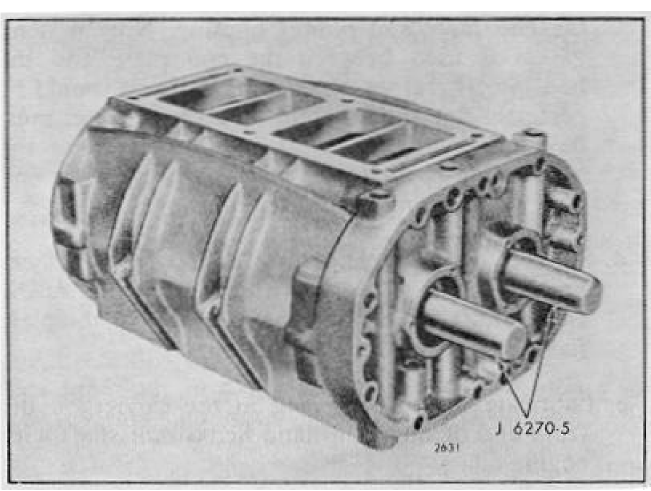


FIG. 17 - Assembling Blower Rotors in Housing and Front End Plate with Oil Seal Pilots

f. Insert the two fillister head screws through the end plate and thread them into the housing. Tighten the screws to 5-10 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

2. Refer to Fig. 17 and install the blower rotors in the blower housing and end plate as follows:

a. Reverse the blower housing on the bench (rear end of housing facing the outside of the bench).

b. Place the rotors in mesh with the omitted serrations in the rotor shafts in a horizontal position and facing to the left as viewed from the gear end. Note that the right-hand helix rotor is marked "GEAR END" on one end. The gear end of the left-hand rotor is that end which has the serrated shaft.

c. Install an oil seal pilot J 6270-5 over the opposite end of each rotor shaft.

NOTE: When oversize oil seals are used in the blower end plate, use oil seal spacer installer J 6270-28 for the oil seal pilots in place of J 6270-5.

d. Insert the rotors straight into the housing and through the front blower end plate.

e. Remove the oil seal pilots from the rotor shafts.

3. Install the blower rear end plate as follows:

NOTE: On the current 12V front blower rear end plate, be sure a 1/4 " teflon coated pipe plug is installed in the lubricating oil supply hole.

a. Install an oil seal pilot J 6270-5 over the serrated end of each rotor shaft.

NOTE: When oversize oil seals are used in the blower end plate, use oil seal spacer installers J 6270-28 for the oil seal pilots in place of J 6270-5.

b. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

c. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005 " below the surface of the end plate.

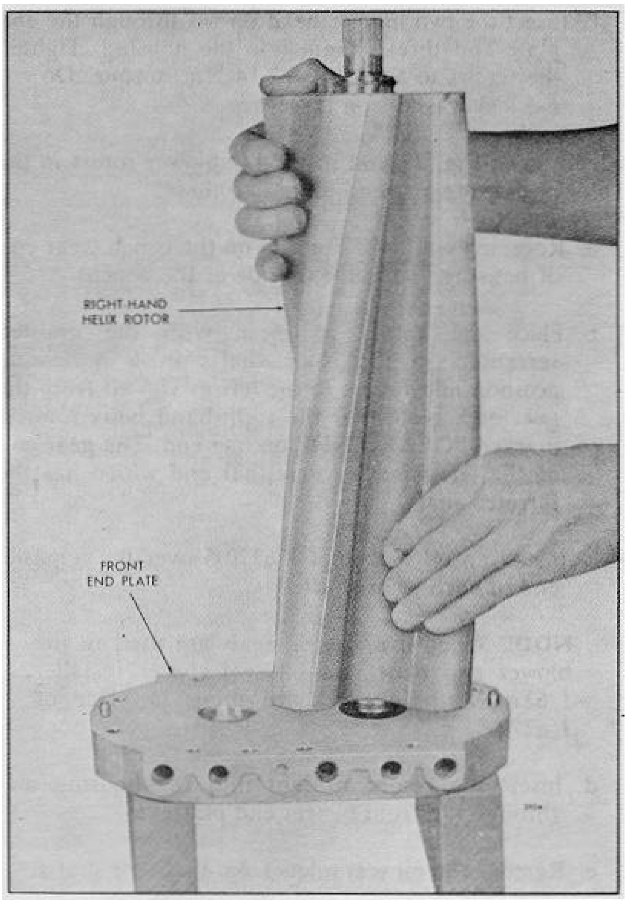


FIG. 18 - Installing Blower Rotor in Front End Plate (Turbocharged Engine Blowers)

NOTE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

d. Apply a light coating of a hi-temperature rubber base sealant between the entire joint face of both the end plate and blower housing. Note that no gasket is used between the end plate and the housing. Therefore, the mating surfaces should be perfectly flat and smooth, however, caution must be used so that no sealant protrudes into the housing. Also, the sealant must not prevent the end plate from laying flat against the housing.

e. With the top of the end plate identified as in Step 1, and its flat finished face towards the blower housing, slide the end plate straight over the oil seal pilots and start the dowel pins straight into the dowel pin holes in the housing. Then push or tap the end plate against the housing.

f. Insert the two fillister head- screws through the end plate and thread them into the housing. Tighten the screws to5-10 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

g. Remove the oil seal pilots from the rotor shafts.

4. Check the relationship of the blower end plates to the housing of the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .0005” above to .0065 " below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

Assemble Rotors and End Plates (Blower with Ring-Type Oil Seals)

1. Install the blower rotors in the blower front end plate as outlined below.

a. Check the dowel pins. The dowel pins must project .320 " from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

b. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

NOTE: When installed, the' inside flats of the sleeve will be parallel to the center line of the housing.

c. Apply a light coating of a hi-temperature rubber base sealant between the entire joint face of both the end plate and blower housing. Note that no gasket is used between the end plate and the housing. Therefore, the mating surfaces should be perfectly flat and smooth, however, caution must be used so that no sealant protrudes into the housing. Also, the sealant must not prevent the end plate from laying against the housing.

d. Support the front end plate on two wood blocks approximately 4 " high, with the inner face of the end plate facing up and the TOP side of the plate facing the serviceman's right (Fig. 18).

e. Lubricate the oil seal ring in the carrier on the front end of the right-hand helix rotor shaft with engine oil.

f. Hold the right-hand helix rotor in a vertical position (gear end up) and position the seal ring in the carrier so the ring protrudes from its

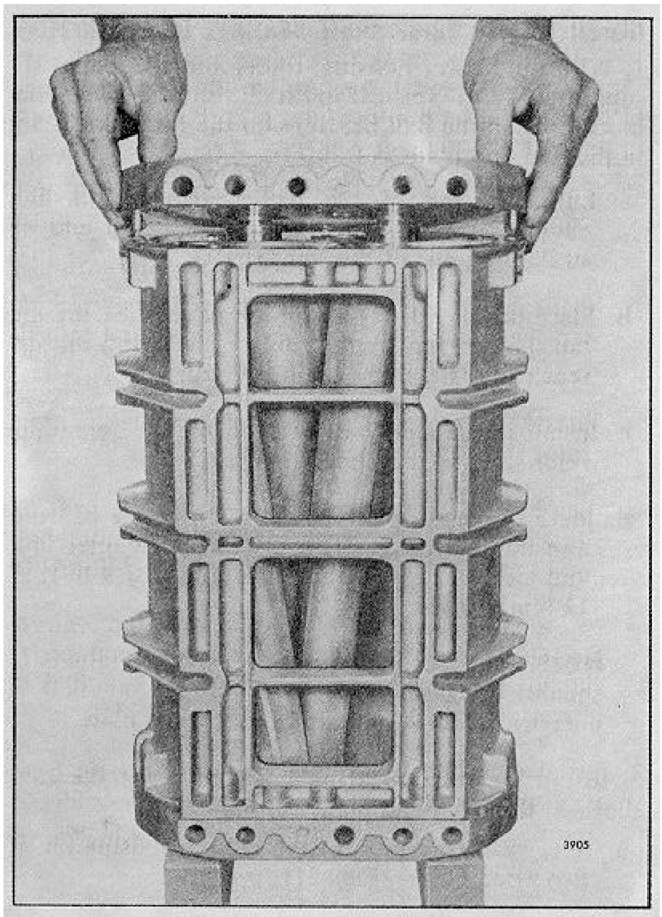


FIG. 19 - Installing Rear End Plate on Blower Rotors and Housing

groove the same amount on each side and the gap is facing away from the serviceman.

g. With the omitted serration in the splines of the shaft facing toward the top side of the end plate, start the end of the rotor shaft into the right-hand shaft opening in the end plate so that the gap portion of the seal ring is started into the ring collar (Fig. 18). Continue to lower the rotor and very carefully apply pressure to the seal ring approximately 180 ° from the gap while gently working the seal ring into the collar until the rotor contacts the end plate.

h. Perform Steps "d'" and "e" above on the left-hand helix rotor.

i. Position the rotors so the lobes are in mesh and the omitted serrations in the splines of both rotor shafts are facing toward the top side of the end plate. Then install the left-hand helix rotor as in Step "f".

2. Install the blower housing over the rotors and attach it to the front end plate as follows:

a. Position the blower housing over the top of the rotors so the bottom face of the housing faces the bottom side of the front end plate. Then lower the housing over the rotors until it contacts the dowel pins in the end plate.

b. Align the dowel pin holes in the housing with the dowel pins in the end plate. Then push the housing tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

c. Insert the two fillister head screws through the front end plate and thread -them into the housing. Tighten the screws to 5-10 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

3. Install the blower rear end plate on the rotor shafts and housing as follows:

a. Check the dowel pins. The dowel pins must project .320 " from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

b. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005 " below the surface of the end plate.

NOTE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

c. Apply a light coating of a hi-temperature rubber base sealant between the entire joint face of both the end plate and blower housing. Note that no gasket is used between the end plate and the housing. Therefore, the mating surfaces should be perfectly flat and smooth, however, caution must be used so that no sealant protrudes into the housing. Also, the sealant must not prevent the end plate from laying flat against the housing.

d. Lubricate the oil seal rings in the carriers on the rotor shaft with engine oil.

e. Position the oil seal rings in the carriers so the ring protrudes from its groove the same amount on each side.

f. Position the rear end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the TOP side of the end plate facing the top side of the blower housing.

g. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the

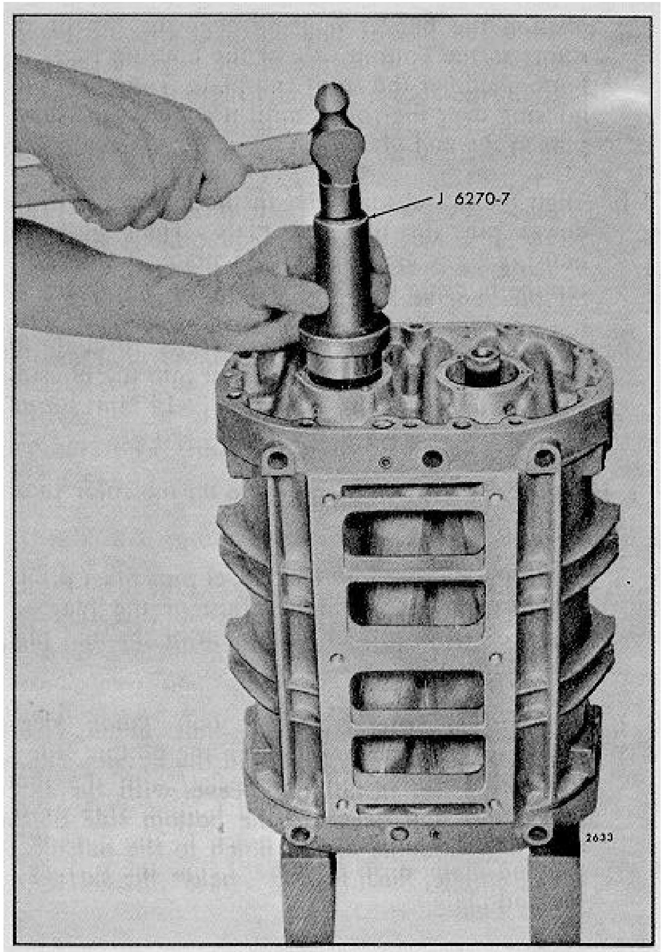


FIG. 20 - Installing Ball Bearings on Rotor Shafts and in Rear End Plate

blower housing (Fig. 19). Then carefully work the dowel pins into the dowel pin holes in the housing and the oil -seal rings into the collars. Push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

h. Insert the two fillister head screws through the rear end plate and thread them into the housing. Tighten the screws to 5-10 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

4. Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .0005 " above to .0065 " below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

Install Slower Rotor Shaft Bearings and Gears

1. With the blower housing, rotors and end plates still supported in a vertical position on the two wood blocks, install the ball bearings on the rotor shafts and in the rear end plate as follows:

a. Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

b. Place installer J 6270-7 on top of the bearing and tap the bearing straight on the shaft and into the rear end plate as shown in Fig. 20.

c. Install the second ball bearing on the remaining rotor shaft in the same manner.

d. Place the bearing retainers on top of the bearings and the end plate. Then install the retainer bolts and lock washers. Tighten the bolts to 7-9 lb-ft (9-12 Nm) torque.

NOTE: The scallops in the current retainers should be positioned to allow oil to flow unrestricted out of the orifice in the end plate.

2. Install the roller bearing inner races on the rotor shafts at the front end plate as follows:

a. Reverse the position of the blower housing on the two wood blocks (Fig. 21).

b. Position the roller bearing inner race, flange side down, over the front end of the rotor shaft and press the race on the shaft with tool J 6270-4 until the bearing contacts the shoulder on the shaft.

c. Install the bearing inner race on the front end of the other rotor in the same manner.

3. Install the roller bearing outer race assemblies in the front end plate as follows:

a. Lubricate one of the roller bearings with light engine oil. Start the bearing (shoulder side up) over the rotor shaft and bearing inner race and into the end plate.

b. Place installer J 6270-4 on top of the bearing and tap the bearing straight on the shaft and into the front end plate as shown in Fig. 21.

c. Install the second roller bearing on the remaining rotor shaft in the same manner.

d. Place the hearing retainers on top of' the bearings and the end plate. Then install the retainer bolts and lock washers. Tighten the bolts to 7-9 lb-ft (9-12 Nm) torque.

NOTE: The scallops in the current retainers should be positioned to allow oil to flow unrestricted out of the orifice in the end plate.

4. Make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gage as shown in Fig. 26. Refer to Fig. 24 for minimum blower clearances.

5. Before installing the blower rotor timing gears on the rotor shafts, observe precautions "2" and "3" relative to the rotor shaft and timing gear alignment under *Assemble Blower.*

The center punch mark in the end of each rotor shaft at the omitted serration will assist in aligning the gears on the shafts.

If shims were removed from the back side of the gears (between the inner race of the bearing and the gear), they should be replaced in their original positions before installing the gears on their respective shafts. Install the blower timing gears as follows:

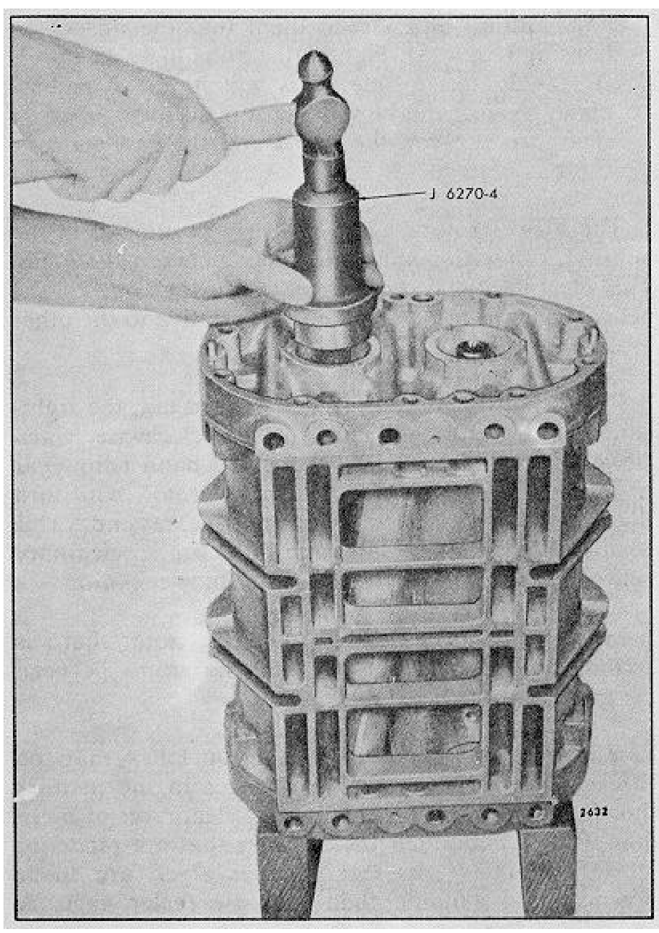


FIG. 21 - Installing Roller Bearings on Rotor Shafts and in Front End Plate

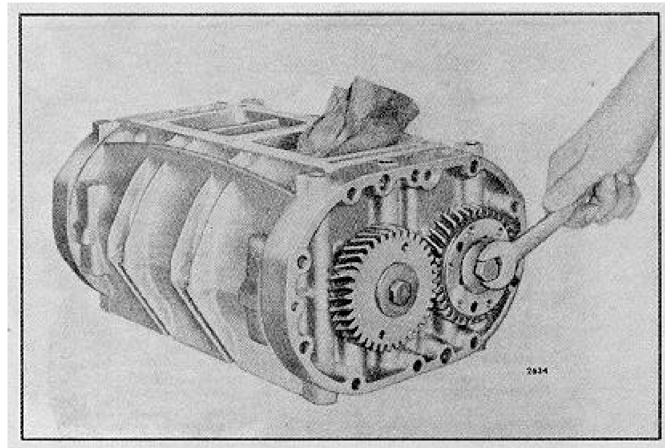


FIG. 22 - Installing Blower Rotor Timing Gears

a. Place the blower assembly on a bench, with the top of the housing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench.

b. Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing to the left.

c. Install the same number and thickness of shims on each rotor shaft that were removed at the time of disassembly.

d. Lubricate the serrations of the rotor shafts with light engine oil.

e. Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.

f. Start both rotor gears straight on the rotor shafts with the right-hand helix gear on the right-hand helix rotor and the left-hand helix gear on the left-hand helix rotor, with the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.

g. Thread a 1/2 "-20 x 1.10 " bolt with integral washer into the end of each rotor shaft. Place a clean folded cloth between the lobes of the rotors to prevent the gears from turning. Draw the gears into position tight against the shims and the bearing inner races as shown in Fig. 22.

h. Remove the two bolts and washers that were used to draw the gears into position on the rotor shafts.

i. Lubricate the threads of the 1/2 "-20 x 1.10 " gear retaining bolts with engine oil. Tighten the bolts to 100-110 lb-ft (136-150 Nm) torque. Remove the cloth from the blower rotors.

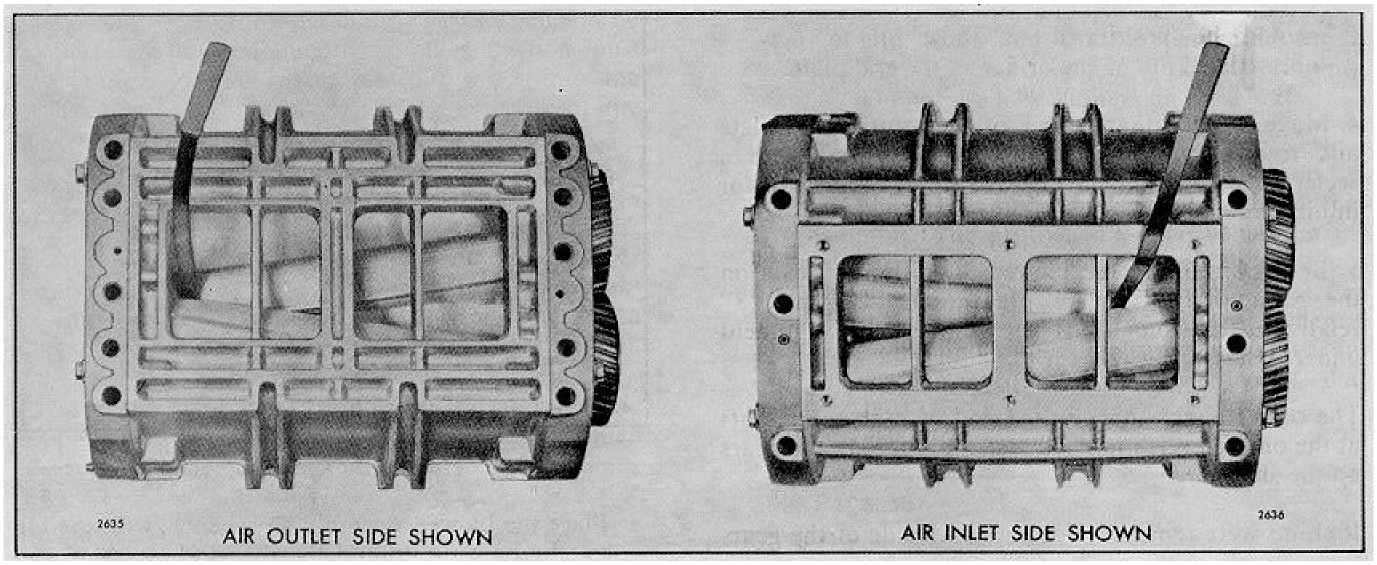


FIG. 23. Measuring “CC” and “CC” Clearance Between Blower Rotor Lobes

NOTE: Effective with engine serial numbers 6VA102087, 8VA369634 and 12VA56841 a 1/2" -20 x 1.10" slotted head rotor timing gear retaining bolt with integral washer (identified with yellow paint on the head) replaced the 1/2"-20 x 1-1/4" bolt and plain washer combination. The former 1/2"-20 x *1-1/4"* bolt with plain washer was tightened to 75-85 lb-ft (102-15 Nm) torque. With early engines the bolt with plain washer was tightened to 55-65 lb-ft (75-88 Nm) torque.

IMPORTANT: The 1/2 "-20 x 1.10 " Allen head blower timing gear retaining bolts incorporate a special nylon insert and must be lubricated before installing them in the rotor shafts.

j. With the new rotor timing gear retaining bolts a new blower drive cam and blower rotor gear driven sprocket (12V-71 engine only) are required. These new parts are necessary because of the reduced pilot area, as a result of the retaining bolts.

Use only the new 1/2 "-20 x 1.10 " retaining bolt when installing the blower rotor timing gears with the new drive can and driven sprocket (I 2V-7 1 engine only). Only the new drive cam and driven sprocket will be serviced and they will fit on former blowers. The new retaining bolts cannot be used with the former drive cam and driven sprocket, due to interference between attaching or mating parts.

Timing Blower Rotors

After the blower rotors and timing gears are installed, the blower rotors must be timed.

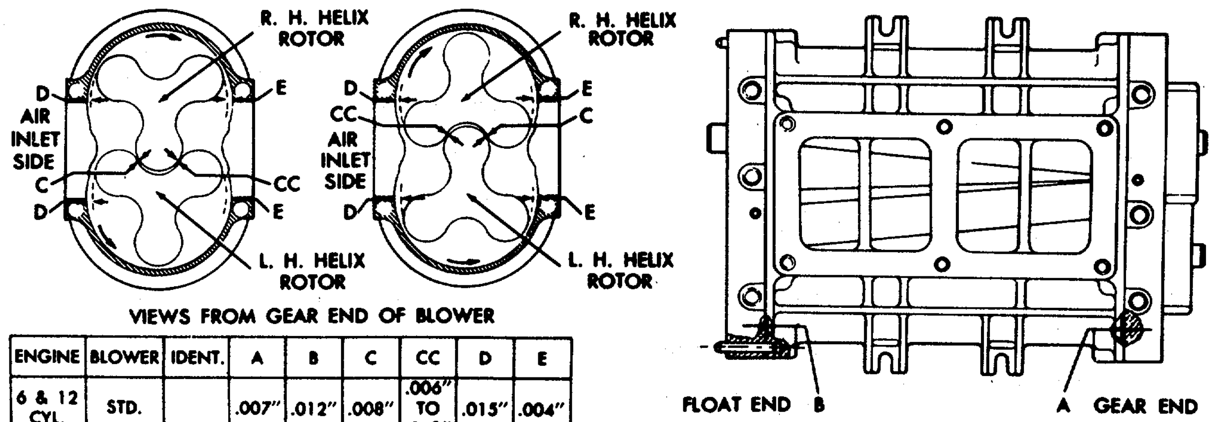
NOTE: Before timing the blower, install four 5/16 "-18 x 1-7/8 " bolts with flat washers through four bolt holes in each end plate (top and bottom) and thread them into the blower 'housing (Fig. 15). Tighten the bolts to 13-17 Ib-ft (18-23 Nm) torque. This will hold the end plates against the blower housing so the proper clearance between the rotors and the end plate can be obtained.

1. The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

2. If the right-hand helix gear is moved out, the right-hand helix rotor will turn counterclockwise when viewed from the gear end. If the left-hand helix gear is moved out, the left-hand helix rotor will turn clockwise when viewed from the gears end. This positioning of the gears, to obtain the proper clearance between the rotor lobes, is known as blower timing.

3. Moving the gears OUT or IN on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

4. The clearance between the rotor lobes may be checked with 1/2 " wide feeler gages in the manner shown in Fig. 23. When measuring clearances of more than .005 ", laminated feeler gages that are made up of .002 ", .003 " or .005 " feeler stock are more practical and suitable than a single feeler gage. A specially designed feeler gage set J 1698-02 for the blower clearance operation is available. Clearances should be measured from both the inlet and outlet sides of the blower.



ENGINE	BLOWER	IDENT.	A	B	C	CC	D	E
6 & 12 CYL.	STD.		.007"	.012"	.008"	.006" TO .010"	.015"	.004"
6 & 12 CYL.	TURBO		.007"	.012"	.008"	.006" TO .010"	.015"	.004"
8 CYL.	STD.		.007"	.014"	.010"	.004" TO .008"	.015"	.004"
8 CYL.	TURBO		.007"	.014"	.010"	.004" TO .008"	.015"	.004"
8 CYL.	TURBO	LT	.007"	.024"	.010"	.004" TO .008"	.030"	.004"

NOTE: Time rotors to dimensions on chart for clearance between trailing side of R.H. Helix Rotor and leading side of L.H. Helix Rotor (cc) from both inlet and outlet side of blower.

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*IDENTIFICATION STAMPED ON BLOWER HOUSING

FIG. 24 - Chart of Minimum Blower Clearances

5. Refer to Figs. 23 and 24 and time the rotors to the specified clearance between the *trailing* edge of the right-hand helix rotor and the *leading* edge of the left-hand helix rotor ("CC" clearance)measured from both the inlet and outlet sides. Then check the clearance between the *leading* edge of the right-hand helix rotor and the *trailing* edge of the left-hand helix rotor ("C" clearance) for the minimum clearance. Rotor-to-rotor measurements should be taken I " from each end and at the center of the blower.

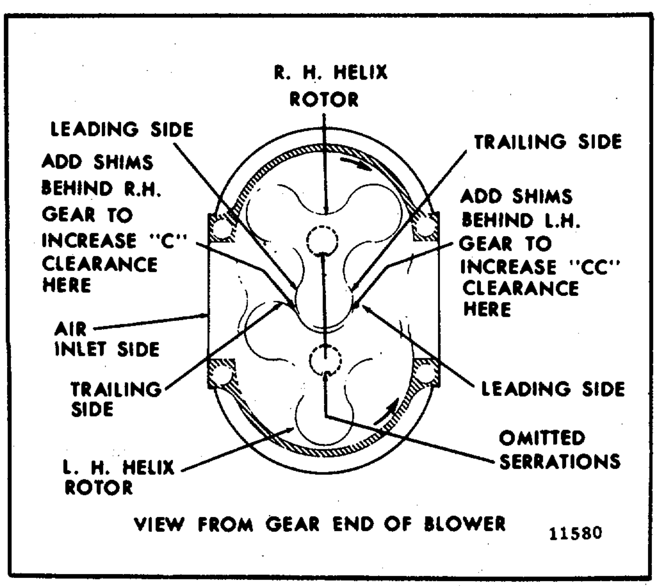


Fig. 25 - Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

NOTE: If the proper clearances cannot be obtained between the rotors, a mix of the former and current rotors, which have a different helix angle, may have occurred.

6. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear as shown in Fig. 25 to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a .003 " shim in back of a rotor gear will revolve the rotor .001 ".

7. Install the required thickness of shims back of the proper gear and next to the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.

8. Determine the minimum clearances at points "A" and "B" shown in Fig. 24. Insert the feeler gages, as shown in Fig. 26, between the end plates and the ends

of the rotors. This operation must be performed at the ends of each lobe, making 12 measurements in all. See Fig. 24 for the minimum clearances.

9. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side -- 12 measurements in all. Refer to Fig. 24 for the minimum clearances.

After the blower rotors are timed, complete assembly of the blower as outlined below:

1. Place the fuel pump drive disc spacer over the forward end of the right-hand helix rotor shaft. Then place the special lock washer and the drive disc on the retaining bolt and thread the bolt into the rotor shaft against the spacer. Tighten the bolt to 55-65 lb-ft (75- 88 Nm) torque. Bend one tang of the lock washer over into the slot in the drive disc and two tangs over against the flat sides of the bolt head.

2. If disassembled, install the springs and blower drive cam in the blower drive coupling support as follows:

a. Place the drive coupling support on two wood blocks (Fig. 27).

b. Apply a light coat of grease to the back of the spring seats. Place the half round spring seats in the grooves inside the support and the flat spring seats inside the support at each end of the opening (Fig. 28).

c. Lubricate the springs with light engine oil. Then place the spring packs, consisting of 21 leaves per pack, in the support with the spring seats in position as shown in Fig. 27.

d. Place the blower drive cam over the end of the installer J 1471, with the large chamfered inside diameter end of the cam facing up. Insert the tapered end of the installer between the spring packs (Fig. 27) and push the drive cam until it is centered between the spring packs. Remove the installer from the drive cam.

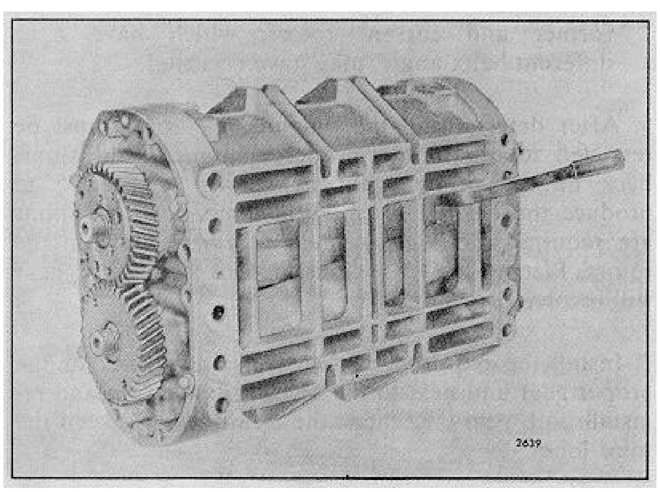


FIG. 26 - Measuring End Clearance Between Blower Rotors and End Plate

Attach Accessories to Slower

1. Attach the blower drive coupling to the blower as follows:

a. Place the blower assembly on end on two wood blocks with the rotor gears up.

b. Place the blower drive coupling assembly and coupling spring retainer on the right-hand helix gear, align the bolt holes and install the six bolts and lock washers.

NOTE: Be sure that the cam in the drive coupling is installed with the retainer groove toward the gears.

c. Tap the drive coupling cam with a plastic hammer to seat it on the rotor gear.

d. Place the alignment clamp adaptor J 21834-1 in the coupling cam (Fig. 28). Then install the alignment clamp J 21834-2 and tighten it only enough to prevent any misalignrnent during assembly of the coupling to the gear.

NOTE: Insert a rag between the rotor gears to keep them from turning.

e. Tighten two bolts that are opposite to one another to 20-25 lb-ft (27-34 Nm) torque and then remove the alignment clamp and tighten the remaining bolts to the same torque. The cam spline runout should not exceed .020" total indicator reading.

2. Remove the four bolts and flat washers holding each end plate to the blower housing.

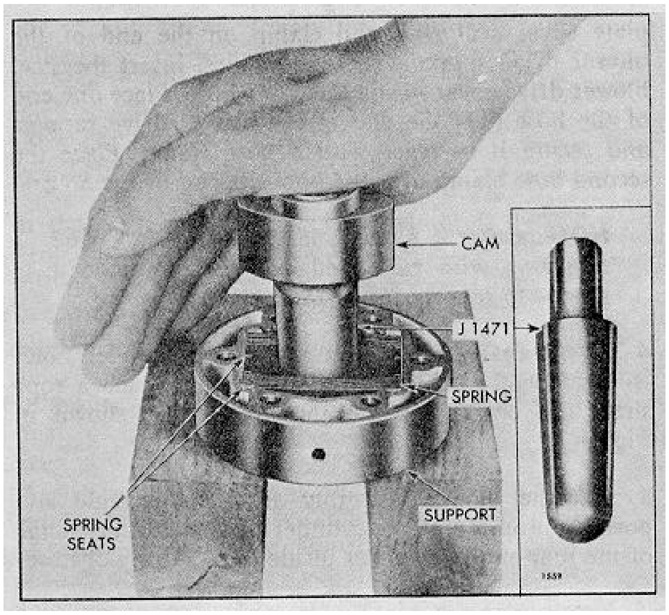


FIG. 27 - Inserting Blower Drive Cam in Springs

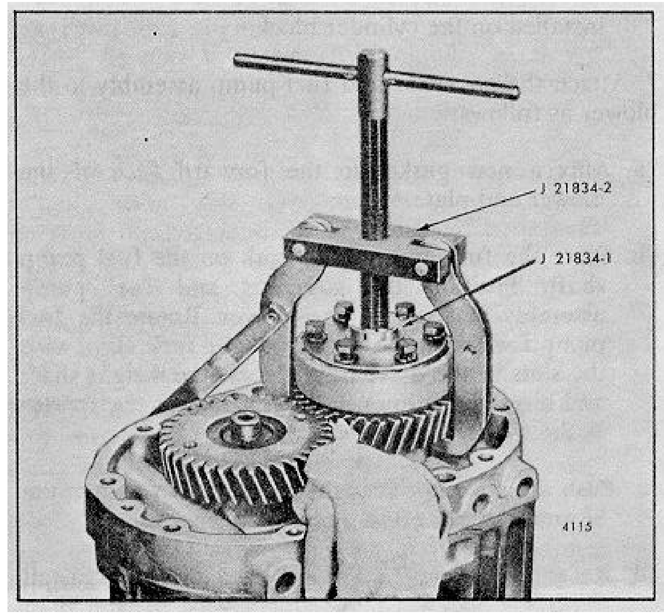


FIG. 28 - Aligning Blower Drive Coupling

3. Affix a new gasket to the blower rear end plate cover. Place the cover over the gears and against the end plate, with the opening in the cover over the blower drive coupling attached to the right-hand helix gear. Install the eight 5/16"-18 x 2-1/16" bolts, lock washers and special flat washers in the eight holes at each end and the bottom side of the cover. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

NOTE: The tab on the gasket is to assure the gasket is in place.

4. On current 6V and 12V engines, attach the adaptor and dry seal connector to the rear blower end plate when installing the blower on an engine.

5. On all 8V engines, attach the lubricating oil tube and dry seal connector to the rear blower end plate when installing the blower on the engine.

6. On all former engines, attach the lubricating oil tube and seal ring retaining plate to the blower, when installing them on an engine, as follows:

a. Insert a new oil tube seal ring in the oil hole counterbore at the top rear face of the rear end plate.

b. If removed, place the oil tube fitting nut on the oil tube.

c. Place the oil seal retaining plate on the oil tube with the sharp beveled end of the plate to the left and facing down as viewed from the rear of the blower. Then place the seal ring retaining flat washer on the oil tube.

d. Insert the end of the oil tube through the seal ring in the counterbore of the end plate. Push the flat washer against the seal ring and the retaining plate against the cover. Install the two 5/16"-18 x 2-1/4" bolts and lock washers. Do not tighten the

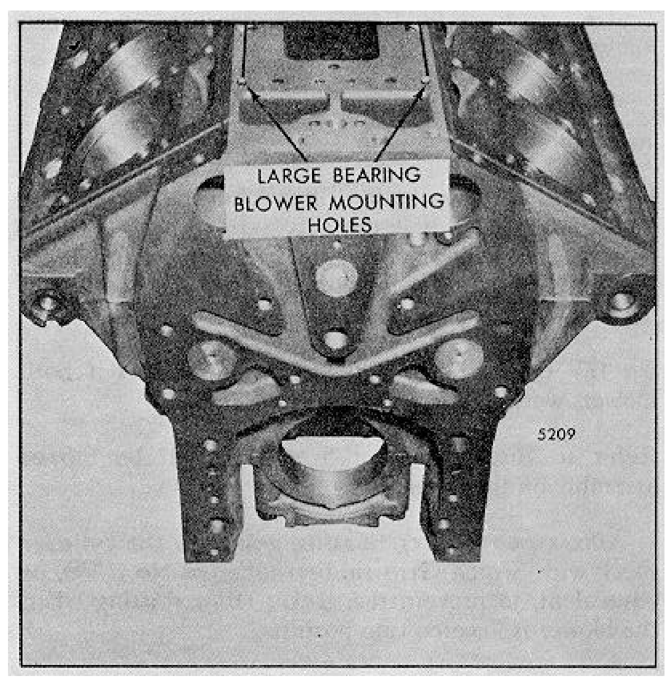


FIG. 29 - Location of Large Bearing Blower Mounting Holes

bolts until after the blower assembly has been installed on the cylinder block.

7. Attach the governor and fuel pump assembly to the blower as follows:

a. Affix a new gasket to the forward face of the blower end plate.

b. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines in the blower rotor.

c. Push the governor straight on the dowel pins in the blower end plate and against the gasket.

d. Refer to Section 2.7.1 for the location and install the bolts, lock washers, copper washers and plain washer which secure the governor to the blower. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

8. On the 12V engines, refer to Fig. 5 and install the drive sprocket on the right-hand helix rotor shaft of the rear blower and secure it in place with an Allen head bolt and special washer. Install the driven sprocket on the right-hand helix gear of the front blower with three Allen head bolts. Affix a new gasket to both the front and rear blower end plate covers.
Then place the covers against the blower end plates and secure them with bolts, lock washers and special flat washers.

Install Blower on Engine

When installing a standard blower on the current 8V- 71 cylinder block, it is not necessary to plug the four large bearing blower (Section 3.4.1) mounting holes (Fig. 29). The blower to cylinder block gasket seals off these holes.

On 12V engines, install the rear blower first if both blowers were removed.

Refer to Figs. 3, 4 and 5 and install the blower assembly on the engine as follows:

1. Affix a new blower housing gasket to the cylinder block with Scotch Grip rubber adhesive No. 1300, or equivalent, to prevent the gasket from shifting when the blower is lowered into position.

2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing and tighten the clamps.

3. On the 6V and 12V engines, place the blower end plate cover seal ring and clamp on the end of the blower drive support. On 8V engines, insert the steel blower drive cover inside the cover hose. Place one end of the hose over the end of the blower drive support and secure it in place with a hose clamp. Place the second hose clamp over the opposite end of the hose.

NOTE: Current 8V engines have a 2.86" wide seal ring with raised edges, which provide a groove to retain each of the hose clamps.

4. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts as shown in Fig. 6.

5. Lift the blower assembly at a slight angle and position it on top of the cylinder block, with the flange of the rear end plate cover inside the seal ring or hose.

6. Install loose the 7/16"-14 x 8-1/4" blower end plate bolts and special washers. Install loose the 3/8"-16 x 5-l/2" bolts and retaining washers at each side of the blower housing. Install the alignment tool J 24619 and position the blower for alignment. Proper alignment is obtained when the tool can be removed easily and then reinstalled.

NOTE: The lip at the beveled end of the bolt retaining washer goes in the small recess in the housing just above the bolt slot.

7. With the alignment tool in place and the blower properly aligned, tighten the bolts as follows:

a. Tighten the blower-to-block end plate bolts to 40-45 lb-ft (54-61 Nm) torque.

b. Tighten the blower housing-to-block side angle bolts uniformly to 30-35 lb-ft (41-47 Nm) torque in 5 lb-ft (7 Nm) increments. Remove the alignment tool.

c. Recheck the blower-to-block end plate bolts.

8. On the 12V engine, position the drive chain, blower seal and clamp on the rear blower. Then place the front blower in position on the cylinder block with the drive chain over the drive sprocket on the front blower. Make sure the drive chain is in position on the drive and driven sprockets, then slide the seal into position and tighten the clamp screw. Install the blower-to-block bolts and tighten them as outlined in Step 7.

9. Place the blower rear end plate cover seal ring and hose clamp into position and tighten it.

NOTE: To retain seal load on the molded blower drive seal rings, a new 4.87" diameter spring loaded T-bolt style clamp is now being used. This is effective with engines built approximately December, 1978.

After installing the new T-bolt style clamp on the blower drive seal, tighten the clamp nut on the bolt until the spring in the clamp is completely compressed.

10. Connect the lubricating oil tube to the fitting in the blower drive support. Then tighten the two seal ring retaining plate bolts to 13-17 lb-ft (18-23 Nm) torque.

11. Insert the blower drive shaft through the blower drive flexible coupling and into the blower drive coupling (Fig. 1) and install the snap ring in the flexible coupling. Then attach the flywheel housing cover to the flywheel housing.

NOTE: Certain engines use a heavier blower drive shaft and a solid drive coupling.

To improve wear resistance, a new nitride hardened blower drive shaft is now being used on the 8V-71T and TA Coach engines. This is effective with engine serial number 8VA391731. The new 6.67" long blower drive shaft is interchangeable in a Coach engine with the former 6.67" long blower drive shaft, however, when replacing the former shaft because of a drive shaft failure, it is recommended that the blower drive coupling also be replaced.

NOTE: The new blower drive shaft can be identified by its gray color.

12. Attach the tachometer drive adaptor, if used, to the blower. Then connect the tachometer drive cable to the drive adaptor.

13. Slide each fuel rod cover tube hose down on the cover tubes attached to the cylinder heads and tighten the hose clamps.

14. Install the fuel rods between the cylinder heads and governor as follows:

a. Insert the end of the left-bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

b. Raise the connecting pin up in the connecting link lever. Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

d. Insert the end of the right-bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

e. Remove the short screw pin from the control fink operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

15. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing, with the pin in the speed control or stop lever shaft assembly in the slot in the differential lever and the dowel pins in the housing in the dowel pin holes in the cover. Install the eight cover attaching screws and lock washers. Tighten the screws securely.

16. If the engine is equipped with a battery-charging alternator, attach the alternator and support bracket to the cylinder head and connect the wires to the alternator.

17. Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

18. If removed, install the front engine lifter bracket.

19. Place the water by-pass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the by-pass tube so it clears the governor, fuel pump and fuel oil lines. Then tighten the hose clamps.

20. Attach the air shutdown adaptor to the blower and the air shutdown housing assembly to the adaptor as outlined in Section 3.3.

21. Connect the cable assembly to the air shut-off cam pin handle at the side of the air shutdown housing.

22. Connect the air inlet hoses to the air cleaners. On engines equipped with turbochargers, connect the air inlet and outlet tubes to the turbochargers.

23. Connect the throttle control rods to the speed control and stop levers on the governor.

24. Attach any other accessories to the engine that were removed.

25. Close the drain cocks and fill the engine cooling system.

26. Perform the governor and injector rack control adjustment as outlined in Section 14. Check for and correct any coolant or oil leaks detected.

BLOWER (Large Bearing)

The large bearing (2.441 " O.D.) blowers used on current 8V turbocharged engines have either a 1.95:1 or 2:1 ratio blower-to-engine speed (Table 1). A large bearing pumper (P) 2.05:1 ratio blower is used when higher pressures are required on the 8V engine, such as for bulk unloading.

The blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in a housing bolted to the top deck of the cylinder block, between the two banks of cylinders. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form (Fig. 1).

Two timing gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance; therefore, as the lobes of the two rotors do not touch at any time, no lubrication is required.

Metal ring-type oil seals are incorporated in the large bearing blower (Fig. 1). Each ring-type oil seal consists of a carrier pressed on the rotor shaft, a collar pressed into the end plate and a seal ring contained in a groove of the carrier. The outside diameter of the seal ring rides against the collar to prevent leakage of air or oil.

Each, rotor is supported in the doweled end plates of the blower housing by a roller bearing at the front end and a double-row pre-loaded radial and thrust ball bearing at the gear end.

The right-hand helix rotor of the blower is driven by the blower drive shaft. The blower drive shaft is splined at one end to a drive hub attached to the blower drive gear and at the other end to a drive hub attached to the right-hand helix blower timing gear. The mating left-hand helix timing gear drives the left-hand helix rotor.

Blower	Ratio Blower to Engine Speed	No. Teeth in Blower Drive Gear
8V Turbocharged	1.95:1	40
8V Pumper (P)	2.05:1	38

TABLE 1

The blower rotors are timed by the two rotor gears at the rear end of the rotor shafts. This timing must be correct, otherwise the required clearance between the rotor lobes will not be maintained. A change in rotor timing is obtained by the use of shims between the gears and the bearings.

Normal gear wear causes a decrease of rotor-to-rotor clearance between the leading edge of the right-hand helix (drive) rotor and the trailing edge of the left-hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be corrected by adjustment, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds .0041", replace the gears.

Lubrication

The blower bearings, timing gears, governor drive and fuel pump drive are pressure lubricated by oil passages in the top deck of the cylinder block which lead from the main oil galleries to an oil passage in each blower end plate (Fig. 2).

A cup shaped oil strainer has been incorporated in the vertical oil passage at the bottom side of each blower end plate to remove any foreign material in the lubricating oil (Fig. 2).

The oil flows upward in the end plate and leaves through a small orifice just above the centerline of the end plate. The oil is ejected from this orifice against the timing gears at the rear and the governor weights at the front of the blower and is then carried by splash to the bearings. Oil which collects at the bottom of each end plate overflows into two drain passages which lead back to the crankcase via oil passages in the cylinder block.

The blower drive support bearings receive oil under pressure from a tube which connects the oil passage in the rear end plate to passages in the blower drive support. Excess oil drains back to the crankcase by way of the gear train.

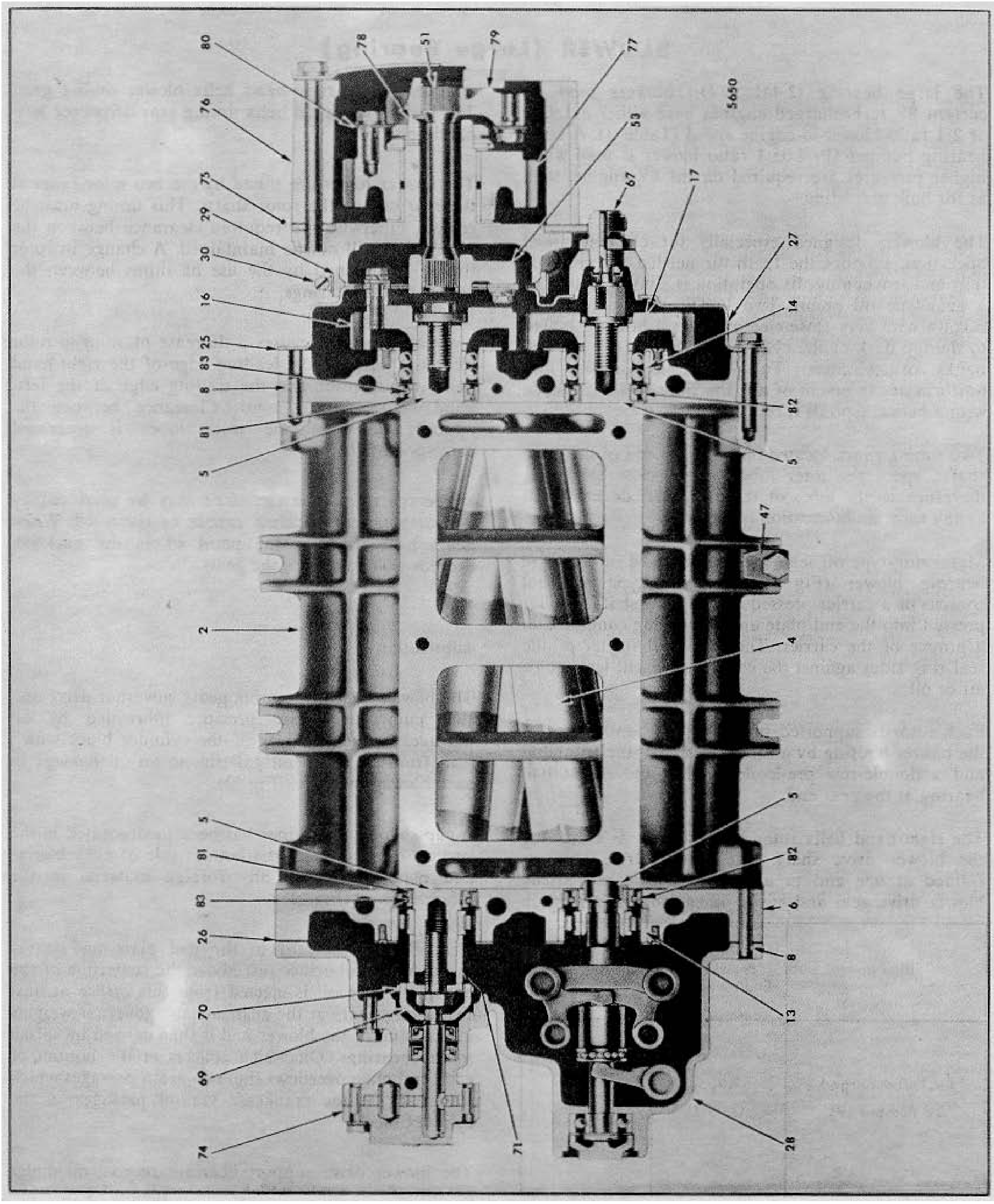


FIG. 1 - Blower and Drive Assembly and Accessories Attached to Blower

- 2. Housing--Blower
- 4. Rotor Assy--Blower
- 5. Shaft--Rotor
- 6. Plate--Blower End
- 8. Pin--Dowel
- 13. Bearing--Front (Roller)
- 14. Bearing--Rear (Ball)
- 16. Gear--Rotor Timing (Drive)
- 17. Gear--Rotor Timing (Driven)
- 25. Gasket--Rear End Plate Cover
- 26. Gasket--Front End Plate Cover
- 27. Cover--Rear End Plate
- 28. Housing--Governor (Front End Plate Cover)
- 29. Seal--Rear End Plate Cover
- 30. Clamp--Rear End Plate Cover Seal
- 47. Lug--Mounting Bolt
- 51. Shaft--Blower Drive
- 53. Drive Hub
- 67. Fitting--Tachometer Drive Adaptor
- 69. Fork--Fuel Pump Drive
- 70. Disc--Fuel Pump Drive
- 71. Spacer--Fuel Pump Drive Disc
- 74. Pump Assy.--Fuel
- 75. Plate--Cylinder Block Rear End
- 76. Housing--Flywheel
- 77. Gear--Blower Drive
- 78. Support--Blower Drive
- 79. Coupling--Blower Drive
- 80. Plate--Blower Drive Coupling
- 81. Collar--Blower End Plate
- 82. Carrier--Seal Ring
- 83. Ring--Seal (Piston Type)

FIG. 1 - Blower and Drive Assembly and Accessories Attached to Blower

Inspection

The blower may be inspected for any of the following conditions without being removed from the engine. However, the air inlet housing, air shutdown housing and adaptor must first be removed.

> **CAUTION:** When inspecting a blower on an engine with the engine running, keep fingers and clothing away from moving parts of the blower and run the engine at low speeds only.

1. Dirt or chips, drawn through the blower, will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and -"dress" the parts to eliminate interference, or replace the rotors if they are badly scored.

2. Leaky oil seals are usually manifest by the presence of' oil on the blower rotors or inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals toward the inlet of the blower is indicative of leaking seals.

3. A worn blower drive may be detected by grasping the right-hand helix rotor firmly and attempting to rotate it. The rotors may move from 3/8" to 5/8", measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4".

4. Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. Worn or damaged bearings will cause rubbing between mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing or the end plates. This condition will usually show up at the end where the bearings have failed.

5. Excessive backlash between the blower timing gears usually results in the rotor lobes rubbing throughout their entire length. This usually is on the trailing (close clearance) side.

6. Inspect the blower inlet screen periodically (if used). as noted in Section 15.1, for an accumulation of dirt which, after prolonged operation, may affect the air flow. Servicing of the screen consists of thoroughly washing it in fuel oil and cleaning with a stiff brush until the screen is free of all dirt deposits. If broken wires are found in the blower screen. replace the screen.

7. Check the lubricating oil connection between the blower and the blower drive support for excessive oil leakage. If oil leakage exists. retighten or replace the fittings.

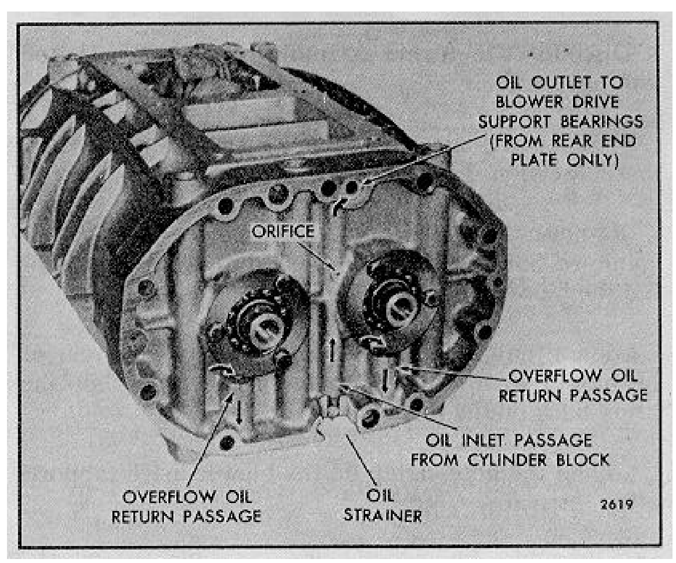


FIG. 2 - Blower Lubrication

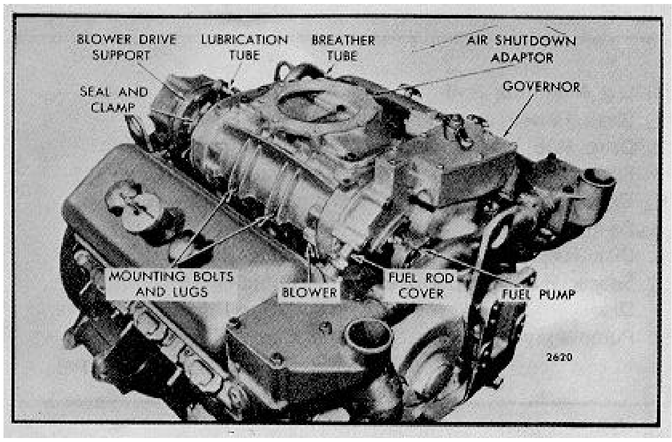


FIG. 3 - Typical Blower Mounting (binge Blower)

To correct any of the conditions cited in Items 1 through 6, the blower must be removed from the engine and either repaired or replaced.

Remove Blower from Engine

The engine governor components are assembled in a combination governor housing and blower front end plate cover. The fuel pump is also attached to the front end of the blower. Therefore, when removing the blower assembly from the engine, the governor and fuel pump will also be removed at the same time. Refer to Fig. 3 and proceed as follows:

1. Disconnect the air cleaner to turbocharger tubing as required (Section 3.5).

2. Remove the turbocharger and attaching parts (Section 3.5).

3. Disconnect the cable assembly from the air shutoff cam pin handle.

4. Remove the air shutdown housing assembly and gasket (Section 3.3).

5. Remove the bolts and washers securing the air shutdown housing to the blower. Remove the adaptor and the blower screen.

6. Loosen the oil pressure line fitting from the rear of the blower to the blower drive support and slide the fitting back on the tube.

7. Loosen the hose clamp on the blower drive support-to-blower seal.

8. Disconnect the tachometer drive cable, if used, from the adaptor at the rear of the blower.

9. Remove the flywheel housing cover at the blower drive support.

10. Remove the snap ring and withdraw the blower drive shaft from the blower.

11. Open the drain cocks and drain the engine cooling system.

12. Loosen the hose clamps and slide the hoses back on the bypass tube between the thermostat housings. Remove the bypass tube.

13. Remove the fuel inlet and outlet lines to the fuel pump. Also remove the fuel return crossover tube between the cylinder heads.

14. Remove or disconnect the breather pipe at the top of the cylinder block.

15. Remove the front engine lifter bracket if necessary.

16. Disconnect the throttle control rods, from the governor.

17. Clean and remove the rocker cover from each cylinder head.

18. Remove the eight governor cover screws and lockwashers and remove the governor cover.

19. Disconnect the fuel rods from both injector control tube levers and the governor and remove the fuel rods.

20. Loosen the hose *cl*amps on the fuel rod cover tube hoses next to each cylinder head and slide each hose and clamp up on the tube in the governor housing.

21. Remove the two bolts and washers through the top of each end plate which secure the blower to the cylinder block.

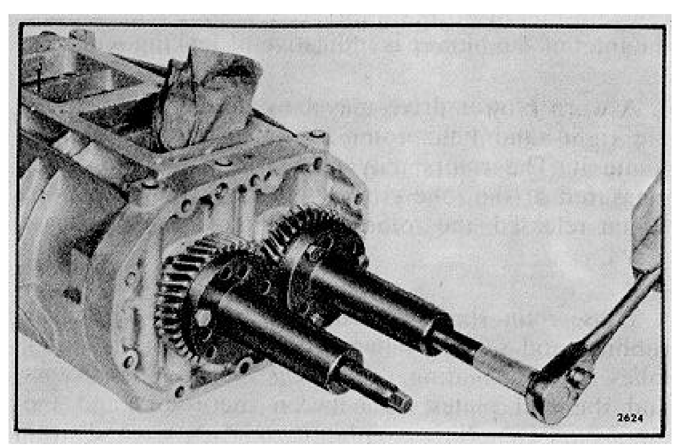


FIG. 4 - Removing Blower Gears with Tool J 6270-31

22. Remove the blower-to-block bolts and retaining washers on each side of the blower.

23. Disconnect and remove any tubing or accessories which may interfere with removal of the blower.

24. Thread eyebolts in the diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts.

25. Lift the blower up slightly and move it forward to detach the blower from the seal at the drive end. Then lift the blower up and away from the engine. Remove the blower gasket.

With the blower, fuel pump and governor assembly removed from the engine, cover the air inlet and outlet openings of the blower housing and install the governor cover. Wash the exterior of the blower and governor housing with clean fuel oil and dry them with compressed air.

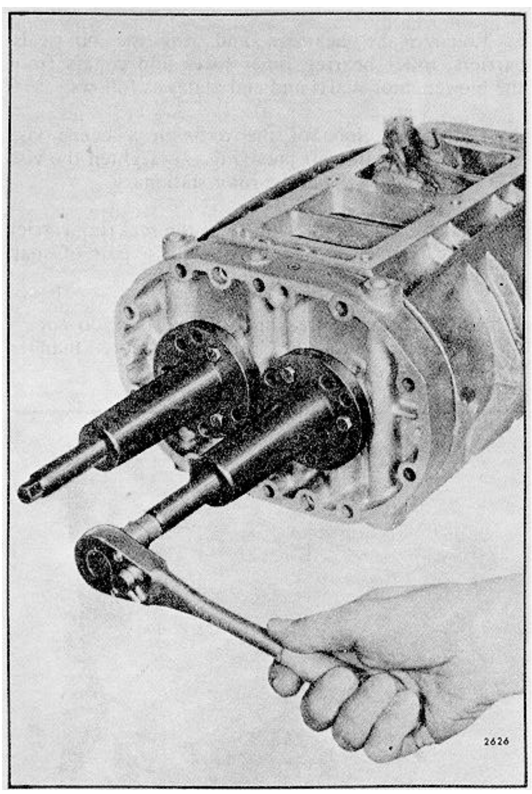


FIG. 5 - Removing Blower End Plate and Bearings from Housing and Rotors with Tool J 6270-31

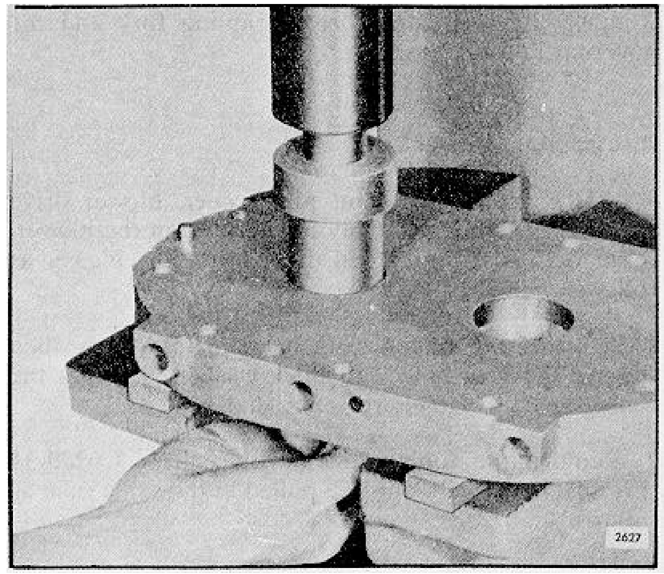


FIG. 6 - Removing Oil Seal Ring Collar and Bearing from End Plate with Tool J 6270-3

Remove Blower Rear End Plate Cover

Remove the blower rear end plate cover, governor and fuel pump assembly from the blower as follows:

1. Remove the remaining bolts, lock washers and special washers securing the rear end plate cover to the end plate. Remove the cover and gasket from the end plate.

2. Remove the three bolts and washers securing the flex plates to the right-hand blower rotor gear. Remove the drive hub from the gear.

> **NOTE:** The thin hub spacers are not readily accessible, and some mechanics may not be aware that they are behind the *new* flex plate. Consequently, when working on the blower hub assemblies, remove the flex plate attaching bolts carefully to avoid dropping the thin hub spacers into the gear train. If spacers are inadvertently dropped into the gear train, removal of the engine flywheel housing and/or oil pan may be required to retrieve them.

3. Note the location of the two copper washers, one plain washer and eight lock washers on the governor- to-blower bolts before removing them. Then remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.

4. Tap the sides of the governor housing slightly with a plastic hammer to loosen the governor from the blower. Then pull the governor and fuel pump assembly from the dowels in the blower end plate.

Remove the fuel pump drive coupling fork and the governor housing gasket.

Disassemble Blower

With the blower rear end plate cover, blower drive hub and governor assembly removed from the blower, refer to Figs. 1 and 9 and disassemble the blower as follows:

1. Place a clean folded cloth between the rotors, then remove the lock bolts and thick washers securing the timing gears to the blower rotor shafts.

2. Remove the timing gears with pullers J 6270-31 (Fig. 4). Both gears must be pulled at the same time as follows:

a. Back out the center screws of both pullers and place the flanges against the gear faces, aligning the flange holes with the tapped holes in the gears. Secure the pullers to the gears with-5/16"- 24 x 1-1/2" bolts (two bolts on the L.H. helix gear and three bolts on the R.H. helix gear).
b. Turn the two puller screws uniformly clockwise and withdraw the gears from the rotor shafts as shown in Fig. 4.

3. Remove the shims from the rotor shafts, after the gears have been removed, and note the number and thickness of shims on each rotor shaft to ensure identical replacement when reassembling the blower.

4. Remove the self locking screws securing the rotor shaft bearing retainers to the front and rear end plates. Remove the retainers.

5. Remove the blower rear end plate and ball bearing assembly from the blower housing and rotors with the two pullers J 6270-31 as follows:

a. Remove the two fillister head screws securing the rear end plate to the blower housing and loosen the two fillister head screws securing the front end plate to the housing approximately three turns.
b. Back out the center screws of the pullers far enough to permit the flange of each puller to lay flat on the face of the end plate.
c. Align the holes in each puller flange with the tapped holes in the end plate and secure the pullers to the end plate with six 1/4"1-20 x 1-1/4" or longer bolts.

NOTE: Be sure that the 1/4"-20 bolts are threaded all the way into the tapped holes in the end plate to provide maximum anchorage for the pullers and to eliminate possible damage to the end plate.

d. Turn the two puller screws uniformly clockwise and withdraw the end plate and bearings from the blower housing and rotors as shown in Fig. 5.

6. Remove the blower front end plate and roller bearing assembly from the blower housing and rotors as follows:

a. Remove the fuel pump drive bolt, washer and spacer.

b. Remove the two fillister head screws securing the front end plate to the blower housing.

c. Remove the front end plate and roller bearings from the housing and rotors.

7. Withdraw the blower rotors from the housing.

8. Remove the bearings and *ring-type* oil seals, carriers, roller bearing inner races and collars from the blower rotor shafts and end plates as follows:

a. Clamp one lobe of the rotor in a bench vise equipped with soft jaws (Fig. 7). Tighten the vise just enough to hold the rotor stationary.

b. Remove the oil seal ring from the seal ring carrier on each blower rotor shaft with a pair of snap ring pliers as shown in Fig. 7.

NOTE: To avoid breakage or distortion, do not spread or twist the ring any more than necessary to remove it.

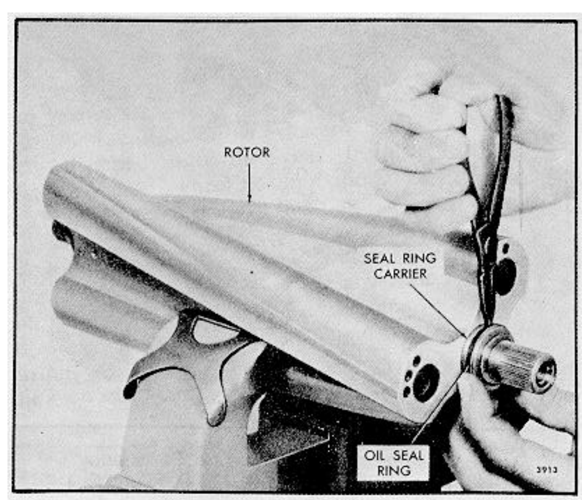


FIG. 7 - Removing Oil Seal Ring from Carrier

c. Refer to Fig. 8 and place the seal ring carrier remover adaptor J 6270-2 over the carrier. Make sure the adaptor is seated in the groove of the carrier.

d. Back out the center screw of puller J 6270-31 far enough to permit the puller flange to lay flat against the adaptor J 6270-2.

e. Place the puller over the end of the rotor shaft and against the adaptor on the oil seal ring carrier. Align the holes in the puller flange with the tapped holes in the adaptor, then secure the puller to the adaptor with two bolts.

f. Turn the puller screw clockwise and pull the oil seal ring carrier and roller bearing inner race (front end of blower rotors only) from the rotor shaft (Fig. 8).

g. Remove the remaining oil seal ring carriers from the rotor shafts in the same manner.

h. Refer to Fig. 6 and support the outer face of the blower end plate on wood blocks on the bed of an arbor press.

i. Place the long end of the oil seal remover and installer J 6270-3 down through the oil seal ring collar and into the bearing, with the opposite end of the remover under the ram of the press (Fig. 6). Then press the bearing and oil seal ring collar out of the end plate.

j. Remove the remaining bearings and oil seal ring collars from the end plates in the same manner.

The oil seal ring collar can be removed from the blower end plate with the bearing in place as follows:

a. Insert the two piece collar remover with the rubber "O" ring J 26221-15 in the collar with the lip of the remover on the inside edge of the collar.

b. Support the inner face of the blower end plate on wood blocks.

c. Insert the small end of the driver handle J 26270- 17 through the inside diameter of the bearing and into the collar remover, spreading it tight in the collar.

d. Press or tap on the driver handle to remove the collar.

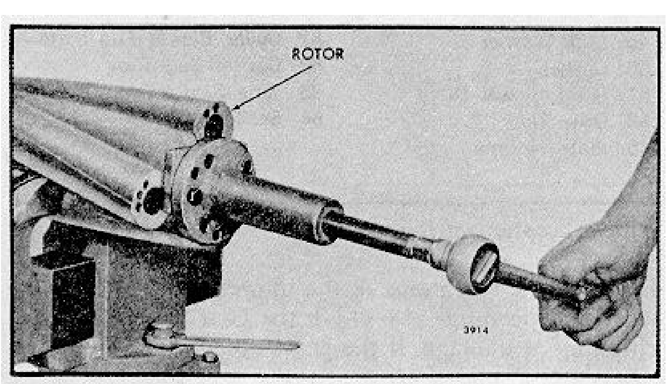


FIG. 8 - Removing Oil Seal Ring Carrier from Blower Rotor Shaft with Tools J 6270-2 and J 6270-31

Inspection

Wash all of the blower parts in clean fuel oil and dry them with compressed air.

Examine the bearings for any indications of corrosion or pitting. Lubricate each ball bearing with light engine oil. Then, while holding the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.

The double-row ball bearings are pre-loaded and have no end play. A new bearing will seem to have considerable resistance to motion when revolved by hand.

Check the oil seal rings, carriers and collars for wear and scoring. If worn excessively, they must be replaced. The current oil seal rings are chrome flashed and the carriers are liquid nitrided. When replacement of an oil seal ring or carrier is necessary, both parts must be replaced together.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. Rotors must be smooth for satisfactory operation of the blower. If the rotors are slightly scored or burred, they may be cleaned up with emery cloth.

Examine the rotor shaft serrations for wear, burrs or peening. Also inspect the bearing and oil seal contact surfaces of the shafts for wear and scoring.

Inspect the inside surface of the blower housing for burrs and scoring. The inside surface must be smooth for efficient operation of the blower. If the inside surface of the housing is slightly scored or burred, it may be cleaned up with emery cloth.

Check the finished ends of the blower housing for flatness and burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be

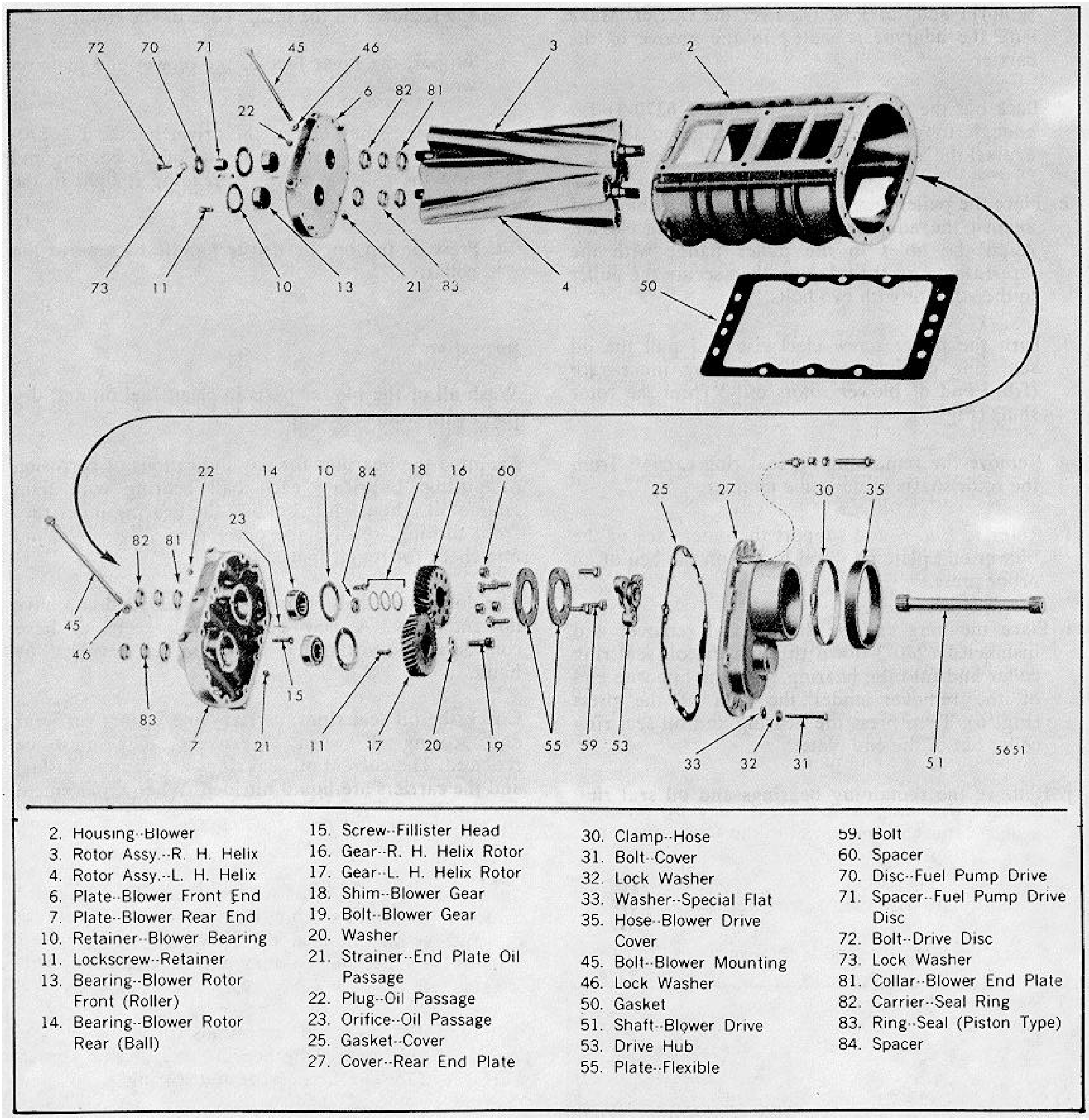


FIG. 9 -Blower Details and Relative Location of Parts

smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

NOTE: Be careful not to remove metal at the joint face between the end plates and the housing. Air or oil leaks could develop after assembly.

Examine the serrations in the blower timing gears for wear and peening; also check the gear teeth for wear, chipping or damage. If the gears are worn to the point where the backlash between the gear teeth exceeds .004" or damaged sufficiently to require replacement, both gears must be replaced as a set.

Check the blower drive shaft serrations for wear or

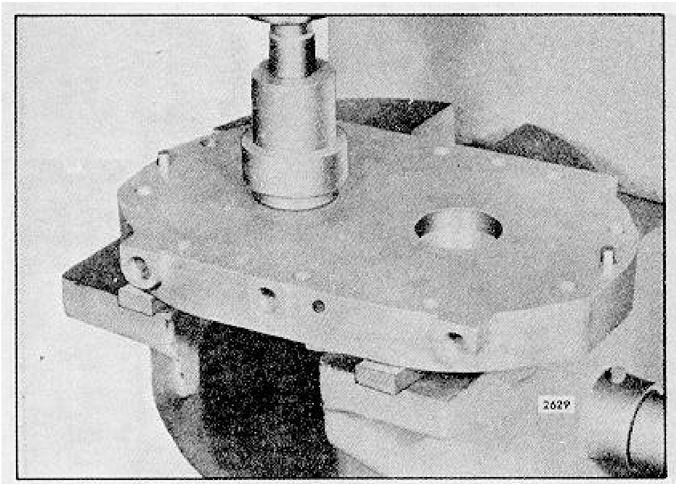


FIG. 10 - Installing Oil Seal Ring Collar in End Plate with Tool J 6270-3

peening. Replace the shaft if it is bent, cracked or has excessive spline wear.

Replace all worn or excessively damaged blower parts.

Clean the oil- strainer in the vertical oil passage at the bottom side of each blower end plate and blow out all oil passages with compressed air.

Assemble Blower

Several precautions are given below to assure proper assembly of the rotors and gears for correct blower timing.

1. The lobes on the *driving* blower rotor and the teeth on its gear form a right-hand helix while the lobes and teeth of the *driven* rotor and gear form a left-hand

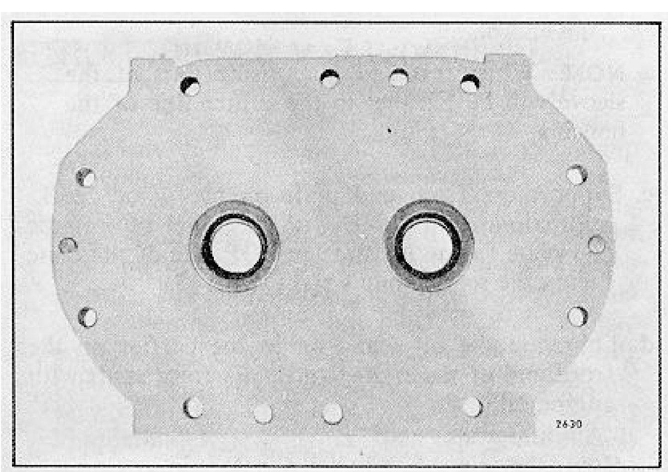


FIG. 11 - Location of Oil Seal Ring Collars in End Plate

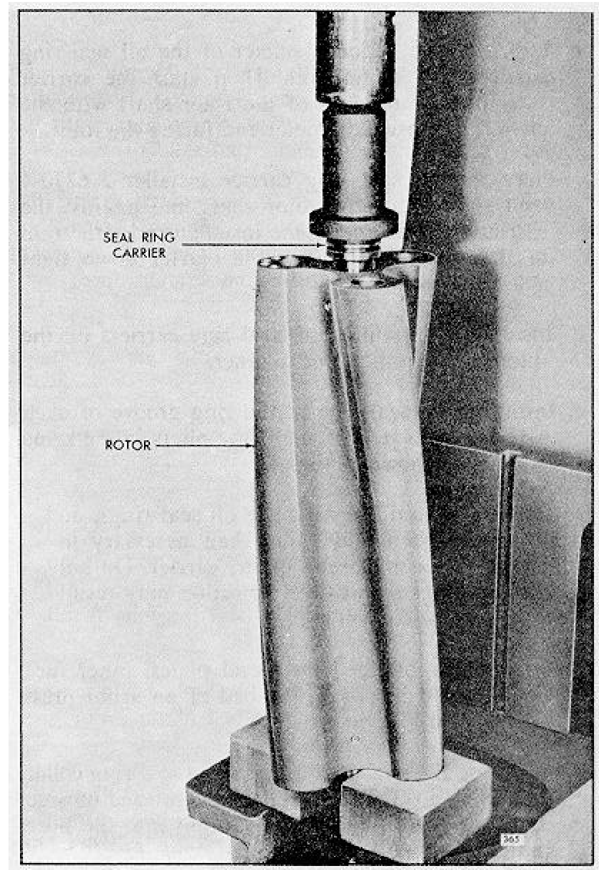


FIG. 12 - Installing Oil Seal Ring Carrier on Blower Rotor Shaft with Tool J 6270-4

helix. Hence, a rotor with right-hand helix lobes must be used with the gear having right-hand helix teeth and vice versa.

2. One serration is omitted on the drive end of each blower rotor shaft and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serrations in alignment.

3. The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned as shown in Fig. 21.

With these precautions in mind, proceed with the blower assembly, referring to Figs. 9 through 21 as directed in the text:

Install the *ring-type* oil seal, carriers, collars and roller bearing inner races (front end of blower rotors only) on the rotor shafts and in the end plates as follows:

a. Support one of the rotor assemblies on wood blocks on the bed of an arbor press as shown in Fig. 12.

b. Lubricate the inside diameter of the oil seal ring carrier with engine oil. Then start the carrier straight over the end of the rotor shaft with the chamfered inside diameter end facing the rotor.

c. Place the oil seal ring carrier installer J 6270-4 over the end of the rotor shaft and against the carrier with the end of the installer under the ram of the press. Then press the carrier down tight against the rotor.

d. Install the remaining oil seal ring carriers on the rotor shafts in the same manner.

e. Install an oil seal ring in the ring groove of each carrier with a pair of snap ring pliers in the same manner as shown in Fig. 7.

NOTE: To avoid breaking the oil seal rings, do not spread them any more than necessary to place them over the end of the carrier. Do not twist the rings or possible distortion may result in loss of side contact area.

f. Support one of the blower end plates, inner face up, on wood blocks on the bed of an arbor press as shown in Fig. 10.

g. Lubricate the outside diameter of a seal ring collar with engine oil. Then start the chamfered outside diameter end of the collar straight into the bore in the end plate.

h. Place the oil seal ring collar installer J 6270-3 on top of the seal ring collar and under the ram of the press (Fig. 10). Then press the collar into the end plate until the shoulder on the installer contacts the end plate.

NOTE: A step under the shoulder of the installer will position the collar approximately .005" below the finished face of the end plate. This is within the .002” to .008"' specified.

i. Install the remaining oil seal ring collars in the end plates in the sarne manner.

Assemble Rotors and End Plates

1.Install the blower rotors in the blower front end plate as outlined below.

a. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the front end plate to assure proper alignment of the end plate with the housing.

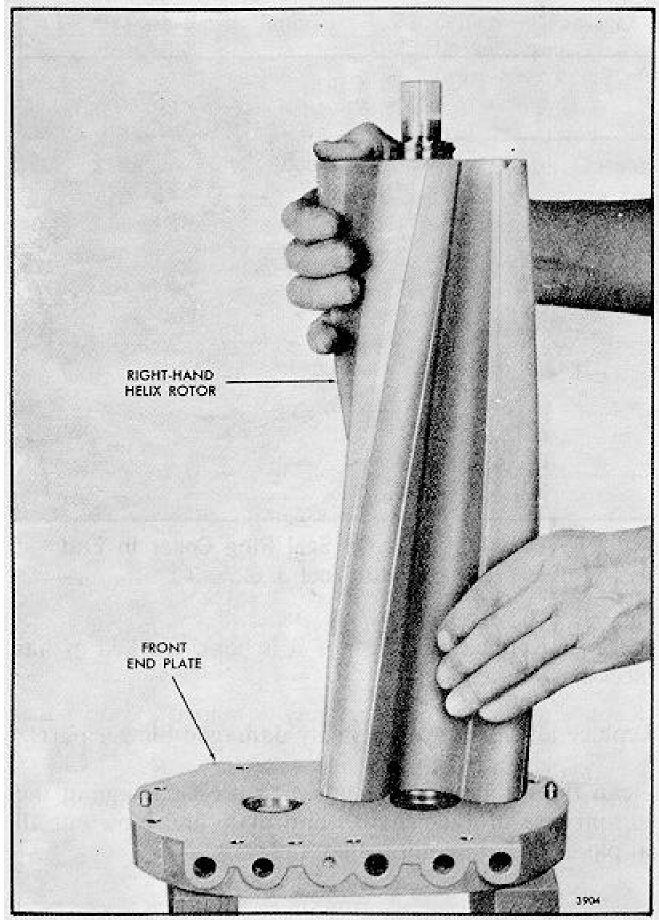


FIG. 13 - Installing Blower Rotor in Front End Plate

b. If removed, press a new bolt guide sleeve (bushing) into one boit hole in the bottom side of the end plate. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005" below the surface of the end plate.

NOTE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

c. Support the front end plate on two wood blocks approximately 4" high, with the inner face of the end plate facing up and the TOP side of the plate facing the serviceman's right (Fig. 13).

d. Lubricate the oil seal ring in the carrier on the front end of the right-hand helix rotor shaft with engine oil.

e. Hold the right-hand helix rotor in a vertical position (gear end up) and position the seal ring in the carrier so the ring protrudes from its groove the same amount on each side and the gap is facing away from the serviceman.

f. With the omitted serration in the splines of the shaft facing toward the top side of the end plate, start the end of the rotor shaft into the right-hand shaft opening in the end plate so that the gap portion of the seal ring is started into the ring collar (Fig. 13). Continue to lower the rotor and very carefully apply pressure to the seal ring approximately 180° from the gap while gently working the seal ring into the collar until the rotor contacts the end plate.

g. Perform Steps "d" and "e" above on the left-hand helix rotor.

h. Position the rotors so the lobes are in mesh and the omitted serrations in the splines of both rotor shafts are facing toward the top side of the end plate. Then install the left-hand helix rotor as in Step "f".

2. Install the blower housing over the rotors and attach it to the front end plate as follows:

a. Position the blower housing over the top of the rotors so the bottom face of the housing faces the bottom side of the front end plate. Then lower the housing over the rotors until it contacts the dowel pins in the end plate.

b. Align the dowel pin holes in the housing with the dowel pins in the end plate. Then push the housing tight against the end plate. If necessary, tap the housing lightly with a plastic hammer.

c. Insert the two fillister head screws through the front end plate and thread them into the housing. Tighten the screws to 5-10 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

3. Install the blower rear end plate on the rotor shafts and housing as follows:

a. Check the dowel pins. The dowel pins must project .320" from the flat inner face of the rear end plate to assure proper alignment of the end plate with the housing.

b. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate. Install the sleeve, with the three

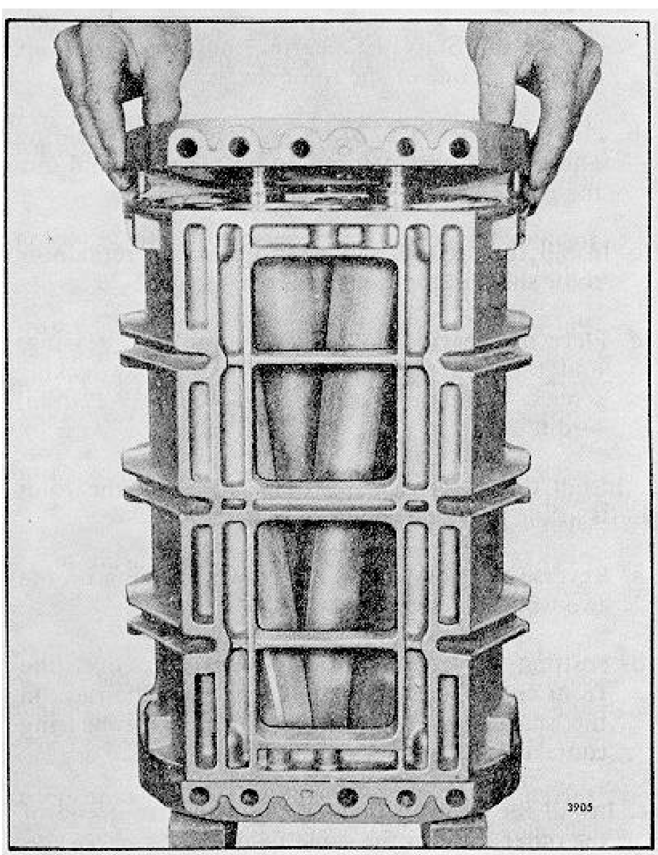


FIG. 14 - Installing Rear End Plate on Blower Rotors and Housing

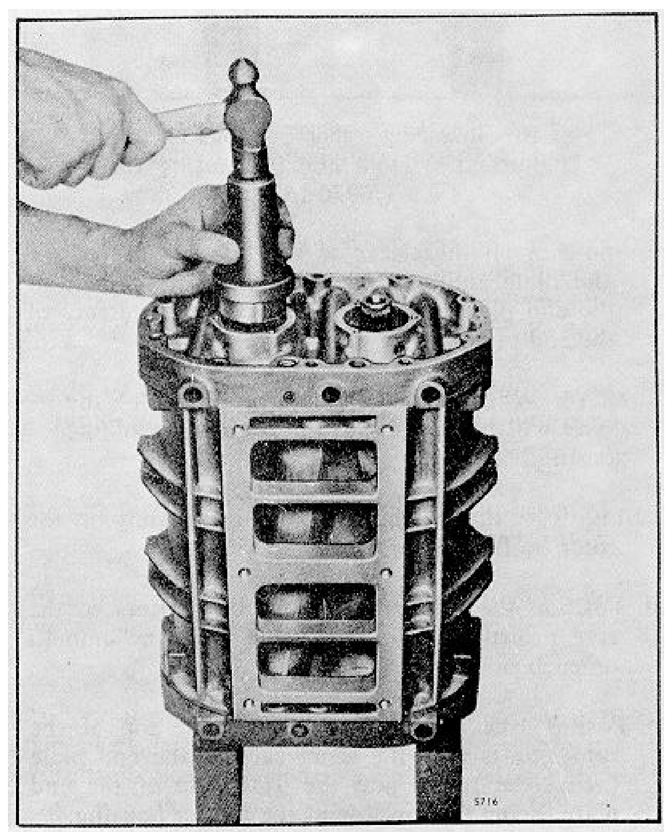


FIG. 15 Installing Ball Bearings on Rotor Shaft and in Rear End Plate using Tool J 6270-13

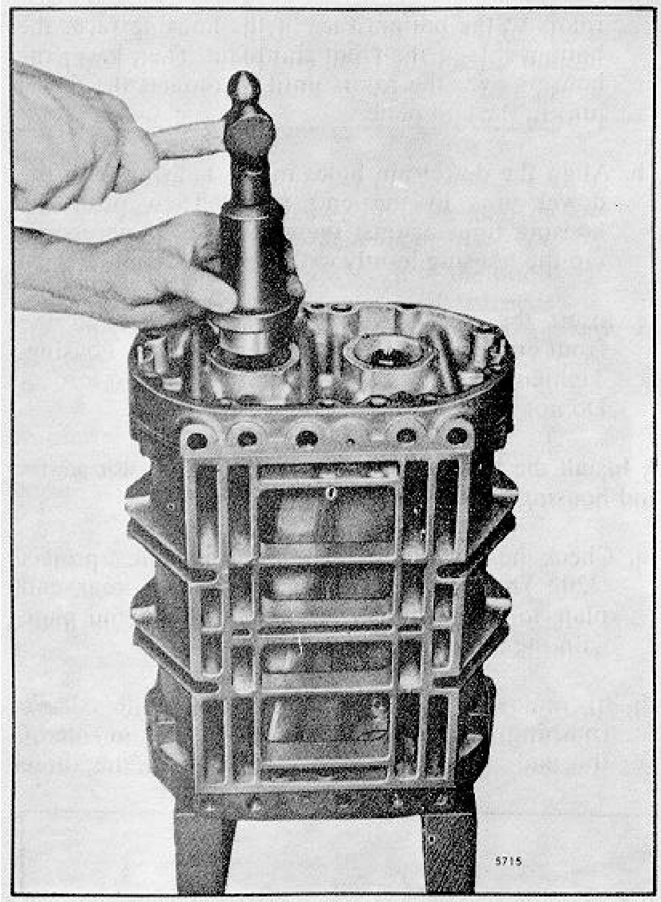


FIG. 16 - Installing Roller bearings on Rotor Shafts and in Front End Plate using Tool J 6270-13

notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to .005", below the surface of the end plate.

NOTE: When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

c. Lubricate the oil seal rings in the carriers on the rotor shaft with engine oil.

d. Position the oil seal rings in the carriers so the ring protrudes from its groove the same amount on each side.

e. Position the rear end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors and the TOP side of the end plate facing the top side of the blower housing.

f. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing (Fig. 14). Then carefully work the dowel pins into the dowel pin holes in the housing and the oil seal rings into the collars. Push the end plate tight against the housing. If necessary, tap the end plate lightly with a plastic hammer.

g. Insert the two fillister head screws through the rear end plate and thread them into the housing. Tighten the screws to 5-10 lb-ft (7-14 Nm) torque. Do not use lock washers on these screws.

4. Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than .0005" above to .0065 " below the end plate. Excessive protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

Install Blower Rotor Shaft Bearings and Gears

1. With the blower housing, rotors and end plates still supported in a vertical position on the two wood blocks, install the ball bearings on the rotor shafts and in the rear end plate as follows:

a. Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

b. Place installer J 6270-13 on top of the bearing and tap the bearing straight on the shaft and into the rear end plate as shown in Fig. 15.

c. Install the second ball bearing on the remaining rotor shaft in the same manner.

d. Place the bearing retainers on top of the bearings and the end plate. Then install the self-locking screws. Tighten the screws to 7-9 lb-ft (9-12 Nm) torque.

2. Install the roller bearing inner races on the rotor shafts at the front end plate as follows:

a. Reverse the position of the blower housing on the two wood blocks (Fig. 16).

b. Position the roller bearing inner race over the front end of the rotor shaft and press the race on the shaft with tool J 6270-13 until the bearing contacts the shoulder on the shaft.

c. Install the bearing inner race on the front end of the other rotor in the same manner.

3. Install the roller bearing outer race assemblies in the front end plate as follows:

a. Lubricate one of the roller bearings with light engine oil. Start the bearing (shoulder side up) over the rotor shaft and bearing inner race and into the end plate.

b. Place installer J 6270-13 on top of the bearing and tap the bearing straight on the shaft and into the front end plate as shown in Fig. 16.

c. Install the second roller bearing on the remaining rotor shaft in the same manner.

d. Place the bearing retainers on top of the bearings and the end plate. Then install three self-locking retainer screws in each retainer. Tighten the screws to 7-9 lb-ft (9-12 Nm) torque.

4. Make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gage as shown in Fig. 21. Refer to Fig. 19 for minimum blower clearance.

5. Before installing the blower rotor timing gears on the rotor shafts, observe precautions "2" and "3" relative to the rotor shaft and timing gear alignment under *Assemble Blower.*

The center punch mark in the end of each rotor shaft at the omitted serration will assist in aligning the gears on the shafts.

If shims were removed from the back side of the gears (between the inner race of the bearing and the gear), they should be replaced in their original positions before installing the gears on their respective shafts.

Install the blower timing gears as follows:

a. Place the blower assembly on a bench, with the top of the housing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench.

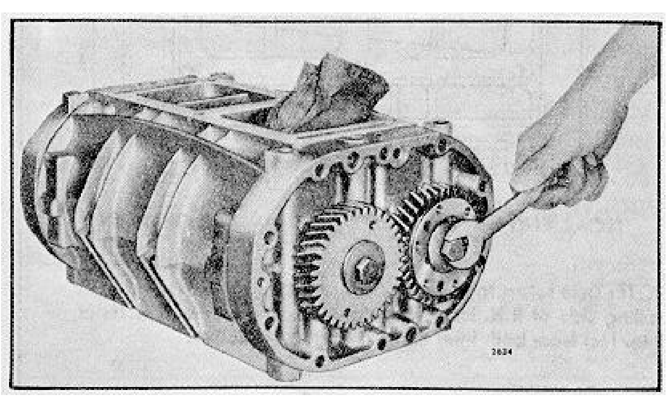


FIG. 17 - Installing Blower Rotor Timing Gears

b. Rotate the rotors to bring the omitted serrations on the shafts in alignment and facing to the left.

c. Install a .140" thick gear spacer and the same number and thickness of shims on each rotor shaft that were removed at the time of disassembly.

d. Lubricate the serrations of the rotor shafts with light engine oil.

e. Place the teeth of the rotor gears in mesh so that the omitted serrations inside the gears are in alignment and facing the same direction as the serrations on the shafts.

f. Start both rotor gears straight on the rotor shafts with the right-hand helix gear on the right-hand helix rotor and the left-hand helix gear on the left-hand helix rotor, with the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.

g. Thread a 1/2"-20 x 1-1/4" bolt with a thick washer into the end of each rotor shaft. Place a clean folded cloth between the lobes of the rotors to prevent the gears from turning. Draw the gears into position tight against the spacers and shims and the bearing inner races as shown in Fig. 17.

h. Remove the two bolts and washers that were used to draw the gears into position on the rotor shafts.

i. Lubricate the threads of the 1/2"-20 x I 1/2" gear retaining bolts with engine oil. Place a spacer (.340" thick) on each of the bolts and thread them into the rotor shafts. Tighten the bolts to 100-1 10 lb-ft (136-150 Nm) torque. Remove the cloth from the blower rotors.

Timing Blower Rotors

After the blower rotors and timing gears are installed, the blower rotors must be timed.

NOTE: Before timing the blower, install four 5/16"-18 x 1-7/8" bolts with flat washers through four bolt holes in each end plate (top and bottom) and thread them into the blower housing (Fig. I1). Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque. This will hold the end plates against the blower housing so the proper clearance between the rotors and the end plate can be obtained.

1. The blower rotors, when properly positioned in the housing, run with a slight clearance between the lobes. This clearance may be varied by moving one of the

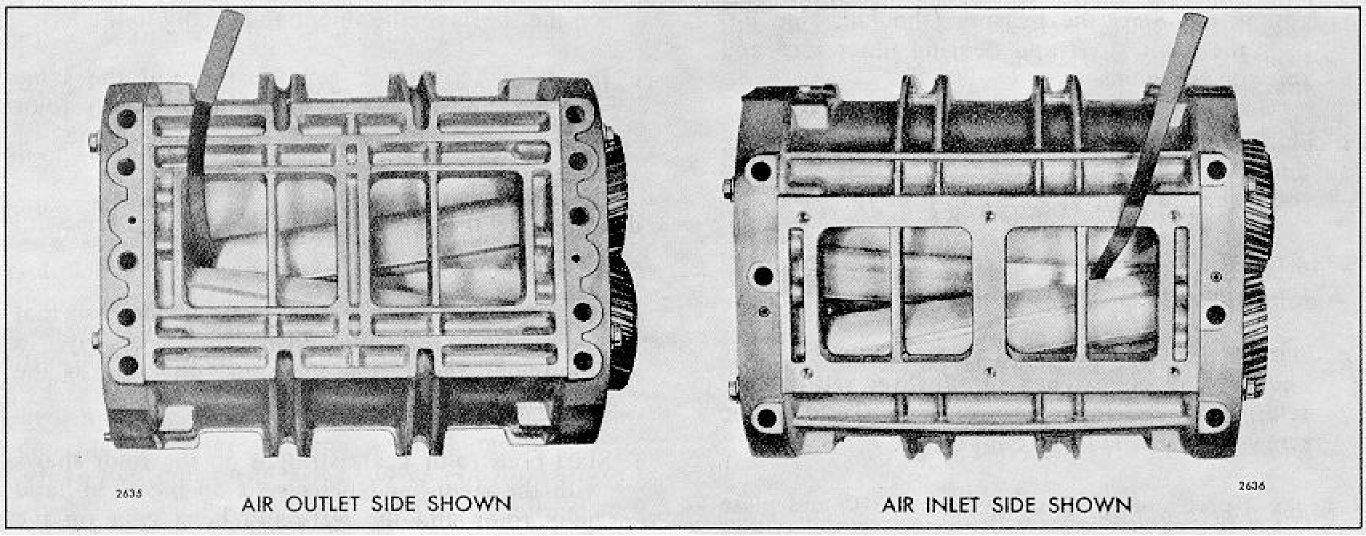


FIG. 18 - Measuring “CC” and “C” Clearance Between Blower Rotor Lobes

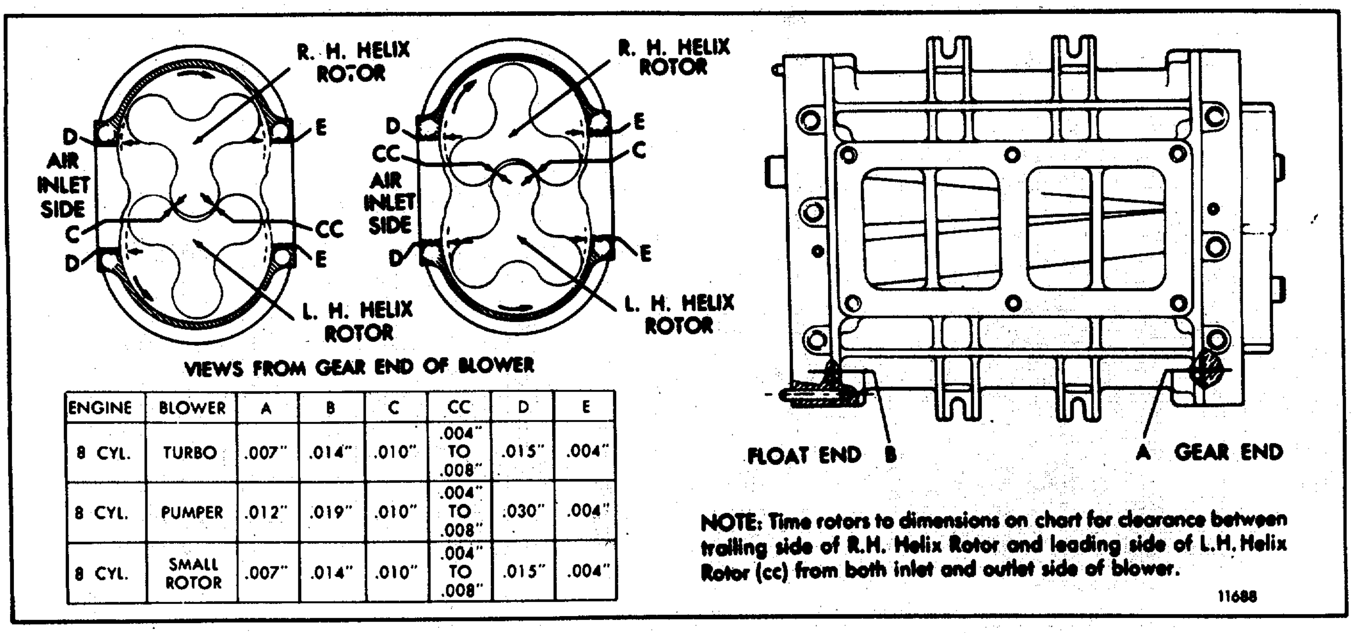
helical gears in or out on the shaft relative to the other gear.

2. If the right-hand helix gear is moved out, the right-hand helix rotor will turn counterclockwise when viewed from the gear end. If the left-hand helix gear is moved out, the left-hand helix rotor will turn clockwise when viewed from the gear end. This positioning of the gears, to obtain the proper clearance between the rotor lobes, is known as blower timing.

3. Moving the gears OUT or IN on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

4. The clearance between the rotor lobes may be checked with 1/2"1 wide feeler gages in the manner shown in Fig. 18. When measuring clearances of more than .005", laminated feeler gages that are made up of .002", .003", or .005" feeler stock are more practical and suitable than a single feeler gage. A specially designed feeler gage set J 1698-02 for the blower clearance operation is available. Clearances should be measured from both the inlet and outlet sides of the blower.

5. Refer to Figs. 18 and 19 and time the rotors to the specified clearance between the *trailing* edge of the



ENGINE	BLOWER	A	B	C	CC	D	E
8 CYL.	TURBO	.007"	.014"	.010"	.004" TO .008"	.015"	.004"
8 CYL.	PUMPER	.012"	.019"	.010"	.004" TO .008"	.030"	.004"
8 CYL.	SMALL ROTOR	.007"	.014"	.010"	.004" TO .008"	.015"	.004"

FIG. 19 - Chart of Minimum Blower Clearances

right-hand helix rotor and the *leading* edge of the left-hand helix rotor ("CC" clearance) measured from both the inlet and outlet sides. Then check the clearance between the *leading* edge of the right-hand helix rotor and the *trailing* edge of the left-hand helix rotor ("'C" clearance) for the minimum clearance. Rotor-to-rotor measurements should be taken 1" from each end and at the center of the blower.

6. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims back of the proper gear as shown in Fig. 20 to produce the desired result. When more or less shims are required, both gears must be removed from the rotors. Placing a .003" shim in back of a rotor gear will revolve the rotor .00 I".

7. Install the required thickness of shims back of the proper gear and next to the .140" thick gear spacer which is against the bearing inner race and re-install both gears. Recheck the clearances between the rotor lobes.

8. Determine the minimum clearances at points "A" and "B" shown in Fig. 19. Insert the feeler gages, as shown in Fig. 2 1, between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making 12 measurements in all. Refer to Fig. 19 for the minimum clearances.

9. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side --12 measurements in all. Refer to Fig. 19 for the minimum clearances.

After the blower rotors are timed, complete assembly of the blower as outlined below:

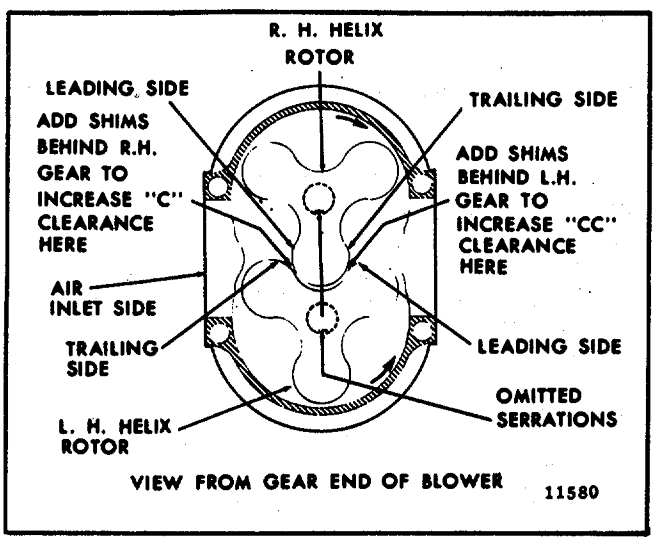


FIG. 20 Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearances

1. Place the fuel pump drive disc spacer over the forward end of the right-hand helix rotor shaft. Then place the special lock washer and the drive disc on the retaining bolt and thread the bolt into the rotor shaft against the spacer. Tighten the bolt to 55-65 lb-ft (75-88 Nm) torque. Bend one tang of the lock washer over into the slot in the drive disc and two tangs over against the flat sides of the bolt head.

2. Attach the two flex plates and spacers to the drive hub with three new washer head type lock patch bolts. *Do not attempt to reuse parch bolts.* Tighten the bolts to 25-30 lb-ft (34-41 Nm) torque.

NOTE: Only the *new* flex plates, bolts and thin hub spacers should be used to service V-71 engines with large bearing blowers.

3. Attach the drive hub and spring plate assembly to the right-hand helix blower rotor timing gear with three spacers, bolts, flat washers and lock washers. Tighten the bolts to 25-30 lb-ft (34-41 Nm) torque.

4. Affix a new gasket to the blower rear end plate cover. Place the cover over the gears and against the end plate, with the opening in the cover over the blower drive hub attached to the right-hand helix gear. Install the rear cover using ten 5/16"-18 x 2-1/4" bolts and lock washers. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

NOTE: The tab on the gasket is to assure the gasket is in place.

5. On all 8V engines, attach the lubricating oil tube and dry seal connector to the rear blower end plate when installing the blower on the engine.

6. Attach the governor and fuel pump assembly to the blower as follows:

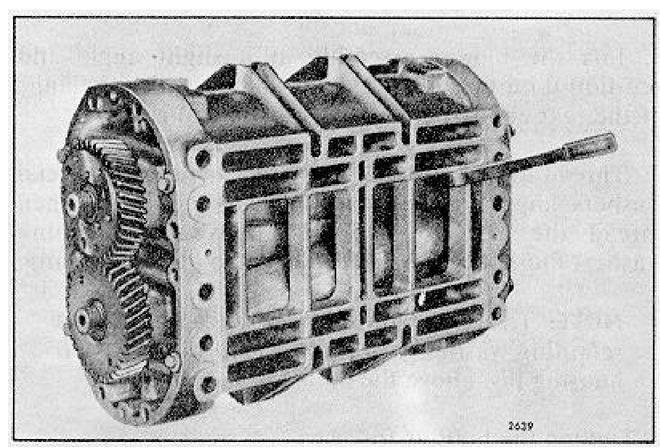


FIG. 21 Measuring End Clearance Between Blower Rotors and End Plate

a. Affix a new gasket to the forward face of the blower end plate.

b. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the prongs of the fork align with the slots in the drive disc. Rotate the weight shaft and align the splines on the shaft with the splines in the blower rotor.

c. Push the governor straight on the dowel pins in the blower end plate and against the gasket.

d. Refer to Section 2.7.1 for the location and install the bolts, lock washers, copper washers and plain washer which secure the governor to the blower. Tighten the bolts to 13-17 lb-ft (18-23 Nm) torque.

Install Slower on Engine

Refer to Fig. 3 and install the blower assembly on the engine as follows:

1. Affix a new blower housing gasket to the cylinder block with Scotch Grip rubber adhesive No. 1300, or equivalent, to prevent the gasket from shifting when the blower is lowered into position.

2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing and tighten the clamps.

3. Place the blower end plate cover seal ring and clamp on the end of the blower drive support.

4. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Then attach a rope sling and chain hoist to the eyebolts.

5. Lift the blower assembly at a slight angle and position it on top of the cylinder block, with the flange of the rear end plate cover inside the seal ring.

6. Thread two 7/16"-14 x 8-1/4" bolts and special washers finger tight in each blower end plate. Then thread the 3/8"-16 x 5-1/2" bolts and retaining washers finger tight at each side of the blower housing.

NOTE: The lip at the beveled end of the bolt retaining washer goes in the small recess in the housing just above the bolt slot.

7. Tighten the bolts as follows:

a. First tighten the blower-to-block end plate bolts to 40-45 lb-ft (54-61 Nm) torque.

b. Then tighten the blower housing-to-block side angle bolts uniformly to 30-35 lb-ft (41-47 Nm) torque in 5 lb-ft (7 Nm) increments.

c. Recheck the blower-to-block end plate bolts.

8. Place the blower rear end plate cover seal ring and hose clamp into position and tighten it. The former rubber seal ring (.740" wide) incorporates two raised edges which provide a groove to retain the hose clamp.

NOTE: To retain seal load on the molded blower drive seal rings, a new 4.87" diameter spring loaded T-bolt style clamp is now being used.

After installing the new T-bolt style clamp on the blower drive seal, tighten the clamp nut on the bolt until the spring in the clamp is completely compressed.

9. Connect the lubricating oil tube to the fitting in the blower drive support.

10. Insert the blower drive shaft through the blower drive coupling and into the blower drive hub (Fig. 1). Install the snap ring in the coupling. Then attach the flywheel housing cover to the flywheel housing.

NOTE: The new 48-tooth *blower drive shafts* have been carbonitride hardened and drilled to accept a spring. The spring *must* be removed for 8V and 16V-71 usage. To remove the spring, grasp it firmly with pliers and pull it out. Make sure the entire spring has been removed before using the drive shaft.

11. Attach the tachometer drive adaptor, if used, to the blower. Then connect the tachometer drive cable to the drive adaptor.

12. Slide each fuel rod cover tube hose down on the cover tubes attached to the cylinder heads and tighten the hose clamps.

13. Install the fuel rods between the cylinder heads and governor as follows:

a. Insert the end of the left-bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

b. Raise the connecting pin up in the connecting link lever. Insert the end of the fuel rod between the two bosses on the lever and insert the connecting pin through the fuel rod and into the lower boss.

c. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

d. Insert the end of the right,-bank fuel rod through the hole in the cylinder head and up through the fuel rod cover tube to the control link operating lever.

e. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.

f. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

14. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the speed control or stop lever shaft assembly in the slot in the differential lever and the dowel pins in the housing in the dowel pin holes in the cover. Install the eight cover attaching screws and lock washers. Tighten the screws securely.

15. If the engine is equipped with a variable speed governor, attach the governor booster spring to the speed control lever.

16. If the. engine is equipped with a battery-charging alternator, attach the alternator and support bracket to the cylinder head and connect the wires to the alternator.

17. Install and connect the crossover fuel oil line to each cylinder head and connect the fuel oil lines to the fuel pump.

18. If removed, install the front engine lifter bracket.

19. Place the water bypass tube between the two thermostat housings and slide the hoses part way on the thermostat housings. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Then tighten the hose clamps.

20. Attach the air shutdown adaptor to the blower and the air shutdown housing assembly to the adaptor as, outlined in Section 3.3.

21. Connect the cable assembly to the air shut-off cam pin handle at the side of the air shutdown housing.

22. Install the turbocharger and attaching parts (Section 3.5).

23. Connect the air cleaner to the turbocharger tubing as required (Section 3.5).

24. Connect the throttle control rods to the speed control and stop levers on the governor.

25. Attach any other accessories to the engine that were removed.

26. Close the drain cocks and fill the engine cooling system.

27. Perform the governor and injector rack control adjustment as outlined in Section 14. Check for and correct any coolant or oil leaks detected.

TURBOCHARGER (Airesearch)

The turbocharger (Figs. 1 and 2) is designed to increase the over-all efficiency of the engine. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

The turbocharger consists of a radial inward flow turbine wheel and shaft, a centrifugal compressor wheel, and a center housing which serves to support the rotating assembly, bearings, seals, turbine housing and compressor housing. The center housing has connections for oil inlet and oil outlet fittings.

The turbine wheel is located in the turbine housing and is mounted on one end of the turbine shaft. The compressor wheel is located in the compressor housing and is mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly.

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings which are retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings, thrust washer, thrust collar and thrust spacer.

The turbine housing is a heat resistant alloy casting which encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially-located turbocharger exhaust gas outlet. The T18A40 turbine housing is bolted to the turbine end of the center housing and the TV71 and 81 turbine housings are secured to the turbine end of the center housing with a "V" band coupling, thus providing a compact and vibration free assembly.

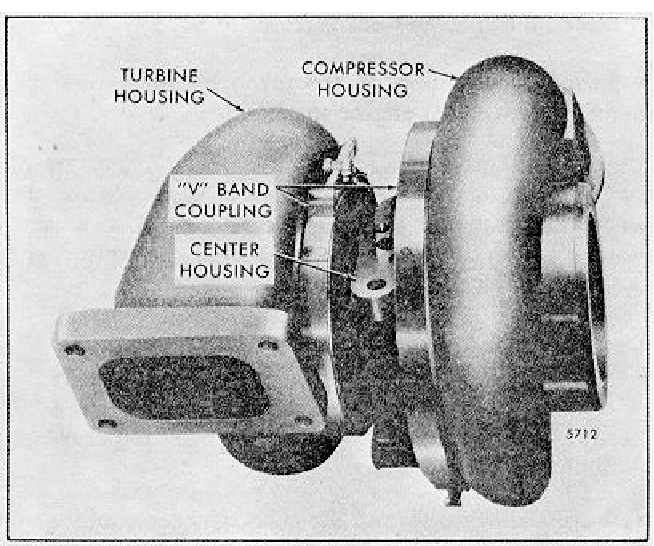


FIG. 1 Typical Turbocharger Assembly

Fig. 1 - Typical Turbocharger Assembly

The compressor housing which encloses the compressor wheel provides an ambient air inlet and a compressed air discharge outlet. The compressor housing is secured to the compressor end of the center housing backplate assembly with a "V" band coupling.
The Airesearch T1 8A40 and Schwitzer 4MF-782 turbochargers are interchangeable on the 6 and 8V-71 engines, only (see Table 1).

Airesearch T1 8A40 A/R	**Schwitzer 4MF-782 IN^2**
1.0	4.7
1.50	6.54

TABLE 1

NOTE: Due to Certification implications, the Airesearch thick blade 1.5 and 1.0 A/R turbochargers cannot be interchanged on Certified automotive engines.

Operation

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate (Fig. 3). The gases are discharged into the atmosphere after passing through the turbine housing.

The compressor wheel, which is mounted on the opposite end of the turbine wheel shaft, rotates with the turbine wheel. The compressor wheel draws in fresh air, compresses it and delivers high pressure air through the engine blower to the engine cylinders.

During operation, the turbocharger responds to the engine load demands by reacting to the flow of the engine exhaust gases. As the engine power output increases or decreases, the turbocharger responds to the engine's demand to deliver the required amount of air under all conditions.

Certain vehicle engines, to comply with the emission standards, are equipped with an aftercooler to cool the air going into the engine, after it passes through both the turbocharger and the engine blower (refer to Section 3.5.3).

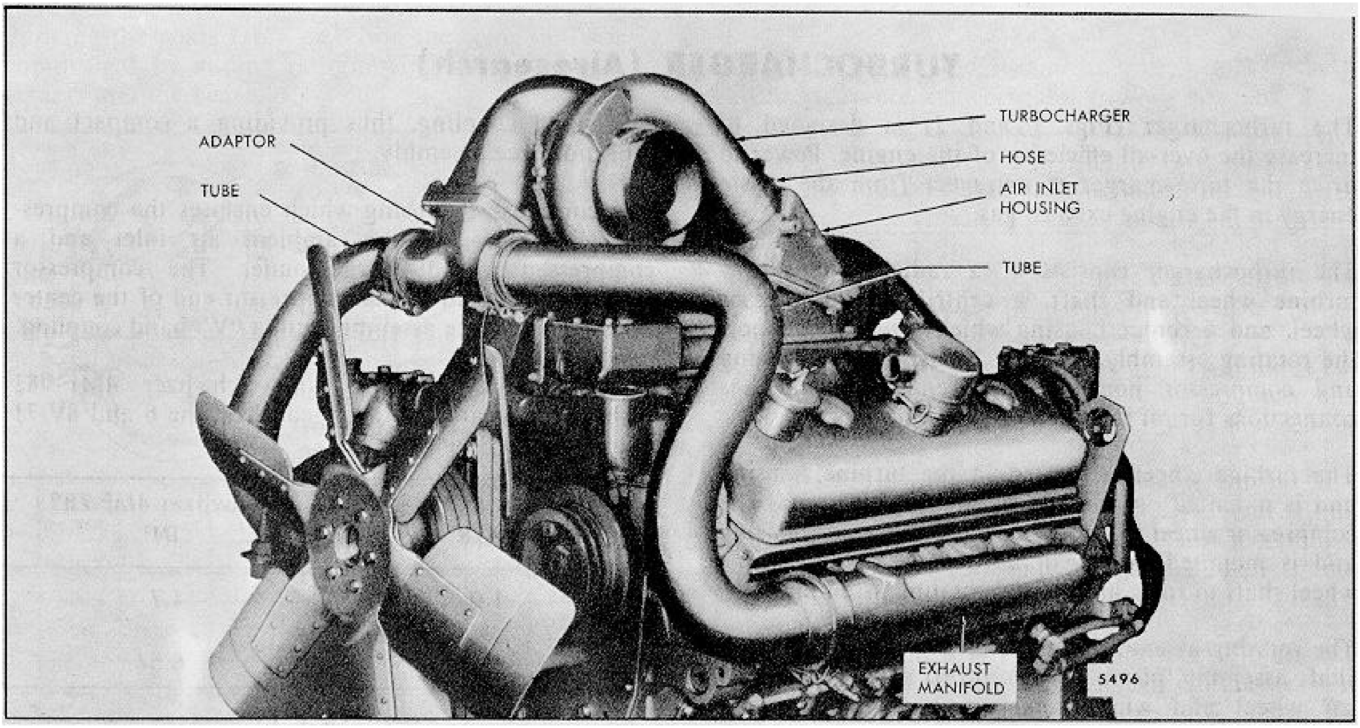


FIG. 2 - Typical Turbocharger Mounting

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing and backplate or thrust plate (Fig. 4). The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block. Before the initial engine start, when .a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger.*

NOTE: Failure to perform the prelubrication procedure may result in premature bearing failure due t6 *oil lag* or lack of lubrication.

Periodic Inspection

NOTE: A turbocharger compressor inlet shield J 26554, (Fig. 5) is available for use anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects from entering the turbocharger and prevents a serviceman from touching the moving impeller. The use of this shield *does not* preclude any other safety practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust rnanifold gasket.

NOTE: Do not operate the engine it leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.-

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air

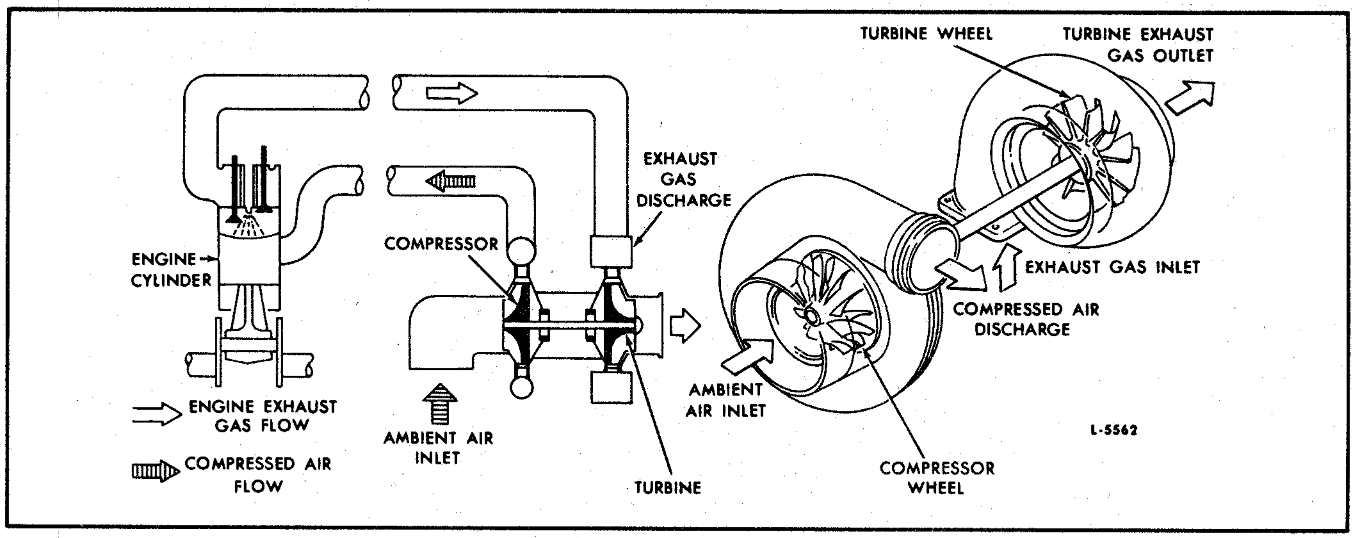


FIG. 3 - Schematic Air Flow Diagram

filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Trouble Shooting Charts* (Fig. 6). Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

NOTE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt and dust build-up.

For proper operation, the turbocharger rotating assembly must turn free. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 6. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine.

NOTE: Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housings.

Check for signs of oil leaking from the turbocharger housings.

Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 6.

Oil pull-over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pullover.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 6.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

1. A worn or defective oil seal, which must be replaced.

2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.

3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these

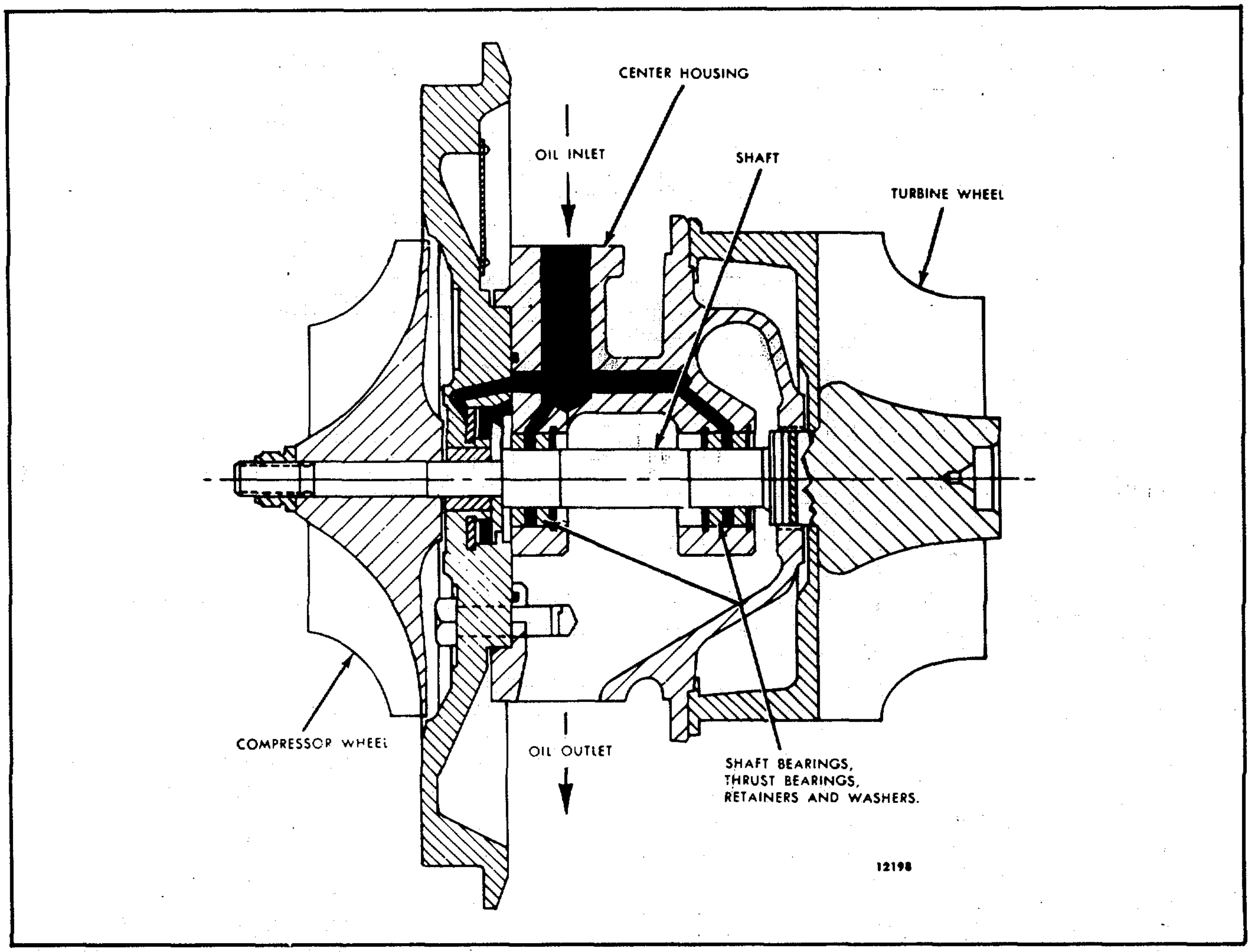


FIG. 4. Turbocharger Oil Flow Diagram

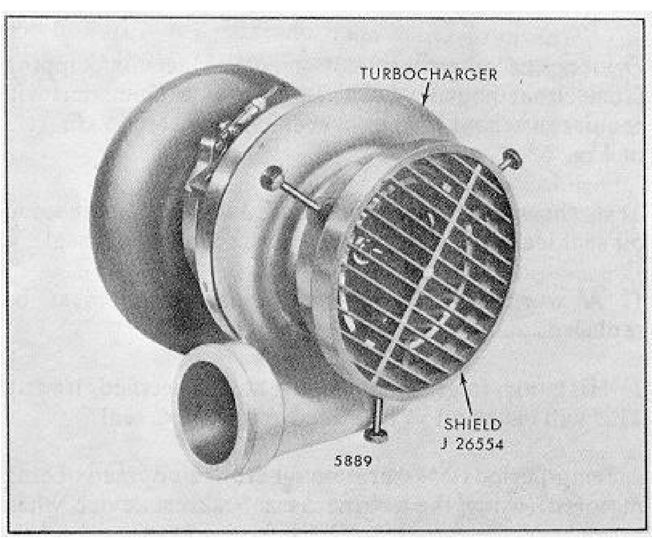


FIG. 5 - Inlet Shield

conditions, remove the compressor housing and inspect the backplate. If the surface is wet with oil, it indicates leakage.

If this test does not show leakage patterns, the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit. Refer to Section 13.2.

2. Be certain that the turbocharger oil drain line is unrestricted.

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

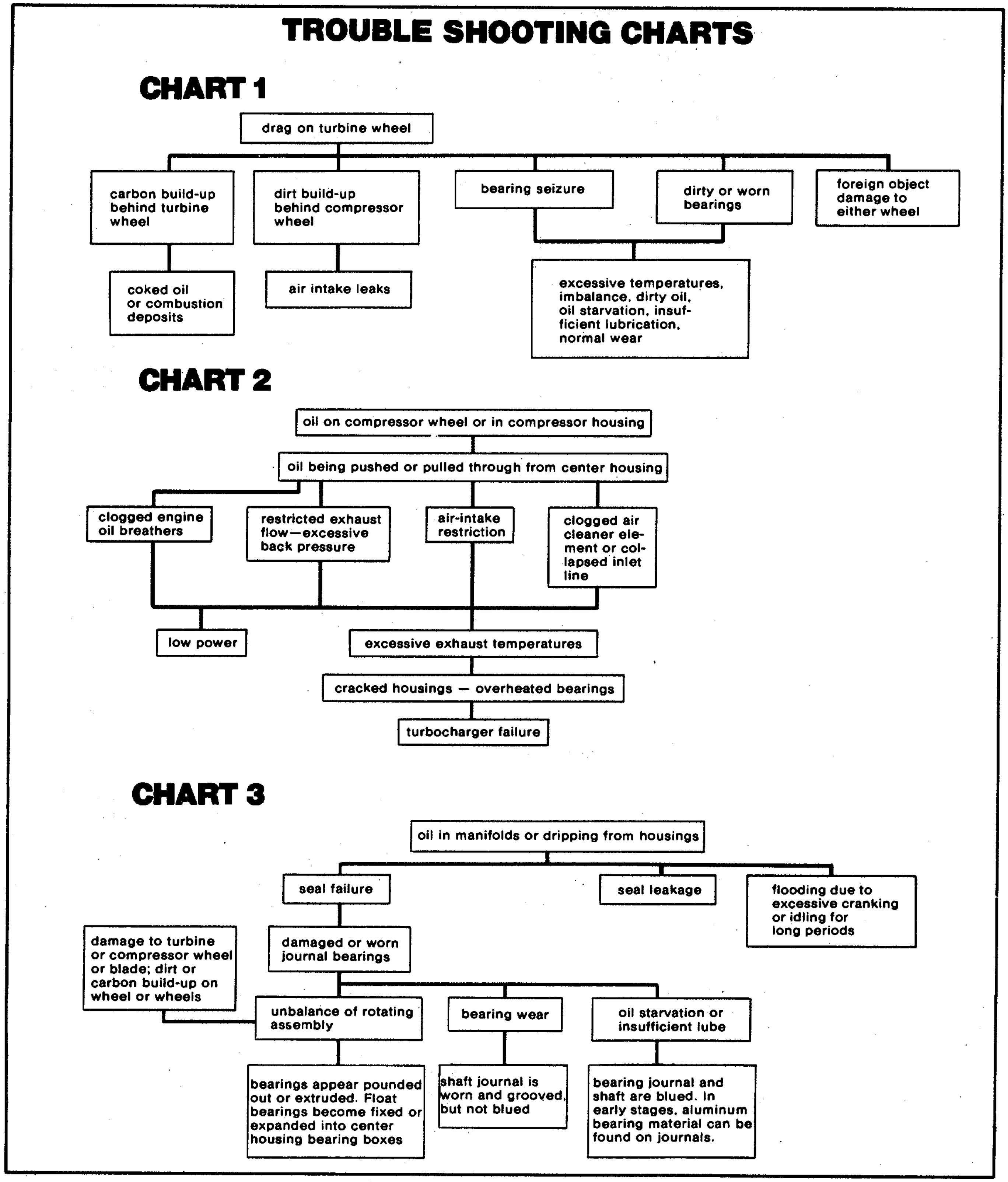


FIG. 6 - Inspection Checks for Turbocharger

4. Remove air intake ducting. Inspect inside of ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with the compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaners, air compressor line, or a leak near an oil source such as an engine breather, etc.

5. Remove the compressor housing from the turbocharger.

6. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the backplate annulus with suitable solvent spray and then dry completely with shop air.

7. Spray the backplate annulus with a light coating of *Spot-Check* developer type SKD-MF, or equivalent.

8. Install the compressor housing on the turbocharger and reconnect the inlet and outlet connections.

9. Warm up the engine to normal operating temperature.

10. Operate the engine at no load at the governor limited high speed for approximately five minutes.

11. Return the engine to low idle and then stop it.

12. Remove the intake duct and outlet hose and then remove the compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the *Spot-Check* developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

T18A40, TV71 AND TV81 Turbochargers

Remove Turbocharger

1. Disconnect the exhaust manifold adaptor attached to the turbine housing.

2. Disconnect the air inlet hose attached to the compressor housing.

3. Remove the oil inlet line from the top of the center housing.

4. Remove the oil outlet line from the bottom of the center housing.

5. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

6. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket. Then lift the turbocharger assembly away from the engine and place it on a bench.

7. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material.

Disassemble Turbocharger

Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly and proceed as follows:

> **NOTE:** Mark related positions of the compressor housing, center housing and turbine housing with a punch or scribe prior to disassembly to assure reassembly in the same relative position.

1. Refer to Fig. 7 or 8 and loosen the "V" band coupling (l) securing the compressor housing (2) to the backplate assembly (14) and remove the compressor housing and "V" band.

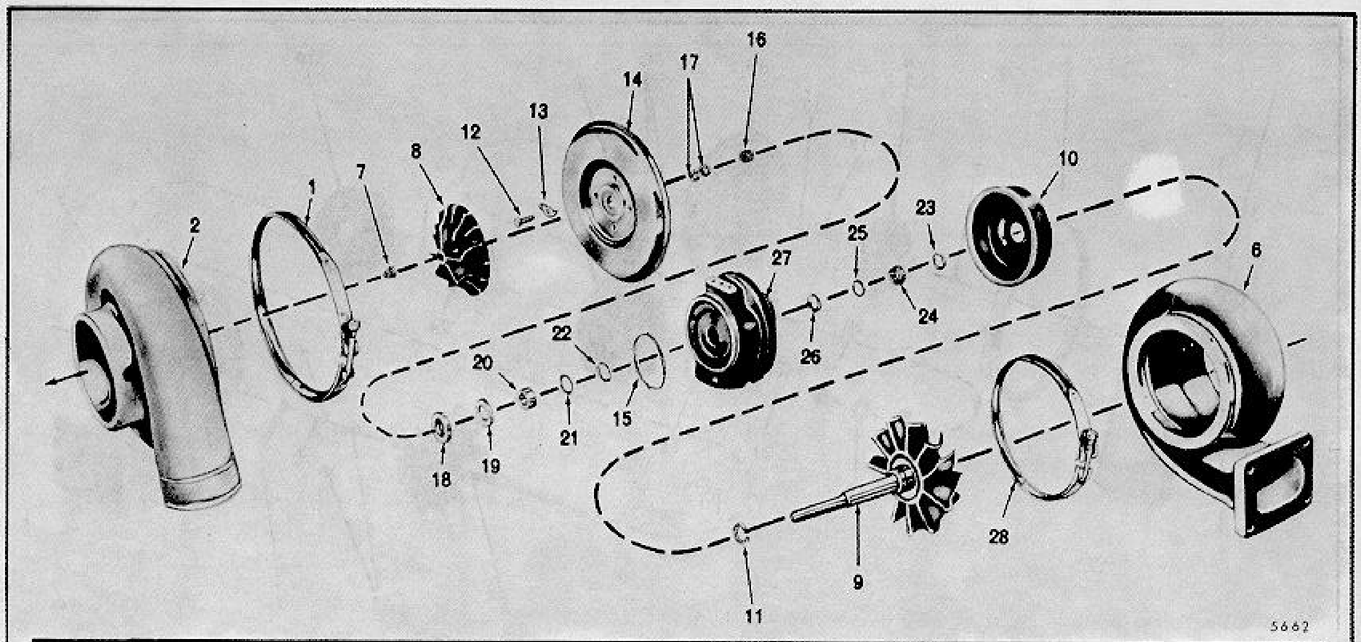
> **NOTE:** Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. With the T18A40 turbocharger, bend down the ends of the lockplates (4) and remove the eight bolts (3) securing the four lockplates and turbine housing clamps (5) *t*o the center housing (27) and turbine housing (6). With the TV71 and TV81 turbocharger, loosen the "V" band coupling (28) securing the turbine housing (6) to the center housing (27). Remove the turbine housing from the center housing.

> **NOTE:** Tap the housing with a soft hammer if force is needed for removal.

3. Position the turbine wheel (9) of the center housing assembly in a suitable holding fixture (Fig. 8). Remove the wheel nut (7) from the shaft.

> **NOTE:** If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright and remove the wheel nut from the shaft.



1. Coupling--"V" Band
2. Housing--Compressor
6. Housing--Turbine
7. Nut--Self-Locking
8. Wheel--Compressor
9. Shaft--Turbine Wheel Assembly
10. Shroud--Turbine Wheel
11. Ring--Turbine Piston
12. Screw
13. Lockplate
14. Backplate Assembly
15. Ring--Seal
16. Spacer--Thrust
17. Ring--Piston
18. Collar--Thrust
19. Washer--Inboard Thrust
20. Bearing
21. Washer--Bearing
22. Ring--Snap
23. Ring--Snap
24. Bearing
25. Washer--Bearing
26. Ring--Snap
27. Housing--Center
28. Coupling--"V" Band

FIG. 7 - T18A40 Turbocharger Details and Relative Location of Parts

IMPORTANT: To prevent the possibility of bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

4. Press the compressor wheel (8) from the wheel shaft assembly (9).

5. Withdraw the wheel shaft assembly (9) from the center housing. The wheel shroud (10), which is not retained, will fall free when the wheel shaft is removed.

6. With the TV7 1 and TV8 1 turbochargers, remove and discard the turbine piston ring (11) from the wheel shaft.

7. Bend down the lock tabs and remove the four bolts (12) and lockplates (13) securing the backplate assembly (14) to the center housing (27) and remove the backplate assembly.

NOTE: Tap the backplate lightly to remove it from the center housing recess.

8. Remove and discard the seal ring (15) from the groove in the center housing.

9. Remove the thrust spacer (16) and piston ring(s) (17) from the backplate assembly. Discard the piston ring(s).

10. Remove the thrust collar (18), inboard thrust washer (19), bearing (20), bearing washer (21) and snap ring (22) from the center housing. Discard the thrust washer, bearing, washer and snap ring.

11. Remove the snap ring (23), bearing (24), bearing washers (25) and snap ring (26) from the opposite end of the center housing. Discard the snap rings, bearing and washers.

Cleaning

Before cleaning, inspect the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non-caustic cleaning solvent for about 25 minutes. After soaking, use a stiff bristle

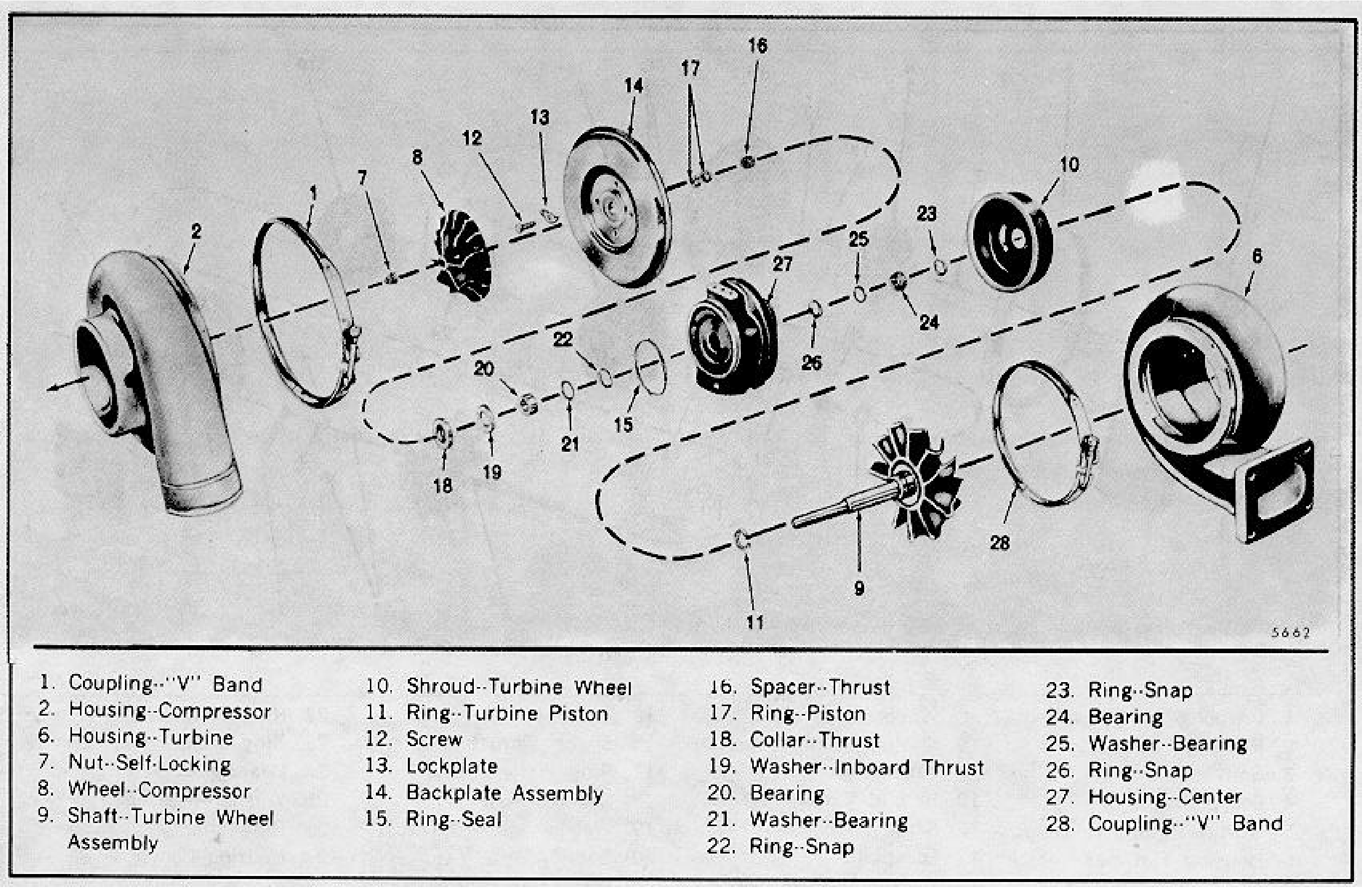


FIG. 8 - TV71 and TV81 Turbocharger Details and Relative Location of Parts

brush and remove all dirt particles. Dry all of the parts thoroughly.

> **CAUTION:** Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air.

Clean the oil passage in the center housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

Inspection

Inspect all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel for signs of rubbing. For shaft bearing journal dimensions and wear limits, refer to Section 3.0.

Inspect the shaft for signs of scoring, scratches or bearing seizure.

Check the compressor wheel for signs of rubbing or damage from foreign material. Check to see that the wheel bore is not galled. The wheel must be free of dirt and other foreign material.

Inspect the seal parts for signs of rubbing or scoring of the running faces.

Inspect the housing for contact with the rotating parts. The oil and air passages must be clean and free of obstructions.

Minor surface damage may be burnished or polished.

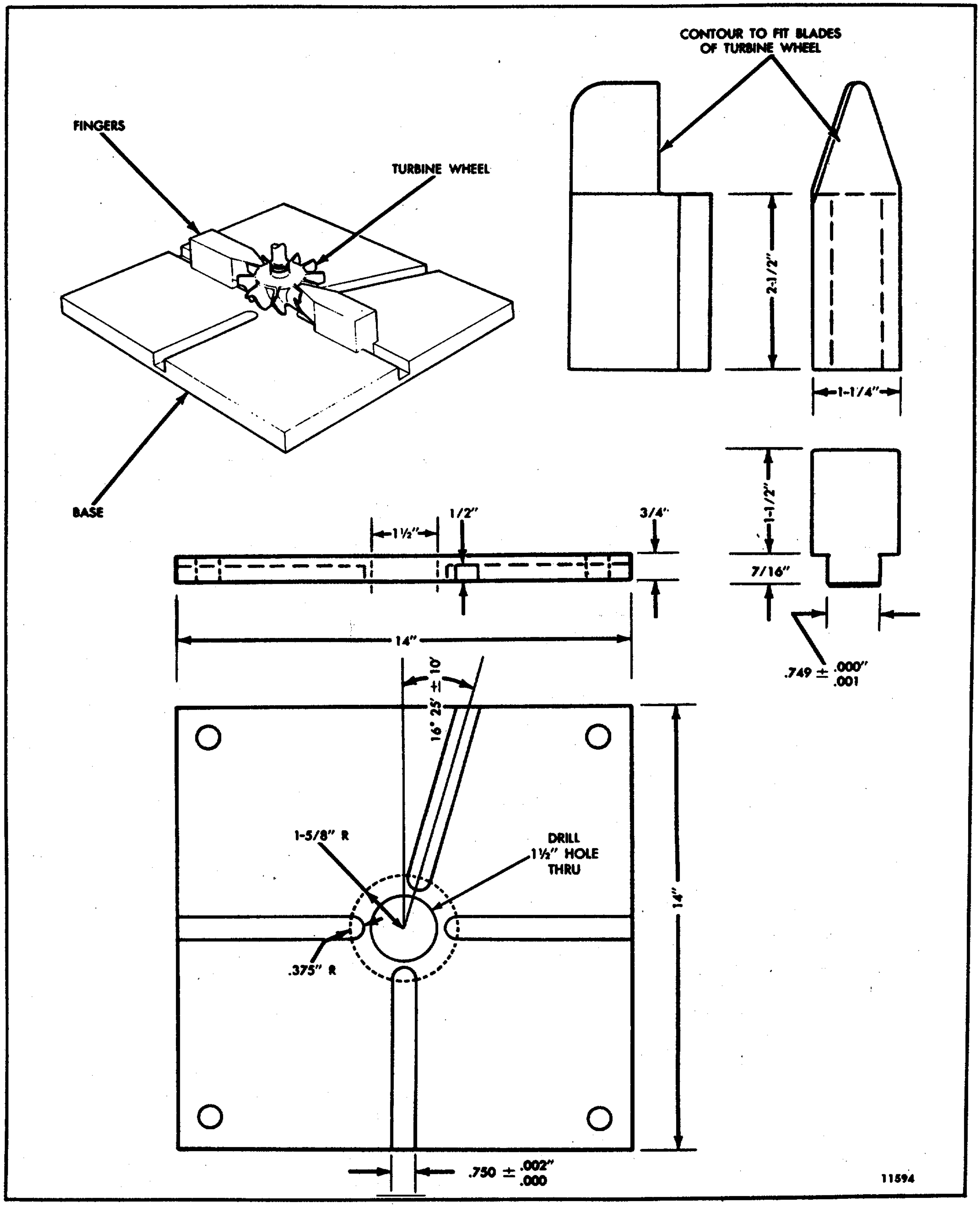


FIG. 9 - Turbocharger Holding Fixture

Use a Silicone Carbide abrasive cloth for aluminum parts or a crocus abrasive cloth for steel parts.

It is recommended that the piston rings, thrust washers, bearing, bearing washers and snap rings be replaced at time of disassembly.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

Assemble Turbocharger

Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material.

Refer to Figs. 7 and 8 for parts orientation and proceed as follows:

1. Lubricate the new bearings (20 and 24) with clean engine oil.

2. Install a new snap ring (26), bearing washer (25), bearing (24) and snap ring (23) in the turbine end of the center housing (27).

3. Install a new snap ring (22), bearing washer (21) and bearing in the compressor end of the center housing.

NOTE: Install the current inboard thrust bearing (three oil grooves) with the smooth side against the center housing.

4. Install a new piston ring(s) (17) on the thrust spacer (16) and gently insert the spacer into the backplate assembly (14).

NOTE: With the T18A40 turbocharger, make sure the *current* small diameter thrust spacer (.672 "-.673 ") is used with the current thrust collar (Fig. 10). The former spacer was .677"-.678 " in diameter. The current thrust spacer (16) has two grooves. When replacing the former one groove spacer with the two groove spacer, be sure and include two piston rings.

IMPORTANT: Do not force the piston ring(s) into place.

5. Make sure the compressor bearing is in place, then position the new inboard thrust washer (19) flat against the center housing with the hole and cutout in the thrust washer in alignment with the pins in the center housing.

6. Install the thrust collar (18) snugly against the thrust washer. Lubricate the thrust collar and thrust washer with clean engine oil.

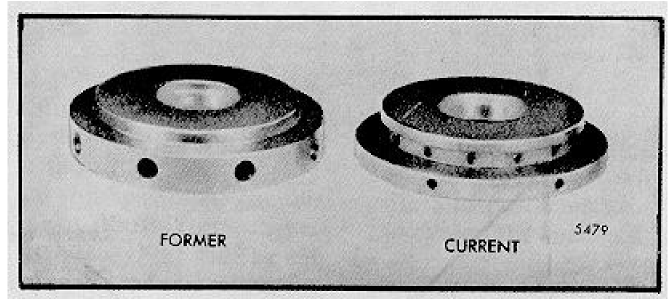


FIG. 10 - Former and Current Thrust Collar (T18A40 Turbocharger)

7. Install a new seal ring (15) in the groove at the compressor end of the center housing.

8. Align the oil feed holes in the center housing (27) and the backplate assembly (14) and attach the backplate to the center housing with four bolts (12) and new lockplates (13). Tighten the T18A40 bolts to 90-110 lb-in(I0-12 Nm) torque or the TV71 and TV81 bolts to 80-100 lb-in (9-11 Nm) torque and bend the lockplate tangs up against the side of the bolt heads.

NOTE: If a new backplate with a warning plate is inadvertently installed, *the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.*

9. On TV71 and TV81 turbochargers, install a new turbine piston ring (11) on the wheel shaft assembly.

NOTE: Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.

10. Position the wheel shroud (10) against the center housing (27) and insert the wheel shaft assembly (9) through the wheel shroud and into the center housing.

NOTE: Be careful not to scuff or scratch the bearings when installing the shaft.

11. Place the turbine wheel shaft assembly, shroud, center housing and backplate upright in a suitable holding fixture as shown in Fig. 9.

NOTE: If a holding fixture is not available, clamp a suitable socket or box wrench in a vise and place the extended hub on the shaft in the socket or wrench.

12. With the compressor wheel at room temperature, position it over the shaft.

13. Lightly lubricate the shaft threads and wheel face that will be under the nut with engine oil and install

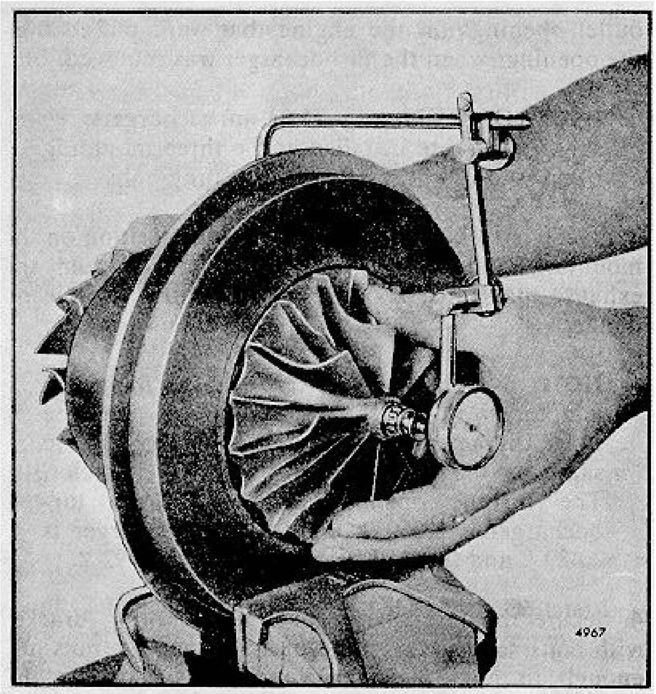


FIG. 11 - Checking Bearing Axial End Play

the retaining nut. Tighten the nut to 125-150 **lb-in** (14-17 Nm) torque to seat the compressor wheel against the thrust spacer.

14. Loosen the nut and inspect the nut face and front face of the compressor wheel to be sure they are smooth and clean.

15. Retighten the nut to 35-55 **lb-in** (4-6 Nm) torque.

16. Continue to tighten the retaining nut until the shaft increases in length .007 "-.008 " (T18A40) or .009 "-.010 " (TV71 and TV81).

IMPORTANT: Tighten the nut in such a manner as not to impose bending loads on the shafts.

NOTE: If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 35-55 **lb-in** (4-6 Nm) torque. Then continue to tighten the nut through an angle of 110-110 turn for the T18A40 or 120-130 ° turn for the TV71 and TV81 (90 ° = 1/4 turn).

17. Check the bearing axial end play:

a. Clamp the center housing assembly in a bench vise equipped with soft jaws as shown in Fig. 11.

b. Fasten the dial indicator and magnetic base (J7872-2) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side (Fig. 11).

c. Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be between .004 " and .009 " (T18A40) or .003 " and .010 " (TV71 and TV81). If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

18. Position the turbine housing (6) as marked at disassembly against the center housing (27) and secure it in place.

a. Secure the T18A40 turbine with four, clamps (5), four new lockplates (4) and eight bolts (3). Tighten the bolts to 100-130 **lb-in** (11-15 Nm) torque.

b. Secure the TV71 and 81 turbine housing with the "V" band coupling (28). Tighten the toggle nut as follows:

1. Lubricate the toggle bolt threads with a high temperature anti-seize compound, such as Jet Lube (Mil Spec A-907D), or equivalent.

2. Tighten the nut on the "V" band toggle bolt to approximately 160 **lb-in** (18 Nm) torque.

IMPORTANT: Do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.

3. Loosen the "V" band coupling nut to approximately 50 **lb-in** (6 Nm) torque, then re-torque the nut to 152-168 **lb-in** (17-19 Nm) torque.

19. Position the compressor housing (2) as marked at disassembly against the backplate (14) and secure it in place with the "V" band coupling (1). Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 110-130 **lb-in** (12-15 Nm) torque.

20. Check the shaft radial movement:

a. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 on the flat surface of the turbine housing inlet flange as shown in Fig. 12.

b. Fasten the dial indicator extension rod J 7872-1 to the dial indicator J 8001-3 and attach the dial indicator to the swivel adaptor.

c. Insert the extension rod J 7872-1 into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and is perpendicular to the shaft.

NOTE: Make sure the extension rod does not make contact with the sides of the center

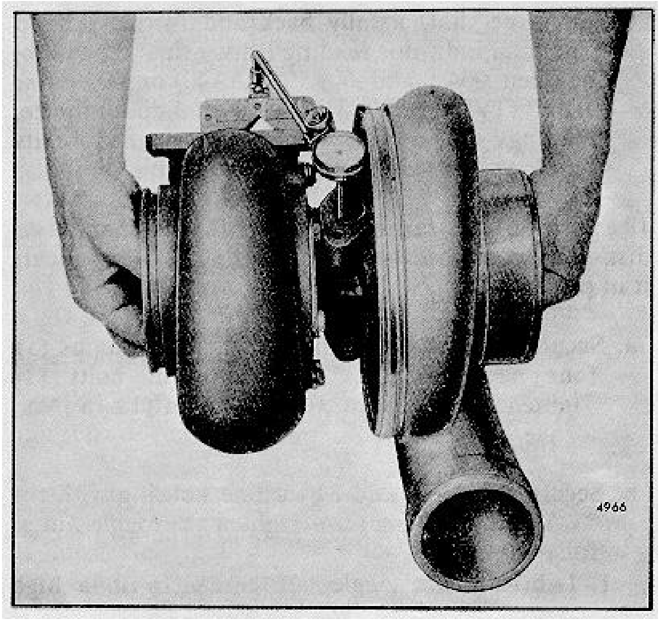


FIG. 12 - Checking Shaft Radial Movement

housing, otherwise it will be impossible to obtain an accurate reading.

d. Grasp each end of the rotating assembly (Fig. 12) and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003 " and .007 ". If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

21. If it is to be stored, lubricate the unit internally and install protective covers on all openings.

22. Stamp the letter "R" in the lower left-hand corner of the name plate to identify that the turbocharger has been reworked.

Install Turbocharger

If a turbocharger is to be installed on a new or overhauled engine, operate the engine for approximately one hour *before* the turbocharger is installed. This must be done to ensure that no foreign material is carried from the engine into the turbocharger lubrication system.

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

2. Remove the covers from the air inlet and exhaust outlet openings on the engine that were placed over the openings when the turbocharger was removed.

NOTE: On TV71 and TV81 turbochargers, be sure gaskets are installed at the three mounting bracket to flywheel housing attaching bolts.

3. Place the turbocharger assembly into position on the mounting bracket. Use a new gasket between the exhaust manifold adaptor and the turbine housing flange.

NOTE: When attaching the exhaust flange or adaptor to the turbine housing, be sure the inner diameter of the flange or adaptor is the same as the turbine housing inner diameter. The turbine opening in the T18A40 turbocharger is 3.850 ", the TV71 turbocharger is 3.480 " and the TV81 turbocharger is 3.892 ".

4. Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the bracket.

IMPORTANT: When self-locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self-locking nuts on the bolts.

5. Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

6. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.

7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.

8. Attach the oil inlet line to the cylinder block.

9. After installing a rebuilt or new turbocharger, it is very important that all moving parts of the turbocharger center housing be lubricated as follows:

a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 5).

b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

c. Add additional clean engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig or 69 kPa at idle speed).

CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

10. Check all ducts and gaskets for leaks.

11. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

T18 AND T18A TURBOCHARGER

Remove Turbocharger

1. Disconnect the exhaust manifold adaptor attached to the turbine housing.

2. Disconnect the air inlet tube attached to the compressor housing.

3. Remove the oil inlet line from the top of the center housing.

4. Remove the oil outlet line from the bottom of the center housing.

5. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

6. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket. Then lift the turbocharger assembly away from the engine and place it on a bench.

7. Cover the end of each oil inlet and oil outlet line and the air inlet and exhaust outlet openings on the engine to prevent the entry of foreign material.

Disassemble Turbocharger

Refer to Figs. 13 and 21 for the location of the various parts and disassemble the turbocharger assembly as follows:

1 Thoroughly clean the exterior of the turbocharger with a non-caustic cleaning solvent.

2. Matchmark the compressor housing, center housing and the turbine housing with a punch or chisel (Fig. 14) so they may be installed in the same relative position.

3. Remove the twelve bolts, lock washers and clamps securing the T18 turbocharger compressor housing to the center housing. Then remove the compressor housing from the center housing. On the T18A turbocharger, loosen the "V" band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and "V" band. If necessary, tap the compressor housing with a plastic hammer to loosen it.

4. Bend the ends of the turbine housing attaching bolt lockplates down. Then remove the six bolts (T18) or eight bolts (T18A) securing the turbine housing to the center housing. If necessary, tap the turbine housing with a plastic hammer to loosen it.

5. Remove the compressor wheel from the shaft as follows:

NOTE: The hexagon countersunk hole in the end of the turbine wheel must be scraped clean before installing it in the holding fixture.

a. Clamp the turbine wheel holding fixture J 21225 in a bench vise. Then place the center housing and rotating assembly in the holding fixture, turbine wheel down (Fig. 15), with the hexagon countersunk hole in the turbine wheel over the protruding hexagon head in the holding fixture. If required, use a suitable holding fixture as shown in Fig. 24.

b. To prevent the possibility of bending the shaft,

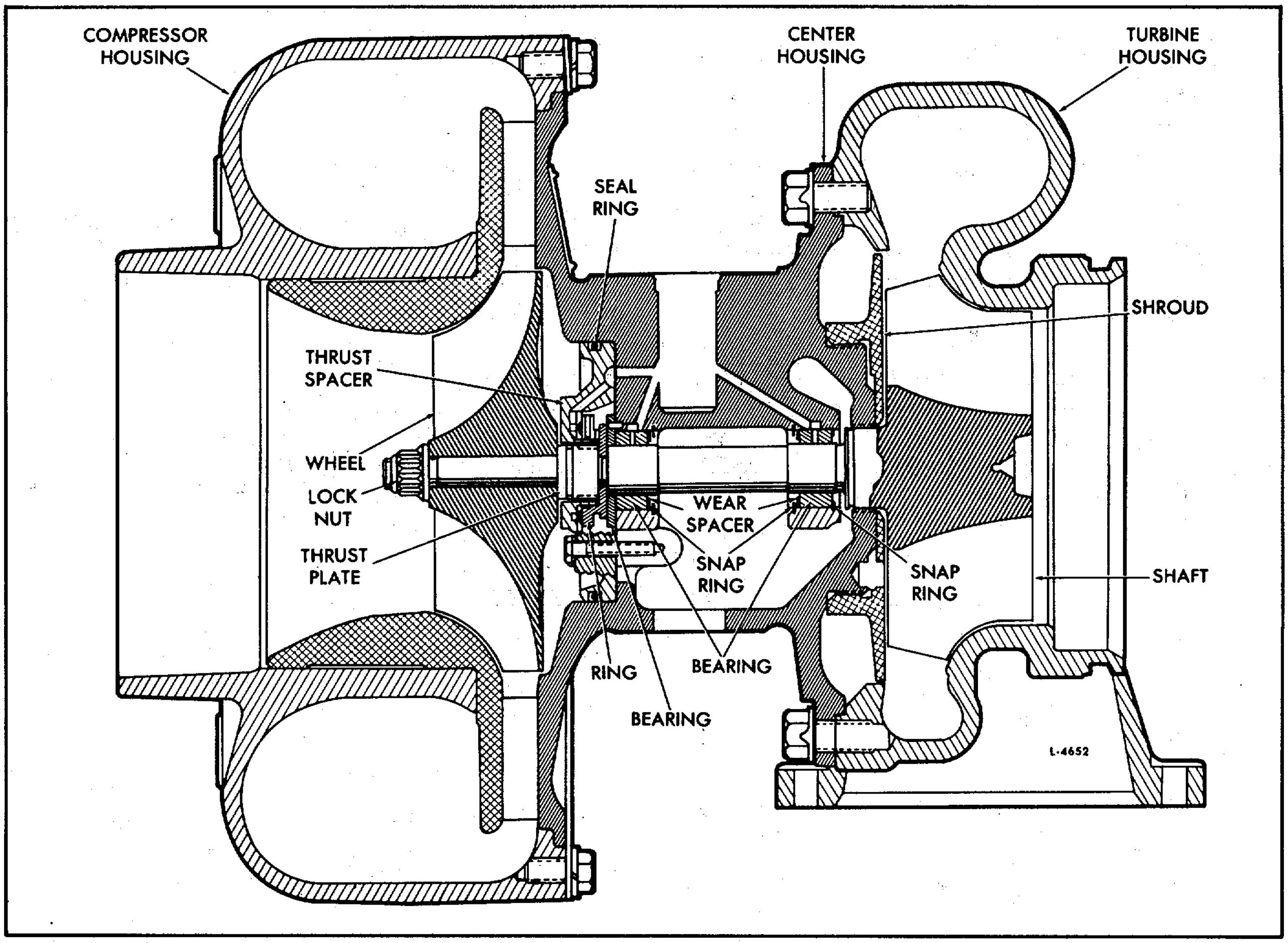


FIG. 13 - T18 Turbocharger Assembly

remove the lock nut from the shaft with a double universal socket and a tee handle (Fig. 15).

c. Place the center housing and rotating assembly in an oven, furnace or hot oil that has been preheated to 350-375 °F (177-190 °C) for no longer than ten minutes. If a hot oil bath is used, immerse only the compressor wheel in the oil.

IMPORTANT: Be careful not to damage the wheel blades when placing the assembly in the oven or furnace. Do not heat the compress-or wheel above 375 °F (190 °C).

d. After heating the compressor wheel, remove the center housing and rotating assembly and support it on the bed of an arbor press with the compressor wheel end up (Fig. 16).

CAUTION: To avoid being burned, use a pair of heat resisting or asbestos gloves when handling the center housing and rotating assembly.

e. Place a clean shop towel on the bed of the press and under the turbine wheel to protect the blades. Then place the tapered end of the removing tool J 9496 in the center of the shaft and the opposite end under the ram of the press (Fig. 16). Press the shaft out of the compressor wheel.

f. Remove the compressor wheel from the top of the center housing, then remove the center housing and shaft from the arbor press and place them on a bench. Pull the shaft assembly straight out of the center housing to prevent the threads on the end of the shaft from damaging the shaft bearings.

6. Place the center housing, compressor housing end up, on the bench (Fig. 17).

7. Bend the end of the center housing thrust plate attaching bolt lockplates down, then remove the four bolts and lockplates securing the thrust plate to the center housing.

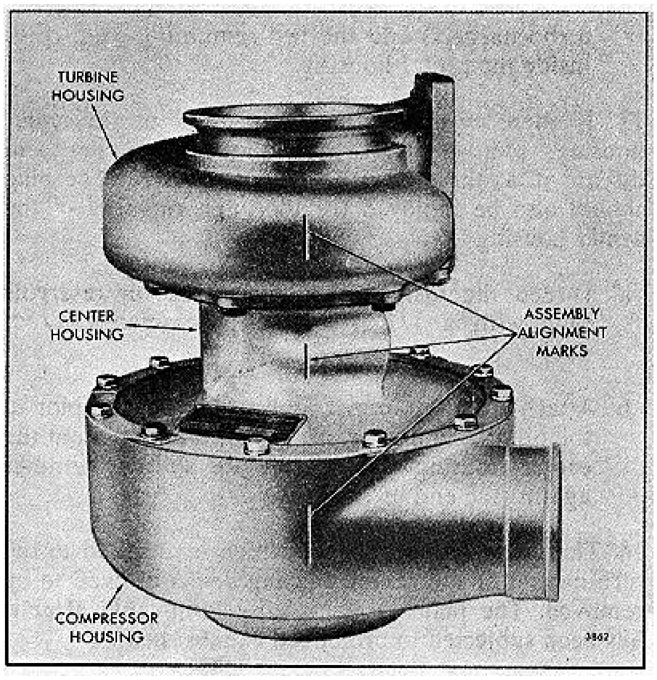


FIG. 14 - Assembly Alignment Marks on Housings

8. Support the center housing on edge on the work bench (Fig. 18). Then insert a 1/2 " wood dowel approximately 8" long through the shaft bearings and against the thrust plate. Tap the thrust plate out of the center housing with a hammer.

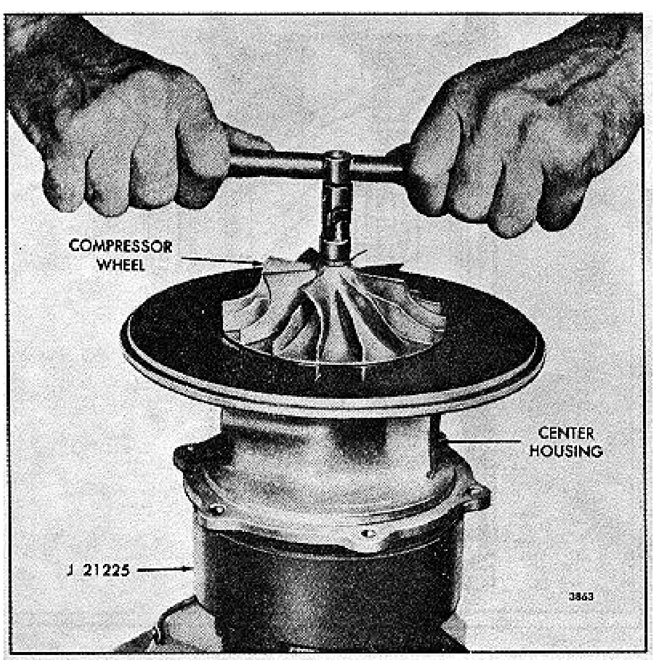


FIG. 15 - Removing Compressor Wheel Lock Nut

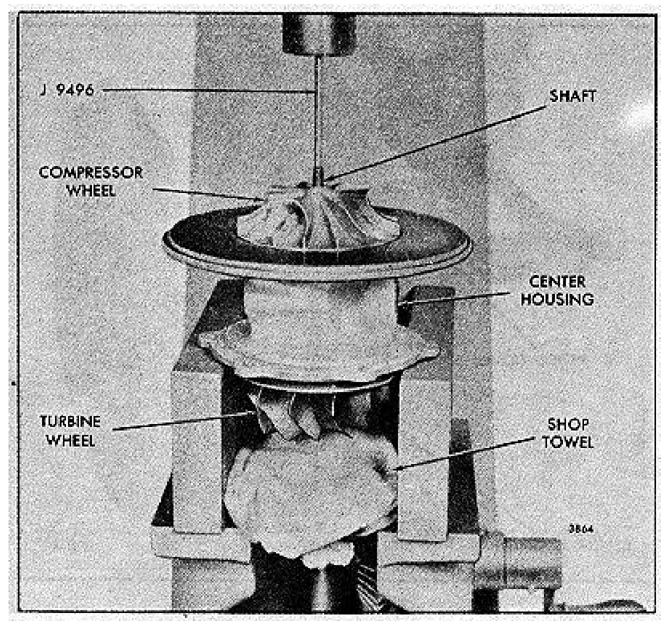


FIG. 16 Removing Shaft from Compressor Wheel

9. Remove the thrust spacer and seal ring from the thrust plate, then remove the seal ring from the outside diameter of the thrust plate.

10. Remove the thrust ring and the thrust plate bearing from the center housing.

11. Remove the shaft bearing from the compressor wheel end of the center housing by lifting it straight up out of the housing with one finger inserted in the bearing.

12. Remove the shaft bearing from the turbine end of the center housing as follows:

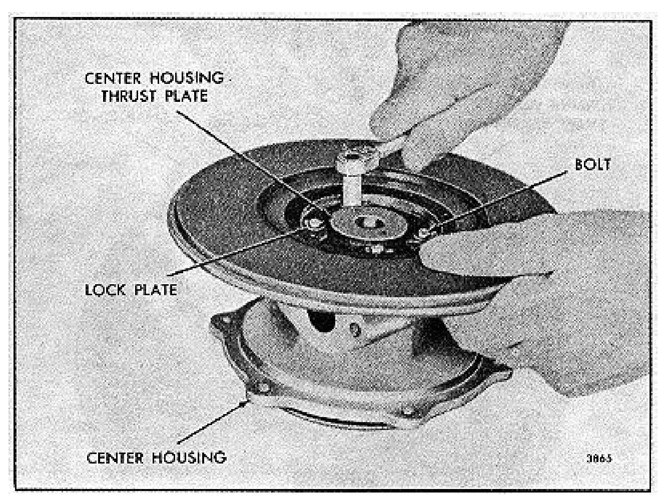


FIG. 17 Removing Center Housing Thrust Plate Bolts

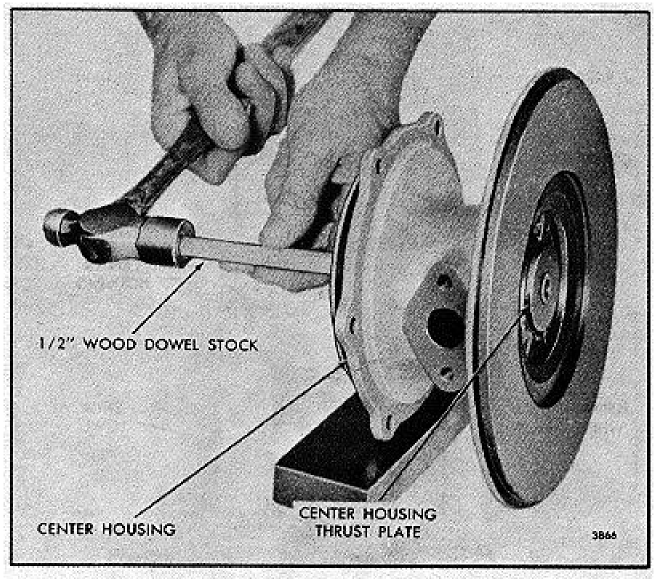


FIG. 18 - Removing Center Housing Thrust Plate

a. Place the center housing, turbine housing end up, on the bench (Fig. 19).

b. Remove the shaft bearing retaining ring from the center housing with a pair of snap ring pliers.

c. Lift the bearing straight-up out of the housing.

d. If necessary, remove the two spacers (on current turbochargers) and the two remaining snap rings inside the center housing.

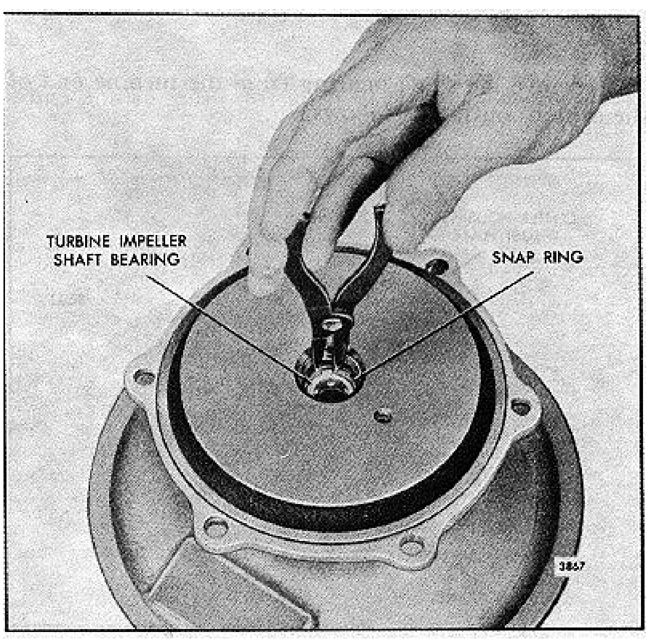


FIG. 19 Removing Shaft Bearing Retaining Ring

13. If there is an oil reservoir plug in the center housing, remove it in the following manner and discard it, as the plug is no longer required. The plug should also be removed for thorough cleaning of the center housing.

a. Thread the inside diameter of the oil reservoir plug with a 1/2 "-13 tap approximately 1/2 deep.

b. Attach a slide hammer and a 1/2 "-13 adaptor to the oil reservoir plug. Then pull the plug from the center housing by striking the sliding hammer against the end of its shaft.

14. The turbine wheel shroud which is attached to the turbine end of the center housing does not need to be removed. The plate is not readily removable after it has been subjected to prolonged exhaust heat.

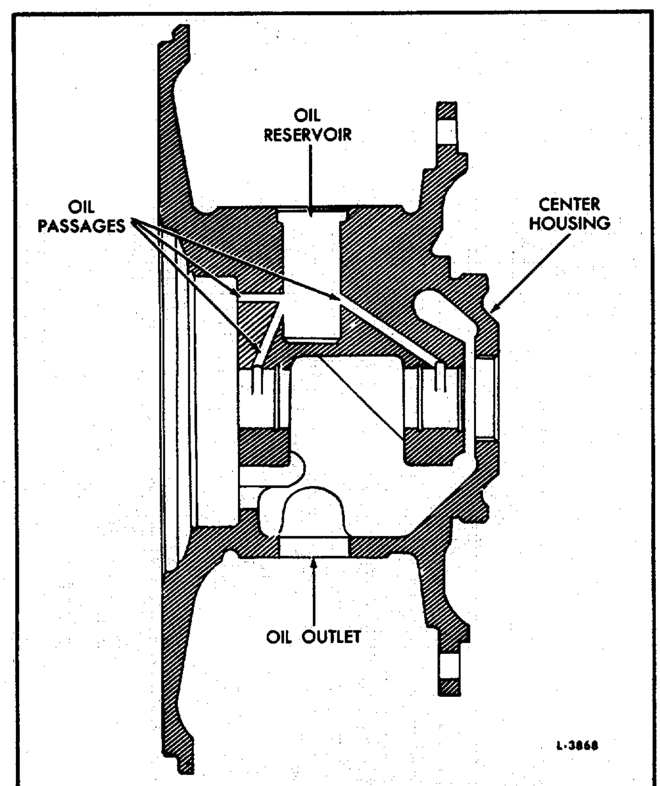


FIG. 20 - Location of Oil Passages in Center Housing

Cleaning

Before cleaning, inspect the parts for signs of burning, rubbing or other damage which might not be evident after cleaning.

Soak all parts in a non-caustic cleaning solvent for about 25 minutes. Use a stiff bristle brush and remove all dirt particles. Dry all of the parts thoroughly.

> **CAUTION:** Never use a caustic cleaning solution for cleaning as this will damage certain parts. Use the cleaning solution in an open or well ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean the parts.

Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.

Clean all of the internal cavities and oil passages in the center housing thoroughly with dry compressed air. Make sure all of the metal chips, from the tapping operation, are removed from the oil reservoir and oil passages in the center housing.

Clean the oil passage in the center housing thrust plate with dry compressed air.

Remove the oil inlet and outlet lines from the engine and thoroughly clean the oil lines inside and out. An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.

Inspection

Inspect the turbocharger parts for signs of damage, corrosion or deterioration. If necessary, replace with new parts.

Examine the turbine wheel for signs of rubbing or wear. For shaft bearing journal dimensions and wear limits, refer to Section 3.0.

Examine the compressor wheel for signs of rubbing and bent blades. The wheel must be free of dirt and foreign material.

Check the compressor and turbine housings for signs of wheel contact.

Examine the thrust ring, shaft bearings and wear spacers, thrust spacer, seal ring and thrust plate bearing for signs of rubbing, scoring or wear. For shaft bearing dimensions and wear limits, refer to Section 3.0.

Assemble Turbocharger

> **IMPORTANT:** If foreign particles fall into the turbocharger during the assembly procedure, remove the particles immediately, even though extensive disassembly is required.

Refer to Figs. 13 and 21 for the location of the various parts and assemble the turbocharger as follows:

1. Install the shaft bearings in the center housing as follows:

   a. Place the center housing on the bench with the turbine end of the housing facing up.

   b. If removed, reinstall the inner shaft bearing retaining ring in the lower ring groove in the turbine wheel end bearing bore.

   c. On current turbochargers, reinstall the wear spacer.

   d. Lubricate the outside diameter of a shaft bearing with engine oil, then place the bearing straight into the bearing bore in the center housing as shown in Fig. 22 and push it down against the wear spacer. On former turbochargers, push it down against the bearing inner retaining ring.

   e. Install the outer shaft bearing retaining ring in the ring groove in the center housing bearing bore.

   f. Turn the center housing over on the bench so the compressor end of the housing is facing up.

   g. If removed, reinstall the shaft bearing retaining ring in the ring groove in the compressor end of the center housing bearing bore.

   h. On current turbochargers, reinstall the wear spacer.

2. Clamp the shaft holding fixture J 21225 in a bench vise. Place the shaft assembly in the holding fixture with the hexagon countersunk hole in the turbine wheel over the protruding hexagon head in the holding fixture as shown in Fig. 23. If required, use a suitable holding fixture (Fig. 24).

3. Lubricate the shaft bearing journals with engine oil, then place the center housing over the shaft with the turbine end of the housing facing down. Carefully lower the center housing straight down over the shaft until it seats on the hub of the turbine wheel (Fig. 25).

4. Lubricate the outside diameter of the second shaft

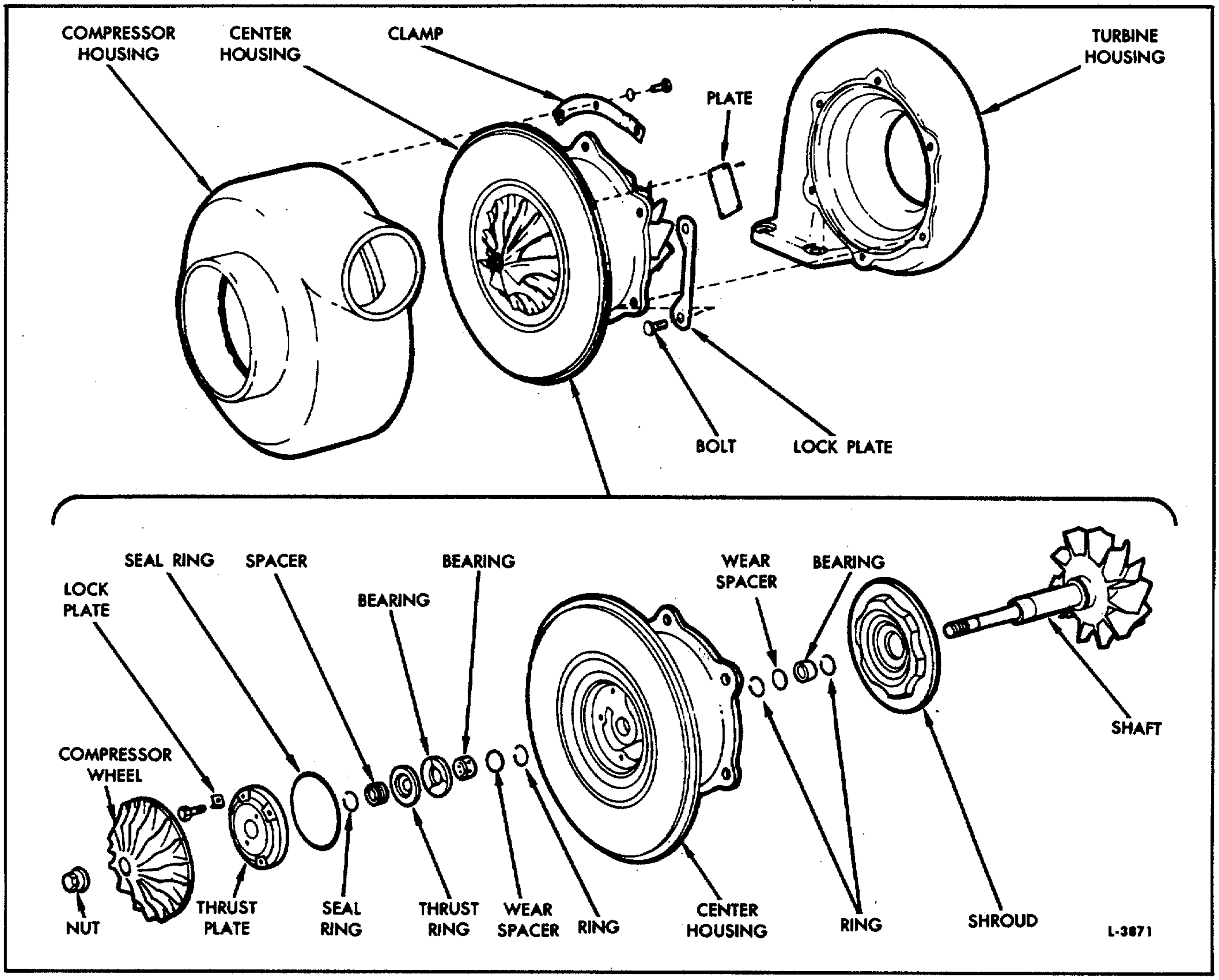


FIG. 21 - Turbocharger Details and Relative Location of Parts

bearing with engine oil, then place the bearing over the shaft and start it straight into the bearing bore as shown in Fig. 26. Push the bearing down in the bearing bore against the wear spacer. On former turbochargers, push the bearing down against the retaining ring.

5. Lubricate the thrust plate bearing with engine oil then place it on the shaft with the three oil grooves in the face-of the bearing facing up (Fig. 27). Align the hole and slot in the bearing with the dowel pins in the center housing, then place the bearing over the dowel pins and against the housing.

> **NOTE:** Make sure the thrust plate bearing is seated flat against the face of the center housing.

6. Place the thrust collar over the end of the shaft, recess side facing up (Fig. 28), and against the thrust plate bearing.

7. Install a new seal ring in the groove in the thrust spacer.

8. Place the center housing thrust plate, less the thrust spacer and the rubber seal ring, over the shaft, with the bolt holes and the oil hole in the under side of the thrust plate in alignment with the oil and bolt holes in the center housing (Fig. 30).

9. Remove the thrust plate from the center housing. Then install the thrust spacer and seal ring assembly in the thrust plate (Fig. 29).

10. Lubricate a new thrust plate seal ring (rubber) with engine oil, then place the seal ring in the seal ring groove in the outside diameter of the thrust plate.

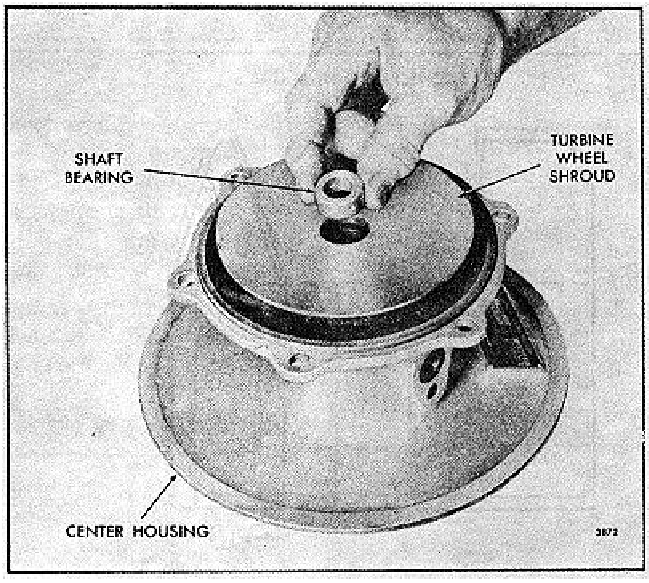


FIG. 22 - Installing Shaft Bearing in Center Housing (Turbine End)

11. Position the thrust plate, with the thrust spacer and seal ring, over the end of the shaft with the oil holes and bolt holes in the thrust plate and center housing in alignment as shown in Fig. 30. Then place the thrust plate on the shaft and lower it straight down against the center housing, being careful not to let the thrust spacer move up out of the thrust plate.

12. To align the thrust plate, insert two of the thrust plate attaching bolts into the bolt holes in the thrust plate and thread them into the center housing.

13. Carefully push the thrust plate in the center

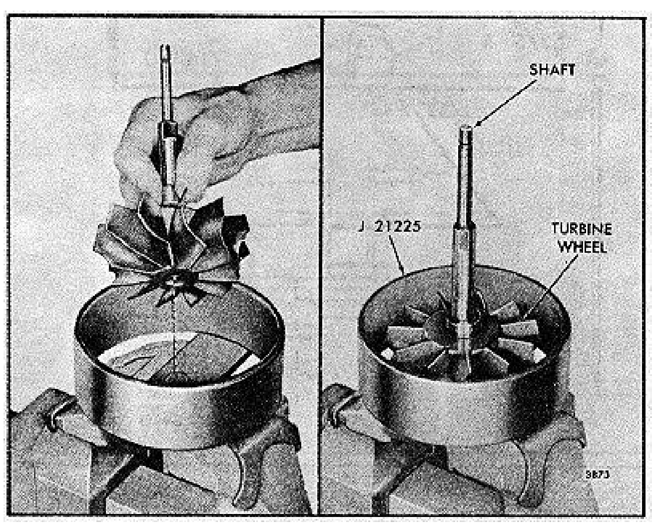


FIG. 23 - Installing Shaft Assembly in Holding Fixture

housing until it contacts the thrust ring. Be sure the thrust spacer stays in the thrust plate.

NOTE: If the thrust spacer moves out of the thrust plate unseating the seal ring, repeat Steps 9 through 13 above.

14. Place a new lockplate on each thrust plate bolt and thread the bolts into the center housing. Tighten the 10-24 bolts to 30-40 **lb-in** (3-5 Nm) torque (T18 turbocharger) or to 90-110 l**b-in** (10-12 Nm) torque on the 5/16"-18 bolts on the T18A turbocharger (Fig. 31). Then bend one corner of each lockplate up against the flat side of each bolt head.

NOTE: A new steel lockplate and high strength bolts are now being used in the T18A Series turbocharger. The new high strength bolts and lockplates must be used together and the bolts must be tightened to 160 - 180 l**b-in** (18-20 Nm) torque. Be sure and bend the lockplate tangs up against the side of the bolt heads, after tightening the bolts. Only the current steel lockplate and high strength bolt are serviced.

15. Install the compressor wheel on the shaft as follows:

a. Place the compressor wheel in an oven, furnace or in hot oil that has been pre-heated to 350-375 °F (177-190 °C) for not longer than ten minutes.

CAUTION: To avoid being burned, use a pair of heat resisting or asbestos gloves when handling the compressor wheel.

b. After heating the compressor wheel, remove the wheel and start it straight on the shaft (Fig. 32). Push the wheel down against the thrust spacer.

NOTE: Place the compressor wheel on the shaft as soon as possible after removing it from the oven, furnace or hot oil.

c. While the compressor wheel is still hot, install the lock nut and tighten it to 100-130 **lb-in** (12-14 Nm) torque.

NOTE: To prevent the possibility of bending the shaft, use a double universal socket with the torque wrench.

d. After the compressor wheel has -been allowed to cool to less than 15 °F (66 °C), remove the lock nut from the shaft.

e. Inspect the flat surface of the lock nut and the top face of the wheel hub for being smooth and clean.

f. Lubricate the threads and the flat surface of the

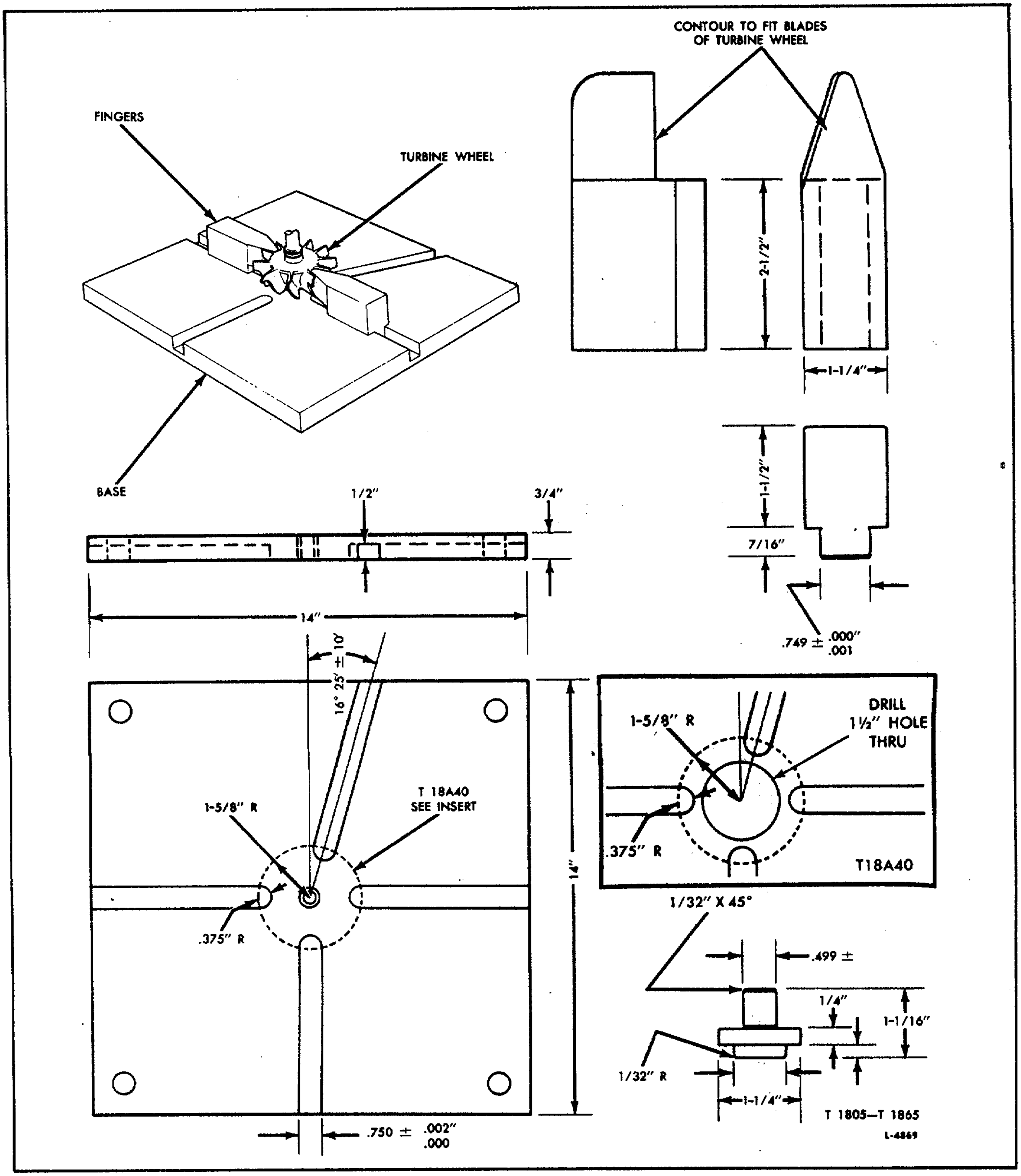


FIG. 24 - Turbocharger Holding Fixture

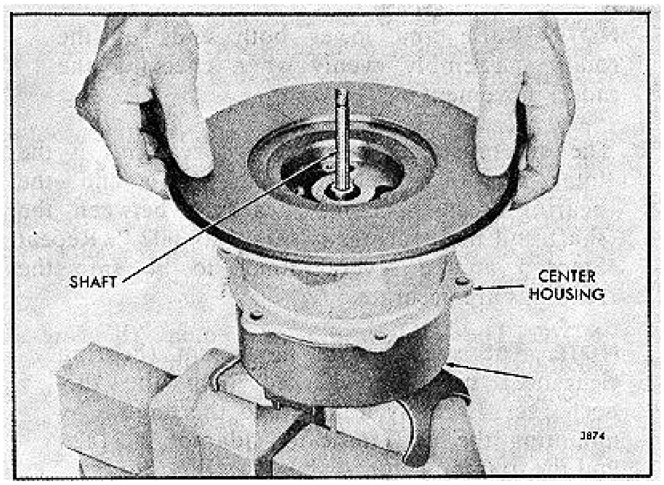


FIG. 25 - Installing Center Housing on Shaft

wheel lock nut lightly with engine oil, then install the lock nut on the shaft and tighten it to 18-20 **lb-in** (2 Nm) torque After tightening the lock nut, turn it an additional 1/4 turn or 90°

g. Place wrench J 21223-01 on the lock nut and attach a sliding tee handle to the wrench (Fig. 33).

h. Place a magnetic base dial indicator on the center housing and position the stem of the indicator on the end of the shaft as shown in Fig. 33.

i. Set the hand of the dial indicator at zero. Then tighten the lock nut until the shaft length increases .006" to .007". The current shaft requires 285 lb-in (32 Nm) torque to increase or stretch the shaft length .006 11 to .007". The former "necked down" shaft requires only 260 lb- in(29 Nm) torque.

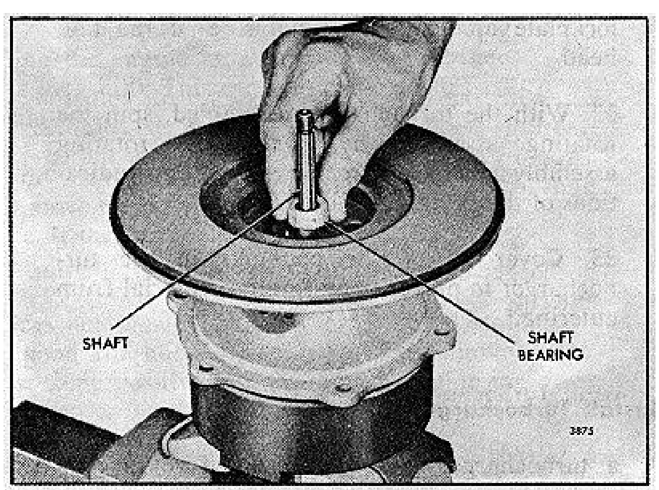


FIG. 26 Installing Shaft Bearing in Center Housing (Compressor End)

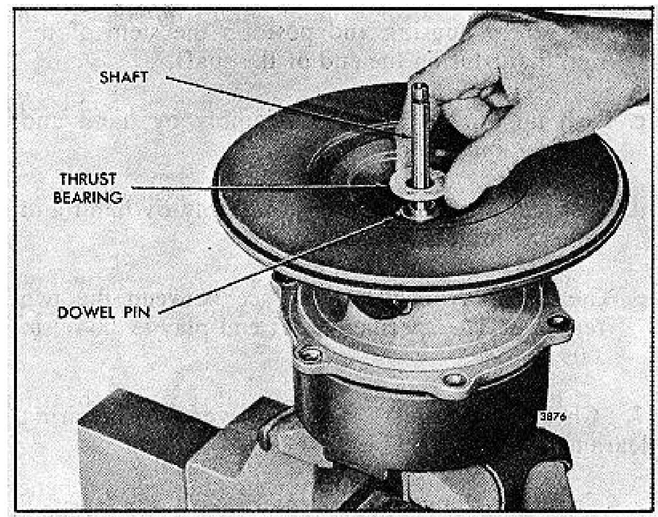


FIG. 27 - Installing Thrust Bearing in Center Housing

IMPORTANT: Do not use a box wrench or any other type wrench to tighten the lock nut as the excessive side strain may bend the shaft. Use a sliding tee handle with wrench J 21223-01 and apply an even pressure on each end of the tee handle. This will eliminate the possibility of bending the shaft while tightening the lock nut.

16. Check the shaft end play as follows:

a. Clamp the turbine housing and center housing and rotating assembly in a bench vise equipped with soft jaws as shown in Fig. 34.

b. Attach a clamp or a magnetic base indicator on

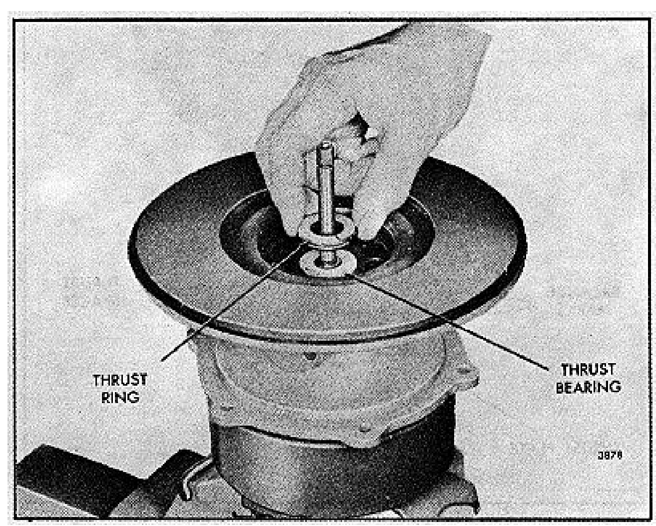


FIG. 28 - Installing Thrust Ring in Center Housing

the center housing and position the stem of the dial indicator on the end of the shaft.

c. Push up on the rotating assembly by hand and note the indicator reading.

d. Push down on the rotating assembly by hand and note the indicator reading.

e. The end play is the difference between the two readings. The specified shaft end play is .004" to .009"

17. Check the shaft radial movement (bearing clearance) as follows:

a. Clamp the flange of the center housing in a bench vise equipped with soft jaws (Fig. 35), with the oil outlet opening in the center housing facing up.

b. Place the dial indicator adaptor J 21224 over the oil outlet opening in the center housing with the large flat end of the plunger against the center of the shaft and secure the tool in place with two 3/8"-16 bolts of suitable length.

c. Attach a clamp or a magnetic base type indicator to the dial indicator adaptor and position the stem of the dial indicator on the end of the plunger.

NOTE: For a true reading, the dial indicator stem must be on the same center line as the plunger of the dial indicator adaptor.

d. Raise the rotating assembly up by hand as shown in Fig. 35 and note the indicator reading. Then push the rotating assembly down by hand and note the indicator reading.

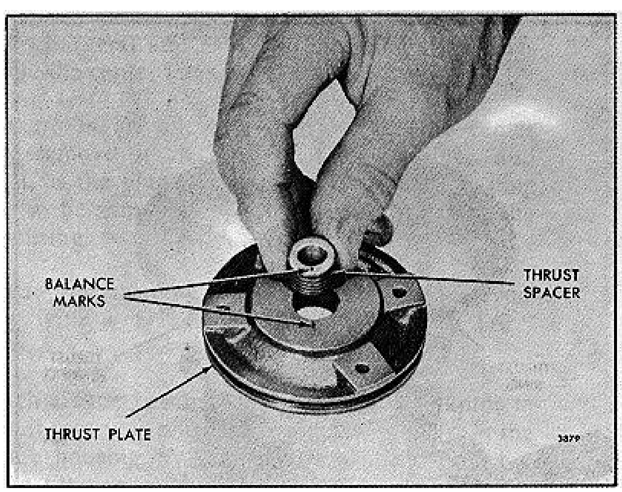


FIG. 29 - Installing Trust Spacer in Center Housing Thrust Plate

NOTE: Raise and lower both ends of the rotating assembly evenly when checking the radial movement.

e. The difference between the two readings is the total clearance between the shaft and the bearings. The specified clearance between the shaft and the bearings is .003" to .007"'. Repeat Steps d and e several times to be sure the readings are accurate.

NOTE: The shaft radial movement (bearing clearance) may be checked with the turbocharger assembly attached to the engine by mounting the dial indicator adaptor J 21224 and the dial indicator as shown in Fig. 36.

18. Place the compressor housing over the compressor wheel and against the center housing, with the marks previously placed on the housings in alignment.

19. Install the twelve bolts, lock washers and clamps that secure the T18 compressor housing to the center housing. Tighten the bolts to 100-110 Ib-in (11-12 Nm) torque. On the T18A turbocharger, position the compressor housing against the center housing and secure it in place with the "V" band coupling. Tighten the nut on the "V" band to 40-60 Ib-in(5-7 Nm) torque.

20. Place the turbine housing over the turbine wheel and against the center housing, with the marks previously placed on the housings in alignment.

21. Lubricate the threads of the turbine housing retaining bolts with a high temperature anti- seize lubricant. Then install the three lockplates and six bolts securing the turbine housing to the center housing. Tighten the bolts to 100-110 Ib-in(11-12 Nm) torque. Bend both ends of each lockplate up against the flat side of the bolt head.

22. With the turbocharger assembled, spin the rotating assembly by hand. The rotating assembly must turn freely without any indications of dragging or binding.

23. Cover all of the openings in the turbocharger to prevent any foreign material from entering.

Install Turbocharger

If a turbocharger is to be installed on a new or overhauled engine, operate the engine for approximately one hour *before* the turbocharger is installed. This must be done to ensure that no foreign material

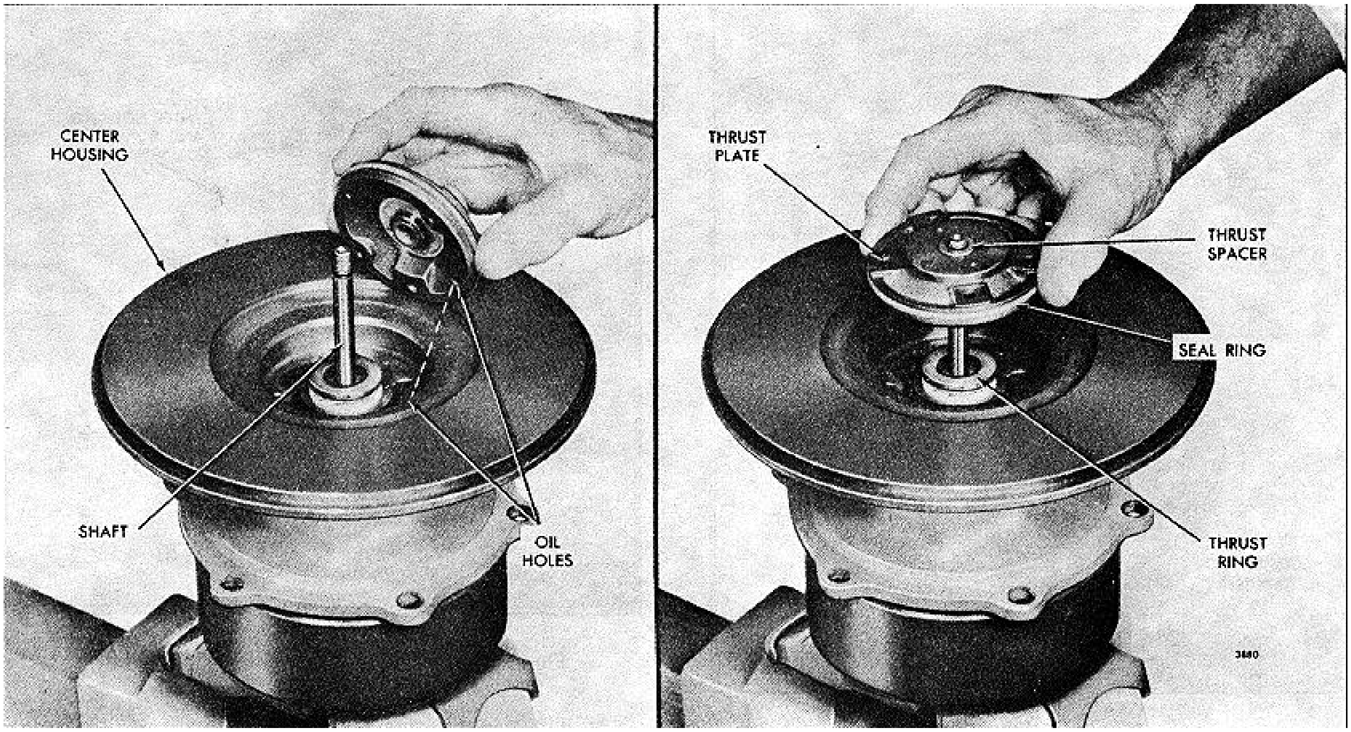


FIG. 30 - Installing Thrust Plate in Center Housing

is carried from the engine into the turbocharger lubrication system.

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.

2. Remove the covers from the air inlet and exhaust outlet openings that were placed over the openings when the turbocharger was removed.

3. Place the turbocharger assembly into position on the mounting bracket.

4. Place a new gasket between the exhaust manifold adaptor and the exhaust flange of the turbine housing, then secure the turbocharger to the adaptor with four bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the adaptor at this time.

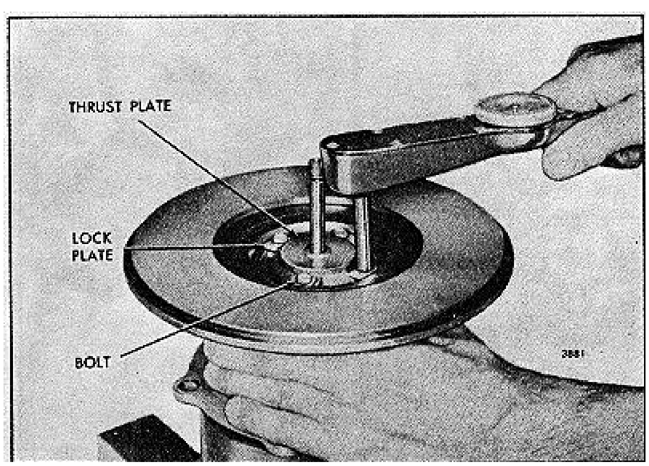


FIG. 31 - Tightening Thrust Plate Retaining Bolts

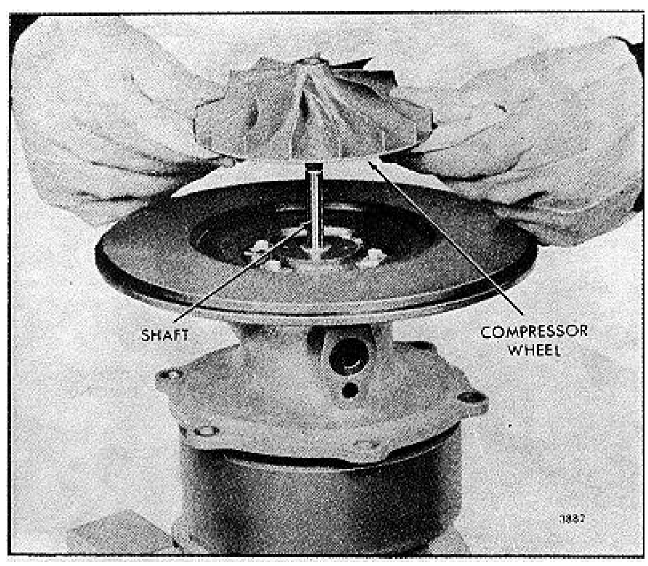


FIG. 32 - Installing Compressor Wheel on Shaft

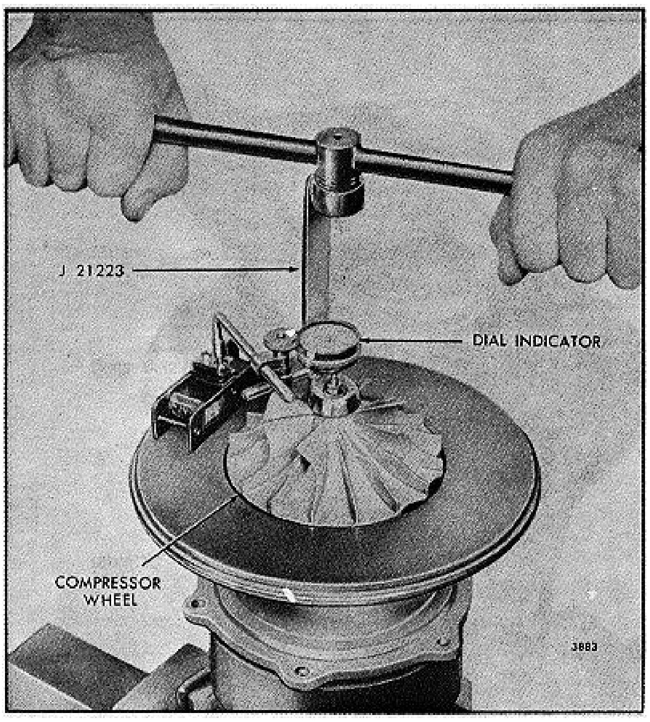


FIG. 33 - Tightening Compressor Wheel Lock Nut

5. Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

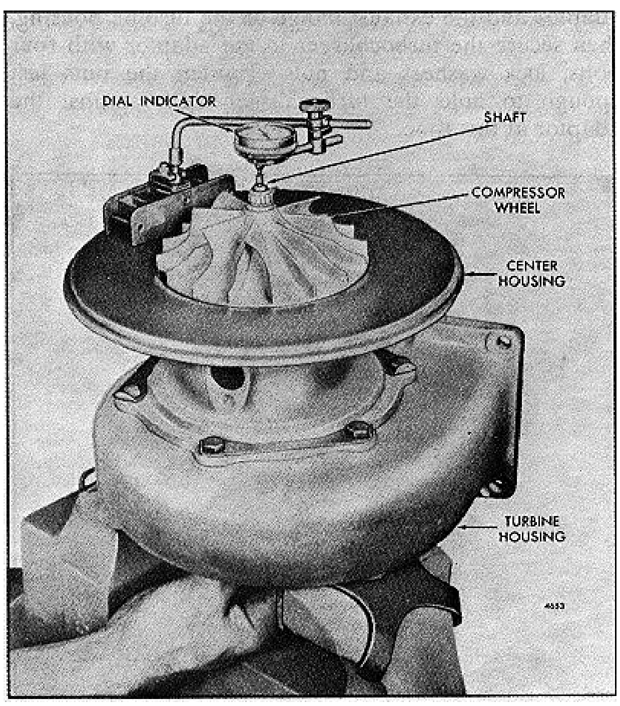


FIG. 34 - Checking Shaft End Play

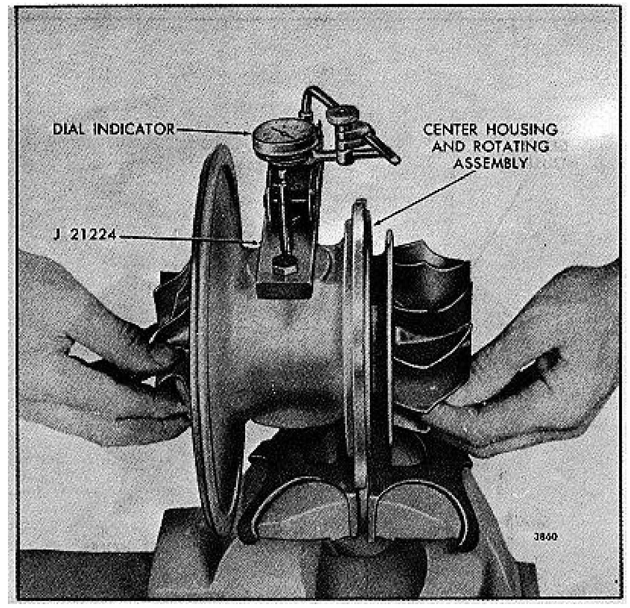


FIG. 35 - Checking Shaft Radial Movement

6. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.

7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.

8. Attach the oil inlet line to the cylinder block.

9. After installing a rebuilt or new turbocharger, it is

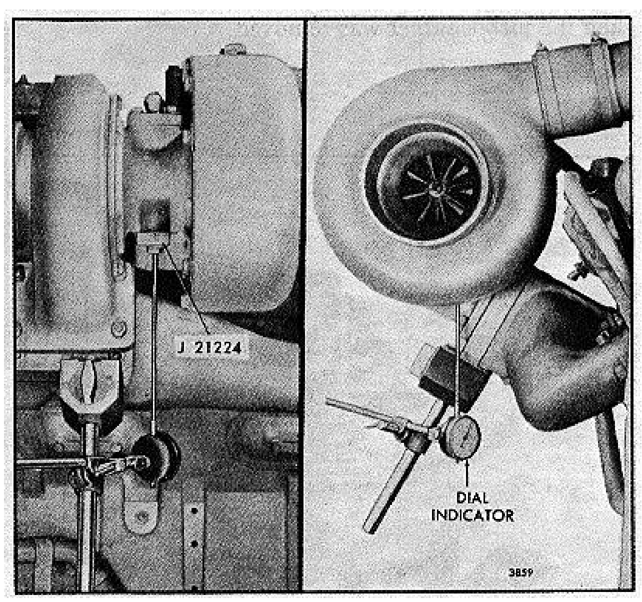


FIG. 36 - Indicator Mounting for Checking Shaft Radial Movement

very important that all moving parts of the turbocharger center housing be lubricated as follows:

a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing (Fig. 5).

b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

c. Add additional clean engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all of the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig or 69 kPa at idle speed).

CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

10. Check all ducts and gaskets for leaks.

11. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, stop the engine immediately and correct the cause.

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TURBOCHARGER (Schwitzer)

The Schwitzer turbocharger, Model 4MF-782 (7.38 square inches), (Fig. 1) is comprised of a centrifugal compressor which shares a bearing system and rotor shaft with an exhaust gas driven turbine. The turbocharger boosts the blower intake pressure of an engine above that which would prevail if the engine were naturally aspirated. The rotating assembly is supported radially by free-floating, pressure lubricated, sleeve type bearings. Axial end play is controlled by a stationary pressure lubricated thrust plate, with attendant hardware in the compressor end of the bearing housing.

The oil cavity is separated from the air and exhaust chambers by piston type seal rings located in the cylindrical bores at both axial extremities of the bearing housing.

The external configuration of both the Schwitzer and the Airesearch turbochargers are identical and hardware connections will not change. However, the internal components are different.

Certain vehicle engines, to comply with the emissions standards, are equipped with an aftercooler to cool the air going into the engine after it passes through both the turbocharger and the engine blower (refer to Section 3.5.3).

The Airesearch T18A40 and Schwitzer 4MF-782 turbochargers are interchangeable on the 6 and 8V-71 engines, only (see Table 1).

Airesearch T18A40 A/R	Schwitzer 4MF-782 IN^2
1.0	4.7
1.50	6.54

TABLE 1

> **NOTE:** Due to Certification implications, the Airesearch thick blade 1.5 and 1.0 A/R. turbochargers cannot be interchanged on Certified automotive engines.

Lubrication

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing and thrust plate. The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be pre-lubricated as outlined under *Install Turbocharger.*

> **NOTE:** Failure to perform the prelubrication procedure may result in premature bearing failure due to *oil lag* or lack of lubrication. Periodic Inspection

Periodic Inspection

> **NOTE:** A turbocharger compressor inlet shield J 26554, (Fig. 2) is available for use anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects from entering the turbocharger and prevents a serviceman from touching the moving impeller. The use of this shield *does not* preclude any other safety practices contained in this manual.

Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits (refer to Section 13.2).

A periodic inspection of the turbocharger should be made along with an engine inspection.

Inspect the turbocharger mountings and check all of the air ducting and connections for leaks. Make the inspection with the engine running and with it shut down. Check for leaks at the manifold connection, the turbine inlet and exhaust manifold gasket.

> **NOTE:** Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

Remove the inlet duct to the turbocharger compressor housing and check for carbon or dirt buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system. Remove all such accumulations and determine and correct the cause. Refer to *Trouble Shooting Turbocharger* in Section 3.0 Uneven deposits left on the compressor wheel can affect the balance and cause premature bearing failure.

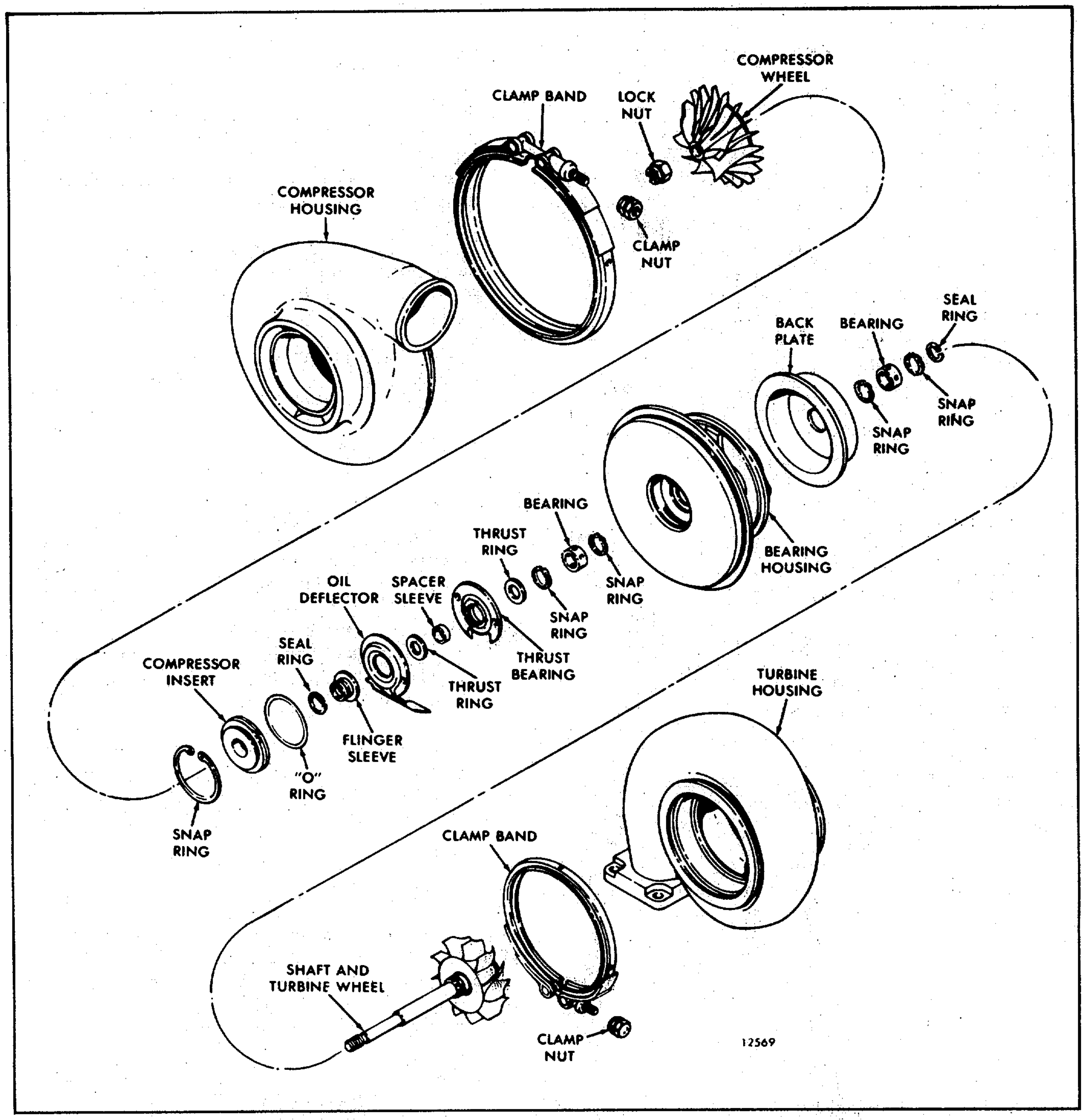


FIG. 1 - Model 4MF Turbocharger and Relative Location of Parts

NOTE: Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, an unbalanced condition would exist and subsequent failure of the bearings would result if the turbocharger is operated.

assembly must turn free. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, refer to Chart 1 of Fig. 3. Inspect the compressor and turbine wheels for nicks or loss of material. Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly opt of balance and shorten the life of the turbocharger.

For proper operation, the turbocharger rotating

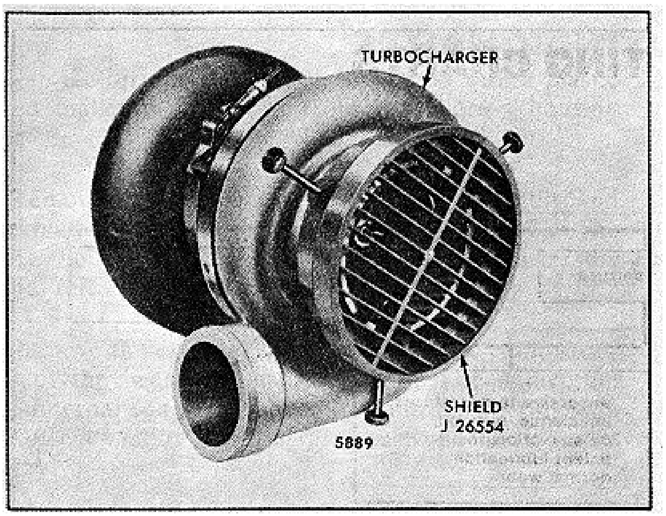


FIG. 2 - Inlet Shield

Inspect the oil inlet and oil return lines to make certain all of the connections are tight and that the lines are not dented or looped so that oil flow to and from the center housing is restricted. Looping the oil return lines disrupts gravity flow of the oil back to the engine.

> **NOTE:** Be sure the oil inlet lines are filled with oil and that they are clear of the turbine housings.

Check for signs of oil leaking from the turbocharger housing. Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. However, after the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, oil in these sections should disappear. If the oil does not disappear, refer to Chart 2 of Fig. 3.

Oil pull-over from an oil bath type air cleaner can also cause oil to enter the compressor housing. Check for a dirty air cleaner element or for too low viscosity oil in the air cleaner. Also, too small an air cleaner could create excessive air flow velocity and result in oil pull-over.

Evidence of oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require overhaul of the turbocharger. Refer to Chart 3 of Fig. 3.

Tests show there are three conditions that contribute to oil seal leakage at the internal turbocharger oil seal.

1 A worn or defective oil seal, which must be replaced.

2. High air inlet restriction (above specified limits). This will cause oil to be pulled past the oil seal.

3. Long periods of operation where the engine is being motored (using the engine as a braking device when going down a long hill). This can also cause oil to pass by the oil seal.

To confirm oil leakage from one or more of these conditions, remove the compressor housing and inspect the back plate. If the surface is wet with oil it indicates leakage.

If this test does not show leakage patterns the oil seal assembly is good for normal operation. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within Detroit Diesel maximum limit. Refer to Section 13.2.

2. Be certain that turbocharger oil drain line is unrestricted.

3. Be certain that the turbocharger has not obviously been damaged and in need of major repair.

4. Remove air intake ducting. Inspect inside of ducting for evidence of oil. If oil is found in the intake system, determine the source before proceeding with compressor seal test and also thoroughly remove oil from the intake. Some external sources of oil are oil bath air cleaner, air compressor line, or a leak near an oil source such as an engine breather, etc.

5. Remove compressor housing from turbocharger.

6. Thoroughly clean internal surfaces of compressor housing, impeller cavity behind impeller, and backplate annulus with suitable solvent spray and then dry completely with shop air.

7. Spray backplate annulus with a light coating of "Spot-Check" developer type SKD-MF, or equivalent.

8. Install compressor housing on turbocharger and reconnect inlet and outlet connections.

9. Warm up engine to normal operating temperature.

10. Operate engine at no load at the governor limited high speed for approximately five (5) minutes.

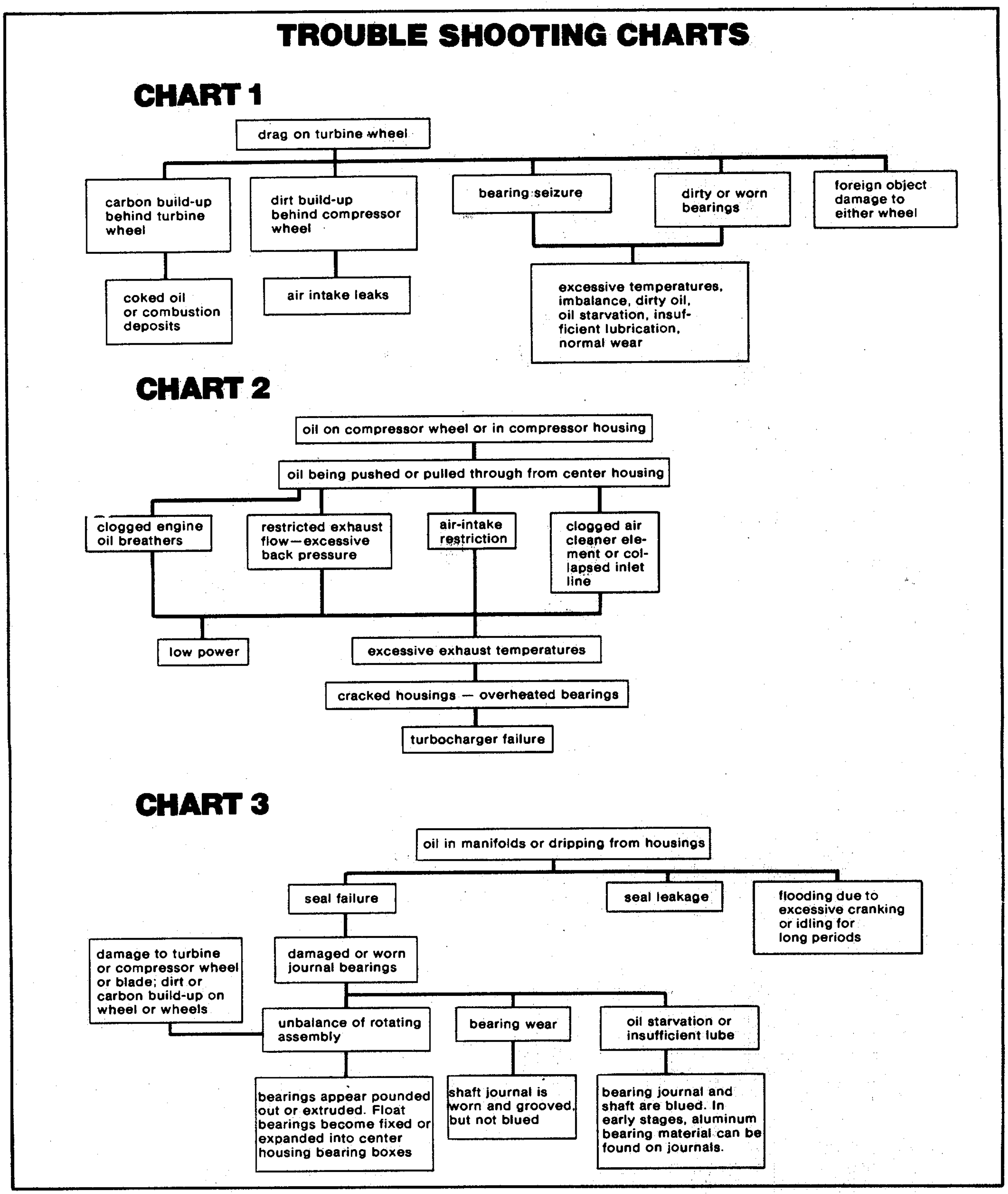


FIG. 3 - Inspection Checks for Turbocharger

11. Return engine to low idle and then shut off

12. Remove intake duct and outlet hose and then remove compressor housing. Evidence of compressor end shaft seal oil leakage will be observed as oil streaks in the "Spot-Check" developer on the backplate annulus. This surface should be completely free of oil streaks after the test.

13. If leakage is detected, and oil is positively not entering through the intake duct, then the turbocharger may be removed from the engine and inspected for damaged components.

Remove Turbocharger

1. Disconnect the air inlet connection and the exhaust outlet connection from the compressor housing and turbine housing respectively. This will permit inspection of the compressor and turbine wheels. Spin and wobble the rotor assembly variously by hand for evidence of wheel to turbine housing and impeller to compressor housing contact.

2. Remove the oil inlet and outlet lines from the top and bottom of the bearing housing.

3. Attach a suitable lifting sling to the turbocharger.

4. Remove the nuts and lock washers securing the turbocharger to the mounting bracket. Lift the turbocharger from the engine.

5. Cover the oil inlet and outlet openings and the air inlet and exhaust openings on the engine to prevent the entry of foreign material.

Disassemble Turbocharger

1. Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly and proceed as follows:

> **NOTE:** Exercise care when removing the compressor housing and turbine housing from the bearing housing to prevent damage to the compressor and turbine wheels.

2. Loosen the clamp band securing the compressor housing from the bearing housing. Use a plastic faced mallet and remove the compressor housing and clamp band.

3. Loosen the clamp band securing the turbine housing to the backplate and bearing housing. Use a plastic faced mallet and remove the turbine housing and clamp band.

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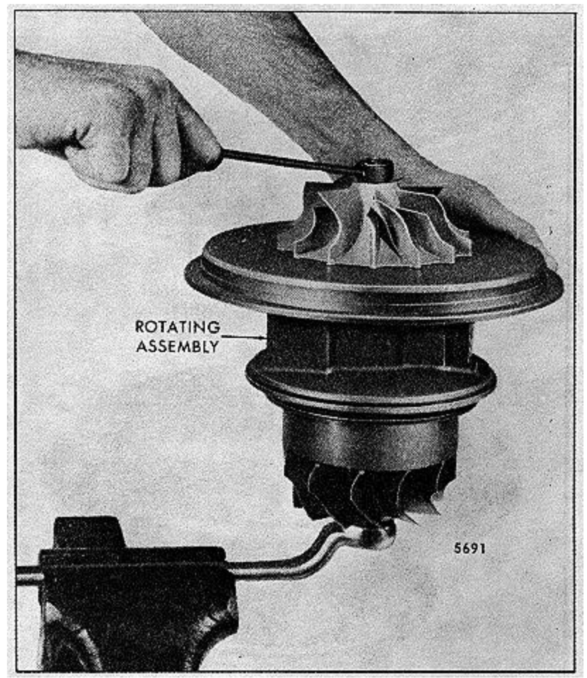


FIG. 4 - Removing Compressor Wheel Lock Nut

4. With the turbine wheel lug of the rotating assembly in a 1 " wrench (Fig. 4), remove and discard the compressor wheel lock nut.

5. Remove the compressor wheel from the turbine shaft assembly by hand (Fig. 5). The wheel is a slip fit on the shaft.

6. Tap the turbine shaft assembly gently with a plastic faced mallet to release it from the bearing housing (Fig. 6).

7. Remove the turbine wheel and shaft assembly and backplate from the bearing housing (Fig. 7). The shaft should slip freely out of the bearings after the initial release by tapping.

8. Remove the external snap ring from the compressor end of the bearing housing (Fig. 8). Use a medium size internal snap ring pliers and *restrain the ring with a shop cloth to prevent injury, in the event the ring goes astray.*

9. Remove the compressor insert from the bearing housing by prying evenly and gently with screw drivers placed under the lip of the insert (Fig. 9).

IMPORTANT: If the insert tilts and binds, tap it back into place and repeat the procedure. *Do not force* the insert from the bearing housing.

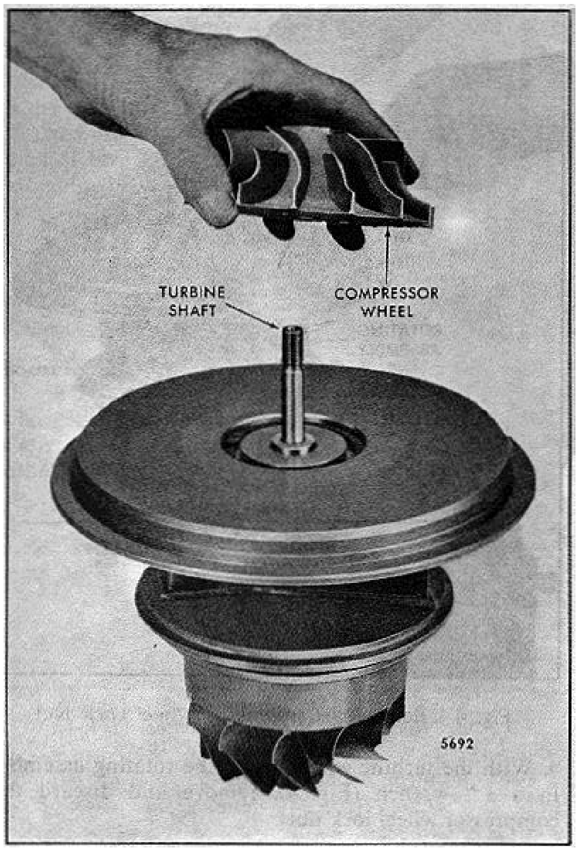


FIG. 5 Removing Compressor Wheel from Turbine Shaft

10. Remove the oil deflector, outer thrust ring, spacer sleeve, thrust bearing (discard) and inner thrust ring from the cavity in the bearing housing.

NOTE: Do not remove the dowel from the bearing housing.

11. Disassemble the compressor insert assembly. It consists of the compressor insert, seal "O" ring (discard), flinger sleeve and seal ring (discard).

12. Remove and discard the outer internal snap ring from the compressor end of the bearing housing bore (Fig. 10). Use a small internal snap ring pliers.

13. Remove and discard the turbine shaft bearing from the compressor end of the bearing housing bore (Fig. 11).

14. Remove and discard the inner internal snap ring from the compressor end of the bearing housing bore.

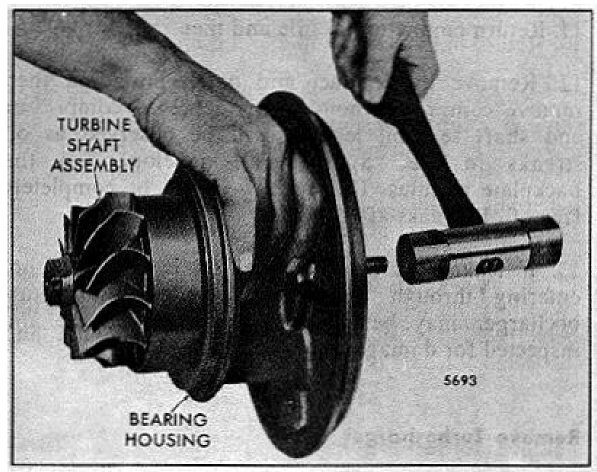


FIG. 6 ..Tapping Turbine Shaft Assembly trom Bearing Housing

Do not scratch the bearing bore when removing the snap ring.

15. Remove and discard the outer internal snap ring from the turbine end of the bearing housing bore.

NOTE: If the seal ring bore in the housing is encrusted with carbon, preventing removal of the bearing components, scrape away the carbon with a sharp-edged tool. Do not scratch or gouge the seal ring bore surface.

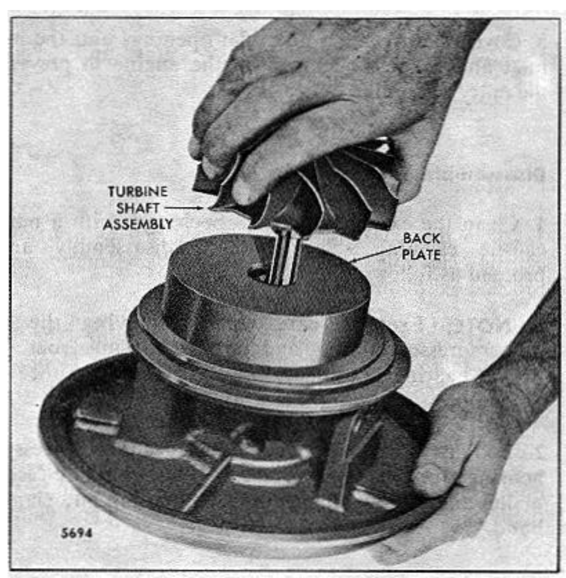


FIG. 7 - Removing Turbine Shaft Assembly and Backplate from Bearing Housing

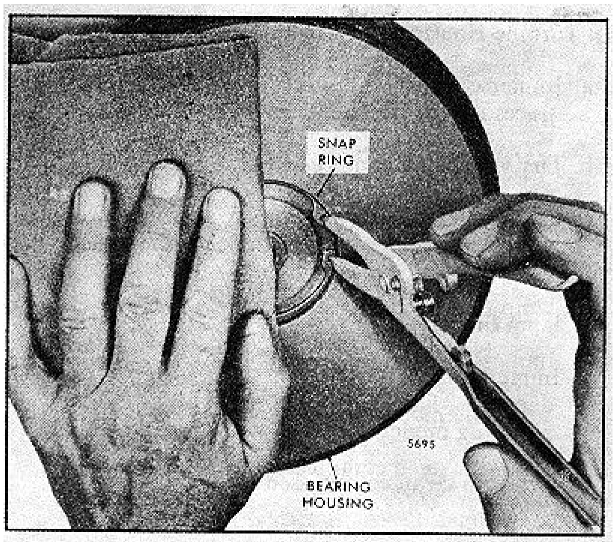


FIG. 8 Removing External Snap Ring trom Bearing Housing

16. Remove and discard the shaft bearing from the turbine end of the bearing housing bore.

17. Remove and discard the inner internal snap ring from the turbine end of the bearing housing bore. Do not scratch the bearing bore during removal of the snap ring.

18. Remove and discard the seal ring from the turbine wheel-and-shaft by prying and breaking with a screw driver. Take care not to mar the hub or groove surfaces of the turbine wheel.

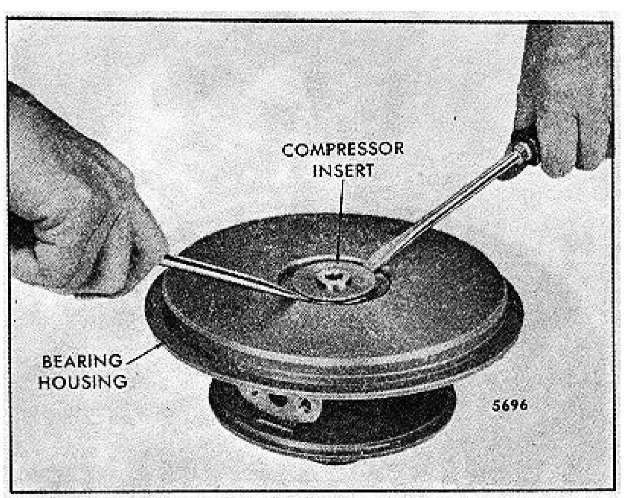


FIG. 9 Removing Compressor Insert from Bearing Housing

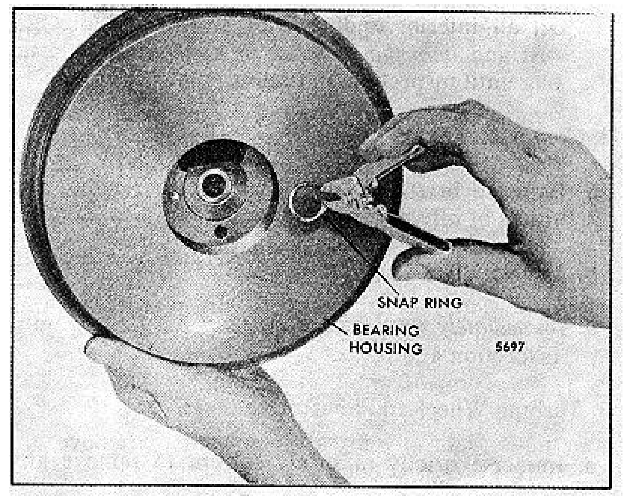


FIG. 10 - Removing Internal Snap Ring from Bearing Housing

Cleaning Procedures

1. Bearing Housing and Dowel Assembly:

   a. Scrape or wipe appropriately any loose or heavy foreign material accumulations from the exterior surfaces.

   b. Immerse briefly in safety solvent to remove any traces of oily residue.

   c. Dry with clean compressed air, again taking care that all drilled oil passages are thoroughly cleaned.

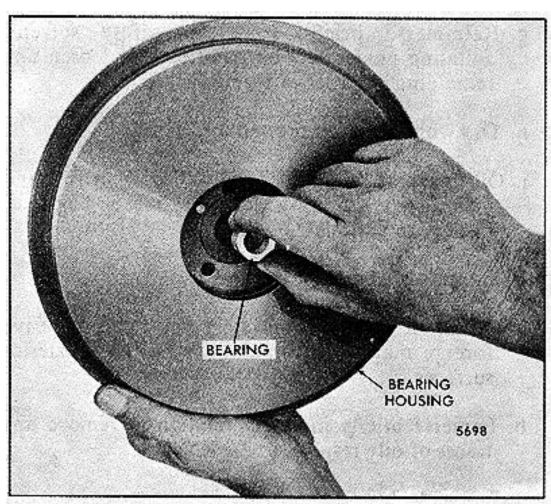


FIG. 11 - Removing Turbine Shaft Bearing from Bearing Housing

d. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

2. Compressor Wheel:
   a. Immerse briefly in safety solvent to remove any traces of oily residue.

   b. Dry with clean compressed air.

   c. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.

3. Turbine Wheel-and-Shaft Assembly:

   a. Immerse briefly in safety solvent to remove any traces of oily residue.

   b. Dry with clean compressed air.

   c. Mask the entire shaft section with either appropriately sized rubber hose or adhesive backed cloth tape.

   d. Vapor blast or dry hone the entire turbine wheel and the hub to total cleanliness, taking care not to concentrate on the seal ring groove.

   e. Remove the masking material.

   f. Mount the small diameter shaft section in a lathe chuck, taking care not to mar the shaft surface. Lightly polish the bearing journal section of the shaft, at 300 to 600 rpm, with 400 grit abrasive paper and clean engine oil.

   g. Reimmerse briefly in clean safety solvent, agitating moderately by hand to help loosen any remaining particles of foreign material.

   h. Dry with clean compressed air.

   i. Oil the shaft surfaces liberally to prevent rust and immediately wrap in a clean, dry plastic bag until inspection and reuse.

4. Compressor Housing:
   a. Scrape or wipe appropriately any loose or heavy foreign material accumulations from the exterior surfaces.

   b. Immerse briefly in safety solution to remove any traces of oily residue.

   c. Dry with clean compressed air.

d. *Immediately* wrap in a clean, dry plastic bag until inspection and reuse.

5. Turbine Housing and Turbine Backplate:

   a. Immerse briefly in safety solvent to remove any traces of oily residue.

   b. Dry with clean compressed air.

   c. Oil all interior and exterior surfaces to prevent rust and *immediately* wrap in a clean, dry plastic bag until inspection and reuse.

6. Clamp Bands:

   a. Immerse in safety solvent until foreign material deposits have been softened or dissolved, agitating moderately and occasionally by hand.

   b. Dry with clean compressed air.

   c. Wrap immediately in a clean, dry plastic bag until inspection and reuse.

7. Small Internal Parts:

   a Immerse briefly in clean safety solvent to remove any traces of oily residue.

   b. Wipe dry with a clean shop rag.

   c. Oil liberally to prevent rust and wrap *immediately* in

   a. clean, dry plastic bag until inspection and reuse.

Inspection

1. Bearing Housing and Dowel Assembly:

   a. Inspect visually for evidence of cracks and

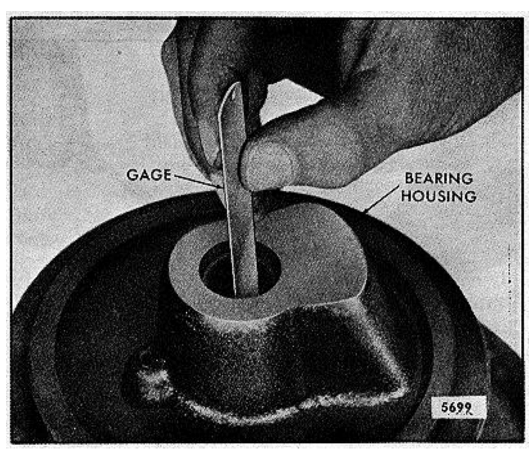


FIG. 12 - Checking Turbine Seal Ring Gap in Bearing Housing

fractures pitting (as from corrosion or hot gas erosion) of gasket and other machined surfaces, and warpage of the turbine end flange. Replace if any of the above conditions are excessive.

b. Closely inspect the bearing bore visually for evidence of surface distress. The condition of the bearings that were removed during disassembly will serve as a good indicator of probable bore condition. Replace if the bore condition is sub- standard. The maximum bore diameter is .8768 ".

c. Install the turbine seal ring in its bore, inspect visually for full circle contact, and measure the ring gap with a feeler gage (Fig. 12). The gap range is .002 " to .009 ". Replace if the ring fit is faulty.

NOTE: Do not attempt to restore the bore condition by reaming or honing.

2. Compressor Wheel:

Inspect visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the backplate. Replace if this damage is present. Slightly nicked vanes are acceptable.

NOTE: Do not attempt to straighten bent vanes.

3. Turbine Wheel and Shaft Assembly:

a. Inspect the wheel visually for evidence of bent, burred or eroded vanes and for evidence of scuffing on the back face. Replace if damaged.

NOTE: Do not attempt to straighten bent vanes.

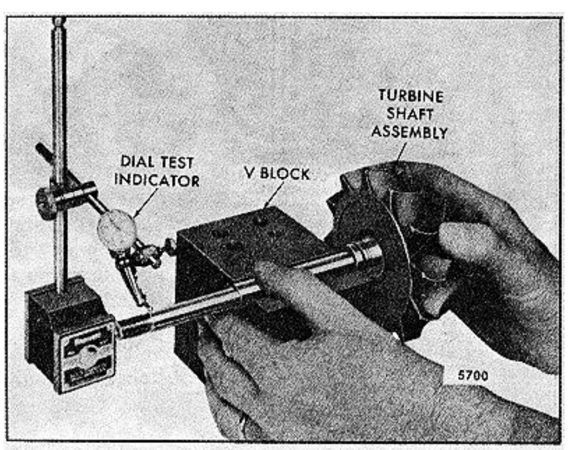


FIG. 13 - Measuring Concentricity Between Large and Small Turbine Shaft Diameters

b. Inspect the hub visually for evidence of smearing (as from high speed contact with the bearing housing bore) and for deterioration of the seal ring groove. Replace if damage is excessive.

c. Inspect bearing journals visually for evidence of other than superficial deterioration (as from a bearing failure). Replace if journal condition is sub-standard. The minimum journal diameter is .5611 ".

d. Measure the concentricity between the large and small turbine shaft diameters with a dial test indicator and vee-block (Fig. 13). Limit of eccentricity is .0015 " total indicator reading. Replace if the measurement is excessive.

NOTE: Do not attempt to straighten a bent shaft.

4. Compressor Housing:

Inspect visually for evidence of contour damage (as from high speed wheel contact). Replace if damaged.

5. Turbine Housing and Backplate:

Inspect visually for evidence of contour damage (as from high speed wheel contact) and for evidence of excessive heat damage, to internal. and flanged surfaces, such as cracking, pitting or warpage. Replace if damaged.

6. Small Internal Parts:

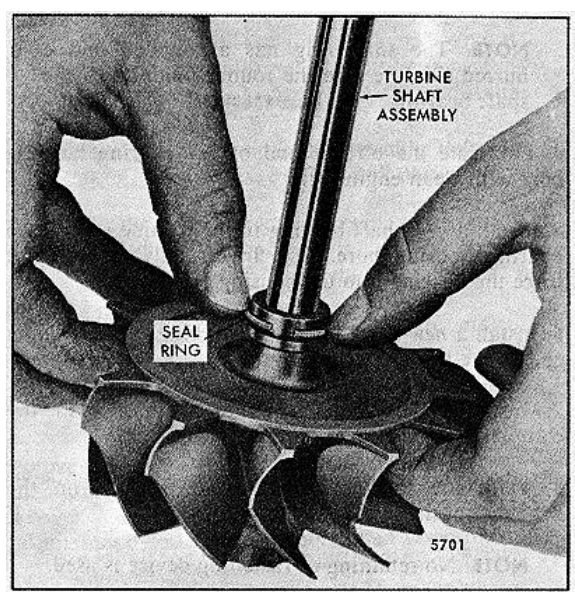


FIG. 14 - Installing Seal Ring on Turbine Shaft

a. Install the compressor seal ring in the insert bore, inspect visually for full circle contact and measure the ring gap with a feeler gage. Gap range is .002 " to .009 ". Replace the insert if the ring fit is faulty.

NOTE: Do not attempt to restore bore condition by reaming or grinding.

b. Inspect both thrust rings visually for evidence of wear and scratching. Replace if damaged.

Assemble Turbocharger

1. Install a *new* turbine seal ring on the turbine wheel and shaft assembly. Use the thumbs only as shown in Fig. 14.

2. Assemble the compressor insert as follows:

a. Install a new seal "O" ring on the compressor insert.

b. Install a new compressor seal ring on the flinger sleeve. Use fingers only.

c. Install the flinger sleeve and seal assembly in the compressor insert.

3. Install a new inner internal snap ring in the turbine end of the bearing bore. Do not scratch the bearing bore and be certain the snap ring seats fully in its groove,.

NOTE: The snap ring has a rounded and a burred side. Be sure the rounded side faces the shaft bearing,

4. Lubricate the turbine end of the bearing housing bore with clean engine oil.

5. Install a *new* shaft bearing in the turbine end of the bearing housing bore. Use fingers only and do not force the bearing into the housing bore.

6. Install a *new* outer internal snap ring in the turbine end of the bearing housing bore.

7. Install a *new* inner internal snap ring in the compressor end of the bearing housing bore.

8. Place the turbine backplate in position on the bearing housing.

NOTE: No retaining or fastening device is used.

9. Lubricate the bearing journal area of the turbine wheel and shaft assembly with clean engine oil.

10. Install the turbine wheel and shaft assembly in the bearing housing. Use a wobbling motion to compress the seal ring and do not force it into the bearing housing.

NOTE: Do not try to install the turbine wheel and shaft assembly in the bearing housing without the backplate in position.

11. Invert the bearing housing and turbine wheel and sh4ft assembly on a work bench. Lubricate the compressor end of the bearing housing bore with clean engine oil.

12. Install a new shaft bearing in the compressor end of the bearing housing bore. Do not force the bearing into the housing bore.

13. Install a new outer internal snap ring in the compressor end of the bearing housing bore.

14. Install the inner thrust ring on the turbine wheel and shaft assembly.

15. Install the spacer sleeve on the wheel and shaft assembly.

16. Lubricate the face of the inner thrust ring with clean engine oil.

17. Install the thrust bearing in the compressor end cavity of the bearing housing. Lubricate the face of the thrust bearing with clean engine oil.

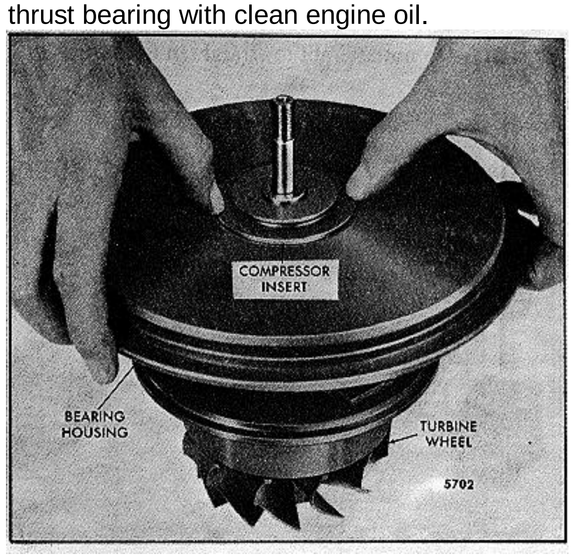


FIG. 15 - Installing Compressor Insert in Bearing Housing

18. Install the outer thrust ring on the turbine wheel and shaft assembly.

19. Install the oil deflector in the bearing housing cavity. Be sure the dowel and the dowel hole in the deflector are in alignment.

20. Lubricate the seal "O" ring on the compressor insert with clean engine oil.

21. Install the compressor insert assembly in the cavity of the bearing housing as shown in Fig. 15.

22. Install the external snap ring in the compressor end cavity of the bearing housing. Be sure the ring seats fully in its groove, by twist-prying against the insert rim with a screw driver.

23. Install the compressor wheel on the turbine shaft.

24. Install a new lock nut on the turbine shaft finger tight (until elastic of nut engages the shaft threads).

25. Insert the turbine wheel lug in a 1 " wrench and tighten the compressor lock nut with a torque wrench (Fig. 16) to 30-32 lb-ft (41-43 Nm) torque.

26. Install the turbine end clamp band, without the retaining nut, on the turbine housing flange.

27. Install the rotating assembly in the turbine housing. Be sure to engage and seat the clamp band.

28. Install the clamp band retaining nut and hand tighten, snugly.

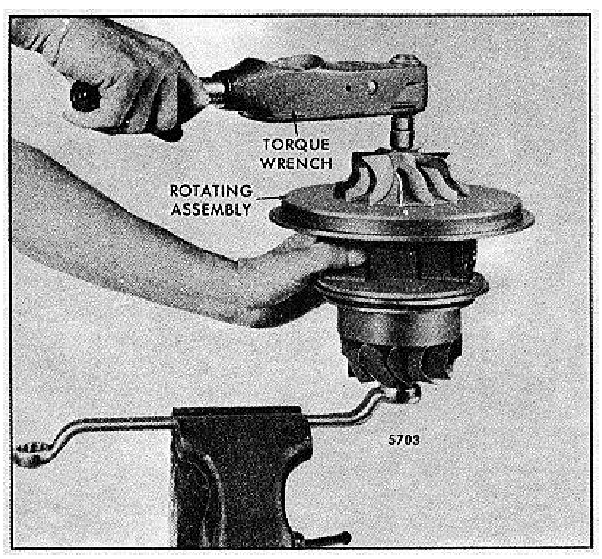


FIG. 16 - Tightening Compressor Lock Nut

29. Install the compressor end clamp band, without the retaining nut, on the compressor housing flange.

30. Install the compressor housing on the rotating assembly (bearing housing) and turbine housing. Be sure to engage and seat the clamp band.

31. Install the compressor end clamp band retaining nut and hand tighten, snugly.

32. Inject approximately 1/4 ounce of clean engine oil into the oil inlet port of the bearing housing.

33. Spin the rotating assembly by hand to assure smooth and free rotation.

34. Seal the completed unit in a clean, dry plastic bag until installed on the engine.

Install Turbocharger

1. Inspect the intake and exhaust systems leading to the turbocharger to insure absence of foreign material (even small particles can cause severe damage to the rotating assembly when inducted at high speeds).

2. Use new gaskets at all of the air, oil and exhaust connections to the turbocharger.

> **IMPORTANT:** Do not use joint compound at the oil inlet and exhaust connections.

3. Use anti-seize thread compound on all threaded fasteners used to mount the turbocharger.

4. Attach a chain hoist and a suitable lifting sling into the turbocharger assembly.

5. Position the turbocharger so that it aligns with all corresponding connections on the engine.

6. Tighten the compressor housing and turbine housing clamp band retaining nuts to 10 Ib-ft (14 Nm) torque.

7. Secure the turbocharger to the mounting bracket with bolts, lock washers and nuts. Tighten the nuts just enough to hold the turbocharger tight against the brackets.

> **NOTE:** When self locking nuts are used to secure the turbocharger to the mounting bracket, be sure there is full thread engagement (at least one full thread above the nut) of the self locking nuts on the bolts.

8. Slide the blower air inlet tube hose over the compressor housing outlet and secure it in place with hose clamps.

9. Tighten the turbocharger to exhaust manifold adaptor bolts securely.

10. Connect the oil inlet line to the cylinder block.

11. After installing a rebuilt or new turbocharger it is very important that all the moving parts of the turbocharger center housing be lubricated as follows:

a. Clean the area and disconnect the oil inlet (supply) line at the bearing (center) housing.

b. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

c. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

d. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving' parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig - 69 kPa at idle speed).

CAUTION: Do not hold the compressor wheel, for any reason, while the engine is running. This could result in personal injury.

The free floating bearings in the turbocharger bearing housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speeds* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed, above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

12. Check all connections, ducts and gaskets for leaks.

13. Operate the engine at rated output and listen for sounds of metallic contact from the turbocharger. If any such noise is apparent, shut the engine down immediately and correct the cause.

NOTE: After the turbochafger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and eliminated.

TURBOCHARGER AFTERCOOLER

The aftercooler mounts in the cylinder block opening between the cylinders, beneath the blower assembly (Fig. 1). The aftercooler (Fig. 2) cools the air going into the engine after it passes through both the turbocharger and the blower. The air flows downward through the aftercooler and the coolant flows from rear to front through the aftercooler and returns through the left-bank thermostat housing.

The top deck of the current cylinder block has been revised to accept the aftercooler. A water inlet adaptor plug replaces the rear 2 1/2 " core plug in the bottom of the cylinder block opening (Fig. 3) to supply water to the aftercooler. Tool J 25275 should be used to install or remove this adaptor plug.

6 and 8V-71 ENGINES

Remove Aftercooler

1. Loosen the two 7/16"-14 x 5 1/4" attaching bolts and lift the turbocharger from the air inlet adaptor (refer to Section 3.5).

2. Remove the air inlet adaptor from the blower.

3. Remove the blower and any accessories attached to the blower from the cylinder block (refer to Section 3.4).

4. Loosen the hose clamps and slide the cylinder block water outlet tube hose back against the thermostat housing.

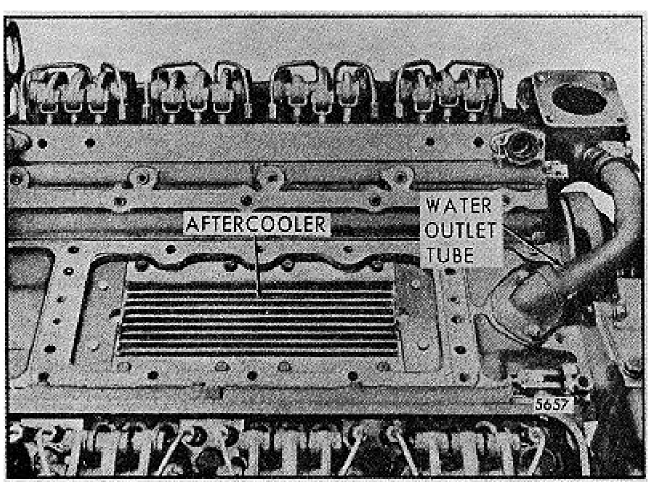


FIG. 1 - Aftercooler Mounted in Cylinder Block

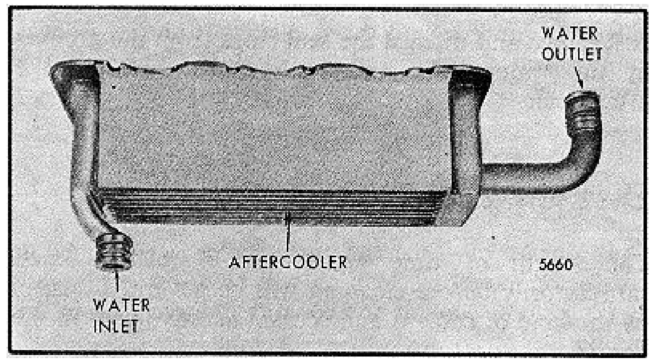


FIG. 2 - Aftercooler

5. Remove the water outlet tube from the front of the cylinder block. Discard the gasket.

6. Remove and discard the 5/16 " -18 x 9/16 " attaching bolts with nylon locking patch and lift the aftercooler from the cylinder block opening between the cylinders. *Do not remove the four bolts in the top face of the aftercooler (Fig. 1). They are part of the aftercooler assembly and need not be removed for any reason.*

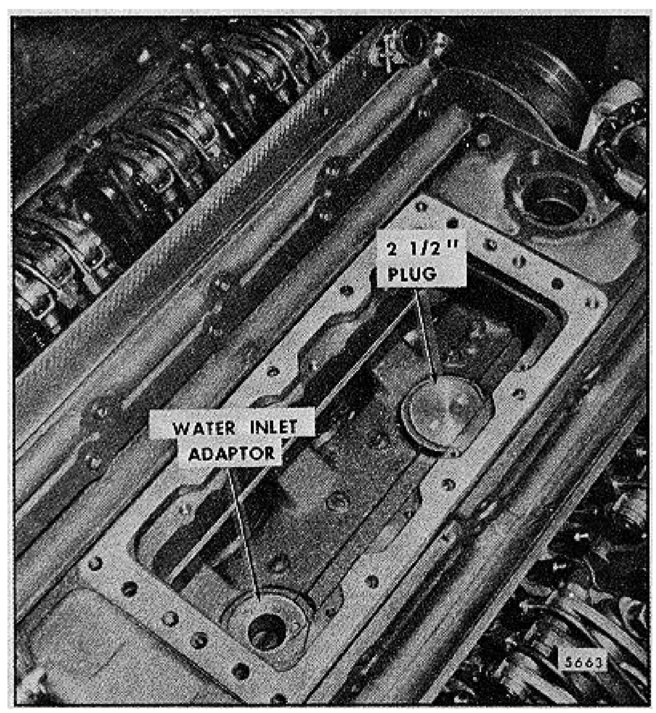


FIG. 3 - Location of Water Inlet Adaptor Plug in Cylinder Block

CAUTION: Be careful not to damage the cooler fins when lifting the aftercooler from the cylinder block.

7. Remove and discard the seal rings from the grooves in the water inlet and outlet tube ends of the aftercooler.

Clean Aftercooler

The length of time an aftercooler will function satisfactorily before cleaning will be governed largely by the kind of coolant and coolant additive used in the engine.

Check all of the cooler fins and air and water passages for plugging at major overhaul. Clean the fins of dirt or any other foreign obstructions with a small brush. Do not apply more than 40 psi (276 kPa) air pressure.

Install Aftercooler

1. Install new seal rings in the two grooves on the water inlet and outlet tube ends of the aftercooler. Coat the seal rings lightly with engine oil or vegetable shortening. Do not scratch or nick the sealing edge of the seal rings.

2. Place the aftercooler, water outlet end first, into the cylinder block opening between the cylinders. The water inlet end of the cooler seats in the water inlet adaptor plug (Fig. 3). Install new, 5/16" -18 x 9/16" attaching bolts with nylon locking patch (six -6V-71, eight - 8V-71).

Do not tighten the bolts until the water outlet tube to thermostat housing hose and clamps are aligned and tightened.

3. Use a new gasket and attach the water outlet tube with two 5/ 16" bolts and lock washers to the cylinder block. Do not tighten the attaching bolts.

4. Align the water outlet tube to the thermostat housing with the hose and clamps in position. Tighten the clamps.

5. Tighten the two 5/16" water outlet tube bolts, then tighten the aftercooler attaching bolts.

6. Use a new blower to cylinder block gasket and install the blower and any accessories attached to the blower (refer to Section 3.4).

7. Attach the air inlet adaptor to the blower with the 7/16" -14 x l 1/2" attaching bolts and lock washers (eight - 6V-71, ten - 8V-71). Tighten the bolts to 46-50 lb-ft (62-68 Nm) torque.

8. Install the turbocharger (refer to Section 3.5). Tighten the two 7/16" -14 x 5 1/4" bolts to 46-50 lb-ft (62-68 Nm) torque.

SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

REWORKING BLOWER END PLATE FOR DRY SEAL CONNECTOR

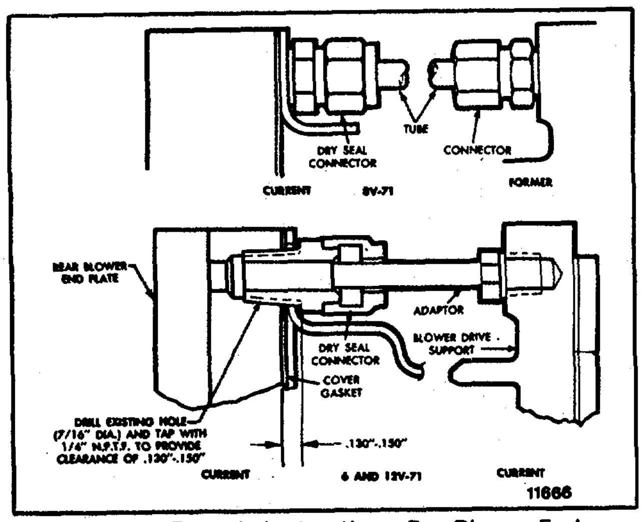


FIG. 1 - Rework Instructions For Blower End Plate

When oil leakage is a problem, a former blower rear end plate can be reworked to incorporate a dry seal connector (Fig. 1). The dry seal connector consists of a connector, seal ring and nut.

To use these parts, the blower assembly must be removed from the engine so the rear end plate can be drilled and tapped (1/4 " NPTF) to accept the connector. Perform the drilling and tapping on a drill press to ensure that proper alignment can be maintained when the tube is installed between the blower and the blower drive support. The hole should only be tapped deep enough to maintain a clearance of .130 " to .150 " between the surfaces of the end plate and the bottom edge of the flats on the connector when it is installed in the end plate. This clearance is necessary to prevent interference between the connector and the blower end cover when they are assembled. The former 12V front blower rear end plate cover will also have to have a hole drilled deep enough to prevent interference between the 1/4 " pipe plug in the end plate and the cover. Since the retaining plate is not used, the two end cover bolts (5/16 "- 18 x 2-l/4 ") that secure the plate to the blower must be replaced by two shorter bolts (5/16 "-18 x 2-1/16 ").

When rework is done on a 6V or 12V engine, use the new adaptor at the blower drive support housing to connect with the dry seal connector at the blower end plate. On an 8V engine, use the present oil tube and connector at the blower drive support to connect with the dry seal connector at the blower end plate.

The rubber seal ring used between the blower end plate and the blower drive support can be replaced without removing the blower as follows:

1. Remove the clamp and cut and remove the old seal ring.

2. After thoroughly cleaning the blower drive groove area, make a square cut on a new seal ring and install the seal ring around the groove, with the cut at the top. Attach the two ends of the seal ring together with Loctite No. 06, or equivalent, as follows:

a. The cutting blade to be used must be clean and free of contaminants. If a razor edge is to be used, remove the protective oil film by wiping with solvent.

b. Make a square cut in the replacement seal. The cut ends must remain clean to achieve a satisfactory bond.

c. Apply a thin film of Loctite Super Bonder Adhesive to one of the cut ends. Shake off excess adhesive. Use adhesive sparingly and avoid contact with skin.

d. Position the seal in the blower drive groove, locating the adhesive treated end first. Place the other end of the seal in the groove and slide it into the adhesive end to make the joint. Apply light pressure to the joint and hold firmly for 30 seconds.

e. To remove excess adhesive around the joint, apply a chlorinated solvent (Acetone, MEK or Methylene Chloride) to a cloth and wipe the joint.

CAUTION: *This adhesive contains cyanoacrylate. Keep away from children. Irritating liquid and vapor. Hazardous if swallowed. Use with adequate ventilation. In case of skin contact, flush with plenty of water. For eye or mouth contact, get medical attention.*

3. Install the plain clamp between the raised edges of the seal ring and tighten.

NOTE: If a former seal ring (without groove) is issued, it is advisable to use a hose clamp with three tangs to ensure proper sealing.

TROUBLE SHOOTING

TURBOCHARGER

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
NOISY OPERATION OR VIBRATION	WHEEL SHAFT BEARINGS ARE NOT BEING LUBRICATED	Locate cause of loss of oil pressure and repair. Remove, disassemble and inspect turbocharger for bearing damage
	IMPROPER CLEARANCE BETWEEN TURBINE WHEEL AND HOUSING	Remove, disassemble, and inspect turbocharger.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
ENGINE WILL NOT DELIVER RATED POWER	CLOGGED AIR INTAKE OR EXHAUST MANIFOLD	Check air cleaner and clean air intake ducts.
	FOREIGN MATERIAL LODGED IN COMPRESSOR OR TURBINE WHEELS	Remove, Disassemble and clean turbocharger.
	EXCESSIVE DIRT BUILD-UP IN COMPRESSOR	Thoroughly clean compressor assembly. Clean air cleaner and check for leaks.
	LEAK IN ENGINE AIR INTAKE OR EXHAUST MANIFOLD	Tighten all loose connections or replace exhaust manifold gaskets as necessary.
	ROTATING ASSEMBLY BEARING SEIZURE	Remove and overhaul turbocharger.

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.

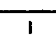
ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
Blower			
Backlash (timing gears)	.0005"	.0025"	.0040"
Oil Seal (below end plate surface)	.0020"	.0080"	
Oil Strainer (below end plate surface)	.0000"	.0150"	
Dowel Pin (projection beyond inside face of front end plate)	.3200"		
Dowel Pin (projection beyond inside face of rear end plate)	.3200"		
Clearances:			
Rotor to end plate (gear end)	.0070"		
Rotor to end plate (front end - 6V and 12V)	.0120"		
Rotor to end plate (front end - 8V)	.0140"		
Rotor to housing (inlet side)	.0150"		
Rotor to housing (outlet side)	.0040"		
Trailing edge of R.H. helix rotor to leading edge of L.H. helix rotor (6V and 12V)	.0060"	.0100"	.0100"
Trailing edge of R.H. helix rotor to leading edge of L.H. helix rotor (8V and 16V)	.0040"	.0080"	.0080"
Leading edge of R.H. helix rotor to trailing edge of L.H. helix rotor (6V and 12V)	.0081"		
Leading edge of R.H. helix rotor to trailing edge of L.H. helix rotor (8V and 16V)	.0100"		
T18A40 Turbocharger (Airesearch)			
End play -- rotating shaft	.0040"	.0090"	
Radial movement -- rotating shaft	.0030"	.0070"	
Turbine wheel shaft journal bearing:			
Inside diameter	.6268"	.6272"	
Outside diameter	.9780"	.9785"	
Journal diameter -- turbine wheel shaft	.6247"	.6250"	
Bearing bore -- center housing	.9830"	.9835"	
Back Plate Seal Bore:			
Inside diameter	.6875"	.6885"	.6895"
Thrust Collar:			
Thickness	.2990"	.3000"	.2970"
Bore - Inside diameter	.3754"	.3758"	.3778"
Thrust Spacer:			
Outside diameter	.6715"	.6725"	.6705"
Ring groove width	.0685"	.0695"	.0715"
Thrust Washer, Inboard:			
Thickness	.0900"	.0920"	
Compressor Wheel Bore:			
Inside diameter	.3736"	.3739"	.3749"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	LIMITS
TV71 and TV8I Turbocharger (Airesearch)			
End play -- rotating shaft	.0030"	.0100"	
Radial movement-- rotating shaft	.0040"	.0050"	
Turbine wheel shaft journal bearing:			
Inside diameter	.6268"	.6272"	
Outside diameter	.9782"	.9787"	
Journal diameter - turbine wheel shaft	.6250"	.6254"	
Bearing bore - center housing:			
Inside diameter	.9827"	.9832"	.9842"
Back Plate Seal Bore:			
Inside diameter	.6875"	.6885"	.6895"
Thrust Collar:			
Thickness	.2990"	.3000"	.2970"
Bore Inside diameter	.3754"	.3758"	.3778"
Thrust Spacer:			
Outside diameter	.6715"	.6725"	.6705"
Ring groove width	.0685"	.0695"	.0715"
Thrust Washer, Inboard:			
Thickness	.0900"	.0920"	
Compressor Wheel Bore:			
Inside diameter	.3736"	.3739"	.3749"
Turbocharger (Schwitzer)			
Journal diameter--turbine wheel shaft	.5611"		

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	Nm
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 over 3/4 to 1 1/2	74,000 60,000
 Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
 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
 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 SIZE	TORQUE lb-ft	TORQUE Nm
Blower drive coupling-to-rotor gear bolt	5/16-24	20-25	27-34
Air inlet housing adaptor-to-blower housing bolt	3/8 -16	16-20	22-27
Air inlet housing-to-adaptor bolt	3/8 -16	16-20	22-27
Blower end plate-to-cylinder block bolt	7/16-14	40-45	54-61
Blower rotor gear retainer bolt (Allen head)	1/2 -20	75-85	102-115
Fuel pump drive disc bolt	1/2 -20	55-65	75-88
Blower rotor gear retainer bolt (large bearing blower)	1/2 -20	100-110	136-150

SERVICE TOOLS

TOOL NAME	TOOL NUMBER
Blower	
Blower clearance feeler set	J 1698-02
Blower drive cam installer	J 1471
Blower drive coupling aligning tool set	J 21834-01
Blower drive shaft alignment tool	J 24619
Blower service tool set	J 6270- F
Turbocharger (Airesearch)	
Compressor wheel remover	J 9496
Compressor wheel nut wrench	J 21223-01
Dial indicator adaptor	J 21224
Dial indicator set (magnetic base)	J 7872
Turbine wheel holding fixture	J 21225
Turbocharger inlet shield	J 26554-A
Turbocharger Aftercooler	
Adaptor cup plug installer	J 28711
Adaptor plug remover and installer	J 25275

SECTION 4

LUBRICATION SYSTEM

CONTENTS

LUBRICATION SYSTEM

Figures 1 and 2 schematically illustrate the flow of oil through a typical 6V, 8V or 12V engine lubrication system including the various components such as the oil pump, full-flow oil filter, oil cooler, pressure regulator and by-pass valve.

The oil pump on the 6V and 8V engines is located in the crankshaft front cover and consists of a pair of spur gears, one large and one small, which mesh together and ride in a cavity inside the crankshaft cover. The large gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump idler gear is much smaller and runs on a bushing and hardened steel shaft pressed into the crankshaft cover.

The gear-type oil pump used on the 12V engine is mounted on the main bearing caps and is gear driven from the front end of the crankshaft.

In either case, oil is drawn by suction from the oil pan through the intake screen and pipe to the oil pump where it is pressurized. The oil then passes from the pump into a short gallery in the cylinder block to the oil cooler adaptor plate. At the same time, oil from the pump is directed to a spring-loaded pressure relief valve mounted on the cylinder block. This valve discharges excess oil directly to the oil sump when the pump pressure exceeds 100 psi or 689 kPa (6V and 8V engines) or 120 psi (827 kPa) on 12V engines.

From the oil cooler adaptor plate, the oil passes into the full-flow filter, through the oil cooler and then back into the cylinder block where a short vertical oil gallery and a short diagonal oil gallery carry the oil to the main longitudinal oil gallery through the middle of the block. Valves are also provided to by-pass the oil filter and oil cooler should either one become plugged.

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a pressure regulator valve located at the end of a vertical oil gallery connected to the main oil gallery. This vertical gallery is located at the front of the cylinder block on the side opposite the cooler (Figs. 1 and 2). When the oil pressure at the valve exceeds 50 psi (345 kPa), the regulator valve opens, discharging excess oil back into the sump.

From the main oil gallery, the pressurized oil flows through drilled passages to each main bearing then passes to an adjacent pair of connecting rods by means of grooves in the unloaded halves of the main and connecting rod bearings and drilled passages in the crankshaft. The drilled connecting rods carry oil from the rod bearings to the piston pin bushing and to the nozzles at the upper end of each connecting rod which provide the cooling oil spray for the piston crowns.

At the rear of the block. two diagonally drilled oil

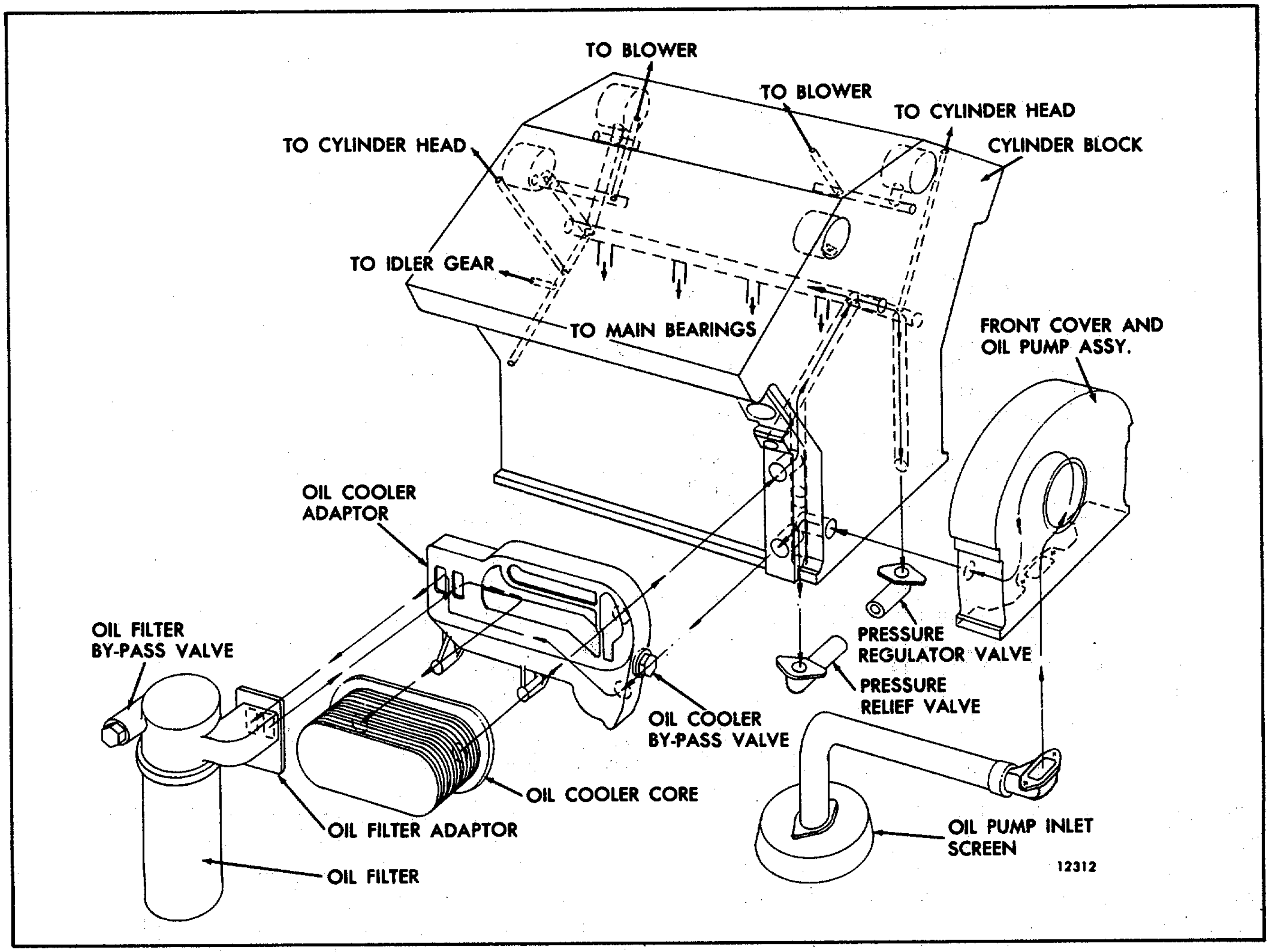


FIG. 1. Schematic Diagram of Typical 6V and 8V Lubrication Systems

passages, which intersect the main oil gallery carry oil to the two rear camshaft end bearings. Oil is then conducted through the rifle drilled camshaft to the intermediate and front end bearings. Oil from the camshaft intermediate bearings is directed against the camshaft lobes and cam rollers which run in an oil bath. This oil from the intermediate bearings provides lubrication of the cam lobes immediately after starting the engine when the oil is cold and before camshaft bearing oil flow and oil drainage from the cylinder head have had time to build up.

The diagonally drilled oil passage on the right side at the rear of the block intersects with a vertical passage to carry oil to the right bank cylinder head. A short gallery also intersects with this diagonal passage to lubricate the idler gear bearing. Another gallery intersecting the diagonal passage at the front of the block supplies oil to the left bank cylinder head.

Drilled passages, intersecting longitudinal galleries which parallel the camshafts, lead to the blower and supply oil for the blower drive gears and bearings.

To increase the size of the cam pocket drains and improve crankcase breathing, the oil tube (1 " long spring pin) in the right front cam pocket drain hole has been eliminated. Lubricating oil from the right bank camshaft pocket was formerly directed through this tube (spring pin) to lubricate the water pump drive gear and bearings and the front camshaft gear.

NOTE: Sufficient lubrication is obtained for the water pump gear by the drain back oil from the right front camshaft end bearing.

The gear train is lubricated by the overflow of oil from the camshaft pockets spilling into the gear train compartment and by splash from the oil pan. A

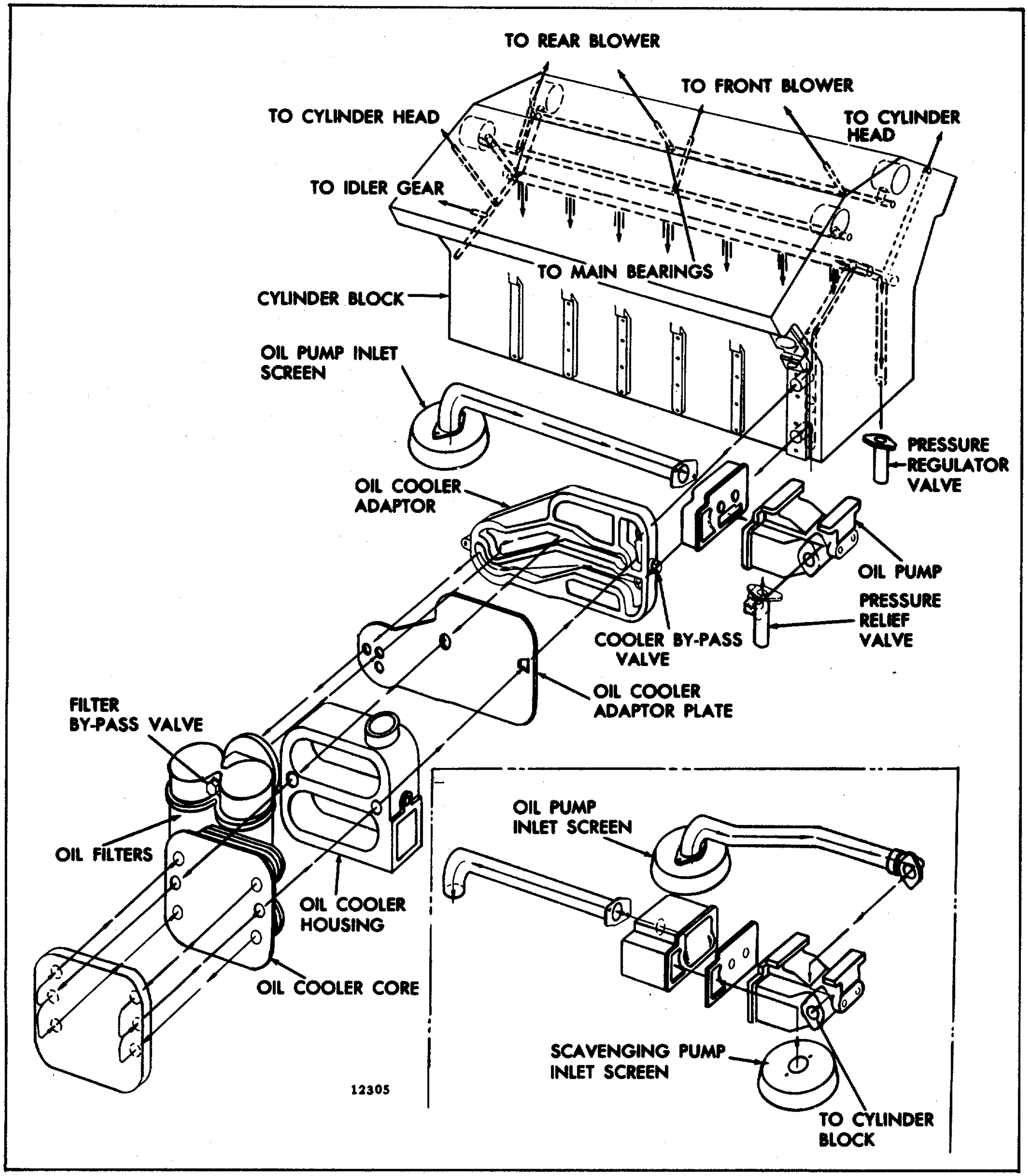


FIG. 2. Schematic Diagram of Typical 12V Lubrication System

certain amount of oil also spills into the gear train compartment from both camshaft rear end bearings, the blower drive gear bearing and the idler gear bearing.

The blower drive gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

The valve and injector operating mechanism is lubricated from a longitudinal oil passage, on the camshaft side of each cylinder head, which connects to the main oil gallery in the cylinder block. Oil from this passage enters the drilled rocker arm shafts through the lower end of the rocker shaft bolts and rocker shaft brackets. Excess oil from the rocker arms lubricates the exhaust valves and cam followers.

Lubrication System Maintenance

Use the proper viscosity grade and type of *heavy duty* oil as outlined in the *Lubricating Oil Specifications* in Section 13.3. Change the oil and replace the oil filter elements at the periods recommended by the oil supplier (based on his analysis of the drained engine oil) to ensure trouble-free lubrication and longer engine life.

The oil level should never be allowed to drop below t*he low* mark on the dipstick. Overfilling the crankcase may contribute to abnormal oil consumption, high oil temperatures and also result in oil leaking past the crankshaft rear oil seal.

To obtain the true oil level, the engine should be stopped and sufficient time (approximately twenty minutes) allowed for the oil to drain back from the various parts of the engine. If more oil is required, add only enough to bring it to the proper level on the dipstick.

Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol antifreeze solution or other soluble material, refer to Section 5 for the recommended cleaning procedures.

The gear type lubricating oil pump is mounted in the crankshaft front cover, which also functions as the oil pump body (Fig. 1). The pump consists of two spur gears which mesh and rotate in a cavity inside the crankshaft cover. The pump drive gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump driven gear and bushing assembly rotates on a hardened steel shaft. One end of the driven gear shaft is pressed into the crankshaft front cover and the other end is supported in the oil pump gear retaining plate.

Certain engines require a higher capacity oil pump that includes wider drive and driven gears.

Operation

As the gears revolve, a vacuum is created on the inlet side -of the pump and oil is drawn from the oil pan through the intake screen and pipe assembly into a passage, in the crankshaft front cover, which leads to the inlet port in the pump. The oil then enters the cavities between the gears and the crankshaft front cover and is then forced out under pressure through the discharge port into a short gallery in the cylinder block which leads to the oil filter, oil cooler and cylinder block main oil gallery. At the same time, the oil is directed through a short vertical gallery to the pressure relief valve which opens at approximately 100 psi (689 kPa) to return excess oil to the oil pan.

Remove Oil Pump

1. Drain the oil and remove the oil pan.

2. Remove the oil pan gasket and clean all traces of the gasket from both the oil pan and the cylinder block.

3. Remove the bolts and lock washers which secure the oil inlet pipe and screen support to the crankshaft front cover and to the main bearing cap. Then remove the oil inlet pipe and screen support as an assembly.

4. Remove the crankshaft front cover from the engine as outlined in Section 1.3.5.

5. Remove the oil pump drive hub and key from the crankshaft.

Disassemble Oil Pump

1. Remove the self-locking bolts that secure the oil pump gear retaining plate to the crankshaft front cover. Then remove the retaining plate.

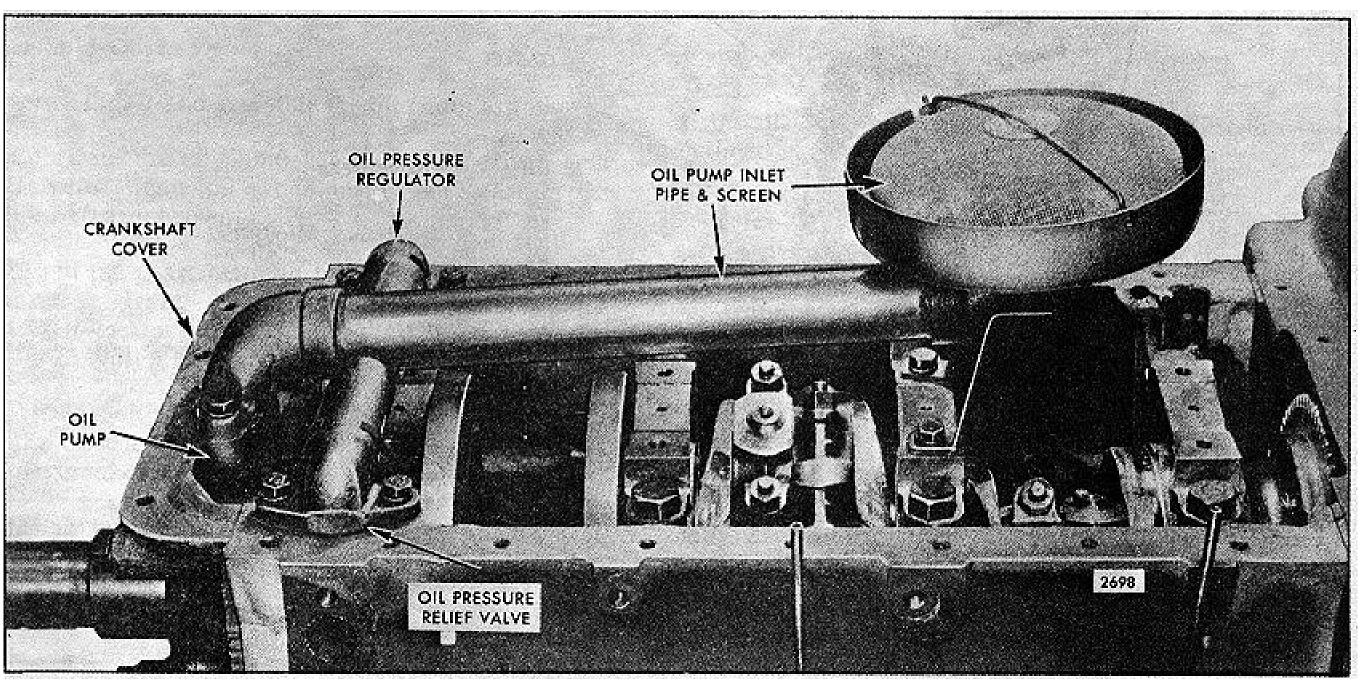


FIG. 1 - Typical Lubricating Oil Pump Mounting (6V or 8V Engine)

2. Remove the oil pump drive and driven gears from the crankshaft front cover.

Inspection

Clean all of the parts with fuel oil and dry them with compressed air.

Replace the crankshaft front oil seal as outlined in Section 1.3.2.

Examine the oil pump gear cavity in the crankshaft front cover. Replace the cover if the surfaces are worn or scored excessively.

The depth of the gear cavity in the front cover is .982" - .984" for the narrow gear oil pumps and 1.302 " - 1.304 " for the wide gear oil pumps. The width of the narrow drive and driven gears is .979 " - .981 "and for the wide drive and driven gears it is 1.299"- 1.301".
Replace the driven gear shaft if it is worn or scored excessively. When a new shaft is pressed in place, the shoulder on the shaft must be flush to .020 " below the finished face of the crankshaft front cover.

The clearance between the driven gear bushing and the shaft is 001," to .0025 " when new parts are used, or a maximum of .0035 " with used parts.

Inspect the teeth on the oil pump gears and the pump drive hub. Also examine the bushing in the driven gear for wear. The bushing is not serviced separately, therefore if the bushing is worn it will be necessary to replace both the drive and driven gears as they are only serviced as a set. The use of excessively worn gears will result in low oil pressure which may cause serious damage throughout the engine.

NOTE: A new oil pump assembly was used on 6V engines effective with Engine Serial No. 6VA-21896. The new pump assembly has narrower drive and driven gears and the gear cavity depth in the pump body has been reduced. The former and new pump *assemblies* are interchangeable, but the component parts are not.

Inspect the inner face of the oil pump gear retaining plate. Replace the retaining plate if it is scored or worn.

Remove the screen and cover from the oil inlet pipe assembly. Then clean the parts with fuel oil and dry them with compressed air. Reassemble the screen, cover and oil intake pipe.

Whenever the oil pump is removed for service, remove and inspect the oil pressure regulator and oil pressure relief valves as outlined ill Section 4.1.1.

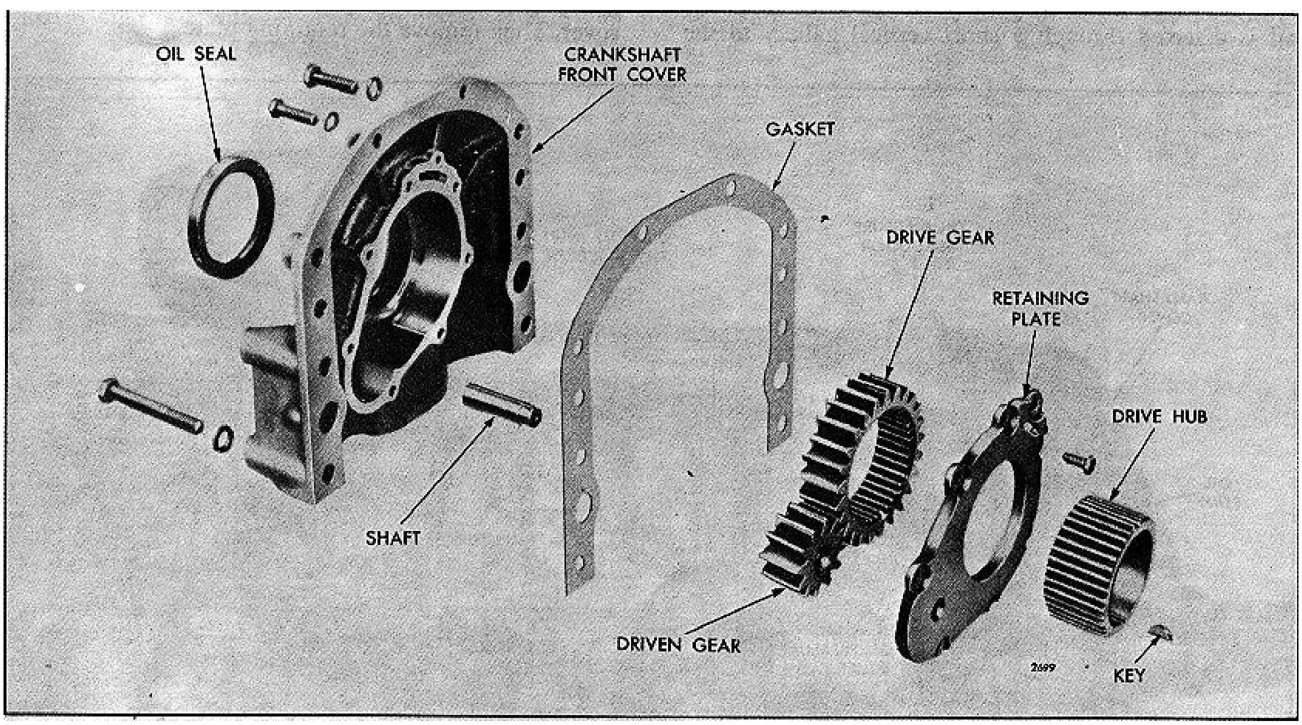


FIG. 2 - Lubricating Oil Pump Details and Relative Locations of Parts (6V or 8V Engine)

Assemble Oil Pump

Refer to Fig. 2 and assemble the oil pump as follows:

1. Lubricate the oil pump gears and the driven gear shaft with engine oil. Then install the gears in the crankshaft front cover.
2. Install the gear retaining plate and secure it to the crankshaft front cover with eight 5/16"-18 x 3/4" self-locking bolts. Tighten the bolts to 13-17 lb- ft (I 8-23 Nm) torque.

NOTE: Self-locking bolts must be used due to the close clearance between the oil pump and the crankshaft.

3. Install the key in the crankshaft and slide the oil pump drive hub in place.

Install Oil Pump

1. Install the crankshaft front cover on the engine as outlined in Section 1.3.5.

2. Refer to Fig. I and install the oil inlet pipe and screen assembly. Use a new gasket between the oil inlet pipe and the crankshaft front cover.

3. Install the oil pan, using a new gasket. Starting with the center bolt on each side and working toward each end of the oil pan, tighten the 3/8" -16 bolts to 15-20 lb-ft (20-27 Nm) torque.

4. Fill the oil pan, to the proper level on the dipstick, with the lubricating oil recommended in the *Lubricating Oil Specifications* in Section 13.3.

LUBRICATING OIL PUMP (12V Engine)

The gear-type lubricating oil pump used on the 12V engine is mounted on the No. I and 2 main bearing caps at the front of the engine and is driven by a gear mounted on the crankshaft (Fig. 3). On some 12V vehicle engines, the oil pump is mounted at the rear on the No. 6 and 7 main bearing caps and is driven by a gear which is attached to the crankshaft timing gear.

An oil outlet opening is provided on each side of the pump housing to accommodate connections to the oil cooler and filter mounted on either the right or left front side of the cylinder block. By changing the position of the pump drive-driven gear from one pump shaft to the other, the oil pump may be driven in either left-hand or right-hand rotation. A scavenging pump section may be installed in tandem when required.

Operation

Oil is drawn by suction from the oil pan through the intake screen and pipe into the oil pump where it is pressurized. The oil then passes from the pump through the block and out to the full-flow oil filters, through the oil cooler and into the oil galleries in the cylinder block.

An oil pump pressure relief valve (Fig. 3) is located between the oil pump outlet and the cylinder block vertical oil gallery leading to the oil filter and oil

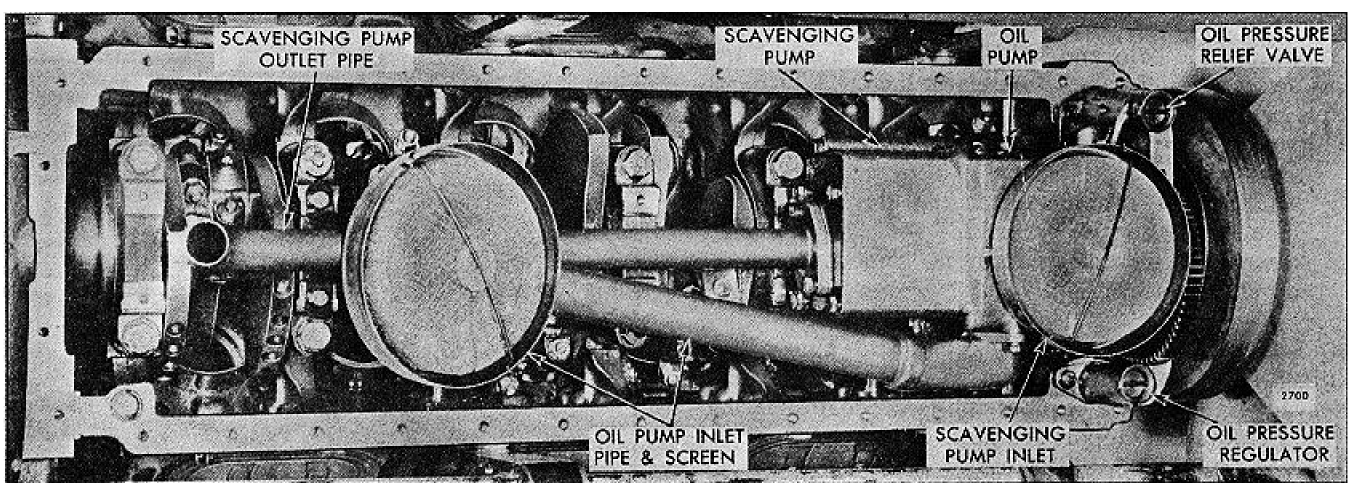


FIG. 3 - Typical Lubricating Oil Pump Mounting (12V Engine)

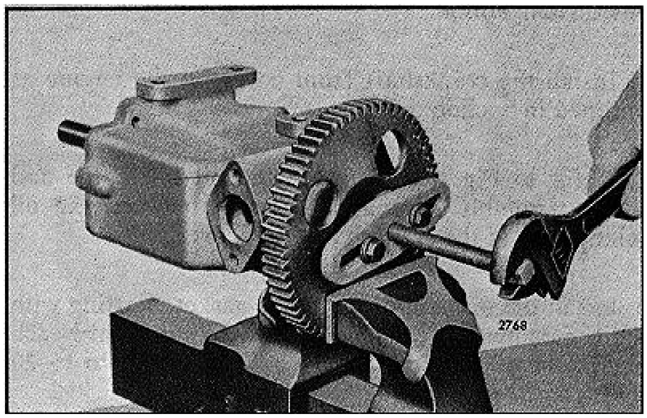


FIG. 4 - Removing Oil Pump Drive-Driven Gear

cooler. This valve opens at approximately 120 psi (827 kPa) and returns excess oil to the oil pan.

Stabilized lubricating oil pressure is maintained in the engine at all speeds, regardless of the oil temperature, by means of a regulator valve mounted beneath the cylinder block at the lower end of the vertical oil gallery on the side opposite the oil cooler (Fig. 3). This valve opens at approximately 50 psi (345 kPa) and returns excess oil directly into the oil sump.

Remove Lubricating Oil Pump

Refer to Fig. 3 and remove the oil pump from the engine as follows:

1. Drain the oil and remove the oil pan.

2. Remove the oil pan gasket and clean any traces of the old gasket from both the oil pan and the cylinder block.

3. Remove the bolts and lock washers which attach the oil pressure relief valve assembly to the cylinder block and oil pump. Remove the valve assembly from the engine.

NOTE: It is recommended that the pressure regulator also be removed for inspection whenever the oil pump is removed for inspection or overhaul.

4. Remove the bolts, lock washers and nuts which attach the support brackets to the oil pump inlet and scavenging pump outlet pipes and to the main bearing cap. Remove the support brackets.

5. Remove the bolts and lock washers which attach the oil inlet pipe assembly to the pump housing and remove the pipe assembly.

6 . Unhook the screen retainer and remove the screen from the cover. Remove the retaining bolts, lock washers and nuts and detach the screen cover from the oil inlet pipe.

7. Remove the bolts and lock washers which attach the oil outlet pipe to the scavenging pump housing and remove the pipe.

8. Unhook the screen retainer and remove the screen from the oil inlet cover on the pump housing. Remove the bolts and lock washers which attach the screen cover t9 the pump housing and remove the cover.

9. Remove the nuts and lock washers which attach the pump to the main bearing caps and remove the pump assembly.

> **NOTE**: Shims are used between the oil pump mounting feet and the main bearing caps. Whenever the original pump from an engine is reinstalled, the same shims or an equal number of new (identical) shims must be placed under both the front and rear mounting feet and the number then adjusted to obtain the proper clearance between the. pump driving gears.

Disassemble Lubricating Oil Pump

Observe carefully the relative position of all parts during disassembly so as to facilitate the reassembly of the pump:

1. Remove the five bolts and lock washers which secure the pump cover or scavenging pump body to the pump and separate the cover or body from the pump.

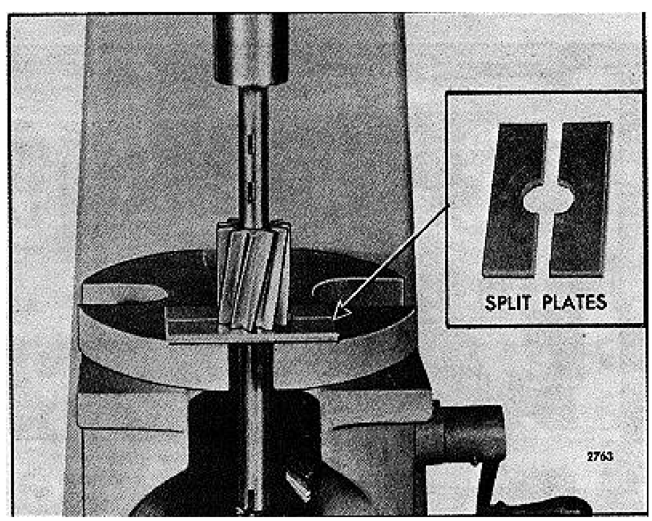


FIG. 5 - Pressing Oil Pump Gear From Shaft

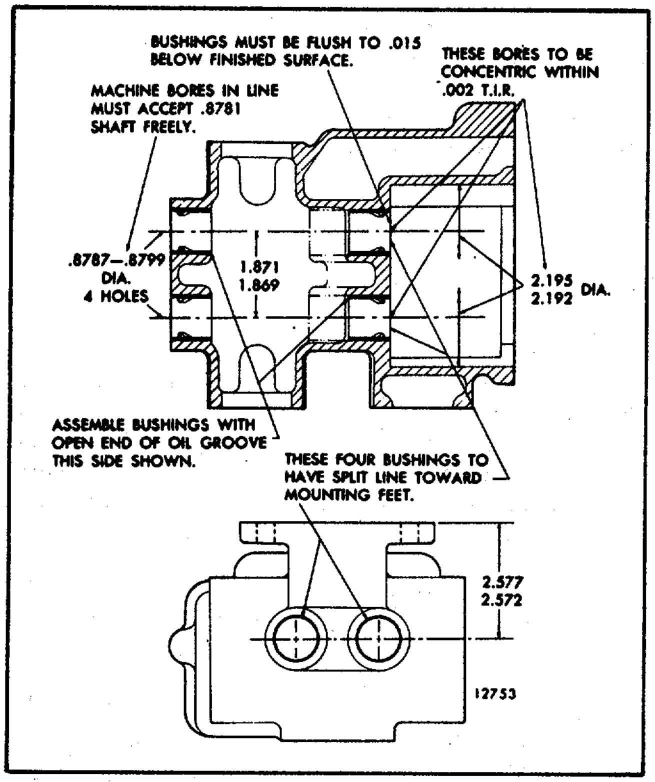


FIG. 6 - Diameter and Location of Bushing in Oil Pump (12V Engine)

2. Remove the scavenging pump drive and driven gears from the pump shafts. These gears are a slip fit. Remove the keys from the keyways in the shafts.

3. Remove the spacer plate if a scavenging pump is used.

4. Attach the puller J 24420 to two 5/16" -24 tapped holes provided in the gear. Then turn the puller screw clockwise to withdraw the gear from the pump drive shaft as shown in Fig. 4.

NOTE: Place washers or a small nut between the shaft and the puller screw to protect the end of the pump shaft.

Remove the key from the keyway in the shaft. Make sure the shaft is not burred at the edges of the key slot.

5. Withdraw the pump drive and driven gear and shaft assemblies from the pump body.

6. If inspection reveals replacement of gears is necessary, use an arbor press and sleeve to press the pump gears from the shafts. Press the gears off the scavenging pump end of the shafts (Fig. 5). Remove the keys from the keyways in the shafts.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

The greatest amount of wear in the oil pump is imposed on the internal drive and driven gears. This wear may be kept to a minimum by keeping the lubricating oil clean and acid-free. If dirt and sludge are allowed to accumulate in the lubricating system, pronounced gear wear may occur in a comparatively short period of time. Proper servicing of oil filters will increase the life of the gears.

Examine the internal gear cavity of the pump body and scavenger pump, if used, for wear or scoring. Also inspect the pump cover, or spacer between the pump and the scavenger pump bodies, for wear. Replace the parts if necessary.

Inspect the bushings in the pump body and cover (or scavenging body). If the bushings are worn excessively, replace the pump body and cover (or scavenging body) unless suitable boring equipment is available for finishing the new bushings. When installing new

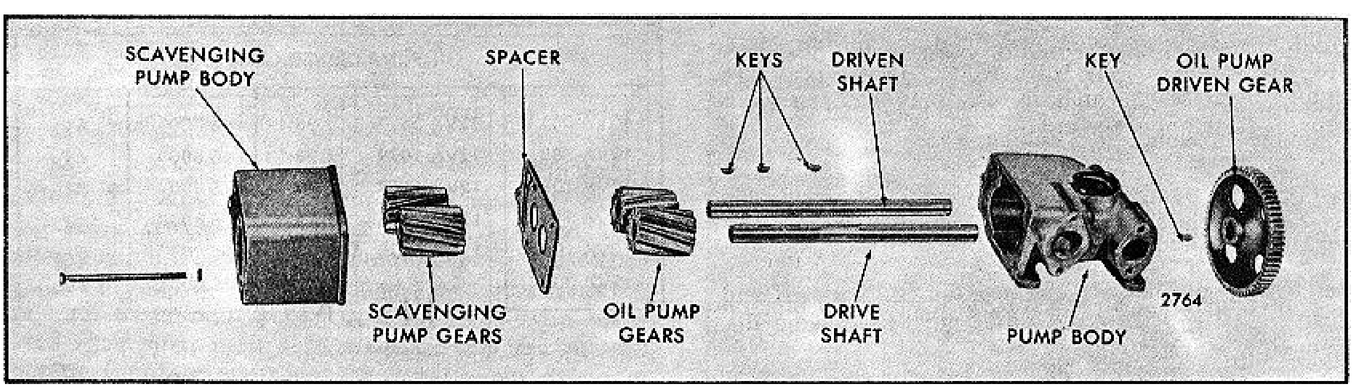


FIG. 7 - Lubricating Oil Pump Details and Relative Location of Parts (12V Engine)

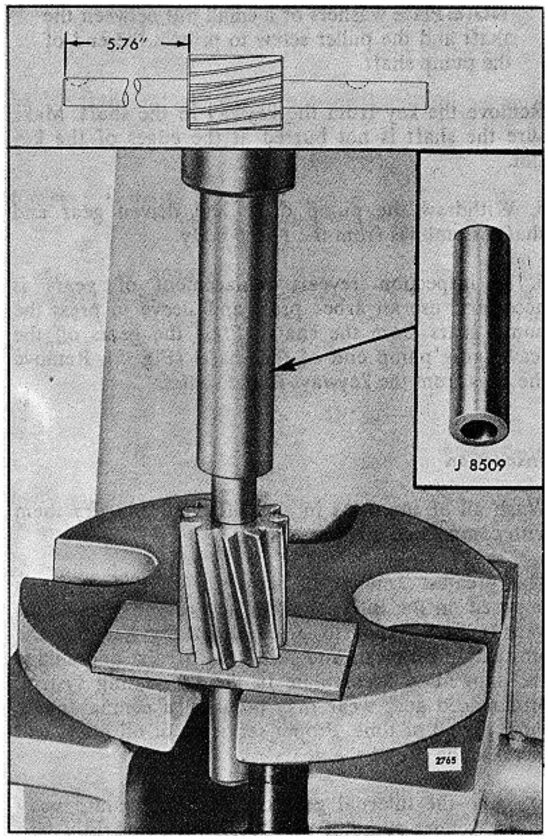


FIG. 8 - Installing Oil Pump Gear on Shaft

bushings, replace all of the bushings in the pump. The bushings must be located and positioned as shown in Fig. 6. The gear bore and the bushing bore must be concentric within .002"total indicator reading. The shaft-to-bushing clearance with new parts is .0015 " to .0032".

If the gear teeth are scored or worn, install new gears. The use of excessively worn gears will result in low engine oil pressure which, in turn, may lead to serious damage throughout the engine:

Inspect the pump shafts for wear and check the keyways. Replace the shafts if necessary.

Remove the oil inlet screen from the oil inlet pipe and clean both the screen and pipe with fuel oil and dry them with compressed air.

Inspect the external pump drive-driven gear for wear and replace it if necessary

Inspection of the pressure relief valve and oil pressure regulator are covered in Section 4.1.1.

Assemble Lubricating Oil Pump

Refer to Fig. 7 and assemble the oil pump as follows:

1. If the pump gears were removed, insert a Woodruff key in the keyway of one of the shafts and apply a light coat of engine oil to the shaft. Start the gear squarely on the key of one of the shafts, then slip tool J 8509 over the drive gear (or opposite) end of the shaft and press the gear on the shaft as shown in Fig. 8. Tool J 8509 will position the gear 5.76" from the end of the shaft as well as prevent the shaft from bending. Assemble the second shaft and gear in a similar manner.

2. Install the drive gear and shaft assembly in the pump body. The shaft with the right-hand helix gear is the drive shaft for a left-hand rotation engine and the shaft with a left-hand helix gear is the drive shaft for a right-hand rotation engine. The right-hand helix gear must be on the right-hand side (viewing the pump from the cover end and the mounting flanges facing up).

3. Insert the Woodruff key in the end of the drive

OIL PUMP DRIVE GEAR				
Effective with Engine Serial No.	To Engine Serial No.	Drive Ratio	Gear Diameter	No. of Teeth
12VA-001	12VA-1079	1.23:1	8.100"	79
12VA-1080	12VA-1189	1.50:1	8.800"	86
12VA-1190	12VA-1345	1.23:1	8.100"	79
12VA-1346	12VA-3038	1.50:1	8.800"	86
12VA-3039	Current	1.23:1	8.100"	79
OIL PUMP DRIVEN GEAR				
12VA-001	12VA-587	1.23:1	6.600"	64
*12VA-588	12VA-1079	1.23:'	6.600"	64
12VA-1080	12VA-1189	1.50:1	5.900"	57
12VA-1190	12VA-1345	1.23:1	6.600"	64
12VA-1346	12VA-3038	1.50:1-	5.900"	57
12VA-3039	Current	1.23:1	6.600"	64

*Increased gear bore - revised shaft.

TABLE 1

shaft. Then place the pump in the arbor press with the gear end down. Start the external pump drive-driven gear, with the extended hub side facing the pump, straight on the shaft, aligning the key in the shaft with the keyway in the gear. Position a large flat washer with a center hole slightly larger than the O.D. of the pump drive shaft on the gear hub (Fig. 9).

Insert a .010" feeler ribbon between the drive gear and the pump body to properly position the gear on the shaft. Press the gear up to the pump body just far enough to allow a .010" feeler to be readily slipped from place (Fig. 9).

4. Install the driven gear and shaft assembly. When installing the drive or driven gears, Table I will aid in preventing mis-mating and assist in identification of the gears.

5. Align the bolt holes in the pump cover and the pump body and install the cover. Secure the cover to the pump body with five bolts and lock washers. If a scavenging pump is used, the following procedure will apply:

a. Insert the oil pump spacer over the shafts.

b. Insert two Woodruff keys in each shaft and slip the scavenging pump gears over the shafts. Right- hand and left-hand gears are to be in the same relative position as the main pump gears.

c. Install the scavenging pump body and secure it to the pump body with five bolts and lock washers.

6. If an oil opening pad cover was removed, reinstall it with a new gasket and secure it with two bolts and lock washers.

The oil pump must turn freely after assembly. Any bind must be eliminated before the oil pump is installed on the engine by loosening the bolts and tapping the cover or scavenging pump body, then retightening the bolts.

Remove Oil Pump Driving Gear from Crankshaft

With the oil pan and lubricating oil pump removed, remove the oil pump driving gear from the crankshaft as follows:

1. Remove the crankshaft vibration damper and crankshaft front cover (Sections 1.3.5 and 1.3.6).

2. Remove the oil slinger.

3. When the oil pump driving gear is bolted to the crankshaft timing gear (some 12V vehicle engines), refer to Section 1.7.5.

4. Effective with engine 12VA4465, the crankshaft has a slightly larger diameter in the cil pump drive gear area to provide a positive press fit of the oil pump drive gear. Previously.t he gear was a slip fit on the crankshaft. If necessary, use a suitable puller to remove the gear. After removing the gear, remove the Woodruff key from the crankshaft.

Inspection

Wash the gear with fuel oil and dry it with compressed air. Inspect the gear teeth for wear or scoring. Replace the gear, if necessary.

Install Oil Pump Driving Gear on Crankshaft

1. Install the Woodruff key in the crankshaft.

2. If necessary, use tool J 22285 to press the gear on the crankshaft.

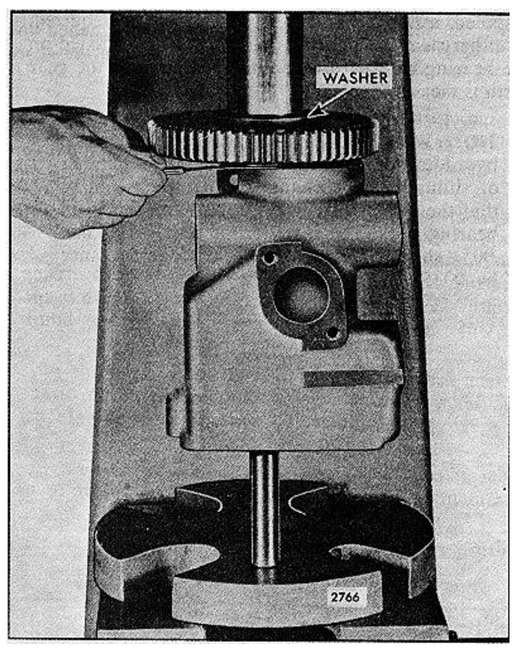


FIG. 9 - Installing Oil Pump Drive-Driven Gear on Shaft

Install Lubricating Oil Pump

Refer to Fig. 3 and install the oil pump on the main bearing caps as follows:

1. Place the pump assembly over the studs and against the main bearing caps so that the oil pump drive-driven gear meshes with the gear on the crankshaft.

2. Align the pump so that the teeth of the pump driving gears are parallel, then secure the pump to the bearing caps with four nuts and lock washers. Check the clearance (backlash) between the gear teeth with a feeler gage or a suitable dial indicator. The proper clearance is from .006 " to .012 ".

> **CAUTION:** Always check the clearance between the oil pump driving gears with the engine in the upright or running position.

If shims were used between the pump mounting feet and the bearing caps on original installation, and new gears are not installed, the same shims (cleaned) or the same number of new shims of identical thickness should be installed and the number then adjusted to obtain the proper backlash between the teeth of the driving gears. However, if new gears have been installed, a larger number of shims may be required. In either case, the pump must be securely tightened on the bearing caps before the backlash between the gear teeth is measured.

NOTE: When adjusting for gear tooth clearance by adding or deleting shims, the same number of shims must be changed under each foot so that the pump will always be level on the main bearing caps. The insertion or removal of one .005 " shim will change the gear tooth clearance by .0035".

3. Attach new gaskets to the pressure relief valve assembly and bolt the valve assembly to both the body and the cooler side of the cylinder block.

4. Place a new gasket at the end of the vertical oil gallery on the side of the block opposite the oil cooler and secure the pressure regulator to the block with two bolts and lock washers.

5: Use new gaskets and attach the scavenger pump oil discharge and oil pump inlet pipes to the pump body and secure them with bolts and lock washers.

6. Attach the support brackets to the oil pump inlet and scavenging pump discharge pipes. Secure the brackets together and to the main bearing cap with bolts, lock washers and nuts.

7. Use new gaskets and set the oil inlet screen covers over the oil pump inlet pipe and over the pump body and secure them in place with bolts, lock washers and nuts.

8. Place the screens in the covers and lock them in place with screen retainers.

9. Re-check all of the bolts and nuts for tightness to assure there will be no leaks in the oil pump and the pipe mounting connections.

10. Place a new gasket on the oil pan and install the pan on the cylinder block. Start all of the oil pan bolts before any of them are tightened. Bolts should be tightened snugly but not excessively, starting with the center bolts and working toward each end of the oil pan. Excessive tightening of the bolts will crush the oil pan gasket unnecessarily.

11. Fill the oil pan to the proper level with the oil recommended in the *Lubricating Oil Specifications* in Section 13.3.

LUBRICATING OIL PRESSURE REGULATOR AND RELIEF VALVES

OIL PRESSURE REGULATOR VAVLE

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator valve. The valve is installed at the end of the vertical oil gallery near the front of the cylinder block on the side opposite the oil cooler (Figs. 1 and 2).

The oil pressure regulator consists of a valve body, a hollow piston-type valve, a spring, a spring seat and a pin to retain the valve assembly within the valve body (Fig. 3).

The valve is held on its seat by the spring, which is compressed by the pin in back of the spring seat. The entire assembly is bolted to the lower flange of the cylinder block and sealed against leaks by a gasket between the block and the valve body. When conditions are such that the oil pressure at the valve exceeds 50 psi (345 kPa), the valve is forced from its seat and oil from the engine oil gallery is bypassed to the engine oil pan. Thus stabilized lubricating oil pressure is maintained at all times.

Under normal conditions, the oil pressure regulator should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

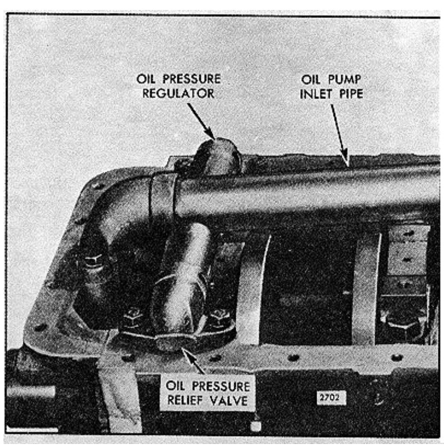


FIG. 1 Regulator Valve and Pressure Relief Valve) Mounting (6 or 8V Engine)

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

1. Remove the two regulator-to-cylinder block attaching bolts and lock washers.

2. Tap the regulator body lightly to loosen it from. The gasket and the cylinder block. Remove the regulator and the gasket.

Disassemble Oil Pressure Regulator

1. Clamp the regulator assembly in the soft jaws of a bench vise and remove the spring seat retaining pin from the regulator body.

2. Remove the spring seat, spring and valve from the regulator body.

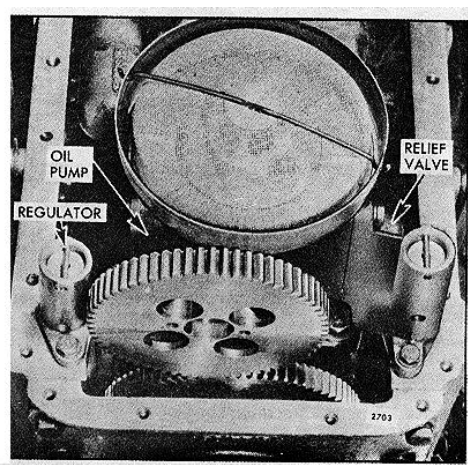


FIG. 2 Regulator Valve and Pressure Relief Valve Mounting (12V Engine)

Inspection

Clean all of the regulator components with fuel oil and dry them with compressed air. Then inspect the parts for wear or damage.

The regulator valve must move freely in the valve body. If the valve or the valve body is scored and cannot be cleaned up with crocus cloth, replace them.

Replace a pitted or fractured spring.

Assemble Oil Pressure Regulator

After the parts have been cleaned and inspected, refer to Fig. 3 and assemble the regulator as follows:

1. Apply clean engine oil to the outer face of the valve and slide it into the regulator body, closed end first.

2. Insert the spring in the valve and install the spring seat. While compressing the spring, install the retaining pin behind the spring seat. Press the pin flush to .010" below the surface of the valve body.

NOTE: The valve body used on the 6V and 8V engines (with an oil pump in the front cover) has two retaining pin holes (Fig. 3). Install the pin in the outermost hole for the regulator valve. The inner hole is used when the valve is assembled as an oil pump relief valve assembly. It is important that the retaining pin be positioned correctly so the proper valve opening pressure will be obtained.

Install Oil Pressure Regulator

1. Remove all traces of old gasket material from the regulator body and the cylinder block.

2. Affix a new gasket to the regulator body and secure the regulator assembly to the cylinder block with two bolts and lock washers.

OIL PRESSURE RELIEF VALVE

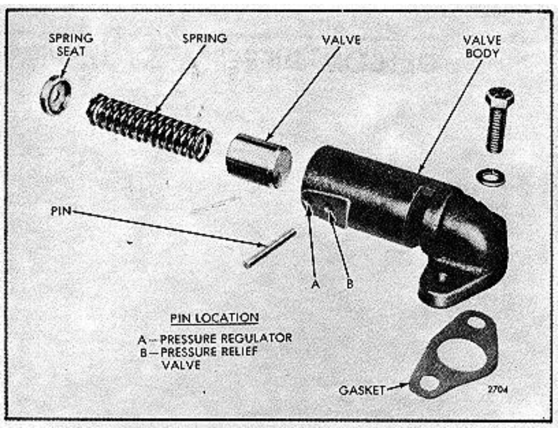


FIG. 3 - Regulator Valve and Relief Valve Details and Relative Location of Parts (6V or 8V Engine, Oil Pump In Front Cover)

Oil leaving the pump under pressure passes into the pressure relief valve. The spring-loaded valve opens when the pressure exceeds approximately 100 psi or 689 kPa (6V or 8V engines) or 120 psi or 827 kPa (12V engines) and directs the excess oil to the oil pan. The pressure relief valve is located at the lower end of the vertical oil gallery near the front of the cylinder block on the oil cooler side (Figs. I and 2).

The pressure relief valve consists of a valve body, a hollow piston-type valve, a spring, spring seat and a pin to retain the valve assembly within the valve body.

The relief valve assembly used on the 6V and 8V engines is composed of the same parts as the regulator valve assembly (Fig. 3). However, the retaining pin is located in the inner pin hole in the valve body to provide the necessary tension on the spring.

The relief valve assembly used on the earlier 12V engines opened at a pressure of 100 psi (689 kPa) and differs only in the valve body which is bolted to both the cylinder block and the oil pump assembly.

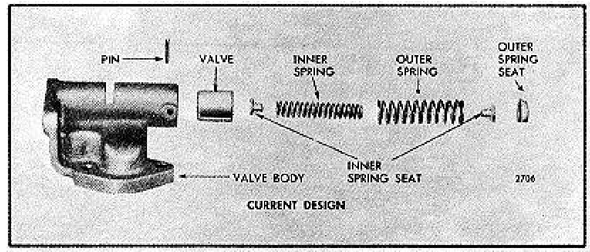


Fig. 4 - Oil Pressure Relief Valve Details and Relative Location of Parts (6V or 8V Bearing Cap Mounted Oil Pump and 12V Engines)

However, the current 12V engine (and 6 and 8V engines with a bearing cap mounted oil pump) oil pressure relief valve opens at a pressure of 120 psi (827 kPa) and incorporates two springs, one located inside the other (Fig. 4).

To provide sufficient clearance between the relief valve housing and the stabilizer bolts, on engines equipped with a main bearing cap mounted lubricating oil pump, a new relief valve is now being used. To eliminate the possibility of cracking the valve housing at assembly, the casting was thickened and the corner of the valve housing at the stabilizer bolt location was removed. The former and new relief valves are not separately interchangeable and only the new relief valve will be serviced.

NOTE: Be sure and use the correct main bearing cap bolt and washer at the stabilizer positions to obtain minimum clearance.

It is recommended that the current type pressure relief valve be installed on earlier units at time of overhaul or the first time the oil pan is removed.

Service operations for the pressure relief valve are similar to those of the regulator valve.

The large spring in the 6, 8 and early 12V relief valve assemblies is the same as used in the oil pressure regulator assemblies of all V-71 engines.

LUBRICATING OIL FILTERS

The V-71 engines are equipped with a full-flow type lubricating oil filter. A bypass type oil filter may be used in addition to the full-flow type filter when additional filtration is desired.

Full-Flow Oil Filter

The full-flow type lubricating oil filter is installed ahead of the oil cooler in the lubrication system. The 6V and 8V engines are equipped with a single filter (Fig. 1). The 12V engines use a dual filter (Fig. 2).

The filter assembly consists of a replaceable element enclosed within a shell which is mounted on an adaptor or base. When the filter shell is in place, the element is restrained from movement by a coil spring.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adaptor or base to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud and out through another passage in the filter adaptor or base and then to the oil cooler.

A valve, which opens at approximately 18-21 psi (124-145 kPa), is located in the filter adaptor or base and

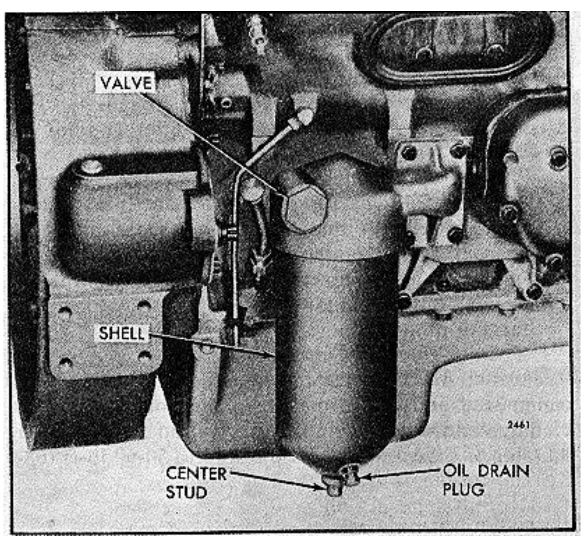


FIG. 1 Typical Full- Flow Oil Filter Mounting (6V or 8V Engine)

will bypass the oil directly to the oil cooler should the filter become clogged.

Conversion adaptor kit (K-4) for spin-on, full-flow lube oil filters are now available as field replacement items for 8V-71 engines.

NOTE: Spin-on filters should not replace filter assemblies on transmissions.

The spin-on lubricating oil filter (throwaway type) and mounting adaptor are now being installed on certain engines. The spin-on filter requires a new mounting adaptor which in some cases is part of the oil cooler cover.

Bypass Oil Filter

When additional filtration is desired, an oil filter of the bypass type may also be installed on the engine. However, *the size of the orifce on the discharge side of the filter must not exceed.101" (6 V and 8V engines) or .125" (12V engine)* to control the oil flow rate and to provide sufficient oil pressure when the engine is running at idle speed.

When the engine is running, a portion of the lubricating oil is bled off the oil gallery and passed through the bypass filter. Eventually all of the oil passes through the filter, filtering out fine foreign particles that may be present.

The bypass filter assembly consists of a replaceable

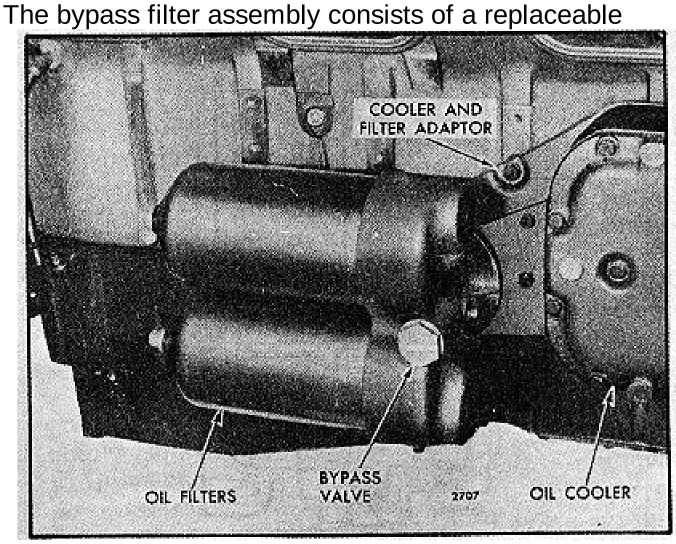


FIG. 2 Typical Full-Flow Oil Filter Mounting (12V Engine)

element contained in a shell mounted on a combination base and mounting bracket (Fig. 3). When the shell is in place, the filter element is restrained from movement by a coil spring at the top. A hollow center stud serves as the outlet passage from the filter as well as securing the shell in place.

Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found on the filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles and carbon must be ensured by replacement of the oil filter elements at the time the
engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

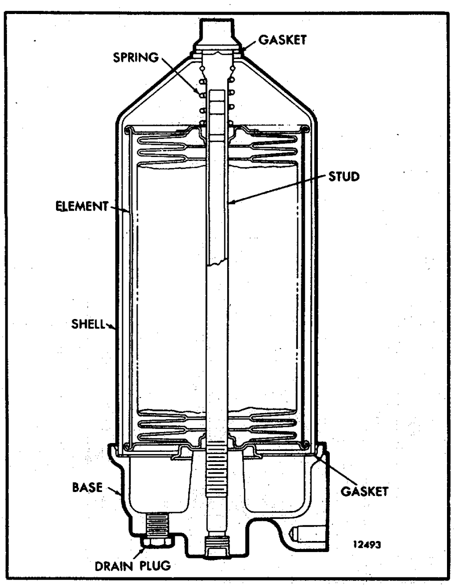


FIG. 3 - Typical Bypass Type Oil Filter

Replace Oil Filter Element

Replace the element in either the full-flow or bypass type oil filter assembly (Figs. 3 and 4) as follows:

1. Remove the drain plug from the filter shell or the filter adaptor or base and drain the oil.

2. Back out the center stud and withdraw the shell, element and stud as an assembly. Discard the element and the shell gasket.

3. Remove the center stud and gasket. Retain the gasket unless it is damaged and oil leaks occurred.

4. Remove the nut or snap ring on the full-flow filter center stud.

> **NOTE:** The center stud on the current full-flow oil filter has been revised by removing the snap ring groove and increasing the 5/8"-18 thread length approximately 1/2". To conform with this change, a 5/8"-18 nut replaces the snap ring formerly used to retain the filter spring and seal.

5. Remove and discard the element retainer seal (Fig. 4). Install a new seal.

6. Clean the filter shell and the adaptor or base.

7. Install the center stud gasket and slide the stud (with the spring, washer, seal and retainer installed on the full-flow filter stud) through the filter shell.

8. Install a new shell gasket in the filter adaptor or base.

NOTE: Before installing the filter shell gasket, be sure all of the old gasket material is removed from the filter shell and the adaptor or base. Also make sure the gasket surfaces of the shell and the adaptor or base have no nicks, burrs or other damage.

9. Position the new filter element carefully over the center stud and within the shell. Then place the shell, element and stud assembly in position on the filter adaptor or base and. tighten the stud to 50-60 lBC-ft (68-81 Nm) torque.

10. Install the drain plug.

11. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been

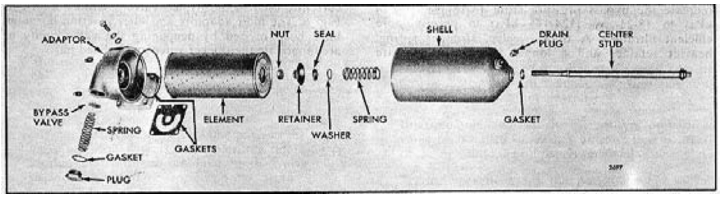


FIG. 4 - Full Flow Oil Filter Details and Relative Location of Parts

corrected and the engine has been stopped long enough (approximately twenty minutes) for the oil from various parts of the engine to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

Replace Spin-On Filter

1. Remove the oil filter using strap wrench tool J 24783 which must be used with a 1/2" drive socket wrench and extension.

2. Discard the used oil filter.

3. Clean the filter adaptor with a clean, lint-free cloth.

4. Lightly coat the oil filter gasket (seal) with clean engine oil.

5. Start the new filter on the adaptor and *tighten by hand* until the gasket touches the mountikng adaptor head. Tighten an additional two-thirds turn.

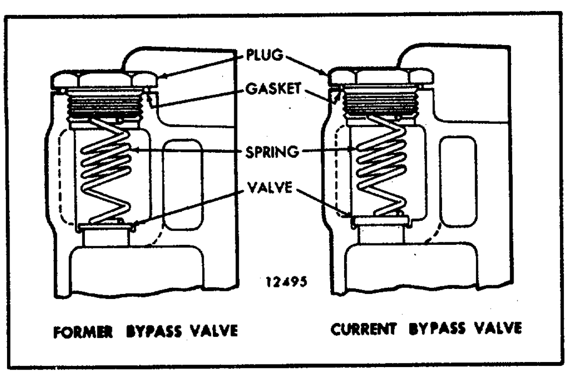


FIG. 5 - Bypass Valve Assembly Secured by Plug

NOTE: Mechanical tightening will distort or crack the filter adaptor.

6. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough for oil from the various parts of the engine to drain back to the crankcase (approximately 20 minutes), add sufficient oil to raise the oil level to the proper mark on the dipstick.

Remove and Install Bypass Valve

1. Remove the plug and gasket (Fig. 5) or the screw and retainer (Fig. 6) and withdraw the spring and bypass valve.

2. Wash all of the parts in clean fuel oil and dry them with compressed air.

3. Inspect the parts for wear. If necessary, install new parts.

4. Reassemble and install the bypass valve. Use only the current bypass valve and spring (Fig. 5) or service. The current thicker valve and stiffer spring

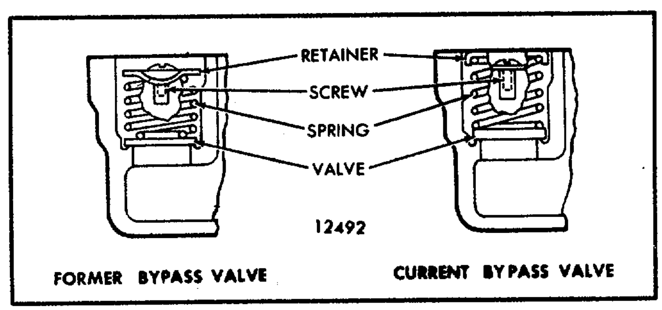


FIG. 6 - Bypass Valve Assembly Secured by Retainer and Screw

increase the bypass pressure from 13-18 psi (90-124 kPa) to 18-21 psi (124-145 kPa) to permit more efficient filtration. A thicker valve, stronger spring, heavier retainer and a longer retaining screw are currently used in the bypass valve assembly shown in Fig. 6. To filter adaptors and filter junction housings have been revised by deepening the valve cavity to accommodate the thicker valve and related parts.

Lubricating Oil Cooler (Plate Type)

In order to perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits . If the oil is too cold, it will not flow freely . If the oil is too hot, it cannot support the bearing loads, it cannot carry away enough heat and it may result in too great an oil flow . As a consequence, oil pressure may drop below acceptable limits and oil consumption may become excessive .

In performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat and this heat must be dissipated by an oil cooler .

Each engine is provided with an oil cooler mounted on the side of the cylinder block at the lower front corner (Figs . I and 2) . The oil cooler is mounted on the left- hand side of "A" and "B" models and on the right- hand side of "C" and "D" models, as viewed from the flywheel end of the engine .

Current 12V two valve engines are equipped with a twin plate (24 plates) oil cooler . Early engines were equipped with a single plate (12 plates) oil cooler .

To improve sealing between the oil cooler housing adaptor, gasket and plate on while engines additional bolt holes and 5/16"-18 bolts have been added (Fig . 3) . Only the new adaptor . plate and gasket will be available for service . To use the former adaptor plate with the new gasket and adaptor, drill two additional holes as indicated in Fig . 3 .

Oil from the lubricating oil pump flows through a passage in the oil cooler adaptor to the oil filter, then through the oil cooler, . and finally through the outlet passage in the cooler adaptor which leads to the cylinder block oil galleries . The engine coolant is pumped through the oil cooler and completely surrounds the oil cooler core .

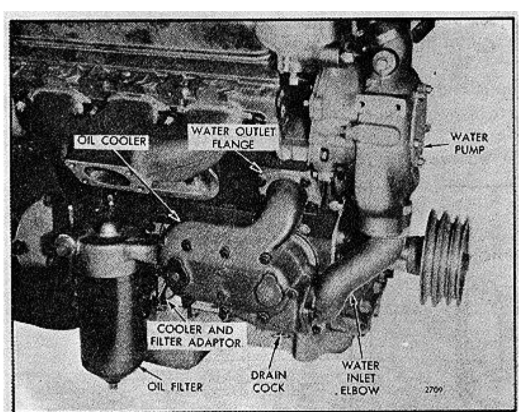


FIG 1 - Typical Oil Cooler Mounting (6V or 8V Engine)

To ensure continuing engine lubrication should the oil cooler become plugged, a bypass valve is installed in the oil cooler adaptor (Fig . 4) .

Remove Oil Cooler Assembly

1 . Drain the cooling system by opening the drain cock at the bottom of the oil cooler housing or water inlet elbow .

2 . Remove any accessories or equipment necessary, such as the full flow oil filter, to provide access to the oil cooler .

3 . Loosen the clamps and slide the hose down on the water inlet elbow .

4 . Remove the bolts and lock washers which retain the water inlet elbow to the oil cooler housing . Then remove the elbow and gasket .

5 . If a water outlet elbow is used, loosen the seal clamp . Remove the bolts, nuts and lock washers and withdraw the water outlet flange and seal, or water outlet elbow, seal and gasket

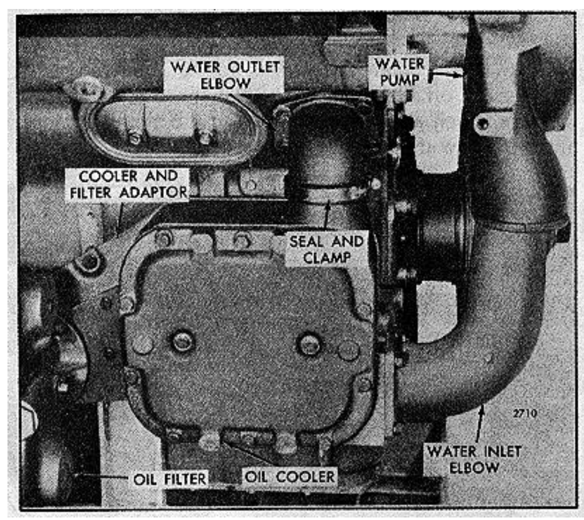


FIG - 2 - Typical Oil Cooler Mounting (12V Engine)

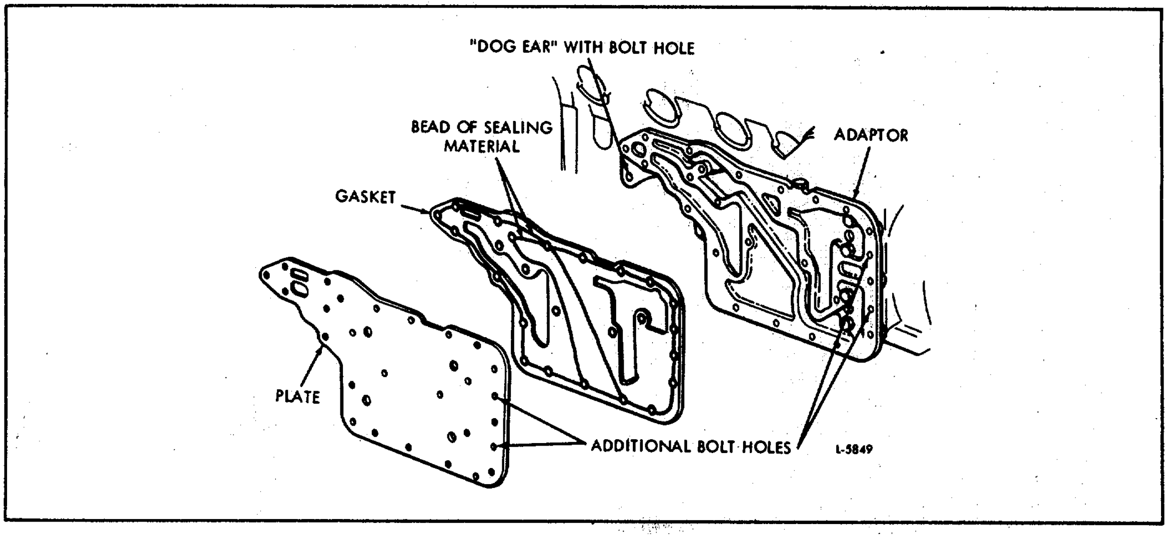


FIG.3 Oil Cooler Adaptor

6 . Remove the bolts and lock washers and withdraw the oil cooler housing and oil cooler core as an assembly, using care to avoid dropping the oil cooler core .

If the engine is equipped with a twin plate oil cooler (Fig . 8), remove the two outer bolts at the top of the oil cooler cover and install two studs (approximately 8-1/2" long and with a 5/16"-18 thread at one end) to support the housing, oil cooler core and cover . Then remove the remaining bolts, lock washers and two copper washers . The cover, oil cooler core, housing and gaskets may then be removed .

7 . If the oil cooler adaptor is to be remove4, first remove the oil filter . Then remove the bolts and lock washers which attach the adaptor to the cylinder block and withdraw the adaptor and gaskets . To remove the oil cooler adaptor used with the twin plate cooler, the adaptor plate must be removed first .

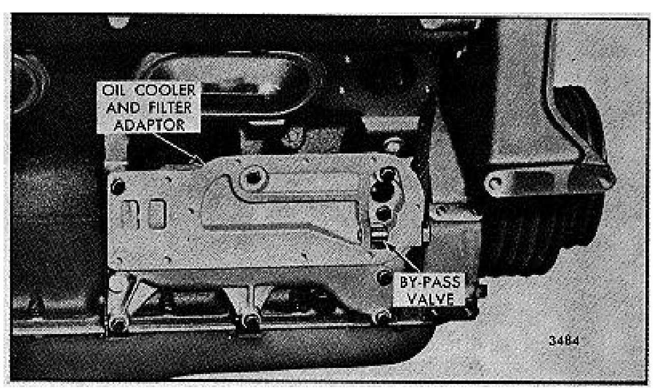
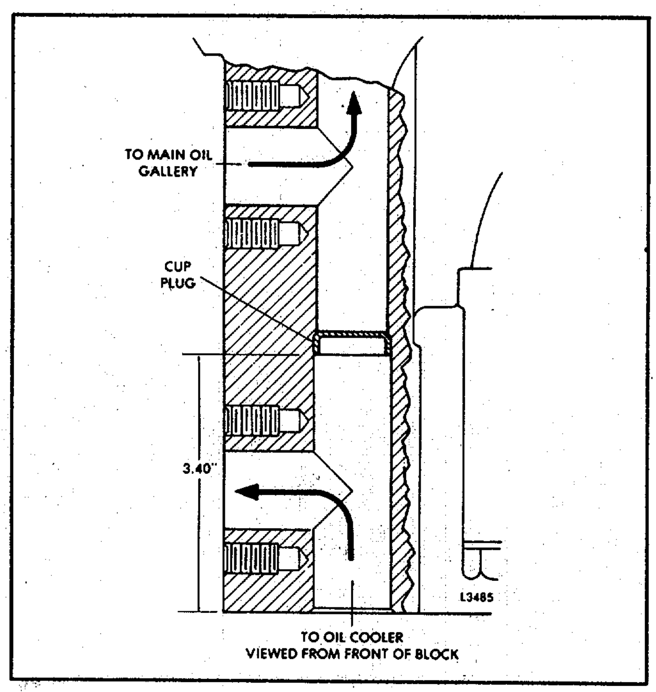


FIG . 4 - Oil Cooler Adaptor and Bypass Valve

8 . Clean all traces of gasket material from the cylinder block and the oil cooler components .

9 . 1nspect the vertical oil passage in the cylinder block for the presence of the cup plug which directs the flow of oil through the oil cooler (Fig . 5) . Absence of this



Mounting FIG . 5 - Location of Cylinder Block Oil Gallery Cup Plug

plug will result in high oil temperature or low oil pressure (resulting from high oil temperature) .

Clean Oil Cooler Core

1 . Clean the oil passages in the oil cooler core by circulating a solution of trichloroethylene through the passages with a force pump .

CAUTION: Perform this operation in the open or in a well ventilated room . Avoid breathing the fumes or direct contact of the chemicals with your skin .

Clean the oil cooler core before the sludge hardens . If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the oil cooler core and flush it thoroughly with clean, hot water .

NOTE: Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil . In this instance, replace the oil cooler core .

2 . After cleaning the oil passages, clean the water side of the oil cooler core by immersing it in a solution made as follows: add 1/2 pound of oxalic acid to each 2-1/2 gallons of a solution composed of 1/3 muriatic acid and 2/3 water. The cleaning action is evident by the bubbling and foaming . Carefully observe the process and remove the oil cooler core from the solution when the bubbling stops (this usually takes from 30 to 60 seconds). Then thoroughly flush the oil cooler core with clean, hot water . After cleaning, dip the oil cooler core in light oil .

CAUTION: Protect your eyes and avoid breathing the fumes or direct contact of the acid with your skin .

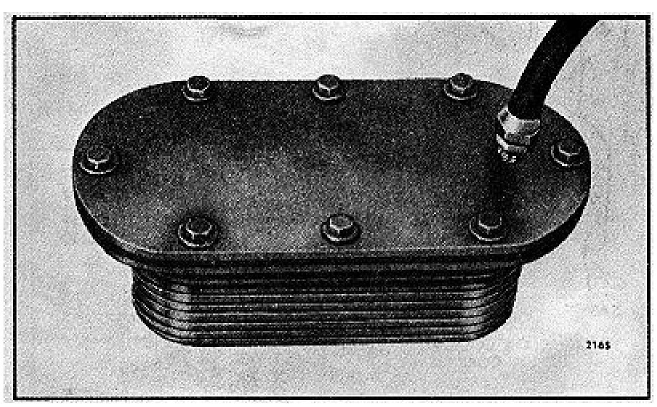


FIG . 6 - Oil Cooler Core Prepared for Pressure Check Pressure Check Oil Cooler Core

1 . Make a suitable plate and attach it to the flanged side of the oil cooler core . Use a gasket made from rubber to ensure a tight seal . Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the oil cooler core (Fig . 8) .

2 . Attach an air hose and apply approximately 75-150 psi (517-1 034 kPa) air pressure . Then submerge the oil cooler core and plate assembly in a tank of water heated to 180°F (82°C) . Any leaks will be indicated by air bubbles in the water .

CAUTION: When making this pressure test be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core .

3 . After the pressure check is completed, remove the plate and air hose and dry the oil cooler core with compressed air . Replace the oil cooler core if leaks were indicated .

NOTE: In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be flushed immediately to prevent serious damage (refer to Section 5) .

Install Oil Cooler Assembly

Refer to Figs . 7 and 8 and install the oil cooler as follows:

1 . If the oil cooler adaptor was removed, use new gaskets and attach the adaptor to the cylinder block with bolts and lock washers . If a twin plate oil cooler is used, use a new gasket and attach the adaptor plate to the oil cooler adaptor .

2 . Affix new gaskets to the inner and outer faces of the flange and insert the oil cooler core in the oil cooler housing .

NOTE: The inlet and outlet openings in the oil cooler core are marked "IN" and "OUT" . Make sure the oil cooler core is reinstalled in its original position, otherwise the oil flow will be reversed and could result in foreign particles that may not have been removed to be loosened and circulated through the engine . If the openings are unidentified, it is suggested that they be marked before reinstalling the oil cooler core .

3 . Place the housing and oil cooler core against the adaptor and secure them with bolts and lock washers .

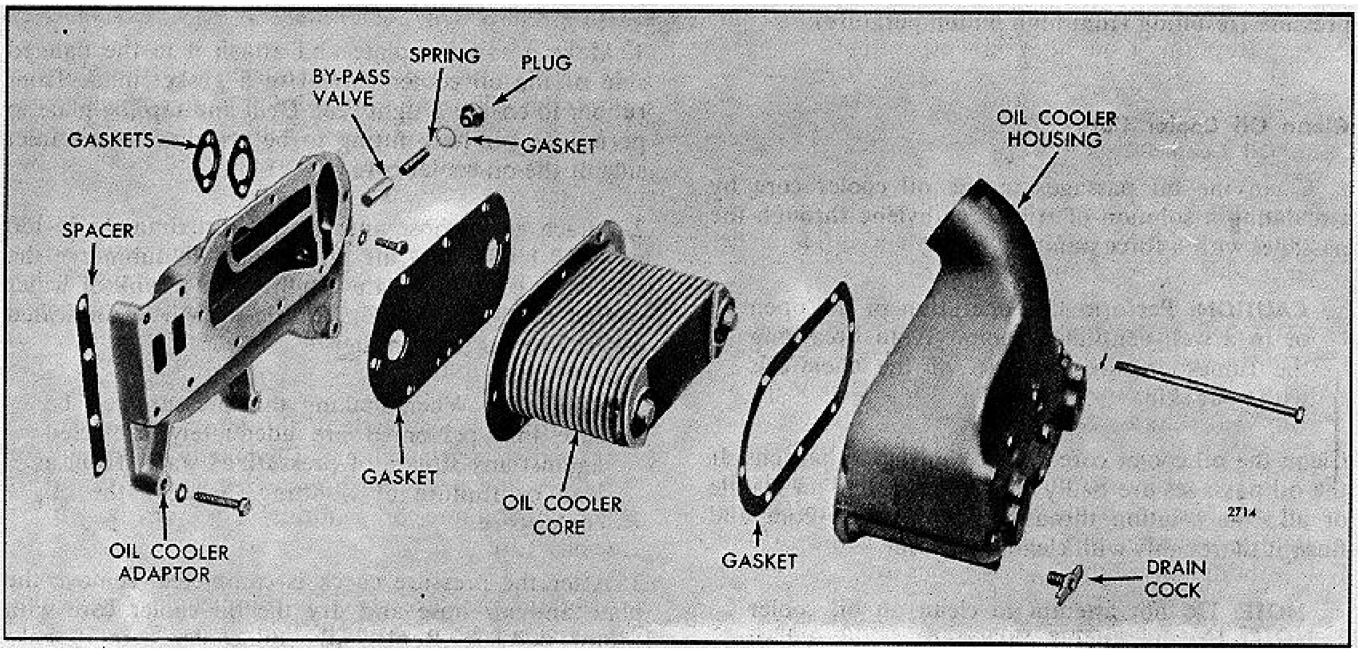


FIG . 7 - Typical Oil Cooler Details and Relative Location of Parts

If a twin plate oil cooler is used, install two guide studs . Then, using new gaskets, slide the housing, oil cooler core and cover over the dowels in the order illustrated in Fig . 8 and secure them in place with bolts, lock washers and new copper washers . Remove the studs and install the remaining two bolts and lock washers .

NOTE: A tab is provided on current cover

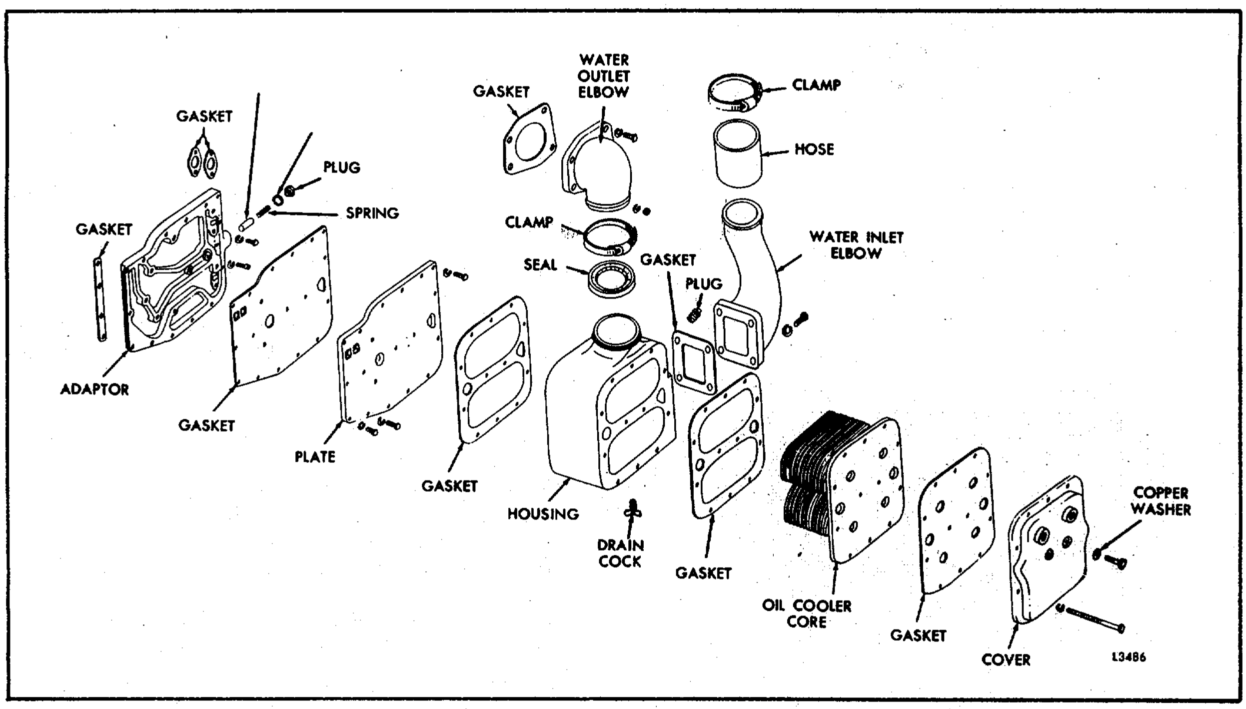


FIG . 8 - Twin Plate Oil Cooler Details and Relative Location of Parts gaskets to ensure the gasket is installed correctly .

4 . Install the water outlet flange and seal, or water outlet elbow, seal and gasket . Secure the flange or elbow to the cylinder block with bolts, nuts and lock washers . If an elbow is used, tighten the seal clamp .

5 . Affix a new gasket to the oil cooler housing at the water inlet opening and secure the water inlet elbow to the housing with bolts and lock washers .

6 . Slide the water inlet elbow hose in position and tighten the clamps .

7 . Install any accessories which were removed to provide access to the oil cooler .

8 . Close the drain cock in the oil cooler housing and fill the cooling system to the proper level .

9 . Add sufficient oil to the crankcase to bring the oil level to the proper level on the dipstick .

10 . Start and run the engine for a short period and check for oil and water leaks . After any leaks have been corrected and the engine has been stopped long enough (20 minutes) for the oil from various parts of the engine to drain back to the crankcase, bring the oil level up to the proper level on the dipstick .

To ensure engine lubrication should the oil cooler become plugged, a bypass valve is installed in the inlet passage of the oil cooler adaptor (Fig . 4) . The valve opens and allows the oil to bypass the oil cooler when the pressure at the inlet side exceeds the pressure at the outlet side by 40 psi (276 kPa) .

LUBRICATING OIL COOLER BYPASS VALVE

The bypass valve assembly, which consists of a valve, spring, retaining plug and gasket, should be removed, cleaned and reassembled whenever the oil cooler core is cleaned or replaced . However, the bypass valve can be disassembled without removing the oil cooler on most models .

Remove Oil Cooler Bypass Valve

Remove the retaining plug and withdraw the gasket, spring and valve from the oil cooler adaptor .

Inspection

Clean the bypass valve components with fuel oil and dry them with compressed air .

Inspect the valve and spring for wear and replace them if necessary . The bypass valve spring has a free length of approximately 2-1 /64" . Use spring tester J 22738-02 to check the spring load . When a force of 12 pounds (53 . 4 N) or less will compress the spring to 1 . 793", replace the spring.

Install Oil Cooler Bypass Valve

Refer to Figs . 7 and 8 and install the bypass valve as follows:

1 . Apply clean engine oil to the outside surface of the valve and place it in the oil cooler adaptor valve cavity, closed end first .

2 . Place the spring inside of the valve and place a new gasket on the retaining plug . Install and tighten the plug to 30-40 lb-ft (41-54 Nm) .

Certain engines are equipped with a tube-type oil cooler mounted on the side of the engine . The Hydraulic Retarder units use a dual oil cooler of which one section cools the engine oil and three sections are used to cool the brake oil (Fig . 9) .

A serviceable tube type oil cooler with removable tube bundles is now being used on certain 8V and 12V engines . The tube type oil cooler consists of a shell, two tube bundles, four seal rings and a front and rear cover (Fig . 10) .

NOTE: An improved seal ring is now being used in the single and dual tube type oil coolers effective with engines built March, 1979 . The improved seal ring is used at four locations on the oil cooler and should be used at overhaul, or whenever the oil cooler is serviced . Only the improved seal ring is serviced .

The coolant from the engine water pump flows through a passage in the oil cooler front cover, passes through the tubes of each section of the oil cooler, back to the outlet passage in the front cover, and finally to the water jackets in the cylinder block (Fig . 10) .

The engine oil from the lubricating oil pump enters a passage in the oil cooler front cover, passes through the remote mounted oil filter, then around the tubes in the engine section of the oil cooler, back through the outlet passage in the front cover, and then to the oil galleries in the cylinder block (Fig . 13) .

A bypass valve is provided which will permit the engine oil to flow directly through the oil cooler should the oil filter become clogged .

Oil from the Hydraulic Retarder flows through a flexible hose connected to an oil passage in the oil cooler front end-casting, through the retarder oil cooler sections and out through an oil passage in the oil cooler rear end-casting . A flexible hose carries the cool oil back to the Hydraulic Retarder (Fig . 10) .

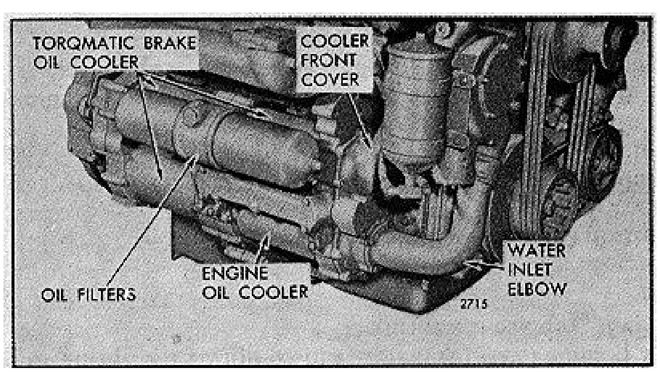


FIG. 9 - Dual Tube-Type Oil Cooler Mounting

Remove Oil Cooler

1 . Open the drain cock at the bottom of the rear oil cooler cover and drain the cooling system .

2 . Disconnect the oil filter lines and the torque converter oil lines at the cooler . Also remove any accessories necessary to provide access to the oil cooler .

3 . Loosen the clamps and slide the hose down on the water inlet elbow . Then remove the bolts and lock washers which attach the elbow to the oil cooler front cover and withdraw the elbow and gasket .

4 . Loosen the clamp on the water outlet flange seal . Then remove the bolts, nuts and washers which attach the flange to the cylinder block . Remove the flange, gasket, seal and clamp .

5 . Remove the bolts and lock washers which attach the oil cooler to the cylinder block and the oil cooler support bracket . Remove the oil cooler and the gaskets .

6 . Drain the oil from the oil cooler .

7 . Clean the exterior surfaces of the oil cooler with fuel oil .

Remove Tube Type Bundles (Current Engines)

The tube bundles are a snug fit in the shell and easily removed . Puller holes are located in the ends of the tube bundles for help in removal . The tube bundles are serviced separately .

NOTE: The oil coolant tube bundles must be reinstalled in their respective positions (Fig . I 1) . If necessary, match mark them before removing the tube bundles from the shell .

Clean Oil Cooler

1 . Clean the engine oil portion of the oil cooler as follows:

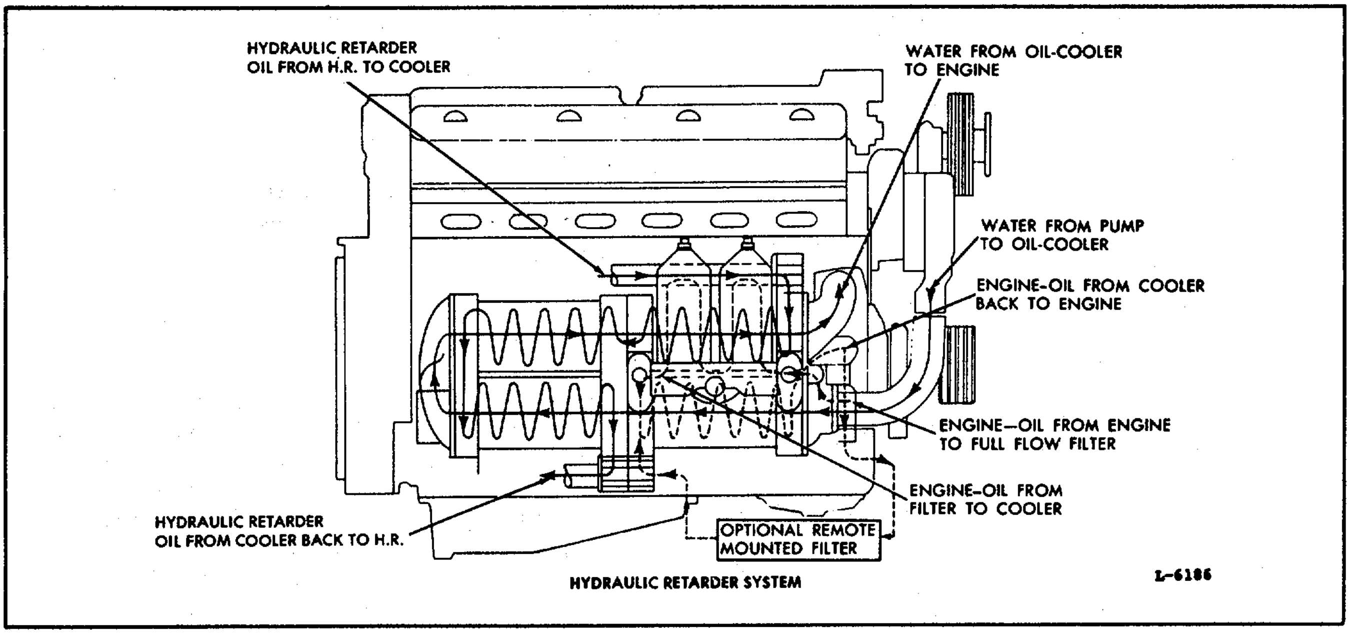


FIG . 10 - Tube-type Oil Cooler Flow Diagrams

NOTE: Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil . In this instance, replace the oil cooler core .

a . Replace the oil bypass tube and the oil bypass valve assembly with a long tube connected between the front and rear end castings of the oil cooler .

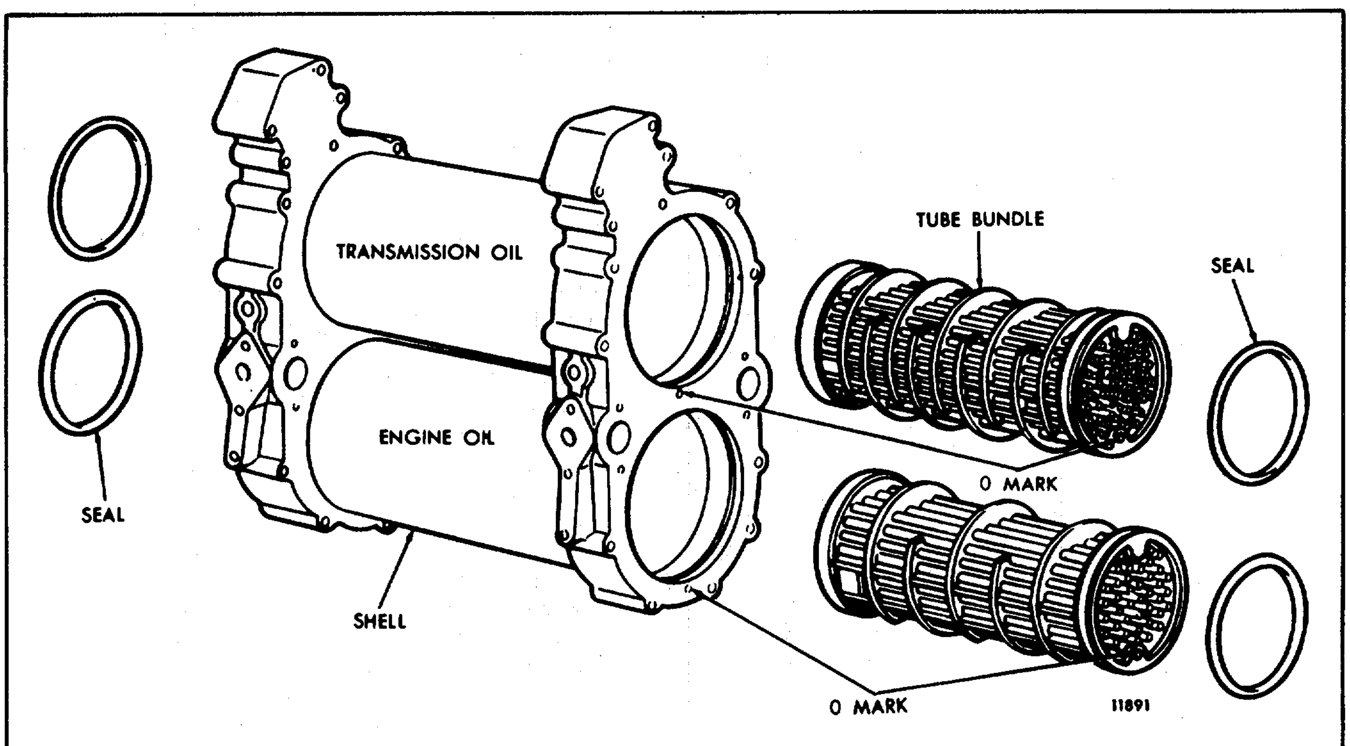


FIG . 11 - Tube-Type Oil Cooler (Removable Bundles) and Relative Location of Parts b . Seal the oil outlet (to filter) and oil inlet (from filter) openings in the front and rear oil cooler covers with steel plates and gaskets .

c . Attach a steel plate, which is fitted with an air hose connection, to the oil outlet (to engine) in the front cover .

d . Attach an air hose, which is connected to an air supply capable to maintaining approximately 100 psi (689 kPa) pressure during the process of expelling the solvent . Then stand the oil cooler on end so the baffles inside the cooler shell will be in a horizontal position .

e . Fill the oil cooler with a cleaning solvent and apply air pressure to expel the solvent and sludge . CAUTION: This operation should be performed in the open or in a well ventilated room when toxic chemicals are used . Also, since the solvent and sludge will be expelled with considerable force, it is suggested that the oil cooler be lowered upright in a barrel to prevent injury to personnel and to keep the spray of sludge contained within a small area .

f . Refill the oil cooler with clean solvent and attach the air hose fitting to the inlet side of the cooler . Apply air pressure to expel the solvent . Repeat the flushing operation in alternate directions until the solvent comes out clean twice from each direction .

g . Remove the tube which replaced the oil bypass tube and valve assembly .

2 . Clean the torque converter oil portion of the oil cooler by circulating a cleaning solvent through the oil passages .

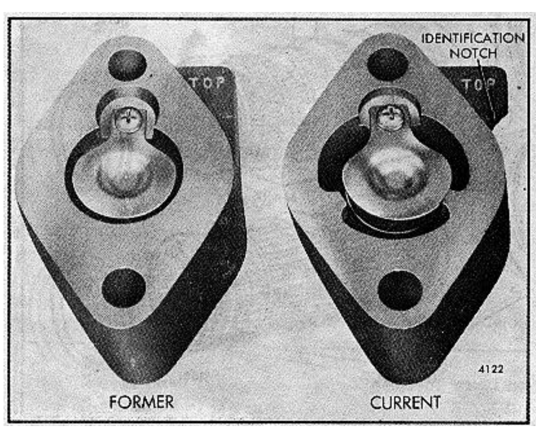


Fig . 12 - Oil Cooler Bypass Valve Assemblies

3 . Clean the water side of the oil cooler by circulating a solvent such as Oakite through the tubes . Then remove the end covers and run a brush through the tubes . After the brushing is completed, rinse the tubes with clean, hot water .

NOTE: Precautions must be taken so the cleaning agents do not corrode the tubes . If an acid solution is used, the residue must be neutralized .

Inspect Oil Bypass Valve

Remove the spring retainer screw and withdraw the retainer, spring and valve from the valve housing . Use spring tester J 22738-02 to check the valve spring load . Replace the spring if a load of less than 6-1/2 pounds will compress it to a length of 13/16" . Examine the spring retainer . If the retainer is bent, install a new valve assembly . The current valve assembly (Fig . 12) has an 'increased bypass area around the spring retainer to permit a larger volume of cold oil to bypass when starting the engine .

Assemble Removable Tube Type Bundles

For ease in assembling, each tube bundle is marked with an "O" and the cooler shell is marked with an "O" (Fig . 10) . The "O’s must line up to ensure proper location of the baffles in the shell . The tube bundles can be installed either end first .

To avoid cutting the seal rings and leaking seal rings it is important that each tube bundle be installed in the shell as follows:

1 . Place the shell in a vertical position on the floor .

2 . Install the bottom seal ring in the seal ring groove and coat it with lubricating oil .

NOTE: The seal ring groove must be free of burrs and foreign material .

3 . Prior to inserting the tube bundle, inspect both ends of the element at the lead in chamfer for nicks, dents or burrs .

NOTE: Be sure the correct bundle is used in its proper location prior to installation using the bundle part number identification on the spacer bar for reference only .

4 . Insert the tube bundle into the shell and carefully press the bundle just pass the upper seal ring groove .

NOTE: Do not directly hammer on the tubes in the bundles as solder breakage or tube damage could occur .

5 . Install the upper seal ring in the seal ring groove and coat with lubricating oil .

6 . Invert the tube and shell assembly and press the tube bundle in the opposite direction .

7 . The tube bundle should now be flush with the shell at both ends .

The above procedure applies whenever the oil cooler is assembled, even if the tube bundle has slipped out during shipment .

The new front and rear covers have a 3/8" tang on the top and bottom surface to retain the tube bundles in their proper position .

The former and current tube type oil cooler assemblies are completely interchangeable on an engine . Only the current oil cooler assemblies and their component parts will be serviced .

NOTE: When rebuilding a tube type oil cooler, it is important to note that the current design oil cooler cannot be used with a former design oil cooler in a twin oil cooler application . If one half of a former twin oil cooler application needs replacing, it will be necessary to replace both halves of the oil cooler .

Assemble Oil Cooler

1 . Place the bypass valve and spring in the valve housing . Then install the spring retainer .

2 . Install a new seal ring in each oil bypass tube flange and slide one flange over each end of the tube . Attach a new gasket to each flange .

3 . Install two 3/8"-16 x 5" bolts, with lock washers, through the flange and gasket at one end of the tube . Place the bypass valve assembly and a new gasket over the ends of the bolts .

4 . Place the oil bypass valve and tube assembly in position and thread the bolts into the front end casting of the oil cooler . Then install two 3/8"-16 x 3-1/2" bolts and lock washers in the flange at the other end of the tube . Tighten all four bolts to 30-35 lb-ft (41-47 Nm) torque .

5 . Install the-oil hole covers and gaskets used on the opposite side of the oil cooler, if they were previously removed .

6 . Use a new front gasket (Fig . , 13) and attach the Fig . 13 - Cover Gaskets For Dual Tube Type Oil Cooler front cover to the oil cooler with ten 3/8"-16 x 3" bolts and lock washers . Tighten the bolts to 30-35 lb-ft (41-47 Nm) torque .

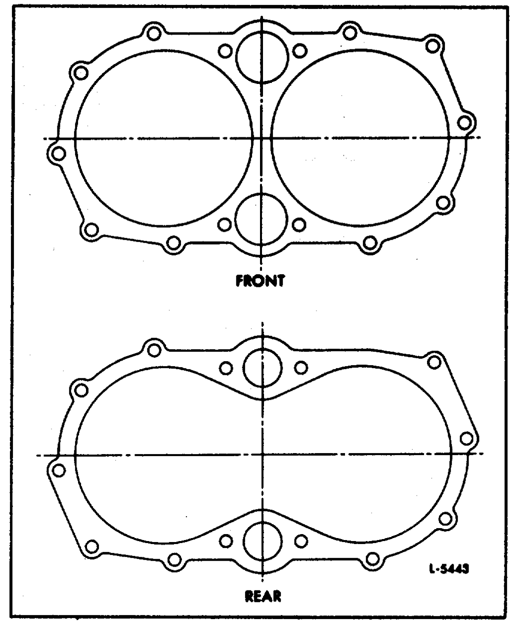


FIG . 13 - Cover Gaskets for Dual Tube Type Oil Cooler

7 . Use a new rear gasket (Fig . 13) and attach the rear cover to the oil cooler with ten 3/8"-16 x 3" bolt and lock washers . Tighten the bolts to 30-35 lb-ft (41-47 Nm) torque .

8 . On a dual tube type oil cooler (Fig . 14) assemble the two rear cooler cover support plates, the upper retainer plate and the necessary . 062", shims with three 3/8"-16 x 1-5/8" bolts . Then assemble the lower retainer plate and necessary . 062" shims using a new gasket between the oil cooler cover and support plate with five 3/8"-16 x 1-1/8" bolts and lock washers . Also include the center bolt and lockwasher . Tighten the bolts to 30-35 lb-ft (41-47 Nm) torque .

Install Oil Cooler

1 . Attach new gaskets to the mounting pads on the oil cooler front cover and place the oil cooler in position against the cylinder block . Secure the front end of the oil cooler to the cylinder block with four 3/8"-16 x 2-1/4" bolts and lock washers . Then secure the rear end of the oil cooler to the support bracket with four

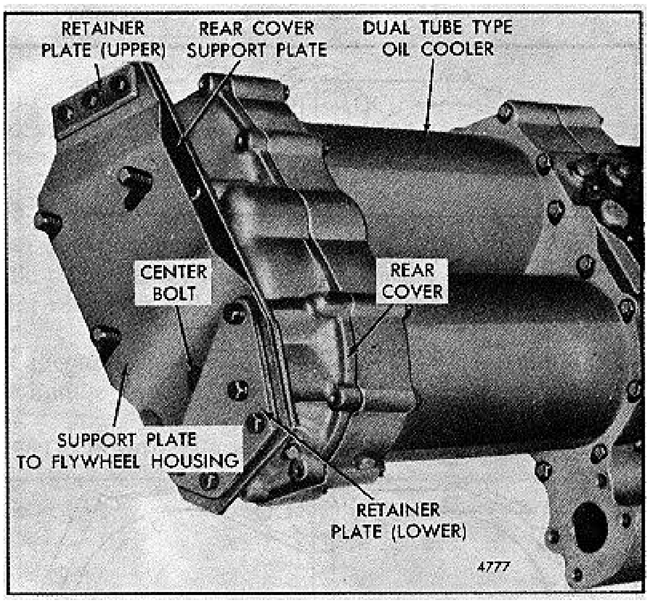


FIG . 14 - Dual Type Oil Cooler

3/8"-16 x 1" bolts and lock washers . Tighten all of the oil cooler mounting bolts to 30-35 lb-ft (41-47 Nm) torque .

2 . Place the water outlet flange seal and clamp in position . Then use a new gasket and install the flange . Use new copper washers with the two bolts . Tighten the bolts and nuts to 30-35 lb-ft (41-47 Nm) torque . 3 . Use a new gasket and attach the water inlet elbow to the oil cooler front cover with four 3/8"-16 x 1-1/8" bolts and lock washers . Tighten the bolts to 30-35 lb-ft (41-47 Nm) torque . Then slide the water inlet elbow hose in place and tighten the clamps .

4 . Connect the oil filter and torque converter oil lines to the oil cooler .

5 . Install any accessories that were removed to provide access to the oil cooler .

6 . Install 4any pipe plugs that were removed .

7 . Close the drain cock in the oil cooler rear cover and fill the cooling system to the proper level .

8 . Add sufficient oil to the crankcase to bring the oil level to the proper level on the dipstick .

9 . Start and run the engine for a short period and check for oil leaks . After any oil leaks have been corrected, and the engine has been stopped long enough (20 minutes) for the oil from various parts of the engine to drain back to the crankcase, bring the oil level up to the proper level on the dipstick .

OIL LEVEL DIPSTICK

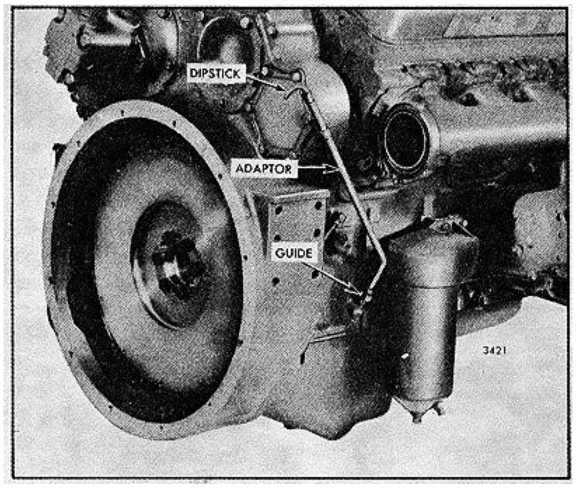


FIG . 1 - Typical Oil Level Dipstick Mounting

A ribbon type oil level dipstick is used to determine the quantity of oil in the engine oil pan . The dipstick is located in an adaptor attached, by means of a guide, to an opening in the cylinder block which leads to the oil pan (Fig . 1) . The current engines include a 3/4" long rubber oil seal inside the cap of the dipstick . This prevents the escape of vapors carrying oil from the dipstick tube .

Maintain the oil level between the full and low marks on the dipstick and never allow it to drop below the low mark . No advantage is gained by having the oil level above the full mark . Overfilling will cause the oil to be churned by the crankshaft throws causing foaming or aereation of the oil . Operation below the low mark will expose the pump pick-up causing aereation and/or loss of pressure .

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan .

Dipsticks are marked for use only when the vehicle the engine powers is on a level surface . Improper oil levels can result if the oil level is checked with the vehicle on a grade .

Fill the crankcase with oil as follows:

1 . Fill the oil pan to the full mark on the dipstick .

2 . Start and run the engine for approximately ten minutes .

3 . Stop the engine and wait a minimum of twenty minutes . Then add the required amount of oil to reach the full mark on the dipstick .

OIL PAN

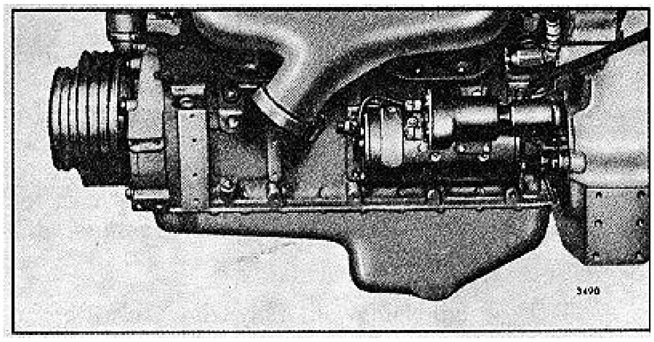


FIG . 1 - Typical Oil Pan Installation

The engines may be equipped with either a stamped steel or cast iron oil pan (Fig . 1) .

A sectional oil pan gasket, consisting of two side sections and two end sections, incorporate all the necessary bolt holes .

Remove and Install Oil Pan

1 . Remove the drain plug and drain the oil .

2 . Remove the bolt and washer assemblies and detach the oil pan, being careful not to damage the oil pump piping and inlet screen .

3 . Remove all of the old gasket material from the cylinder block and the oil pan . Clean the oil pan with fuel oil and dry it with compressed air .

4 . Inspect the oil pan for dents or other damage which may necessitate repair or replacement . Check for misaligned flanges or raised surfaces surrounding the bolt holes by placing the pan on a surface plate or other large flat surface .

5 . When installing the oil pan, use new gaskets and, starting with the center bolt on each side and working alternately toward each end of the pan, tighten the 3/8 "-16 bolts to 10-20 lb-ft (14-27 Nm) torque . Do not overtighten the bolts . Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the current type oil pan gasket . If a leak should develop at the oil pan, check if the lock washer is compressed . If not, the bolt may b)e tightened . However, if the lock washer is compressed and leaking occurs, remove the oil pan and determine the cause of the leakage .

> **NOTE**: Effective with engine serial number 1 2VA-5206 1, the center drilled through bolt hole at the rear reinforcement strips uses a bolt with seal and lock washer rather than a plain bolt and copper washer .

> **NOTE**: Current oil pan bolts (stamped metal pans) are coated with a locking material . To re-activate the locking ability of the bolts, apply a drop or two of Loctite J 26588-242, or equivalent, to the threads of the bolts at re- assembly .

6 . Install and tighten the drain plug to 25-35 lb-ft (34- 47 Nm) torque (refer to Section 4 . 0) .

7 . Fill the oil pan with new oil (refer to Section 4 . 6 and 13 . 3) to the full mark on the dipstick . Start and run the engine for about ten minutes to check for oil leaks . 8 . Stop the engine and, after approximately twenty minutes, check the oil level . Add oil, if necessary .

VENTILATING SYSTEM

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system .

Breathing is through two openings in the rear main bearing bulkhead of the crankcase, which connects to a chamber shielded by a semi-circular cast wall and covered by the rear cylinder block end plate . Two crimped-steel mesh breather pads, which cover the openings (Fig . 1), filter out the oil as the vapors pass into the chamber . This chamber connects with a breather cavity which provides a large cross-sectional area and maximum height for efficient breathing . A large air handling capacity, unaffected by the operating angle of the engine, results by breathing from the high central crankcase location which cannot be flooded and where air flowing to the breather exit does not rise past and impede the drainage of oil from some higher section of the engine .

NOTE: Turbocharged engines do not require breather pads .

The new breather pads were used beginning with engine 6VA-16943, 8VA-7508 and 12VA-2332 . The new pad differs from the two former pads in width only . To compensate for the decrease in width, two retainers have been provided to hold the new pads in the cavities behind the cylinder block rear end plate (Fig . 1) .

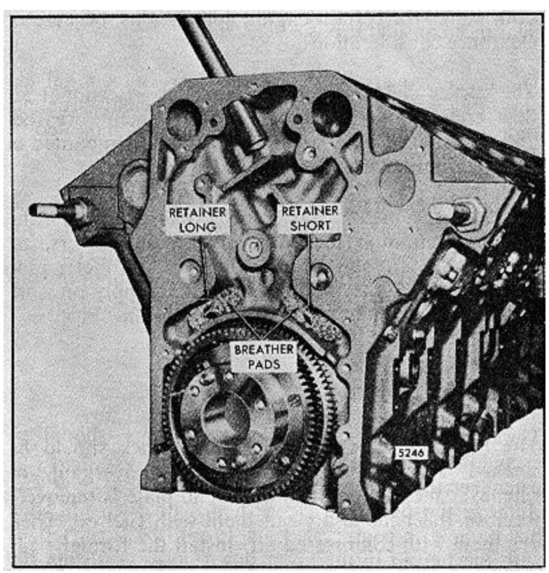


FIG . 1 - Current Breather Pads and Retainers Installed in Cylinder Block

A breather pipe is pressed into or flange mounted on top of the cylinder block to provide an exit for the crankcase vapors (Fig . 2) .

Some engines have an additional breather assembly mounted on the flywheel housing (Fig . 4) or on one of the valve rocker covers (Fig . 6) .

On certain turbocharged engines, external crossover tubes connect the cylinder block exit hole to a hole at the rear of each cylinder head .

The current left bank cylinder head to cylinder block breather system used on 6V engines is now being used in 8V engines effective with 8V-368656 . An elbow is bolted to the side of the cylinder head and a tube pressed in the opening at the top rear end of the cylinder block (Fig . 3) . They are joined with a rubber hose and clamps . The former breather system continues for the right bank cylinder head to cylinder

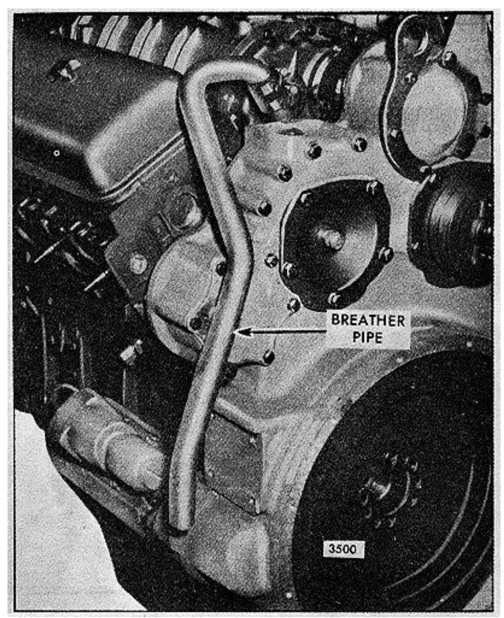


FIG . 2 Typical Mounting of Breather Pipe from Top of Cylinder Block

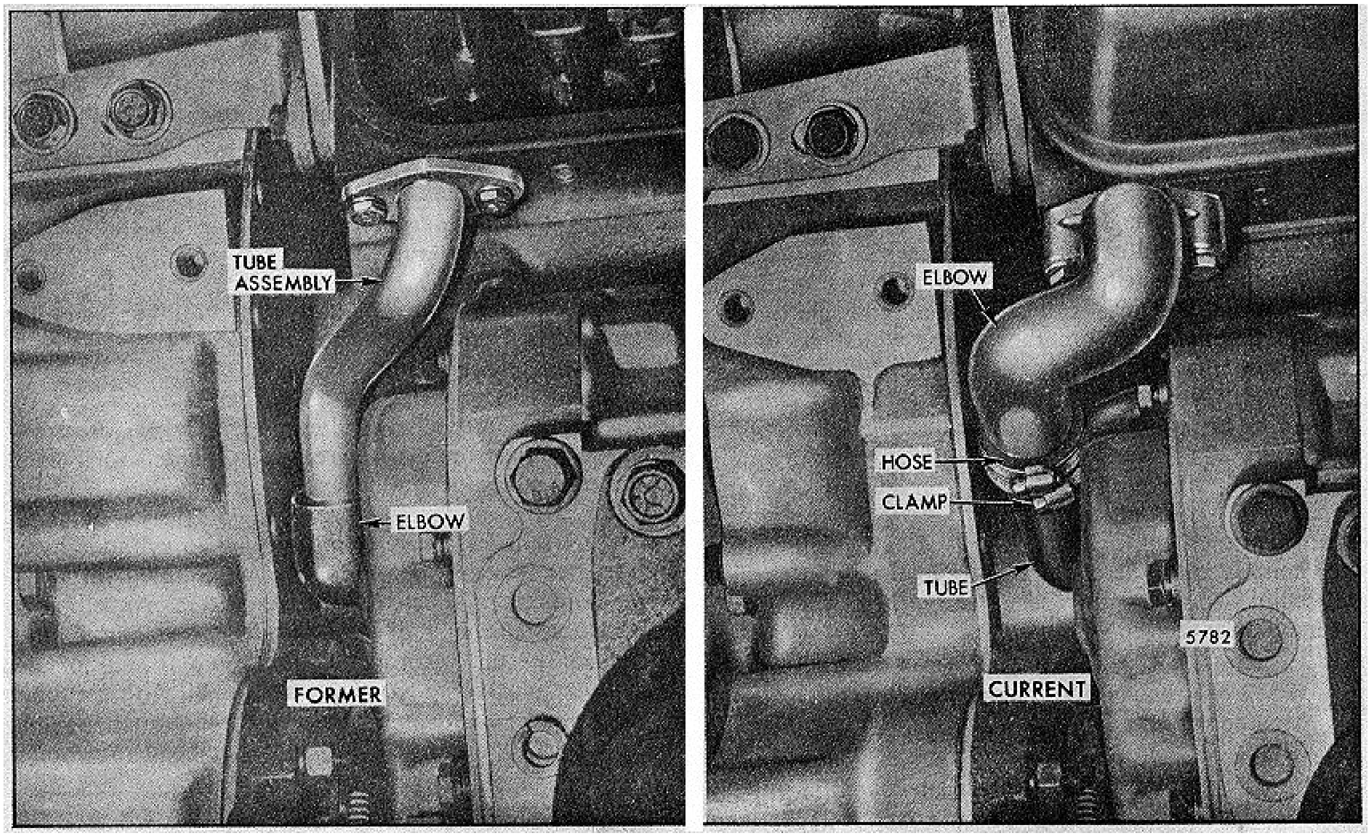


FIG . 3 - Cylinder Block to Cylinder Head Breather Systems for Certain 6V and 8V Engines

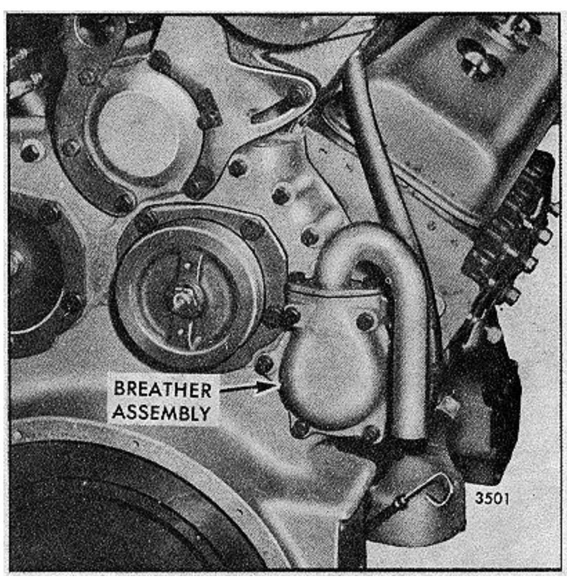


FIG . 4 - Typical Mounting of Breather Assembly at Accessory Hole in Flywheel Housing

block breather system, and will continue to be used on both banks for certain engine applications, because of clearance considerations .

The rocker covers provide a large cross sectional air flow area at maximum height for efficient breather and oil separation . A breather assembly is mounted at the opening in each rocker cover .

To index the breather assembly exhaust outlet on the current aluminum die cast valve rocker covers, no disassembly is required . Insert a l 1/8"a diameter pipe or wood dowel into the breather outlet, apply pressure and rotate the outlet to the desired location .

Service

The breather pads in the cylinder block should be cleaned at the time of an engine overhaul, or whenever the rear cylinder block end plate is removed . Remove the pads and clean them with fuel oil . Then dry them with compressed air . Install the former pads with the tie pin in the up or down position . Install the current breather pads as shown in Fig . 1 .

NOTE: Since the former breather pads were not

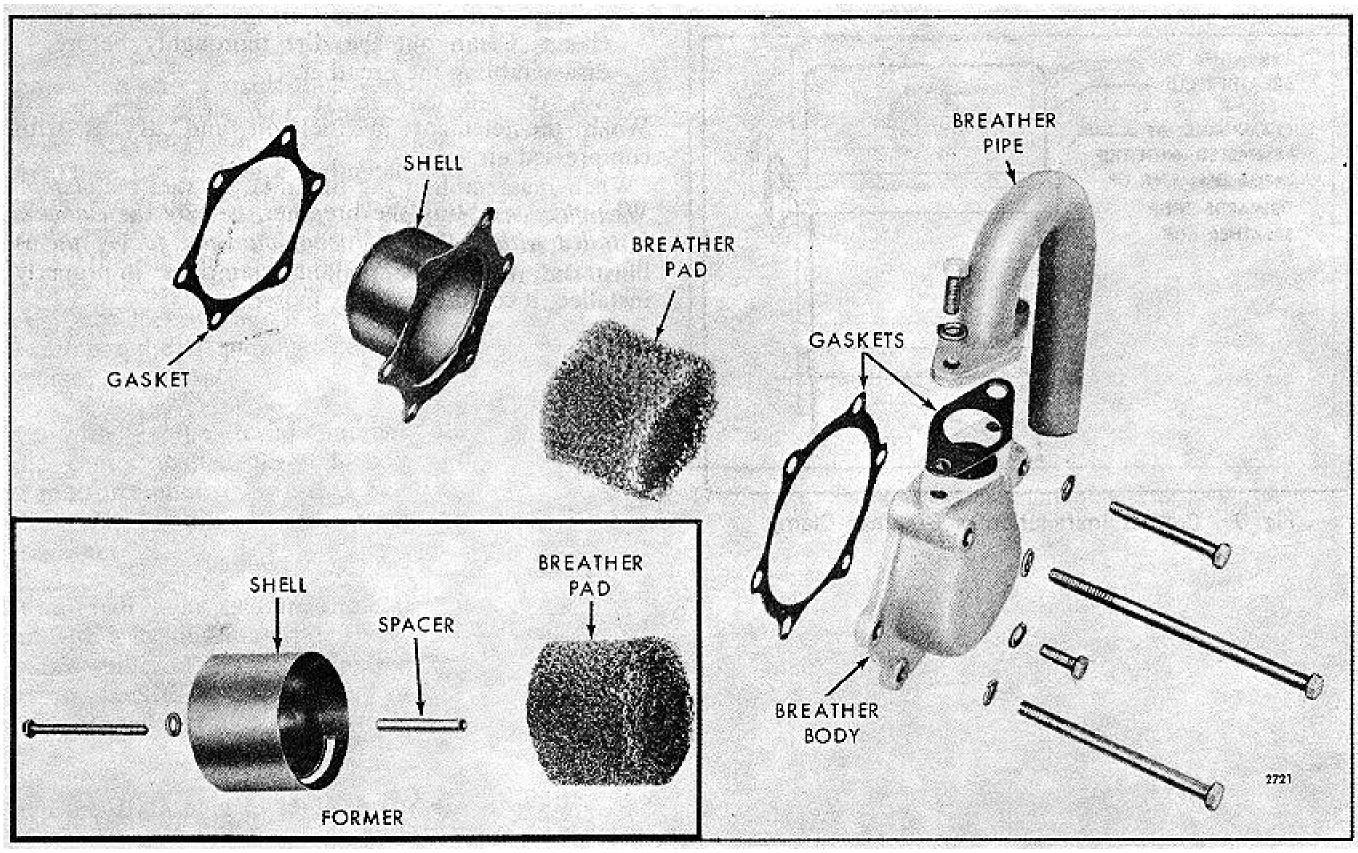


FIG. 5 - Flywheel Housing Mounted Breather Assembly Details and Relative Location of Parts

the same size, be sure to reinstall them in their original locations.
The breather assembly illustrated in Figs. 4 and 5 consists of a wire mesh pad, a steel shell and a breather body. T he pad filters out any oil which may be present in the crankcase vapors; a slot in the steel shell permits the oil to drain back to the crankcase.

The breather assembly shown in Fig. 6 consists of a wire mesh pad, two screens and a steel shell. Remove the breather pad and screens, if used, from the shell. Clean them with fuel oil and dry them with compressed air. Reassemble the breather assembly.

1. When the breather is mounted on the flywheel housing, reassemble the breather with the slot in the steel shell at the bottom and with approximately 9/16" space between the pad and the back of the breather, housing.

NOTE: Be sure the pad covers the slot in the shell.

2. The element in the breather assembly mounted on the valve rocker cover should be cleaned if excessive crankcase pressure occurs. Also clean the breather pipe.

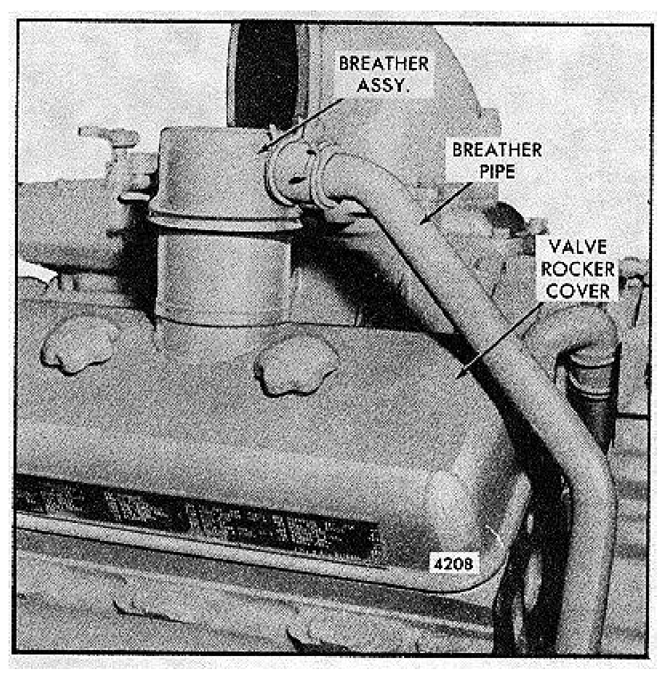


FIG. 6 - Typical Mounting of Breather Assembly on Valve Rocker Cover

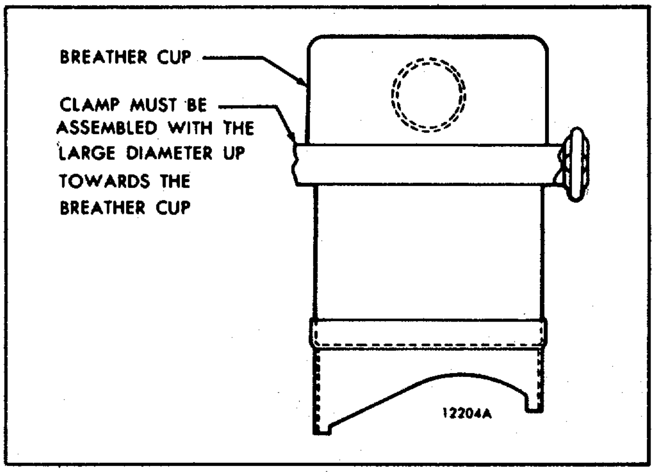


FIG. 7 - Correct Installation of Breather Clamp

NOTE: Dirt can collect around the breather clamp. Clean out the dirt thoroughly before disassembling the breather.

Wash the element in fuel oil and dry it with compressed air.

When reassembling the breather, *be sure the clamp is installed with the large (open) diameter facing up* as illustrated in Fig. 7. If the clamp is improperly installed, it could eventually loosen.

SPECIFICATION - SERVICE TOOLS

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	Nm
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. (osi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4	74,000
			over 3/4 to 1 1/2	60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1	120,000
			over 1 to l 1/2	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
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 SIZE	TORQUE (lb-ft)	TORQUE (Nm)
Oil pan	5/16 "-18	10-12	14-16
Oil pan bolts	3/8"-16	15-20	20-27
Lubricating oil filter center -	5/8"18	50-60	68-81
Oil pan drain plug (nylon washer)	18mm	25-35	34-47

SERVICE TOOLS

TOOL NAME	TOOL NO.
Bar type gear puller	J 24420
Oil pump drive shaft gear installer (6 and 8V)	J 22397
Oil pump driven shaft gear installer (6 and 8V)	J 22398
Oil pump driving gear installer (12V)	J 22285
Oil pump gear installer (12V)	J 8509
Spring tester	J 22738302
Strap wrench (spin-on filter)	J 24783

SECTION 5
COOLING SYSTEM

CONTENTS

COOLING SYSTEM

To effectively dissipate the heat generated by the engine. a radiator and a fan. are provided to cool the engine. The system is provided with a centrifugal type water pump that circulates the engine coolant. Thermostats are utilized to maintain a normal engine operating temperature (refer to Section 13.2).

Upon starting a cold engine or when the coolant is below operating temperature, the coolant is restricted at the thermostat housing. a by-pass provides water circulation within the engine during the warm-up period

RADIATOR COOLING SYSTEM

Coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler housing and into the cylinder block.

From the cylinder block, the coolant passes up through the cylinder heads and, when the engine is at normal operating temperature. through the thermostat hous- ings and into the upper portion of the radiator. Then the coolant passes down a series of tubes where the coolant temperature is lowered by the air stream created by the revolving fan.

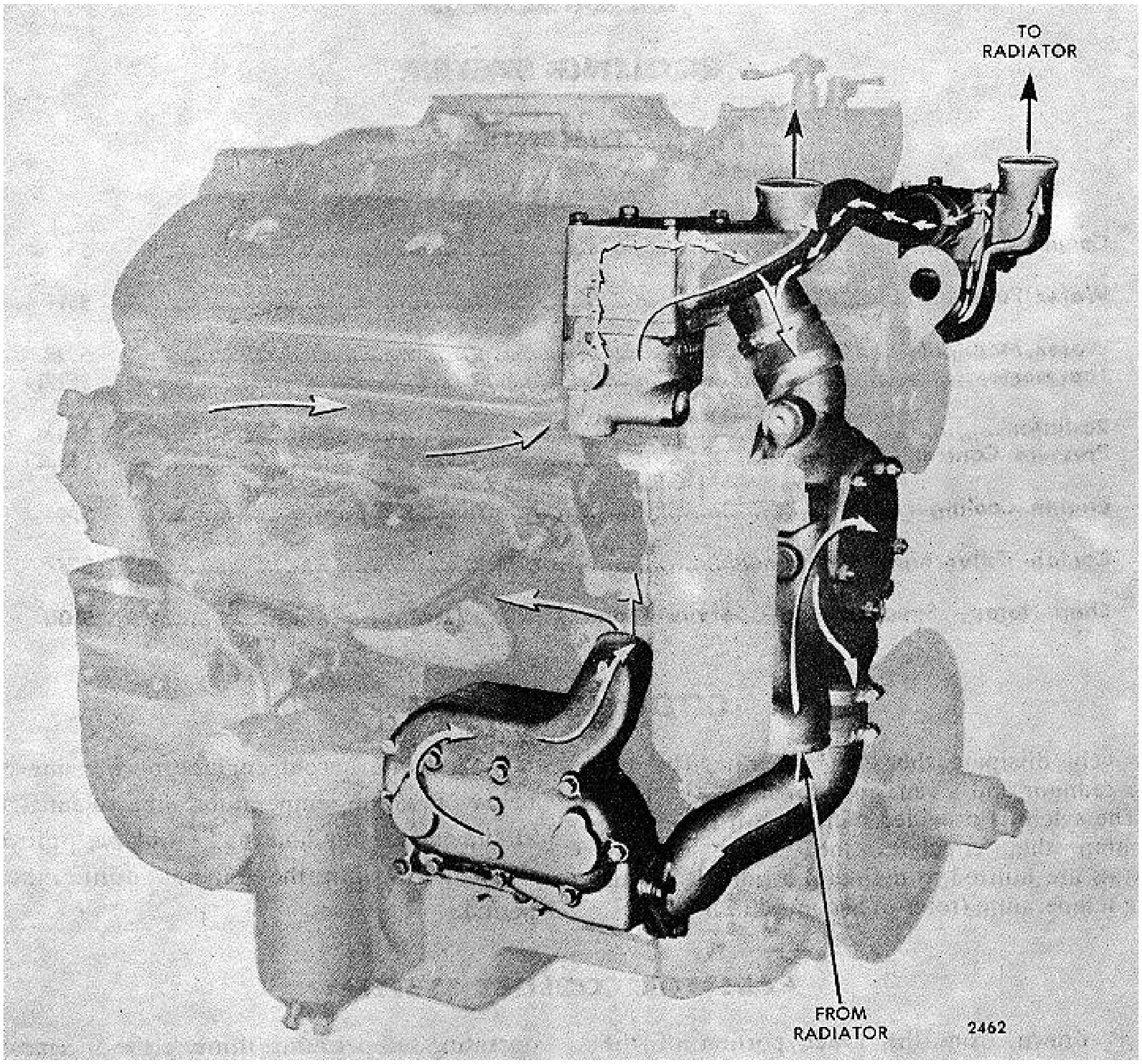


FIG 1 - Cooling System

ENGINE COOLING SYSTEM MAINTENANCE

A properly maintained and clean cooling system will reduce engine wear and increase the satisfactory engine operating time between engine overhauls. This is accomplished by the elimination of hot spots within the engine. Thus, when operating within the proper engine temperature range and when not exceeding the recommended horsepower output of the unit, all engine parts will be within their operating temperature range and at their proper operating clearances.

Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from the component parts such as exhaust valves, cylinder liners and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil-to-water oil cooler. Refer to Section 13.3 for coolant recommendations.

Cooling System Capacity

The capacity of the basic engine cooling system, (cylinder block, head, water manifold, thermostat housing and oil cooler housing) is shown in the following chart.

To obtain the complete amount of coolant in the cooling system of a unit, the additional capacity of the radiator, hoses, etc. must be added to the capacity of the basic engine. The capacity of radiators and related equipment should be obtained from the equipment supplier.

Drain Cooling System

The engine coolant is drained by opening the cylinder block and radiator (heat exchanger) drain cocks and removing the cooling system filler cap. Removal of the filler cap permits air to enter the cooling passages and the coolant to drain completely from the system.

Drain ,cocks are located on each side of the cylinder block at both the front and rear of the engine. The drain cocks at the rear of the engine are below the exhaust manifold. The front surface of the cylinder block has drain cocks on each side above the engine front cover.

In addition to the drains on the block, the oil cooler housing has a drain cock at the extreme bottom. Radiators, etc., that are not provided with a drain cock are drained through the oil cooler housing drain cock.

To ensure that all of the coolant is drained completely from a unit, all cooling system drains should be opened. Should any entrapped water in the cylinder block or radiator freeze, it will expand and may cause damage. When freezing weather is expected, drain all units not adequately protected by antifreeze. Leave all drain cocks open until refilling cooling system.

COOLING SYSTEM CAPACITY

(BASIC ENGINE)

ENGINE→	CAPACITY			
	FORMER BLOCK		†† WBP BLOCK	
	GALLONS	LITRES	GALLONS	LITRES
6V-71, T	5-1/2	20.8	7	26.5
6V-71 TA	-	-	7-1/2	28.4
SV-71, T, TT	7-3/4	29.3	7-3/4	29.3
8V-71 TA, TTA	-	-	8	30.3
12V-71, T	10-1/2	39.9	13-3/4	52.0

†† WATER BELOW PORT CYLINDER BLOCK
Cylinder block water locket capacity -
3.5gal. (13.2 liter)-6Vor 7.0 gal. (26.4 liter)-12V
4.4 gal. (16.9 liter)-8V

Fill Cooling System

Before starting the engine, close all of the drain cocks and fill the cooling system with coolant (refer to Section 13.3).

Start the engine and, after the normal operating temperature has been reached allowing the coolant to expand to its maximum, check the coolant level. The coolant level should be within 2 " of the top of the filler neck.

Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility of gases leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube from the overflow pipe to a water container. Bubbles in the water in the container during engine operation will indicate leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the water outlet line.

Flushing Cooling System

If a coolant filter is used and properly maintained, the cooling system need not be flushed. Otherwise, the cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, thus cleaning the system for the next solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the unit.

2. Refill with soft clean water. If the engine is hot, fill the unit *slowly* to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for 15 minutes to thoroughly circulate the water.

4. Drain the engine completely.

5. Refill with the solution required for the coming season (refer to Section 13.3).

Cooling System Cleaners

If the engine overheats and the fan and water level have been found to be satisfactory, it will be necessary to clean and flush the entire cooling system. Scale formation should be removed by using a reputable and safe de-scaling solvent. Immediately after using the de-scaling solvent. neutralize the system with the neutralizer. It is important that the directions printed on the container of the de-scaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse-flush before filling the system.

Reverse Flushing

After the engine and radiator have been thoroughly cleaned, they should be reverse flushed. The water pump should be removed and the radiator and engine reverse flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse flushing is accomplished by hot water, under air pressure, being forced -through the cooling system in a direction opposite to the normal flow of coolant, thus loosening and forcing scale deposits out.

The radiator is reverse flushed as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.
2. Attach a hose at top of the radiator to lead water away from the engine.
3. Attach a hose to the bottom of the radiator and insert the flushing gun in the hose.
4. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.
5. Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.

NOTE: Apply air gradually. Do not exert more than 30 pounds (psi) air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

The cylinder block and cylinder head water passages are reverse flushed as follows:

1. Remove the thermostats and the water pump.
2. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.
3. Attach a hose to the water outlet at top of the engine and insert the flushing gun in the hose.
4. Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.
5. Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system should be checked periodically to keep the engine operating at peak efficiency. T he cooling system hoses, thermostats and radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are installed, be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps. All external leaks should be corrected as soon as detected.

The fan belt must be checked and adjusted, if necessary, to provide the proper tension and the fan shroud must be tight against the radiator core to prevent re-circulation of air which may lower the cooling efficiency.

Contaminated Engines

When the engine cooling or lubricating system becomes contaminated, it' should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination, that is damaging to the engine if it is not corrected immediately, is a cracked oil cooler core.

With a cracked oil cooler core, oil will be forced into the cooling ,system while the engine is operating and, when it is stopped, coolant will leak into the lubricating system.

Cooling contamination of the lubricating system is especially harmful to engines during the cold season when the cooling system is normally filled with an ethylene glycol antifreeze solution. If mixed with the oil in the crankcase, this antifreeze forms a varnish which quickly immobilizes moving engine parts.

To remove such contaminants from the engine, both the cooling system and lubricating system must be thoroughly flushed as follows:

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, this flushing procedure is recommended.

1. Prepare a mixture of Calgon, or equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.

2. Remove the engine thermostat(s) to permit the Calgon and water mixture to circulate through the engine and the radiator/heat exchanger.

3. Fill the cooling system with the Calgon solution.

4. Run the engine for five minutes.

5. Drain the cooling system.

6. Repeat Steps 1, 2, 3 and 4.

7. Fill the cooling system with clean water.

8. Let the engine run five minutes.

9. Drain the cooling system completely.

10. Install the engine thermostat(s).

11. Close all of the drains and refill the cooling system with fresh coolant.

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution, or other soluble material, the following cleaning procedure, using Butyl Cellosolve, or equivalent, is recommended.

> **CAUTION**: Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water. If the engine is still in running condition, proceed as follows:

1. Drain all of the lubricating oil.

2. Remove and discard the oil filter element. Clean and dry the filter shell] and replace the element.

3. Mix two parts of Butyl Cellosolve. or equivalent. with one part SAE 10 engine oil. Fill the engine crankcase to the proper operating level with the mixture.

4. Start and run the engine at a fast idle (1.000 to 1,200 rpm) for 30 minutes to one hour. Check the oil pressure frequently.

5. After the specified time, stop the engine and immediately drain the crankcase and the filter. Sufficient time must be allowed to drain all of the fluid.

6. Refill the crankcase with SAE 10 oil after the drain plugs are replaced and run the engine at the same fast idle for ten or fifteen minutes and again drain the oil thoroughly.

7. Remove and discard the oil filter element. clean the filter shell and install a new element.

8. Replace the drains and fill the crankcase to the proper level with the oil recommended for normal engine operation.

9. To test the effectiveness of the cleaning procedure. It is recommended that the engine be started and run at a fast idle (1,000 to 1.200 rpm) for approximately 30 minutes. Then stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.

10. If the procedures for cleaning the lubricating oil system were not successful. it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

Make certain that the cause of the internal coolant /leak has been corrected before returning the engine to service 'ice.

WATER PUMP

6, 8 AND 12V ENGINES

The centrifugal-type water pump (Fig. l) circulates the engine coolant through the cylinder block, cylinder heads, radiator and the oil cooler.

The pump is mounted on the engine front cover and is driven by the front camshaft gear.

NOTE: The current water pump gear has 42 teeth and can only be used with the current 66 tooth front camshaft gear. Effective with engine serial numbers 6VA-65090, 8VA-177724 and 12VA-48235, a new light weight gear is used. The length of the gear teeth of the light weight gear is .600" while the length of the gear teeth of the former gear is .760". On early engines, the water pump gear had 59 teeth which meshed with a camshaft gear that had 92 teeth. The 92 tooth canishaft gear must be replaced before installing a water pump with a 42 tooth gear.

IMPORTANT: Effective with engine serial number 8VA-370083 the 8V engine water pump (driven) gear and the front camshaft (drive) gear are nitride hardened. The new drive and driven gears can be identified by the letter "H" stamped on the gears. Also the helix angle of the gear teeth *have been reversed.* The current water pump has a *right* hand helix gear and the camshaft has a *left* hand helix gear. This is to prevent former soft and current hard gears from being mixed on an engine. The former drive and driven gears are not interchangeable on an 8V-71 engine with the current nitride hardened drive and driven gears. When replacing a former water pump assembly with the current water pump assembly it is necessary to replace the front camshaft '(drive) gear with the nitride harden "H" stamped gear.

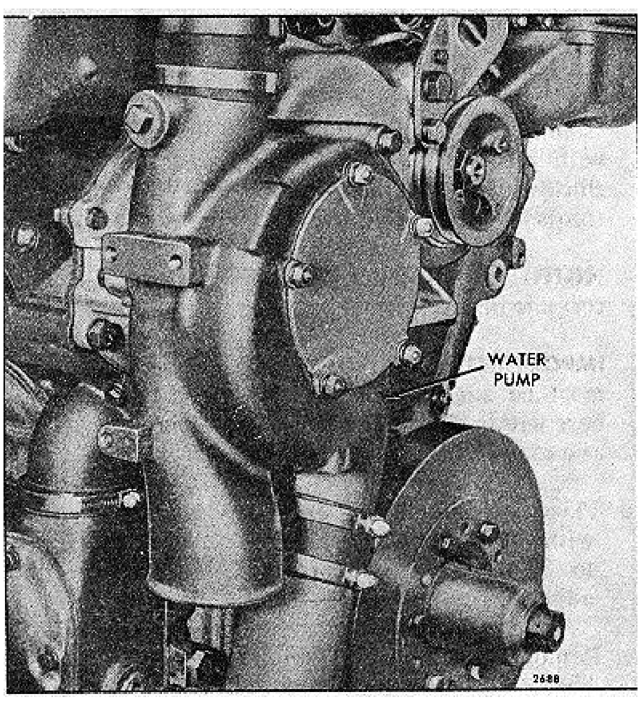


FIG. 1 - Water Pump Mounting

A bronze impeller is secured to one end of a stainless steel shaft by a lock nut. The water pump gear is pressed on the opposite end of the shaft. Two ball bearings are used to carry the shaft. The larger bearing is used at the drive gear end of the shaft to accommodate the thrust load (Fig. 6).

An oil seal is located in front of the smaller bearing and a spring-loaded face type water seal is used behind the impeller.

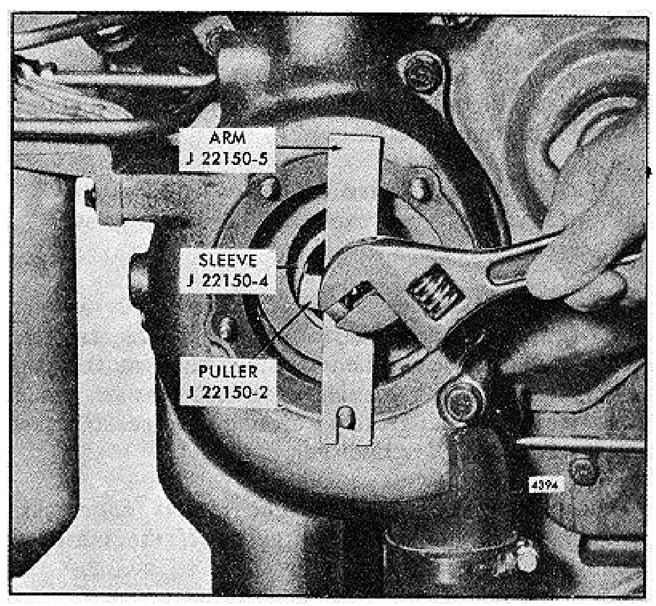


FIG. 2 Removing Water Seal from Pump using Tool Set J 22150-B

Lubrication

The pump ball bearings are lubricated with oil splashed by the camshaft gear and the water pump gear.

Replace Water Seal

The water seal can be replaced without removing the pump if the radiator, fan and fan shroud have been removed.

1. Remove the pump cover and gasket (Fig. 6).

   NOTE: For high-capacity pump refer to Fig. 10.

2. Remove the lock nut and washer and withdraw the impeller with puller J 24420.

   NOTE: Use care to prevent damage to the ceramic impeller insert. Place the impeller on the bench with the insert up.

3. Install the seal removal tool (J 22150B) in the pump and secure it in place with the pump cover snap ring or bolts or retaining nuts.

   NOTE: On the current 6 and 8V high capacity water pump, the cover seal ring should be left in place to avoid damage to the seal ring groove.

   a. Turn the puller shaft nut (J 22150-4) in a counterclockwise direction until the spears puncture the water seal case. Then, turn the puller shaft in a clockwise direction one eighth of a turn to lock the spears in place.

   b. Rotate the puller shaft nut in a clockwise direction to remove the water seal.

NOTE: ON the current 6 and 8V high capacity water pump, remove and discard the cover seal ring.

4. To reduce possible coolant leakage, apply a light coat of non-hardening sealant on the outside diameter of a new water seal. Then tap the seal into the seal cavity with a suitable sleeve which' has an inside diameter large enough to fit around the seal and rest on the brass cartridge lip.

5. Inspect the ceramic impeller insert for cracks, scratches and bond to the impeller. If the insert is damaged, replace it as follows:

   a. Bake the insert and impeller assembly at 500°F (260°C) for one hour. The insert can be removed easily while the adhesive is hot. After removing

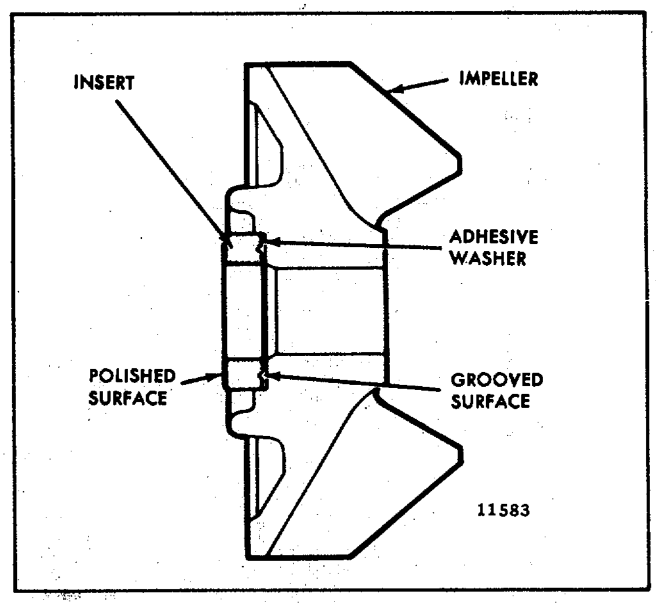


FIG. 3 - Impeller with Ceramic Insert

the insert, clean the insert area of the impeller with sandpaper, wire brush, or a buffing wheel to remove the old adhesive, oxide, scale, etc.

   b. Wet a clean cloth with a suitable solvent such as alcohol and thoroughly clean the impeller insert area and the grooved side of a new ceramic insert. Then wipe the parts with a clean, dry cloth.

   c. Place the adhesive washer in the impeller bond area with the ceramic insert on top. The polished face of the ceramic insert should be visible to the assembler (Fig. 3).

Clamp the ceramic insert and impeller together with a 3/8" bolt and nut and two *smooth* .125" thick washers. Tighten the bolt to 10 Ib-ft (14 Nm) torque.

NOTE: Do not mar the polished surface of the ceramic insert.

IMPORTANT: The face of the ceramic insert must be square with the axis of the tapered bore within .004". The pump shaft may be used as a mandrel for this inspection.

   d. Place the impeller assembly in a level position, with the ceramic insert up, in an oven preheated to 350°F (177°C) for one hour to cure the adhesive.

   e. Remove the impeller from the oven and, after it has cooled to room temperature, install it in the pump. Do not loosen or remove the clamping. Bolt and washers until the assembly cool.

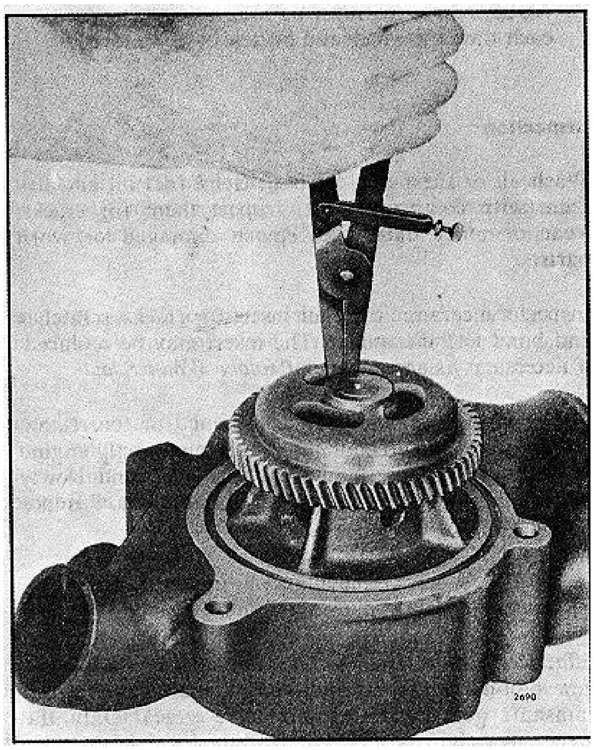


FIG. 4 - Removing Retaining Ring using Tool J 4646

6. Make sure the mating Surfaces of the water seal and the ceramic insert (Fig. 6) are free of dirt, metal particles and oil film.

7. Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.

8. Place the impeller and washer on the shaft and start a new lock nut on the shaft. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the lock nut. Tighten the nut to 45-50 lb-ft (61-68 Nm) torque.

9. Loosen the clamps and remove the hose from the water outlet opening of the pump.

10. Insert a feeler gage into the water outlet opening of the pump. The minimum clearance between the impeller and the pump body must be .015".

11. Use a new gasket and install the water pump cover. Tighten the nuts or bolts securely.

> **NOTE**: When the water pump cover is secured by cadmium plated bolts with nylon inserts, inspect them carefully to make sure the nylon inserts are in place and protrude sufficiently beyond the threads to prevent leakage. *Under no circumstances should a standard bolt be used.* The high-capacity pump cover is secured by a retaining ring.

12. Install and secure the hose on the water outlet opening with the clamps.

Remove Pump

1. Refer to Section 5 and drain the cooling system.

2. Remove the radiator, fan shroud and fan, if necessary.

3. Loosen the hose clamps and remove the hoses from the pump body.

4. Remove the pump body-to-engine front cover mounting bolts and detach the pump. Use care to prevent damage to the gear teeth when disengaging the pump gear from the front camshaft gear (water pump drive gear).

Disassemble Pump

1. Turn the pump gear so the slot is over the ends of the bearing retaining ring, insert pliers J 4646 into the slot and, with the aid of a small screw driver, remove the ring from the groove (Fig. 4).

2. Remove the pump cover and gasket.

3. Hold the gear securely and remove the impeller lock nut and washer.

> **NOTE:** While holding the gear, use care to prevent damage to the gear teeth.

4. Use puller J 24420 to remove the impeller.

5. Press the shaft, bearings and pump gear assembly out of the pump body.

6. Place the gear on the bed of an arbor press with the shaft extending downward, then place a short piece of .625 " diameter bar stock between the shaft and the ram of the press and press the shaft out of the gear as shown in Fig. 5.

7. Support the shaft assembly on the inner race of the larger bearing with the threaded end down. Place flat stock between the ram of the press and the shaft and press the pump shaft out of the large bearing.

8. Invert the shaft, support it on the inner race of the small bearing and repeat the process described in Step 7.

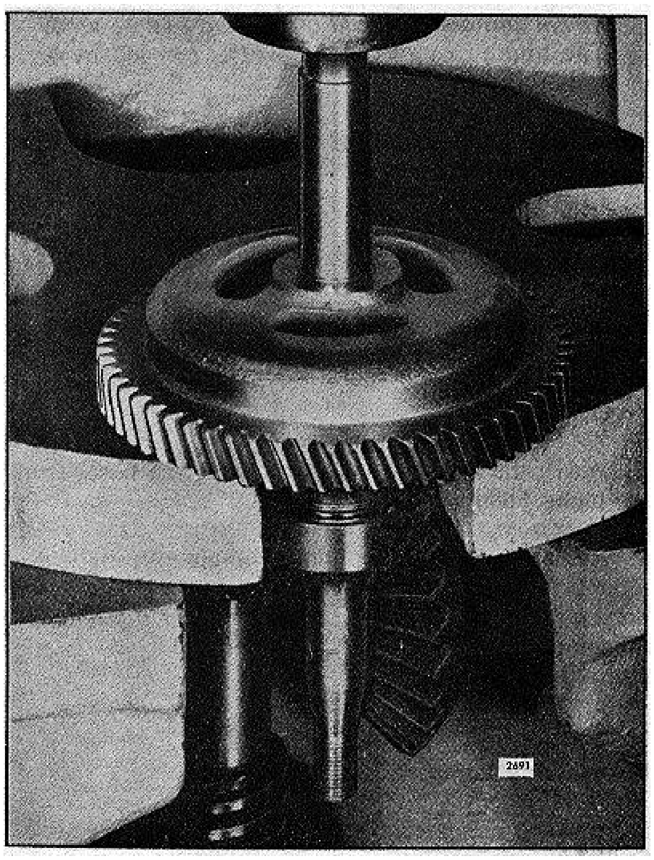


FIG. 5 - Pressing Shaft Out of Gear

9. If necessary, remove the water seal as described under *Replace Water Seal.*

10. Push the oil seal out of the pump body.

NOTE: New seals must be used as replacements each time the water and oil seals are removed.

Inspection

Wash all of the pump parts in clean fuel oil and dry them with compressed air. Inspect them for cracks, wear or other damage.. Replace damaged or worn parts.

Inspect the ceramic impeller insert for cracks, scratches and bond to the impeller. The insert may be replaced, if necessary, as noted under *Replace Water Seal.*

The bearings should be examined for corrosion, pitting, wear and freedom of movement. Apply engine oil to the bearings, hold the inner race and slowly revolve the outer race to check for roughness. Replace the. bearings, if necessary.

NOTE: When replacing an inner or outer bearing always replace the other bearing.

Effective with engine serial number 8VA-1 15016, a new bolt-on balance weight is attached to the front camshaft gear (water pump drive gear). Only the current weight is serviced for either the trunk type or the cross-head type piston 8V engines. The current weight must be used with the cross-head piston engines.

Assemble Pump

1. Lubricate the bearing bores and shaft bearing surfaces. Use bearing and gear installer J 25257 and install the bearings on the shaft (Fig. 8).

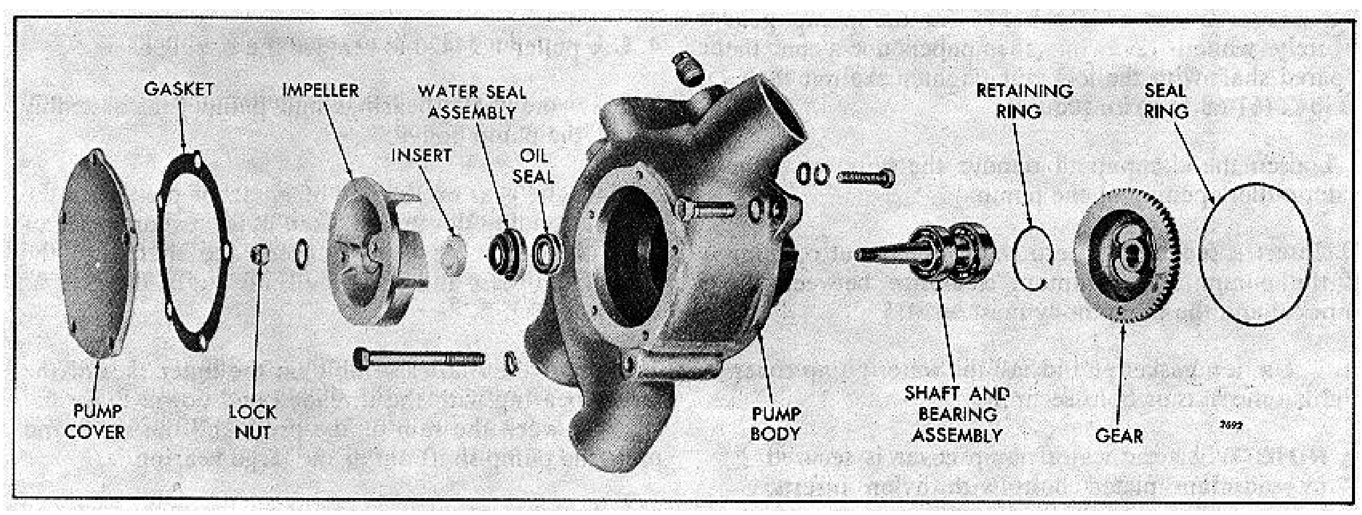


FIG. 6 - Water Pump Details and Relative Location of Parts

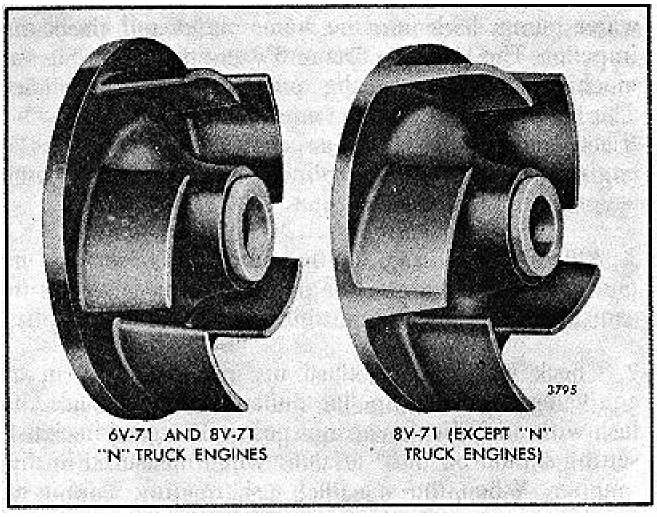


FIG. 7 Comparison of 6V and 8V Engine Water Pump Impeller Assemblies

> **NOTE**: Apply pressure to the inner races of the bearings only during assembly on the shaft.

2. Support the pump body on the bed of' an arbor press with the cover side down. Then press the shaft

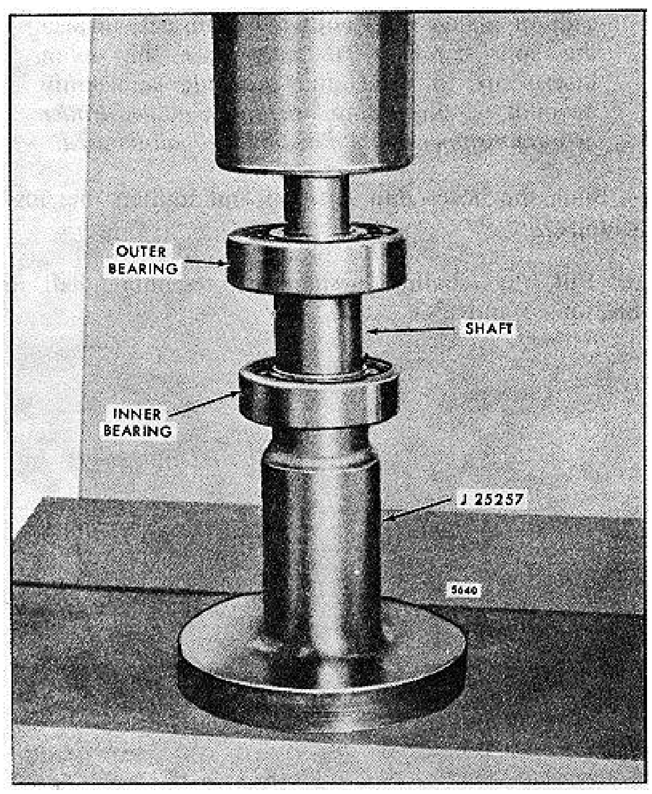


FIG. 8 - Pressing bearing on Hump Shaft using Tool J 25257

and bearing assembly in place by applying pressure on the outer race of the large bearing.

> **NOTE:** Support the pump body so the studs (if used) do not rest on the bed of the arbor press.

3. Install the bearing retaining ring.

4. With gear installer J 25257 (Fig. 9) positioned on the impeller end of the shaft, place the gear between the shaft and the ram of the press. Press the gear on the shaft so it is flush with the end of the shaft.

> **NOTE:** Tool J 25257 will hold the shaft vertically to ensure the gear is pressed squarely on the shaft.

5. Apply a film of engine oil to the sealing lip of the oil seal and the lip contact surface of the shaft. Then insert the seal into the pump body. With a suitable sleeve, tap the seal into place.

> **NOTE:** The oil seal must be flush with the water seal counterbore in the pump body.

6. Place the pump body on the bed of an arbor press. To reduce possible coolant leakage, apply a light coat of non-hardening sealant on the outside diameter of a new water seal. Then insert the seal in the cavity in the pump body and, with a sleeve large enough to fit around the seal and resting on the brass cartridge lip, press the seal into place.

7. Make sure the mating surfaces of the water seal and the ceramic insert are free of dirt, metal particles and oil film.

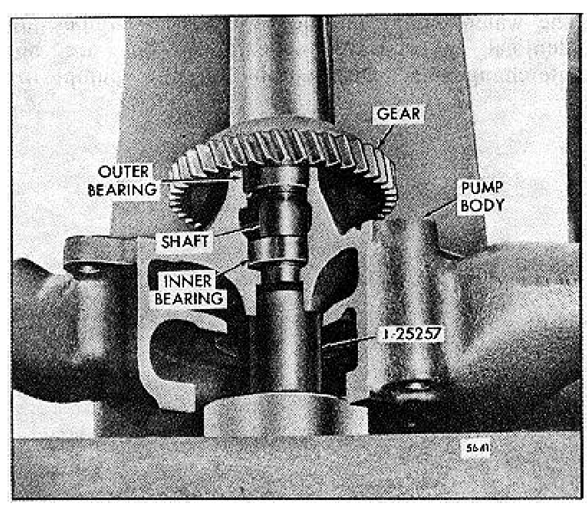


FIG. 9 Pressing Gear on 6V and 8V Pump Shaft using Tool J 25257

8. Apply a small quantity of International Compound No. 2, or equivalent, to the threads of the pump shaft.

9. Place the impeller washer and new lock nut on the shaft. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the lock nut. Tighten the nut to 45-50 lb-ft (61-68 Nm) torque.

> **NOTE**: Do not damage the gear teeth while holding the gear.

> **IMPORTANT:** The water pump impellers for the 6V and 8V engines are not interchangeable. However, beginning with engine 8VA-18256, Model 7087-7043 and engine 8VA-18197, Model 7087-7041, all 8VN truck engines use the same water pump as the 6V engines. The impeller used in an 8V engine water pump (prior to the above truck models) may be identified by the fl.t machined surface on the outer ends of the impeller blades (Fig. 7).

> **NOTE:** The impeller on some 12V engine water pumps has a smaller diameter and is not interchangeable with the standard large diameter impeller.

10. Insert a feeler gage into the water outlet opening of the pump. The clearance between the impeller Rod the pump body must be .015” minimum.

11. Install the hose on the water outlet opening and secure it with clamps.

Install Pump on Engine

The water pumps on the 6V and 8V engines are identical in outward appearance, but are not interchangeable. Disassembly of the pump for identification is not necessary. Before installing a water pump, look into the water outlet and check the impeller. The impeller for an 8V engine pump has flat machined surfaces on the outer ends of the blades. The blades on an impeller used in the 6V and 8V "N" truck engines has the cast ends (Fig. 7). The 12V engines with two valve cylinder heads use the same water pump as the 8V engines.

1. Affix the seal ring to the pump body. Mount the pump on the engine so the pump gear meshes with the camshaft gear. Install and tighten the mounting bolts.

2. Check the gear backlash by installing a bolt, or equivalent, in the impeller puller holes. Measure the lash with an indicator at that point. The gear backlash setting should be .001” to .006" when measured in this manner. When the specified lash reading cannot be obtained, loosen the pump attaching bolts and pivot the pump at the dowel as required to obtain the proper lash adjustment. Retighten the mounting bolts.

3. Use a new gasket and install the pump cover. Tighten the bolts or nuts securely.

> **NOTE:** The current water pump cover has the word *out* stamped on the outside for proper assembly.

> **IMPORTANT:** When the cover is secured by cadium plated bolts with nylon inserts, inspect the bolts carefully to make sure the nylon inserts are in place and protrude sufficiently beyond the threads to prevent leakage. *Under no circumstances should a standard bolt be used.*

4. Slide the hoses into position and tighten the hose clamps.

5. Fill the cooling system as recommended in Sections 5 and 13.3.

HIGH CAPACITY WATER PUMP (8V-71)

The high-capacity water pump used on certain 8V-71 engines provides increased coolant circulation. The pump has a larger impeller larger diameter inlet and outlet openings and a pump cover secured by a retained ring (Fig. 10).

A 32 plate oil cooler core and a camshaft vibration damper are used in conjunction with the high-capacity water pump. The oil cooler housing has a larger diameter waiter inlet. The camshaft vibration damper has a smaller outside diameter to provide clearance between the damper and the larger water pump body.

The disassembly and assembly procedures for the high-capacity pump are the same as for the centrifugal-type pump except for removal and installation of the pump cover.

Remove and Install Pump Cover

Remove the pump cover retaining ring (Fig. 10). from the groove in the pump body, with a screw driver.

Remove the pump cover and discard the seal ring. The 1/4 "-20 nut attached to the front cover is provided to facilitate removal of the cover. Use a new seal ring when installing the pump cover.

Install the cover retaining ring by hand. *Tap the cover lightly to be .sure the ring is completely seated in the groove.*

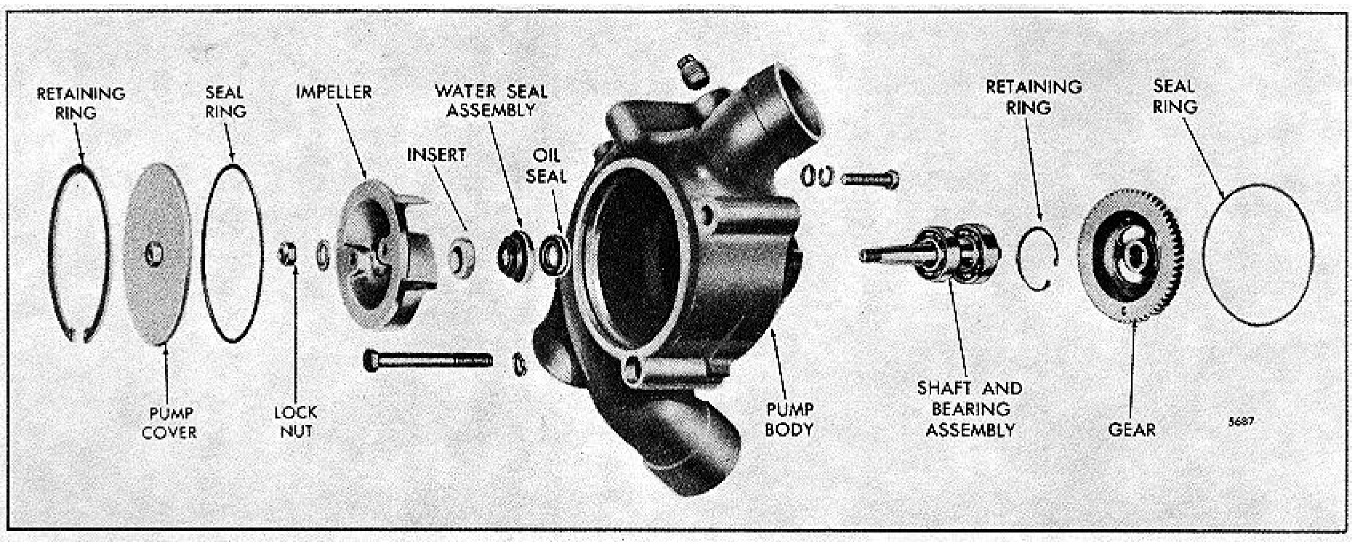


FIG. 10 - High-Capacity Water Pump Details and Relative Location of Parts (8V-71)

The 6 and 8V engines do not require external water manifolds. All 12V (except certain vehicle engines) and 16V engines are equipped with external water manifolds (one per cylinder head).

Coolant leaving the cylinder head through an opening directly over each exhaust port, enters the water manifold which is attached to the cylinder head, with two nuts and lock washers at each of the water openings. A separate gasket is used at each attaching flange between the manifold and cylinder head.

Effective approximately October, 1975 new four leg external water manifolds replaced the former six leg and four leg external water manifolds. The reduction of two legs from the former six leg manifold has no detrimental effect on engine cooling.

> **NOTE**: The number of water access holes are the same or more in the new four leg manifold, however, these access holes may be in a different location because the manifold is shorter.

When replacing a former six leg or a four leg external water manifold it will be necessary to include two plates, two gaskets, and four 3/8"-16 x 1" bolts.

Remove Water Manifold

1. Drain the cooling system, to level necessary, by opening the cylinder block drain cocks.

2. Loosen seal clamp, at the front end of the water manifold. Then, slide the seal over the neck of the thermostat housing or the water manifold.

3. Remove the water manifold stud nuts and lock washers and lift the manifold straight up off of the studs.

4. Remove the water manifold gaskets.

Install Water Manifold

1. Install new water manifold gaskets.

2. Attach the water manifold to the cylinder head with nuts and lock washers. Tighten the nuts to 20-25 lb-ft (27-34 Nm) torque.

3. Slide the seal onto the outlet end of the water manifold and secure the seal with the clamp.

4. Fill the cooling system to the proper level.

The temperature of the engine coolant is automatically controlled by a thermostat located in a housing attached to the water outlet end of each cylinder head. Blocking type thermostats (Fig. 1 or 3) are used when a standard cooling system is employed; semi-blocking type thermostats (Fig. 2) are used with the rapid warm-up cooling system. Two thermostats are employed in 6 and 8V engines; four thermostats are used in the 12V engines.

Operation

At coolant temperatures below 160°-0180°F (71° 82 °C) depending upon the thermostat used - the valves remain closed and block the flow of coolant to the radiator. During this period, all of the coolant in the standard system is circulated through the engine and is directed back to the suction side of the water pump via the by-pass tube. In the rapid warm-up system enough coolant to vent the system is by-passed to the radiator top tank by means of a separate external de-aeration line and then back to the water pump without going through the radiator cores. As the coolant temperature rised above 160 °-180°F (71 - 82 °C), the thermostat valves start to open, restricting the by-pass system, and permit a portion of the coolant to circulate through the radiator. When the coolant temperature reaches approximately 185 - 197°F (85°-92 °C) the thermostat valves are fully open, the by-pass system is completely blocked off and all of the coolant is directed through the radiator.

A defective thermostat which remains closed, or only partially open, will restrict the flow of coolant and cause the engine to overheat. A thermostat which is stuck in a full open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold engine operation will result in excessive carbon deposits on the pistons, rings and valves.

Properly operating thermostats are essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160°-197 °F (71 °-92 °C), the thermostats should be removed and checked.

> **NOTE:** Engines using shutters and equipped with 180°-197°F (82°-92 °C) thermostats may have an effect on the operation of the shutters.

Remove Thermostat

Refer to Fig. 1 and remove the thermostats as follows:

1. Drain the cooling system to the necessary level by opening the drain cocks, or removing the drain plugs on the cylinder block.

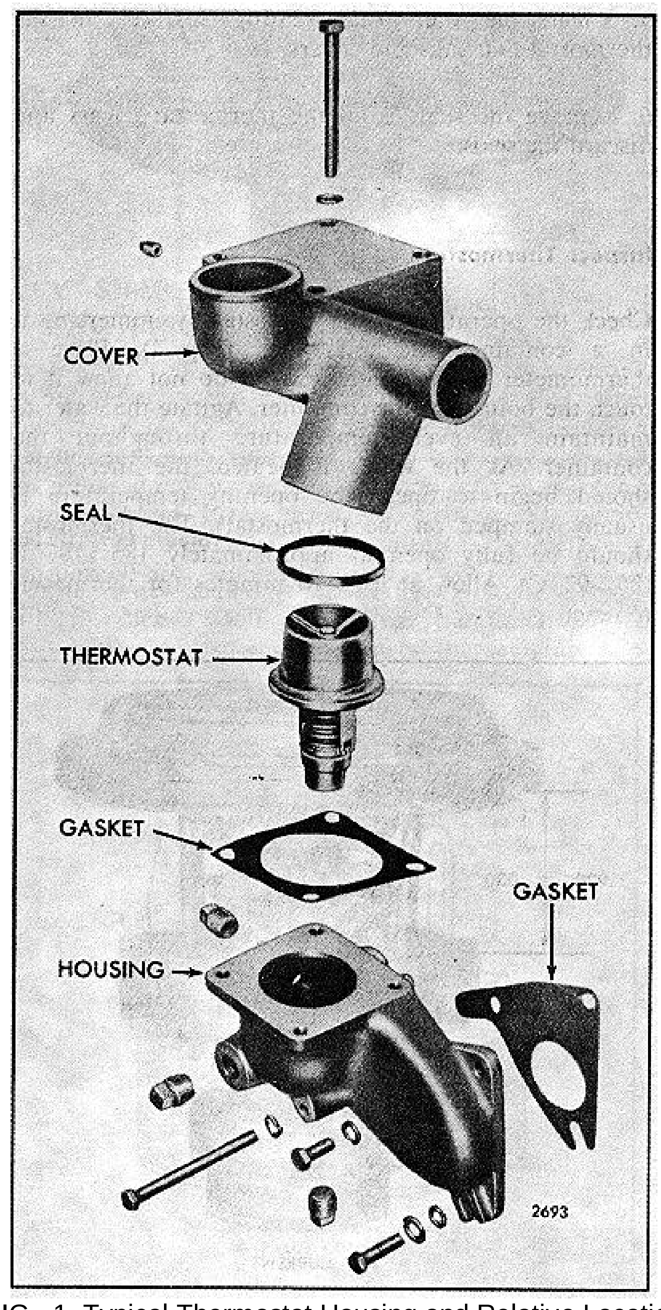


FIG. 1 Typical Thermostat Housing and Relative Location of Parts

2. Loosen the hose connections and remove the by-pass (cross-over) tube. Then loosen the hose connections between the water pump and the right bank thermostat housing cover.

3. Remove the bolts and lock washers securing the covers to the thermostat housings. Then remove the thermostat housing covers and gaskets.

4. Remove the thermostats.

5. Clean the thermostat seating surfaces in the thermostat housings and covers.

6. Remove the seals from the thermostat covers and discard the seals.

Inspect Thermostat

Check the operation of a thermostat by immersing it in a container of hot water (Fig. 4). Place a thermometer in the container, but do not allow it to touch the bottom of the container. Agitate the water to maintain an even temperature throughout the container. As the water is heated. the thermostat should begin to open (the opening temperature is usually stamped on the thermostat). The thermostat should be fully open at approximately 185°-197° F (85 °-92 °C). Allow at least 10 minutes for thermostat to react.

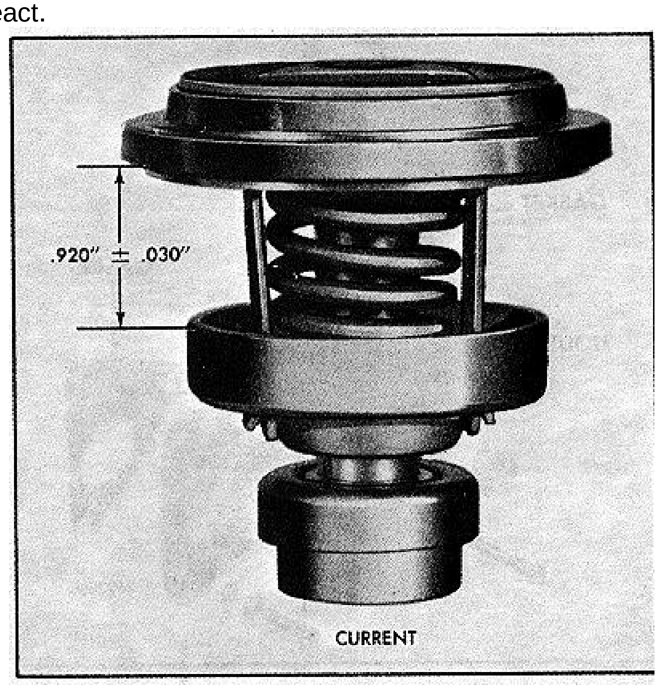


FIG. 2 - Semi-Blocking (Shielded) Type Thermostat

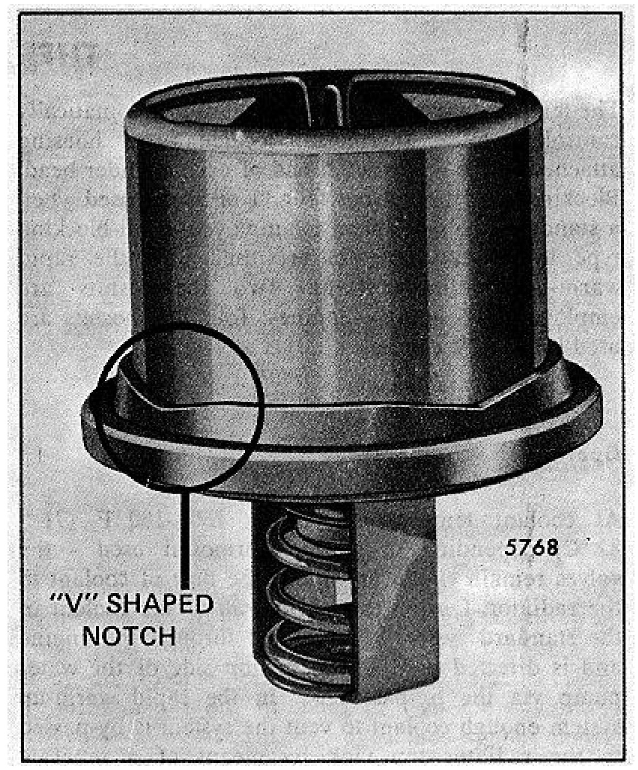


FIG. 3 Weir Type Thermostat

Install Thermostat

1. Install a new seal(s) in the thermostat housing cover with installer J 8550 and driver handle J 7079-2. Position the seal so that the lip of the seal faces up

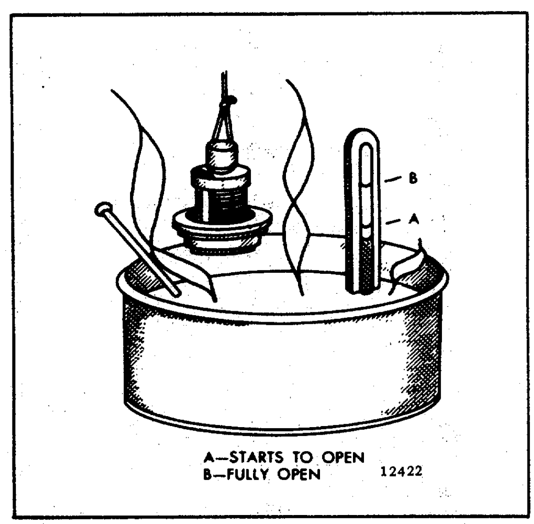


FIG. 4 - Method of Checking Thermostat Operation

(away from the thermostat) when the cover is installed on the thermostat housing. The seal installing tool assures that the seal is positioned the correct distance from the bottom face of the cover and parallel with the cover face.

2. Place a new gasket on the thermostat housing.

3. Set the thermostats in the thermostat housing.

4. Attach the covers to the thermostat housings with bolts and lock washers. Tighten the 3/8 "-16 bolts to 30-35 lb.-ft (41-47 Nm) torque.

5. Slide the hose in place between the water pump and the right bank thermostat housing cover. Tighten the clamps.

6. Install the by-pass (cross-over) tube and tighten the hose clamps.

7. Close the drain cocks in the cylinder block. Then fill the cooling system.

8. Start the engine and check for leaks.

RADIATOR

The temperature of the coolant circulating through the engine is lowered by the action of the radiator and the fan. The radiator is mounted in front of the engine so that the fan will draw air through it, thereby lowering and maintaining the coolant temperature to the degree necessary for efficient engine operation.

The life of the radiator will be considerably prolonged if the coolant used is limited to either clean, soft water and a corrosion inhibitor or a mixture of water and a high boiling point type antifreeze. The use of any other type antifreeze is not recommended.

To increase the cooling efficiency of the radiator, a metal shroud is placed around the fan. The fan shroud must be fitted airtight against the radiator to prevent recirculation of the hot air drawn through the radiator. Hot air which is permitted to pass around the sides or bottom of the radiator and is again drawn through the radiator will cause overheating of the engine.

Another cause of overheating is slippage of the fan drive belts which is caused by incorrect belt tension, worn belts or worn fan belt pulley grooves, or the use of fan belts of unequal length when two or more belts are used. The belt tension and condition of the belts should be checked periodically as outlined in Section 15.1.

A radiator that has a dirty, obstructed core or is leaking, a leak in the cooling system, or an inoperative thermostat will also cause the engine to overheat. The radiator must be cleaned; the leaks eliminated, and defective thermostats replaced immediately to prevent serious damage from overheating. The external cleanliness of the radiator should be checked if the engine overheats and no other causes are apparent.

Cleaning Radiator

The radiator should be cleaned whenever the foreign deposits are sufficient to hinder the flow of air or the transfer of heat to the air. In a hot, dusty area, periodic cleaning of the radiator will prevent a decrease in efficiency and add life to the engine.

The fan shroud and grille should be removed, if possible, to facilitate cleaning of the radiator core.

An air hose with a suitable nozzle is often sufficient to remove loose dust from the radiator core. Occasionally, however, oil may be present requiring the use of a solvent, such as mineral spirits, to loosen the dirt. The use of gasoline, kerosene, or fuel oil is NOT recommended as a solvent. A spray gun is an effective means of applying the solvent to the radiator core. Use air to remove the remaining dirt. Repeat this process as many times as necessary, then rinse the radiator with clean water and dry it with air.

NOTE: Provide adequate ventilation of the working area to avoid possible toxic effects of the cleaning spray.

Another method of cleaning the radiator is the use of steam or a steam cleaning device, if available. If the foreign deposits are hardened, it may be necessary to apply solvents.

The scale deposit inside the radiator is a result of using hard, high mineral content water in the cooling system. The effect of heat on the minerals in the water causes the formation of scale, or hard coating, on metal surfaces within the radiator, thereby reducing the transfer of heat. Some hard water, instead of forming scale, will produce a silt-like deposit which restricts the flow of water. This must be flushed out at least twice a year -- more often if necessary.

To remove the hardened scale, a direct chemical action is necessary. A flushing compound such as .sal-ammoniac, at the specified rate of 1/4 pound per each gallon of radiator capacity, should be added to the coolant water in the form of a dissolved solution while the engine is running. Operate the engine for at least 15 minutes,-then drain and flush the system with clean water.

Other flushing compounds are commercially available and should be procured from a reliable source. Most compounds attack metals and should not remain in the engine for more than a few minutes. A neutralizer should be used in the cooling system immediately after a de-scaling solvent is used.

For extremely hard, stubborn coatings, such as lime scale, it may be necessary to use a stronger solution. The corrosive action of a stronger solution will affect the thin metals of the radiator, thereby reducing its operating life. A complete flushing and rinsing is mandatory and must be accomplished skillfully.

After the solvent and neutralizer have been used and the cooling system is flushed, completely drain the entire system again and fill it with clean, soft water plus a rust inhibitor or high boiling point type antifreeze. After filling the cooling system, inspect the radiator and engine for water leaks.

NOTE: When draining or filling, the cooling system must be vented.

After the radiator core has been thoroughly cleaned and dried, reinstall the fan shroud and grille, if removed.

Remove Radiator

1. Remove the radiator filler cap and open the drain cock to drain the cooling system. Also open the drain cock on the oil cooler and the engine block.

2. Remove the bolts, lock washers and nuts which attach the fan guards to the fan shroud.

3. Loosen the hose clamps at the radiator inlet hose and remove the hose.

4. Loosen the hose clamps at the radiator outlet hose and remove the hose.

5. Use a chain hoist and a suitable lifting device (through the filler neck or otherwise) and draw the hoisting chain taut to steady the radiator.

6. Remove the bolts, lock washers, plain washers, nuts and bevel washers (if used) which attach the radiator shell to the engine base.

NOTE: Since the shroud is very close to the tips of the fan blades, to prevent damage to these, parts great care must be exercised whenever the radiator is removed.

7. Lift the radiator enough to clear the engine base and move it directly away from the engine.

8. Remove the fan shroud and the radiator core by removing the bolts securing them in place.

Inspection

Clean all radiator parts thoroughly, removing dirt, scale and other deposits. Examine the radiator for cracks or other damage. The core fins should be straight and evenly spaced to permit a full flow of cooling air. The core tubes should be clean inside and outside and have no leaks. If repainting the radiator core becomes necessary, it is recommended that a thin coat of du]] black radiator paint or another high quality flat black paint be used. Ordinary oil paints have an undesirable glossy finish and do-not transmit heat as well. Check all radiator hoses and clamps. Replace cracked and deteriorated hoses and damaged clamps.

Install Radiator

Assemble the radiator, grill and shroud. Then mount the assembly on the engine base by reversing the procedure given for removal.

Check for clearance between the tips of the fan blades and radiator shroud after the radiator is in place. There must be sufficient clearance or damage to the fan and shroud will result when the engine is started. Use shims between the radiator and base. if necessary to obtain the proper clearance.

CROSS-FLOW DESIGN RADIATOR

Certain on-highway vehicle engines incorporate a cooling system radiator of a cross-flow design rather than the conventional down-flow design.

As the name implies, a cross-flow radiator has a core of horizontally positioned tubes and coolant flow moves across rather than down the radiator. Two reasons for using the cross-flow design radiator are:

1. The reduced height of the radiator permits a lower hood line design, thus providing better road visibility.

2. The area ahead of the engine crankshaft and below the radiator is open for mounting a -power takeoff unit, if desired.

The intent here is to describe briefly how the cross-flow radiator functions and to identify some of the components unique in the cross-flow system.

One such component is a Y-shaped device called an aspirator (Fig. 1) which is mounted externally on the filler cap side of the radiator and serves to rid the cooling system of air. The aspirator directs coolant under pressure through a venturi where entrapped air inside the radiator is picked up and moved to the supply chamber of the radiator where it is vented. The coolant line providing the drive flow originates at the engine thermostat housing. This hookup provides a flow of coolant to the aspirator regardless of whether the thermostat is open or closed. As the coolant flow passes through the aspirator, its action pulls coolant and any air that is present from the top of the radiator core outlet chamber into an internal "U" tube which vents near the filler cap inside the radiator supply chamber to complete the deaeration process. This "U" tube insures that the entire cooling circuit, other than the supply chamber, remains completely full when the engine is stopped. Also, it keeps the coolant from seeking a common level throughout the system and, thereby, eliminates an aerated system at the next engine start-up.

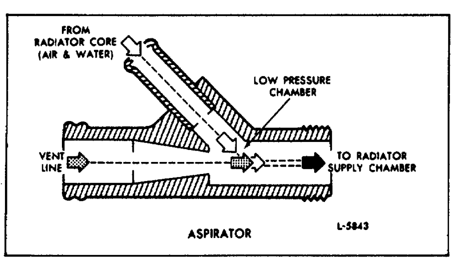


FIG. 1. Aspirator for Cross-Flow Design Radiator

The cross-flow system (Fig. 2) requires a bypass restriction to provide sufficient pressure in the system for adequate engine deaeration and aspirator performance.

Properly installed hose connections are required for adequate cross-flow radiator efficiency.

The cross-flow cooling system should always be drained at the radiator drain cock. This will insure that both the radiator and internal "U" tube is empty. If the "U" tube is not emptied, refilling the system will prove difficult.

Due to the design of the cross-flow radiator, air may be trapped inside of the radiator during the fill process resulting in a false coolant level reading. Therefore, after filling the cooling system, the engine should be run for approximately 10 minutes at 1200-1400 rpm so that any entrapped air can be vented. Generally, additional coolant (approximately 3 to 4 quarts or 2.8 to 3.8 liters) will be required to bring the coolant to the proper level.

For efficient operation of the cross-flow radiator system, it is important that no leak exists between the radiator core and the supply tank. If an internal leak has developed between the radiator core and the supply tank it can cause the cooling system to become

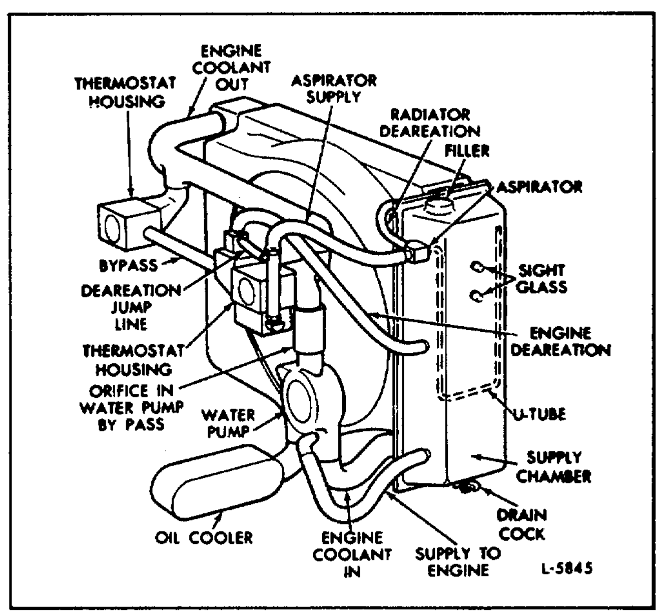


FIG. 2. Cross-Flow Design Radiator

aerated at low RPM and following engine shut down. The radiator should be tested periodically for possible internal leaks. The procedure to determine if a leak is present is as follows:

1. Remove the radiator cap and run the engine for approximately 10 minutes at high idle to completely deaerate the cooling system. While the engine is running, add additional coolant to the supply chamber to bring the coolant level to the bottom of the filler neck.

2. Stop the engine and drain 4 quarts (3.8 liters) of coolant from the radiator.

3. Start and run the engine at high idle for approximately 10 minutes and observe the coolant level.

4. Stop the engine and again observe the coolant level. If the coolant *rises* substan4ialJy in the supply tank, an internal leak is present and immediate corrective action should be taken to repair the leak. If the coolant level remains constant or falls, the system is satisfactory.

5. After the test is completed, refill the cooling system to the proper coolant level.

If the leak situation is not corrected, the engine will be operating with an aerated coolant for abnormal periods of time which could lead to an engine failure.

COOLANT PRESSURE CONTROL CAP

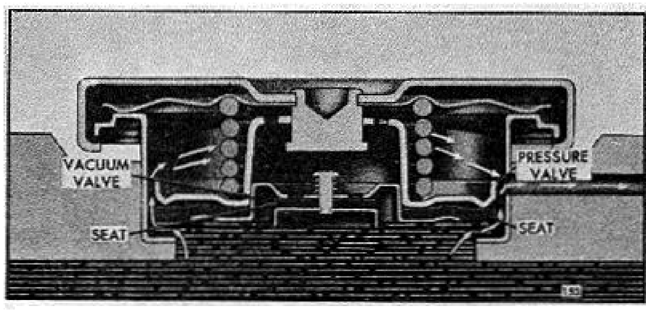


FIG. 1. Pressure Control Cap (Pressure Valve Open)

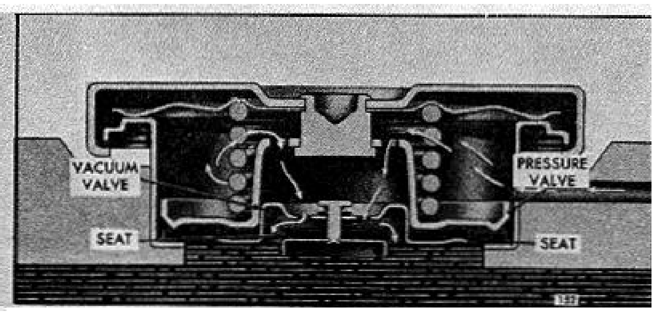


FIG. 2. Pressure Control Cap (Vacuum Valve Open)

The radiator has a pressure control cap with a normally closed valve. The cap, -with a number 7 stamped on its top, is designed to permit a pressure of approximately seven pounds in the system before the valve opens. This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools.

CAUTION: Use extreme care when removing the coolant pressure control cap. Remove the cap *slowly* after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

To ensure against possible damage to the cooling system from either excessive pressure or vacuum, check both valves periodically for proper opening and closing pressures. If the pressure valve does not open between 6.25 psi (43.1 kPa) and 7.5 psi (51.7 kPa) or the vacuum valve does not open at .625 psi (4.3 kPa) (differential pressure), replace the pressure control cap.

ENGINE COOLING FAN

The engine cooling fan is belt driven from the crankshaft pulley.

The three-groove pulley hub (Fig. 1) turns on a double-row ball bearing at the front and a single-row (shielded) ball bearing at the rear of the hub. A new three-groove pulley hub turns on a front ball bearing and a rear roller bearing and also includes a hub cap (with relief valve), adjust cap and a grease fitting (Fig. 2). On compact front end engines, the pulley hub turns on tapered roller bearings (Fig. 3).

Spacers (individually or in combination) provide a means for setting the proper clearance between the back of the fan blades and front groove of the crankshaft pulley.

Lubrication

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to Section 15.1 for the maintenance schedule.

Fan Belt Adjustment

Adjust the belt(s) periodically as outlined in Section 15.1.

Remove Fan Hub and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

1. Remove the belt and fan guards.

2. Remove the attaching bolts, lock washers and nuts, then remove the fan and spacer (if used).

> **NOTE:** If insufficient clearance exists between the fan and radiator, remove the fan, hub and adjusting bracket as an assembly.

3. Loosen the fan hub adjusting bracket bolts and remove the drive belts. Then withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

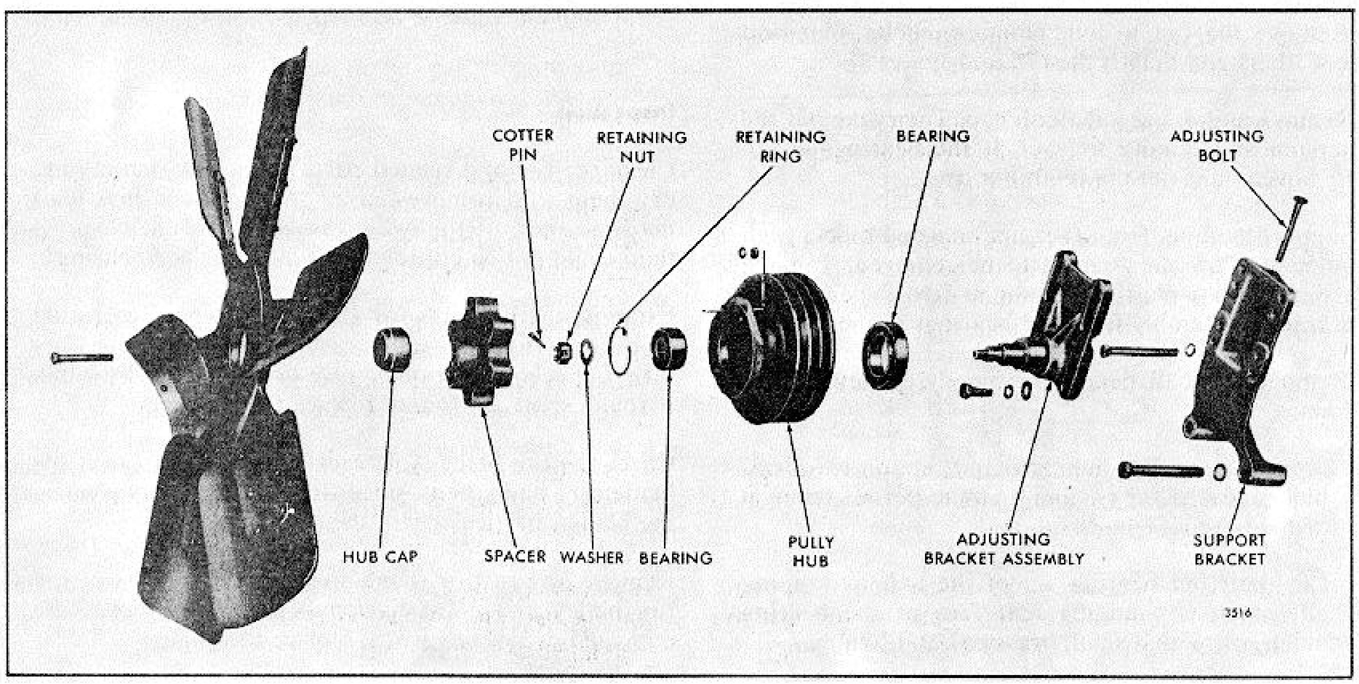


FIG. 1 Typical Fan, Three Groove Pulley Hub and Adjusting Bracket Details and Relative Location of Parts

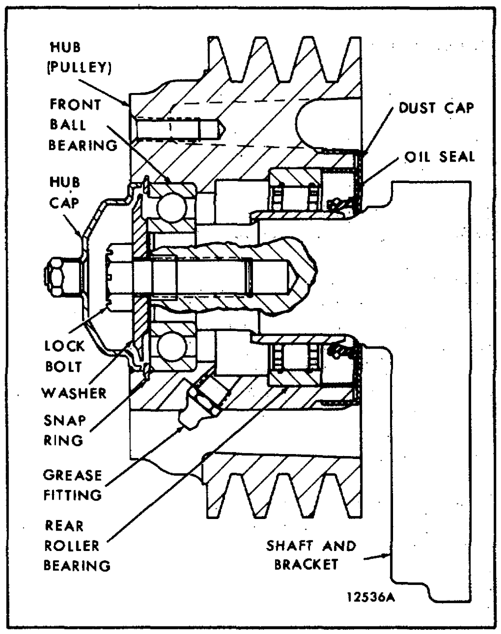


FIG. 2 - Three Groove Pulley Hub (Current)

Disassemble Fan, Three-groove Pulley Hub and Bracket (Fig. 1 and 2)

1. Remove the fan to hub mounting bolts, nuts and lock washers and detach the fan and spacer.

2. Remove and discard the hub cap. Then take out the cotter pin and remove the nut. If the bearings are to be removed, take out the retaining ring.

3. Support the hub, front face up, on wood blocks high enough to allow the bracket to be removed. Tap the fan shaft with a plastic hammer to free the fan shaft and bracket assembly from the bearings in the hub.

4. Remove the ball bearings from the pulley hub as follows:

a. Support the pulley hub, rear face up, on two wood blocks spaced far enough apart to permit removal of the bearing from the hub.

b. Tap the front bearing out of the hub by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.

c. Reverse the pulley hub on the wood blocks and remove the rear bearing from the hub in the same manner.

Disassemble Fan, Hub and Bracket (Compact Front End--Fig. 3)

1. Remove the fan to hub mounting bolts. nuts and lock washers and detach the fan and spacer.

2. Remove and discard the hub cap, then remove the pulley retaining bolt and retainer.

3. Support the pulley hub, front face up, on wood blocks high enough to allow the adjusting bracket assembly to be removed. Tap the shaft with a plastic hammer to free the adjusting bracket assembly from the bearings in the pulley hub.

4. Remove the bearings and oil seal as follows:

a. Remove the inner race from the front (outer) bearing.

b. Remove the shims and bearing spacer.

c. Tap the outer race of the front {outer) bearing out of the pulley hub by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.

d. Reverse the pulley hub and drive the oil seal from the hub. Discard the oil seal.

e. Remove the rear (inner) bearing in the same manner as outlined in Items a and c.

f. Remove the grease retainer from the pulley hub.

Inspection

Clean the fan and related parts with clean fuel oil and dry them with compressed air. *Shielded bearings must not be washed;* dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing.

Examine the bearings for any indications of corrosion or pitting. Hold the inner race or cone so it does not turn and revolve the outer race or cup slowly by hand. If rough spots are found, replace the bearings.

Check the fan blades for cracks. Replace the fan if the blades are badly bent since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

Examine and measure the fan hub shaft front and rear journals (industrial engines). The front journal diameter of a new shaft is .7866" - .7871" and the rear

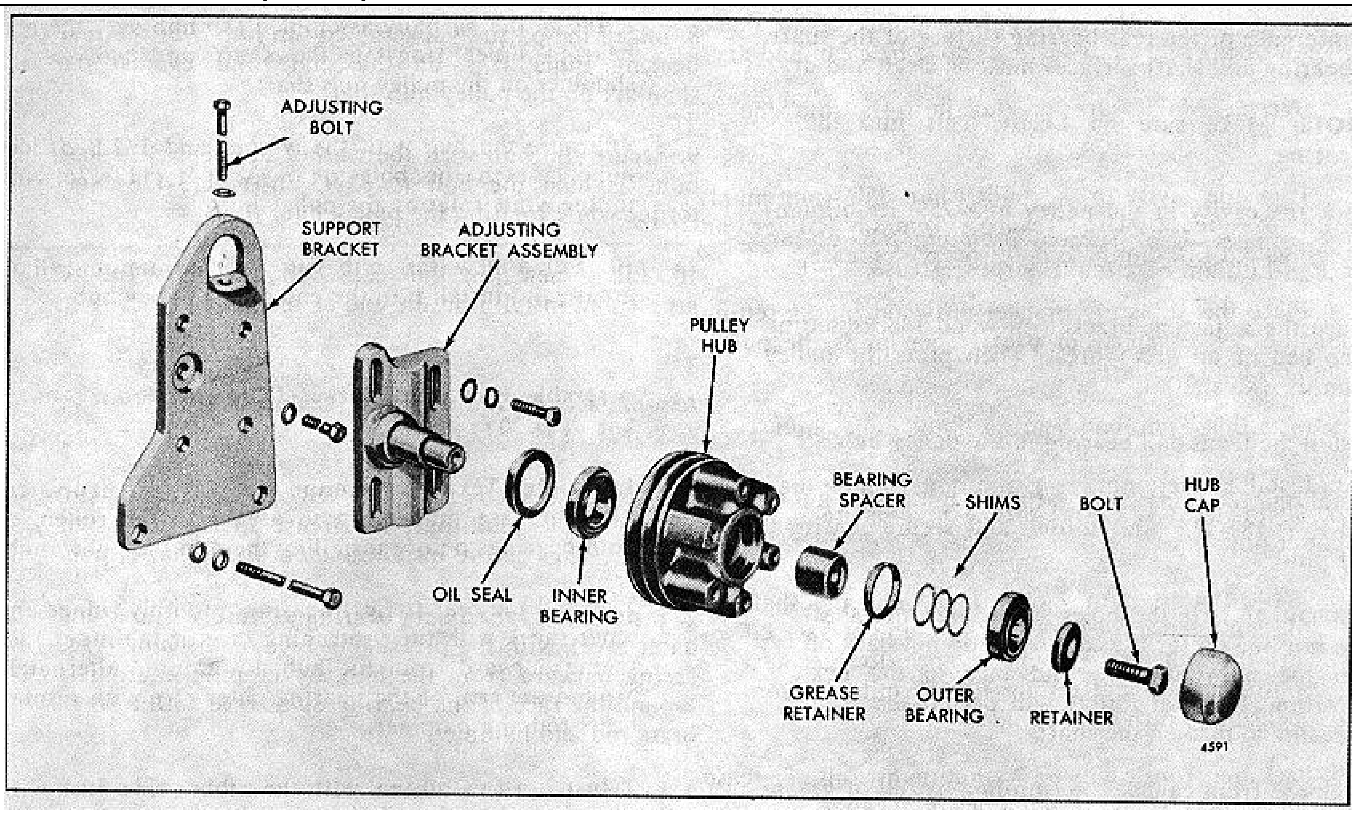


FIG. 3 - Fan Pulley, Hub and Adjusting Bracket Details for compact Front End Engines.

journal is 1.7705" - 1.7713". If the journals are worn excessively, replace the fan shaft.

Look for cracks in the adjusting and support bracket castings. When replacement of either the fan shaft or adjusting bracket is necessary, a new fan shaft and bracket assembly must be used.

The current fan shaft rear bearing inner race should be inspected for any measureable wear. Replace the inner race if the outer diameter is less than 1.7297" or 2.6333" (Heavy Duty).

> **NOTE:** The inner and outer races are only serviced as a rear roller bearing assembly.

When installing the rear bearing inner race, press it on the shaft and position it 1.92 " to 1.94 " or 2.31 to 2.33 " (Heavy Duty) from the end of the shaft.

New .500" thick and .800" thick fan hub spacers and a new fan hub cap replace the former spacer and cap assemblies to provide spacers compatible with the six bolt hole mounting fan hub assemblies. The spacers (individually or in combination) also provide a means for setting the different clearances between the back of the fan blades and front groove of the crankshaft pulley.

The spacers have a flange on one side that serves as a pilot for the fan as well as a spacer pilot for the second spacer when two or more spacers are used together.

> **EXAMPLE: A** former 1.800" thick spacer and cap assembly have been replaced by two .500" thick spacers, one .800" thick spacer and the new fan hub cap.

When replacing the former fan hub spacer. be sure and include the new cap.

Fan hubs equipped with roller bearings may be modified by adding a grease fitting (refer to Section 5.0).

Assemble Three Groove Hub and Bracket (Fig. 1)-Former

1. Install the rear ball bearing in the pulley hub.

SERVICE NOTE: When rebuilding a three groove pulley fan hub assembly for any reason, add the new hardened washer under the retaining nut.

2. To prevent the possibility of the inner bearing race spinning on the shaft, apply a small quantity of Loctite No. RC601, or equivalent, to the full

circumference of the rear bearing surface of the shaft. The bearing and shaft surfaces must be clean and dry.

NOTE: Make sure no Loctite gets into the bearing.

3. Pack the cavity in the pulley hub 75% (minimum) full of grease. Use Texaco Premium RB or an equivalent Lithium base multi-purpose grease.

4. Place the adjusting bracket on wood blocks setting on the bed of an arbor press. Then press the pulley hub on the fan shaft.

5. Install the front ball bearing in the pulley hub.

6. Install the retaining ring and nut. Tighten the nut to 60-90 lb.-ft (81-122 Nm) torque and secure it with a cotter pin.

IMPORTANT: If the holes in the nut and shaft do not line up for the cotter pin, do not back off on the nut but rather advance to the next position. Low nut torque will permit the front bearing to turn on the shaft.

7. Pack the front cavity 75% (minimum) full of grease (refer to Step 3) and install a new hub cap.

Assemble Three Groove Hub and Bracket (Fig. 2)-Current

1. Apply Texaco Premium RB grease or an equivalent Lithium base multi-purpose grease to the front ball bearing and the rollers of the rear bearing, before installing them in the pulley hub.

NOTE: Do not overgrease.

2. Install the front bail bearing against the shoulder counterbore in the pulley hub. Then install the snap ring in the pulley hub.

3. Install the rear roller bearing outer ring and roller assembly against the shoulder in the counterbore of the pulley hub.

4. Install a new oil seal with rubber side flush with the outer edge of the hub.

5. Install the dust cap (if used) over the oil seal in the hub.

6. Place the shaft and bracket on wood blocks setting on the bed of an arbor press. Then press the rear bearing inner ring or race onto the fan shaft.

7. Pack the cavity in the hub 75% minimum full with Texaco Premium RB grease.

8. Install the partially assembled fan hub over the rear bearing inner ring on the shaft and against the shoulder on the pulley hub shaft.

9. Secure the hub with the washer and 1/2"-20 lock bolt. Tighten the bolt to 83-93 lb.-ft (I 13-126 Nm) torque while rotating the pulley hub.

10. Fill a new fan hub cap 75% minimum full of grease and install it in the end of the pulley hub.

Assemble Hub and Bracket (Compact Front End--Fig. 3)

1. Apply Texaco Premium RB or an equivalent Lithium base multi-purpose grease to the rollers of both bearings before installing them in the pulley hub.

2. Install the rear (inner) bearing assembly (inner and outer race), with the protruding face of the inner race facing outward from the hub, by tapping alternately around the face of the bearing outer race with a small brass rod and hammer.

3. Install a new oil seal with the rubber side flush with the outer edge of the hub.

4. Place the adjusting bracket assembly on wood blocks setting on the bed of an arbor press. Then press the pulley hub on the fan shaft and install the bearing spacer.

5. Pack the cavity between the bearings 20-30% full with the type of grease as outlined in Step 1 and install the grease retainer.

NOTE: The grease retainer is not required when a grease fitting is installed in the pulley hub (refer to Section 5.0).

6. Place the shims against the bearing spacer. Then install the front (outer) bearing assembly (inner and outer race), with the protruding face of the inner race facing outward from the hub. as mentioned in Item 2.

7. Secure the hub with the retainer and bolt. Tighten the 1/2 "-20 bolt to 83-93 lb.-ft (I 13-126 Nm) torque while rotating the pulley.

8. Rotate the assembly and check the end play with the spindle (shaft) in a horizontal position. The end play must be within .001 " to .006 ". If necessary, remove the bolt, washer and front (outer) bearing and adjust the number and thickness of shims .to obtain the required end play. Shims are available in .015" .020" and .025" thickness. Then reassemble the fan hub and check the end play.

9. Fill a new fan hub cap 75% (minimum) full of grease and install it in the end of the fan hub (pulley).

Install Fan, Hub and Bracket

1. Secure the fan and spacer to the pulley hub with the six bolts, nuts and lock washers. Tighten the nuts to 15-19 lb.-ft (20-26 Nm) torque.

2. Place the fan belt(s) on the pulley.

3. Position the fan, hub and adjusting bracket against the support bracket and install the bolts finger tight in the support.

NOTE: The new bolts differ from the former in that their effective lengths in inches are indicated in 1/4" high raised numbers on the bolt heads. This makes them easier to identify than the former bolts which had to be measured. Some of the new bolts are also longer than the bolts they replace.

4. Adjust the bracket to provide the proper tension on the fan belts (refer to Section 15.1). Tighten the bracket and bracket adjusting bolts.

THERMO-MODULATED FAN

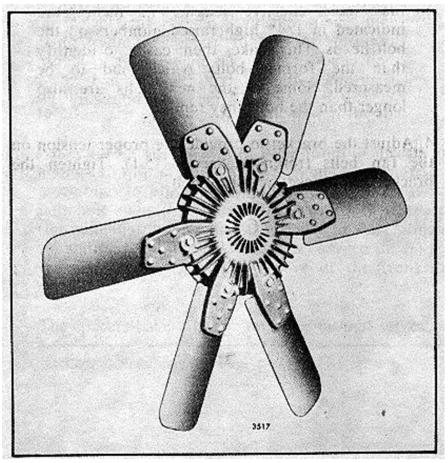


FIG. 4 - Typical Thermo-Modulated Fan Assembly

A thermo-modulated suction fan assembly has been provided on some engines (Fig. 4).

This fan assembly is designed to regulate the fan speed and maintain an efficient engine coolant temperature regardless of the variations in the engine load or outside air temperature.

The entire fan drive assembly is a compact integral unit (Fig. 5) which requires no external piping or controls and operates on a simple principle. This principle consists of transmitting torque from the input shaft to the fan by the shearing of a silicon fluid film between the input and output plates in a sealed multiplate, fluid filled clutch housing.

The thermostatic control element, which is an integral part of the fan drive, reacts to changes in engine temperature and varies the fluid film thickness between the plates and thereby changes the fan speed. Proper selection of the control element setting is determined by the vehicle manufacturer to maintain optimum cooling and no further adjustment should be necessary.

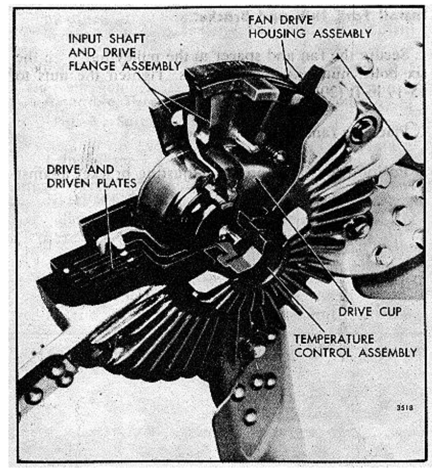


FIG. 5 - Typical Thermo-Modulated Fan Drive Assembly

The thermo-modulated fan is mounted and driven by the engine in the same manner as the conventional fan.

Lubrication

The fan drive assembly is prelubricated by the manufacturer. However, the drive fluid level and the roller bearing should be checked periodically (refer to Section 15.1).

Adjust Fan Belt

The adjustment of the fan belt tension is the same as on the conventional type fans.

Remove and Install Fan and Drive Assembly

The fan blades and fan drive may be taken off by removing the four shaft to pulley mounting bolts, and installed by reversing this procedure.

COOLANT FILTER CONDITIONER

The engine cooling system filter and conditioner is a compact bypass type unit with a replaceable canister type element (Fig. 1), a spin-on type element (Fig. 2) or a clamp-on type element (Fig. 3).

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid-free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system (refer -to Section 13.3). The other components of the element perform the function of cleaning and preparing the cooling passages while the corrosion inhibitors protect them.

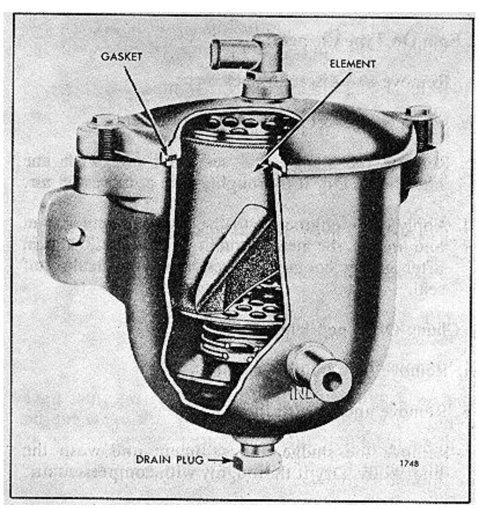


FIG.1 - Coolant Filter and Conditioner (Canister Type)

Filter Installation

If a coolant filter and conditioner is to be installed on an engine which has been in service, drain and flush the cooling system prior to installation of the filter.

Filter Maintenance

Replace the chemically activated element, following the manufacturer's recommended change periods (refer to Section 15.1). The lower corrosion resistor plate (if used) must be buffed each time (discard the plate if excessive metal loss or pitting is evident) to ensure effective protection of the cooling system.

If the filter is installed on an engine which has previously been in service, it may be necessary to change the filter element two or three times at intervals of approximately 200 hours or 6,000 miles, or

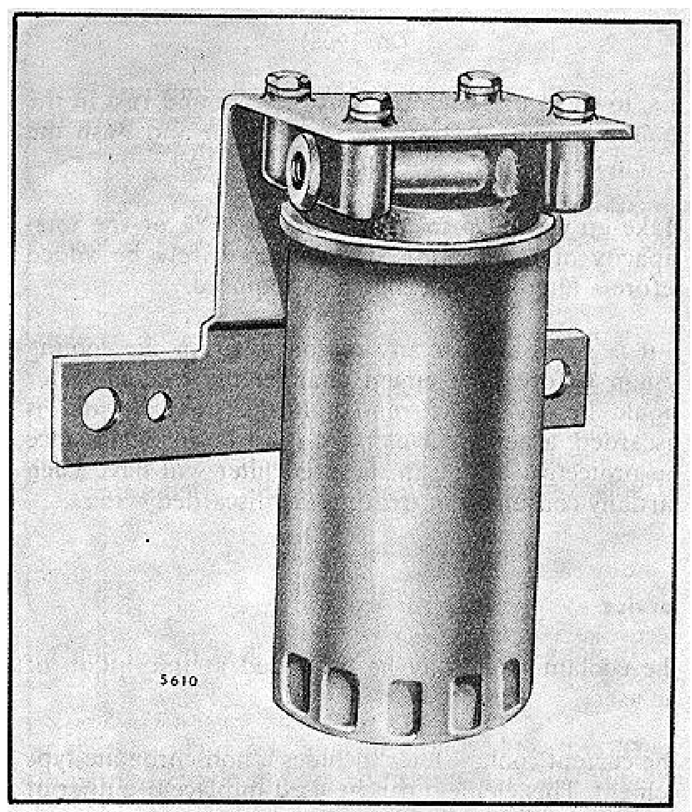


FIG. 2 - Coolant Filter and Conditioner (Spin-On Type)

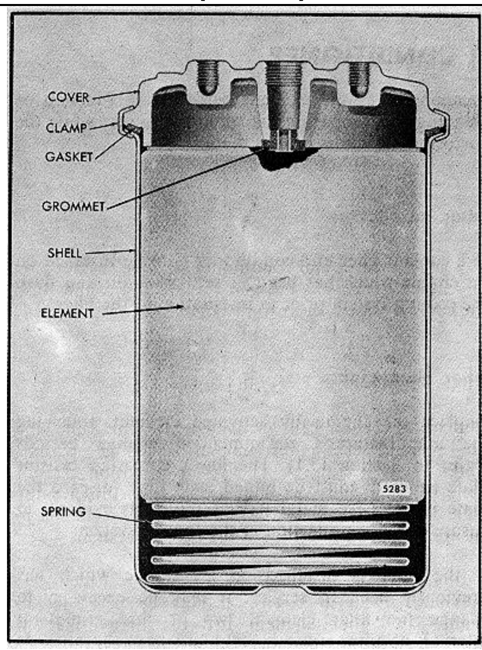


FIG. 3 - Coolant Filter and Conditioner (Clamp-On Type)

less, to clean up accumulations of scale and rust in the cooling system. It is advisable to drain and flush the system during these initial change intervals.

Make-up water up to approximately 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

If it is necessary for any reason to drain the cooling system before an element change, the treated water should be saved and reused. If the treated water is discarded, a new filter element must be installed since the protective agents in the used filter will have been partially consumed in treating the discarded water.

Service

The coolant filter may be grounded at the option of the user.

The current coolant filter includes a non-chromate type element. This element can' be used in place of either of the former filter elements (permanent type anti-freeze or plain water type) and thus provides year around cooling system protection. The current and the former filter elements are completely interchangeable in the former filter can (refer to Section 13.3).

Replace the element and service the filter and conditioner as follows:,

1. Close the filter inlet and outlet shutoff valves. If shutoff valves are not provided, vise grip pliers can be used to clamp each hose closed during the filter change.

NOTE: Use caution to avoid damaging the hoses with the vise grip pliers.

2. Canister Type Element:

   a. Remove the drain plug in the bottom of the filter body and let drain. '

   b. Remove the filter cover-to filter body bolts.

   c. Remove and discard the element.

   d. Remove and discard the corrosion resistor plates.

   e. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

   f. Replace the drain plug in the bottom of the filter.

   g. Insert the new element.

   h. Use a new filter cover gasket and install the filter cover and tighten the bolts evenly.

3. Spin-On Type Element:

   a. Remove and discard the element.

   b. Clean the gasket seal on the filter cover.

   c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

   d. Apply clean engine oil to the filter element gasket and install the new element. A 1/2 to 3/4 turn after gasket contact assures a positive leakproof seal;

4. Clamp-On Type Element:

   a. Remove the retaining clamp.

   b. Remove and discard the element.

   c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

   d. Insert the new element.

   e. Secure the filter body in place with the clamp,

5. Open the inlet and outlet lines by opening the shutoff valves or removing the vise grip plier clamps.

6. Operate the engine and check for leaks. The top of the filter and the outlet line should feel warm to the touch with the rise in coolant temperature. If not, disconnect the filter outlet line at the end opposite the filter connection to bleed the air from the system and reconnect the line. Use caution to minimize coolant loss.

SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

FAN HUB SPACER

The new fan hub spacers are similar to the former spacers except for the flange pilot radius and the width of the spacers (Fig. 1). The flange on the spacer serves as a pilot for the fan, as well as a pilot for the second spacer, when two or more spacers are used together.

The former and new spacers are interchangeable on a former fan pulley hub assembly but only the new spacers are serviced.

The former .800" thick spacer must not be used with the current shaft type fan pulley hub assemblies, unless it is reworked (see Service Note).

Use of the former thick spacer will crush the fan hub cap causing the drive to bind.

SERVICE NOTE: The former .800'" thick spacer can be reworked into the new .800, thick spacer by removing material at the radius (Fig. I). A reworked spacer should be mated with the fan hub assembly. If a former thin spacer (.500" thick) is used in conjunction with the reworked thick spacer, it should be positioned against the fan.

NOTE: The .500" thick spacer cannot be reworked into the new .560, thick spacer.

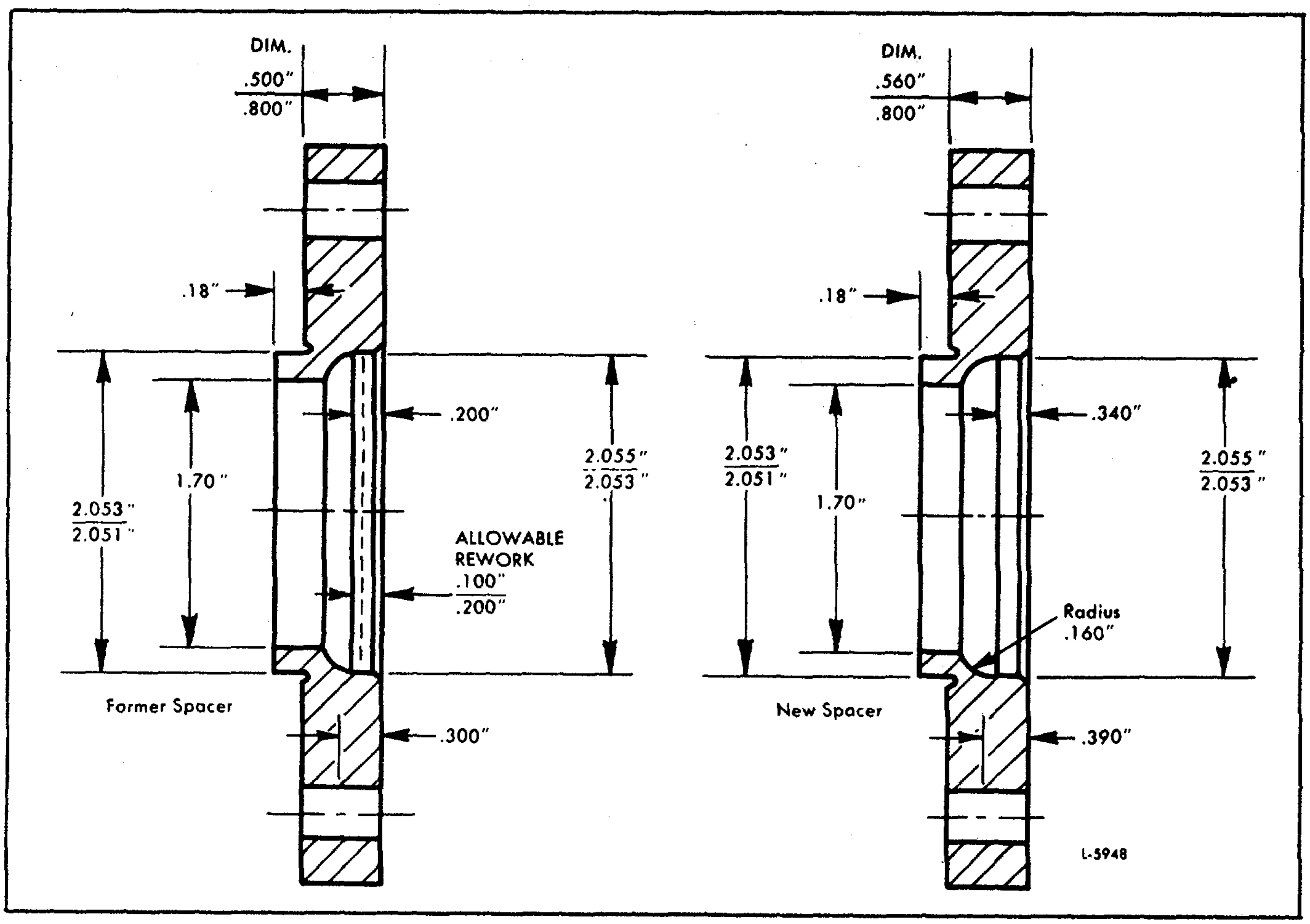


FIG. 1 - Former and New Spacers

FAN HUB GREASE FITTING

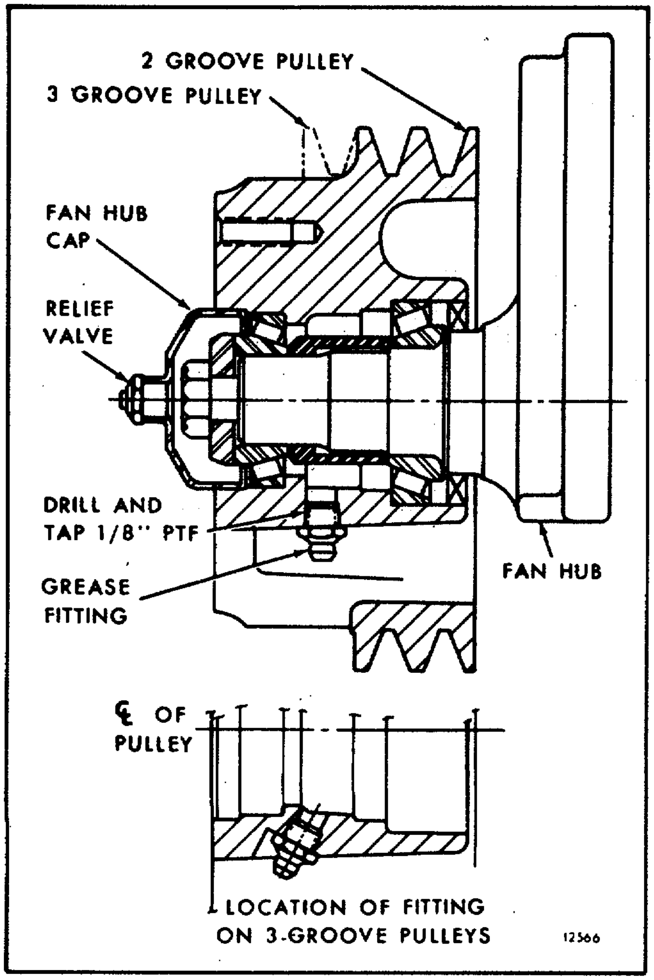


FIG. 2 Location of Fan Hub Grease Fitting and Relief Valve

A grease fitting may be added to former fan hub assemblies used on vehicle engines to permit periodic lubrication of the bearings.

Rework the fan hub as follows:

1. Refer to Section 5.4 and disassemble the fan hub assembly and clean the parts thoroughly.

2. Drill and tap the fan hub, at the location shown in Fig. 2, to accept a 1/8"PTF x 1/16" threaded lubricator fitting. Clean the hub to remove any metal chips.

3. Refer to Section 5.4 and reassemble the fan hub. Discard the former grease retainer as it is not required when a grease fitting is used.

4. Install a *new* fan hub cap which is threaded for a relief valve (Fig. 2).

5. Install a grease fitting in the fan hub and a relief valve in the fan hub cap.
Refer to Section 15.1 for the maintenance schedule.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260m BOLTS TORQUE (lb-ft)	Nm	THREAD SIZE	280m OR BETTER TORQUE (lb-ft)	Nm
1/4 -20	5- 7	7- 9	1/4 -20	7-9	10-12
1/4 -28	6- 8	8-11	1/4 -28	8-1	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 -2	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 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
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
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

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb ft)	TORQUE (Nm)
Water pump impeller retaining nut..................................	7/16-20	45-50	61-68
Water manifold nut...	3/8 -24	20-25	27-34

STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE (lb ft)	TORQUE (Nm)
Water pump body stud	10-20	14-27
Water pump cover stud	12-15	16-20

SERVICE TOOLS

TOOL NAME	TOOL NO.
Handle	J 7079-2
Oil seal installer	J 8501
Pliers	J 4646
Puller	J 24420
Thermostat seal installer	J 8550
Water Pump Bearing and Gear Installer	J 25257
Water pump seal remover set	J 22150-B

SECTION 6

EXHAUST SYSTEM

CONTENTS

EXHAUST SYSTEM

Vehicle engines are equipped with an air-cooled exhaust manifold. The location and angle of the exhaust outlet of the manifold varies with the engine application.

The exhaust manifold is secured to the cylinder head with nuts and special washers attached to studs located between the exhaust ports and at the outer sides of the end ports of the cylinder head.

EXHAUST MANIFOLD (Air Cooled)

The cast air-cooled manifold has a uniform circular cross-section and tapers upward from each end toward the center where a flange is provided for the attachment of the exhaust piping or muffler (Fig. 1).

A new exhaust manifold hold-down crab is now being used. The new hold-down crab is made of a hardened steel and is heavier then the former hold-down crab. This will minimize wear and gouging of the manifold, crab and cylinder head mating surfaces, which results in a loss in the torque on the hold-down crab nut. The former and the new hold-down crab are interchange-able on an engine however only the new crab will be serviced.

Also a new special washer is now used at the center portions of the exhaust manifolds. This new washer will more accurately control the seating area for the 7/16" nut or bolt. Only the new special washer will be serviced.

Remove Exhaust Manifold

Usually, the exhaust manifold will be removed with the cylinder head, however when the exhaust manifold gaskets only need to be replaced, the manifold may be removed in the following manner without removing the cylinder head:

1. Loosen the flange seal connecting the exhaust manifold at the outlet tube.

2. Disconnect the exhaust pipe or muffler from the exhaust manifold flange.

3. Loosen and remove the nuts and bevel washers which secure the exhaust manifold to the cylinder head. It is suggested, that, as a safeguard, one nut and washer be loosened and left on one of the center studs until all other nuts and washers have been removed.

4. Support the manifold and remove the nut and washer from the center stud.

5. Lift the manifold away from cylinder head.

6. Remove the manifold gaskets.

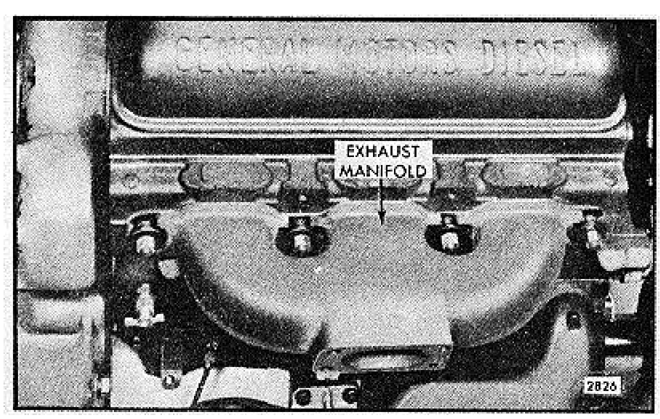


FIG. 1 - Typical Cast Air - Cooled Exhaust Manifold Mounting

Inspection

Remove the loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. It is especially important to clean the manifold used on a turbocharged unit to eliminate the possibility of loose scale entering and damaging the turbocharger.
Examine the exhaust manifold studs for damage. If necessary, replace the studs. New studs are driven in to 25-40 lb-ft (34-54 Nm) torque.

Install Exhaust Manifold

With all traces of the old gaskets removed from the cylinder head and bolting flanges of the exhaust manifold, install it as follows:

1. Make sure the internal walls of the manifold are clean to eliminate possible damage to the tur-bocharger, if used.

2. Place new gaskets over the studs and up against the cylinder head. Metal-clad gaskets may look reusable, but once they've been used and taken a "set" they cannot be reused.

NOTE: When installing the metal clad exhaust

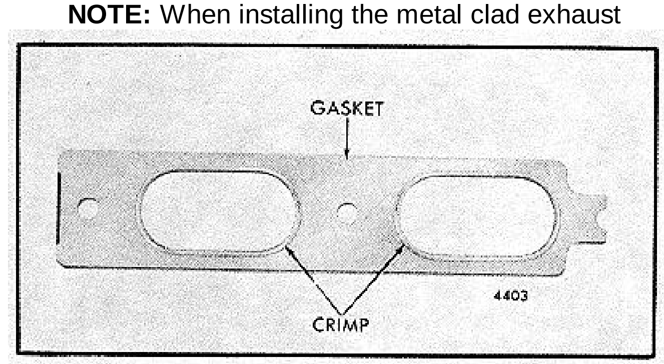


FIG. 2 Metal Clad Exhaust Manifold Gasket

manifold gasket(s) be sure the crimped side of the gasket faces the cylinder head (Fig. 2).

3. Position the exhaust manifold over the studs and up against the gasket.

NOTE: Be sure the locating pads on the exhaust manifold rests on the cylinder block locating pads.

4. Install the bevel washers and nuts on the studs and draw the exhaust manifold up against the gasket. Tighten the nuts to 30-35 Ib-ft (4147 Nm) torque.

NOTE: Set the bevel washers in position so that outer diameter will rest on the manifold and the crown at the center is next to the nut.

IMPORTANT: Tighten the exhaust manifold stud nuts from the center of the exhaust manifold outward, alternating toward either end.

5. Connect the exhaust pipe or muffler to the exhaust manifold flang**e.**

6. Tighten the flange seal connecting the exhaust manifold to the outlet tube.

NOTE: Do not allow exhaust piping to impose excessive loads on the turbocharger.

7. Inset the exhaust outlet piping for dents, holes and potential sources of water infiltration such as loose clamps or deteriorated seals. Repair or replace, if necessary.

SECTION 7
ELECTRICAL EQUIPMENT, INSTRUMENTS AND PROTECTIVE SYSTEMS

CONTENTS

ELECTRICAL SYSTEM

A typical engine electrical system generally consists of a starting motor, a battery-charging generator (alternator, a transistor combination voltage regulator, current regulator and cutout relay to protect the electrical system, a storage battery and the necessary wiring.

Detailed information on maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the equipment manufacturer. Information regarding equipment manufactured by the Delco - Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from AC- Delco service outlets, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the manufacturer of the equipment. Replacement parts far electrical equipment should be ordered through the equipment manufacturer's outlets, since these parts are not normally stocked by Detroit Diesel Allison. For electrical equipment manufactured by Delco-Remy Division, repair service and parts are available through AC-Delco branches and repair stations.

BATTERY - CHARGING GENERATOR AND ALTERNATOR

The battery-charging circuit consists of a generator or alternator, regulator (Section 7.1.1), battery (Section 7.2) and the wiring. The battery-charging generator (Fig. 1) or alternator (Fig. 2 or 3) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the generator or alternator.

HINGE - MOUNTED GENERATOR OR ALTERNATOR (Belt - driven)

Direct current generators are manufactured in a wide range of sizes and types, but the basic design of all generators is the same. The size and type of generator applied to a particular engine depends on many factors, including maximum electrical load, type of service, percentage of engine idling to running time, type of drive, drive ratio (engine speed to generator speed), generator mounting and environmental conditions.

The hinge-mounted alternating current self-rectifying alternator is belt driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and one that has to operate for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase A. C. voltage to provide D. C. voltage at the battery terminal of the alternator, thereby eliminating the need for an external rectifier.

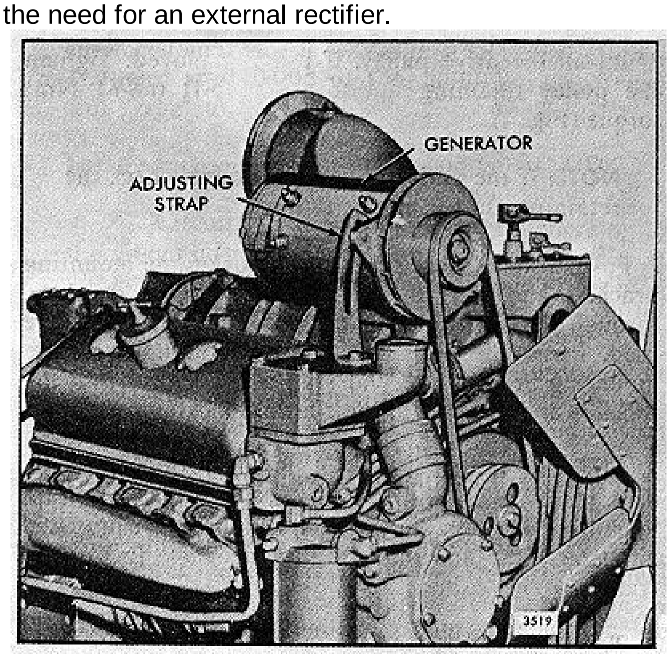


FIG. 1 - Typical Hinge-Mounted Generator

The alternator is also available in various sizes and types, depending upon the specific application.

The SI series alternators have replaced the DN series alternator. With the new alternators, the need for a separately mounted voltage regulator is eliminated.

NOTE: Effective with November, 1979 build engines, the 1OS1 alternators were converted to metric dimension, such as the attaching bolts, nuts and lockwashers. Also, hole sizes of some mounting parts will be changed to accommodate the new metric fasteners. The output terminal (BAT) thread will be changed from a 12-24 to a M6X1 thread.

The access hole permitting the external adjustment of the voltage regulator has been eliminated on current alternators. To adjust the voltage setting on the current alternators, remove the rectifier end plate. The voltage regulator adjustment is located on the voltage regulator circuit board. Refer to the pertinent Delco Service Bulletin for complete adjustment procedure.

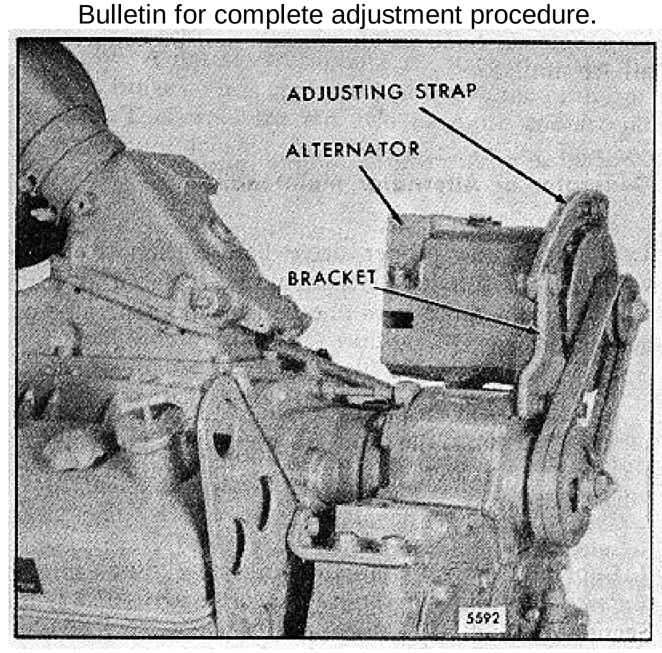


FIG. 2 - Typical Hinge-Mounted Alternator (Belt- Driven)

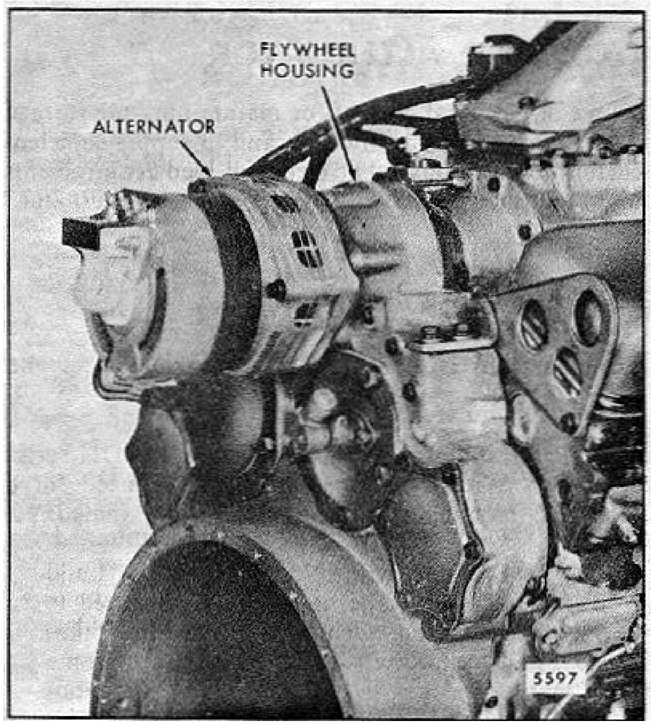


FIG. 3 - Typical Flange-Mounted Alternator (Beltless)

The proper selection of a generator or alternator which will meet the needs of the battery-charging circuit on ;he particular engine is mandatory. This, together with adherence to the recommended maintenance procedures will reduce generator or alternator troubles to a minimum. Since most generators or alternators adhere to the same basic design, the maintenance, removal and installation procedures for all are similar.

Generator or Alternator Maintenance

1. Maintain the proper drive belt tension. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the generator or alternator drive.

> **NOTE:** When installing or adjusting the drive belt. be sure the bolt at the pivot point is properly tightened, as well as the bolt in the adjusting slot.

2. Lubricate the generator bearings as outlined in the *Lubrication and Preventive Maintenance Chart* in Section 15.1.

3. Alternator bearings are permanently lubricated There are no external oiler fittings.

Remove Generator or Alternator

1. Disconnect the cables at the battery supply. If the generator or alternator has a separately mounted regulator and field relay, disconnect all other leads from the ,Generator or alternator and tag each one to ensure correct reinstallation.

2. Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

3. While supporting the generator or alternator, remove the adjusting strap bolt and washers. Then remove the mounting bolts, washers and nuts. Remove the generator or alternator carefully and protect it from costly physical damage.

4. Remove the pulley assembly if the generator or alternator is to be replaced.

Generator or Alternator Service

Repairs and overhaul work on generators and alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for generators and alternators should be ordered through the equipment manufacturer's outlets. For generators and alternators manufactured by Delco-Remy Division, repair service and parts are available through AC Delco branches and repair stations.

Install Generator or Alternator

1. Install the drive pulley, if it was removed. Tighten the pulley retaining nut to 50-60 lb-ft (68-81 Nm) torque (Fig. 4).

> **NOTE:** If the pulley was not removed, check the retaining nut for proper torque.

2. Position the generator or alternator on the mounting brackets and start the bolts, with washers in place, through the bolt holes in the end frames. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and end frame. Make sure that the washers and nuts are in their proper locations.

3. Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the washers, through the slot of the adjusting strap and into the threaded hole in the end frame.

4. Place the drive belts in the grooves of the pulleys.

5. Adjust the belt tension as outlined in Section 15.l.

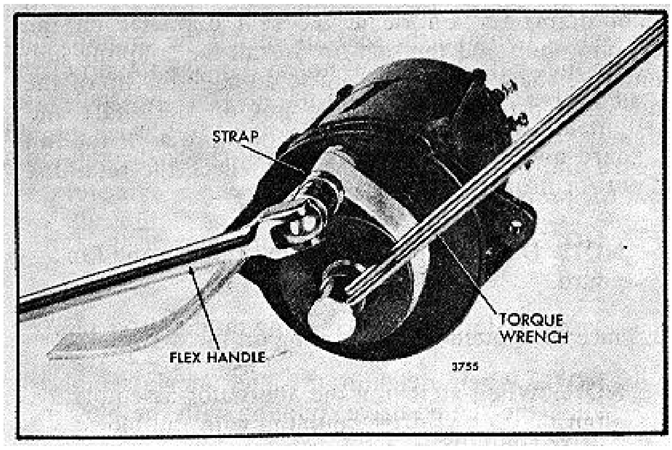


FIG. 4 - Tighten Generator or Alternator Pulley Retaining Nut

Tighten all of the bolts after the belt tightening is completed.

6. Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the generator or alternator. Keep all connections clean and tight.

FLANGE - MOUNTED ALTERNATOR (Beltless)

The flange-mounted alternator (Fig. 2) is coupling-driven through a drive hub attached to the blower drive gear. It is a self load limiting alternator with a fully adjustable solid state integral regulator. It is designed with slow speed characteristics which allow lower rotational speed of the alternator without sacrificing any amperage output at idle or top speed. The alternator shaft may be rotated in either direction without affecting the output or cooling of the unit. Six silicon diodes mounted in heat sinks convert alternating current from the delta wound stator into direct current.

The brushes and integral voltage regulator are located in a waterproof housing that may be removed for replacement or inspection.

Alternator Maintenance

1. Keep the mounting bolts securely tightened to prevent vibration damage.

2. Be sure the plug that seals the integral regulator adjusting hole is in place.

Remove Alternator

i. Disconnect the cables at the battery supply. Disconnect the leads from the alternator and tag each - one to ensure correct reinstallation.

2. Loosen the three alternator mounting bolts.

3. While supporting the alternator, remove the mounting bolts, hardened washers and lock washers and lift the alternator and fan guard as a unit from the mounting adaptor. Protect the alternator and fan guard assembly from physical damage following removal from the engine.

> **NOTE:** The fan guard, which includes an oil seal, should not be separated from the alternator until the alternator half of the coupling is removed. Any attempt to separate the fan guard from the alternator could damage the oil seal.

4. Loosen the retaining nut and remove the coupling hub keyed to the alternator shaft.

5. If the alternator is to be replaced, separate the fan guard from the alternator.

6. Remove the alternator flange mounting adaptor from the flywheel housing, if necessary.

Alternator Service

To service the alternator, contact your nearest Detroit Diesel Allison distributor or Leece Neville dealer.

Inspection

Inspect the drive coupling and hub for wear at the seal surface and the drive tangs. If worn excessively, replace them with new parts.

Oil leaks indicate a worn or damaged oil seal. Replace the oil seal in the fan guard. if necessary.

Inspect the alternator housing and flange adaptor for cracks at the mounting bolt holes. Also inspect the pilot diameters for damage, cracks or distortion. Replace them if necessary.

Install Alternator

1. If removed, use a new gasket when attaching the alternator mounting adaptor to the flywheel housing. The adaptor is secured to the engine by two short bolts into the flywheel housing and four long bolts through the flywheel housing, end plate and blower drive support.

Make sure the alternator is properly fitted to the adaptor before it is bolted in place. Improper installation of the alternator can disturb adaptor alignment and cause gear train damage. See Section 1.7.7 for alignment procedure.

NOTE: Special hardened, plain washers seat in the six counterbored bolt holes in the adaptor. Also the current gasket has a positioning identification tab.

2. If the fan guard and hub were removed, locate the fan guard on the alternator by engaging the mating pilot diameters. Lubricate the seal diameter on the coupling hub and the seal lip. Install the coupling hub onto the shaft, Be careful not to damage the lip of the oil seal. Install the retaining nut on the shaft and tighten it to 70-80 Ib-ft (95-108 Nm) torque. If the fan guard and hub were not removed, check the retaining nut for proper torque.

NOTE: Do not support the alternator on the fan guard.

3. Place the slotted drive coupling on the drive hub.

NOTE: When attaching the alternator assembly, align the slotted drive coupling with the blower drive coupling.

4. Align the bolt holes in the fan guard 'with the mounting holes in the alternator housing. Support the alternator assembly against the mounting flange adaptor. Use a new gasket, and install the three 3/8"- 16 x 3 1/.2 bolts, lock washers and hardened washers through -the alternator housing and fan guard mounting holes into the 'mounting adaptor. Tighten the bolts to 30-35 Ib-ft (41-47 Nm) torque.

5. Attach the wires and cables. Be sure each one is correctly installed in accordance with its previous location on the alternator. Keep all connections clean and tight.

POLARIZING GENERATOR (Direct Current)

After each check or adjustment of the voltage regulator or generator, particularly after the leads have been disconnected and then reconnected, it is necessary to polarize the generator before starting the engine. This is to ensure correct polarity with respect to the battery.

NOTE: Never attempt to polarize an alternator.

Failure to polarize a generator will result in burned or stuck cutout relay contact points in the regulator, a rundown battery and damage to the generator.

The procedure for correctly polarizing a generator will vary with the type of electrical equipment installed and upon the generator regulator wiring circuit. If the generator field is grounded through the regulator, it is an "A" circuit; if it is internally grounded, it is a "B" circuit.

If Delco-Remy electrical equipment is installed, reference can be made to the Delco-Remy "Electrical Equipment Manual" and "Test Specifications" (refer to Section 7) to determine the type of circuit applicable to the regulator being used. Since it is possible to have either an "A" or "B" circuit regulator with any given generator, the polarizing procedures must be carefully adhered to. Use of the wrong polarizing procedure or neglecting to polarize will result in reversed generator polarity and serious damage to the electrical components.

After ascertaining the correct circuit used, polarize the generator as outlined below.

1. "A" Circuit:

Connect a jumper lead momentarily between the "BAT" and "GEN" terminals of the regulator.

2. "B" Circuit:

Remove the "F" lead from the regulator and momentarily connect it to the "BAT" terminal of the regulator.

A momentary surge of current to the generator correctly polarizes it with respect to the battery.

Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

Accidentally reversing the battery connections must be avoided.

Never disconnect the battery while an alternator is in operation. Disconnecting the battery will result in damage to the diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the battery connected or as a booster for battery output.

Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.

If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to be sure that a ground strap is present and is correctly installed.

BATTERY-CHARGING GENERATOR REGULATOR

D.C. CHARGING CIRCUIT

To regulate the voltage and current output of the battery-charging generator and to maintain a fully charged storage battery, several protective devices are employed, depending on the type of electrical system. The most representative of these devices is the "three-unit" regulator (Fig. 1).

These regulators are identified as:

a. A "Circuit A" unit in which the generator field circuit is connected to ground within the regulator, and is used only with generators having an externally grounded field circuit.

b. A "Circuit B" unit in which the generator field circuit passes through the regulator and returns to ground inside the generator itself. This regulator must be used only with "Circuit B" generators in which the field is internally grounded.

The regulators are dust and moisture-proofed. On most applications, it is necessary to use shock mounts which insulate the regulator against vibration but necessitates the installation of a ground lead.

The three-unit regulator consists of a cutout relay, a voltage regulator and a current regulator mounted in a single assembly as shown in Fig. 1. These three units are basic and generally apply to most regulators in a D.C. generator system.

CUTOUT RELAY

The cutout relay (Fig. 2) has two windings assembled on one core; a series winding of a few turns of heavy

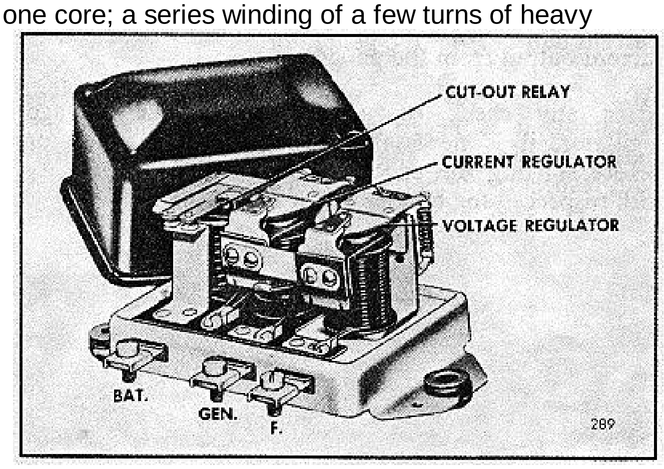


FIG. 1 - Typical Regulator Assembly

wire and a shunt winding of many turns of fine wire. The relay core and windings are assembled into a frame. A flat steel armature is attached to the frame by a hinge so it is centered just above the center of the core. The armature has two or more contact points which are located just above a similar number of stationary contact points.

Operation

When the engine is not running, the armature contact points of the relay are held away from the stationary points by tension of a leaf spring.

As the engine starts and the generator speed increases, the current flowing through the shunt winding builds up until it reaches the value for which the relay has been set. At this point, sufficient magnetism overcomes the armature spring tension, the contact points close and the current flows to the battery. Then the current which flows through the series winding is in the right direction to add to the magnetic force holding the armature down and the points closed.

When the engine is slowed down or stopped, current

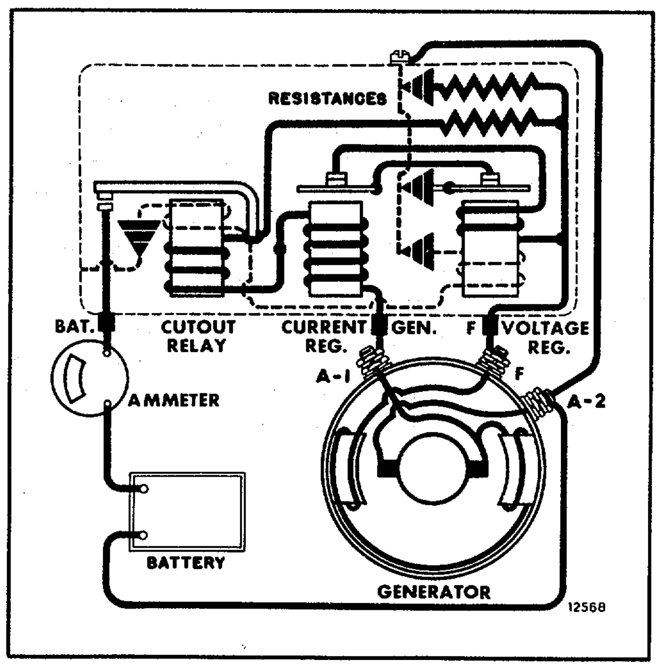


FIG. 2 - Wiring Circuit of Typical Three-Unit Regulator

will begin to flow from the battery to the generator. This reverses the direction of current flow through the series winding, causing a reversal of the series winding magnetic field. The magnetic field of the shunt winding does not reverse. Therefore the two windings now oppose each other magnetically and the resultant magnetic field is not strong enough to hold the armature down. The leaf spring pulls the armature away from the core and the points separate, opening the circuit between the generator and the battery.

CAUTION: The regulator cutout relay contact points must never be closed by hand with the battery connected. This would cause a high current flow through the units and damage them.

VOLTAGE REGULATOR

The voltage regulator (Fig. 2) has two windings on a single core. One is a shunt winding consisting of many turns of fine wire which, in series with a resistor, is shunted across the generator at all times. The second winding is a field current winding which is connected between the generator field circuit and ground whenever the regulator contact points are closed. In addition to the core frame, armature and contact points, the unit has a spiral spring which holds the armature away from the core so the two contact points are touching when the voltage regulator is not operating.

Operation

When the generator voltage reaches the value for which the voltage regulator is adjusted, the combined magnetic field produced by the shunt winding and the field current winding overcomes the armature spring tension, pulls the armature down and separates the voltage regulator contact points. This introduces resistance into the generator field circuit so the generator field current and generator voltage are reduced. The lowering of the output of the generator causes the points to close again, thereby removing the resistance and increasing the generator output. The complete cycle of opening and closing the points and the alternate inserting and removing of the resistance in the generator field circuit is done rapidly, thus limiting the generator voltage to a predetermined maximum value. With the generator voltage limited, the generator supplies varying amounts of current to meet the requirements of varying states of battery charge and, electrical loads.

CURRENT REGULATOR

The current regulator (Fig. 2) contains two windings assembled on one core: a series winding and a field current winding. The series winding, consisting of a few turns of heavy wire, is connected into the charging circuit so that the full output of the generator passes through it. The field current winding is connected in series with the generator field circuit so that the field current flows through the field winding when the regulator contact points are closed.

The outward appearance of the current regulator is similar to that of the voltage regulator.

Operation

The magnetism produced by current flowing through the series winding overcomes the armature spring tension and the contact points open when the current reaches the value for which the current regulator is adjusted. This inserts a resistance into the generator field circuit, resulting in a drop in generator output. Immediately, the magnetic field of the series winding is weakened, the contact points close, the generator output starts to increase and the cycle is repeated. This action prevents the generator from exceeding its rated output.

Therefore, when the load demand is heavy, generator output will increase until it reaches the current value for which the current regulator is set; then the current regulator will begin to operate and pre-regulate the current output from the generator.

After any check or adjustment of the voltage regulator, it is necessary to polarize the generator before starting the engine to assure correct polarity with respect to the battery (refer to Section 7. 1).

BATTERY-CHARGING GENERATOR REGULATOR

A.C. CHARGING CIRCUIT

TRANSISTORIZED AND TRANSISTOR REGULATORS

In addition to the standard regulator, there are two other types of regulators used with the self- rectifying A.C. generators in the battery-charging circuit. One is a transistorized regulator which contains a vibrating voltage regulator unit and a field relay unit. The other is a transistor regulator which contains no moving parts and is used with a separately mounted field relay.

TRANSISTORIZED REGULATOR

The transistorized regulator (Fig. 3), for use on a negative ground circuit, contains a vibrating voltage regulator unit and a field relay unit. The regulator uses a single transistor and two diodes. The transistor works in conjunction with the conventional voltage unit having a vibrating contact point to limit the generator voltage to a pre-set value. A field discharge diode reduces arcing at the voltage regulator contacts by dissipating the energy created in the generator field windings when the contacts separate. A suppression diode prevents damage from transient voltages which may appear in the system.

Certain transistorized regulators are equipped with a choke coil to permit the installation of a capacitor between the regulator and the "BAT" terminal on installations experiencing radio interference. The capacitor suppresses the radio noise and the choke coil acts to prevent oxidation of the voltage regulator contacts. Regulators incorporating the choke coil are identified by a spot of green paint on the regulator base, next to the single mounting bolt hole.

> **CAUTION:** A capacitor must not be installed unless the transistorized regulator incorporates the choke coil.

Operation

When the engine starting switch is closed, the field relay winding is energized and causes the contacts to close. Current then flows from the battery through the relay contacts to the regulator "F2" terminal. From this point, the current flows through the generator field

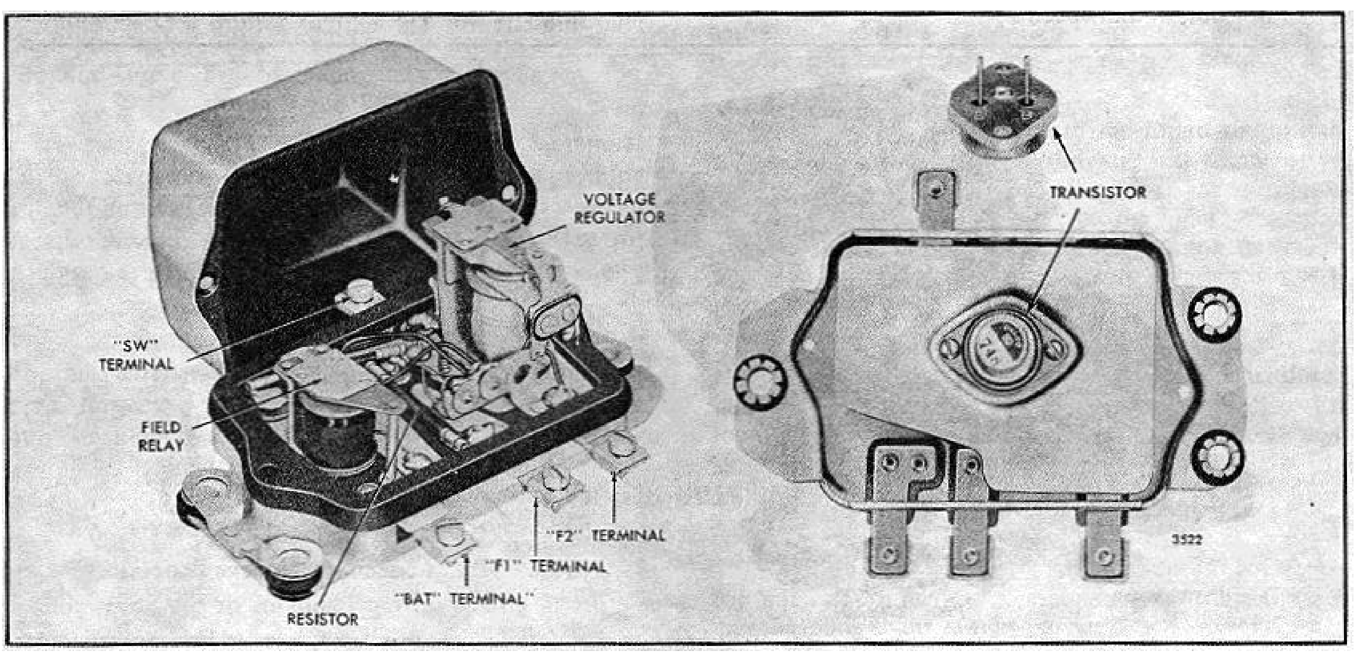


FIG. 3 - Transistorized Regulator

winding and then through the transistor and voltage contact points to ground.

As the generator speed increases, the increased voltage from the generator "BAT" terminal is impressed through the field relay contacts across the regulator shunt winding. The magnetism created in the winding causes the voltage contacts to open, thus causing the transistor to shut off the field current. The generator voltage then decreases and the voltage contacts reclose. This cycle repeats many times per second, thereby limiting the generator voltage to the value for which the regulator is set.

The magnetism produced in an accelerator winding, when the voltage contacts are closed, aids the shunt winding in opening the contacts. When the contacts are open, the absence of the magnetism in the accelerator winding allows the spring to immediately re-close the contacts. This action speeds up the vibration of the contacts.

CAUTION: Do not short across or ground any of the terminals on the regulator or the generator and *do not* attempt to polarize the generator.

TRANSISTOR REGULATOR

The transistor regulator is composed principally of transistors, diodes, capacitors and resistors to form a completely static electrical unit containing no moving parts.

The transistor is an electrical device which limits the generator voltage to a pre-set value by controlling the generator field current. The diodes, capacitors and resistors act together to aid the transistor in performing this function, which is the only function that the regulator performs in the charging circuit:

The voltage at which the generator operates is determined by the regulator adjustment. Once adjusted, the generator voltage remains almost constant, since the regulator is unaffected by length of service, changes in temperature or changes in generator output and speed.

A separately mounted field relay connects the regulator "POS" terminal and the generator field windings to the battery when the engine starting switch is closed.

The voltage regulator illustrated in Fig. 4 is designed for negative ground battery-charging circuits only. It has two exposed terminals. The voltage setting may be adjusted by relocating a screw in the base of the regulator.

The voltage regulator shown in Fig. 5 has shielded plug-in connections and requires a cable and plug assembly to connect the regulator into the battery charging circuit. This type of regulator may be used in negative ground, positive ground and insulated charging circuits. The voltage setting may be adjusted

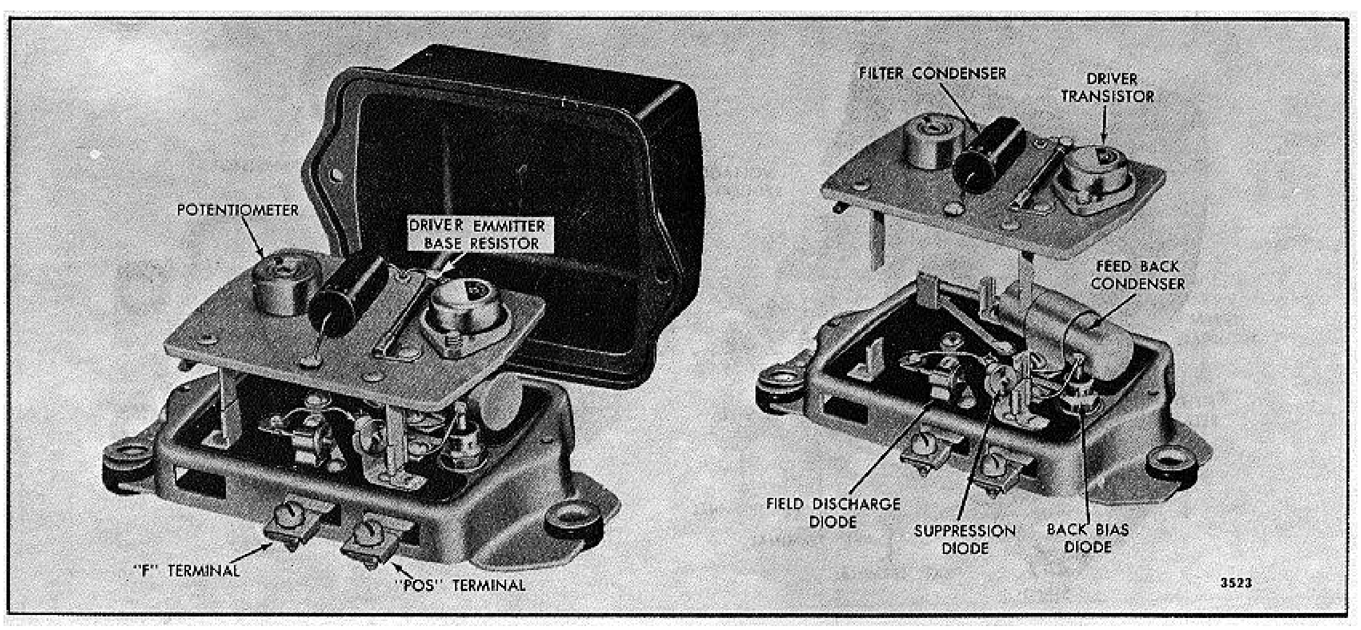


FIG. 4 - Former Transistor Regulator (Negative Ground Circuits Only)

by removing a plug in the cover and turning a slotted adjusting button inside the regulator.

Operation

When the engine starting switch is closed, the field relay winding is energized, which causes the relay contacts to close.

In the **negative ground circuit**, with the field relay contacts closed and the engine not running, generator field current can be traced from the battery through the relay contacts to the regulator "POS" terminal. Current then continues through the back-bias diode (D-1) and power transistor (TR-1) to the regulator "FLD" terminal and then through the generator field winding to ground, completing the circuit back to the battery.

When the generator begins to operate, A.C. voltages are induced in the stator windings. These voltages are changed, or rectified, to a D.C. voltage which appears at the output, or "BAT", terminal on the generator. The generator then supplies current to charge the battery and operate various accessories.

As generator speed increases, the voltage reaches the pre-set value and the components in the regulator cause transistor TR-1 to alternately 'turn off" and "turn on" the generator field voltage. The regulator thus operates to limit the generator output voltage to the pre-set value.

In the positive ground circuit, when the switch is closed and the engine is not running, the field current can be traced from the battery positive ground to generator ground and then to the regulator "POS" terminal. The current continues through diode D-1 and transistor TR-1 to the regulator "FLD" terminal, and then through the field winding and field relay contacts back to the battery, thus completing the circuit. Except for this primary difference, this circuit operates in the same manner as that described for the negative ground circuit.

REGULATOR PRECAUTIONS

Never short or ground the regulator terminals; *do not attempt to polarize the circuit.*

Make sure all connections in the charging circuit are tight to minimize resistance.

Refer to *A.C. Generator Precautions* in Section 7.1.

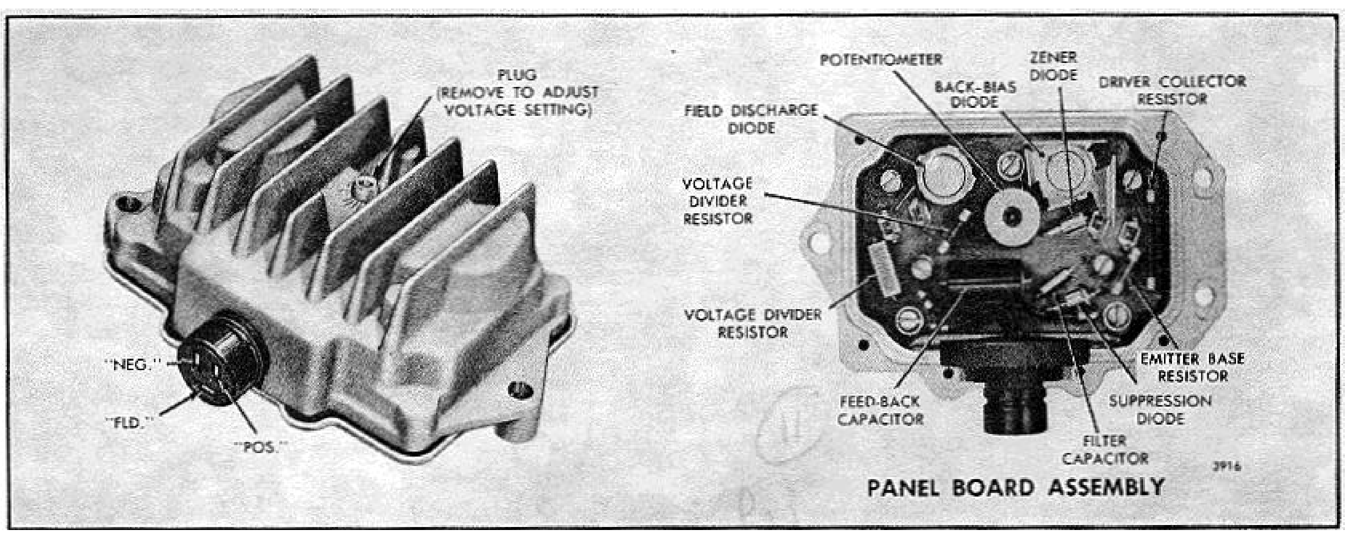


FIG. 5 - Transistor Regulator with Plug-In Connections

STORAGE BATTERY

The lead-acid storage battery is an electro-chemical device for converting chemical energy into electrical energy.

Function of Battery

The battery has three major functions:

1. It provides a source of current for starting the engine.

2. It acts as a stabilizer to the voltage in the electrical system.

3. It can, for a limited time, furnish current when the electrical demands exceed the output of the generator.

Types of Batteries

There are two types of batteries in use today.

1. The *dry charge* battery contains fully charged positive plates and negative plates separated by separators. The battery contains no electrolyte until it is activated for service in the field and therefore leaves the factory dry. Consequently, it is called a *dry charge* battery.

2. If the battery has been manufactured as a *wet* battery, it will contain fully charged positive and negative plates plus an electrolyte. This type of battery will not maintain its charged condition during storage and must be charged periodically to keep it ready for service.

NOTE: In the selection of a replacement battery, it is always good practice to select one of an "electrical size" at least equal to the battery originally engineered for the particular equipment by the manufacturer.

Install Battery

While the battery is built to satisfactorily withstand the conditions under which it will normally operate, excessive mechanical abuse leads to early failure.

Install the battery as follows:

1. Be sure the battery carrier is clean and that the battery rests level when installed.

2. Tighten the hold-down clamps evenly until snug. However, do not draw them down too tight or the battery case will become distorted or will crack.

3. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition. To make the cable connections as corrosion resistant as possible, place a felt washer at the base of each terminal beneath the cable clamps. Coat the entire connection with a heavy general-purpose grease. Be sure the ground cable is clean and tight at the engine block or frame.

12 Volt Batteries for 12 or 24 Volt Systems						
Engine	Starting Motor Voltage	Qty.	S.A.E. Cold Cranking AMP@0°F. (−17.8°C) AMP Per Battery	Total S.A.E. Cold Cranking AMP@0°F.(−17.8°C) AMP Per Bank	Reference S.A.E. 20 AMP Hour Rate Per Bank	Connect Batteries
6V-71	12V	1	900	Single Battery	205	Single
	24V	2	600	600	150	Series
8V-71	12V*	2	900	1800	410	Parallel
	24V	2	900	900	205	Series
12V-71	24V ±	2	900	900	205	Series

Note — Bank Refers to the Combined Connected Batteries
* 12 Volt High Output Starter
± 5-9/16" Frame Starter Only

BATTERY RECOMMENDATIONS

4. Check the polarity to be sure the battery is not reversed with respect to the generating system.

5. Connect the *grounded* terminal of the battery last to avoid short circuits which will damage the battery.

Servicing the Battery

A battery is a perishable item which requires periodic servicing. Only when the battery is properly cared for as described below can long and trouble-free service be expected.

1. Check the level of the electrolyte regularly. Add water if necessary, but do not overfill. Overfilling can cause poor performance or early failure.

2. Keep the top of the battery clean. When necessary, wash with a baking soda solution and rinse with fresh water. Do not allow the soda solution to enter the cells.

3. Inspect the cables, clamps and hold-down bracket regularly. Clean and re-apply a coat of grease when needed. Replace corroded or damaged parts.

4. Use the standard battery test as the regular service test to check the condition of the battery.

5. Check the electrical system if the battery becomes discharged repeatedly.

Many electrical troubles caused by battery failures can be prevented by systematic battery service. In general, the care and maintenance recommendations for storage batteries are the same today as they have always been.

Battery Safety Precautions

When batteries are being charged, an explosive gas mixture forms beneath the cover of each cell. Part of this gas escapes through the holes in the vent plugs and may form an explosive atmosphere around the battery itself if ventilation is poor.

> **CAUTION**: Explosive gas may remain in and around the battery for several hours after it has been charged. Sparks or flames can ignite this gas causing an explosion which could shatter the battery. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.

STARTING MOTOR

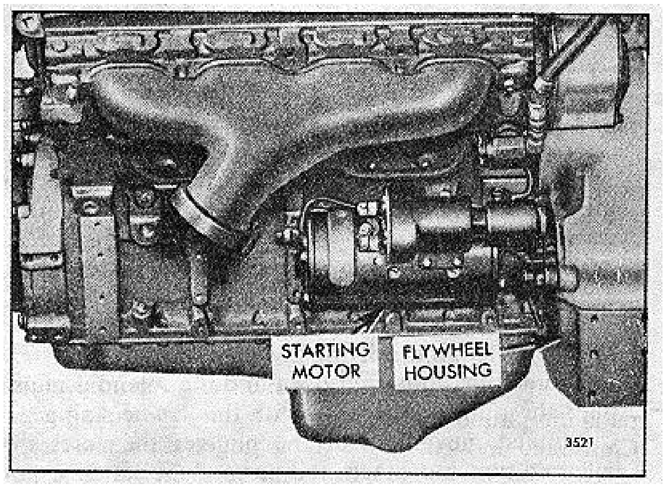


FIG. 1 - Sprag Overrunning Clutch Type Starting Motor Mounting (Current)

The starting motor is mounted on the flywheel housing as illustrated in Fig. 1. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the starting motor. To accomplish this, the starting motor is equipped with a heavy-duty sprag overrunning clutch or a Dyer drive.

Sprag Overrunning Clutch Type Starting Motor

A solenoid switch, mounted on the starting motor housing, operates the current sprag type overrunning clutch drive by linkage and a shift lever (Fig. 2). When the starting switch is engaged, the solenoid is energized and shifts the starting motor pinion into mesh with the flywheel ring gear and closes the main contacts within the solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. To protect the armature from excessive speed when the engine starts, the clutch "overruns", or turns faster than the armature, which permits the pinion to disengage itself from the flywheel ring gear.

The solenoid plunger and shift lever on this type of starting motor is totally enclosed to protect them from dirt, water and other foreign material.

An oil seal, between the shaft and the lever housing, and a linkage sea] (Fig. 2) prevents the entry of transmission oil into the main frame of the starting motor and solenoid case, allowing the motor to be used on wet clutch applications.

The nose housing on the sprag clutch type starting motor can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. The nose housing, on starters equipped with the heavy-duty clutch, is attached to the lever housing by

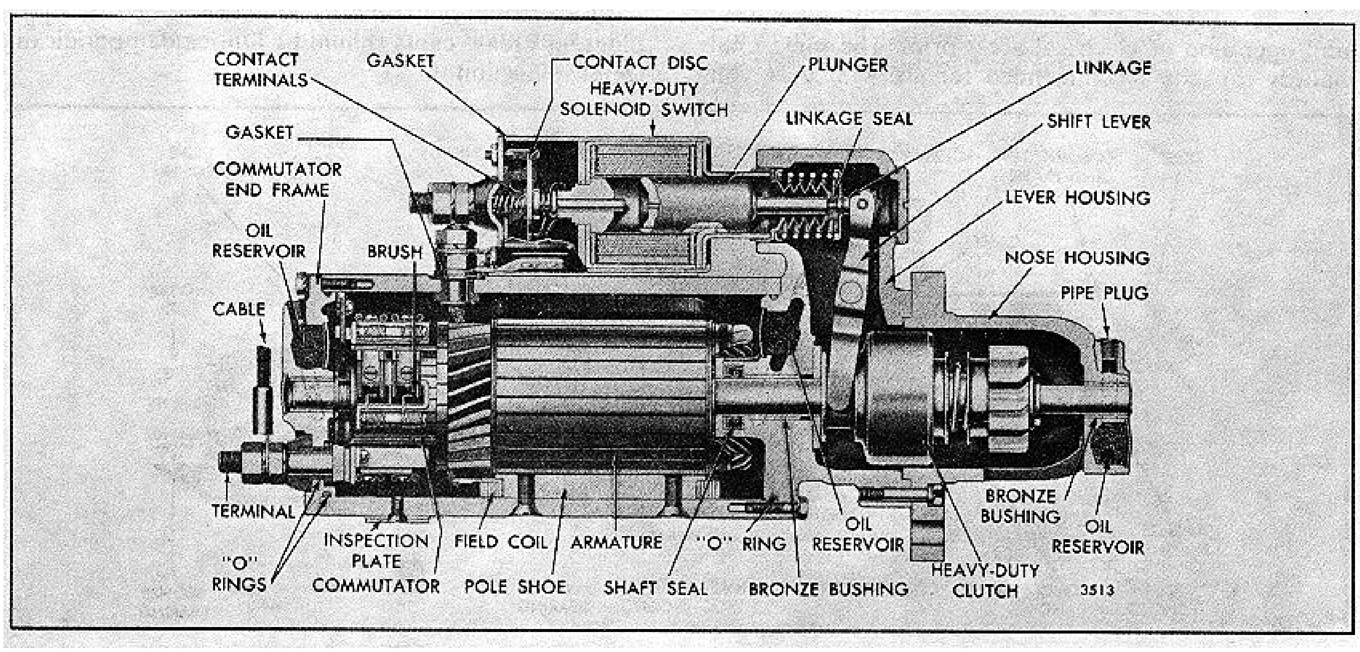


FIG. 2 - Cross-section of Starting Motor with Sprag Heavy-Duty Clutch Drive

six bolts located around the outside of the housing (Fig. 2).

> **NOTE:** When installing a current flywheel housing on an early engine, the starting motor nose housing may have to be indexed to reposition the solenoid.

When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

1. Remove the six socket head screws (1 short and 5 long) and six neoprene plugs, if a twelve hole starter mounting flange is used.

2. Turn the nose housing to the required position.

> **NOTE**: The solenoid must never be located below the centerline of the starter or dust, oil, moisture and foreign material can collect and cause solenoid failures.

3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole starter mounting flange is used.

4. Tighten the screws to 13-17 lb-ft(l-23Nm) torque.

High-Output Starting Motor

A high-output 12 volt starting motor, with a sprag overrunning clutch type drive, is provided for certain vehicle applications which require the equivalent of 24 volts for starting the engine and 12 volts for lighting and operation of electrical accessories. The same total battery capacity recommended for use with a 24 volt starter (two 205 ampere-hour batteries) must be retained and connected in parallel for the high-output 12 v6lt starter.

Dyer Drive Type Starting Motor

The former Dyer drive type starting motor (Fig. 3) is operated through a solenoid starting shift]ever and switch mounted on the motor. The Dyer drive mechanism provides positive engagement of the starting motor pinion with the engine flywheel ring gear- before the starting motor switch is closed and the armature begins to rotate.

When the engine starting switch is closed, the starter solenoid (Fig. 3) is energized and the solenoid plunger pulls the pinion into mesh with the flywheel ring gear. Continued movement of the plunger then closes the solenoid switch contacts and permits the starting motor to crank the engine. As soon- as the engine starts, the pinion is automatically de-meshed by the reversal of torque so the armature will not be subjected to excessive speeds.

> **NOTE**: When a current flywheel housing is installed on an early engine, it may be necessary to replace the Dyer drive starting motor with a sprag clutch type motor.

Lubrication

Starting motors which are provided with lubrication fittings (hinge cap oilers, oil tubes sealed with pipe plugs, or grease cups) should be lubricated periodically (refer to Section 15.1).

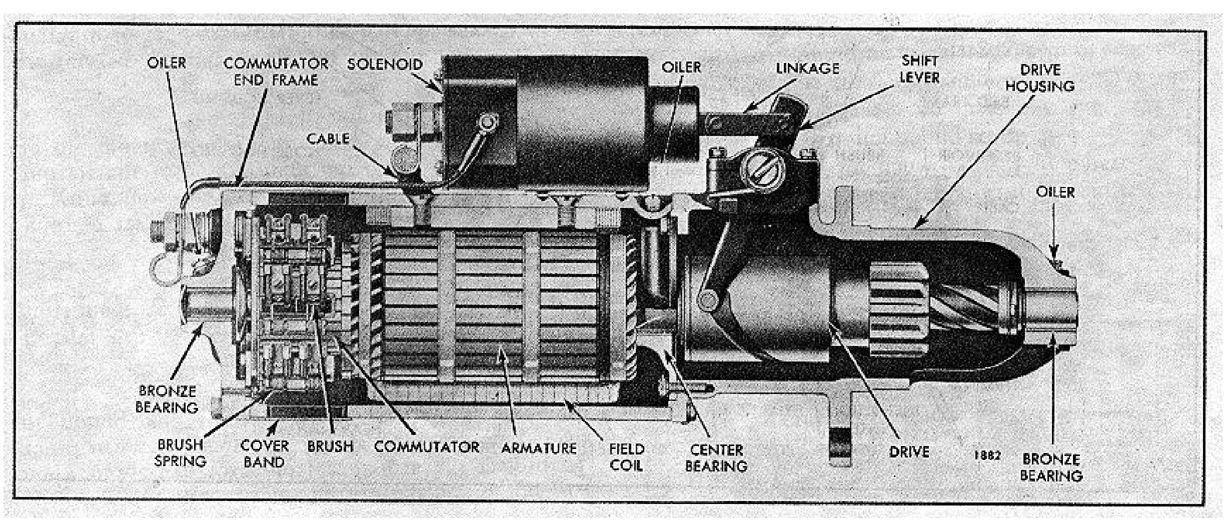


FIG. 3 Cross-section of Starting Motor with Dyer Drive

Flywheel Ring Gears

The starting motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth. Flywheel ring gear teeth have either no-chamfer, a Bendix chamfer or a Dyer chamfer (Fig. 4).

Flywheel ring gears with no chamfer are used with starting motors equipped with an overrunning clutch drive. Ring gears with a Bendix chamfer are used with starting motors equipped with either a Bendix drive or an overrunning clutch drive. Ring gears with the Dyer chamfer, used with Dyer drive type starting motors, may be reversed and used with the overrunning clutch drive type starting motors.

If the wrong type of ring gear is used, repeated starting attempts will be required for engagement of the drive pinion and burring of the gear teeth will result.

Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine or a defective starting motor.

If the engine, battery and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.

2. Disconnect the starting motor cables and solenoid wiring.

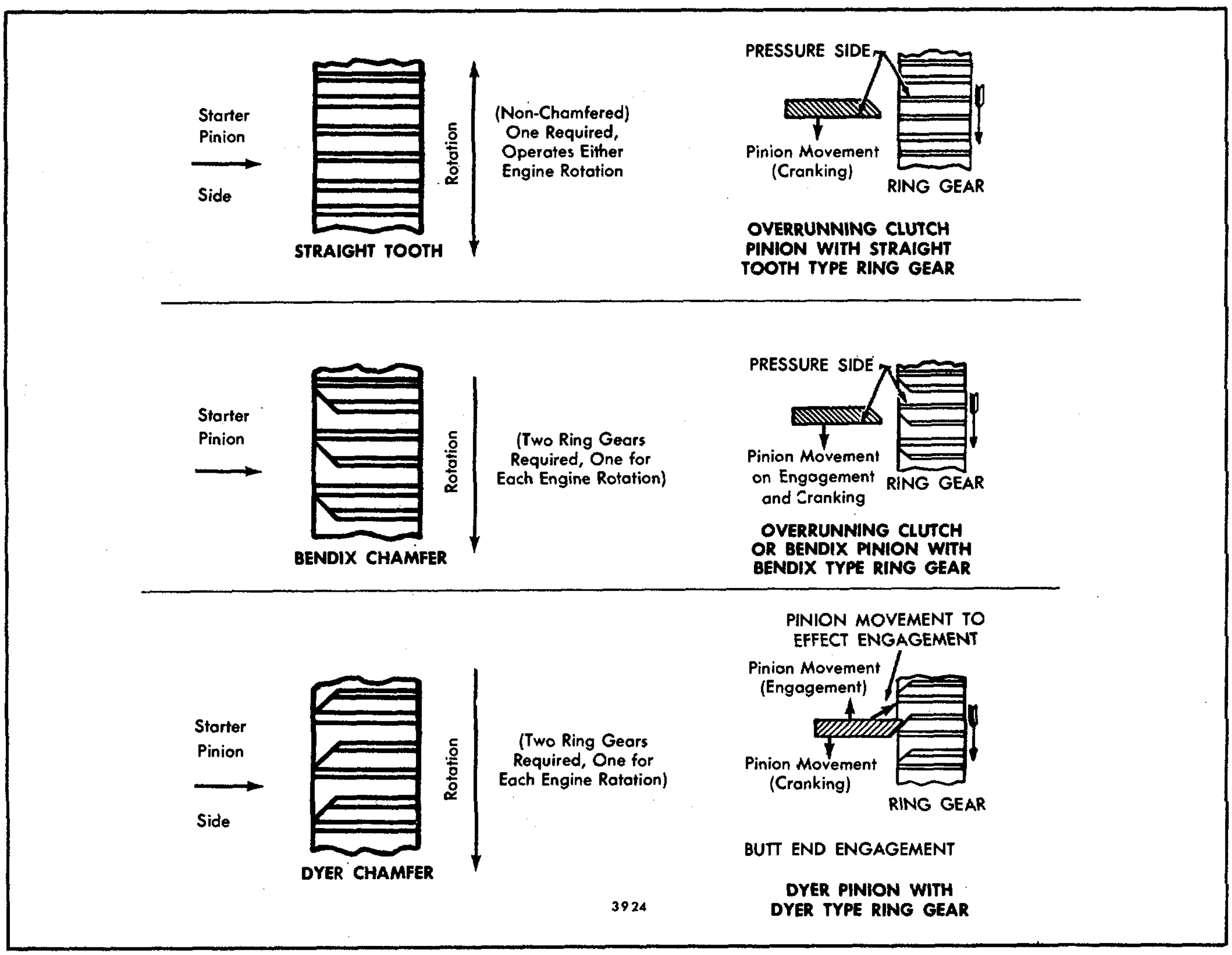


FIG. 4 - Types of Flywheel Ring Gears

NOTE: Tag each lead to ensure correct connections when the starting motor is reinstalled.

3. Support the motor and remove the three bolts and lock washers which secure it to the flywheel housing. Then pull the motor forward to remove it from the flywheel housing.

Check the starting motor in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal. Tighten the 5/8 "-11 starter attaching bolts to 137-147 lb-ft (186-200 Nm) torque.

Keep all of the electrical connections clean and tight. When instal1ing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connecti6ns to 16-30 **lb-in** (1.8-3.4 Nm) torque and the 1/2 "-13 connections to 20-25 lb-ft (27-34 Nm) torque.

INSTRUMENTS AND TACHOMETER DRIVE

INSTRUMENTS

The instruments generally required in the operation of a diesel engine consist of an oil pressure gage, water temperature gage, an ammeter and a mechanical tachometer. Instruments with slotted cases are available for use with lighted dashes. Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starting switch, engine stop knob and an emergency stop knob.

Oil Pressure Gage

The oil pressure gage registers the pressure of the lubricating. oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed in the *Operating Conditions* in Section 13.2, the engine should be stopped and the cause of the low oil pressure determined and corrected before the engine is started again.

Current oil pressure gages have male threads and require female fittings. When replacing a former gage with female threads, a new mounting clamp and connector must be used.

Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

Incorrect coolant temperature readings will be registered if the gage assembly is incorrectly installed or the capillary tube is damaged.

To prevent damage to the gage assembly from vibration, the capillary tube must be securely fastened to the engine the full length with suitable clips at intervals of ten inches or less. Sharp bends in the tube must be avoided, particularly at the gage or bulb connection areas. Where the tube must be bent around any object, the bend must not be less than one inch radius.

Any extra length can be taken up by coiling, the diameter of which should not be less than two inches. The coils must be located so that they may be securely fastened to prevent vibration.

Ammeter

The ammeter is wired into the electrical circuit to show the current flow to and from the battery. After starting the engine, the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery to replenish the current used to start the engine. As the engine continues to operate, the ammeter should show a decline in the charge rate to the battery. The ammeter will not show zero charge rate since the regulator voltage is set higher than the battery voltage. The small current registered prevents rapid brush wear in the battery-charging generator. If lights or other electrical equipment are connected into the circuit, then the ammeter will show discharge when these items are operating and the engine speed is reduced.

Tachometer

The tachometer, driven by the engine, registers the speed of the engine in revolutions per minute (rpm).

Throttle Control

The engine throttle is connected to the governor speed control shaft through linkage. Movement of the speed control shaft changes the speed setting of the governor and thus the engine speed.

Engine Starting Switch

To start the engine, a switch (Fig. 1) is used to energize the starting motor. Starting switches may vary in design and their contacts must be rated sufficiently to carry the starter solenoid current.

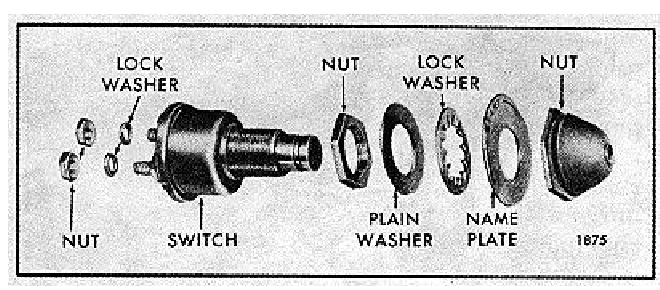


FIG. 1 - Typical Engine Starting Switch Assembly

NOTE: Tighten the starting switch mounting nut to 36-48 lb-in(4-5.5 Nm) torque.

Engine Stop Knob

A stop knob is used to stop the engine. When stopping an engine, the engine speed should be reduced to idle and the engine allowed to operate at idle for a few minutes to permit the coolant to reduce the temperature of the engine's moving parts. Then pull the stop knob and hold it until the engine stops. Pulling on the stop knob manually places the injector racks in the no-fuel position. Return the stop knob to its original position after the engine stops.

Emergency Stop Knob

In an emergency, or if the engine continues to operate after pulling the stop knob, the emergency stop knob may be used to stop the engine. When the emergency stop knob is pulled, the air shut-off valve, located between the air intake and the blower, will trip and shut off the air supply to the engine. Lack of air to the engine will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed -back in after the engine is stopped and the air shut-off valve must be re-set manually. The cause of the malfunction should be determined before the engine is started again.

TACHOMETER DRIVE

A tachometer drive shaft may be installed at any one of several locations on the engine.

At the front end of the engine, the tachometer drive shaft is pressed into the end of the right bank camshaft and extends through an adaptor attached to the balance weight cover (Fig. 2).

At the rear of the engine, the tachometer drive shaft may be installed in the end of either camshaft, the blower drive shaft or the L.H. helix blower rotor shaft (Fig. 3). A tachometer drive shaft adaptor is attached,

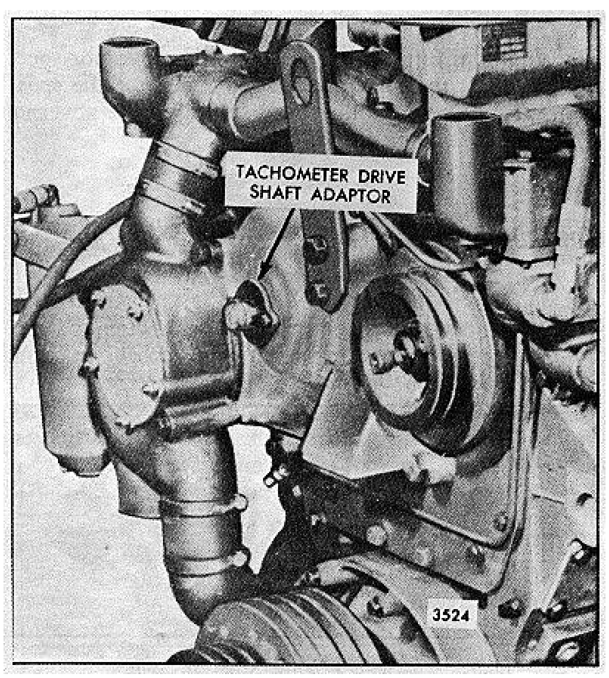


FIG. 2 - Front Mounted Tachometer Drive

to the flywheel housing cover or the blower rear end plate cover.

When required, a tachometer drive cable adaptor is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adaptor.

The cable connection at the current tachometer head is a 5/8 " threaded connection in place of the former 7/8 " connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size has been increased from 5/32 " to SAE 3/16 ". New flexible drive cables are also required with the current tachometers and angle drives.

Remove Tachometer Drive (Camshaft or Blower Drive Shaft Driven)

If replacement is necessary, remove the tachometer drive shaft as follows:

1. Disconnect the tachometer drive cable from the tachometer drive cable adaptor.

2. If used, remove the tachometer drive cable adaptor and key (key and seal assembly if the tachometer drive shaft is driven by the blower, drive shaft).

3. Remove the tachometer drive shaft adaptor and gasket from the balance weight cover if the tachometer drive is located at the front of the engine. For a rear mounted tachometer drive, remove the flywheel housing cover and adaptor assembly and gasket. Examine the oil seal, if used, for wear or damage. Replace the oil seal (camshaft drive) or oil seal unit (blower drive shaft drive), if necessary.

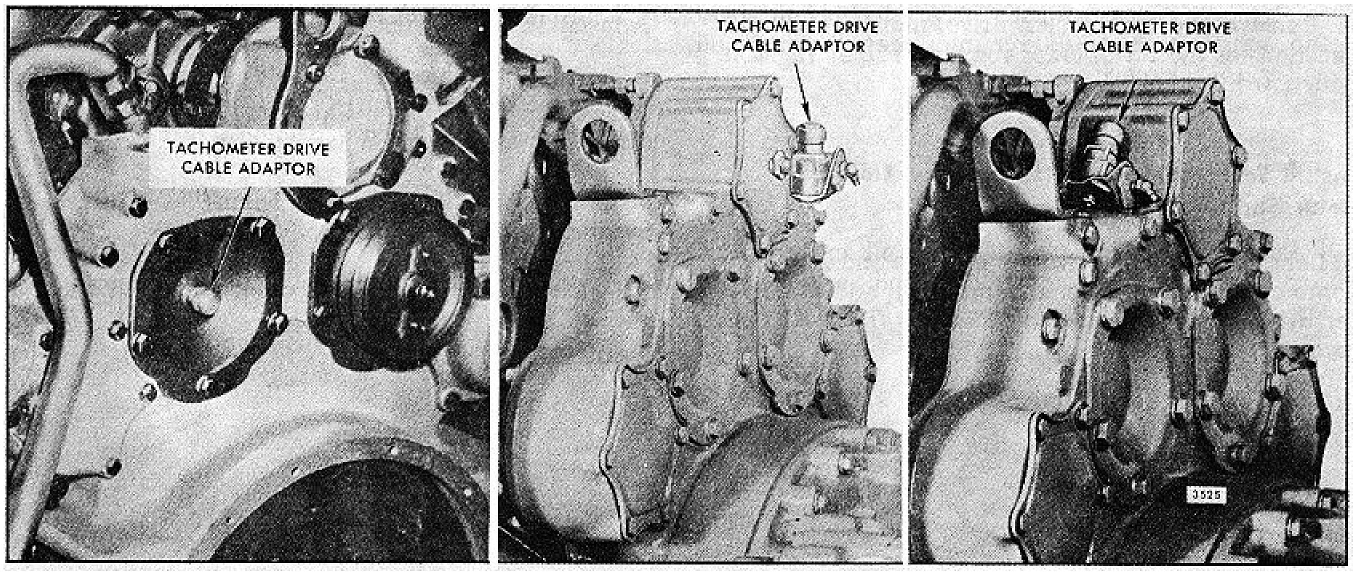


FIG. 3 • Rear Mounted Tachometer Drives

4. If the tachometer drive shaft is driven by the blower drive shaft, remove the blower drive shaft.

5. If the tachometer drive shaft is pressed into the end of the camshaft, it cannot be turned since the end is either square or knurled. Remove the drive shaft as follows:

a. If threads (5/16 "-24 or 3/8 "-24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901-3 on the shaft. Then attach slide hammer J 23907-I to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.

b. If threads are not provided on the outer end of the tachometer drive shaft, or if the end of the shaft is broken off, drill and tap the shaft. Then thread a stud into the shaft and remove the shaft with the remover and slide hammer.

NOTE: Use adequate protective measures to prevent metal particles from falling into the gear train and oil pan.

Install Tachometer Drive (Camshaft or Blower Drive Shaft Driven)

When installing a tachometer drive cover assembly or a drive adaptor, it is important they be aligned properly with the tachometer drive shaft (Section 7.0).

1. Start the tachometer drive shaft in the end of the camshaft or blower drive shaft. Then, using a suitable sleeve, tap or press against the shoulder on the tachometer drive shaft until the shoulder contacts the camshaft or blower drive shaft.

2. Install the blower drive shaft.

3. Use a new gasket and install the tachometer drive cover and adaptor on the balance weight cover or flywheel housing.

4. Check alignment of the tachometer drive shaft as outlined in Section 7.0.

5. Install the oil seal and key assembly (blower drive shaft driven tachometer drive).

6. If used, install the tachometer drive cable adaptor and key. Lubricate the tachometer drive cable adaptor with grease through the fitting provided.

7. Attach the tachometer drive cable.

Remove Tachometer Drive (Driven by Blower Rotor Shaft)

If replacement is necessary, remove the tachometer drive shaft as follows:

1. Disconnect the tachometer drive cable from the tachometer drive cable adaptor.

2. Remove the tachometer drive cable adaptor and key.

3. Remove the blower from the engine as outlined in

4. Remove the blower rear end plate cover.

5. Remove the tachometer drive shaft, which also functions as the L. H. blower rotor gear retaining bolt, with a 3/4 " wrench.

Install Tachometer Drive (Driven by Blower Rotor Shaft)

1. Lubricate the threads with engine oil and install the combination blower rotor retaining bolt and tachometer drive shaft. Tighten it to 55-65 lb-ft (75-88 Nm) torque.

2. Install the blower rear end plate cover.

3. Align the blower rear end plate cover with the tachometer drive shaft. Check the alignment of the drive shaft as outlined in Section 7.0.

4. Install the blower on the engine as outlined in Section 3.4.

5. Install the tachometer drive cable adaptor and key.

6. Attach the tachometer drive cable.

ENGINE PROTECTIVE SYSTEMS
MANUAL SHUTDOWN SYSTEM

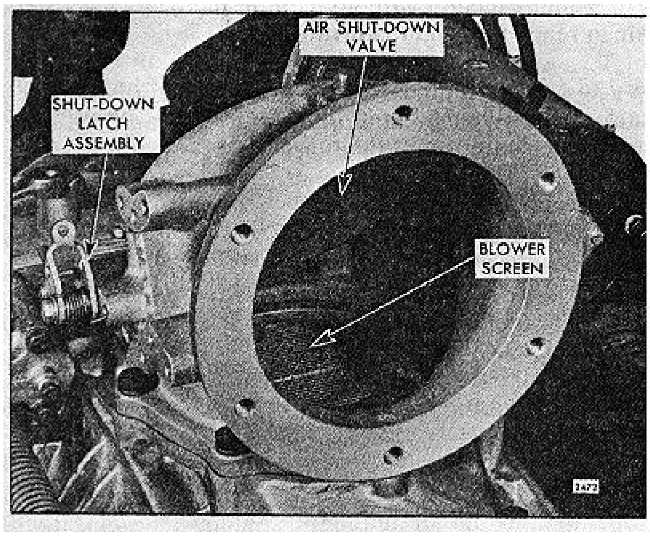


FIG. 1-Manually Operated Emergency Engine Shutdown Valve Mounting

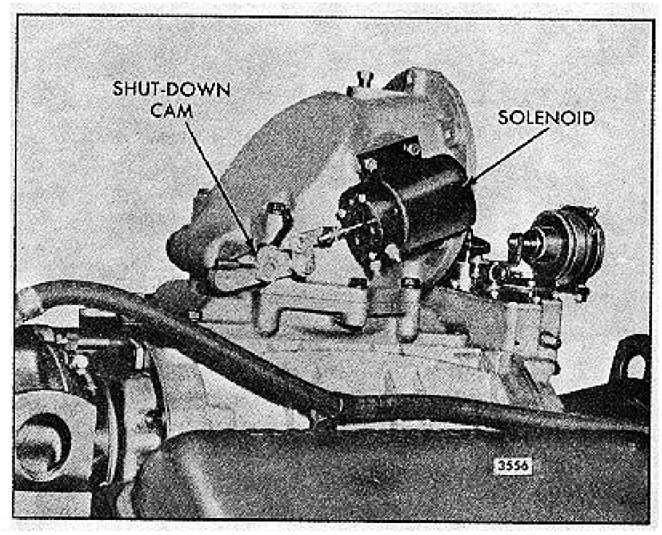


FIG. 2-Solenoid Operated Emergency Engine Shutdown Device Mounting

A manually operated emergency engine shutdown device, mounted in the air shutdown housing, enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the NO-FUEL position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shutdown device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The device consists of a shutdown valve mounted in the air shutdown housing and a suitable operating mechanism (Fig. 1).

The air shutdown valve is retained in the open position by a latch. A Bowden wire or cable assembly is used to trip the latch. Pulling the emergency shutdown knob all the way out will stop the engine. After the engine stops, the operator must push the emergency shutdown knob all the way in and manually reset the air shutdown device before the engine is started again.

NOTE: An electrically operated emergency shutdown device is used on certain engines. This device is similar to the manual shutdown except that a solenoid, operated by a push button switch, is used to trip the shutdown latch (Fig. 2).

Service

For removal and installation or disassembly and assembly of the manual shutdown device, refer to Section 3.3.

SHUTDOWN SYSTEM FOR DIRECT MOUNTED TURBOCHARGED ENGINES

With the use of a direct mounted turbocharger and the spring loaded fuel injector control racks, the air shutoff valve was eliminated from the air inlet housing. The spring loaded injector control racks enable the engine to come out of any advanced fuel position when an emergency situation arises.

When an engine is operating in an atmosphere subject to volatile fuel and is equipped with an air inlet housing without the air shutoff valve, a customer may request that the engine be equipped with an external or remote mounted emergency air shutdown assembly.

The remote mounted emergency air shutdown assembly that is equipped with the air shutoff valve can be installed upstream of the air inlet side of the turbocharger.

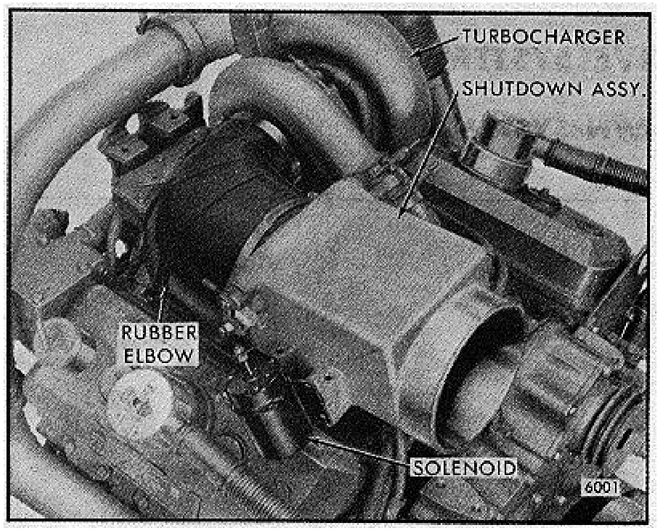


FIG. 3-Emergency Shutdown Assembly (Direct Mounted Turbocharger)

Care should be taken when installing the emergency air shutd6wn assembly (Fig. 3) between the turbocharger and the air cleaner. Because the engine shutdown system is activated, all of the piping between the shutdown system and the engine will be subjected to an abnormally high suction which may cause some of the piping components, i.e., rubber hoses and elbows to collapse. Therefore, it is recommended that all of these components be designed to withstand the maximum suction without a failure which would allow air to reach the engine air intake.

A 7 to 5 inch diameter reducing 90 rubber hose or a 7 to 5 inch diameter hump hose reducer can be used to adapt the shutdown to the turbocharger.

The rubber elbow can be obtained from the manufacturer; Griffin Rubber Mills in Portland, Oregon under their part number 51759.

For the relative position of the emergency air shutdown system when installed on a Detroit Diesel engine in a direct mounted location refer to Fig. 3. The customer is also required to provide the mounting support brackets.

The emergency air shutdown assembly is manually operated. To be an automatic shutdown system, it will be necessary to install a solenoid.

SHOP NOTES - TROUBLE SHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

CHECK ENGINE STARTING SWITCH

If difficulty in starting motor engagement has been experienced in a vehicle which has been repowered by a diesel engine, check to see if the key-type starting switch on the instrument panel has been retained.

Key-type starting switches are usually not capable of carrying the current required for heavy-duty diesel engine starter solenoids. The excessive voltage drop in the solenoid circuit restricts the solenoid pull and results in failure of the starter to engage and crank. When tooth abutment occurs and the switch is turned off and on several times, breaking of the solenoid current causes burning or welding of the switch contacts. Install a push button type starting switch which is capable of making, breaking and carrying the solenoid current without damage (refer to *Engine Starting Motor Switch* in Section 7.4). Otherwise, a heavy-duty magnetic switch should be used in the solenoid control circuit in addition to the key-type switch. The magnetic switch must be capable of making and breaking at least 90 amperes in a 12 volt system; the key switch would then carry no more than one ampere, which is sufficient to operate the magnetic switch.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

Whenever a tachometer drive cover assembly or a tachometer drive adaptor is installed on an engine, it is important that the cover assembly or adaptor be aligned properly with the tachometer drive shaft.

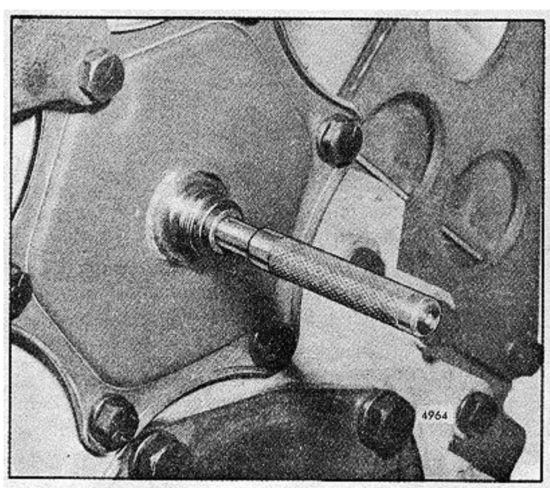


FIG. 1-Checking Tachometer Drive Shaft Alignment

Misalignment of a tachometer drive shaft can impose a side load on a tachometer drive cable adaptor resulting in possible gear seizure and damage to other related components. Use one of three tools in set J 23068 to establish the proper alignment. Figure I illustrates the use of the tools.

Because of the many different combinations of tachometer drive shafts, covers and adaptors, it is not practical to itemize specific usages for each tool. When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool.

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand rotation of the engine is made.

TROUBLE SHOOTING

CHECKING ENGINE ELECTRICAL GENERATING SYSTEM

Whenever trouble is indicated in the electrical generating system, the following quick checks can be made to assist in localizing the cause.

A fully charged battery and low charging rate indicates normal generator-regulator operation.

A low battery and high charging rate indicates normal generator-regulator operation.

A fully charged battery and high charging rate condition usually indicates the voltage regulator is set too high or is not limiting the generator output. A high charging rate to a fully charged battery will damage the battery and other electrical components.

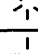
A low battery and low or no charging rate condition could be caused by: Loose connections or damaged wiring, defective battery or generator, generator not or improperly polarized, and defective regulator or improper regulator setting.

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	260M BOLTS TORQUE Nm	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	280M OR BETTER TORQUE Nm
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 over 3/4 to 1 1/2	74,000 60,000
 Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
 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
 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 SIZE	TORQUE lb-ft	TORQUE Nm
Tachometer drive cover bolt	7/16-14	30-35	41-47
Tachometer drive cover bolt	1/2-13	30-35	41-47
Tachometer drive shaft (blower)	1/2-20	55-65	75-88
Starting motor switch mounting nut	5/8-32	§	§

§36-48 **lb-in.** (4-5.5 Nm).

SERVICE TOOLS

TOOL NAME	TOOL NO.
Puller set	J 5901-01
Slide hammer and shaft	J 23907-1
Tachometer drive shaft remover	J 5901-3
Tachometer drive alignment tool set	J 23068

SECTION 12

SPECIAL EQUIPMENT

CONTENTS

AIR COMPRESSOR

The air compressor (Fig. 1) may be mounted on a bracket attached to the cylinder block of the engine and belt-driven from the crankshaft pulley, or it may be flange-mounted to the flywheel housing and gear driven by means of an accessory drive attached to a camshaft gear.

A six bolt design air compressor mounting base, mounting bracket and gasket are used on current engines equipped with a belt-driven air compressor. Formerly, the air compressor was attached to the base and bracket with four bolts. When installing a new air compressor, it is recommended that the new mounting parts be used to eliminate the possibility of the bracket loosening and causing oil seepage at the gasket.

The air compressor runs continuously while the engine is running. While the compressor is running, actual compression of air is controlled by the compressor governor which acts in conjunction with the unloading mechanism in the compressor cylinder block. The governor starts and stops the compression of air by loading or unloading the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During the down stroke of each piston, a partial vacuum is created above the piston which unseats the inlet valve and then allows air drawn from the air box in the engine cylinder block or through an intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves, plus the inlet valve return spring force, closes the inlet valve. The air above the piston is further compressed until the

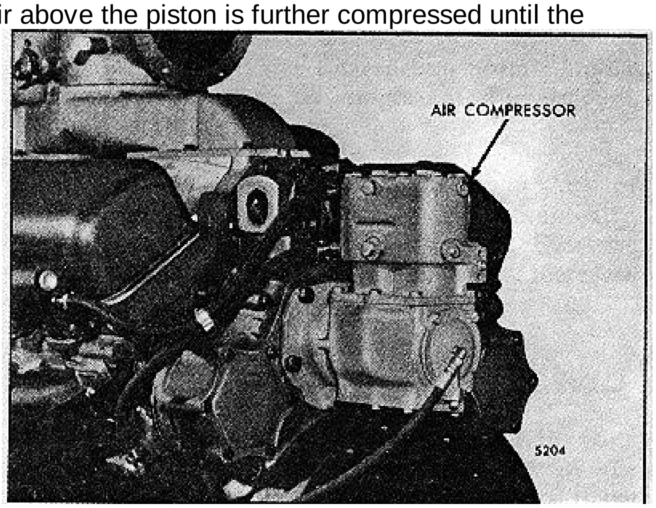


FIG. 1-Air Compressor Mounting

pressure lifts the discharge valve and the compressed air is discharged through the discharge line into the reservoir.

As each piston starts its downstroke, the discharge valve above it returns to its seat, preventing the compressed air from returning to the cylinder and the same cycle is repeated.

When the air pressure in the reservoir reaches the maximum setting of the governor, compressed air from the reservoir passes through the governor into the cavity below the unloading pistons in the compressor cylinder block. The air pressure lifts the unloading pistons which in turn lifts the inlet valves off their seats.

With the inlet valves held off their seats, the air during each upstroke of the piston is merely passed back through the air inlet cavity and to the other cylinder where the piston is on the downstroke. When the air pressure in the reservoir drops to the minimum setting of the governor, the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring then forces the piston down and the inlet valve springs return the inlet valves to their seats and compression is resumed.

Service Note

When installing a pulley or a drive hub on a flange mounted air compressor (Fig. 2), it is important the 3/4"-10 drive shaft slotted nut be tightened to 100 3b-ft (136

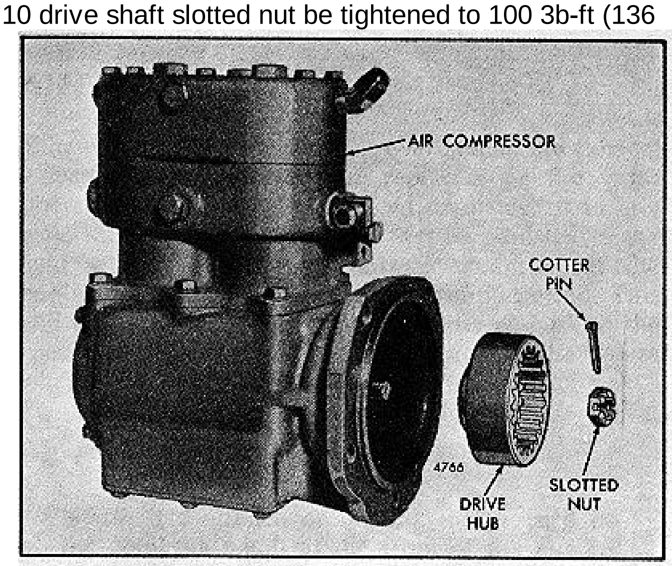


FIG. 2-Typical Air Compressor with Drive Hub

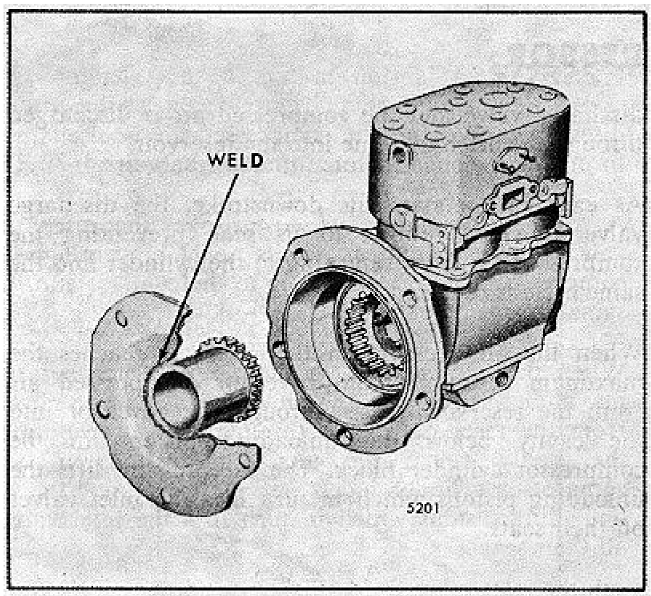


FIG. 3 - Fixture for Holding Drive While Installing or Removing Slotted Nut

Nm) torque minimum before installing the 3 /32 "x 1-1/4 " cotter pin.

The air compressor drive shaft will turn during the torquing operation unless some provision is made to hold it. One way this can be done is to weld a rnodified drive coupling to a support or base which in turn can be anchored to the mounting flange of the compressor. An old flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. With the exterior splines of the coupling in mesh with the internal splines of the drive hub and the entire assembly secured to the compressor housing, the hub and shaft are kept from rotating when the torque is applied. That part of the base within the inner diameter of the coupling must be removed to permit placement of the wrench socket on the nut. Two bolts will secure the base to the compressor during the torquing operation (Fig. 3).

When installing the air compressor support bracket on the upper portion of the flywheel housing on an early engine, it will be necessary to remove the threads in the blower drive support in conjunction with the 3/8"-24 x 6 " mounting bracket attaching bolt. It may be necessary to use shims, as required, to obtain the proper alignment of the air compressor mounting bracket.

COLD WEATHER STARTING

When starting an internal combustion engine in cold weather, a large part of the energy of combustion is absorbed by the pistons, cylinder walls, coolant and in overcoming friction.

Under extremely low outside temperatures, the cold oil in the bearings and between the pistons and cylinder walls creates very high friction and the effort required to crank the engine is much greater than when the engine is warm.

In a diesel engine, the normal means of igniting the fuel sprayed into the combustion chamber is by the heat of the air compressed in the cylinder. This temperature is high enough under ordinary operating conditions, but at extremely low outside temperatures may not be sufficiently high enough to ignite the fuel injected.

To assist in starting an engine under low temperature conditions, cold weather starting devices are available.

NOTE: Starting aids are not intended to correct deficiencies such as low battery, heavy oil, etc. They are for use when other conditions are normal but the air temperature is too low for the heat of compression to ignite the fuel-air mixture.

PRESSURIZED CYLINDER STARTING AID

Operation

Start the engine during cold weather, using the "Quick Start" starting aid system (Fig. l) as follows:

1. Press the engine starter button.

2. Pull out the "Quick Start" knob for one or two seconds, then release it.

3. Repeat the procedure if the engine does not start on the first attempt.

CAUTION: Do not crank the engine more than 30 seconds at a time when using an electric starting motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

Service

Periodically perform the following service items to assure good performance:

1. Remove the fluid cylinder and lubricate the valve around the pusher pin under the gasket with a few drops of oil.

2. Lubricate the actuator cable.

3. Actuate the valve with the cable to distribute the oil on the cable and allow the oil to run down through the valve.

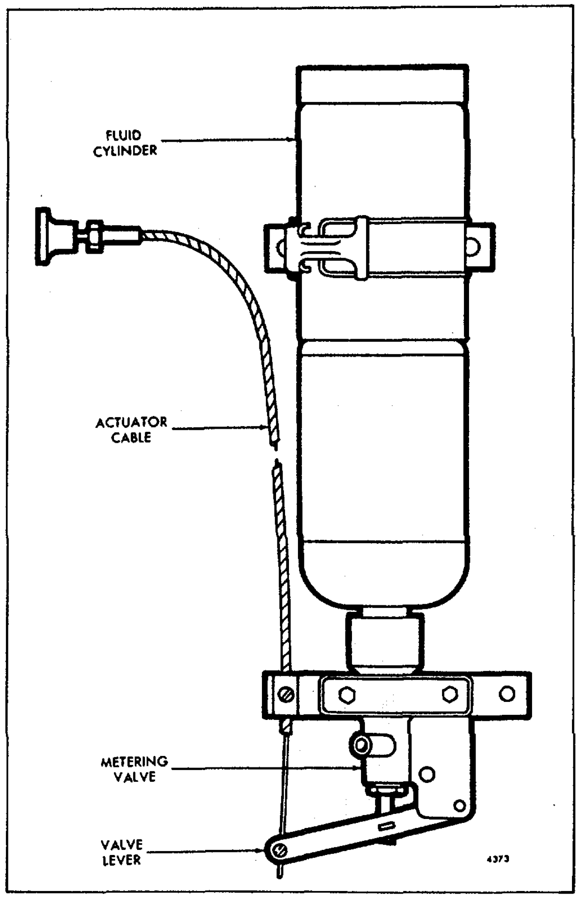


FIG. 1-"Quick Start" Assembly

4. Remove any dirt from the orifice by removing the air inlet housing fitting, the orifice block and the screen. Then blow air through the orifice end only.

5. Assemble and tighten the air inlet housing fitting to the actuator valve and tube.

6. Check for leakage of fluid (fogging) on the outside of the engine air inlet housing by actuating the starting aid while the engine is stopped. If fogging occurs, disassemble and retighten the air inlet housing fitting to the housing.

CAUTION: Do not actuate the starting aid more than once with the engine stopped. *Over-loading the engine air box with this high volatile fluid could result in a minor explosion.*

7. Check the fluid cylinder for hand tightness.

FLUID STARTING AID

The fluid starting aid is designed to inject a highly volatile fluid into the air intake system to assist ignition of the fuel at low ambient temperatures. It consists essentially of a pump and nozzle for injecting the fluid into the air intake and a suitable container for the fluid (Fig. 2). The fluid is contained in suitable capsules to facilitate handling.

This starting aid consists of a cylindrical capsule container fitted with a screw cap. Inside the container is a sliding plunger-like piercing shaft. From the capsule container, a tube leads from the container to a hand-operated pump and another tube leads from the pump to an atomizing nozzle threaded into a tapped hole in the air inlet housing.

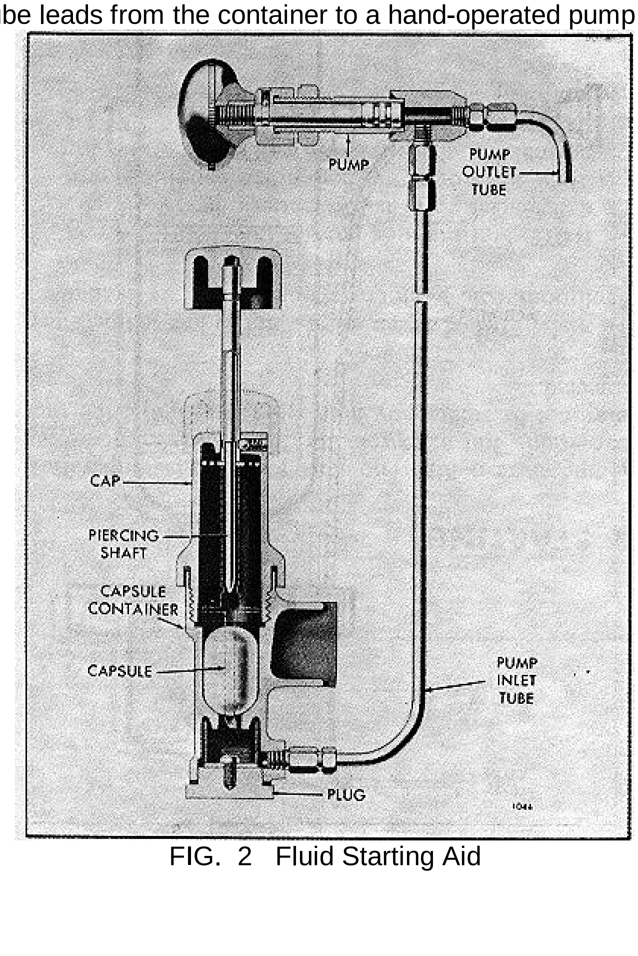


FIG. 2 Fluid Starting Aid

Installation

The pump may be mounted on the instrument panel or in some other convenient location. The capsule container must be mounted in a vertical position away from such high heat areas as the exhaust manifold, muffler, etc. and should not be located under a hood or in a cab. The atomizing nozzle is screwed into a tapped hole in the air inlet housing. The tank-to-pump tube should be 3/16 " O. D. copper tubing and the pump-to-nozzle tube 1/8 " O. D.

Operation

1. Refer to Fig. 2 and remove the cap from the capsule container. Insert a fluid capsule in the container.

CAUTION: Mount the capsule in an upright position within the container. Use care when handling, since the starting fluid is both toxic and inflammable.

2. Pull the piercing shaft all the way out and thread the cap tight on the container.

3. Push the piercing shaft down until it bottoms. This will break the capsule and fill the container with starting fluid vapor.

4. Move the engine throttle to the full-fuel position.

5. Engage the starter and simultaneously pull the pump plunger all the way out. Then push the plunger i*n slowly,* forcing the starting fluid through the atomizing nozzle and into the air intake. Continue to push the pump plunger in until the engine starts. If the plunger is not all the way in when the engine starts, push is in *very slowly* until it locks in the *in* position.

6. Unscrew the cap and remove the used capsule. Do *not leave the empty capsule in the container.*

7. Reinstall the cap tightly on the container body.

NOTE: When not in use, the piercing shaft should be all the way down.

Starting Aid Pump

The principal parts of the starting aid pump are the body, plunger and the spring-loaded ball type inlet and outlet check valves (Fig. 2). The pump body is threaded externally at one end for mounting purposes. One end of the plunger is threaded into the operating knob. Two seal rings of oil resistant material are located in grooves at the other end of the plunger. The inlet check valve, which opens on the suction stroke of the plunger and seats under pressure, is located in the side opening of the pump body. The outlet check valve, which seats under suction and opens under pressure, is installed in the end opening of the pump body. The check valves are identified by the number "1/2" stamped on the inlet valve and the number "30" on the outlet valve. An arrow indicating the direction of flow is also stamped on each check valve.

Remove Pump

Remove the starting aid pump from the mounting panel as follows:

1. Disconnect the starting fluid inlet and outlet tubes from the pump.

2. Unscrew the plunger nut from the pump body and withdraw the plunger assembly.

3. Loosen the pump body jam nut behind the mounting panel.

4. Remove the pump body from the rear of the panel.

5. Remove the jam nut from the pump body.

Disassemble Pump

When the pump was removed from its mounting panel, the plunger assembly was removed from the pump body. If further disassembly is required, proceed as follows:

1. Unscrew the knob from the plunger assembly.

2. Slide the plunger nut from the plunger.

3. The plunger lock ball and spring may be removed by tapping the plunger nut to dislodge them. It is not necessary to remove the plug.

4. Remove the inlet and outlet check valves.

Inspection

Clean the parts with fuel oil and dry them with compressed air. Examine the seal rings for wear or cracks. Replace the seat rings if necessary. The check valves cannot be disassembled. However, they may be cleaned by forcing fuel oil through them with any suitable pump. Inoperative valves must be replaced.

If excessive resistance was encountered during operation of the pump, the nozzle in the air inlet housing may be plugged. Remove and clean the nozzle.

Assemble Pump

1. Install new seal rings on the plunger.

2. Install the lock spring in the plunger nut. Then place the steel ball on top of the spring.

3. Depress the lock ball and slide the plunger nut--hex end first--over the threaded end of the plunger.

4. Thread the knob on the plunger.

5. Install the outlet check valve (marked "30") in the end opening of the pump body. The arrow must point away from the pump body.

6. Install the inlet check valve (marked "1/2") in the side opening of the pump body. The arrow must point toward the pump body.

Install Pump

1. Thread the jam nut on the pump body.

2. Insert the thread end of the pump body through the mounting panel (from the rear of the panel).

3. Lubricate the seal rings and carefully slide the plunger assembly into the pump body. Thread the plunger nut on the end of the pump body and tighten it.

4. Install the starting fluid inlet and outlet tubes.

5. If removed, install the nozzle in the air inlet housing.

SECTION 13

OPERATING INSTRUCTIONS

CONTENTS

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow the instructions in Sections 13 and 14 of this manual. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

> **NOTE:** When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15. *1.*

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped.

Remove the filler cap and fill the cooling system with a coolant specified under *Engine Coolant* in Section 13.3. Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

Close the vents, if used, after filling the cooling system.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 25 psi (172 kPa) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use *heavy-duty* lubricating oil as specified under *Lubricating Oil Specifications* in Section 13.3. Then remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the full mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with *heavy-duty* lubricating oil as specified under *Lubricating Oil Specifications* in Section 13.3. Then prelubricate the upper engine parts by removing the valve rocker covers and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Turbocharger

1. Clean the are and disconnect the oil inlet line at the bearing housing.

2. Fill the bearing housing cavity with clean engine oil. Turn the rotating assembly by hand to coat all of the internal surfaces with oil.

3. Add additional engine oil to completely fill the bearing housing cavity and reinstall the oil line. Clean off any spilled oil.

> **CAUTION:** Do not hold the compressor wheel, for any reason, while the engine is running. This could cause personal injury.

4. Start and run the engine at idle until oil pressure and supply has reached all of the turbocharger moving parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers pressure (10 psig-69 kPa at idle speed).

The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure *before the turbocharger reaches its maximum operating speed* which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with clean engine oil. *Do not overfill.*

Transmission

Check the oil level and, if necessary, add sufficient oil to bring it to the proper level.

Fuel System

Fill the fuel tank with the fuel specified under *Diesel Fuel Oil Specifications* in Section 13.3.

If the unit is equipped with a fuel valve, it must be opened.

To ensure prompt starting, fill the fuel system between the pump and the fuel return manifold with fuel. If the engine has been out of service for a considerable length of time, prime the fuel system between the fuel pump and the fuel return manifold. The fuel system may be primed by removing-the plug in the top of the fuel filter cover and slowly filling the filter with fuel.

NOTE: The fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings (except for fan hub pulley fitting--refer to Section 15.1) with an all purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrication and Preventive Maintenance* in Section 15.1.

Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly and the electrolyte must be at the proper level.

> **NOTE:** When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart,* Section 15.1.

To start the engine, proceed as follows:

1. Apply the hand brake firmly. Put the transmission shift lever in the *neutral* position.

2. Make sure the engine *stop* and *emergency stop* knobs are pushed all the way in.

3. Hold the clutch pedal down. Energize the starter. If the engine does not start within 30 seconds, wait one minute to allow the starting motor to cool before trying again. If the engine does not start after four attempts, it is recommended that an inspection be made to determine the cause. Refer to *Trouble Shooting Charts,* in Section 15.2.

4. Release the starting switch immediately when the engine starts. Check the oil pressure gage; oil pressure should be indicated within a few seconds after starting.

> **NOTE:** Do not push or tow the vehicle to start it. Excessive raw fuel will be introduced into the engine and serious damage to the cylinders and pistons will result.

Starting at air temperatures below 40 °F (4 °C) requires the use of a cold weather starting aid. See *Cold Weather Starting,* Section 12.6.

CAUTION: Starting fluid used in capsules is highly inflammable, toxic and possesses anesthetic properties.

The instructions for the use of a cold weather fluid starting aid will vary dependent on the type being used, Reference should be made to these instructions before attempting a cold weather start.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. Refer to the *Trouble Shooting Charts* in Section 15.2.

Warm-Up

Run the engine at part throttle and no load for approximately five minutes, allowing it to warm-up before applying a load.

Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

Engine Temperature

Normal engine coolant temperature is 160-185 °F (71-85 °C.

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately twenty minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the *heavy duty* lubricating oil specified under *Lubricating Oil Specifications* in Section 13.3.

Cooling System

Remove the radiator cap *slowly* after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or a permanent type antifreeze.

Turbocharger

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

> **NOTE:** When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Normal Stopping

1. Put all of the transmission shift levers in the *neutral* position and apply the hand brake.

2. Allow the engine to run at half speed or slower with no lead for four or five minutes, then turn the control switch to o*ff* and pull the *stop* knob all the way out.

Emergency Stopping

To stop an engine (normal or emergency) equipped with the spring-loaded (one screw) design injector control tube, pull the governor stop lever to the stop position.

If an engine equipped with the non-spring loaded (two screw) design control tube does not stop after using the normal stopping procedure, pull the *Emergency Stop* knob all the way out. This control cuts off the air to the engine. Do not try to restart again until the cause for the malfunction has been found and corrected.

> **NOTE:** The emergency shutdown system should never be used except in an emergency. Use of the emergency shutdown can cause oil to be sucked past the oil seals and into the blower housing.

The air shut-off valve, located on the blower air inlet housing, must be reset by hand and the *Emergency Stop* knob pushed in before the engine is ready to start again.

Fuel System

Fill the fuel tank; a full tank minimizes condensation.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open.

Crankcase

Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.

Transmission

Check and, if necessary, add sufficient oil to bring *it* to the proper level.

Inspection

Make a visual check for leaks in the fuel, lubricating and cooling systems.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to the *Lubrication and Preventive Maintenance Chart* in Section 15.1 and perform all of the daily maintenance operations. Also perform all of the operations required for the number of miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which may have occurred during the previous run.

ENGINE OPERATING CONDITIONS

The engine operating charts are included as an aid for engine operation and trouble shooting. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Make sure that the readings represent true values, and that instruments are accurate, before attempting to make corrections to the engine

V-71 ENGINES (2-Valve Head)

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40-55	50-70	50-70
Min. for safe operation	25	28	30
† Lubricating oil temperature (degrees F.):			
Normal	200-235	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure	1.2	4.3	6.0
At max. exhaust back pressure	2.3	6.8	9.0
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (oil or dry)	12.4	25.0	25.0
Clean air cleaner (with pre-cleaner) (oil or dry)	8.7	13.4	15.9
Clean air cleaner (less pre-cleaner) (dry type)	5.2	9.1	11.5
Crankcase pressure (inches water) - max.	0.2	0.7	1.0
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	3.3	4.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal (.080" orifice)	30-65	45-70	45-70
Minimum	30	30	30
Fuel spill (gpm) - min. at no load	0.8	0.9	0.9
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

V-71E ENGINES (4-Valve Head)

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32-47	50-70	50-70
Min. for safe operation	25	28	30
† Lubricating oil temperature (degrees F.):			
Normal	200-235	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure	1.1	3.8	5.0
At max. exhaust back pressure	2.3	6.4	8.2
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (oil or dry)	12.4	25.0	25.0
Clean air cleaner (with pre-cleaner) (oil or dry)	8.7	13.4	15.9
Clean air cleaner (less pre-cleaner) (dry type)	5.2	9.1	11.5
Crankcase pressure (inches water) - max.	1.0	2.2	3.0
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	3.3	4.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal (.080" orifice - 6 and 8V engines)	45-70	45-70	45-70
Normal (.106" orifice - 12V engines)	45-70	45-70	45-70
Minimum	30	30	30
Fuel spill (gpm) - min. at no load:			
(6, 8 and 12V engines)	0.8	0.9	0.9
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

V-71N ENGINES

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	35-55	50-70	50-70
Min. for safe operation	25	28	30
† Lubricating oil temperature (degrees F.):			
Normal	200-235	200-235	200-235
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
N injector	1.0	3.3	5.0
C and 7E injector	1.0	2.7	4.5
At max. exhaust back pressure (clean ports):			
N injector	2.1	5.8	8.0
C and 7E injector	2.1	5.2	7.5
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (oil or dry)	12.4	25.0	25.0
Clean air cleaner (with pre-cleaner) (oil or dry)	8.7	13.4	15.9
Clean- air cleaner (less pre-cleaner) (dry type)	5.2	9.1	11.5
Crankcase pressure (inches water) - max.	1.0	2.2	3.0
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	3.3	4.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal (.080" orifice - 6, 8 and 12V engines)	45-70	45-70	45-70
Normal (.106" orifice 12V-71 with 3/8" pump)	45-70	45-70	45-70
Minimum	30	30	30
Fuel spill (gpm) - min. at no load:			
(6, 8 and 12V engines)	0.8	0.9	0.9
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
Vehicle engines built 1976 and later	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	565		
Minimum at 600 rpm	515		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

6V-71T ENGINES (with T18A40 TURBOCHARGER)
(1.00 A/R* Turbine Housing)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	0-70	50-70	50-70
Min. for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
C-65 injector	24.0	28.4	30.4
N-70 injector	26.0	30.6	32.9
N75 injector	28.4	32.9	35.2
At max. exhaust back pressure (clean ports):			
C-65 injector	22.5	26.5	28.5
N-70 injector	24.5	28.7	31.0
N-75 .injector	26.9	31.0	33.3
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (dry type)	14.5	18.0	20.0
Clean air cleaner (dry type)	8.7	10.8	12.0
Crankcase pressure (inches water) - max.	1.3	1.8	2.0
Exhaust back pressure (inches mercury) - max.:			
Full load	2.0	2.5	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) (normal)	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
Vehicle engines built 1976 and later	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.
* Turbine Housing Designation.

8V-71T ENGINES (with T1865 TURBOCHARGER)
(1.50 A/R* Turbine Housing)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50-70	50-70	50-70
Min. for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
N-65 injector	21.6	26.0	28.5
N-75 injector	23.1	28.2	31.0
At max. exhaust back pressure (clean ports):			
N-65 injector	20.4	24.2	26.5
N-75 injector	21.9	26.4	29.0
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (dry type)	14.5	18.0	20.0
Clean air cleaner (with pre-cleaner) (dry type)	8.7	10.8	12.0
Clean air cleaner (less pre-cleaner) (dry type)	5.8	7.2	8.0
Crankcase pressure (inches water) - max.	1.3	1.7	2.0
Exhaust back pressure (inches mercury) - max.:			
Full load	1.5	2.2	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) (normal)	45-70	45-70	45-70
Fuel spill (gpm) - min. at no load:			
(.070 orifice)	1.8	1.8	1.8
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.
* Turbine Housing Designation.

8V-71T ENGINES (with T18A40 TURBOCHARGER)
(1.50 A/R* Turbine Housing)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50-70	50-70	50-70
Min. for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exh. back pressure (w/o check valves):			
C65 injector	19.5	24.5	27.0
N70 injector	21.5	26.5	29.0
N75 injector	23.5	28.5	31.0
At max. exhaust back pressure:			
C65 injector	17.5	22.0	24.5
N70 injector	19.5	24.0	26.5
N75 injector	21.5	26.0	28.5
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (dry type)	14.5	18.0	20.0
Clean air cleaner (dry type)	8.7	10.8	12.0
Crankcase pressure (inches water) - max.	§1.3	§1.8	§2.0
Exhaust back pressure (inches mercury) - max.:			
Full load	2.0	2.5	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) - normal	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load:			
(.080” orifice)	0.9	0.9	0.9
(.106" orifice)	1.4	1.4	1.4
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
Vehicle engines built 1976 and later	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm.	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

* Turbine Housing Designation.

§ When single block-to-head breathing system is used, ADD:
0.6 in. to maximum limits for C65 injectors.
0.8 in. to maximum limits for N70 injectors.
1.0 in. to maximum limits for N75 injectors.

8V-71T ENGINES (with TV8101 TURBOCHARGER)
(1.39 A/R* Turbine Housing)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50-70	50-70	50-70
Minimum for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure (w/o check valves):			
N65 injector	26.5	32.7	35.9
N70 injector	28.5	34.7	37.9
N75 injector	30.5	36.7	39.9
At max. exhaust back pressure (clean ports):			
N65 injector	25.0	30.7	33.7
N70 injector	27.0	32.7	35.7
N75 injector	29.0	34.7	37.7
Air inlet restriction (clean ports) (inches water) max.:			
Full load speed:			
Dirty air cleaner (dry type)	20.0	20.0	20.0
Clean air cleaner (dry type)	12.0	12.0	12.0
Crankcase pressure (inches water) max.:			
N65 and N70	1.6	1.9	2.0
N75	2.2	2.5	2.6
Exhaust back pressure (inches mercury) - max.:			
Full load	2.0	2.6	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) (normal)	50-70	50-70	50-70
Fuel spill (gpm) min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) normal	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.
* Turbine Housing Designation

8V-71T ENGINES (with TV8101 TURBOCHARGER)
(1.60 A/R* Turbine Housing)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi)			
Normal	50-70	50-70	50-70
Minimum for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) min. full load:			
At zero exhaust back pressure (w/o check valves):			
C65 injector	25.2	30.4	33.0
N70 injector	26.5	31.8	34.5
N75 injector	27.9	33.3	36.0
At max. exhaust back pressure (clean ports):			
C65 injector	23.7	28.4	30.8
N70 injector	25.0	29.8	32.3
N75 injector	26.4	31.3	33.8
Air inlet restriction (clean ports) (inches water) max.:			
Full load speed:			
Dirty air cleaners (dry type)	20.0	20.0	20.0
Clean air cleaner (dry type)	12.0	12.0	12.0
Crankcase pressure (inches water) max.:			
C65 and N70	1.6	1.9	2.0
N75	2.2	2.5	2.6
Exhaust back pressure (inches mercury) max.:			
Full load	2.0	2.6	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) (normal)	50-70-	50-70	50-70
Fuel spill (gpm) min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) normal	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based of the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.
*Turbine Housing Designation.

8V-71T ENGINES (with 4MF 782 TURBOCHARGER)
(6.54 Nozzle Area)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50-70	50-70	50-70
Minimum for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
C65 injector	20.3	26.0	28.9
N70 injector	21.6	27.4	30.4
N75 injector	23.2	29.0	31.9
At max. exhaust back pressure (clean ports):			
C65 injector	18.8	24.1	27.0
N70 injector	20.1	25.5	28.5
N75 injector	21.7	27.1	30.0
Air inlet restriction (clean ports) (inches water) - max.:			
Full load speed:			
Dirty air cleaner (dry type)	14.5	18.0	20.0
Clean air cleaner (dry type)	8.7	10.8	12.0
Crankcase pressure (inches water) max.	§1.3	§1.8	§2.0
Exhaust back pressure (inches mercury) max.:			
Full load	2.0	2.5	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) (normal)	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

§ When single block-to-head breathing system is used, ADD:
0.6 in. to maximum limits for C65 injectors.
0.8 in. to maximum limits for N70 injectors.
1.0 in. to maximum limits for N75 injectors.

8V-71TA ENGINE (with TV7101 TURBOCHARGER)
(1.23 A/R* Turbine Housing)
(7.5 Gram - California)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating, oil pressure (psi)			
Normal	50-70	50-70	50-70
Min. for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air Box Pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
7A50 injector	29.6	35.3	38.4
7A55 injector	31.6	37.7	40.7
7A60 injector	33.5	39.6	42.7
7A65 injector	35.4	41.7	43.7
7A70 injector	38.1	44.1	46.4
7A75 injector	40.3	45.9	48.5
At max. exhaust back pressure (clean ports):			
7A50 injector	28.1	33.3	36.2
7A55 injector	30.1	35.7	38.5
7A60 injector	32.0	37.6	40.5
7A65 injector	33.9	39.7	41.5
7A70 injector	36.6	42.1	44.2
7A75 injector	38.8	43.9	46.3
Air inlet restriction (clean ports) (inches water) - max.:			
Full load speed:			
Dirty air cleaner (dry type)	20.0	20.0	20.0
Clean air cleaner (dry type)	12.0	12.0	12.0
Crankcase pressure (inches water) - max.	1.6	1.9	2.0
Exhaust back pressure (inches mercury) - max.:			
Full load	2.0	2.5	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) (normal)	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

*Turbine Housing Designation.

8V-71TA ENGINES (with TV7101 TURBOCHARGER)
(1.23 A/R* Turbine Housing)
(10 Gram - Federal)

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50-70	50-70	50-70
Minimum for safe operation	30	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure;			
N65 injector	33.2	38.7	41.3
7C70 injector	35.7	41.5	44.0
7C75 injector	38.2	44.0	46.6
At max. exhaust back pressure (clean ports):			
N65 injector	31.7	36.7	39.1
7C70 injector	34.2	39.5	41.8
7C75 injector	36.7	42.0	44.4
Air inlet restriction (clean ports) (inches water) - max.:			
Full load speed:			
Dirty air cleaner (dry type)	20.0	20.0	20.0
Clean air cleaner (dry type)	12.0	12.0	12.0
Crankcase pressure (inches water) - max.:			
N65 and 7C70	1.6	1.9	2.0
7C75	2.2	2.5	2.6
Exhaust back pressure (inches mercury) - max.:			
Full load	2.0	2.6	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) (normal)	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.
* Turbine Housing Designation.

8V-71TT ENGINES (with TV8101 TURBOCHARGER)
(1.39 A/R* Turbine Housing)

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32-70	50-70	50-70
Minimum for safe operation	25	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) - min. full load:			
At zero exhaust back pressure:			
N75 injector	12.5	32.5	35.5
At max. exhaust back pressure:			
N75 injector	11.9	31.0	33.6
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (dry type)	8.8	20.0	20.0
Clean air cleaner (dry type)	5.8	12.0	12.0
Crankcase pressure (inches water) - max.	§0.8	§1.3	§1.5
Exhaust back pressure (inches mercury) - max.:			
Full load	0.8	2.0	2.4
Fuel System			
Fuel pressure at inlet manifold (psi) - normal	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

*Turbine Housing Designation

§ When single block-to-head breathing system is used, ADD: 0.1 in. to maximum limits for N75 injectors.

8V-71TTA ENGINES (with TV7101 TURBOCHARGER)
(1.23 A/R* Turbine Housing)

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32-70	50-70	50-70
Minimum for safe operation	25	30	30
† Lubricating oil temperature (degrees F.):			
Normal	200-250	200-250	200-250
Air System			
Air box pressure (inches mercury) min full load:			
At zero exhaust back pressure:			
7C75 injector (without check valves)	18.0	#33.9	#36.8
7A75 injector (with check valves)	22.7	#36.7	#39.7
At max. exhaust back pressure (clean ports):			
7C75 injector (without check valves)	17.4	#32.4	#35.3
7A75 injector (with check valves)	22.1	#35.2	#37.8
Air inlet restriction (inches water) - max. full load:			
Dirty air cleaner (dry type)	8.8	20.0	20.0
Clean air cleaner (dry type)	5.8	12.0	12.0
Crankcase pressure (inches water) - max.	0.8	1.3	1.5
Exhaust back pressure (inches mercury - max.:			
Full load	0.8	2.0	2.5
Fuel System			
Fuel Pressure at inlet manifold (psi) (normal)	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load	0.9	0.9	0-9"
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	170-195	170-195	170-195
Compression			
Compression pressure (psi at sea level):			
Average - new engine at 600 rpm	475		
Minimum at 600 rpm	425		

† The lubricating oil temperature range is based on the temperature in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.
* Turbine Housing Designation.
# 305 BHP Values.

12V-71T ENGINES (with T18A40 TURBOCHARGER)
(1.00 A/R* Turbine Housing)

	1500 rpm	1800 rpm	2000 rpm	2100 rpm
Lubrication System				
Lubricating oil pressure (psi):				
Normal	42-70	50-70	50-70	50-70
Min. for safe operation	27	30	30	30
† Lubricating oil temperature (degrees F.):				
Normal	200- 250	200- 250	200-250	200-250
Air System				
Air box pressure (inches mercury) - min. full load:				
At zero exhaust back pressure:				
C65 injector	11.5	20.5	26.5	30.0
N70 injector	14.5	23.5	29.5	33.0
N75 injector	15.5	24.5	30.5	34.0
N80 injector	16.5	25.5	-	-
N90 injector	22.5	26.5	-	-
At max. exhaust back pressure (clean ports):				
C65 injector	10.5	19.0	24.7	28.2
N70 injector	13.5	22.0	27.7	31.2
N75 injector	14.5	23.0	28.7	32.2
N80 injector	15.5	24.0	-	-
N90 injector	21.5	25.4	-	-
Air inlet restriction (inches water) - max. full load:				
Dirty air cleaner (dry type)	10.5	14.5	18.0	20.0
Clean air cleaner (dry type)	6.2	8.7	10.8	12.0
Crankcase pressure (inches water) - max.:				
C65, N70, N75 injector	1.0	2.0	2.7	3.0
N80 injector	1.4	2.8	-	-
N90 injector	1.5	3.0	-	-
Exhaust back pressure (inches mercury) - max.:				
Full load	1.4	2.0	2.5	2.5
Fuel System				
Fuel pressure at inlet manifold (psi) - normal	45-70	50-70	50-70	50-70
Fuel spill (gpm) - min. at no load:				
(.080”, orifice)	0.9	0.9	0.9	0.9
(.106" orifice)	1.4	1.4	1.4	1.4
Pump suction at inlet (inches mercury) - max.:				
Clean system	6.0	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0	12.0
Cooling System				
Coolant Temperature (degrees F.) - normal	160-185	160-185	160-185	160-185
Vehicle engines built 1976 and later	170-195	170-195	170-195	170-195
Compression				
Compression pressure (psi at sea level):				
Average - new engine at 600 rpm	475			
Minimum at 600 rpm	425			

* Turbine Housing Designation.

† The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

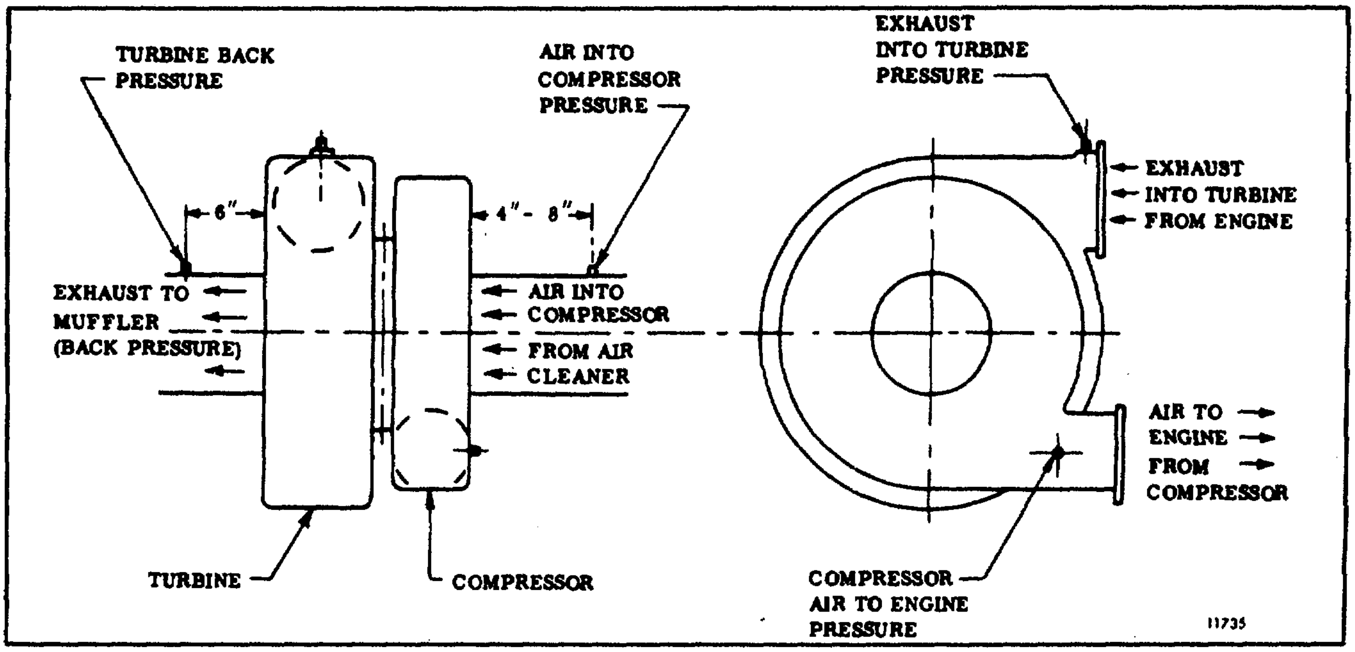


FIG. 1 - Points to Measure intake and Exhaust Restriction

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners or bearings, the engine should be "Run-in" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tune-up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160-185°F or 71-85°C) should be maintained throughout the Run-in.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 100° higher than the water inlet temperature. Though a 10° rise across an engine is recommended, it has been found that a 15° temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Therefore, be sure they are in place and fully operative or the engine will overheat during the Run-In. However, if the dynamometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

The Run-In Schedules are shown on pages 2 and 3. The horsepower shown is at SAE conditions: dry air density .0705 Ib/cu. ft. (1.129 Kg/m 3), air temperature of 85° F (29.4° C), and 500 ft. (152 m) elevation.

DYNAMOMETER TEST AND RUN- IN PROCEDURES

The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the *Basic Engine Run-In Schedule.* The following items are included on the basic engine: blower, fuel pump, water pump and governor. The fan and battery-charging generator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the *Engine Test Report.* The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (Ib-ft) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

$$BHP = (T \times RPM)/5250$$

Where:

BHP = brake horsepower
T = torque in lb-ft
RPM = revolutions per minute

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample on page 4).

RUN-IN SCHEDULE FOR NON-TURBOCHARGED ENGINES

BASIC ENGINE RUN-IN SCHEDULE

(Trunk-Type Pistons)

Time (Minutes)	Speed (rpm)	Injectors	Engine Horsepower				
			6V-71		8V-71	12V-71	
			2-valve	4-valve		2-valve	4-valve
10	1200	All	42	42	56	84	84
30	1800	All	170	170	227	300	340
30	2100	S-50	-	-	-	335	-
*30	2100	S-55	180	186	247	-	372
		N-55	180	188	252	-	377
		S-60	195	195	260	-	403
		N-60	188	195	260	-	403
		N-65	188	195	260	-	403
	2300	N-70	-	-	-	-	-
		S-70	-	217	285	-	428
		N-70	-	225	300	-	428

FINAL ENGINE RUN-IN SCHEDULE

(Trunk-Type Pistons)

Time (Minutes)	Speed (rpm)	Injectors	6V-71 2-valve	6V-71 4-valve	8V-71	12V-71 2-valve	12V-71 4-valve
*30	1800 †	S-50	-	-	-	321	-
		S-55	171	177	236	-	354
		N-55	171	179	239	-	359
		N-55Ø	169	-	-	-	-
		N-60	183	189	252	-	378
		S-60	183	189	252	-	378
		N-60Ø	180	-	-	-	-
		N-65	-	205	273	-	409
		S-70	-	207	275	-	413
		N-70	-	215	286	-	429
	2000 †	S-50	-	-	-	350	-
		S-55	183	190	253	-	379
		N-55	183	192	256	-	384
		N-55Ø	181	-	-	-	-
		S-60	197	204	272	-	408
		N-60	197	204	272	-	408
		N-60Ø	192	-	-	-	-
		N-65	-	221	295	-	442
		S-70	-	224	298	-	447
		N-70	-	233	311	-	466
	2100 †	S-50	-	-	-	360	-
		S-55	188	195	260	-	390
		N-55	188	197	263	-	394
		N-55Ø	185	-	-	-	-
		S-60	203	210	280	-	420
		N-60	203	210	280	-	420
		N-60Ø	198	-	-	-	-
		N-65	-	228	304	-	456
		S-70	-	231	307	-	461
		N-70	-	240	320	-	480
	2300 †	S-70	-	241	321	-	482
		N-70	-	250	333	-	500

Ø Coach engines only.
* Use the Speed-injector combination applicable to the engine test.
† Within ± 5% of broke horsepower rating shown above at governed speed.

▲ RUN-IN SCHEDULE FOR TURBOCHARGED ENGINES

BASIC ENGINE RUN-IN SCHEDULE

Time (Minutes)	Speed (rpm)	Injectors	Engine Horsepower	
			8V-71T	12V-71T
10	1200	All	0	0
60	2300	All	-	0
60	2500	All	0	-
*30	2100	N-65	-	160
		N-65	-	345
		N-70	-	160
		N-70	-	345
		N-75	-	160
		N-75	-	345
*30	2300	N-65	107	-
		N-65	230	-
		N-70	107	-
		N-70	230	-
		N-75	107	-
		N-75	230	-

FINAL ENGINE RUN-IN SCHEDULE (Trunk-Type Pistons)

Time (Minutes)	Speed (rpm)	Injectors	Engine Horsepower	
			8V-71T	12V-71T
*30	1800†	N-70	-	-
		N-75	-	-
	2000 †	N-70	-	-
		N-75	-	-
	2100 †	N-65	308	465
		N-70	333	500
		N-75	350	525

(Cross-Head Pistons)

Time (Minutes)	Speed (rpm)	Injectors	Engine Horsepower		
			6V-71T	8V-71T1 8V-71TA	12V-71T
10	1200	All	42	56	84
30	2100	All	174	232	348
30	2100	All	195	260	390
30	2100	All	†	†	†

* Use speed-injector combination applicable to engine on test and run for 30 minutes at each horsepower shown.
† Within ± 5% of broke horsepower rating shown above at governed speed.
▲ Also for non-turbocharged engines with cross-head pistons.

Instrumentation

Certain instrumentation is necessary so that data required to complete the *Engine Test Report* may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

c. Adaptor for connecting a pressure gage or mercury manometer to the engine air box.

d. Water temperature gage installed in the thermostat housing or water outlet manifold.

e. Adaptor for connecting a pressure gage or water manometer to the crankcase.

f. Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

g. Adaptor for connecting a vacuum gage or water manometer to the blower inlet.

h. Adaptor for connecting a fuel pressure gage to the fuel manifold inlet passage.

i. Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water = psi x 27.7
Inches of mercury = psi x 2.04"

NOTE: Before starting the Run-In or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation for Starting Engine First Time* in Section 13.1.

Run- In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report.*

ENGINE TEST REPORT

Date ______________________ Unit Number ______________________

Repair Order Number ______________________ Model Number ______________________

A PRE-STARTING

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJ.	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B BASIC ENGINE RUN-IN

TIME AT SPEED	TIME		RPM	BHP	WATER TEMP.	LUBE OIL PRESS.
	START	STOP				

C BASIC RUN-IN INSPECTION

1. Check oil at rocker arm mechanism	
2. Inspect for lube oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D INSPECTION AFTER BASIC RUN-IN

1. Tighten Cylinder Head & Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E FINAL RUN-IN

TIME		TOP RPM		BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L
START	STOP	NO LOAD	FULL LOAD				

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN. F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE		IDLE SPEED
				FULL LOAD	IDLE	

F INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings	6. Tighten Oil Pump Bolts
2. Inspect Blower	7. Inspect Oil Pump Drive
3. Check Generator Charging Plate	8. Replace Lube Filter Elements
4. Wash Oil Pan, Check Gasket	9. Tighten Flywheel Bolts
5. Clean Oil Pump Screen	10. Rust Proof Cooling System

REMARKS:

Final Run OK'd ______________ Dynamometer Operator ______________ Date ______________

NOTE: Operator must initial each check and sign this report.

A. PRE-STARTING

1. Fill the lubrication system as outlined under *Lubrication System -- Preparation for Starting Engine First Time* in Section 13. 1.

2. Prime the fuel system as outlined under *Fuel System-- Preparation for Starting Engine First Time* in Section 13.1.

3. A preliminary valve clearance adjustment must be made before the engine is started. See *Valve Clearance Adjustment* in Section 14.1.

4. A preliminary injector timing check must be made before starting the engine. See *Fuel Injector Timing in Section 14.2.*

5. Preliminary governor adjustments must be made as outlined in Section 14.

6. Preliminary injector rack adjustment must be made (Section 14).

> **NOTE:** Prior to starting a turbocharged engine, remove the oil supply line at the turbocharger and add clean engine oil to the oil inlet to ensure pre-lubrication of the turbochargers. Reconnect the oil lines and idle the engine for at least one minute after starting and before increasing the speed.

B. BASIC ENGINE RUN-IN

The operator should be observant at all times, so that any malfunction which may develop will be detected. Since the engine has just been reconditioned, this Run-in will be a test of the workmanship of the serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 lb-ft on the torque gage (or 10-15 HP on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events for the test and run-in, and to the *Bask Engine Run-In Schedule* which indicates the speed (rpm), length of time and the brake horsepower required for each phase of the test. Also refer to the *Operating Conditions* in Section 13.2 which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full-load speed designated for the Run-in. If a governor is encountered which cannot be adjusted to this speed, a stock governor should be installed for the Run-in.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the *Basic Engine Run-In Schedule.*

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature and lubricating oil pressure on t*he Engine Test Report.*

Run the engine at each speed and rating for the length of time indicated in the *Bask Engine Run-In Schedule.* This is the Basic Run-In. During this time, engine performance will improve as new parts begin to "seat in". Record all of the required data.

C. BASIC RUN-IN INSPECTION

While the engine is undergoing the Basic Run-In, check each item indicated in Section "C" of the *Engine Test Report.* Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the Basic Run-In, the engine should be inspected for fuel oil, lubricating oil and water leaks.

Upon completion of the Basic Run--In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN-IN

The primary purpose of this inspection is to provide a fine engine tune-up. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tune-up procedure. Refer to Section 14.

E. FINAL RUN-IN

After all of the tests have been made and the *Engine Test Report* is completed through Section "D", the engine is ready for final test. This portion of the test and Run-in procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm-up period of 10 minutes at the same speed and load used for warm-up in the Basic Run-In. If piston rings, cylinder liners or bearings have been replaced as a result of findings in the Basic Run-In, the entire Basic Run-In must be repeated as though the Run-in and test procedure were started anew.

All readings observed during the Final Run-In should fall within the range specified in the *Operating Conditions* in Section 13.2 and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine *water temperature* should be taken during the last portion of the Basic Run-In at full load. It should be recorded and should be within the specified range.

The *lubricating oil temperature* reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The *lubricating oil pressure* should be recorded in psi after being taken at engine speeds indicated in the *Operating Conditions,* Section 13.2.

The *fuel oil pressure* at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine speed during the Final Run-In.

Check the *air box pressure* while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0-15 psi) .or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the *crankcase pressure* while the engine is operating at maximum Run-in speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the Run-in indicating that new rings are beginning to "seat-in".

Check the *air inlet restriction* with a water manometer connected to a fitting in the air inlet ducting located 2" above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4" pipe tapped hole in the engine air inlet housing. If a hole is not provided, a stock housing should be drilled, tapped and kept on hand for future use.

The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of one of the turbochargers. The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting,

Check the normal *air intake vacuum* at various speeds (at no-load) and compare the results with the *Engine Operating Conditions* in section 13.2. Record these readings on the *Engine Test Report.*

Check the *exhaust back pressure* (except turbocharged engines) at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adaptor installed at the tapped hole. If the exhaust manifold does not provide a 1/8" pipe tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6 " to 12 " from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the *Maximum Exhaust Back Pressure* for the engine (refer to Section 13.2).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full-load and no-load speeds.

Refer to the *Final Engine Run-In Schedule* and determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run- In. Apply the load thus determined to the dynamometer. The engine should be run at this speed and load for 1/2 hour. While making the Final Run-In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the Basic Run-In. This will ordinarily require a governor adjustment.

All information required in Section "E", Final Run- In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the Final Run-In has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The Final Run-In is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the Final Run-In and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined in Section 15.3 and adding a rust inhibitor into the cooling system (refer to Section 13.3). The lubricating oil filters should also be changed.

FUEL OILS FOR DETROIT DIESEL ENGINES

DIESEL FUEL OILS GENERAL CONSIDERATIONS

The quality of fuel oil used for high-speed diesel engine operation is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels.

COMPLETELY DISTILLED FLUID

Fuel selected should be completely distilled material. That is, the fuel should show at least 98% by volume recovery when subjected to ASTM D-86 distillation. Fuels marketed to meet Federal Specification VV-F-800 (grades DF-1 and DF-2) and ASTM Designation D-975 (grades 1-D and 2-D) meet the completely distilled criteria. The differences in properties of VV F-800 and ASTM D-975 fuels are shown in the following table.

FEDERAL SPECIFICATION & ASTM DIESEL FUEL PROPERTIES

Specification or Classification Grade	VV-F-800 DF-1	ASTM D-975 1-D	VV-F-800 DF-2	ASTM D-975 2-D
Flash Point, min.	104°F 40°C	100°F 38°C	122°F 50°C	125°F 52°C
Carbon Residue (10% residuum), % max.	0.15	0.15	0.20	0.35
Water & Sediment, % by vol, max.	0.01	trace	0.01	0.05
Ash, % by wt., max.	0.005	0.01	0.005	0.01
Distillation Temperature, 90% by vol. recovery, min.	—	—	—	540°F (282°C)
max.	572°F (300°C)	550°F (288°C)	626°F (330°C)	640°F (338°C)
End Point, max.	626°F (330°C)	—	671°F (355°C)	—
Viscosity 100°F (38°C) Kinematic, cSt, min.	1.4	1.4	2.0	2.0
Saybolt, SUS, min.	—	—	—	32.6
Kinematic, cSt, max.	3.0	2.5	4.3	4.3
Saybolt, SUS, max.	—	34.4	—	40.1
Sulfur, % by wt., max.	0.50	0.50	0.50	0.50
Cetane No.	45	40	45	40

FUEL CLEANLINESS

Fuel oil should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water or water-emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier.

FUEL SULFUR CONTENT

The *sulfur content* of the fuel should be as low as possible to avoid premature wear, excessive deposit formation, and minimize the sulfur dioxide exhausted into the atmosphere. Limited amounts can be tolerated, but the amount of sulfur in the fuel and engine operating conditions can influence corrosion and deposit formation tendencies.

The deleterious effect of burning high sulfur fuel is reflected in Detroit Diesel lube oil change interval recommendations. Detroit Diesel recommends that the Total Base Number (TBN-ASTM D-664) of the lube oil be monitored frequently and that the oil drain interval be drastically reduced. Consult the FUEL OIL SELECTION CHART.

IGNITION OUALITY-CETANE NUMBER

There is a delay between the time the fuel is injected into the cylinder and the time that ignition occurs. The duration of this delay is expressed in terms of cetane *number* (rating). Rapidly ignited fuels have high cetane numbers; e.g., 50. Slowly ignited fuels have low cetane numbers; e.g., 40 or less. The lower the ambient temperature, the greater the need for a fuel that will ignite rapidly; i.e., high cetane.

Difficult starting may be experienced if the cetane number of the fuel is too low. Furthermore, engine knock and puffs of white smoke may be experienced during engine warm-up especially in severe cold weather when operating with a low cetane fuel. If this condition is allowed to continue for any prolonged period, harmful fuel derived deposits will accumulate within the combustion chamber. Consult the FUEL OIL SELECTION CHART.

DISTILLATION END POINT

Fuel can be burned in an engine only after it has been vaporized. The temperature at which fuel is completely vaporized is described as the *distillation endpoint* (ASTM D-86). The distillation (boiling) range of diesel fuels should be low enough to permit complete vaporization at combustion chamber temperatures. The combustion chamber temperature depends on ambient temperature, engine speed, and load. Mediocre to poor vaporization is more apt to occur during severe cold weather and/or prolonged engine idling and/or light load operation. Therefore, engines will show better performance operating under the conditions described above when lower distillation end point fuels are used. Consult the FUEL OIL SELECTION CHART.

CLOUD POINT

The cloud *point* is that temperature at which wax crystals begin to form in diesel fuel. The selection of a suitable fuel for low temperature operability is the responsibility of the fuel supplier and the engine user. Consult the FUEL OIL SELECTION CHART.

FUEL OIL SELECTION CHART

Application	General Fuel Classification	Final Boiling Point (Max.)	Cetane Number (Min.)	Sulfur Content (Max.)	Cloud Point
City Buses	No. 1-D	550°F 288°C	45	0.30	SEE NOTE 1
	Winter No. 2-D*	675°F 357°C	45	0.50	
	Summer No. 2-D*	357°C	40	0.50	
All Other Applications	Winter No. 2-D	675°F 357°C	45	0.50	SEE NOTE 1
	Summer No. 2-D	675°F 357°C	40	0.50	

*No 2-D diesel fuel may be used in city coach engine models that have been certified to pass Federal and California emission standards.

Note 1 The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

Note 2 When prolonged idling periods or cold weather conditions below 32° F (0°C) are encountered, the use of lighter distillate fuels may be more practical. The same consideration must be made when operating at altitudes above 5, 000 ft.

DETROIT DIESEL FUEL OIL SPECIFICATIONS

Detroit Diesel Allison designs, develops and manufactures commercial diesel engines to operate on diesel fuels classified by the ASTM as Designation D-975 (grades 1 -D and 2-D). These grades are very similar to grades DF-1 and DF-2 of Federal Specification VV-F-800.

Burner fuels (furnace oils or domestic heating fuels) generally require an open flame for satisfactory combustion. The ignition quality (cetane rating) of burner fuels (ASTM D-396) is poor when compared to diesel fuels (ASTM D-975).

In some regions, however, fuel suppliers may distribute one fluid that is marketed as either diesel fuel (ASTM D-975) or domestic heating fuel (ASTM D-396) sometimes identified as burner, furnace, or residual fuel. Under these circumstances, the fuel should be investigated to determine whether the properties conform with those indicated in the FUEL OIL SELECTION CHART.

The FUEL OIL SELECTION CHART also will serve as a guide in the selection of the proper fuel for various applications. The fuels used must be clean, completely distilled, stable, and non-corrosive. *Distillation Range,* Cetane Number, *Sulfur Content, and* Cloud *Point* are four of the most important properties of diesel fuels that must be controlled to insure satisfactory engine operation. Engine speed, load, and ambient temperature all influence the selection of diesel fuels with respect to distillation range and cetane number.

All diesel fuels contain a certain amount of sulfur. Too high a sulfur content results in excessive cylinder wear. For most satisfactory engine life, fuels containing less than 0.5%0 sulfur should be used.

During cold weather engine operation the cloud *point* (the temperature at which wax crystals begin to form in diesel fuel) should be 10°F (6°C) below the lowest expected fuel temperature in order to prevent clogging of the fuel filters by wax crystals.

A reputable fuel oil supplier is the only one who can assure you that the fuel you receive meets the *Distillation End Point,* Cetane Number, *Sulfur Content, and Cloud Point* property limits shown in the FUEL OIL SELECTION CHART. The responsibility for clean fuel and fuel that meets Detroit Diesel Alison specifications lies with the fuel supplier as well as the operator.

At temperatures below + 32°F (0°C) particular attention must be given to cold weather starting aids for efficient engine starting and operation.

NUMEROUS FUELS BURNED IN DDA ENGINES

Numerous fuels meeting the properties shown in the FUEL OIL SELECTION CHART may be used in Detroit Diesel engines. The table (top, right) shows some of the alternate fuels (some with sulfur and/or cetane limits) that have been burned in Detroit Diesel engines. Among these are No. 1 and No. 2 diesel fuels, kerosene, aviation turbine (jet) fuels, and burner fuels.

FUELS BURNED IN DETROIT DIESEL ENGINES

ASTM Designation	Federal Standard	Military Spec.	NATO Code	Grade	Description/Comments
D-975				1-D 2-D	Diesel Fuel
D-396				1, 2	Burner Fuel (Furnace Oil) ***Caution: If Used, The Max. Sulfur Content Allowed Is 0.50 WT. % and the Minimum Cetane No. Is 45. (See Fuel Oil Selection Chart).***
	VV-F-800		F-54	1, 2	DF-1 Winter Grade, DF-2 Regular Grade
	VV-F-800		F-56		DF-A (Arctic Grade). Limited Supply For Military.
		MIL-T-5624		JP-5	Kerosene
D-1655		MIL-T-83133	F-34	JP-8	Jet A-1, Kerosene Type Plus Special Anti-Icer
D-1655			F-35		Jet A, Kerosene
		MIL-F-16884	F-76	DFM	Diesel Fuel - Marine (DFM). ***Caution: If Used, The Max. Sulfur Content Allowed Is 0.50 WT. %.***
		MIL-F-5161		JP-6	Referee Grade JP-5 Type Jet Fuel. Limited Quantities Supplied To Military Only.

PROPOSED ASTM D-975, GRADE 3-D

Detroit Diesel Allison does NOT recommend the use of proposed grade 3-D diesel fuel in any of its engines. This grade of fuel has been proposed to, but not accepted by, the American Society for Testing and Materials (ASTM).

The proposed grade 3-D is undesirable in that it possesses poor ignition quality (i.e., lower cetane), allows greater sulfur content (up to 0.70% by weight), allows the formation of more carbon deposits (Conradson carbon residue), and allows the blending of heavier, more viscous boiling point fractions that are difficult to burn. The latter tend to increase combustion chamber deposits. This type of fuel usually manifests poor cold weather properties (wax formation tendencies). In addition, the poor ignition quality adversely affects noise and emission levels.

A comparison of ASTM D-975 grade 2-D and the proposed grade 3-D fuel properties is shown in the following table.

COMPARISON OF ASTM D-975
GRADE 2-D AND PROPOSED GRADE 3-D PROPERTIES

Property	Grade: Recommended 2-D	Grade: Not Recommended 3-D
Cetane No., Min.	40.0	37.0
Sulfur, WT. %, Max.	0.50	0.70
Carbon Residue On 10% Residuum, %, Max.	0.35	0.40
Viscosity @ 40° Celsius, Centistokes	1.9 - 4.1	2.0 - 7.0
Distillation		
deg. Celsius (Fahrenheit)		
90% Recovery, Max.	338 (640)	360 (680)

USING DRAINED LUBE OIL IN DIESEL FUEL

Detroit Diesel Allison does not recommend the use of drained lubricating oil in diesel fuel. Furthermore, Detroit Diesel Allison will not be responsible for any detrimental effects which it determines resulted from this practice

BURNING MIXTURES OF ALCOHOL, GASOLINE, GASOHOL OR DIESOHOL WITH DIESEL FUEL

Alcohol, gasoline, gasohol, or diesohol should never be added to diesel fuel. An explosive and fire hazard exists if these blends are mixed and/or burned. See DIESEL FUEL LINE DE-ICER below.

DIESEL FUEL LINE DE-ICER

Very small amounts of isopropyl alcohol (isopropanol) may be used to preclude fuel line freeze-up in winter months. No more than ONE PINT of isopropyl alcohol should be added to 125 GALLONS of diesel fuel for adequate protection.

LUBRICATING OILS FOR DETROIT DIESEL ENGINES

DIESEL LUBRICATING OILS GENERAL CONSIDERATIONS

All diesel engines require heavy-duty lubricating oils. Basic requirements of such oils are lubricating quality, high heat resistance, and control of contaminants.

LUBRICATING QUALITY. The reduction of friction and wear by maintaining an oil film between moving parts is the primary requisite of a lubricant. Film thickness and its ability to prevent metal-to-metal contact of moving parts is related to oil viscosity. The optimums for Detroit Diesel engines are SAE 40 or 30 weight.

HIGH HEAT RESISTANCE. Temperature is the most important factor in determining the rate at which deterioration or oxidation of the lubricating oil will occur. The oil should have adequate thermal stability at elevated temperatures, thereby precluding formation of harmful carbonaceous and/or ash deposits.

CONTROL OF CONTAMINANTS. The piston and compression rings must ride on a film of oil to minimize wear and prevent cylinder seizure. At normal rates of consumption, oil reaches a temperature zone at the upper part of the piston where rapid oxidation and carbonization can occur. In addition, as oil circulates through the engine, it is continuously contaminated by soot, acids, and water originating from combustion. Until they are exhausted, detergent and dispersant additives aid in keeping sludge and varnish from depositing on engine parts. But such additives in excessive quantities can result in detrimental ash deposits. If abnormal amounts of insoluble deposits form, particularly on the piston in the compression ring area, early engine failure may result.

Oil that is carried up the cylinder liner wall is normally consumed during engine operation. The oil and additives leave carbonaceous and/or ash deposits when subjected to the elevated temperatures of the combustion chamber. The amount of deposits is influenced by the oil composition, additive content, engine temperature, and oil consumption rate.

OIL QUALITY is the responsibility of the oil supplier. (The term "oil supplier" is applicable to refiners, blenders, and rebranders of petroleum products, and does not include distributors of such products).

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The selection of a suitable lubricant in consultation with a reliable oil supplier, observance of his oil drain recommendations (based on used oil sample analysis and experience), and proper filter maintenance will provide the best assurance of satisfactory oil performance.

It should be noted that lube oil manufacturers may reformulate an oil while maintaining the same API classification, or may reformulate to a new API classification and continue the brand name designation. For example, SE oils being reformulated to SF letter code classification may perform differently after this reformulation. A close working relationship with the lube oil manufacturer should be maintained so that any reformulation can be reviewed and decision made as to its affect on continued satisfactory performance.

COLD WEATHER OPERATION

Two important considerations relate to satisfactory operation under cold ambient temperature conditions. These are: (1) the ability to crank the engine fast enough to secure starting, and (2) providing adequate lubrication to internal wearing surfaces during starting and warm-up. Once started and warmed up, external ambient temperatures have little effect on internal engine temperatures. Both cold weather considerations can be adequately met through proper lube oil selection and the use of auxiliary heat prior to starting. Auxiliary heat can be used in the form of jacket water and oil pan heaters, hot air space heaters applied to engine compartments, or some combination of these.

Proper oil selection and oil heat can assure lubricant flow immediately upon starting. Improper oil selection and oil heat may result in starting with cold oil congealed in the oil pan, and little or no oil flow for lubricating internal parts once the engine has started.

Proper oil selection and jacket water heating can assure cranking capability by maintaining an oil film on cylinder walls and bearing surfaces in a condition which provides low friction, and hence, less cranking effort to achieve cranking speeds necessary for reliable starting. Improper oil selection and jacket water heating may result in congealed oil films on cylinder walls and bearing surfaces, which result in high friction loads and more cranking effort than is available, thus preventing sufficient cranking speeds to assure reliable starting.

LUBE OIL SPECIFICATIONS

Detroit Diesel Allison lubricant recommendations are based on general experience with current lubricants of various types and give consideration to the commercial lubricants presently available.

RECOMMENDATION

Detroit Diesel 2-cycle engines have provided optimum performance and experienced the longest service life operating with lubricating oils meeting the following ash limits, zinc requirements, oil performance levels, viscosity grades, and evidence of satisfactory performance.

Sulfated Ash Limit (ASTM D-874)

The sulfated ash content of the lubricant shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.5% by weight is allowed. Lubricants having a sulfated ash content between 0.55% and 0.85% by weight, have a history of excellent performance in Detroit Diesel engines. Lubricants having a sulfated ash content exceeding 0.85% by weight, are prone to produce greater deposit levels in the piston ring grooves, exhaust valve faces and seats.

Zinc Content

The zinc content (zinc diorganodithiophosphate) of all the lubricants recommended for use in Detroit Diesel 2-cycle engines shall be a minimum of 0.07% by weight. This requirement is waived where single grade SAE 40, intermediate viscosity index lubricants qualified for use in Electro-Motive Division (EMD) diesel engines are used.

VISCOSITY GRADE AND OIL PERFORMANCE LEVEL

Single Grade SAE 40 & SAE 30 Lubricants

Single grade SAE 40 and SAE 30 grade lubricants are preferred and recommended for use in all Detroit Diesel 2-cycle engines provided they meet the sulfated ash and zinc content requirements indicated above and any of the oil performance levels shown in Table L-1. EVIDENCE OF SATISIFACTORY PERFORMANCE (see section under this title) is desired where new formulation SAE 40 or SAE 30 oils will be used. Selection of the appropriate viscosity grade is shown in Table L-2.

Multigrade Lubricants

Multigrade oils have not provided performance comparable to SAE-40 or SAE-30 lubricants in some engine service applications. Because of this experience, the use of 1 5W-40 and all other multigrade oils is not recommended for Series 149 engines, and restrained usage in Series 53, 71 and 92 engines is advised.

If the use of a 1 5W-40 multigrade oil in Series 53, 71 or 92 engines is being considered, it must meet the CD/SE oil performance level shown in Table L-1. Table L-2 indicates that 15W-40 multigrades may be selected when ambient temperatures are at, or less than, . freezing. However, because our experience has disclosed that the performance of straight grade oils has been superior to multigrade oils in some service applications, Detroit Diesel recommends that the user obtain proven service experience and evidence of satisfactory performance supplied by the lube oil manufacturer or follow the guidelines in the section entitled, "EVIDENCE OF SATISFACTORY PERFORMANCE." Upon request, the Detroit Diesel Allison Regional Office will counsel with customers in selecting a lubricating oil that will be suitable for their specific needs.

Other Multigrade Oils

Detroit Diesel Allison does *not recommend* the use of 1 OW-30, 1 OW-40, 20W-40 or any other multigrade oils in 2-cycle engines. As previously indicated, 1 5W-40 oils are the only lubricants that should be considered if prolonged severe cold, ambient temperatures, are expected.

EVIDENCE OF SATISFACTORY PERFORMANCE

It is recommended that evidence of satisfactory lubricant performance in Detroit Diesel 2-cycle engines be obtained from the oil supplier prior to procurement. Controlled oil performance evaluations in field test engines are recommended. The type of field test used by the oil supplier depends on the Series engine in which the candidate oil will be used and the service application. This information is summarized in Table L-3. The candidate test oil-operated engines should all operate for the mileage/hours indicated. Fuel and lube oil consumption should be monitored during the test period. Any serious mechanical problems experienced should be recorded. All of the oil test engines should be disassembled at the conclusion of the oil test period and inspected. The following oil performance parameters should be compared:

- Ring sticking tendencies and/or ring conditions
- Piston skirt scuffing and cylinder liner wear and scuffing
- Exhaust valve face and seat deposits
- Piston pin and connecting rod bushings (Note: Trunk pistons used in Series 53 engines)
- Overall valve train and bearing wear levels.

USED LUBE OIL ANALYSIS PROGRAM

A used lube oil analysis program should be conducted in conjunction with the oil performance field test. In order to determine the condition of the lube oil that will prevail when subjected to various engine operational modes in specific service applications, it is recommended that frequent, oil samples be investigated. This subject is more comprehensively addressed in the OIL CHANGES section below.

OIL CHANGES

Table L-4 shows the initial oil drain intervals for all Series 2-cycle engines used in the various service applications. Oil drain intervals in all service applications may be increased or decreased with experience using a specific lubricant. Detroit Diesel Allison recommends the use of a controlled, used lube oil analysis monitoring program. This is especially prudent when extended oil drain intervals (e.g., 100, 000 miles) are being considered. The frequency at which used lube oil samples are obtained may be scheduled for the same period as when other preventive maintenance is conducted. For example, a used lube oil sample for analysis may be obtained every 10,000 miles when engines are brought in for fuel and coolant filter replacement. Table L-5 shows the routine specific laboratory tests that are recommended. Sometimes further confirmatory tests are required, especially when fuel and/or coolant dilution is suspected. Table L-5 indicates the routine and confirmatory tests recommended. The lube oil should be drained if any of the maximum tolerable warning limits are exceeded.

THE INFLUENCE OF DIESEL FUEL SULFUR CONTENT ON LUBE OIL CHANGE INTERVALS

Table L-4 shows the reduced oil drain intervals that are recommended if the use of high sulfur fuel is unavoidable. The use of diesel fuels having a sulfur content exceeding 0.50% by weight can have a negative effect on piston ring life and lube oil deposit levels. For this reason, it is recommended that oil drain intervals be drastically shortened to minimize the adverse effect of acid build-up in the lubricant. These relatively short oil drain intervals may be altered if a lubricant with high alkaline reserve (i.e., high TBN - ASTM D-664) and low sulfated ash (i.e., less than 1.000% by weight - ASTM D-874) can be obtained. Table L-5 indicates that the TBN of the used oil should never be less than 1.0 (ASTM D-664). If laboratory analysis reveals that the TBN is less than 1.0, this is an indication that the acceptable drain interval has been exceeded.

MIL-L-46167 ARCTIC LUBE OILS FOR NORTH SLOPE AND OTHER EXTREME SUB-ZERO OPERATIONS

Lubricants meeting this specification are used in Alaska and other extreme sub-zero locations. Generally, they may be described as 5W-20 multigrade lubricants made up of synthetic base stock and manifesting low volatility characteristics. Although they have been used successfully in some severe cold regions, Detroit Diesel Allison does not consider their use as desirable as the use of SAE-40 or SAE-30 oils with auxiliary heating aids. For this reason, they should be considered only where engine cranking is a severe problem and auxiliary heating aids are not available on the engine.

EMD (RR) OILS

Lubricants qualified for use in Electro-Motive Division (EMD) diesel engines may be used in Detroit Diesel 2-cycle engines provided the sulfated ash (ASTM D-874) content does not exceed 1.000% by weight. These lubricants are frequently desired for use in applications where both Detroit Diesel and Electro-Motive powered units are operated. These fluids may be described as SAE-40 lubricants that possess medium Viscosity Index properties and do not contain any zinc additives.

SYNTHETIC OILS

Synthetic lubricants may be used in Detroit Diesel 2-cycle engines provided the ash limit, zinc requirements, and specified oil performance levels (for example, CD/SE or MIL-L-2104B, etc.) shown elsewhere in this specification are met. Viscosity grades SAE-40 or SAE-30 are recommended.

LUBE OIL FILTER CHANGE INTERVAL

Full-Flow Filters

A full-flow filtration system is used in all Detroit Diesel 2-cycle engines. To ensure against physical deterioration of the filter element, it should be replaced at a maximum of 25, 000 miles for on-highway vehicles. For all other applications, the filter should be replaced at a maximum of 500 hours.

By-Pass Filters

Auxiliary by-pass lube oil filters are not required on Detroit Diesel 2-cycle engines.

OIL CHANGE INTERVA BASED ON SURVEY OF SATISFIED END USERS

A number of successful Detroit Diesel (2-cycle engine) customers in numerous service applications do not utilize oil analysis procedures. They prefer conservative lube oil drain and filter change intervals. Lubricant and filters were changed based on experience, and the customer felt he saved money in eliminating costly lube oil analysis programs. Naturally, Detroit Diesel supports the lube oil and filter change practices used in these successful service operations.

Highway Truck Service Application

Oil Change Interval	20, 000 Miles
Filter Change Interval	20, 000 Miles

Large 149 Series Engines Powering Off-Road Equipment (Construction & Mine Site Service Applications)

Oil Change Interval	150 Hours
Filter Change Interval	300 Hours

City Transit Coaches

Oil Change Interval	12, 500 Miles
Filter Change Interval	25, 000 Miles

Pickup & Delivery Metro Area Truck Service

Oil Change Interval	12, 000 Miles
Filter Change Interval	24, 000 Miles

Stationary (Usually Stand-By) Engines

Oil Change Interval	150 Hours or One Year
Filter Change Interval	300 Hours or One Year

LUBE OIL PERFORMANCE LEVELS

API Letter Code Service Classification	Military Specification	SAE Grade
CB	MIL-L-2104A (Supplement 1)	40 or 30
CC	MIL-L-2104B	40 or 30
CD	MIL-L-45199B (Series 3)	40 or 30
CC/SE	MIL-L-46152	40 or 30
CD/SC	MIL-L-2104C	40 or 30
Numerous Combinations of Above	Single Grade Universal No MIL- Spec.	40 or 30
CD/SE	Multigrade Universal No MIL- Spec.	15W-40

Table L-1

VISCOSITY GRADE SELECTION

Ambient Temperature degrees Celsius	Ambient Temperature degrees Fahrenheit	Recommendations Primary	Secondary	Third
above 10	above 50	SAE 40	SAE 30	None
10 to 0	50 to 32	SAE 40 Plus Starting Aids	SAE 30 Usually Unaided	None
0 to 18	32 to 0	SAE 40 Plus Starting Aids	SAE 30 Plus Starting Aids	15W-40 Usually Unaided
below 18	below 0	SAE 40 Plus Starting Aids	SAE 30 Plus Starting Aids	15W-40 Plus Starting Aids

Table L-2

INDIVIDUAL USER SERVICE APPLICATION LUBE FIELD TESTING

Engine Series	Service Application	Test Duration	No. Engines on Candidate Test Oil	No. Sister Engines on Reference Baseline SAE 40 or SAE 30
53	Pickup & Delivery Metro Area	50,000 Miles	5	5
71 & 92	Hwy. Truck 72,000 Lbs. GCW	200,000 Miles	5	5
149	Off Road Rear Dump 120 Ton	10,000 Hours	3*	3

*Single Grade Only - No Multigrades Recommended For Series 149 Engines

Table L-3

LUBE OIL DRAIN INTERVAL

Service Application	Engine Series	Max. Lube Oil Drain Interval* Diesel Fuel Sulfur Content Wt. % 0 to 0.50	0.51 to 0.75	0.76 to 1.00
Hwy. Truck (Long Distance Hauls) and Inter-City Buses	71 & 92	100,000 Miles**	20,000 Miles	10,000 Miles
City Transit Coaches and Pickup and Delivery Truck Service (Stop-And-Go Short Distance	53, 71, 92	12,500 Miles	2,500 Miles	1,250 Miles
Industrial and Marine	53, 71, 92	150 Hours	30 Hours	15 Hours +
Large Industrial and Marine	149	(NA) 500 Hours (T) 300 Hours	100 Hours 60 Hours	50 Hours + 30 Hours +

*Maximum lube oil drain intervals must be based on the laboratory test results obtained from used lube oil samples.

**If supported by oil analysis at 10,000 mile intervals or when recommended fuel filter maintenance is performed.

+These oil change intervals are based upon worst case with chrome-faced rings. Oil change periods with plasma-faced rings can be established by oil analysis.

Table L-4

USED LUBE OIL ANALYSIS WARNING VALUES

	ASTM Designation	Limits	Routine Or Confirmatory
Pentane Insolubles, Wt. %, Max.	D-893	1.00	Routine
TGA Carbon (Soot) Content, Wt. %, Max.	None	0.80	Routine
Viscosity at 100°F, SUS	D-445		Routine
% Max. Increase	&	40.00	
% Max. Decrease	D-2161	15.00	
Iron Content, PPM., Max.	None	150.00	Routine
Total Base Number (TBN), Min.	D-664	1.00	Routine
Water Content, Vol. %, Max.	D-95	0.30	Confirmatory
Flash Point, °F, Max. Reduction	D-92	40.00	Confirmatory
Fuel Dilution, Vol. %, Max.	—	2.50	Confirmatory
Glycol Dilution, PPM., Max.	D-2982	1000.00	Confirmatory
Sodium Content, PPM., Max. Allowed Over Lube Oil Baseline	—	50.00	Routine
Boron Content, PPM., Max. Allowed Over Lube Oil Baseline	—	20.00	Routine

Table L-5

MISCELLANEOUS FUEL AND LUBRICANT INFORMATION

ENGINE OIL CLASSIFICATION SYSTEM

The American Petroleum Institute (API), the Society of Automotive Engineers (SAE), and the American Society for Testing and Materials (ASTM) jointly have developed the present commercial system for designating and identifying motor oil classifications. The table in this section shows a cross-reference of current commercial and military lube oil identification and specification systems.

PUBLICATION AVAILABLE SHOWING COMMERCIAL "BRAND" NAME LUBRICANTS

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled *EMA Lubricating Oils Data Book for Heavy-Duty Automotive and Industrial Engines.* The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION
111 EAST WACKER DRIVE
CHICAGO, ILLINOIS 60601

Upon request, the Detroit Diesel Allison Regional Office will counsel with customers in selecting a lubricating oil that will be suitable for their specific needs.

STATEMENT OF POLICY ON FUEL AND LUBRICANT ADDITIVES

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpt has been taken from a policy statement of General Motors Corporation:

> *"It has been and continues* to be *General Motors policy to build* motor vehicles *that will operate satisfactorily on the commercial fuels and lubricants* of good *quality regularly provided by the petroleum industry through retail outlets."*

Therefore, Detroit Diesel Allison does not recommend the use of any supplementary fuel or lubricant additives. These include all products marketed as fuel conditioners, smoke suppressants, masking agents, reodorants, tune-up compounds, top oils, break-in oils, graphitizers, and friction-reducing compounds.

NOTICE: The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's fuel or lubricating recommendations may not be within the coverage of the warranty.

CROSS REFERENCE OF LUBE OIL CLASSIFICATION SYSTEM

API CODE LETTERS	COMPARABLE MIUTARY OR COMMERCIAL INDIUSTRY SPECIFICATION
CA	MIL-L-2104A
CB	Supplement 1
OC	MIL-L-21048 (See Note Below)
CD	MIL-L-45199B (Series 3)
‡	MIL-L-46152 (Supersedes MIL-L-21048 Military Only)
•	MIL-L-2104C (SupersedesMIL-L-45199B for Military Only)
SA	None
SB	None
SC	Auto Passenger Car 1964 MS Oils - Obsolete System
SD	Auto Passenger Car 1968 MS Oils - Obsolete System
SE	Auto Passenger Car 1972 MS Oils - Obsolete System
SF	Auto Passenger Car 1980 Production

‡ Oil performance meets or exceeds that of CC and SE oils.

• Oil performance meets or exceeds that of CD and SC oils

NOTE: MIL-L-21048 lubricants are obsolete for military service applications only.
MIL-L-21048 lubricants are currently marketed and readily available for commercial use

Consult the following publications for complete descriptions:

1 Society of Automotive Engineers (SAE) Technical Report J-183a.

2. Federal Test Method 9andard 791a.

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. In general, water containing various materials in solution is used for this purpose.

The function of the coolant is basic to the design and to the successful operation of the engine. Therefore, coolant must be carefully selected and property maintained.

COOLANT REQUIREMENTS

Coolant solutions must meet the following basic requirements:

1. Provide for adequate heat transfer.

2. Provide a corrosion-resistant environment within the cooling system.

3. Prevent formation of scale or sludge deposits in the cooling system.

4. Be compatible with the cooling system hose and seal materials.

5. Provide adequate freeze protection during cold weather operation.

The first four requirements are satisfied by combining a suitable water with reliable inhibitors. When freeze protection is required, a solution of suitable water and an antifreeze containing adequate inhibitors will provide a satisfactory coolant. Ethylene glycol-based antifreeze is recommended for use in Detroit Diesel engines.

WATER

Any water, whether of drinking quality or not, will produce a corrosive environment in the cooling system, and the mineral content may permit scale deposits to form on internal cooling system surfaces. Therefore, water selected as a coolant must be properly treated with inhibitors to control corrosion and scale deposition.

To determine if a particular water is suitable for use as a coolant when properly inhibited, the following characteristics must be considered: the concentration of chlorides and sulfates, total hardness and dissolved solids.

Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium salts broadly classified as carbonates) causes deposits of scale. Total dissolved solids may cause scale deposits, sludge deposits, corrosion or a combination

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

TABLE 1

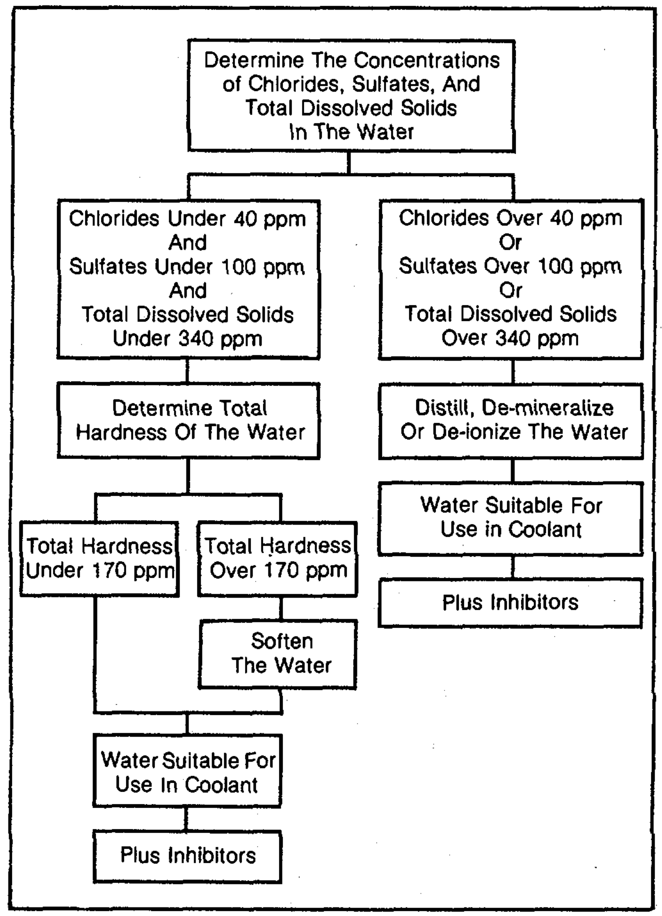


TABLE 2

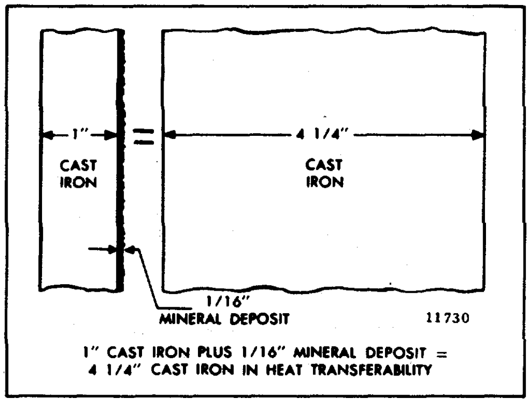


FIG. 1 - Heat Transfer Capacity

of these. Chlorides, sulfates, magnesium and calcium are among the materials which make up dissolved solids. Water, within the limits specified in Table 1 is satisfactory, as an engine coolant when proper inhibitors are added. The procedure for evaluating water intended for use in a coolant solution is shown in Table 2.

CORROSION INHIBITORS VITAL

A corrosion inhibitor is a water-soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites and soluble oil. (Soluble oil is not recommended as a corrosion inhibitor). Depletion of all types of inhibitors occurs through normal operation. Therefore, strength levels must be maintained by the addition of inhibitors at prescribed intervals.

The importance of a properly inhibited coolant cannot be overstressed. A coolant which has insufficient inhibitors, the wrong inhibitors, or-worse-no inhibitors at all invites the formation of rust and scale deposits within the cooling system. Rust, scale, and mineral deposits can wear out water pump seals and coat the walls of the cylinder block water jackets and the outside walls of the cylinder liners. As these deposits build up, they insulate the metal and reduce the rate of heat transfer. For example, a 1/16" deposit of rust or scale on I" of cast iron is equivalent to 4-1/4" of cast iron in heat transferability (Fig. 1).

An engine affected in this manner overheats gradually over a period of weeks or months. Liner scuffing, scoring, piston seizure and cylinder head cracking are the inevitable results. An improperly inhibited coolant can also become corrosive enough to "eat away" coolant passages and seal ring grooves and cause coolant leaks to develop. If sufficient coolant accumulates on top of a piston, a hydrostatic lock can occur while the engine is being started. This. in turn, can result in a bent connecting rod. An improperly inhibited coolant can also contribute to *cavitation erosion.* Cavitation erosion is caused by the collapse of bubbles (vapor pockets) formed at the coolant side of an engine component. The collapse results from a pressure differential in the liquid caused by the vibration of the engine part. As bubbles collapse, they form pin points of very high pressure. Over a period of time, the rapid succession of millions of tiny bursting bubbles can wear away (erode) internal engine surfaces.

Components such as fresh water pump impellers and cylinder liners are especially susceptible to cavitation erosion. In extreme cases their surfaces can become so deeply pitted that they appear to be spongy. and holes can develop completely through them.

Chromates

Sodium chromate and potassium dichromate are two of the best and most commonly used *water* system corrosion inhibitors. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors should *not* be used in antifreeze solutions. Chromium hydroxide, commonly called "green slime", can result from the use of chromate inhibitors with antifreeze. This material deposits on the cooling system passages and reduces the heat transfer rate (Fig. 1) which results in engine overheating. Engines which have operated with a chromate-inhibited water must be chemically cleaned before the addition of antifreeze. A commercial heavy duty descaler should be used in accordance with the manufacturer's recommendation for this purpose.

Soluble Oil

Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if' the concentration exceeds 1% by volume. For example: 1.25% of soluble oil in the cooling system increases fire deck temperatures 6% and a 2.50% concentration raises fire deck temperature up to 15%. *Soluble oil is not recommended as a corrosion inhibitor.*

Non-Chromates

Non-chromate inhibitors (borates, nitrates, nitrites, etc.) provide corrosion protection in the cooling system with the basic advantage that they can be used with either water or a water-and-antifreeze solution.

INHIBITOR SYSTEMS

An inhibitor system is a combination of chemical compounds which provide corrosion protection, pH control and water-softening ability. Corrosion protection is discussed under the heading *Corrosion Inhibitors Vital.* The pH control is used to maintain an acid-free solution. The water-softening ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant filter elements, liquid and dry bulk inhibitor additives and as an integral part of antifreeze.

Coolant Filter Elements

Replaceable elements are available with various chemical inhibitor systems. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted.

Problems have developed from the use of the magnesium lower support plate used by some manufacturers in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate in preference to magnesium is recommended to eliminate the potential of this type of deposit.

High chloride coolants will have a detrimental effect on the water-softening capabilities of systems using ion-exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by a regenerative process caused by high chloride-content solutions.

Bulk Inhibitor Additives

Commercially packaged inhibitor systems are available which can be added directly to the engine coolant or to bulk storage tanks containing coolant solution. Both chromate and non-chromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

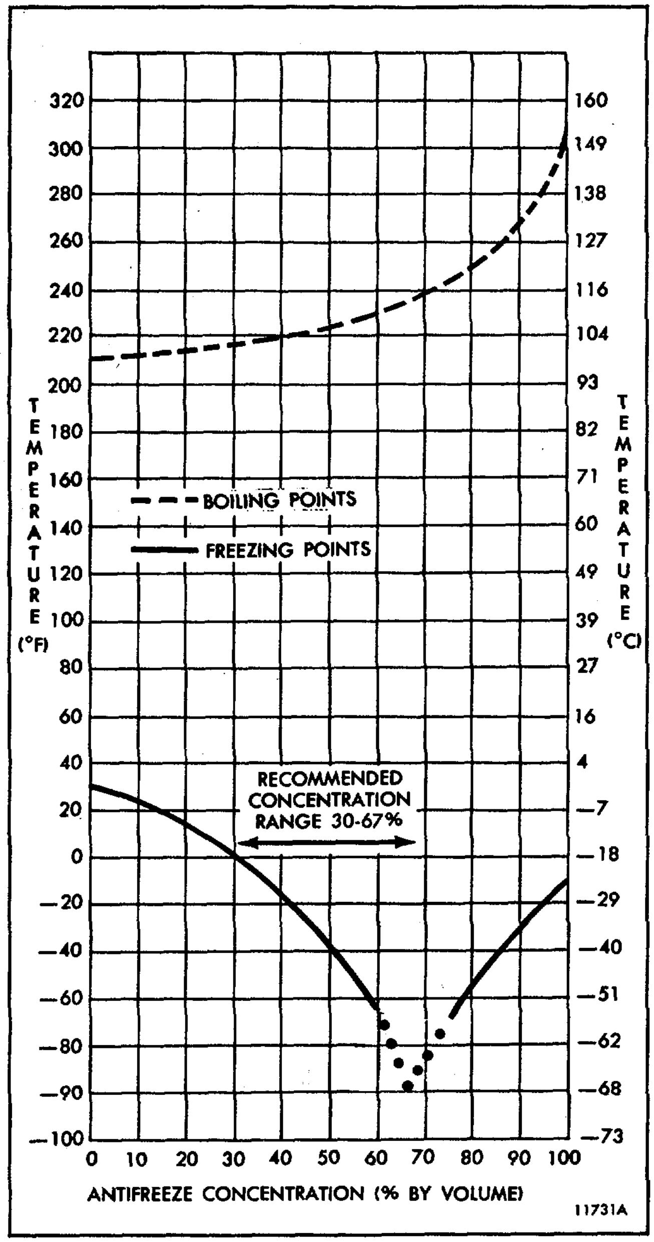


FIG. 2 - Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

Non-chromate inhibitor systems are recommended for use in Detroit Diesel engines. These systems can be used with either water or water-and-antifreeze solutions and provide corrosion protection, pH control and water softening. Some non-chromate inhibitor systems offer the additional advantage of a simple on-site test to determine protection level. Since they are added directly to the coolant, require no additional hardware or plumbing.

All inhibitors become depleted through normal operation and additional inhibitor must be added to the coolant at prescribed intervals to maintain original strength levels. Always follow the supplier's recommendations on inhibitor usage and handling.

TEST STRIPS

Some chemical manufacturers have developed *test strips* for use with their antifreeze or coolant additives. These test strips are used to measure the freeze protection and/or inhibitor strength of ethylene glycol-based antifreeze. To avoid a false reading caused by variations in reserve alkalinity, Detroit Diesel Allison suggests using test strips that measure depletable inhibitor concentration directly. *Do not use one manufacturer's test strips to measure the chemical content of another's antifreeze and/or inhibitor..* Always ,follow the manufacturer's recommended test procedures.

ANTIFREEZE

When freeze protection is required, an antifreeze meeting GM specification 1899M must be used. An inhibitor system is included in this type of antifreeze and no additional inhibitors are required on initial fill if a minimum antifreeze concentration of 30% by volume is used. Solutions of less than 30% concentration do not provide sufficient corrosion protection. Concentrations over 67% adversely affect freeze protection and heat transfer rates (Fig. 2).

Ethylene glycol base antifreeze is recommended for use in all Detroit Diesel engines. Methyl alcohol base antifreeze is not recommended because of its effect on the non-metallic components of the cooling system and because of its low boiling point. Methoxy propanol baste antifreeze is not recommended for use in Detroit Diesel engines due to the presence of fluoroelastomer seals in the cooling system.

Before installing ethylene glycol base antifreeze in a unit that has previously operated with methoxy propanol, the entire cooling system should be drained, flushed with clean water, and examined for rust, scale contaminants, etc. If deposits are present, the cooling system must be chemically cleaned with a commercial grade heavy-duty descaler.

The inhibitors in antifreeze should be replenished at approximately 50( ) hour intervals or by test with a non-chromate inhibitor system. Commercially available inhibitor systems may be used to reinhibit antifreeze solutions.

Sealer Additives

Antifreeze with sealer additives is not recommended for use in Detroit Diesel engines due to plugging possibilities throughout various areas of the cooling system, including cooling system bleed holes and water pump drain holes.

GENERAL RECOMMENDATIONS

All Detroit Diesel engines incorporate pressurized cooling systems which permit operation at temperatures higher than non-pressurized systems. It is essential that these systems be kept clean and leak-free, that filler caps and pressure relief mechanisms be correctly installed at all times and that coolant levels be properly maintained.

Always maintain engine coolant at the proper level. A low coolant level allows the water pump to mix air with the coolant. Air bubbles in the coolant can "insulate" the cylinder walls, preventing normal heat transfer. An abnormally low coolant level can cause the water pump to become (:air-bound," a condition in which it works feverishly but pumps nothing. Without proper heat transfer, silicone elastomer head-to-block water hole seals can deteriorate and cylinder components can expand so that pistons rapidly cut through the lubricant on the liner walls. Scuffing and piston seizure may follow.

> **CAUTION:** Use extreme care when removing a radiator pressure-control cap from an engine. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

An engine may contain the correct amount of properly inhibited coolant, but still fail to adequately cool the engine. In cases where this occurs, other causes of low coolant flow, either engine or cooling system related, should be investigated.

1. Always use a properly inhibited coolant.

2. Do not use soluble oil.

3. Maintain the prescribed inhibitor strength.

4. Always follow the manufacturer's recommendations on inhibitor usage and handling.

5. If freeze protection is required, use a solution of water and antifreeze meeting GM specification 1899M.

6. Reinhibit antifreeze with a recommended non-chromate inhibitor system.

7. Do not use a chromate inhibitor with antifreeze.

8. Do not use methoxy propanol base antifreeze in Detroit Diesel engines.

9. Do not mix ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.

10. Do not use antifreeze containing sealer additives.

11. Do not use methyl alcohol base antifreeze.

12. Use extreme care when removing the radiator pressure-control cap.

SECTION 14

ENGINE TUNE-UP

CONTENTS

ENGINE TUNE-UP PROCEDURES

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

To comply with emissions regulations, injector timing, exhaust valve clearance, engine idle and no-load speeds, and throttle delay or fuel modulator settings must be checked and adjusted if necessary, at 50,000 mile intervals (refer to Section 15.1).

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly.

The governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor.

Normally, when performing a tune-up on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if a cylinder head, governor or injectors have been replaced or overhauled, then certain preliminary adjustments are required. before the engine is started.

The preliminary adjustments consist of the first four items in the tune-up sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

NOTE: If a supplementary governing device, such as the throttle delay mechanism, is used, it must be disconnected prior to the tune-up. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tune-up an engine completely, perform all of the adjustments, in the tune-up sequence given below after the engine has reached normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Use new valve rocker cover gaskets after the tune-up is completed.

Tune-Up Sequence

NOTE: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover, the serviceman 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.

CAUTION: An overspeeding engine can result in engine damage which could cause personal injury.

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the Belleville spring for "TT" horsepower.
8. Adjust the buffer screw.
9. Adjust the supplementary governing device, if used.

EMISSION REGULATIONS FOR ON-HIGHWAY VEHICLE ENGINES

On-highway vehicle and coach engines built by Detroit Diesel Allison are certified to be in compliance with Federal and California Emission Regulations established for each model year beginning with 1970.

Engine certification is dependent on five physical characteristics:

1. Fuel injector type.
2. Maximum full-load engine speed.
3. Camshaft timing.
4. Fuel injector timing.
5. Throttle delay (orifice size).

The following Tables summarize all of the pertinent data concerning the specific engine configurations required for each model year.

When serviced, all on-highway vehicle and coach engines should comply with the specifications for the specific model year in which the engine was built.

Trucks in a fleet containing engines of various model years can be tuned to the latest model year, provided the engines have been updated to meet the specifications for that particular year.

Engine	6V, 8V & 12V-71N (4 Valve)			6V-71N (2 Valve)	6V & 8V-71T	
Injector	71N5 N55 N60	N65	N70	71N5 N55 N60	N65	N70 N75
Maximum Engine Speed	2100	2100	2300	2100	2100	2100
Camshaft Timing	Std.	Adv.	Adv.	Std.	Std.	Std.
Injector Timing	1.460	1.484	1.460	1.460	1.484	1.460
Throttle Delay	No	No	No	.022" Orifice	.022" Orifice	.022" Orifice

TABLE 1 - 1970-1971 ENGINES

Engine	● 6V, 8V & 12V-71N (4 Valve)			6V-71N (2 Valve) 6V & 8V-71N (4 Valve) (Coach)	6V, 8V, & 12V-71T		‡ 8V-71T
Injector	71N5 N55 N60	N65	N70	71N5 N55 N60	N65	N70 N75	N75
▲ Maximum Full Load Engine Speed	2300	2300	2300	2100	2100	2100	2300
Camshaft Timing	Std.	Adv.	Adv.	Std.	Std.	Std.	Std.
■ Injector Timing	1.460"	1.484"	1.460"	1.470"	1.484"	1.460"	1.460"
Throttle Delay	No	No	No	.016" Orifice	.016" Orifice	.016" Orifice	.016" Orifice

● Includes certain highway coach engines.
■ The adjusted height of the fuel injector follower in relation to the injector body.
▲ No load engine speed will vary with injector size and governor type.
‡ 8V-71T Fire Truck Application exempt from certification.

The 6V-71N two valve and 6V and 8V-71N four valve coach engines now have a fuel injector timing of 1.470" and will use injector timing gage J 24236.

TABLE 2 - 1972 ENGINES

Engine	6V, 8V & 12V-71N (4 Valve) ●			6V-71N (2 Valve) 6V & 8V-71N (4 Valve) (Coach)		6V, 8V & 12V-71T		8V-71T ***	
**Injector	71C5	C55 C60	C65 C70	71C5	C55 C60	C65	N70 N75	C65	N70 N75
**Maximum Full Load Engine Speed	2300	2300	2300	2100	2100	2100	2100	2300	2300
Camshaft Timing	Std.	Std.	Adv.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.484	1.460	1.484	1.484	1.470	1.460	1.484	1.460	1.484
*Throttle Delay	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

*Throttle delays must have .016 in. diameter orifice.
**No load engine speed will vary with injector size and governor type.
***Exempt engine rating for fire truck application only (Code No. 851).
● Includes certain highway coach engines.
Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

TABLE 3 - 1973 ENGINES

Engine	6V-71N *	8V-71N *	12V-71N *	6V-71N (2 Valve) Coach ▲	8V-71N Coach ▲	8V-71T
Injectors	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 C70 N75
Maximum Full-Load Engine Speed ◆	2300	2300	2100	2100	2100	2100
Camshaft Timing	71C5, C55, C60 Standard C65 and C70§ Advanced			Standard	Standard	Standard
Injector Timing	71C5, C65, C70§ - 1.484 C55, C60 - 1.460			71C5 - 1.484 C55, C60-1.470		C65 - 1.460 N70, N75-1.484
Throttle Delay	No	No	No	Yes ●	Yes ●	Yes
Yield Link	No	No	No	Yes	Yes	Yes

* Includes Certain Parlor and Suburban Coach Engines.
▲ Uses No. 1 Diesel Fuel for City Coaches.
● .250" Diameter Fill Hole, .016" Diameter Discharge Orifice.
▼ .078" Diameter Fill Hole, .016" Diameter Discharge Orifice
§ Not Certified for 12V-71N.
◆ Not to exceed fuel injector size and maximum operating rpm that has been established for the specific application of the engine.
Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

TABLE 4 - 1974 ENGINES

Engine	FEDERAL					
	6V-71N #	8V-71N #	12V-71N #	6V-71N (2 valve) Coach @	8V-71N (4 valve) Coach @	8V-71T
Injectors	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75
*Maximum Full-Load Engine Speed	2300	2300	2100	2100	2100	2100
Camshaft Timing	71C5, C55, C60 (Standard) C65, C70† (Advanced)			Standard	Standard	Standard
Injector Timing	71C5, C65, C70† - 1.484" C55, C60 - 1.460"			71C5 - 1.484" C55, C60 - 1.470"		C65 - 1.460" N70, N75 - 1.484"
Throttle Delay	No	No	No	Yes ▼	Yes ▼	Yes ■
Yield Link	No	No	No	Yes	Yes	Yes

Engine	FEDERAL AND CALIFORNIA			
	8V-71N	6V-71N (2 valve) Coach	8V-71N (4 valve) Coach	8V-71TA
Injectors	71B5 B55 B60 B65	71B5E B55E B60E	71B5 B55 B60	N65 N70 N75
*Maximum Full-Load Engine Speed	2300	2100	2100	2100
Camshaft Timing	71B5, B55, B60 (Std.) B65 (Advanced)	Standard	Standard	Standard
Injector Timing	71B5, B55, B60 - 1.500" B65 - 1.484"	1.500"	1.500"	N65 - 1.520" N70, N75 - 1.496"
Throttle Delay	No	Yes ▼	Yes ▼	Yes ■
Yield Link	No	Yes	Yes	Yes

* Not to exceed fuel injector size and maximum operating speed (rpm) that had been established for the specific application of the engine.

Includes certain highway coach engines.

@ Uses No. 1 diesel fuel for city coaches.

† Not certified for 12V-71N.

▼ .250" diameter fill hole.

■ .078" diameter fill hole.

Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

TABLE 5 - 1975 ENGINES

FEDERAL								
Engine	(c) 6V-71N	(c) 8V-71N	(c) 12V-71N	(e) 6V-71N Coach	(e) 8V-71N Coach	8V-71T		
						T	OTM	TT
(a) Injectors	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75	C65 N70 N75	N75
Approved Constant Horsepower for TT Engines								305
(b) Maximum Full-load Engine Speed	2300	2300	2100	2100	2100	2100	2100	(d) 1900 Min. 1950 Max.
Camshaft Timing	Std. (71C5, C55, C60) Adv. (C65, C70)			Std.	Std.	Std.	Std.	Std.
Injector Timing	1.484" (71C5, C65, C70) 1.460" (C55, C60)			1.484" (71C5) 1.470" (C55, C60)		1.460" (C65) 1.484" (N70, N75)		
Throttle Delay Yield Link				(f) REQ.	(f) REQ.	(g) REQ.	(g) REQ.	(g) REQ.
Turbocharger A/R						T18A40 1.50 4MF-782 6.54	TV8101 1.60	TV8101 1.60

CALIFORNIA					
Engine	8V-71N	(e) 6V-71N Coach	(e) 8V-71N Coach	8V-71TA After cooled	
				TA	TTA
(a) Injectors	71B5 B55 B60 B65	7B5E B55E B60E	71B5 B55 B60	N65 N70 N75	N75
Approved Constant Horsepower for TT Engines					305
(b) Maximum Full-load Engine Speed	2300	2100	2100	2100	(d) 1900 Min. 1950 Max.
Camshaft Timing	Std. (Adv.-B65)	Std.	Std.	Std.	Std.
Injector Timing	1.500" (1.484"-B65)	1.500"	1.500"	1.496" (1.520"-N65)	1.496"
Throttle Delay Yield Link		(f) REQ.	(f) REQ.	(g) REQ.	(g) REQ.
Turbocharger A/R				TV8101 1.39	TV8101 1.39

(a) Not to exceed injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type.
(b) Use a minimum idle speed of 400 rpm on all coach engines with throttle delay and a minimum idle speed of 500 rpm on all other engines.
(c) Includes certain highway coach engines.
(d) TT (TTA) engines must have full-load speed within the range shown.
(e) Uses No. 1 diesel fuel.
(f) Large fill hole (.250" dia.), .016" discharge orifice.
(g) Small fill hole (.078" dia.), .016" discharge orifice.

TABLE 6 - 1976 ENGINES

FEDERAL								
Engine	(c) 6V-71N	(c) 8V-71N	(c) 12V-71N	(d) 6V-71N Coach	(d) 8V-71N Coach	8V-71T		
						T	OTM	TT
(a) Injectors	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75	C65 N70 N75	N75
(a) Approved Minimum Constant Horsepower								305
(d) Maximum Rated Speed	2300	2300	2100	2100	2100	2100	2100	2100
(a) Minimum Rated Speed	2100 (71C5) 2100 (C55) 1950 (C60) 2100 (C65) 2300 (C70)	2100 (71C5) 1950 (C55) 1950 (C60) 1950 (C65) 2100 (C70)	2100 (71C5) 1950 (C55) 1800 (C60) 2100 (C65)	2000	1800 (71C5) 2000 (C55) 1800 (C60)	2100 1900 (N75)	2100 1900 (N75)	1900
Gear Train Timing	Std. (71C5, C55, C60) Adv. (C65, C70)			Std.	Std.	Std.	Std.	Std.
Injector Timing	1.460" (C55, C60) 1.484" (71C5, C65, C70)			1.484" (71C5) 1.470" (C55, C60)		1.460" (C65) 1.484" (N70, N75)		
Throttle Delay Yield Link Setting				(e) REQ. .570"	(e) REQ. .570"	(f) REQ. .570"	(f) REQ. .570"	(f) REQ. .570"
Liner Port Height	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"
Compression Ratio	18.7:1	18.7:1	18.7:1	18.7:1	18.7:1	17:1	17:1	17:1
Blower Drive Ratio	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1	1.95:1
Governor Type	Limiting Speed							
Thermostat	170-180° F (77-82° C) Nominal Opening Temperature							
Turbocharger A/R						T18A40 1.50 4MF-782 6.54	TV8101 1.60	TV8101 1.60

CALIFORNIA				
Engine	8V-71 TAE		8V-71 TAE	
	TAE	TTAE		
(a) Injectors	7A65 7A70 7A75	7A75	7A50 7A55 7A60	
(a) Approved Minimum Constant Horsepower		305		
(a) Maximum Rated Speed	2100	2100	2100	
Minimum Rated Speed	1950	1900	1800	
Gear Train Timing	Std.	Std.	Std.	
Injector Timing	1.460"	1.460"	1.466" (7A50) 1.466" (7A55) 1.460" (7A60)	
Throttle Delay Yield Link Setting	(f) REQ. .586"	(f) REQ. .586"	# REQ. .686"	
Liner Port Height	.95"	.95"	.95"	
Compression Ratio	17:1	17:1	17:1	
Blower Drive Ratio	1.95:1	1.95:1	1.95:1	
Governor Type	Limiting Speed			
Thermostat	170-180° F (77-82° C) Nominal Opening Temperature •			
Turbocharger A/R	TV7101 1.23	TV7101 1.23	TV7101 1.23	

(a) Not to exceed injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type.
(c) Includes certain highway coach engines.
(d) Uses No. 1 diesel fuel.
(e) Large fill hole (.250" dia.), .016" discharge orifice.
(f) Small fill hole (.078" dia.), .016" discahrge orifice.
Use (e) with Transit Coach Appl. Code No. 345. Use (f) with Parlor Coach Appl. Code No. 341 and 346.

TABLE 7 - 1977 ENGINES

1978 CALIFORNIA CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	(e) 8V-71TAC		(d) 8V-71 TAC COACH
	TAC	TTAC	
INJECTORS (a)	7A65 7A70 7A75	7A75	7A50 7A55 7A60
APPROVED CONSTANT HORSEPOWER FOR TTAC ENGINES		305	
MAXIMUM (b) FULL LOAD SPEED	2100	2100	2100
MINIMUM FULL LOAD SPEED	1950	1900	1800
CAMSHAFT LOBE POSITION	RET	RET	RET
INJECTOR TIMING	1.460	1.460	7A50-1.466 7A55-1.466 7A60-1.460
THROTTLE DELAY YIELD LINK	(f) REQ.	(f) REQ.	(e) REQ.
TURBOCHARGER A/R	TV7101 1.23	TV7101 1.23	TV7101 1.23

1978 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	(c) 6V-71N	(c) 8V-71N	(c) 12V-71N	(d) 6V-71N COACH	(d) 8V-71N COACH	8V-71T			8V-71TA	
						T	OTM	TT	TA	TTA
INJECTORS (a)	71C5 C55 C60 C65 C70	71C5 C55 C60 C65 C70	71C5 C55 C60 C65	71C5 C55 C60	71C5 C55 C60	C65 N70 N75	C65 N70 N75	N75	N65 7C70 7C75	7C75
APPROVED CONSTANT HORSEPOWER FOR TT & TTA ENGINES								305		305
MAXIMUM FULL LOAD SPEED (b)	2300	2300	2100	2100	2100	2100	2100	2100	2100	1950
MINIMUM FULL LOAD SPEED	71C5-1800 C55-1800 C60-1800 C65-1900 C70-1900	71C5-1800 C55-1800 C60-1800 C65-1900 C70-1900	71C5-1800 C55-1800 C60-1800 C65-1900	1800	1800	1900	1900	1900	1900	1900
CAMSHAFT LOBE POSITION	71C5, C55, C60 – STD. C65 and C70 – ADV.			STD.	STD.	STD.	STD.	STD.	RET.	RET.
INJECTOR TIMING	71C5, C65, C70 – 1.484 C55 and C60 – 1.460			71C5-1.484 C55, C60 – 1.470		C65 – 1.460 N70 and N75 – 1.484			N65-1.484 7C70-1.466 7C75-1.460	1.460
THROTTLE DELAY YIELD LINK	NOT REQ.	NOT REQ.	NOT REQ.	(e) (g) REQ.	(e) (g) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.
TURBOCHARGER A/R						*T18A40 1.50 *4MF-782 6.54 Sq. In.	TV8101 1.60	TV8101 1.39	TV7101 1.23	TV7101 1.23

*These turbocharger options to be cancelled effective 9/1/78.

(a) See Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.
(b) Use a minimum idle speed of 400 rpm on all coach engines with throttle delay and a minimum idle speed of 500 rpm on all other engines.
(c) Includes certain highway coach engines.
(d) Uses No. 1 diesel fuel.
(e) Large fill hole (.250" dia.), .016" discharge orifice.
(f) Small fill hole (.078" dia.), .016" discharge orifice.
(g) .570" setting — gage J-25559.

TABLE 8 - 1978 ENGINES

1979 FEDERAL ENGINES

Families	6V-71N Coach	8V-71N***	8V-71N Coach	8V-71TA	8V-71TTA
Injectors	7E50 7E55 7E60	7E65, 7E60 7E55, 7E50	7E50 7E55 7E60	N65 7C70 7C75	7C75
Maximum Full Load Speed	2100	2300	2100	2100	2100
Minimum Full Load Speed	1800	1800 7E65 - 1900	1800	1900	1900
Minimum Idle Speed	400	500	400	500	500
Gear Train Timing	Std.	Std. 7E65 - Adv.	Std.	Std.	Std.
Injector Timing	7E50 - 1.508 7E55 - 1.496 7E60 - 1.500	1.496 7E60-1.500	1.496 7E60-1.500	N65 - 1.484 7C70 - 1.466 7C75 - 1.460	1.460
Throttle Delay Setting	.570**	DNA	.570**	.570%%	.570%%
Liner Port Height	1.05	1.05	1.05	.95	.95
Liner Part Number	5113953	5113953	5113953	5102795	5102795
Turbocharger A/R	DNA	DNA	DNA	TV7101 1.23 A/R	TV7101 1.23 A/R
Turbocharger Part Number	DNA	DNA	DNA	5101509	5101509
Blower Drive Ratio	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1
Blower Part Number	5103589 5103532	5103494 5103588 5147152	5103588 5103494	5101484	5101484
Compression Ratio	18.7:1	18.7:1	18.7:1	17:1	17:1
Exhaust Valve Material	Inconel X Type 751	Inconel X Type 751	Inconel X Type 751	Nimonic 90 Aluminized	Nimonic 90 Aluminized
Exhaust Valve Part Number	5186381	5114288	5114288	5111336	5111336
Certification Label Number	14B7-274	14B7-276	14B7-275	14B7-277	14B7-277

THROTTLE DELAY AND STARTING AID GAGES

J-24889 For .345"
J-28779 For .365"
J-24882 For .385"
J-9509-2 For .404"
J-23190 For .454"
J-29062 For .504"
J-25559 For .570"
J-26927 For .586" & 686"
J-25560 For .636"
J-29064 For .660"

PIN GAGE

J-25558 For .069" & .072"

TIMING GAGES

J-1853 For 1.460"
J-26888 For 1.466"
J-24236 For 1.470"
J-29065 For 1.480"
J-1242 For 1.484"
J-29066 For 1.490"
J-9595 For 1.496"
J-25454 For 1.500"
J-8909 For 1.508"
J-25502 For 1.520"

1979 CALIFORNIA ENGINES

FAMILIES	8V-71TAC	8V-71TAC	8V-71TTAC
Injectors	7A50 7A55 7A60	7A65 7A70 7A75	7A75
Maximum Full Load Speed	2100	2100	2100
Minimum Full Load Speed	1800	1900	1900
Minimum Idle Speed	400 (1)/500 (2)	500	500
Gear Train Timing	Std.	Std.	Std.
Injector Timing	1.466 7A60 - 1.460	1.460	1.460
Throttle Delay Setting	.686 (1)(2)	.586%%	.586%%
Liner Port Height	.95	.95	.95
Liner Part Number	5102795	5102795	5102795
Turbocharger A/R	TV7101 1.23 A/R	TV7101 1.23 A/R	TV7101 1.23 A/R
Turbocharger Part Number	5101509	5101509	5101509
Blower Drive Ratio	1.95:1	1.95:1	1.95:1
Blower Part Number	5101484	5101484	5101484
Compression Ratio	17:1	17:1	17:1
Exhaust Valve Material	Nimonic 90	Nimonic 90	Nimonic 90
Exhaust Valve Part Number	5111336	5111336	5111336
Certification Label Number	14B7-278	14B7-278	14B7-278

** Large fill hole (.250 dia.) .016 diameter discharge orifice.
%% Small fill hole (.078 dia.) .016 diameter discharge orifice.
*** Includes certain highway coach engines.
(1) With application code No. 345. (**)
(2) Without application code No. 345. (%%)

TABLE 9 - 1979 ENGINES

1980 FEDERAL CERTIFIED
AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	(b) 6V-71N Coach	(b) 8V-71N Coach	(c) 8V-71N	8V-71TA	8V-71TTA
Injectors (a)	7E50 7E55 7E60	7E50 7E55 7E60	7E50 7E55 7E60 7E65	7C75	7C75
Maximum Full Load Speed (a)	2100	2100	2300	2100	2100
Minimum Full Load Speed	1800	1800	1800 7E65-1900	1800	1800
Minimum Idle Speed	400	400	500	(k) 500	(k) 500
Gear Train Timing	Std.	Std.	Std. 7E65-Adv.	Std.	Std.
Injector Timing	7E50-1.508 7E55-1.496 7E60-1.500	1.496 7E60-1.500	1.496 7E60-1.500	1.460	1.460
Throttle Delay Setting	(g) .570	(g) .570	DNA	(f) .570	(f) .570
Turbocharger A/R	DNA	DNA	DNA	TV7101 1.23 A/R	TV7101 1.23 A/R

DNA Does not apply
(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.
(b) Use No. 1 Diesel Fuel.
(c) Includes certain highway coach engines.
(f) Small fill hole (.078 dia.) .016 dia discharge orifice.
(g) Large fill hole (.250 dia.) .016 dia. discharge orifice.
(k) 700 rpm for 1800 rpm full load speed

TABLE 10 1980 ENGINES

EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders and, eventually, burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, increased valve face wear and valve lock damage. Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the -valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

ENGINES WITH TWO VALVE CYLINDER HEADS

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Valve Clearance Adjustment (Cold Engine)

1. Remove the loose dirt from the valve rocker covers and remove the covers.

2. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

3. Rotate the crankshaft, with engine barring tool J 22582 or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted.

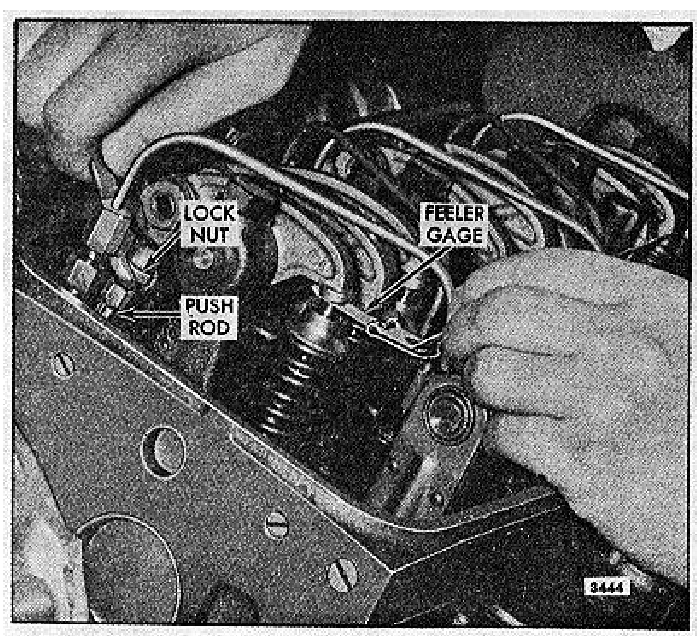


FIG. 1 - Adjusting valve Clearance (two valve Head)

> **NOTE:** If a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may loosen.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a .013" feeler gage, J 9708-OI, between the exhaust valve stem and the rocker arm (Fig. 1). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the lock nut with a 1/2" wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the .0 II" feeler gage will pass freely between the valve stem and the rocker arm, but the .013" feeler gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

Valve Clearance Adjustment (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance, when running at full load, may become insufficient.

1. With the engine at normal operating temperature (refer to Section 13.2), recheck the exhaust valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, the .008" gage will pass freely between the end of the valve stem and the rocker arm and the .010" gage will not pass through. Readjust the push rod, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

Check Exhaust Valve Clearance Adjustment

1. With the engine operating at 100°F (38°C) or less, check the valve clearance.

2. If a .012" feeler gage (J 9708-01)±.004" will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary adjust the push rod.

ENGINES WITH FOUR VALVE CYLINDER HEADS

The exhaust valve bridges must be adjusted and the adjustment screws locked securely at the time the cylinder head is installed on the engine. The necessary adjustment procedure is outlined in Section 1.22.

The exhaust valve bridge balance should be checked when a general valve adjustment is performed. After the bridges are balanced, adjust the valve clearance at t*he push rod only. Do not disturb the exhaust valve bridge adjusting screw.*

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications* at the front of the manual for the engine firing order.

Valve Clearance Adjustment (Cold Engine)

1. Remove the loose dirt from the valve rocker covers and remove the covers.

2. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in t*he stop* position.

3. Rotate the crankshaft, with engine barring tool J 22582 or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted.

> **NOTE:** If a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may loosen.

4. Loosen the exhaust valve rocker arm push rod lock nut.

5. Place a .017" feeler gage, J 9708-01, between the end of the exhaust valve stem and the valve bridge adjustment screw (spring-loaded bridge only) or between the valve bridge and the valve rocker arm pallet (unloaded bridge only) -- refer to Figs. 2 and 3. Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16" wrench and tighten the lock nut with a 1/2" wrench.

7. Recheck the clearance. At this time, if the

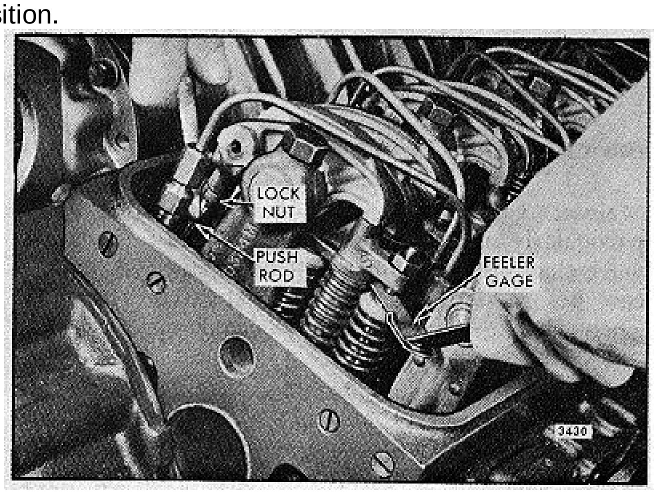


FIG. 2 - Adjusting Valve (Clearance (Spring-Loaded Valve Bridge)

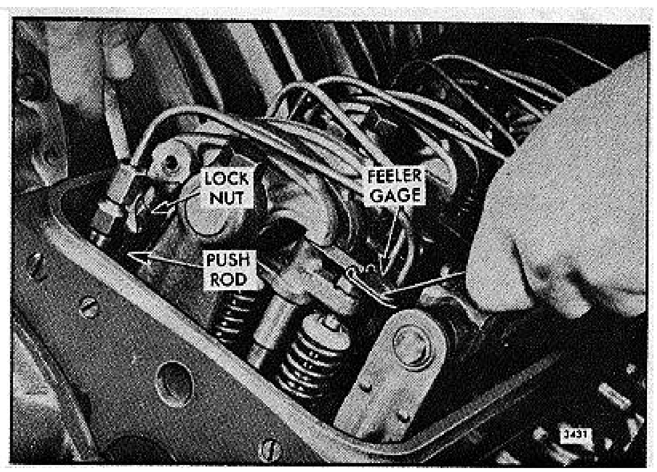


FIG. 3 Adjusting Valve Clearance (Unloaded Valve Bridge)

adjustment is correct, the .01 5" gage will pass freely between the valve stem and the adjustment screw (spring-loaded bridge) or between the valve bridge and the rocker arm pallet (unloaded bridge), but the .017" gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

Valve Clearance Adjustment (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance, when running at full load, may become insufficient.

1. With the engine at normal operating temperature (refer to Section 13.2), recheck the exhaust valve clearance with feeler gage J 9708401. At this time, if the valve clearance is correct, the .Ol33" gage will pass freely between the valve stem and the valve bridge adjusting screw (spring-loaded bridge) or between the valve bridge and the rocker arm pallet (unloaded bridge), but the .015", feeler gage will not pass through. Readjust the push rod, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing (Section 14.2).

Check Exhaust Valve Clearance Adjustment

1. With the engine operating at 100°F (38°C) or less, check the valve clearance.

2. If a .016" feeler gage (J 970801) ± .004" will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary adjust the push rod.

FUEL INJECTOR TIMING

To time an injector property, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed in firing order sequence during one full revolution of the crankshaft. Refer to the *General Specifications at* 'the front of the manual for the engine firing order.

Time Fuel Injector

After the exhaust valve clearance has been adjusted (Section 14.1), time the fuel injectors as follows:

1. Place the governor speed control lever in the *idle* speed position. If a stop lever is provided, secure it in the *stop* position.

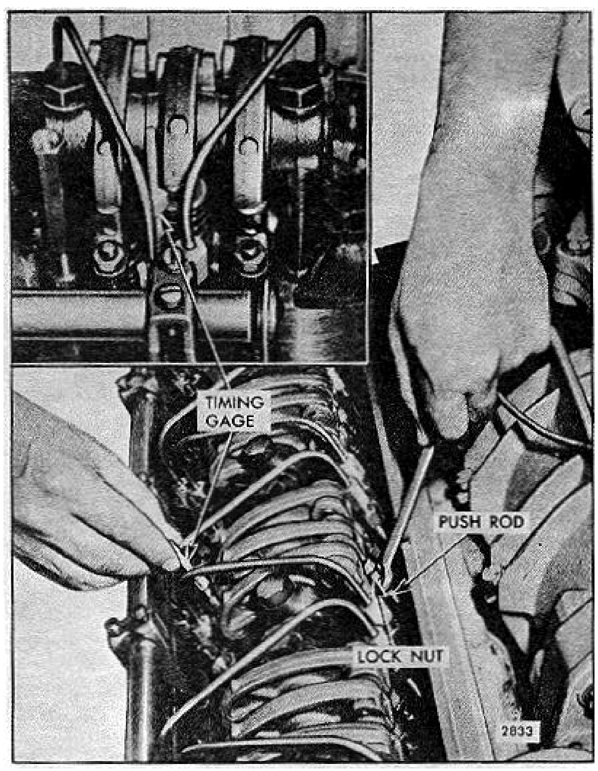


FIG. 1 - Timing Fuel Injector

2. Rotate the crankshaft, with the starting motor or with engine barring tool J 22582, until the exhaust valves are fully depressed on the particular cylinder to be timed.

> **CAUTION:** If a wrench or barring tool is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

3. Place the small end of the injector timing gage in the hole provided in the top of the injector body with the flat of the gage toward the injector follower (Fig. 1). Refer to Table I for early engines equipped with crown valve injectors. Refer to Section 14 for engines equipped with needle valve injectors.

4. Loosen the injector rocker arm push rod lock nut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

6. Hold the push rod and tighten the lock nut. Check the adjustment and, if necessary, re-adjust the push rod.

7. Time the remaining injectors in the same manner as outlined above.

8. If no further engine tune-up is required, install the valve rocker covers, using new gaskets.

Injector	Timing Dimension	Timing Gage
S55	1.460"	J 1853
S60	1.460"	J 1853
S65	1.460"	J 1853
S70	1.460"	J 1853

TABLE 1 (Injector Timing)

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

Two types of limiting speed mechanical governors are used. The difference between each type of governor is in the high-speed spring retainer and spring housing assembly. Certain engines use the standard limiting speed governor while some engine applications use the dual range limiting speed governor. The only variation in the tune-up procedure between each type of governor is in the setting of the maximum no-load speed.

NOTE: For adjustment of an 8V-71 TT Fuel Squeezer engine, refer to Section 14.3.5. Also refer to Section 2.0 for disassembly and assembly of a tamper resistant governor.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

NOTE: Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device as outlined in Section 14. Back out the external starting aid screw.

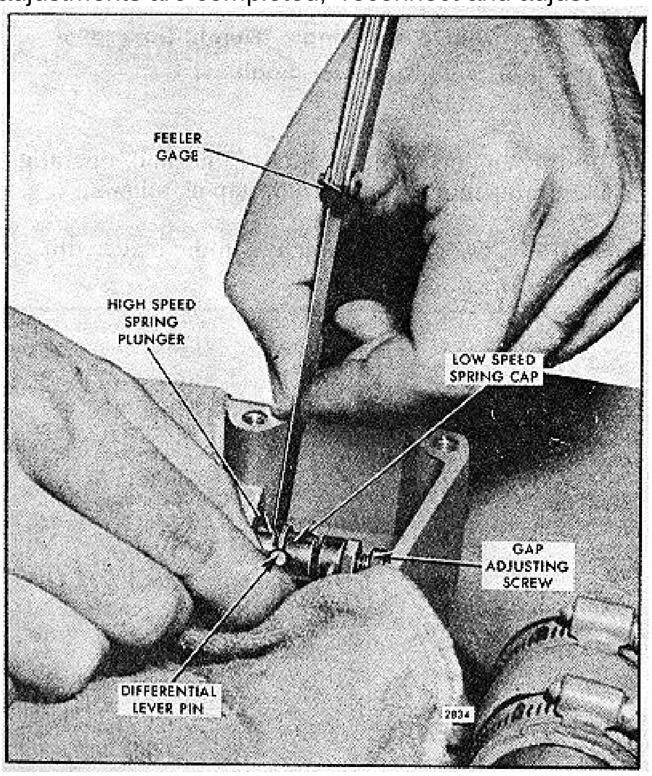


FIG. 1 - Adjusting Governor Gap (Double Weight Governor)

NOTE: On Fuel Squeezer engines back out the Belleville spring retainer nut until there is approximately .060" clearance between the washers and the retainer nut.

Adjust Governor Gap (Double Weight Governor)

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

NOTE: If the governor gap adjustment is to be made with the engine in the vehicle, it is suggested that the fan assembly be removed, due to the closeness of the blades to the engine governor.

1. Remove the high-speed spring retainer cover.

2. Back out the buffer screw until it extends approximately 5/8” from the lock nut (Fig. 12).

3. Start the engine and loosen the idle speed adjusting screw lock nut. Then adjust the idle screw (Fig. 11) to obtain the desired engine idle speed. Hold the screw and tighten the lock nut to hold the adjustment.

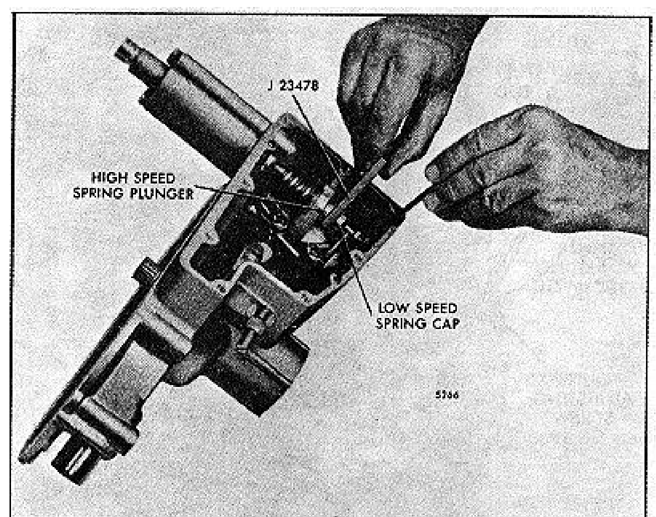


FIG. 2 Adjusting Governor Gap (Single Weight Governor)

NOTE: Limiting speed governors used in turbocharged engines include a starting aid screw threaded into the governor housing (current engines), or the governor gap adjusting screw (early engines). A lock nut is not required on early engines as both the gap adjusting screw and the starting aid screw incorporate a nylon patch in lieu of lock nuts.

IMPORTANT: The recommended idle speed for non-EPA certified engines is 400-450 rpm, but may vary with special engine applications. EPA certified minimum idle speeds are 500 rpm for trucks and highway coaches and 400 rpm for city coaches.

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.

5. Start and run the engine between 100 and 1300 rpm by manual operation of the differential lever.

NOTE: Do not overspeed the engine.

6. Check the gap between the low-speed spring cap and the high-speed spring plunger (Fig. I) with a feeler gage. The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.

7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the lock nut.

8. Recheck the gap with the engine operating between 1100-1300 rpm and readjust if necessary.

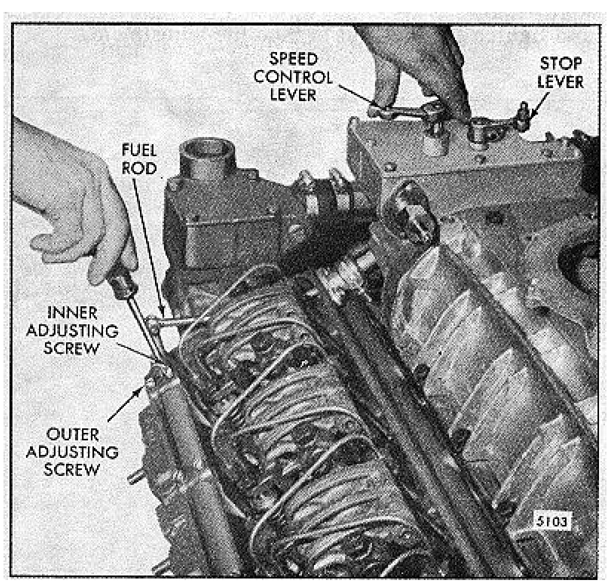


FIG. 3 - Positioning No. 1L injector Rack Control Lever (Two Screw Assembly)

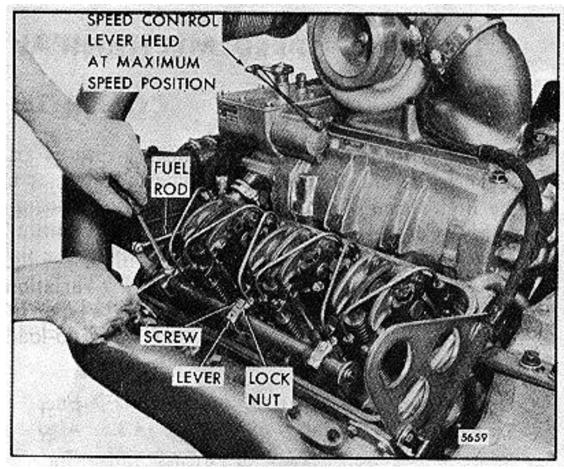


FIG. 4 Position No. 1 Injector Rack Control Lever (One Screw and Lock Nut Assembly)

9. Stop the engine and, using a new gasket, install the governor cover and lever assembly. Tighten the screws.

NOTE: Do not install the governor cover and lever assembly at this time on early engines that include the internal starting aid screw.

Adjust Governor Gap (Single Weight Governor) (Other than Fuel Squeezer Engines)

With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

NOTE: If the gap adjustment is to be made with

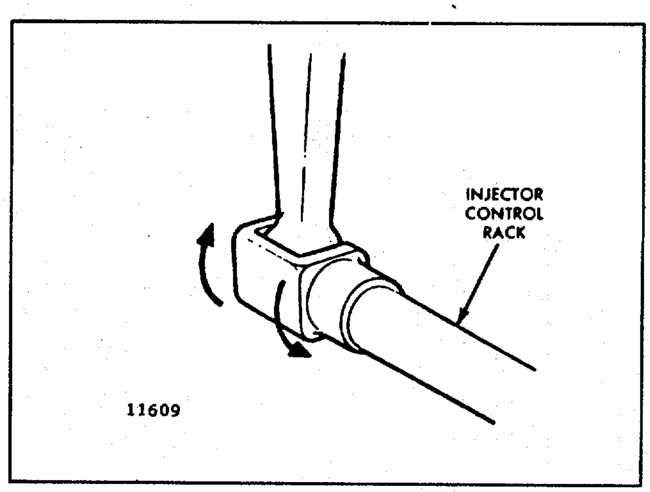


FIG. 5 Checking Rotating Movement of Injector Control Rack

the engine in the vehicle, it is suggested that the fan assembly be removed due to the closeness of the fan blades to the engine governor.

1. Remove the governor high-speed spring retainer cover.

2. Back out the buffer screw (Fig. 12) until it extends approximately 5/8" from the lock nut.

3. Start the engine and loosen the idle speed adjusting screw lock nut. Then adjust the idle screw to obtain the desired engine idle speed. Hold the screw and tighten the lock nut to hold the adjustment.

NOTE: Limiting speed governors used in turbocharged engines include an external starting aid screw threaded into the governor housing.

IMPORTANT: EPA certified minimum idle speeds are 500 rpm for trucks and highway coaches and 400 rpm for city coaches.

If, in going from top no load speed to idle speed, the engine governor will not recover and the engine stalls, it may become necessary to increase the idle speed to a minimum speed of 600 rpm (see Chart).

ENGINE	INJECTOR	DROOP	IDLE SPEED
6, 8 and 12V Turbo	All	Unchanged	600 rpm min. (was 500 rpm min.) All Injector Sizes
6, 8 and 12V Not. Asp.	7E65 mm	175 rpm (was 150 rpm)	Unchanged

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker cover. Discard the gaskets.

5. Remove the fuel rod from the differential lever and the injector control tube lever 6. Check the gap between the low-speed spring cap and the high-speed spring plunger with gage J 23478 (.200"t) as shown in Fig. 2.

NOTE: Be sure the external starting aid screw (if used) is backed out far enough to make it ineffective when making this adjustment.

7. If required, loosen the lock nut and turn the gap adjusting screw until a slight drag is felt on the gage.

8. Hold the adjusting screw and tighten the lock nut.

9. Recheck the gap and readjust if necessary.

10. Install the fuel rod between the governor and injector control tube lever.

I1. Use a new gasket and install the governor cover and lever assembly.

Position Injector Rack Control Levers

The positions of the injector racks must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Certain engines use spring-loaded injector control tube assemblies (Fig. 4) which have a yield spring at each injector rack control lever and only one screw and lock nut to keep each injector rack properly positioned. Adjust the single screw and lock nut on each injector rack control lever the same as for the two screw rack control lever.

NOTE: To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that are to be used with the governor.

Properly positioned injector rack control levers with the engine at full load will result in the following;

1. Speed control lever at the maximum speed position.

2. Governor low-speed gap closed.

3. High-speed spring plunger on the seat in the governor control housing.

4. Injector fuel control racks in the full-fuel position.

The letters R and L indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1 L injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the governor speed control lever.

2. Turn the idle speed adjusting screw until 1/2" of the threads (12-14 threads) project from the lock nut when the nut is against the high-speed plunger.

NOTE: A false fuel rack setting may result if the

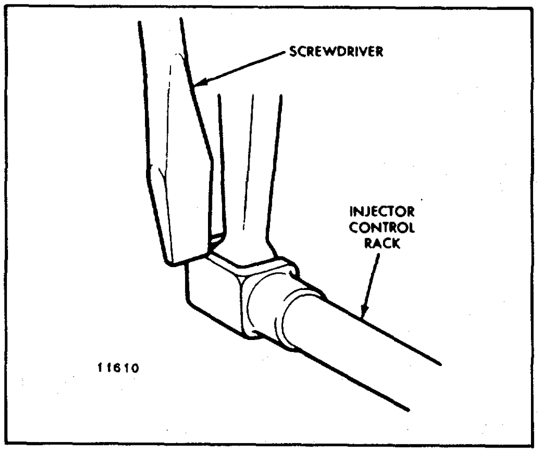


FIG. 6 Checking Injector Control Rack "Spring"

idle speed adjusting screw is not backed out as noted above.

This adjustment lowers the tension of the low-speed spring so it can be easily compressed. This permits closing the low-speed gap without bending the fuel rods or causing the yield mechanism springs to yield or stretch.

Injector racks must be adjusted so the effort to move the throttle from the idle speed position to the maximum speed position is uniform. A sudden increase in effort can result from:

a. Injector racks adjusted too tight causing the yield link to separate.

b. Binding of the fuel rods.

c. Failure to back out idle screw.

3. Back out the buffer screw approximately 5/8"1, if it has not already been done.

4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube]ever.

5. Loosen all of the inner and outer injector rack control lever adjusting screws on both cylinder heads. Be sure all of the injector rack control levers are free on the injector control tubes.

6. Move the speed control lever to the *maximum* speed position; hold it in that position with light finger pressure. Turn the inner adjusting screw of the No. IL injector rack control lever down (Fig. 3) until a slight movement in the control tube lever is observed or a step-up in *effort* to turn the screw driver *is* noted. This will place the No. IL injector rack in the full-fuel position. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube. Then *a*lternately tighten *both* the inner and *outer adjusting* screws.

NOTE: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 in-lbs(3-4 Nm).

IMPORTANT: The above step should result in placing the governor linkage and control tube assembly in the same position that they will attain while the engine is running at full load.

7. To be sure of the proper rack adjustment, hold the speed control lever in the maximum speed position and press down on the injector rack with a screw driver or finger tip and note the "rotating" movement of the injector control rack (Fig. 5). Hold the speed control lever in the maximum speed position and, using a screw driver, press downward on the injector control rack. The rack should tilt downward (Fig. 6) and when the pressure of the screw driver is released, the control rack should "spring" back upward.

If the rack does not return to its original position, it is too loose. To correct this condition, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly.

The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in *effort* required to *move* the speed control lever to the end of its travel. To correct this condition, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.

8. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.

9. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever and position the No. 1 R. injector rack control lever as previously outlined in Step 6 for *the No. IL* injector *rack* control lever.

10. Insert the clevis pin in the fuel rod and the left bank injector control tube lever. Repeat the check on the No. IL and No. 1 R injector rack control levers as outlined in Step 7. Check for and eliminate any deflection which occurs at the bend in the fuel rod where it enters the cylinder head.

11. To adjust the remaining injector rack control levers, remove the clevis pins from the fuel rods and the injector control tube levers, hold the injector control racks in the full-fuel position by means of the lever on the end of the control tube and proceed as follows:

a. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the full-fuel position).

b. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.

c. While still holding the control tube lever in the full-fuel position, adjust the inner and outer adjusting screws to obtain the same condition as outlined in Step 7. Tighten the screws.

IMPORTANT: Once the No. IL and No. 1 R. injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

NOTE: Overtightening of the injector rack control tube lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 in-lbs(3-4 Nm).

12. When all of the injector rack control levers are adjusted, recheck their settings. With the control tube lever in the full-fuel position, check each control rack as in Step 7. All of the control racks must have the same "spring" condition with the control tube lever in the full-fuel position.

13. Insert the clevis pin in the fuel rod and the injector control tube levers.

14. Turn the idle speed adjusting screw in until it projects 3/16" from the lock nut, to permit starting the engine.

15. On current turbocharged engines, adjust the external starting aid screw as follows:

a. With the engine *stopped,* place the governor stop lever in the *run* position and the speed control lever in the *idle* position.

b. Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body (Fig. 7). Select the proper gage and measure the setting at any convenient cylinder. When the starting aid screw is properly adjusted, the gage should have a small clearance of 1/64" in the space along the injector rack shaft between the rack clevis and the injector body.

c. After completing the adjustment, hold the starting aid screw and tighten the lock nut.

d. Check the injector rack clevis-to-body clearance after performing the following.

1. Position the stop lever in the *run* position.

2. Move the speed control lever from the *idle speed* position to the *maximum* speed position.

3. Return the speed control lever to the idle position.

NOTE: Movement of the governor speed control lever is to take-up clearances in the governor linkage. The clevis-to-body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjusting screw.

IMPORTANT: The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start-up.

16. On early turbocharged engines, adjust the internal starting aid screw as follows:

a. With the engine *stopped,* place the governor stop lever in the *run* position and the speed control lever in the *idle* position.

b. Hold the gap adjusting screw, to keep it from turning, and adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body (Fig. 5). The setting is measured at the No. 3R injector rack clevis.

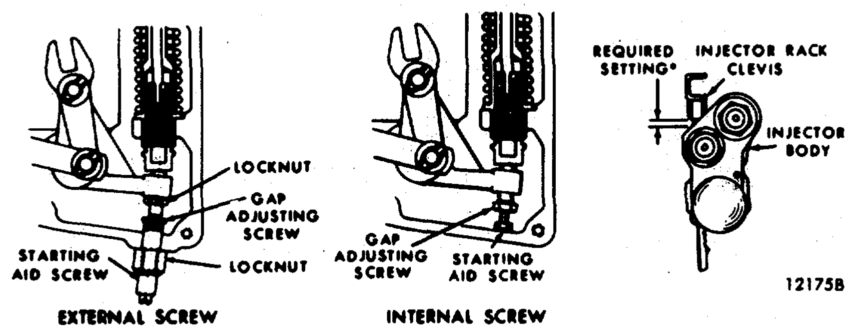
c. Check the injector rack clevis-to-body clearance after performing the following:

1. Position the stop lever in the *run* position.

2. Move the speed control lever from the *idle* position to the *maximum* speed position.

3. Return the speed control lever to the *idle speed* position.

NOTE: Movement of the governor speed control lever is to take-up clearances in the governor linkage. The clevis-to-body clearance can be increased by backing out the starting aid screw or reduced by turning it farther into the gap adjusting screw.



INJECTOR	GAGE SETTING*	TOOL NUMBER
S80	.345"	J 24889
N60	.345"	J 24889
N65	.385"	J 24882
N70	.385"	J 24882
N75	.385"	J 24882
N80	.385"	J 24882
N90	.454"	J 23190
C65	.385"	J 24882
C80	.385"	J 24882
7A50	345"	J 24889
7A55	.345"	J 24889
7A60	.345"	J 24889
7A65	.385"	J 24882
7A70	.385"	J 24882
7A75	.385"	J 24882
7C70	.385"	J 24882
7C75	.385"	J 24882
7E50	.345"	J 24889
7E55	.345"	J 24889
7E60	.345"	J 24889
7E65	.385"	J 24882

FIG. 7 - Starting Aid Screw Adjustment

d. Start the engine and recheck the running gap (.002"-.004") and, if necessary, reset it and reposition the injector racks. Then stop the engine.

e. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover.

NOTE: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever

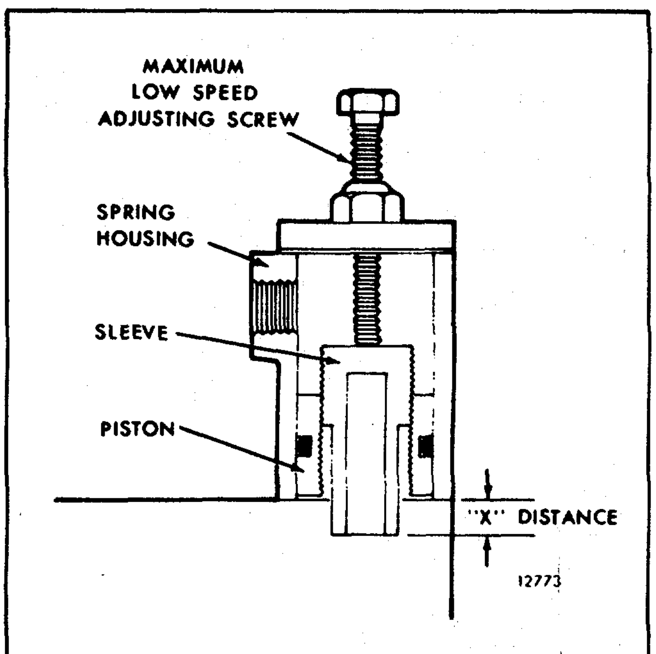


FIG. 8 - Early Dual Range Governor (Top View)

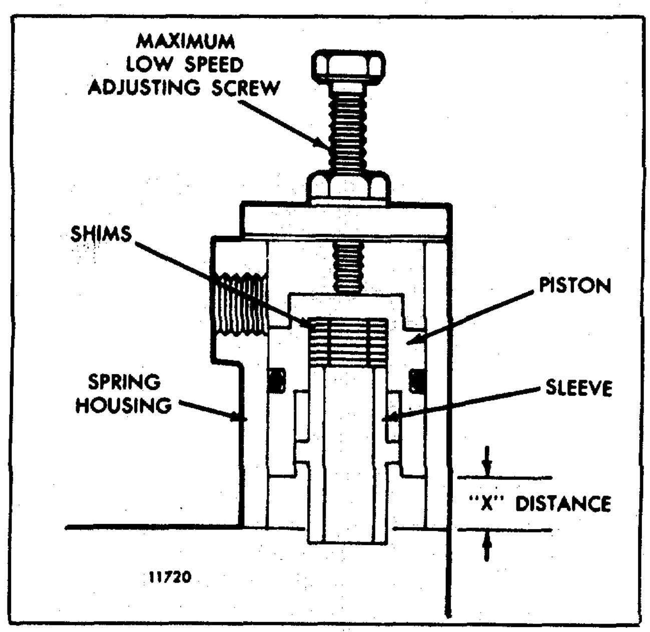


FIG. 9 - Current Dual Range Governor (Top View)

assembly, the serviceman 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.

CAUTION: An overspeeding engine can result in engine damage which could cause personal injury.

17. Use new gaskets and replace the valve rocker covers.

Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no-load speed as given on the engine option plate, set the maximum no-load speed as follows:

STANDARD GOVERNOR

After positioning the injector rack control levers, set the maximum no-load engine speed as follows:

NOTE: Be sure the buffer screw (or fast idle air cylinder) projects 5/8" from the lock nut to prevent interference while adjusting the maximum no-load speed.

1. Loosen the spring retainer lock nut (Fig. 10) and back off the high-speed spring retainer approximately five turns.

2. With the engine running at operating temperature and no-load on the engine, place the speed control lever in the maximum speed position. Turn the high-speed spring retainer until the engine is operating at the recommended no-load speed.

3. Hold the high-speed spring retainer and tighten the lock nut, using spanner wrench J 5345-5.

CURRENT DUAL RANGE GOVERNOR (Fig. 9)

After positioning the injector control levers, set the maximum engine speeds.

NOTE: Be sure the buffer screw (or fast idle air cylinder) projects 5/8" from the lock nut to prevent interference while adjusting the maximum no-load speeds.

With the spring housing assembly mounted on the governor, the piston and sleeve assembled with four .100" shims and ten .010" shims and the low maximum speed screw extending from the spring housing approximately 1-1/4", proceed as follows:

NOTE: Do not apply air or oil pressure to the governor until performing Step 1 f.

1. Set the high maximum no-load engine speed:

   a. Start and warm-up the engine. Then position the speed control lever in the maximum speed position.

   b. Turn the low maximum speed adjustment screw in until the high maximum speed desired is obtained.

   c. Stop the engine and remove the spring housing assembly.

   d. Note the distance ("X" distance, Fig. 9) the piston is from the bottom of the spring housing when it is against the low maximum speed screw, then remove the sleeve from the piston.

IMPORTANT: Do not permit the seal ring on the piston to slide past the air inlet port, since the seal ring will be damaged.

NOTE: When checking this distance, the piston should be held tight against the adjustment screw of - the cover that is held in position, with its gasket, against the end of the spring housing.

   e. Remove a quantity of shims, from the shims within the piston, equal to the distance noted in Step d.

   f. Start the engine and position the speed control lever in the maximum speed position and apply air or oil pressure to the governor and note the engine speed.

   g. Remove the air or oil pressure from the governor and stop the engine. Then install or remove shims as required to obtain the correct high maximum no-load speed. Removing shims will decrease the engine speed and adding shims will increase the engine speed.

NOTE: Each .010" shim removed or added will decrease or increase the engine speed approximately 10 rpm.

2. Set the low maximum no-load engine speed:

   a. Adjust the low maximum speed adjusting screw, with the speed control lever held in the maximum speed position, until the desired low maximum speed is obtained. Turn the screw in to increase or out to decrease the engine speed.

b. Recheck the engine speed and readjust, if necessary.

3. Check both the high maximum and low maximum engine speeds. Make any adjustment that is necessary as outlined in Steps I and 2.

EARLY DUAL RANGE GOVERNOR (Fig. 8)

After positioning the injector rack control levers and setting the idle speed, set the maximum engine speeds.

NOTE: Be sure the buffer screw projects 5/8" from the lock nut to prevent its interference while adjusting the maximum no-load speeds.

IMPORTANT: To prevent air leakage between the piston and sleeve assembly, coat the mating threads with sealant.

With the spring housing assembly mounted on the governor, the piston and sleeve assembly assembled and the low maximum speed adjusting screw extended from the spring housing approximately 3/4" beyond the lock nut, proceed as follows:

NOTE: Do not apply air pressure to the governor until performing Step I h,

1. Set the high maximum no-load speed:

   a. Start the engine and place the engine speed control lever in the maximum speed position.

   b. Loosen the lock nut and turn the low maximum speed adjusting screw in until the desired no-load high maximum speed is obtained.

   c. Stop the engine and remove the spring housing assembly. Note the distance ("X" distance, Fig. 8) the sleeve extends beyond the spring housing.

   NOTE: Do not permit the seal ring on the piston to slide past the air inlet port, since the seal ring will be damaged.

   d. Remove the piston and sleeve from the bottom of the spring housing.

   e. Thread the piston on the sleeve until the sleeve extends the same distance ("X" distance, Fig. 8) beyond the piston as the sleeve extends beyond the spring housing.

   f. Check the adjustment by installing the piston and sleeve in the spring housing. The piston should be flush to 1/64" below the bottom of the spring housing when it is tight against the adjustment screw.

   NOTE: The cover, cover gasket and spring housing must be held as an assembly when checking the piston position.

   g. Replace the piston and sleeve in the governor spring housing and assemble to the governor.

   h. Start the engine and place the speed control lever in the maximum speed position and apply air pressure to the governor.

   NOTE: To overcome the tension of the governor high-speed spring, 50 psi (345 kPa) air pressure will be required in the governor spring housing.

   i. Back out the low maximum speed adjustment screw 1/4". If the piston is adjusted correctly, the engine will operate at the recommended high maximum no-load speed.

   j. Remove the air pressure from the governor.

   k. Make minor adjustment on the piston and sleeve if necessary to establish the exact speed desired.

2. Set the low maximum no-load engine speed:

   a. Adjust the low maximum speed adjusting screw, with the speed control lever in the maximum speed position, until the desired low maximum speed is obtained.

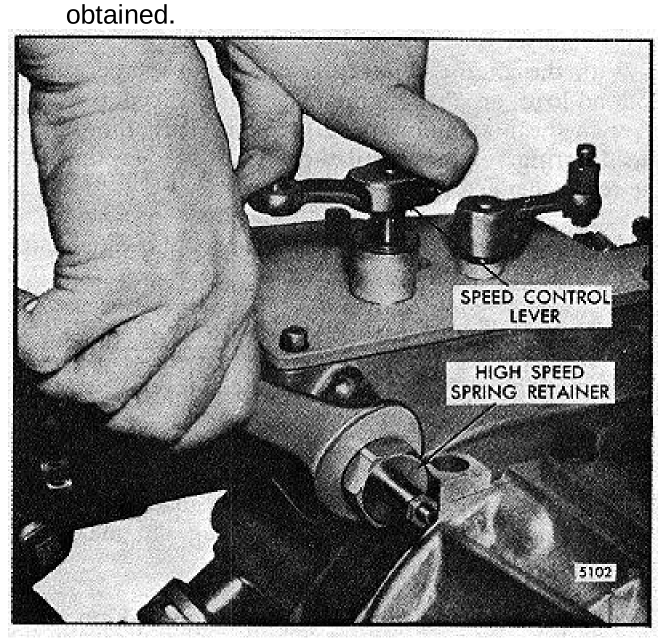


FIG. 10 - Adjusting Maximum No-Load Speed

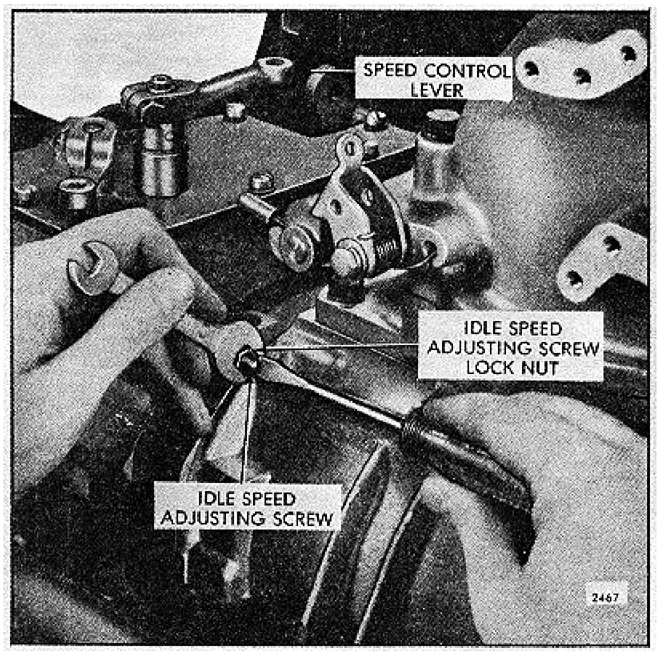


FIG. 11 - Adjusting Engine Idle Speed

b. Turn the screw in to increase or out to decrease engine speed.

3. Check both the high maximum and low maximum engine speeds. Make any adjustment that is necessary as outlined in Steps I and 2.

Adjust Idle Speed

Adjust the idle speed as follows:

1. With the engine running, at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw (Fig. I 1) until the engine operates at approximately 15 rpm below the recommended idle speed.

IMPORTANT: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8").

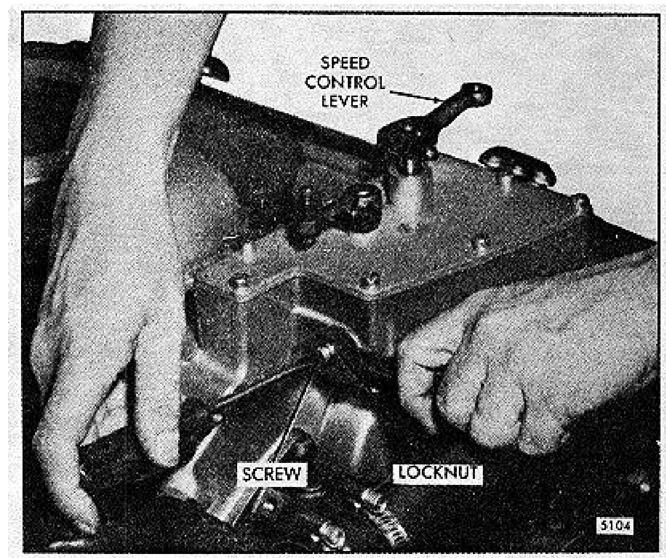


FIG. 12 - Adjusting Buffer Screw

NOTE: The recommended idle speed for non-EPA certified engines is 400-450 rpm, but may vary with special engine applications. EPA certified minimum idle speeds are 500 rpm for trucks and highway coaches and 400 rpm for city coaches.

2. Hold the idle screw and tighten the lock nut.

3. Install the high-speed spring retainer cover and tighten the two bolts.

Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw as follows:

1. With the engine running at normal operating temperature, turn the buffer screw (Fig. 12) in so it contacts the differential lever as lightly as possible and still eliminates engine roll.

NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.

2. Recheck the maximum no-load speed. If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.

3. Hold the buffer screw and tighten the lock nut.

LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT

(Variable Low-Speed)

The variable low-speed limiting speed mechanical governor is used on highway vehicle engines where the same engine powers both the vehicle and the auxiliary equipment for unloading bulk products (such as cement, grain or liquids) and a high idle speed range is desired during auxiliary operation.

The current governor is a single-weight type and provides an idle speed range of 500 to 1800 rpm. The former governor was a double-weight type and provided an idle speed range of 450 to 1300 rpm.

During highway operation, the governor functions as a limiting speed governor, controlling the engine idling speed and limiting the maximum operating speed. At the unloading area, the throttle is left in the idle speed position and the speed adjusting handle, on the cable operated governor (Fig. 1), is turned to the speed required within the above range to operate the auxiliary equipment. For the air operated governor (Fig. 2), the engine speed is changed to the speed required by increasing or decreasing the air supply pressure to the governor. The governor then functions as a variable speed governor, maintaining a constant speed when the load is constantly changing, during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned back to the stop, then turned ahead about one-quarter of a turn. The air operated governor's air supply pressure must be vented before resuming highway operations.

Governor identification is provided by a name plate attached to the governor housing. The letters V.L.S.- L.S. stamped on the name plate denote a variable low-speed limiting speed mechanical governor.

After adjusting the exhaust valves and timing the injectors, adjust the governor and position the injector rack control levers.

Adjust Governor Gap (Single-Weight Type)

With the engine at operating temperature, adjust the governor gap as follows:

1. Stop the engine, remove the two bolts and withdraw the governor spring retainer cover. Discard the gasket.

2. Back out the buffer screw until it extends approximately 5/8" from the lock nut.

3. For *Cable Operated Governors* make a preliminary idle speed (normal highway idle speed) adjustment as follows (Fig. 1):

a. Back out the variable low-speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer.

b. Start the engine. Then hold the lock nut and loosen the low-speed adjusting shaft retainer.

c. Adjust the retainer and shaft assembly to obtain

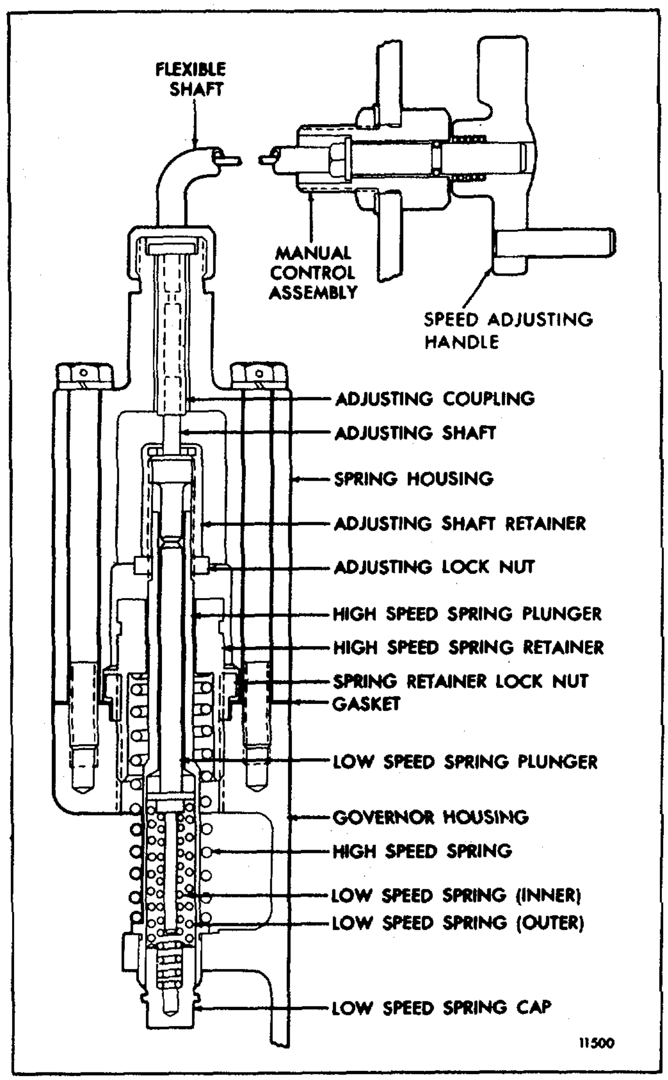


FIG. 1 - Cable Operated Governor Spring Housing and Components

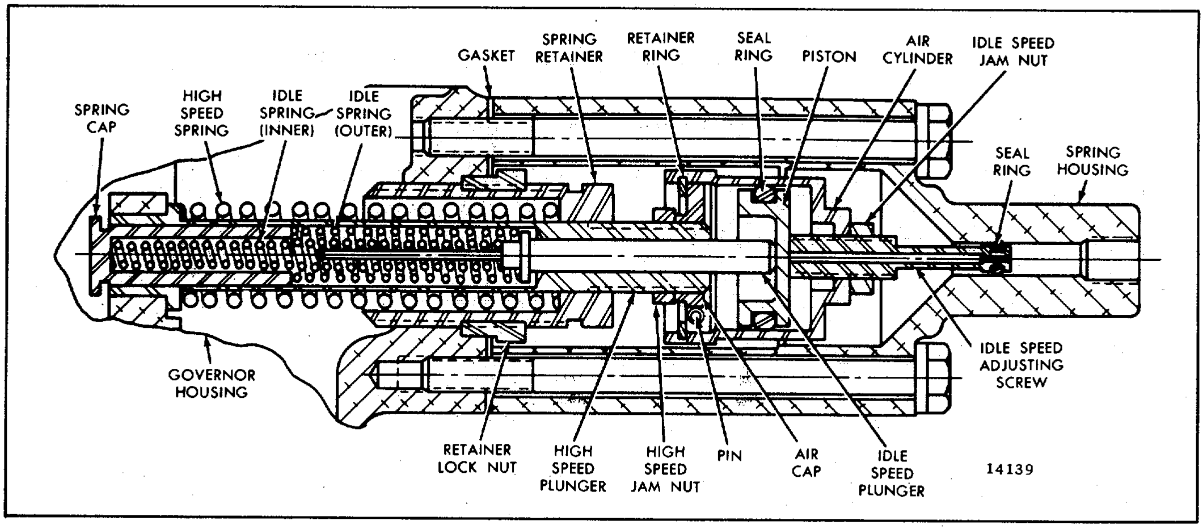


FIG. 2 - Air Operated Governor Spring Housing and Components

the desired idle speed (500 rpm minimum). Then hold the retainer and tighten the lock nut to retain the adjustment.

NOTE: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8").

d. Install the spring housing, using a new gasket. Tighten the attaching bolts.

4. For *Air Operated Governors* make a preliminary idle speed (normal highway idle speed) adjustment as follows (Fig. 2).

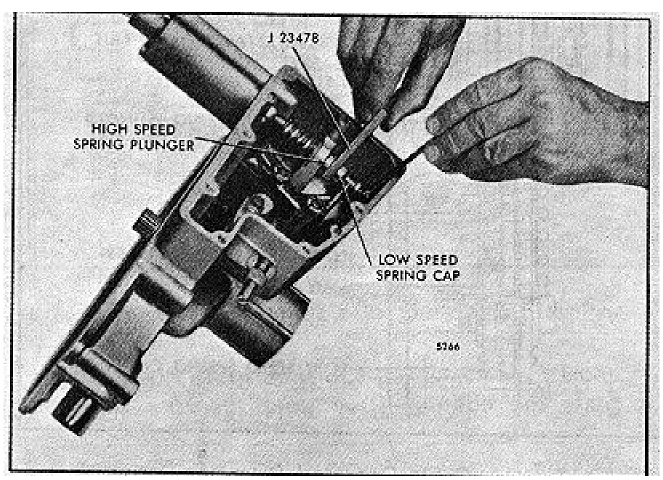


FIG. 3 - Adjusting Governor Gap (Single-Weight Governor)

Adjust the maximum idle speed.

a. Loosen the idle speed and high idle speed jam (lock) nuts.

b. Turn the idle speed, adjusting screw clockwise into the air cylinder, until the piston contacts the air cap.

NOTE: The air cylinder should be 2 or 3 threads from its position of maximum engagement with the high speed spring plunger, to prevent the piston from contacting the high speed plunger before it contacts the air cap.

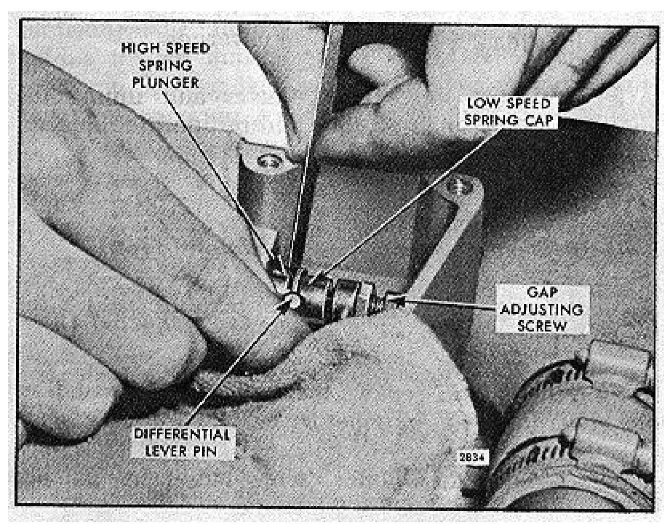


FIG. 4 Adjusting Governor Gap (Double-Weight Governor)

IMPORTANT: Do not force the idle speed adjusting screw.

c. Start the engine. With the speed control lever in the idle position, turn the air cylinder clockwise to raise the idle speed and counterclockwise to lower the idle speed.

d. Lock the air cylinder to the high speed plunger with the jam nut in the position which provides the desired maximum idle speed.

Adjust the minimum idle speed adjustment.

NOTE: Make this adjustment after the maximum idle speed adjustment is completed.

a. Run the engine with the speed control lever in the idle speed position.

b. Turn the idle speed adjusting screw counterclockwise to lower the idle speed and clockwise to raise the idle speed.

c. Lock the idle speed adjusting screw with the jam nut, in the position which provides the desired minimum idle speed.

d. Stop the engine and lubricate the bore of the spring housing with engine lubrication oil.

e. Install the spring housing, using a new gasket. Tighten the attaching bolts.

5. Stop the engine and remove the governor cover and lever assembly.

6. Clean and remove the valve rocker covers.

7. Remove the fuel rods from the differential lever and the injector control tube levers.

8. Check the gap (.200") between the low-speed spring cap and the high-speed spring plunger with gage J 23478 as shown in Fig. 3.

NOTE: A .200" stack-up of feeler gages can be used to check the gap if the gage is not available.

IMPORTANT: Be sure the external starting aid screw is backed out far enough to make it ineffective when making this adjustment.

9. If required, loosen the lock nut and turn the gap adjusting screw until a slight drag is felt on the gage.
10. Hold the adjusting screw and tighten the lock nut.
11. Recheck the gap and readjust if necessary.

12. Install the fuel rods between the governor and the injector control tube levers.

13. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the stop control shaft assembly in the slot of the differential lever and the dowel pins in the housing in the dowel pin holes in the cover.

NOTE: Before starting an engine after an engine speed control adjustment or after removal of the engine governor cover and lever assembly, the serviceman 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.

CAUTION: An overspeeding engine can result in engine damage which could cause personal injury.

Adjust Governor Gap (Double-Weight Type)
Cable Operated Governors Only

With the engine at operating temperature, adjust the governor gap as follows:

1. Stop the engine, remove the two bolts and withdraw the governor spring retainer cover.

2. Back out the buffer screw until it extends approximately 5 /8” from the lock nut.

3. Make a preliminary idle speed (normal highway idle speed) adjustment as follows:

a. Back out the variable low-speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer (Fig. 1).

b. Start the engine. Then hold the lock nut and loosen the low-speed adjusting shaft retainer.

c. Adjust the retainer and shaft assembly to obtain the desired idle speed (450 rpm minimum). Then hold the retainer and tighten the lock nut to retain the adjustment.

NOTE: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/8 1).

d. Install the spring housing, using a new gasket. Tighten the attaching bolts.

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.

5. Start and run the engine between 100 and 1300 rpm by manual operation of the differential lever.

NOTE: Do not overspeed the engine.

6. Check the gap between the low-speed spring cap and the high-speed spring plunger (Fig. 4) with a feeler gage. The gap should be .002"-.004". If the gap setting is incorrect, reset the gap adjusting screw.

7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the lock nut.

8. Recheck the gap with the engine operating between 1100-1300 rpm and readjust if necessary.

9. Reinstall the governor cover and lever assembly.

Position Injector Rack Control Levers

Position the injector rack control levers as outlined in Section 14.3.

Adjust Maximum No-Load Engine Speed

Adjust the maximum no-load engine speed as outlined for the limiting speed mechanical governor in Section 14.3.

Adjust Idle Speed

Adjust the normal highway idle speed as follows:

With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, hold the lock nut and loosen the variable low-speed adjusting shaft retainer. Adjust the retainer and shaft assembly to obtain a minimum of 500 rpm idle speed (current single-weight governor) or 450 rpm (former double-weight governor).

NOTE: It may be necessary to use the buffer screw to eliminate engine roll. Back out the buffer screw, after the idle speed is established, to the previous setting (5/811).

Adjust Buffer Screw

Adjust the buffer screw as outlined in Section 14.3.

After the governor tune-up is completed, install the variable low-speed adjuster coupling and spring housing. Center the coupling before securing the spring housing to the governor. Install the flexible shaft and manual control assembly.

Limiting Speed Mechanical Governor

(Fast Idle Cylinder)

The limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover (Fig. 1). An engine shutdown air cylinder, if used, is also mounted on the governor cover.

The fast idle air cylinder and the throttle locking air cylinder are actuated at the same time by air from a common air line. The engine shutdown air cylinder is connected to a separate air line.

The air supply for the fast idle air cylinder is usually controlled by an air valve actuated by an electric solenoid. The fast idle system should be installed so that it will function only when the parking brake system is in operation to make it tamper-proof.

The vehicle accelerator-to-governor throttle linkage is connected to a yield link so the operator cannot overcome the force of the air cylinder holding the speed control lever in the idle position while the engine is operating at the single fixed high idle speed.

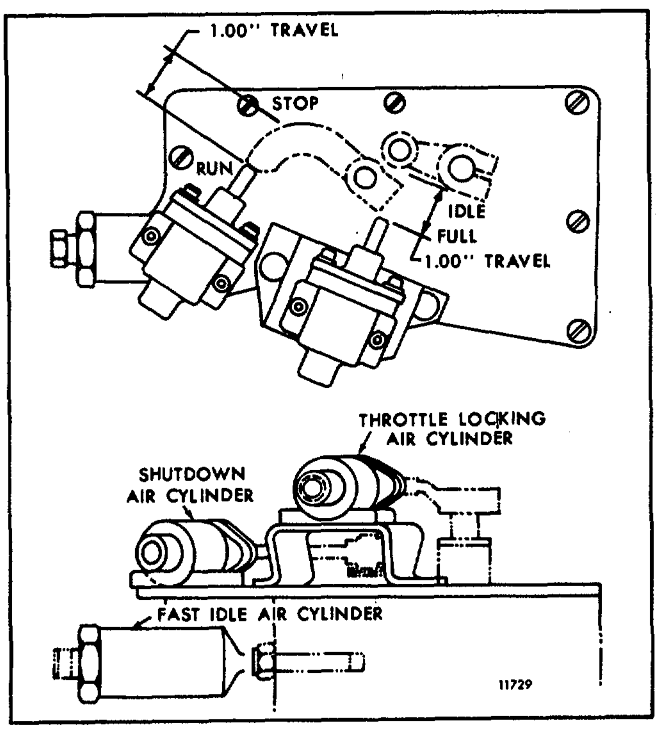


FIG. 1 - Governor with Fast Idle Cylinder

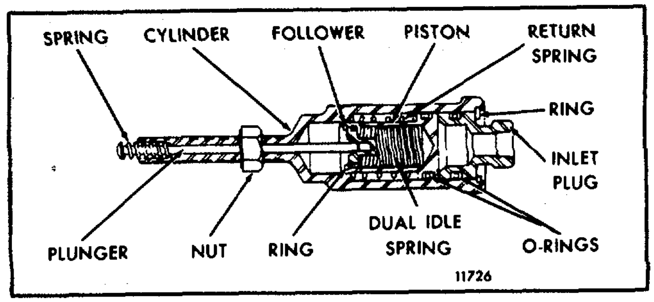


FIG. 2 - Fast Idle Air Cylinder

Operation

During highway operation, the governor functions as a limiting speed governor.

For operation of auxiliary equipment, the vehicle is stopped and the parking brake set. Then, with the engine running, the low-speed switch is placed in the *on* position. When the fast idle air cylinder is actuated, the force of the dual idle spring (Fig. 2) is added to the force of the governor low-speed spring, thus increasing the engine idle speed.

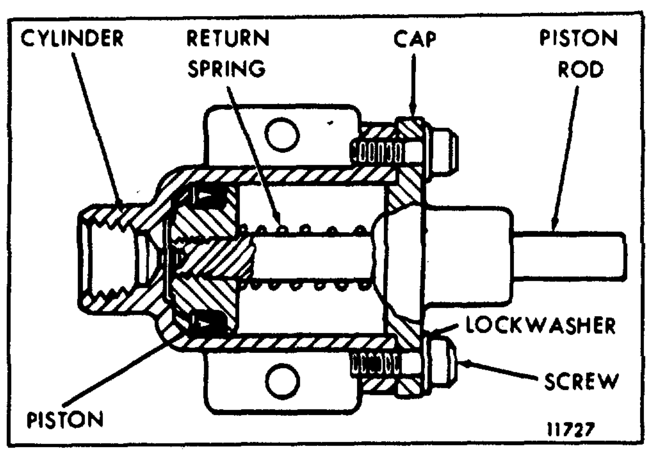


FIG. 3 - Throttle Locking Air Cylinder

The governor now functions as a constant speed governor at the high idle speed setting, maintaining a near constant engine speed regardless of the load within the capacity of the engine. The fast idle system provides a single fixed high idle speed that is not adjustable, except by disassembling the fast idle air cylinder and changing the dual idle spring. As with all mechanical governors, when load is applied, the engine speed will be determined by the governor droop.

Adjust Governor

Adjust the governor as outlined in Section 14.3. However, before adjusting the governor gap, back out the de-energized fast idle air cylinder until it will not interfere with the governor adjustments. After the normal idle speed setting is made, adjust the deenergized fast idle air cylinder as follows:

1. Turn in the fast idle cylinder assembly until an increase of idle speed is noted. The increase in idle speed should not exceed 15 rpm. Tighten the fast idle jam nut.

2. Lock the governor throttle in the idle speed position and apply full shop air pressure to the fast idle air cylinder. The engine idle speed must increase from 325 to 500 rpm ± 50 rpm, depending on the original idle speed setting and fast idle spring used.

The throttle locking air cylinder is adjusted on its mounting bracket so it will lock the throttle in the idle speed position when it is activated, but will not limit the throttle movement when not activated.

GOVERNOR SETTINGS FOR FUEL SQUEEZER ENGINES

V-71TT Engines

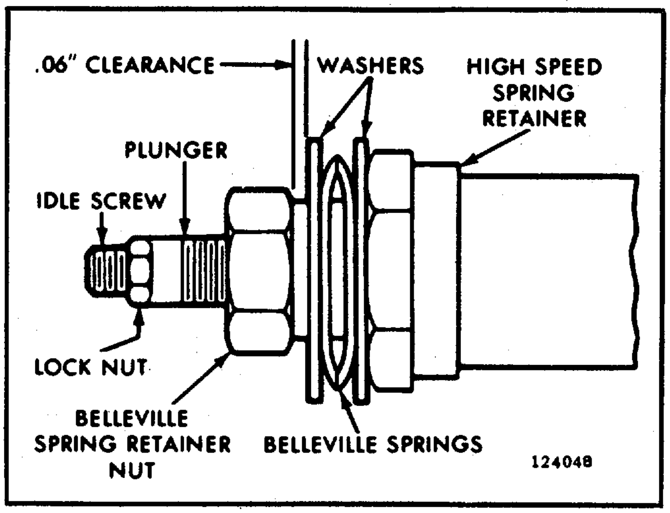


FIG. 1 - Belleville Washer Location

The operating characteristics of a *Fuel Squeezer* engine are - it's ability to maintain reasonably constant horsepower over a wide speed range and its 6% torque rise per one hundred rpm. These characteristics are achieved by the action of two Belleville washers in a limiting speed governor.

> **NOTE:** The horsepower Tables I and 2 for *Fuel Squeezer* engines indicate a flat horsepower performance curve. However, during dynamometer testing an engine may exhibit horsepower readings slightly above or below the flat curve. A 5% horsepower variation from the flat published curve is acceptable.

The spring force provided by the Belleville springs works with the governor weights to pull the injector racks out of fuel as the engine speed is increased. Conversely, as the engine speed is reduced by increased load, the high-speed spring overcomes the force of the Belleville springs and moves the injector racks to an increased fuel position. The racks move progressively into more fuel to maintain the constant horsepower until the racks are in full fuel at a speed near 1500 rpm.

The tune-up of the *Fuel Squeezer* engine is the same as a standard engine tune-up outlined in Section 14.3. with the following exceptions:

1. Prior to tuning an engine. backout the Belleville spring retainer nut (Fig. I) until there is approximately .060" clearance between the washer and the retainer nut.

2. Governor gap adjustment: Set the running engine governor gap at .002"-.004" at 1100-1300 rpm with the engine idle speed adjusted to 500 rpm.

3. After completing the standard engine tune-up of setting injector timing. valve clearance, governor gap, injector racks and engine speeds. adjust the Belleville spring (washer) TT (tailor torqued) device.

> **NOTE:** Use spanner wrench J 5345-5 to loosen or tighten the spring retainer locknut during the no-load speed adjustment. Always use the yield link in the governor when performing the engine tune-up.

Adjustment of the Belleville springs for the TT horsepower can be accomplished by two methods, depending on the equipment available at the service outlet. These methods are:

1. Idle Drop.

2. Power Reduction Factor.

For satisfactory results, both methods require an engine in good condition and properly tuned.

> **NOTE**: Do not attempt Belleville spring adjustment until an engine tune-up has been correctly completed.

METHOD 1- Idle Drop

The idle drop method is an effective, accurate means of setting "TT" horsepower.

The idle drop method requires a specific reduction in engine speed to position the Belleville springs and the governor low and high-speed springs. The positioning of these governor components results in obtaining the desired *Fuel Squeezer* horsepower.

When performing an idle drop horsepower adjustment on a *Fuel Squeezer* engine having a 102 or 118 tooth flywheel, an accurate tachometer is mandatory (Digital Tachometer J 26791 recommended). Each one (I) rpm

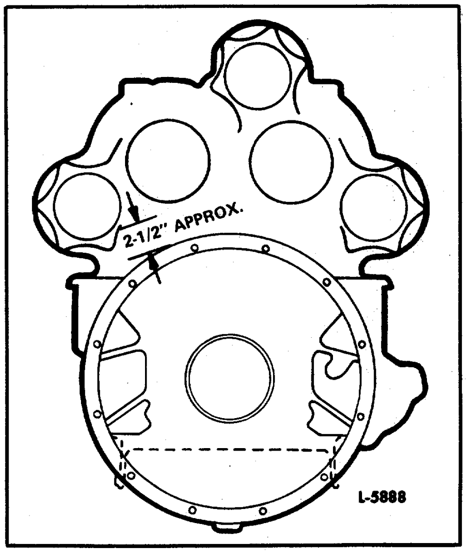


FIG. 2 - Identification of Engine Flywheel

error in setting the idle drop results in a two or three horsepower error.

The tachometer is installed in the flywheel housing drain plug hole and operates by counting the flywheel teeth, using a magnetic probe to pick-up impulses off the flywheel ring gear. The electronic module displays the engine speed digitally to one decimal place within one rpm accuracy. These capabilities make it ideal for setting horsepower on the *Fuel Squeezer* engines using the idle drop method.

To determine the number of teeth on the flywheel, when identification of the engine flywheel part number or type is not known, measure the distance from the camshaft flywheel housing cover lower bolt head and the outer circumference of the flywheel housing bell (Fig. 2). If this distance is approximately 1-1/4", it is a 118 tooth flywheel. For the 102 tooth flywheel, the distance will be approximately 2-1/2".

When the number of teeth on the flywheel is known, set the switch on the tachometer to the proper position. Proceed as follows:

1. Perform the standard engine tune-up. Set the no-load speed as required by the engine type, injector size and governor (refer to Table I - 1978 Engines or Charts I and 2 - 1979 Engines).

2. Disconnect the accelerator linkage from the governor speed control lever if it has not already been done.

3. Run the engine until a stabilized engine coolant temperature' is obtained.

4. Refer to Table I for 1978 engines and, using engine type, injector size and governor. select the initial and specified idle drop numbers for the rated "TT" horsepower and rated engine speed at which the engine is to operate.

RATED HP @ RATED SPEED		INITIAL IDLE	IDLE DROP SETTING
8V-71TT N-75	305 @ 1900	700	670
	305 @ 1950	700	668
	305 @ 2100	750	705
8V-71TTA 7A75	305 @ 1900	700	665
	305 @ 1950	700	664
	305 @ 2100	750	715

Throttle delay setting - .570
TABLE 1 (1978 Engines)

Refer to Charts I and 2 for 1979 engines. Each idle drop chart (I or 2) includes the following information:

Engine Series
Maximum Full Load RPMs
Governor Part Numbers
Belleville Washer Part Numbers
Injector Size
Initial Idle Drop Starting RPM

The above should be considered to insure the correct chart is being used. To maintain certification as required by law, the engine horsepower cannot be adjusted beyond the limits outlined on each chart.

5. Set the initial idle speed (using the idle adjusting screw) to that determined in Step "4" above.

6. With the governor speed control lever in the idle position, turn the Belleville spring retainer nut (Fig. 1) clockwise on the plunger until the specified idle drop speed' is achieved. Secure the retainer nut with the locking screw. When the specified idle speed is achieved, the engine is power controlled to the "TT" horsepower rating.

NOTE: Idle speeds must be exact and steady. If they are not, check for bind or rubbing in the fuel control system: governor, fuel rods, injector control tubes and injector control racks.

7.. Lower the idle speed to the desired operating idle speed, using the idle adjusting screw.

8. Adjust the buffer screw and the starting aid screw

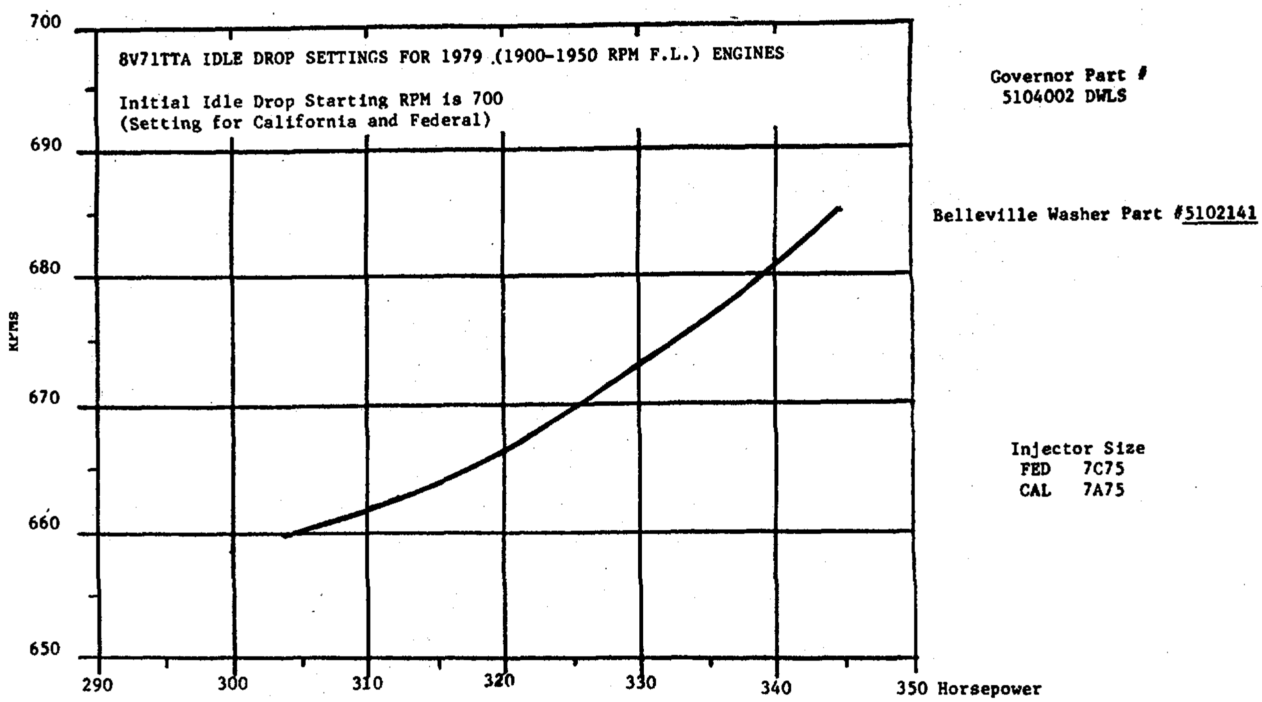


CHART 1 (1979 Engines)

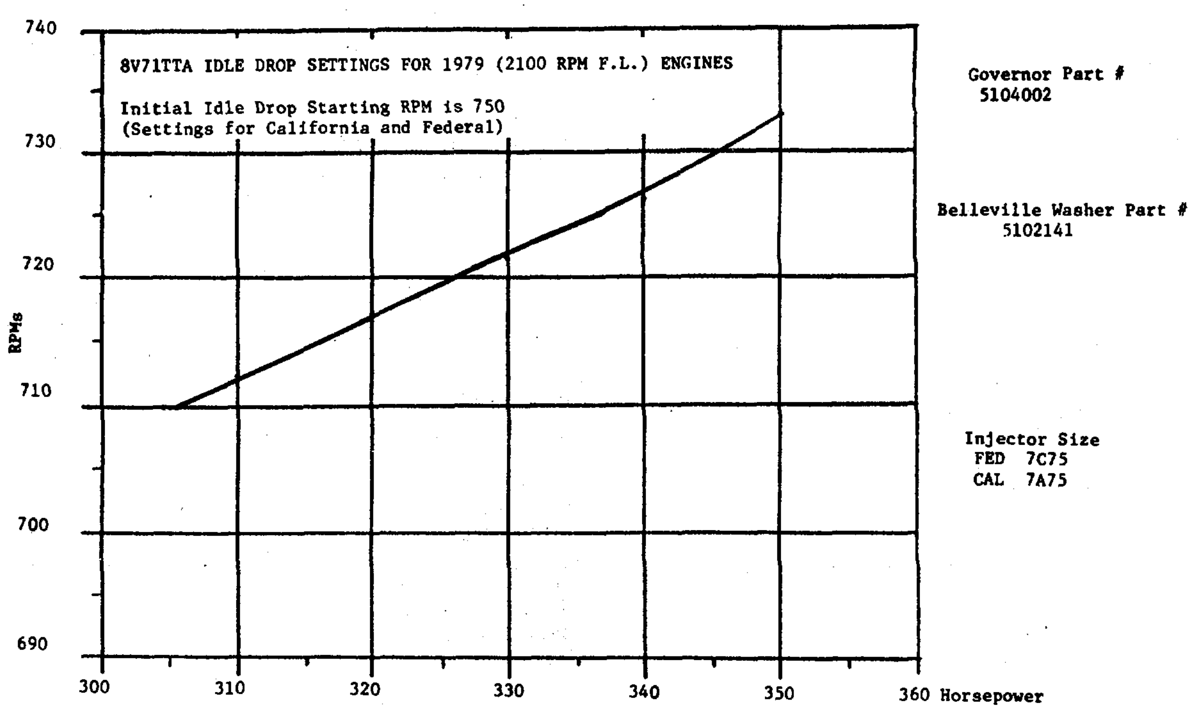


CHART 2 (1979 Engines)

METHOD 2 - Power reduction Factor

POWER REDUCTION FACTOR

ENGINE TYPE	MAXIMUM RATED B.H.P.	RATED "TT" HORSEPOWER	RATED ENGINE SPEED	NO-LOAD SPEED	POWER REDUCTION FACTOR
8V-71TT – N-75 Injectors Federal Certified Throttle delay setting .570	350 @ 2100 RPM 2275 RPM Maximum No-Load	305 305 305	1900 1950 2100	2050 2100 2250	.94 .92 .89
8V-71TTA – 7A75 Injectors California Approved Federal Certified Throttle delay .586	350 @ 2100 RPM 2275 RPM Maximum No-Load	305 305 305	1900 1950 2100	2050 2100 2250	.90 .89 .87
8V-71TTA – 7C75 Injectors Federal Certified Throttle delay setting .570	370 @ 2100 RPM 2275 RPM Maximum No-Load	305 305 305	1900 1950 2100	2050 2100 2250	.88 .87 .84

TABLE 2 (1978 Engines)

This method consists of setting "TT" engine horsepower to a specific percentage below full throttle horsepower as observed on an engine, chassis or output shaft dynamometer.

This method will provide the desired horsepower, within a reasonable tolerance, even with normal variations of test conditions. Some of these variations would be:

Dynamometer Calibration
Driveline Efficiency
Fuel Grade and Temperature
Air Density
Tire Slippage

Proceed as follows:

1. Perform the standard engine tune up.

NOTE: The throttle delay piston must be removed and the *Bell*eville spring retainer nut must be backed out until there is approximately .060"' clearance between the washers and retainer nut (Fig. 1) prior to operating the engine on the dynamometer.

2. Set the no-load speed as required (Table 2 or 3).

3. Run the engine until the engine coolant temperature is above 170° OF (77 ° C).

4. Using an engine, chassis or output shaft dynamometer, measure and record full throttle horsepower at 100 rpm below rated engine speed with the Belleville springs loose as shown in Fig. 1.

NOTE: Satisfactory' power adjustment can be obtained only if the full throttle horsepower and adjusted horsepower (Step 4) are obtained with the engine cooling in the same mode, i.e., operating or not operating.

5. Select the power reduction factor in Table 2 or 3 for the proper engine type, desired rated horsepower and rated engine speed.

6. Multiply the horsepower recorded in Step 4 by the factor selected in Step 5. Record this value.

POWER REDUCTION FACTOR

MAX. RATED B.H.P.	RATED SPEED	NO-LOAD SPEED	FACTOR
*†370 @ 2100 RPM 2275 RPM Maximum No Load	1900 1950 2100	2050 2100 2250	.88 .87 .83
350 @ 2100 RPM 2275 RPM Maximum No Load	1900 1950 2100	2050 2100 2250	.90 .89 .88

Rated TT Horsepower 305.
*8V-71TTA - Federal
†8v-71TTAC - California

TABLE 3 (1979 Engines)

7. Adjust the Belleville spring retainer nut clockwise so that the observed horsepower is reduced to that recorded in Step 6 at 100 rpm below rated engine speed, with the governor speed control lever in the maximum speed position and the fan in the same mode as in Step 4. Verify that the engine is obtaining adjusted "TF" horsepower, within 5%, at rated engine speed. If the adjusted "TT" horsepower cannot be obtained at rated engine speed, governor droop interference may be the cause. If necessary, to eliminate droop interference, readjust the engine no-load speed from 150 to 175 rpm above rated engine speed and repeat the power reduction factor method.

8. Check the idle speed and, if necessary, reset to the specified idle speed.

9. Adjust the buffer screw and starting aid screw.

FEXISPEC ENGINE GOVERNOR ADJUSTMENTS FOR FUEL SQUEEZER ENGINE

When it is desirable to adjust a *Fuel Squeezer "TT"* 8V-71TT or TTA engine to obtain non TT maximum rated horsepower, proceed as follows:

1. Adjust the engine governor to obtain a no-load speed 17'5 rpm above the desired rated speed. Refer to Section 14.3 for the no-load engine speed adjustment.

NOTE: Do not exceed a full-load speed of 2100 rpm or a no-load speed of 2275 rpm.

2. Position the Belleville spring retainer to provide approximately .060" clearance between the Belleville washers and the retainer when the engine is not running (Fig.1).

SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

ENGINE LOAD LIMIT DEVICE

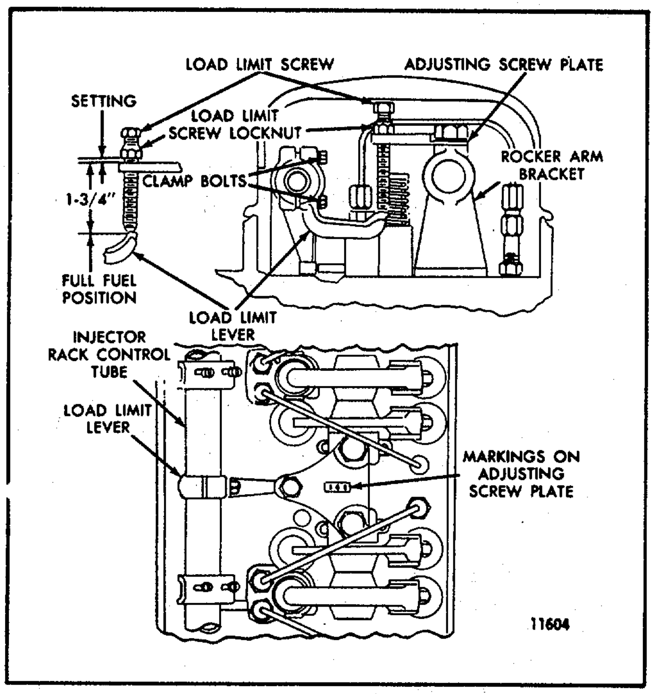


FIG. 1 - Engine Load Limit Device

Engines with mechanical governors may be equipped with a load limit device (Fig. l) to reduce the maximum horsepower.

This device consists of a load limit screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a load limit lever clamped to the injector control tube.

The load limit device is located between the No. 1 and No. 2 cylinders on *each* cylinder bank of a 6V engine, between the No. 2 and No. 3 cylinders on *each* cylinder bank of an 8V engine, or between the No. 3 and No. 4 cylinders on *each* cylinder bank of a 12V engine.

When properly adjusted for the maximum horsepower desired, this device limits the travel of the injector control racks and thereby the fuel output of the injectors.

Adjustment

After the engine tune-up is completed, make sure the load limit devices are properly installed as shown in Fig. 1. Make sure the counterbores in the adjusting screw plates are up. The rocker arm shaft bracket bolts which fasten the adjusting screw plate to the brackets are tightened to 75-85 lb-ft (102-115 Nm) torque (all other rocker arm shaft bracket bolts are tightened to 90-100 lb-ft or 122-136 Nm torque). Then adjust the load limit device, on each cylinder head, as follows:

1. Loosen the load limit screw lock nut and remove the screw.

2. Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.

3. With the screw out of the plate, adjust the load limit screw lock nut so the bottom of the lock nut is 1 3/4 "1 from the bottom of the load limit screw (Fig. 1) for the initial setting.

4. Thread the load limit screw into the adjusting screw plate until the lock nut *bottoms* against the top of the plate.

5. Hold the injector rack control tube in the full-fuel position and place the load limit lever against the bottom of the load limit screw. Then tighten the load limit lever clamp bolts.

6. Check to ensure that the injector racks will just go into the full-fuel position -- readjust the load limit lever if necessary.

7. Hold the load limit screw to keep it from turning, then *set* the lock nut until the distance between the bottom of the lock nut and the top of the adjusting screw plate corresponds to the dimension (or number of turns) stamped on the plate. Each full turn of the screw equals .042 ", or .007 " for each flat on the hexagon head.

NOTE: If the plate is not stamped, adjust the load limit screw while operating the engine on a dynamometer test stand and note the number of turns required to obtain the desired horsepower. Then stamp the plate accordingly.

8. Thread the load limit screw into the plate until the lock nut *bottoms* against the top of the plate. Be sure the nut turns with the screw.

9. Hold the load limit screw to keep it from turning, then tighten the lock nut to secure the setting.

POWER CONTROL DEVICE

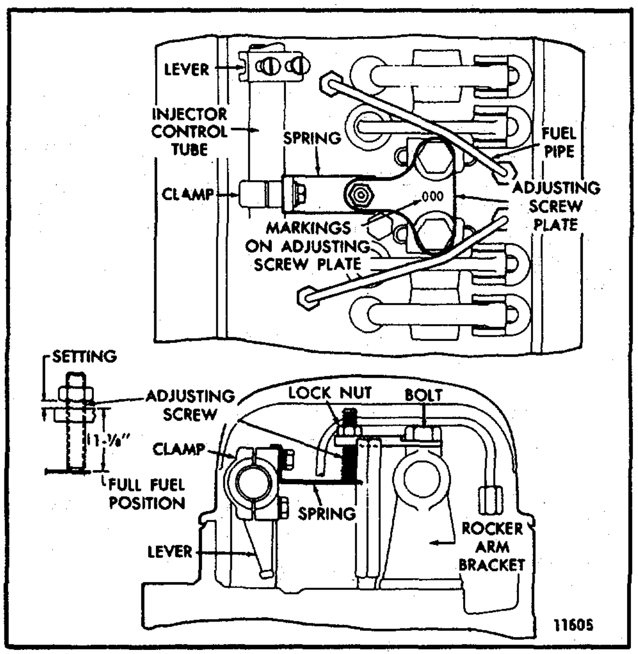


FIG. 2 - Power Control Device

The power control (torque limiting) device (Fig. 2)-is used, on some vehicle engines, to limit the maximum horsepower output at the wheels without diminishing the performance at lower speeds where full power may be required. It limits the horsepower at, or just below, the normal full-load governed speed. These limiting characteristics are proportionately lessened as the engine speed is reduced and the horsepower required is reduced.

This device, one on each cylinder bank, consists of an adjusting screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a spring attached to a clamp on the injector control tube.

NOTE: The rocker arm shaft bracket bolts that retain the adjusting screw plates are tightened to 75-85 lb-ft (102-115 Nm) torque; all other rocker arm shaft bracket bolts are tightened to 90-100 lb-ft (122-136 Nm) torque.

The power control device is located between the No. 1 and No. 2 cylinders on *each* cylinder bank of a 6V engine, between the No. 2 and No. 3 cylinders on *each* cylinder bank of an 8V engine, or between the No. 3 and No. 4 cylinders on *each* cylinder bank of a 12V engine.

Adjustment

After the engine tune-up is completed, adjust the power control device on both cylinder banks as follows:

1. Place the vehicle on a chassis dynamometer and check the maximum wheel horsepower.

2. Loosen the power control spring attaching bolts. Then adjust both springs until they project parallel to the cylinder heads when the injector control racks are held in the full-fuel position. Tighten the spring attaching bolts to 7-9 lb-ft (10-12 Nm) torque to retain the adjustment.

3. Set each power control device, while holding the injector control racks in the full-fuel position, by turning the adjusting screw down (clockwise) until it just touches the spring and the lock nut is tight against the plate. Then release the injector control racks.

NOTE: Wipe the oil from each spring and the bottom of each adjusting screw so the point of contact can be seen readily.

NOTE: Steps 2 and 3 *must* be *completed on* both cylinder banks before proceeding with Step 4.

4. Start the engine. Then, with the engine *running* at full governed speed, check the horsepower. If necessary, readjust the screws to obtain the specified horsepower. Turn the screws down to decrease the horsepower; turn the screws up to increase the horsepower. When the desired wheel horsepower is obtained, hold the screws from turning and tighten the lock nuts.

NOTE: If a dynamometer is not available, back up the lock nuts the distance stamped on the plates. Then turn the screws and lock nuts down together until the lock nuts *bottom on the* plates. Hold the screws from turning and tighten the lock nuts.

THROTTLE DELAY MECHANISM

The throttle delay mechanism is used to retard full-fuel injection when the engine is accelerated. This reduces exhaust smoke and also helps to improve fuel economy.

The throttle delay mechanism (Fig. 3) is installed between the No. I and No. 2 cylinders on the right bank cylinder head. It consists of a special rocker arm shaft bracket (which incorporates the throttle delay cylinder), a piston, throttle delay lever, connecting link, orifice plug, ball check valve and U-bolt.

A yield link replaces the standard operating lever connecting link in the governor.

Operation

Oil is supplied to a reservoir above the throttle delay cylinder through an oil supply fitting in the drilled oil passage in the rocker arm shaft bracket (Fig. 3). As the injector racks are moved toward the no-fuel position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further movement of the piston uncovers an opening which permits oil from the reservoir to enter the cylinder and displace the air. When the engine is accelerated, movement of the injector racks toward the full-fuel position is momentarily retarded while the piston expels the oil from the cylinder through an orifice. To permit full accelerator travel, regardless of the retarded injector rack position, a spring loaded yield link replaces the standard operating lever connecting link in the governor.

Inspection

The current throttle delay bracket has a closer tolerance on the piston and cylinder bore. The current check valve has a nylon check ball in place of the former brass ball. When inspecting the throttle delay hydraulic cylinder, it is important that the check valve be inspected for wear.

To inspect the check valve, fill the throttle delay cylinder with diesel fuel oil and watch for check valve leakage while moving the engine throttle from the idle speed position to the full-fuel position. If more than a drop of leakage occurs, replace the check valve.

Service Note

The current throttle delay cylinder rocker arm bracket has a 5/64" diameter fill hole. The former throttle delay cylinder with a 1/4" diameter fill hole can be modified as follows:

NOTE: Modification of the bracket is not necessary for city coach engines.

1. Ream the fill hole to .2646"-.2666" diameter with a 17/64" reamer.

2. Remove any burrs formed in the throttle delay piston bore with fine emery cloth to be sure the piston moves freely.

3. Press a service bushing in the reamed hole and recheck the piston for free movement.

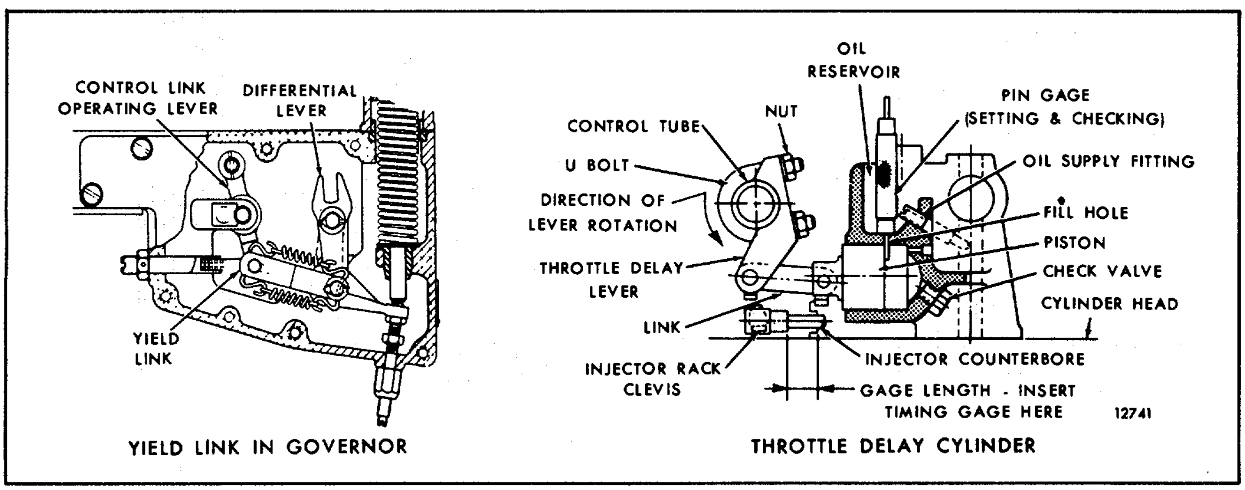


FIG. 3 - Throttle Delay Cylinder and Yield Link

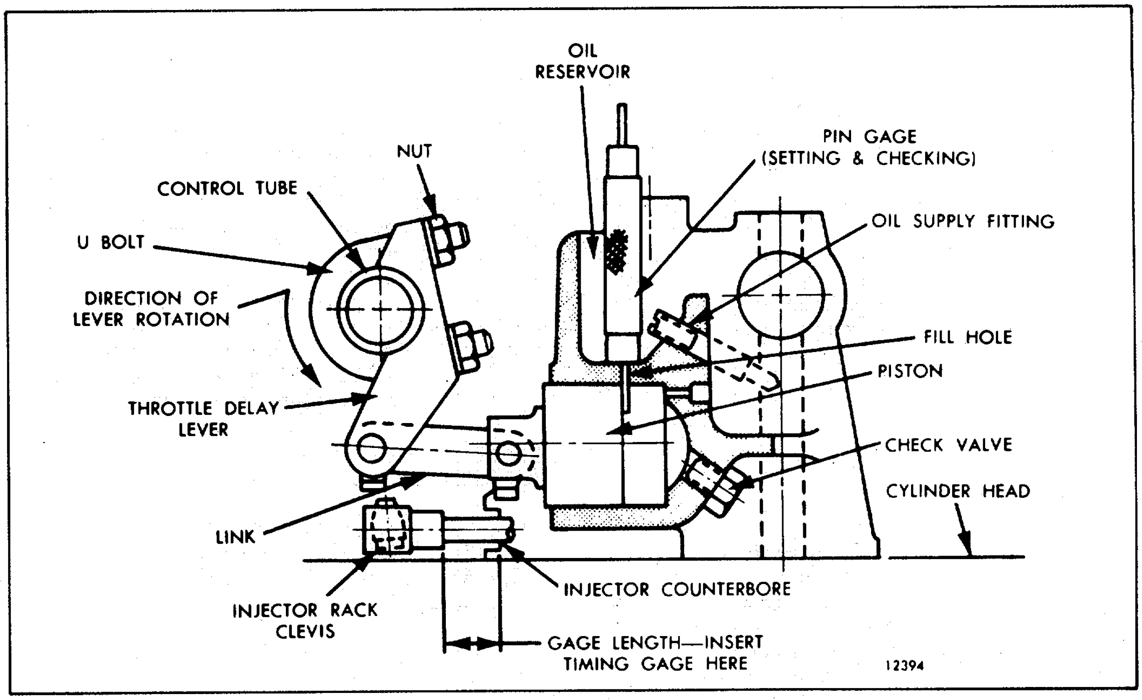


FIG. 4 Adjusting Throttle Delay Cylinder (Current)

4. Remove and discard the original check valve. Install a new check valve.

5. Assemble and install the throttle delay cylinder. Then adjust it as outlined under *Adjustment (former Throttle Delay).*

Adjustment (Current Throttle Delay)

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U-bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

1. Refer to Fig. 4 and insert the timing gage between the injector body and the shoulder on the injector rack clevis of the injector nearest the throttle delay cylinder. Refer to Section 14 and TABLE 9 of that section for the proper gage to set a Certified Vehicle engine.

> **NOTE:** For On-Highway Certified Vehicle engines the former timing gage J 23190 (.454"

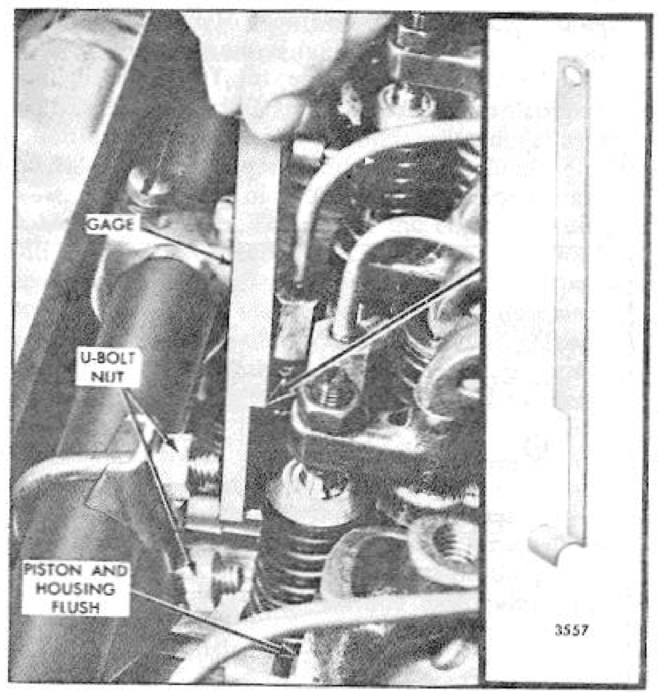


FIG. 5 Adjusting Throttle Delay Cylinder (Former)

gage length) *must not* be used with the current throttle delay cylinder.

2. Hold the governor throttle in the maximum speed position. This should cause the injector rack to move toward the full-fuel position and against the gage.

3. Insert the pin gage J 25558 (.072" diameter setting end) in the cylinder fill hole.

4. Rotate the throttle delay lever in the direction shown in Fig. 4 until further movement is limited by the piston contacting the pin gage.

5. Tighten the U-bolt nuts while exerting a slight amount of torque on the lever; in the direction of rotation. Be careful not to bend the gage or damage the piston by using excessive force.

6. Check the setting as follows:

a. Remove the pin gage.

b. Attempt to reinstall the pin gage. It should not be possible to reinsert the gage without moving the injector racks toward the no-fuel position.

c. Reverse the pin gage to the .069" diameter end and insert it in the cylinder fill hole. It should enter the cylinder without resistance.

NOTE: If the .072" diameter end of the pin gage enters the fill hole (Step 6b), increase the torque on the upper U-bolt nut. If the .069" diameter will not enter the fill hole (Step 6c) without resistance, increase the torque on the lower U-bolt nut.

7. Release the governor throttle and remove the timing gage and pin gage.

8. Move the injector control tube assembly from the no-fuel to the full-fuel position to make sure there is no bind.

9. Refer to *Engine Tune-Up* in Section 15.1 for maintenance.

Adjustment (Former Throttle Delay)

NOTE: Modification at the bracket is not necessary for city coach engines.

Whenever the injector rack control levers are adjusted, disconnect the throttle delay mechanism by loosening the U-bolt which clamps the lever to the injector control tube. After the injector rack control levers have been positioned, the throttle delay mechanism must be readjusted. With the engine stopped, proceed as follows:

1. Refer to Fig. 5 and insert gage J 23190 (.454" setting) between the injector body and the shoulder on the injector rack. Then exert a light pressure on the injector control tube in the direction of full fuel.

2. Align the throttle delay piston so it is flush with the edge of the throttle delay cylinder.

3. Tighten the U-bolt on the injector control tube and remove the gage.

4. Move the injector rack from the no-fuel to the full-fuel position to make sure it does not bind.

5. Refer to *Engine Tune-Up* in Section 15.1 for maintenance.

ADJUSTMENT OF MECHANICAL GOVERNOR SHUTDOWN SOLENOID

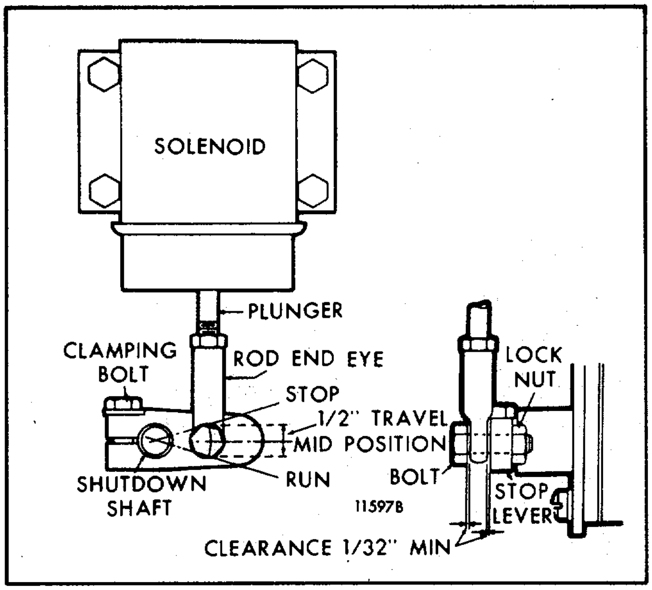


FIG. 6 - Typical Variable Speed Governor Lever Position

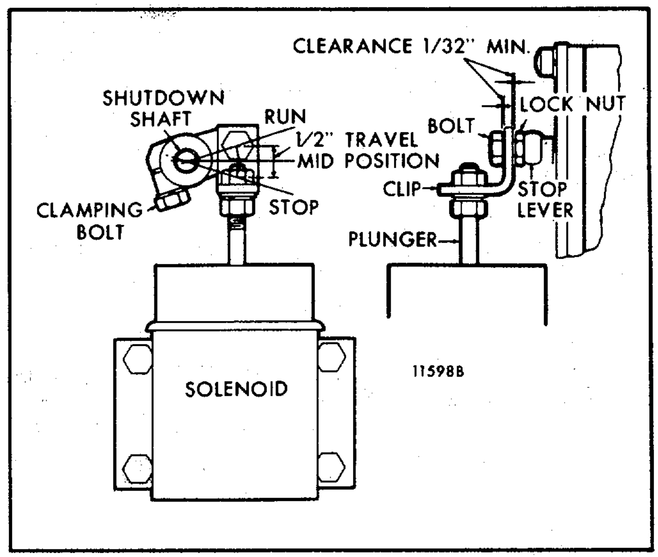


FIG. 7 - Typical Limiting Speed Governor Lever Position

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel.

The solenoid plunger can be properly aligned to the governor stop lever as follows:

1. Remove the bolt connecting the rod end eye (variable speed governor) or the right angle clip (limiting speed governor) to the stop lever (Figs. 6 and 7).' Align and clamp the lever to the shutdown shaft in such a way that, at its mid-travel position, it is perpendicular to the solenoid plunger. This assures that the linkage will travel as straight as possible. The solenoid plunger has available 1/2" travel which is more than adequate to move the injector control racks from the full-fuel to the complete no-fuel position and shutdown will occur prior to attaining complete travel.

2. With the stop lever in the *run* position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt is installed. The oversize hole in the eye or clip will thereby permit the solenoid to start closing the air gap, with a resultant build-up of pull-in force prior to initiating stop lever movement.

3. The bolt through the rod end eye or the right angle clip should be locked to the stop lever and adjusted to a height that will permit the eye or clip to' float vertically. The clearance above and below the eye or clip and the bolt head should be approximately 1/32 " minimum.

NOTE: The lock nut can be either on top of or below the stop lever.

4. Move the lever to the *stop* position and observe the plunger for any possible bind. If necessary, loosen the mounting bolts and realign the solenoid to provide free plunger motion.

FUEL MODULATOR

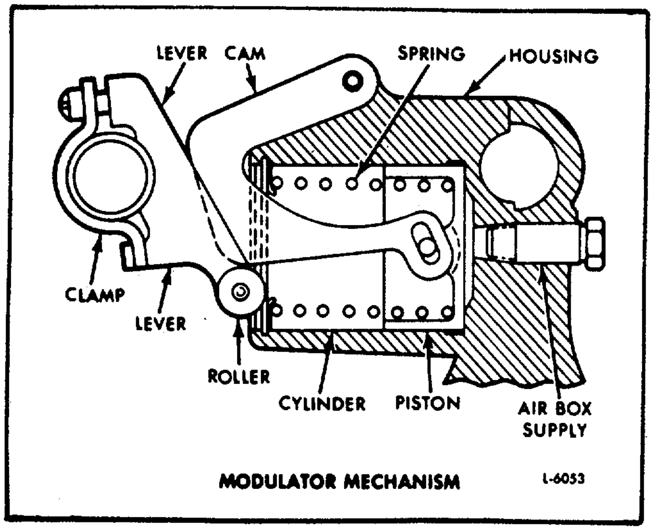


Fig. 8 - Typical Fuel Modulator Assembly

The fuel modulator, used on certain turbocharged aftercooled engines, maintain the proper fuel to air ratio in the lower speed ranges where the mechanical governor would normally act to provide maximum injector output. It operates in such a manner that, although the engine throttle may be moved into the full-speed position, the injector racks cannot advance to the full-fuel position until the turbine speed is sufficient to provide proper combustion.

The fuel modulator will reduce exhaust smoke and also will help to improve fuel economy. The modulator mechanism is installed on the left bank between the No. I and No. 2 cylinders.

A fuel modulator consists of a cast housing containing a cylinder, piston, cam and spring mounted on the cylinder head. A lever and roller which controls the injector rack is connected to the injector control tube. Tubes run from the air box to the housing to supply pressure to actuate the piston.

The modulator tells the fuel system how much fuel the engine can efficiently use based on air box pressure. Increased air box pressure forces the piston and cam out of the cylinder bore allowing the rack to move toward full fuel.

Whenever the fuel injector rack control levers are adjusted, the fuel (air box) modulator lever and roller assembly must first be positioned free of cam contact. This is done by loosening the clamp screw.

Inspection

At major repair or overhaul, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear. Also inspect the operating surface, the lever roller, the roller pins at the cam pivot and the cam attachment to the piston.

Adjust Fuel Modulator

After completing the injector rack control fever and governor adjustment, adjust the fuel modulator, with the engine stopped, as follows:

1. Insert gage J 23190 (.454" setting) between the injector body and the shoulder on the injector rack.

2. Position the governor speed control lever in the maximum speed position and the governor run stop lever in the RUN position.

3. Rotate the air box modulator lever assembly and clamp on the injector control tube until the lever roller contacts the modulator cam with sufficient force to take up the pin clearance.

4. Check to make sure only the roller contacts the cam and not the lever stamping. Tighten the lever and clamp screw.

5. Remove the gage from between the injector body and the shoulder on the injector rack.

SECTION 15

PREVENTIVE MAINTENANCE -

TROUBLE SHOOTING - STORAGE

CONTENTS

LUBRICATION AND PREVENTIVE MAINTENANCE

The *Lubrication and Preventive Maintenance Schedule* is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from a Detroit Diesel engine. The intervals indicated on the chart are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under *Preparation for Starting Engine First Time* under *Operating Instructions* in Section 13. 1.

EMISSION CONTROL MAINTENANCE SERVICE CHART
(VEHICLE ENGINES)

DAILY	
1. — Lubricating Oil	Ⓘ
2. — Fuel Tank	Ⓘ
3. — Fuel Lines	Ⓘ
4. — Cooling System	Ⓘ
5. — Turbocharger	Ⓘ
3000 MILE INTERVALS	
6. — Battery	Ⓘ
7. — Tachometer Drive	Ⓘ
4000-6000 MILE INTERVALS	
8. — Air Cleaner (oil bath)	Ⓘ
9. — Drive Belts	Ⓘ
10. — Air Compressor	Ⓘ
11. — Throttle Control	Ⓘ
15,000 MILE INTERVALS	
(2.) — Fuel Tank	Ⓘ
(8.) — Air Cleaner (oil bath)	Ⓘ
25,000 MILE INTERVALS	
12. — Lubricating Oil Filter	Ⓡ

6 MONTHS OR 10,000 MILE INTERVALS	MONTHS	6	12	18	24	30	36	42	48	54	60
	MILES (1000)	10	20	30	40	50	60	70	80	90	100
13. — Fuel Filter		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
14. — Coolant Filter		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
15. — Starting Motor		Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ	Ⓘ
(2.) — Fuel Tank			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(4.) — Cooling System (hoses)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
(10.) — Air Compressor			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
16. — Air System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
17. — Exhaust System			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
18. — Air Box Drain Tube				Ⓘ			Ⓘ			Ⓘ	
19. — Emergency Shutdown			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
20. — Engine (steam clean)			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
21. — Radiator			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
22. — Shutter Operation			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
23. — Oil Pressure			Ⓘ		Ⓘ		Ⓘ		Ⓘ		Ⓘ
24. — Governor						Ⓘ					Ⓘ
25. — Fuel Injector & Valve Clearance						Ⓘ					Ⓘ
26. — Throttle Delay						Ⓘ					Ⓘ
27. — Generator or Alternator*											
28. — Engine & Transmission Mounts							Ⓘ				
29. — Crankcase Pressure							Ⓘ				
30. — Air Box Check Valves											Ⓘ
(1.) — Lubricating Oil*											
31. — Fan Hub*											

ANNUALLY	
(4.) — Cooling System	Ⓘ
(8.) — Air Cleaner (oil bath)	Ⓘ
32. — Thermostats & Seals	Ⓘ
33. — Blower Screen	Ⓘ
34. — Crankcase Breather	Ⓘ
35. — Fan (thermo-modulated)	Ⓘ
AS REQUIRED	
36. — Engine Tune-Up	

Ⓘ = INSPECT, CORRECT OR REPLACE (IF NECESSARY)

Ⓡ = REPLACE

*** = SEE ITEM**

Item 1 - Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately twenty minutes to allow the oil to drain back to the oil pan. Add the proper grade oil as required to maintain the correct level on the dipstick (refer to Section 13.3).

NOTE: Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

Change the lubricating oil at 100,000 mile intervals (highway trucks and inter-city buses) or 12,500 mile invervals (city transit coach and pick-up and delivery trucks). The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined. Select the proper grade of oil in accordance with the instructions given in the *Lubrication Specifications* in Section 13.3.

NOTE: If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily.

Item 2 - Fuel Tanks

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the *Fuel Specifications* in Section 13.3. Open the drain at the bottom of the fuel tank every 15,000 miles to drain off any water and/or sediment.

Every 12 months or 20,000 miles tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the crossover fuel line. Repair or replace the parts as necessary.

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to fuel systems in itself, but it also promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

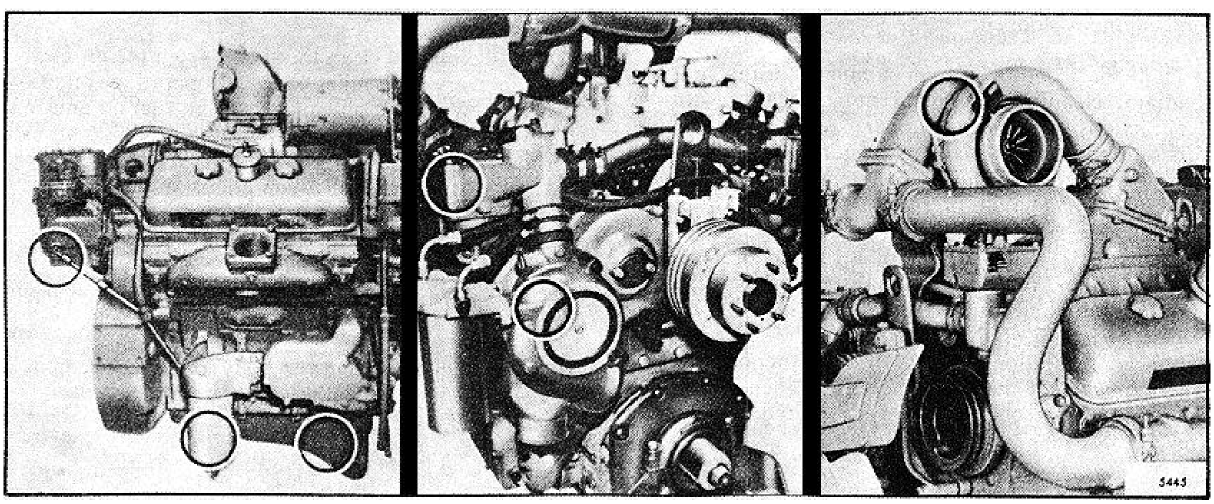
Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Water accumulation can be controlled by mixing is isopropy alcohol (dry gas) into the fuel oil at a ratio of one pint (0.5 liter) per 125 gallons (473 liters) fuel (or 0.10% by volume).

The microbes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of



Items 1 and 12 Item 4 Item 5

commerically available biocides. There are two basic types on the market.

The water soluble type treats *only the tank* where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.

Diesel fuel soluble type, such as "Biobor" manufactured by U. S. Borax or equivalent, treats *the fuel* itself and therefore the entire fuel system.

Units going into storage should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If' the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

Item 3 - Fuel Lines

Make a visual check for fuel leaks at the crossover lines and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

Item 4 - Cooling System

Before starting the engine, always check the coolant level. Make sure the coolant covers the radiator tubes. Add coolant as necessary. *Do not overfill.*

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.

Clean the cooling system annually using a good radiator cleaning compound in accordance with the instructions on the container. After the cleaning operation rinse the cooling system thoroughly with fresh water. Then fill the system with soft water, adding a good grade of rust inhibitor or an ethylene glycol base antifreeze (refer to *Engine Coolant* in Section 13.3). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse flushed.

Inspect all of the cooling system hoses at least once every 12 months or 20,000 miles to make sure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses if necessary.

Item 5 - Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks or restrictions to air flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause.

Item 6 - Battery

Check the specific gravity of the electrolyte in each cell of the battery every 3,000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 7 - Tachometer Drive

Lubricate the tachometer drive every 3,000 miles with an all purpose grease at the grease fitting. At temperatures above +30°F (-1°C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.

Item 8 - Air Cleaner

Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for non-turbocharged engines or 20 inches of water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduce4 air supply to the engine.

Oil Bath

Drain the oil and clean the sludge from the air cleaner oil cup every 6000 miles or less if operating conditions warrant. Wash the oil cup with clean fuel oil and refill it to the proper level with the same grade of oil used in the engine. The frequency of servicing may be varied to suit local dust conditions. If heavy rain or snow has been encountered, check the air cleaner for an accumulation of water.

Remove and steam clean the air cleaner element and baffle annually.

It is recommended that the body and fixed element in the heavy-duty oil bath type air cleaner be serviced every 15,000 miles or as conditions warrant.

Dry Type

Dry type air cleaner elements (Donaldson, Farr, etc.) used in on-highway applications should be discarded and replaced with new elements after one year of service, after 100,000 miles (Donaldson's recommended mileage interval) or when the maximum allowable air intake restriction has been reached (see Section 13.2), whichever comes first. No attempt should be made to clean or reuse on-highway elements after these intervals.

Item 9 - Drive Belts

New drive belts stretch during the first few hours of operation. Run the engine 15 *seconds* to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, pump drive, battery-charging generator or alternator and other accessory drive belts after 15 miles and again after 240 miles of operation. Thereafter check the tension of the drive belts every 6000 miles and adjust, if necessary. Too tight a belt is destructive to the bearings of the driven part, a loose belt will slip.

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032" of their specified center distances.

Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2" to 3/4"1. If belt tension gage BT-33-73FA, J 23600-B or equivalent, is available, adjust the belt tension as outlined in the chart.

NOTE: When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

Model	Fan Drive		Generator Drive	
	2 or 3 Belts	Single Belt	Two 3/8" or 1/2" Belts	One 1/2" Belt
6, 8V-71	60-80	180-100	40-50	50-70
12V-71	70-901		40-50	50-70

BELT TENSION CHART (lbs/belt)

Item 10 - Air Compressor

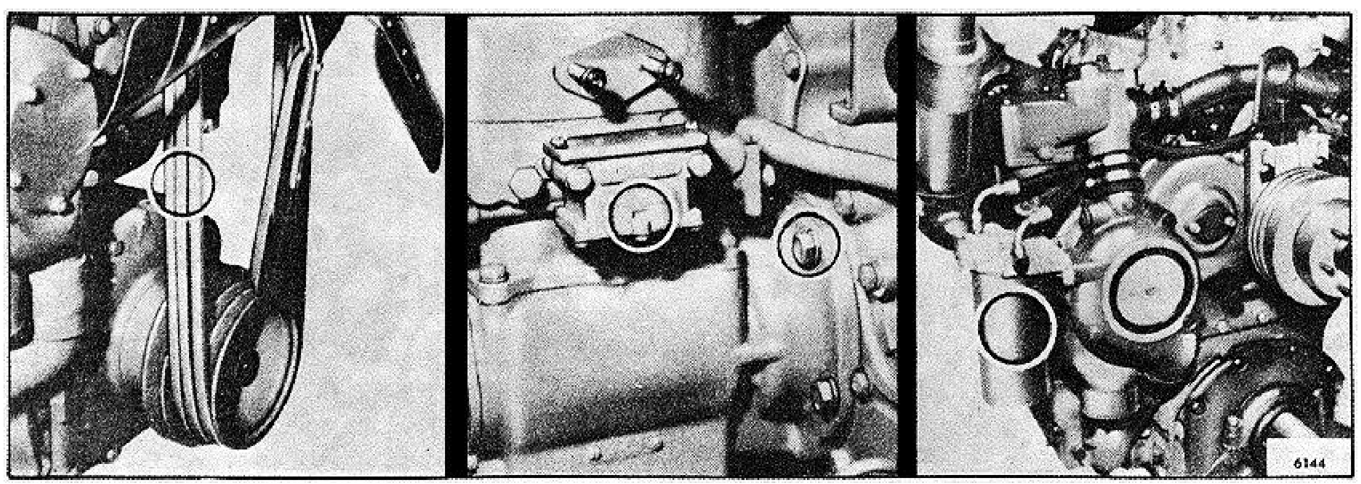
Remove and clean all air compressor air intake parts. To clean either the hair or polyurethane type element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until dirt free. Then dip it in lubricating oil and squeeze it dry before placing the element back in the air strainer.

For replacement of the air strainer element, contact the nearest Bendix Westinghouse dealer; replace with the polyurethane element, if available.

Every 12 months or 20,000 miles tighten the air compressor mounting bolts. If the air compressor is belt driven, check the belts for proper tension.

Item 11 - Throttle Control

Every 6,000 miles lubricate the throttle control mechanism at the grease fittings. Use an all purpose grease (No. 2 grade) at temperatures + 30 F (-1° C) and above. At temperatures below this use a No. 1 grade grease.



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Item 12 - Lubricating Oil Filter

Install new oil filter elements and gaskets at a *maximum* of 25,000 miles or each time the engine oil is changed, whichever comes first. Any deviation, such as changing filters every other oil change, should be based on a laboratory analysis of the drained oil and the used filter elements to determine if such practice is practical for proper protection of the engine.

Make a visual check of all lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

When the engine is equipped with a turbocharger, prelubricate it as outlined under *Install Turbocharger* in Section 3.5 or 3.5.1.1.

Item 13 - Fuel Filter

Install new elements every 6 months or 10,000 miles or when plugging is indicated.

A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury (20.3 kPa). At normal operating speeds, the fuel pressure is 45 to 70 psi (310 to 483 kPa). Change the fuel filter elements whenever the inlet restriction (suction) at the fuel pump reaches 12 inches of mercury (41 kPa) at normal operating speeds and 45 psi (310 kPa).

whenever the fuel pressure at the inlet manifold falls to

Item 14 - Coolant Filter

Replace the coolant filter element every 6 months or 10,000 miles. Select the proper coolant filter element in accordance with the instructions given under *Engine Coolant* in Section 13.3. Use a new filter cover gasket when installing the filter element. After replacing the filter element and cover gasket. start the engine and check for leaks.

Item 15 - Starting Motor

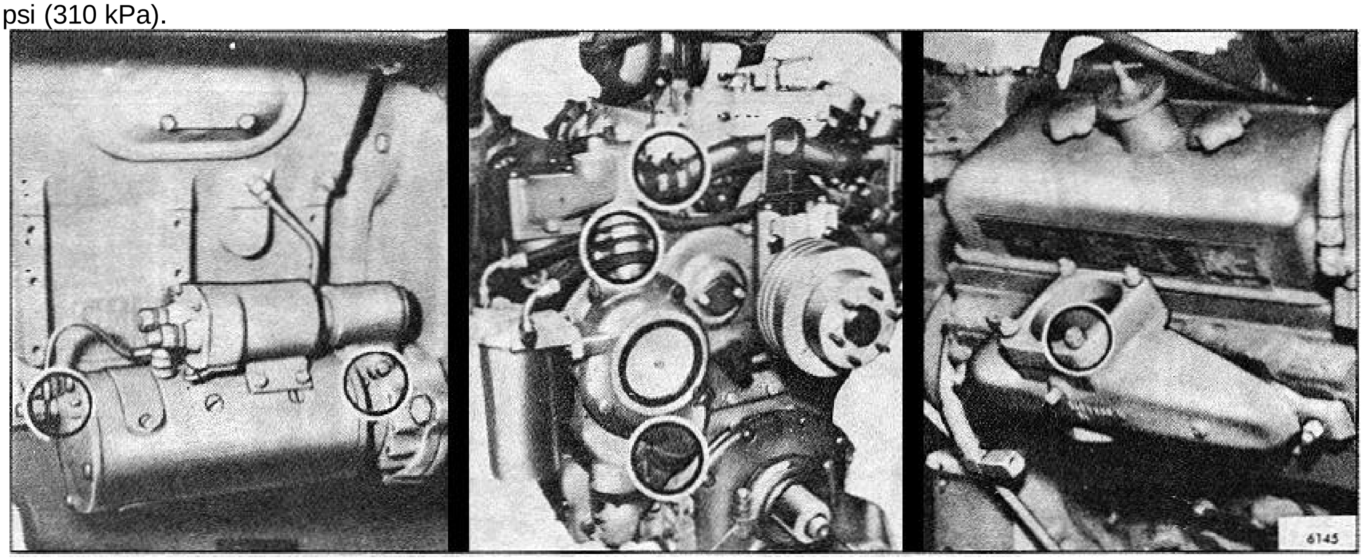
Starting motors which are provided with lubrication fittings (grease cups, hinge cap oilers or oil tubes sealed with pipe plugs) should be lubricated every 6 months or 10,000 miles. Add 8 to 10 drops of oil, of the same grade as used in the engine. to hinge cap oilers; if sealed tubes are provided. remove the pipe plugs, add oil and reseal the tubes. Grease cups should be turned down one turn. Refill the grease cups. If necessary. However, some starting motors do not require lubrication except during overhaul.

Item 16 - Air System

Check all of the connections in the air system to be sure they are tight. Check all hoses for punctures or other damage and replace, if necessary.

Item 17 - Exhaust System

Check the exhaust manifold retaining nuts, exhaust flange clamp and other connections for tightness.



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Check for proper operation of the exhaust pipe rain cap, if one is used.

Item 18 - Air Box Drain Tubes

With the engine running, check for flow of air from the air box drain tubes every 18 months or 30,000 miles. If the tubes are clogged, remove, clean and reinstall the tubes. The air box drain tubes shou1d be cleaned periodically even though a clogged condition is not apparent.

Item 19 - Emergency Shutdown

With the engine running at idle speed, check the operation of the emergency shutdown every 12 months or 20,000 miles. Reset the air shutdown valve in the open position after the check has been made.

Item 20 - Engine (Steam Clean)

Steam clean the engine and engine compartment.

> **NOTE**: Do not apply steam or solvent directly on the battery-charging generator/alternator, starting motor or electrical components as damage to electrical equipment may result.

Item 21 - Radiator

Inspect the exterior of the radiator core every 12 months or 20,000 miles and, if necessary, clean it with a quality grease solvent such as mineral spirits and dry it with compressed air. *Do not use fuel oil, kerosene or gasoline.* It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Item 22 - Shutter Operation

Check the operation of -the shutters and clean the linkage and controls.

Item 23 - Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 12 months or 20,000 miles.

Item 24 - Governor

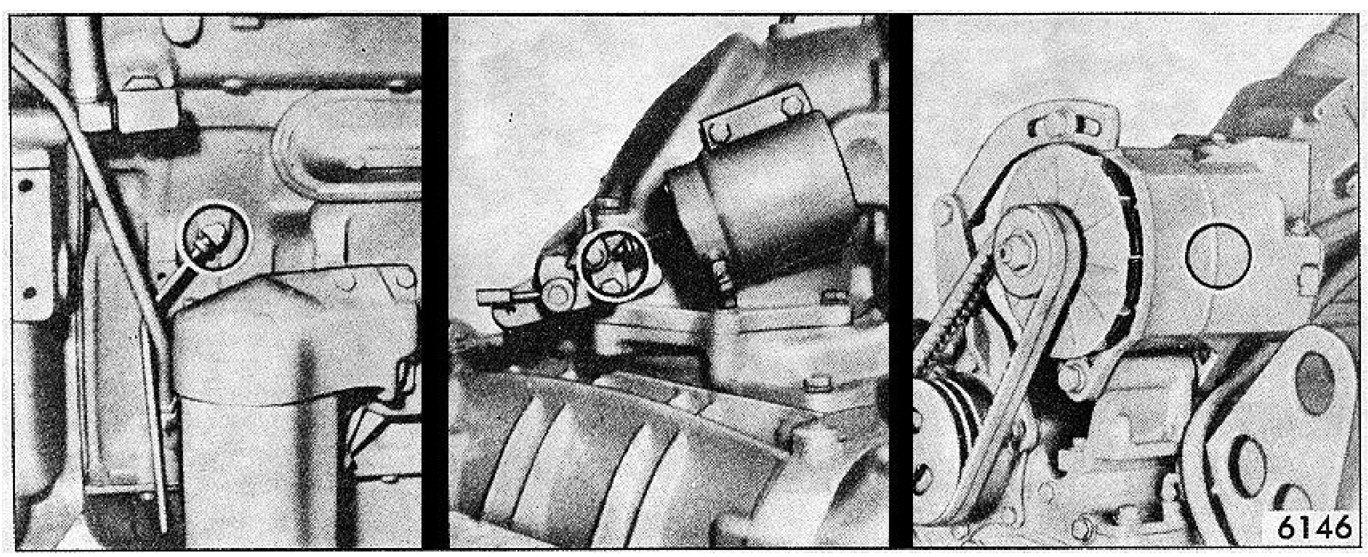
Check and record the engine idle speed and no-load speed. Adjust as necessary.

An idle speed lower than recommended will cause the engine to be accelerated from a speed lower than the speed at which the engine was certified.

A no-load speed higher than recommended will result in a full-load speed higher than rated and higher than the speed at which the engine was certified.

Item 25 - Fuel Injectors and Valve Clearance

Check the injector timing and exhaust valve clearance



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as outlined in Section 14.2 and 14.1 every 50,000 miles. The proper height adjustment between the injector follower and injector body is of primary importance to emission control.

Item 26 - Throttle Delay

Inspect and adjust, if necessary, every 30 months or 50,000 miles.

The throttle delay system limits the amount of fuel injected during acceleration by limiting the rate of injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay (Section 14.14).

Inspect the check valve by filling the throttle delay cylinder with diesel fuel and watching for valve leakage while moving the throttle from the idle to the full-fuel position.

Item 27 - Generator or Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

If the battery-changing generator or alternator is equipped with hinge cap oilers, add a few drops **of** medium grade engine oil to each oiler during the unit or vehicle lubrication period. Generators or alternators having a built-in supply of grease or sealed bearing require no additional lubrication except during engine or unit overhaul.

Item 28 - Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 36 months or 60,000 miles. Tighten and repair as necessary.

Item 29 - Crankcase Pressure

Check and record the crankcase pressure every 36 months or 60,000 miles (refer to Section 15.2).

Item 30 - Air Box Check Valves

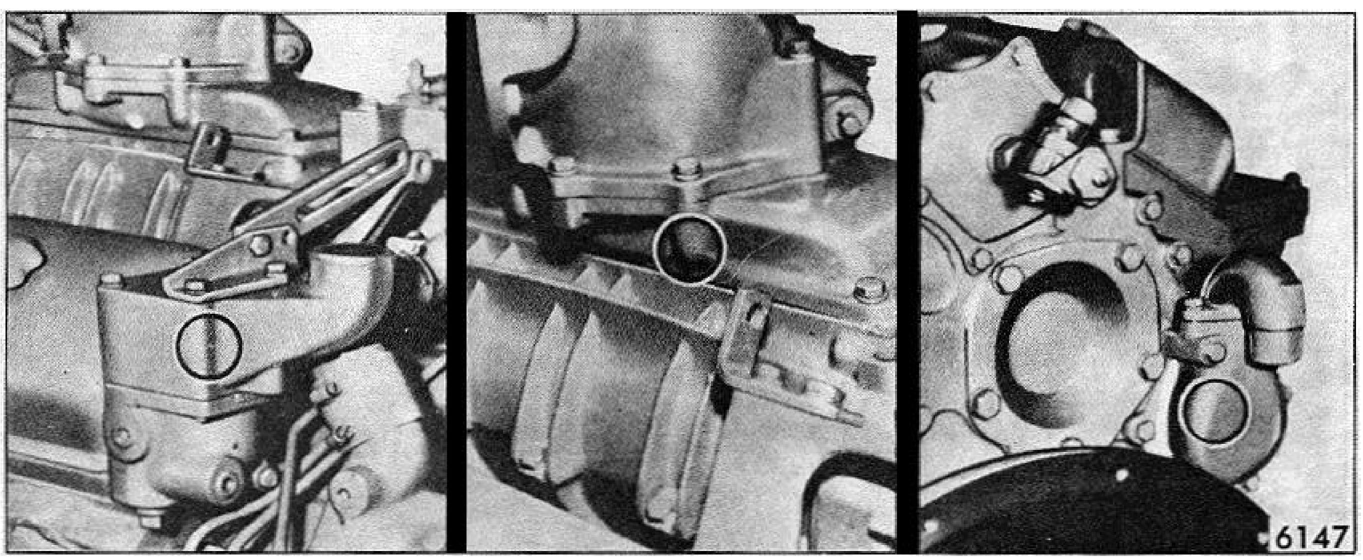
Every 100,000 miles remove the check valves, clean them in solvent and blow out the lines with compressed air. Inspect for leaks after servicing.

Item 31 - **Fan Hub**

If the fan bearing hub assembly is provided with a grease fitting, use a hand grease gun and lubricate the bearings with one shot of Texaco Premium RB grease, or an equivalent Lithium base multi-purpose grease, every 12 months or 20,000 miles.

Every 75,000 miles clean, inspect and repack the fan bearing hub assembly with the above recommended grease'(refer to Section 5.4).

At a major engine overhaul, remove and discard the bearings in the fan hub assembly. Pack the hub assembly, using new bearings, with Texaco



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Premium RB grease, or an equivalent Lithium base multi-purpose grease.

Item 32 - Thermostats and Seals

Check the thermostats and seals (preferably at the time the cooling system is prepared for winter operation). Replace the seals if necessary.

Item 33 - Blower Screen

Inspect the blower screen and gasket assembly annually and, if necessary, clean the screen in fuel oil and dry it with compressed air. Install the screen and gasket assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.

Item 34 - Crankcase Breather

Remove the externally mounted crankcase breather assembly annually and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.

Item 35 - Fan (Thermo-Modulated)

DRIVE FLUID LEVEL:

Check the fan drive fluid level to avoid improper operation and damage to the drive components.

Current modulated fan drive housings have an inspection plug for checking the fluid level. Formerly partial disassembly of the drive was necessary to make the fluid level check. Former units can be updated by installing a current drive housing which includes the fluid inspection plug and a grease fitting for lubricating the bearing.

1. Check the fan drive fluid level after the unit has been idle for at least 1/2 hour.

2. Turn the fan drive so that the inspection plug is 3/4 " below the horizontal center line, then allow the silicone fluid to drain down an additional five minutes.

3. Remove the inspection plug. If fluid begins to flow from the inspection hole, the drive has sufficient fluid. Replace the inspection plug.

4. If the fluid does not flow from the hole, proceed as follows:

   a. Rotate the fan drive downward and observe when the fluid begins to flow from the hole. If it is necessary to lower the drain hole more than 2 " below the horizontal center line, the fan drive should be removed from the engine, disassembled and inspected for possible damage to the components.

   b. Turn the fan drive back so the inspection hole is 3/4 " below the horizontal center line and add fluid until the overflow point is reached. Replace the inspection plug.

NOTE: Use only the manufacturer's Special 20 Cenistroke fluid.

DRIVE BEARING LUBRICATION:

The fan drive bearing should be lubricated as outlined in the chart with a Medium Consistency Silicone Grease (Dow Corning No. 44, or equivalent).

The bearing on current fan assemblies is lubricated through a grease fitting in the drive housing hub. Lubrication of the bearing in former assemblies requires the removal of the fan assembly and partial disassembly. The former assemblies can be updated to include a grease fitting by installing the current housing.

Item 36 - Engine Tune-Up

There is no scheduled interval for performing a complete engine tune-up. As long as the engine performance is satisfactory, a complete tune-up should not be required. Minor adjustments such as injector timing, exhaust valve clearance, governor and throttle delay (Items 24, 25 and 26) should be made every 50,000 miles to compensate for normal wear on parts.

TROUBLE SHOOTING

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages. Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.

2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.

2. Stop the engine and remove the valve rocker covers.

3. Check the valve clearance (Section 14.1).

4. Start the engine. Then hold an injector follower down with a screw driver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly,

Minimum Compression Pressure at 600 rpm				Altitude above Sea Level		†Air Density
Standard and Turbocharged Engines		"N" Engines				
psi	kPa	psi	kPa	feet	meters	
425	2928	515	3548	500	152	.0715
395	2722	480	3308	2,500	762	.0663
365	2515	440	3022	5,000	1,524	.0613
340	2343	410	2825	7,500	2,286	.0567
315	2170	380	2619	10,000	3,048	.0525

†Air density at 500 ft. altitude based on 85° F (29.4° C) and 29.38 in. Hg (99.49 kPa) wet barometer.

TABLE 1

There will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

6. If the cylinder is misfiring, check the following:

   a. Check the injector timing (refer to Section 14..2).

   b. Check the compression pressure.

   c. Install a new injector.

   d. If the cylinder still misfires, remove the cam follower (refer to Section 1.2.1) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. I cylinder.

3. Remove the injector and install an adaptor and pressure gage (Fig. I) from Diagnosis Kit J 953 1 -0 1.

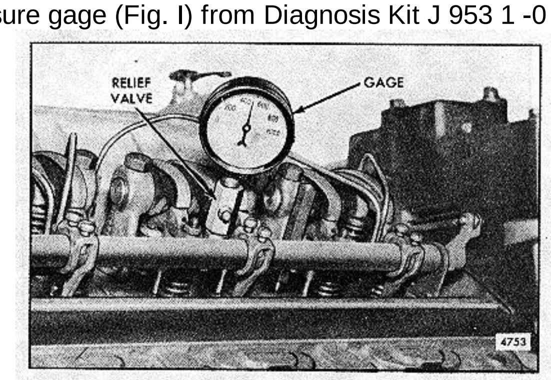


FIG. 1 checking Compression Pressure

Cylinder	Gage Reading	
	psi	kPa
1L	445	3066
1R	440	3032
2L	405	2791
2R	435	2997
3L	450	3101
3R	445	3066

TABLE 2

4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.

5. Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gage. *Do not crank the engine with the starting motor to obtain the compression pressure.*

6. Perform Steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In addition, the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

> **EXAMPLE**: If the compression pressure readings were as shown in Table 2, it would be evident that No. 2L cylinder should be examined an, the cause of the low compression pressure be determined and corrected.

The pressures in Table 2 are for a standard engine operating at an altitude near sea level. Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the

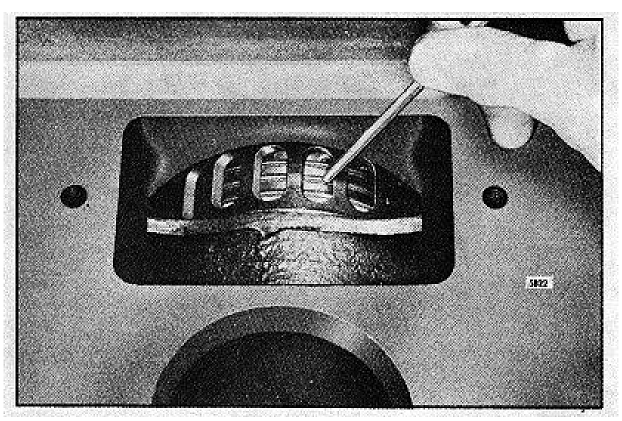


FIG. 2 - Inspecting Piston Rings

No. 2L cylinder compression pressure indicates that something unusual has occurred and that a localized pressure leak has developed.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool (Fig. 2). A broken or stuck ring will not have a "spring-like" action.

B. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

Engine Out of Fuel

The problem in restarting an engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons (38 litres) of fuel.

2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

> **NOTE**: In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in Section 2.0 under *Trouble Shooting.*

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

Check the crankcase pressure with a manometer connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the *Engine Operating Conditions* in Section 13.2.

> **NOTE**: The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

Exhaust Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

Check the exhaust back pressure, measured in inches of mercury, with a manometer. Connect the manometer to the exhaust manifold (except on turbocharged engines) by removing the 1/8 " pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32 " hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8 " pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping 6 " to .12 " from the turbine outlet (Fig. I of Section 13.2). The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no-load) with the *Engine Operating Conditions* in Section 1 3.2.

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or gray exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

Check the air box pressure with a manometer connected to an air box drain tube.

Check the readings obtained at various speeds with the *Engine Operating Conditions* in Section 13.2.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2 " above the air inlet housing (non-turbocharged engine) or the compressor inlet (turobcharged engine). When practicability prevents the insertion of a fitting at this point (non-turbocharged engine), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the Engine Operating Conditions in Section 13.2.

PROPER USE OF MANOMETER

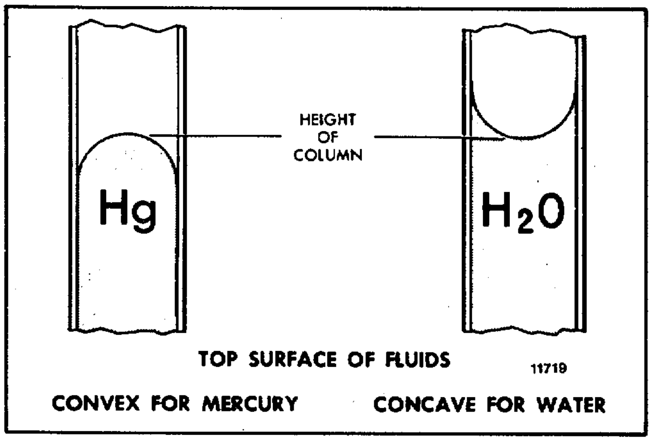


FIG. 3 - Comparison of Column Height for Mercury and Water Manometers

The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

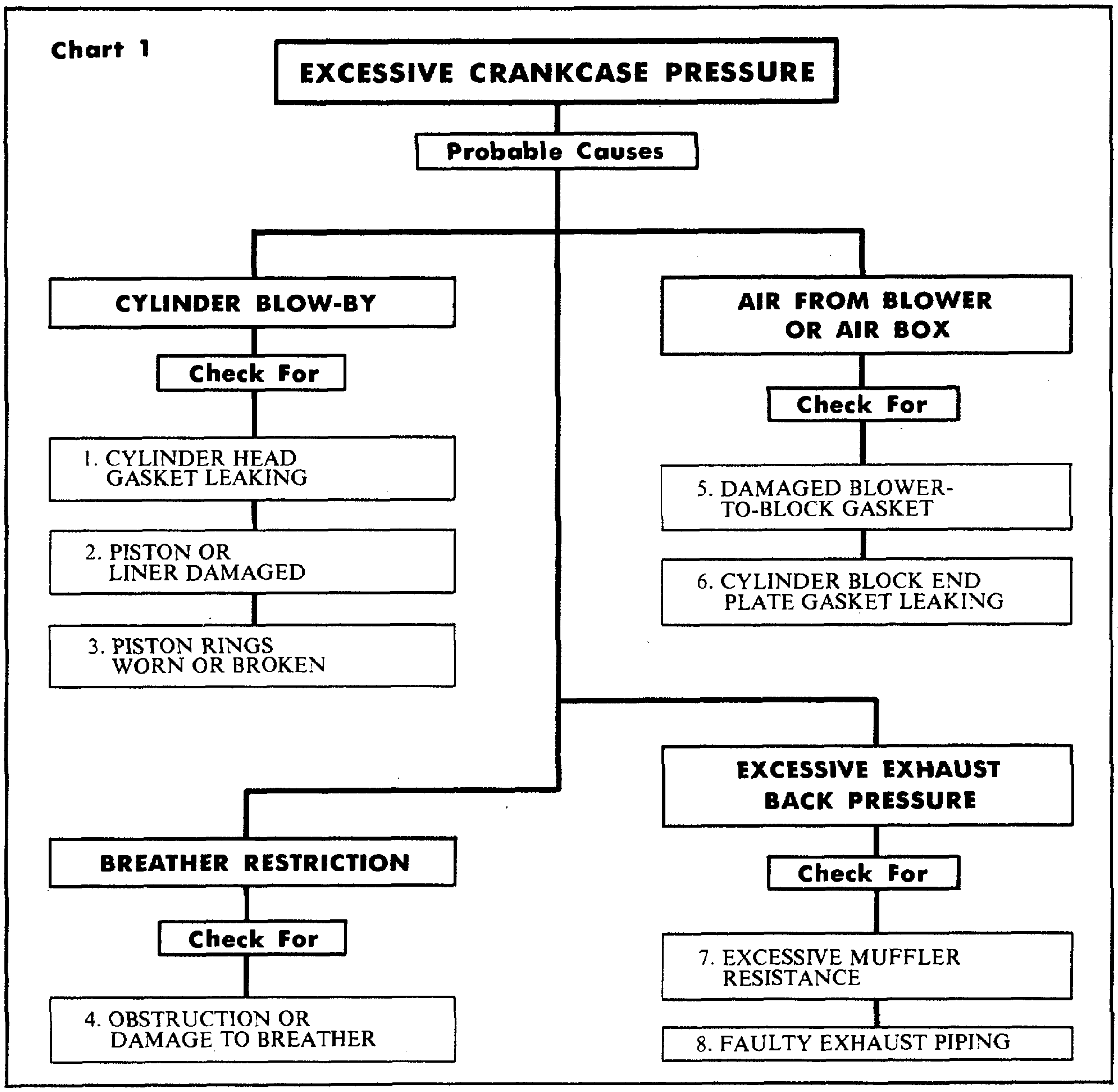
PRESSURE CONVERSION CHART		
1" water	=	.0735" mercury
1" water	=	.0361 psi
1" mercury	=	13.6000" water
1" mercury	=	.4910 psi
1 psi	=	27.7000" water
1 psi	=	2.0360" mercury
1 psi	=	6.895 kPa
1 kPa	=	.145 psi

TABLE 3

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 3) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.



SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.

2. Inspect the piston and liner and replace damaged parts.

3. Install new piston rings.

4. Clean and repair or replace the breather assembly.

5. Replace the blower-to-block gasket.

6. Replace the end plate gasket.

7. Check the exhaust back pressure and repair or replace the muffler if an obstruction is found.

8. Check the exhaust back pressure and install larger piping if it is determined that the piping is too small, too long or has too many bends.

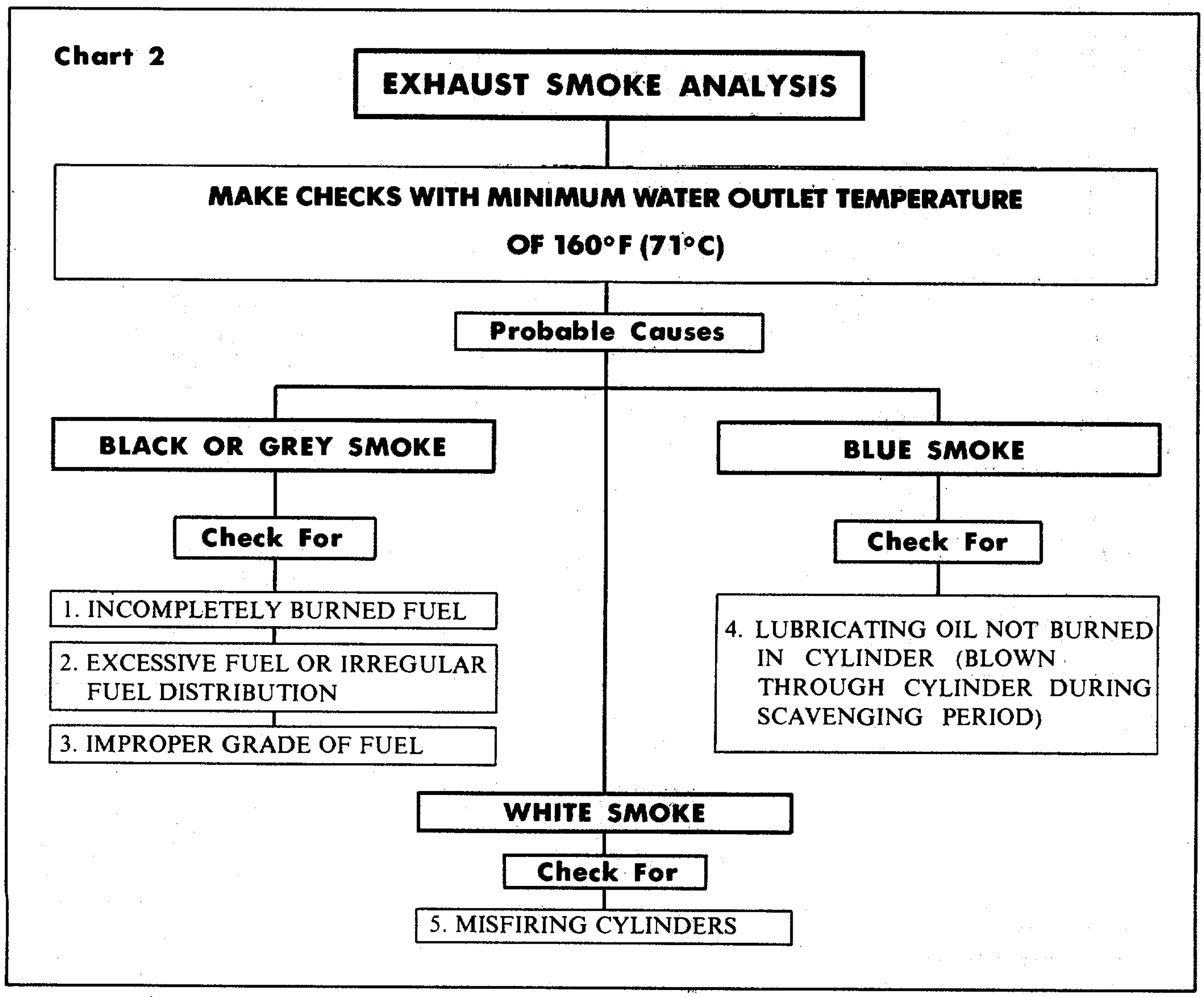


Chart 2
EXHAUST SMOKE ANALYSIS
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F (71°C)
Probable Causes
BLACK OR GREY SMOKE
Check For
1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL
BLUE SMOKE
Check For
4. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)
WHITE SMOKE
Check For
5. MISFIRING CYLINDERS

Chart 2

EXHAUST SMOKE ANALYSIS

SUGGESTED REMEDY

1. High exhaust back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

2 If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune- up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

Avoid lugging the engine as this will cause incomplete combustion. Operate the engine as outlined in the *Drivers Handbook*.

3. Check for use of an improper grade of fuel. Refer to *Fuel Specifications* in Section 13.3.

4. Check for internal lubricating oil leaks and refer to the *High Lubricating* Oil Consumption chart.

5. Check for faulty injectors and replace as necessary. Check for low compression and consult the *Hard Starting* chart.

The use of low cetane fuel will cause this condition. Refer to *Fuel Specifications* in Section 13.3.

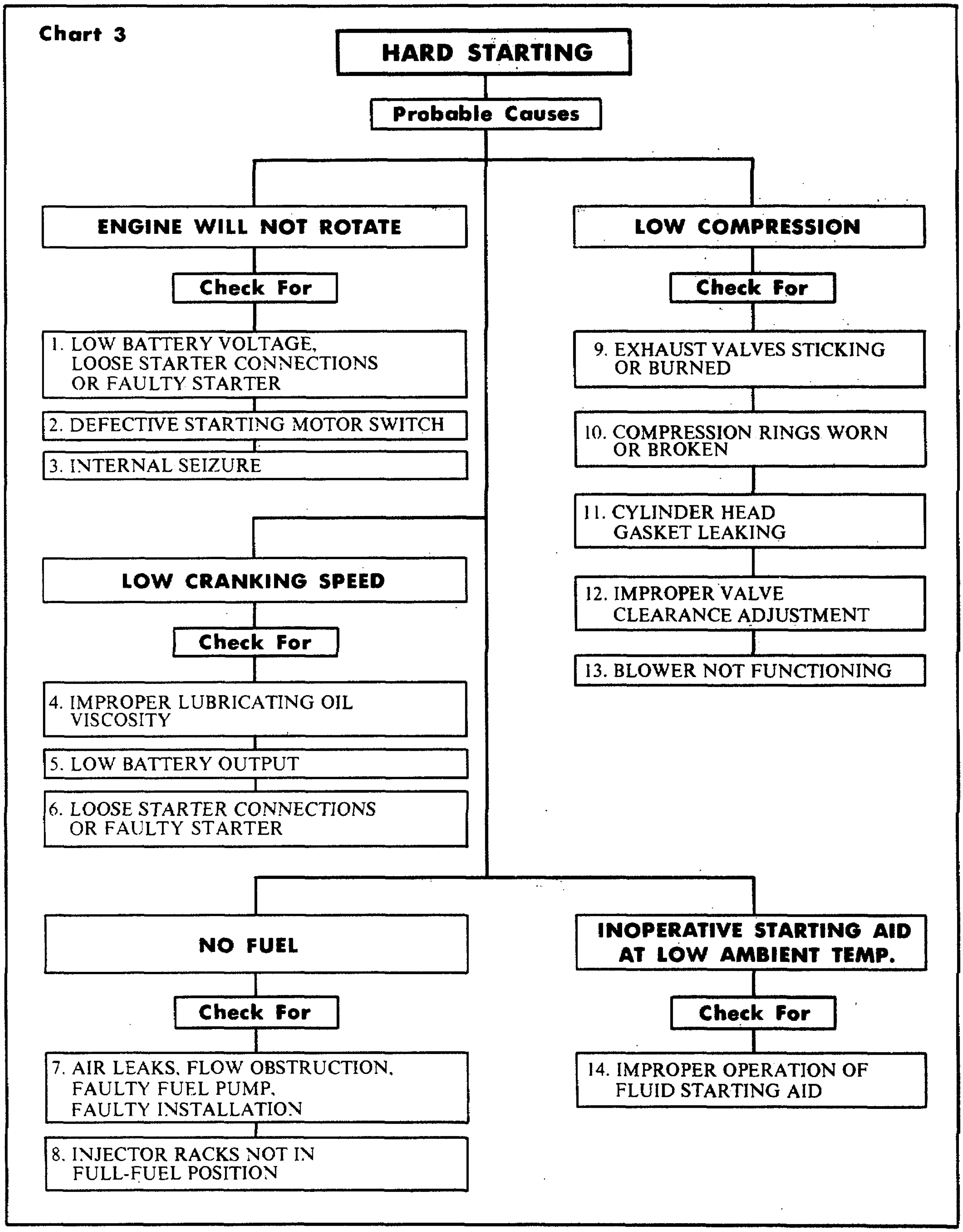


Chart 3
HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
3. INTERNAL SEIZURE
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
NO FUEL
Check For
7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
14. IMPROPER OPERATION OF FLUID STARTING AID

Chart 3

HARD STARTING

SUGGESTED REMEDY

1 Refer to Items 2, 3 and 5 and perform the operations listed.

2. Replace the starting motor switch.

3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

4. Refer to *Lubrication Specifications* in Section 13.3 for the recommended grade of oil.

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

Replace terminals that are damaged or corroded.

At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.

6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for bind in the governor-to-injector linkage. Readjust the governor and injector controls if necessary.

9. Remove the cylinder head and recondition the exhaust valves.

10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

12. Adjust the exhaust valve clearance.

13. Remove the flywheel housing cover at the blower drive support. Then remove the snap ring and withdraw the blower shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (see Section 3.4 or 3.4.1).

14. Operate the starting aid according to the instructions under *Cold Weather Starting Aids*.

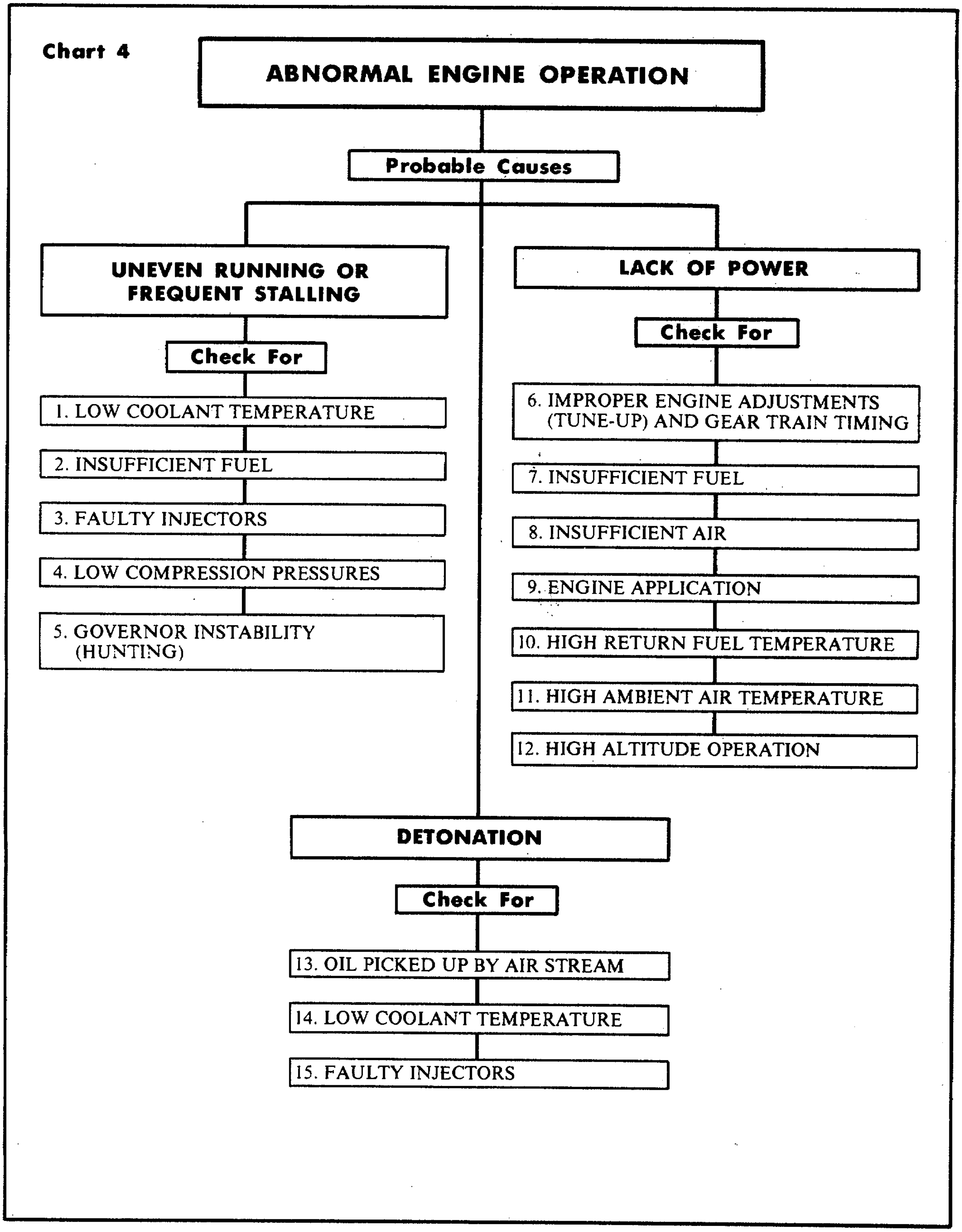


Chart 4
ABNORMAL ENGINE OPERATION
Probable Causes
UNEVEN RUNNING OR FREQUENT STALLING
Check For
1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)
LACK OF POWER
Check For
6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION
DETONATION
Check For
13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

Chart 4

ABNORMAL ENGINE OPERATIONS

SUGGESTED REMEDY

1. Check the engine coolant temperature gage and if the temperature does not reach 160-185°F (71-85°C) while the engine is operating, consult the *Abnormal Engine Coolant Temperature* chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the *Hard Starting* chart if compression pressures are low.

5. Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

Perform an engine tune-up if performance is not satisfactory.

6. If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a *Fuel Flow Test* and, if less than the specified fuel is returning to the fuel tank, consult the *No Fuel or Insufficient Fuel* chart.

8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the *Hard Starting* chart).

9. Incorrect operation of' the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures outlined in the *Drivers Handbook*.

10. Refer to Item 13 on Chart 5.

11. Check the ambient air temperature. A power decrease of .15 to .50 horsepower per cylinder, depending upon injector size. for each I() °F (6 °C) temperature rise above 90 F (32 "C) will occur. Relocate the engine air intake to provide a cooler source of air.

12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

13. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

14. Refer to Item I of this chart.

15. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

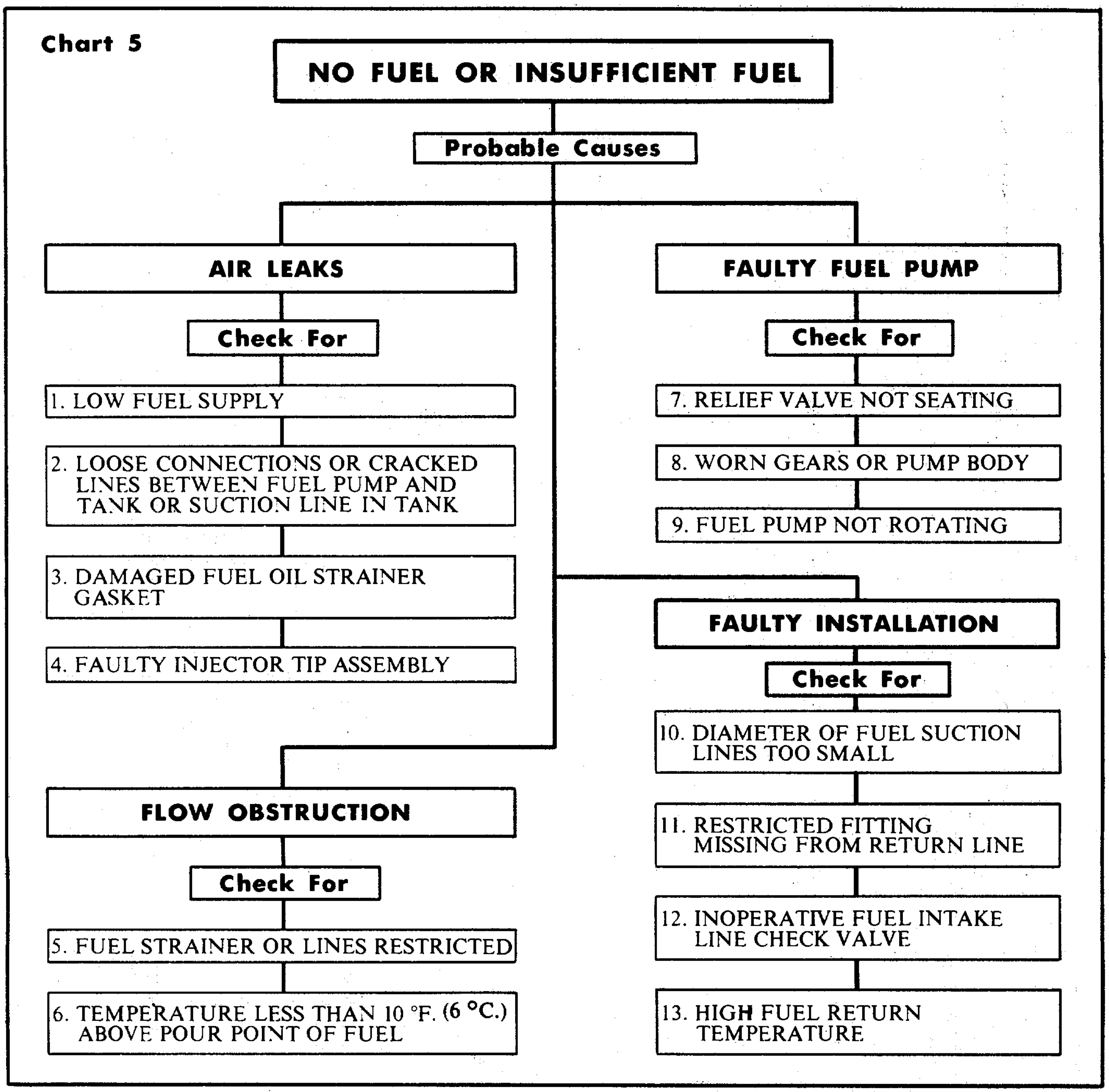


Chart 5
NO FUEL OR INSUFFICIENT FUEL
Probable Causes
AIR LEAKS
Check For
1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY
FLOW OBSTRUCTION
Check For
5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10 °F. (6 °C.) ABOVE POUR POINT OF FUEL
FAULTY FUEL PUMP
Check For
7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING
FAULTY INSTALLATION
Check For
10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart 5

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.

2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.

3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element.

4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.

5. Perform a *Fuel Flow Test* and replace the fuel strainer and filter elements and the fuel lines, if necessary,

6. Consult the *Fuel Specifications* for the recommended grade of fuel.

7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.

8. Replace the gear and shaft assembly or the pump body.

9. Check the condition of the fuel pump drive and blower drive and replace defective parts.

10. Replace with larger tank-to-engine fuel lines.

11. Install a restricted fitting in the return line.

12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.

13. Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150° F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

Chart 6

HIGH LUBRICATING OIL CONSUMPTION

Probable Causes

EXTERNAL LEAKS

Check For

1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. AUTOMATIC OIL FILLER
4. OIL PULLOVER - AIR COMPRESSOR
5. OVER-FILLED CRANKCASE
6. PLUGGED BREATHERS
7. HIGH CRANKCASE PRESSURE
8. BLUE EXHAUST SMOKE
9. EXCESSIVE OIL IN AIR BOX

INTERNAL LEAKS

Check For

10. BLOWER OIL SEALS LEAKING
11. TURBO OIL SEALS LEAKING
12. OIL COOLER CORE LEAKING
13. WORN EXHAUST VALVE GUIDES

OIL CONTROL AT CYLINDER

Check For

14. LOW COMPRESSION
15. PISTON PIN RETAINER LOOSE
16. OIL CONTROL RINGS WORN, BROKEN, IMPROPERLY INSTALLED OR SCORED.
17. EXCESSIVE OIL IN AIR BOX
18. DIRT IN AIR INTAKE SYSTEM
19. SCORED LINERS OR PISTONS
20. EXCESSIVE INSTALLATION ANGLE
21. EXCESSIVE OIL IN CRANKCASE

Chart 6

HIGH LUBRICATING OIL COMPANY

SUGGESTED REMEDY

NOTE: Lube oil consumption must be verified after each repair is made.

I & 2. Repair oil leaks by replacing necessary gaskets, seals or tightening connections. Steam cleaning the engine and operating at no-load rpm, (engine at operating temperature) will often reveal excessive oil leaks.

3. Consult the original equipment manufacturer for proper repair of the automatic oil filler system.

4. Check the air compressor for oil pullover and/or remove and replace the compressor.

5. Check dipstick and tube for proper oil pan levels to correct overfilled crankcase.

6. Check crankcase pressure. Clean breathers and recheck crankcase pressure.

7. Overhaul blower, turbocharger or rekit engine (refer to Items 10, 11, 15 and 16). Also, refer to the *Excessive Crankcase* Pressure chart.

8. Remove and inspect exhaust manifolds and stacks for wetness or oil discharge. Excessive clearance between the valve stem and the valve guide can produce oil in the cylinders and stack. Repair the valve guides and/or install valve stem seals.

9. Refer to the *Abnormal Engine Operation* chart.

10. Remove the piping from the air inlet housing and remove from the to blower. Operate the engine at approximately one-half throttle and at idle and inspect blower end plates for evidence of oil leakage past the seals. Use a flashlight to illuminate the end plates. If excessive oil leakage is evident on the end plates, overhaul blower.

> **CAUTION**: Extreme care should be taken to prevent personal injury.

11. Check for indications of oil on compressor or turbine sides of the turbocharger. Refer to Section 3.5 of the Service Manual for the proper procedure to determine turbocharger oil seal leakage.

12. Pressure test cooling system. If leak is found, remove and replace the oil cooler. Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.

13. Replace worn exhaust valve guides.

14. Take compression test - refer to Item 16.

15. Run engine at idle speed with the air box cover removed (one at a time) to determine if oil is uncontrolled as evidenced by slobbering out the liner ports. Inspect all cylinders as more than one may be slobbering. Repair affected cylinders. Slobbering can also be caused by worn oil control rings.

> **CAUTION:** Extreme care should be taken to prevent personal injury.

16. Check for faulty engine air induction system allowing contaminated air to enter the engine. A compression test with excessively low readings will indicate worn out cylinders. Remove and replace cylinder kits.

17. Refer to Items 10, 11, 15 and 16.

18. Refer to Item 16.

19. Check the crankshaft thrust washers for wear. Replace wore and defective parts.

20. Decrease the installation angle.

21. Fill the crankcase to the proper level only.

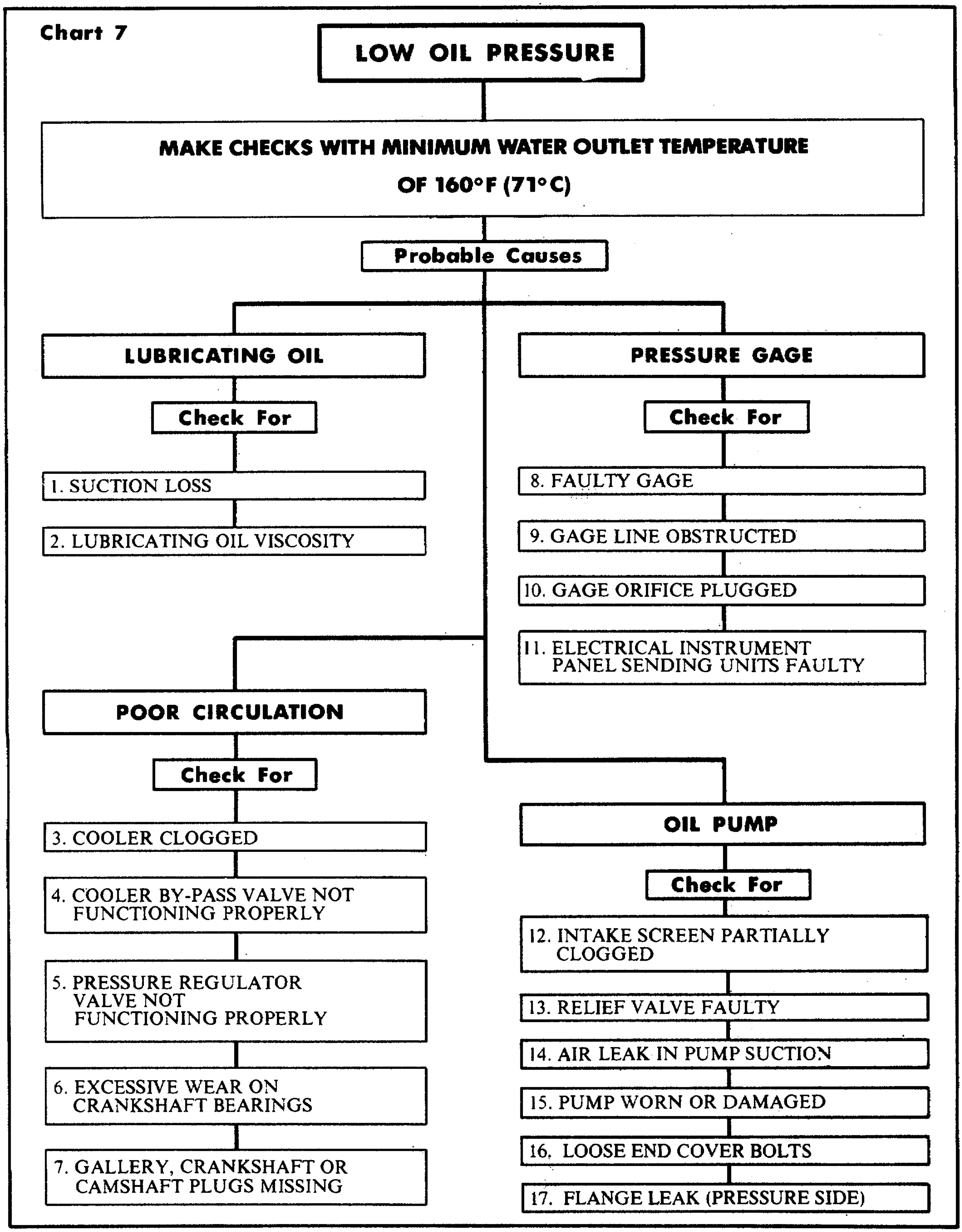


Chart 7
LOW OIL PRESSURE
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F (71°C)
Probable Causes
LUBRICATING OIL
Check For
1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY
PRESSURE GAGE
Check For
8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY
POOR CIRCULATION
Check For
3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING
OIL PUMP
Check For
12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. LOOSE END COVER BOLTS
17. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

2. Consult the *Lubrication Specifications* in Section 13.3 for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution.

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

7. Replace missing plugs.

8. Check the oil pressure with a reliable gage and replace the gage if found faulty.

9. Remove and clean the gage line; replace it, if necessary.

10. Remove and clean the gage orifice.

I 1. Repair or replace defective electrical equipment.

12. Remove and clean the oil pan and oil intake screen. Consult the *Lubrication Specifications* in Section 13.3 for the proper grade and viscosity of oil. Change the oil filters.

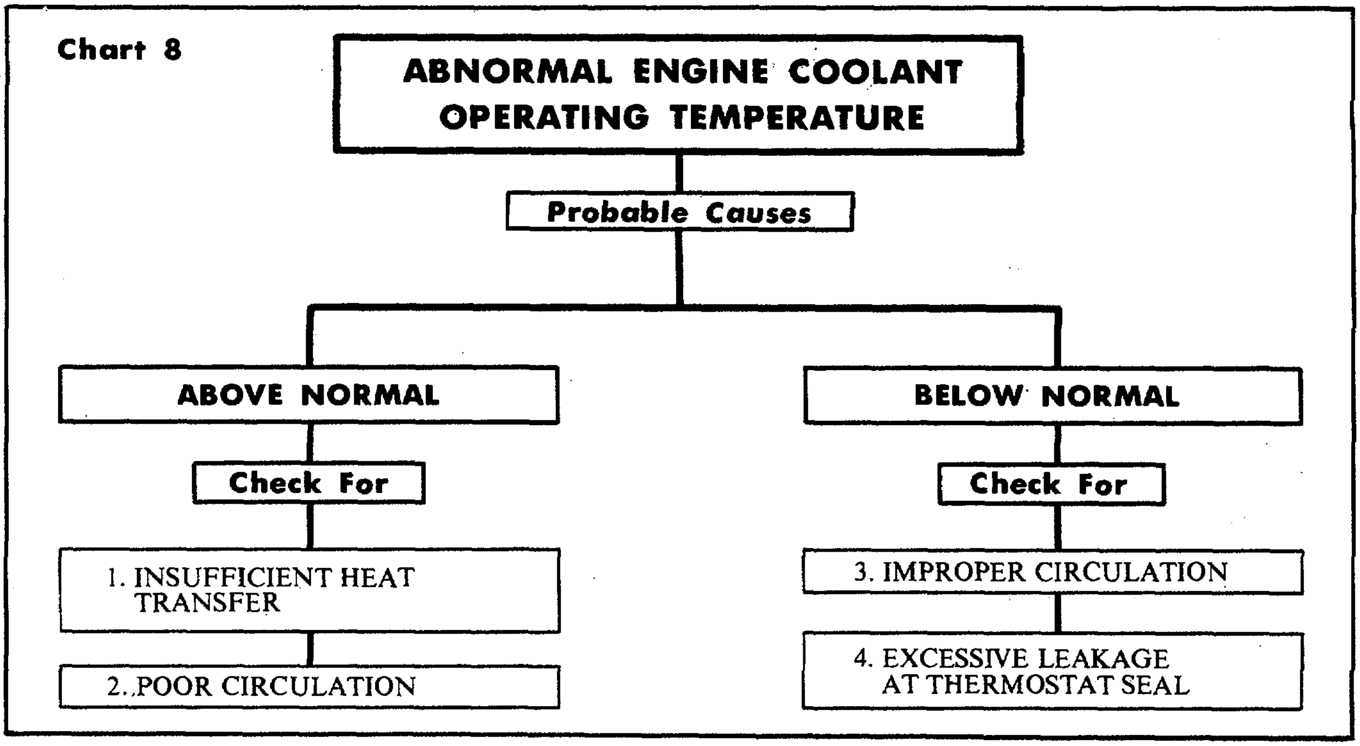
13. Remove and inspect the valve, valve bore and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the oil pan and tighten the oil pump end cover bolts.

17. Remove the flange and replace the gasket.



SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits.

Clean the exterior of the radiator core to open plugged passages and permit normal air flow.

Adjust fan belts to the proper tension to prevent slippage.

Check for an improper size radiator or inadequate shrouding.

Repair or replace inoperative temperature-controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low.

Inspect for collapsed or disintegrated hoses. Replace faulty hoses.

Thermostat may be inoperative. Remove, inspect and test the thermostat replace if found faulty.

Check the water pump for a loose or damaged impeller.

Check the flow of coolant through. the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core.

Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets replaced if combustion gases are entering the cooling system.

Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check, for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

STORAGE
PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 days or less)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.

2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.

3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

   NOTE: Do not drain the fuel system or the crankcase after this run.

4. Check the air cleaner and service it, if necessary, as outlined in Section 3.1l.

5. If freezing weather is expected during the storage period, add a permanent type antifreeze solution in accordance with the manufacturer's recommendations.

6. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.

7. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil and the transmission. operating the engine until normal operating temperature is reached (160-185 °F or 71-85 °C).

EXTENED STORAGE (more than 30 days)

I

1. Drain and thoroughly flush the cooling system with clean, soft water.

2. Refill the cooling system with clean, soft water.

3. Add a rust inhibitor to the cooling system (refer to Corrosion Inhibitors in Section 13.3).

4. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.
5. Re-install the injectors in the engine, turn them and adjust the exhaust valve clearance.

6. Circulate the coolant through the entire system by

7. Stop the engine.
8. Remove the drain plug and completely drain the engine crankcase. Re-install and tighten the drain plug. Install new lubricating oil filter elements and gaskets.
9. Fill the crankcase to the proper level with a 30- weight preservative lubricating oil MIL-L-2 1260, Grade 2 (PIO), or equivalent.
10. Drain the engine fuel tank.

11. Refill the fuel tank with enough rust preventive fuel oil such as American Oil Diesel Run-in Fuel (LF- 4089), Mobil 4Y17, or equivalent, to enable the engine to operate ten minutes. When an engine is to be removed from operation for an extended period of time, prepare it as follows:

12. Drain the fuel filter and strainer. Remove the retaining bolts, shells and elements. Discard the used elements and gaskets. Wash the shells in clean fuel oil and insert new elements. Fill the cavity between the element and shell about two-thirds full of the same rust preventive compound as used in the fuel tank and reinstall the shell.

13. Operate the engine for five minutes to circulate the rust preventive throughout the engine.

14. Refer to Section 3.1 and service the air cleaner.

15. TURBOCHARGER

The turbocharger bearings are lubricated by pressure through the external oil line leading from the engine cylinder block while performing the previous operations above and no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

16. Apply a *non-friction* rust preventive compound to all exposed parts. If it is convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.

> **NOTE:** Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances which can "sweat" out during operation and cause the clutch to slip.

17. Drain the engine cooling system.

18 Remove and clean the battery and battery cables with a baking soda solution and rinse them with fresh water. Do not allow the soda solution to enter the battery. Add distilled water to the electrolyte, if necessary, and fully charge the battery. Store the battery in a cool (never below 32 °F or O °C) dry place. Keep the battery fully charged and check the level and the specific gravity of the electrolyte regularly.

19. Insert heavy paper strips between the pulleys and belts to prevent sticking.

20. Seal all of the openings in the engine,,-including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.

21. Clean and dry the exterior painted surfaces of the engine. Spray the surfaces with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.

22. Cover the engine with a good weather-resistant tarpaulin or other cover if it must be stored outdoors. A clear plastic cover is recommended for indoor storage.

The stored engine should be inspected periodically. If there 'are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

PROCEDURE FOR REASTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. *Do not overlook the exhaust outlet.*

2. Wash the exterior of the engine with fuel oil to remove the rust preventive.

3. Remove the rust preventive from the flywheel.

4. Remove the paper strips from between the pulleys and the belts.

5. Remove the drain plug and drain the preservative oil from the crankcase. Re-install the drain plug. Then refer to *Lubrication system* in Section 13.1 and fill the crankcase to the proper level, using a pressure prelubricator, with the recommended grade of lubricating oil.

6. Fill the fuel tank with the fuel specified under *Diesel Fuel Oil Specifications* (Section 13.3).

7. Close all of the drain cocks and fill the engine cooling system with clean soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a permanent type antifreeze solution (refer to Section 13.3).

8. Install and connect the battery.

9. Service the air cleaner as outlined in Section 3.I.

10. TURBOCHARGER
Remove the covers from the turbocharger air inlet and turbine outlet connections. Refer to the lubricating procedure outlined in *Preparation for Starting Engine First Time* in Section 13. 1.

11 . After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause a smoky exhaust for a few minutes.

> **NOTE**: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune-up.

ALPHABETICAL INDEX

* General Information Section

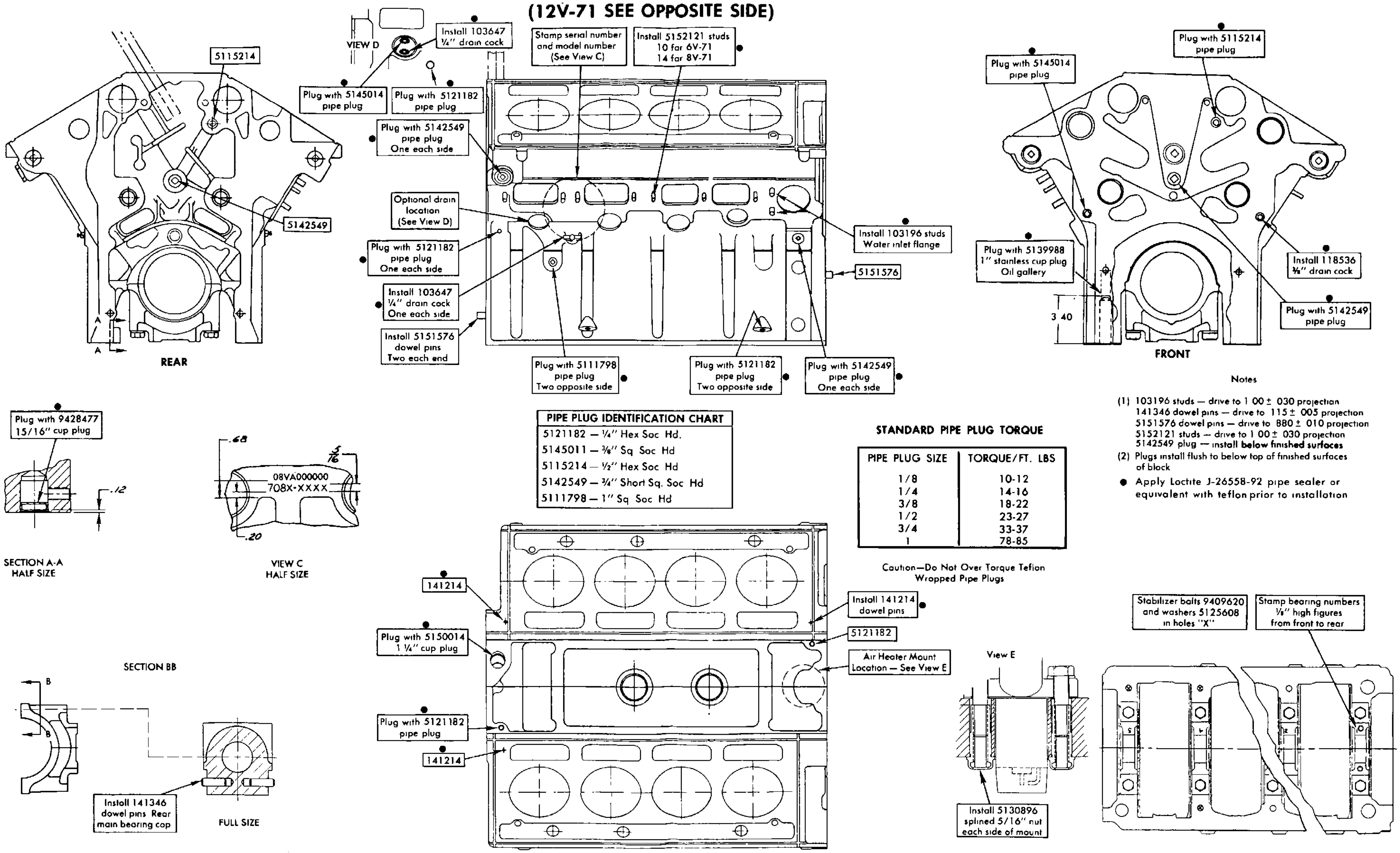
* General Information Section

* General Information Section

* General Information Section

6V-71 & 8V-71 BLOCK PLUGGING CHART
(12V-71 SEE OPPOSITE SIDE)

6V-71 & 8V-71 BLOCK PLUGGING CHART
(12V-71 SEE OPPOSITE SIDE)



PIPE PLUG IDENTIFICATION CHART
5121182 — ¼" Hex Soc Hd.
5145011 — ⅜" Sq Soc Hd
5115214 — ½" Hex Soc Hd
5142549 — ¾" Short Sq. Soc Hd
5111798 — 1" Sq Soc Hd

STANDARD PIPE PLUG TORQUE

PIPE PLUG SIZE	TORQUE/FT. LBS
1/8	10-12
1/4	14-16
3/8	18-22
1/2	23-27
3/4	33-37
1	78-85

Caution—Do Not Over Torque Teflon Wrapped Pipe Plugs

Notes

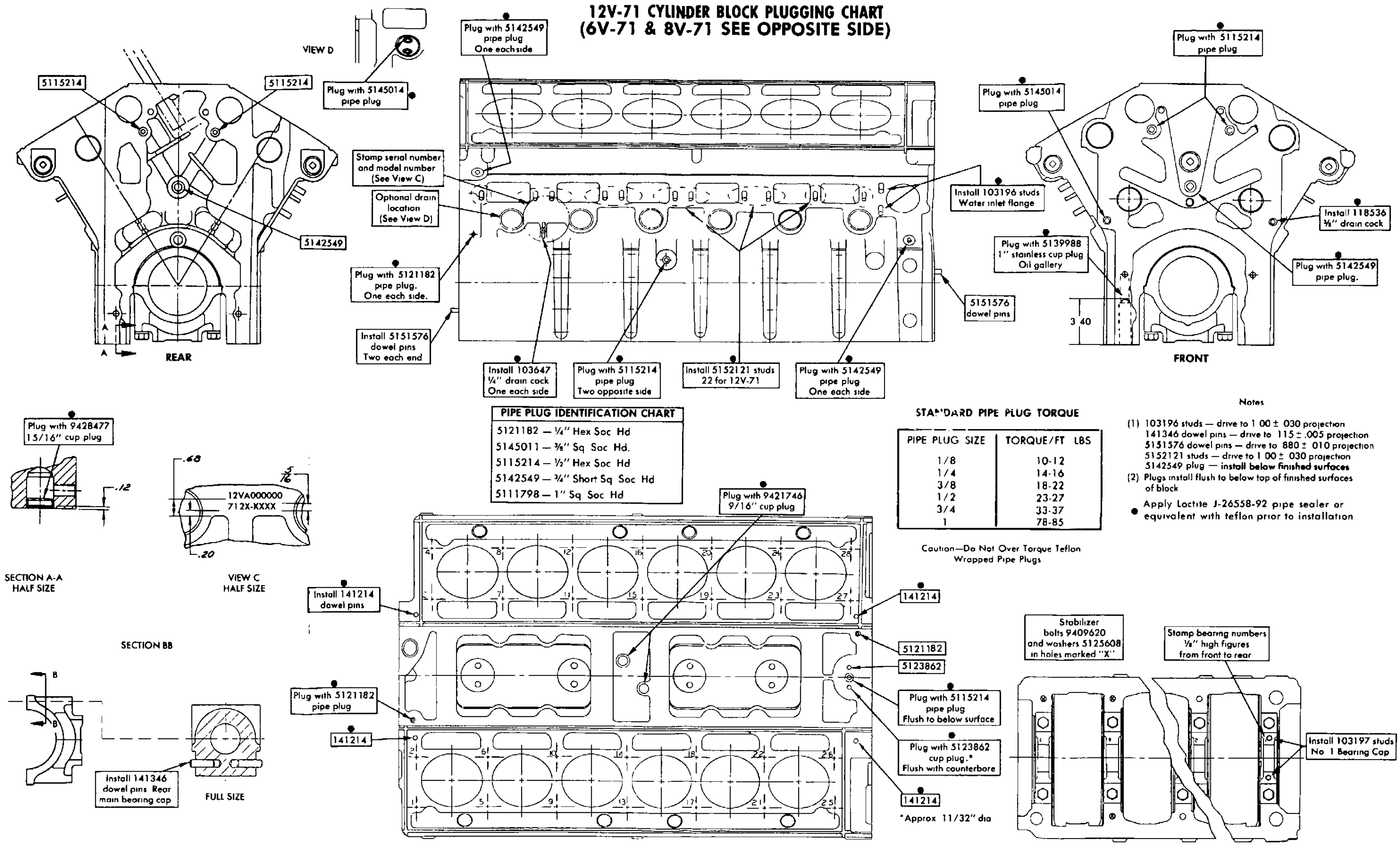
(1) 103196 studs — drive to 1 00 ± 030 projection
141346 dowel pins — drive to 115 ± 005 projection
5151576 dowel pins — drive to 880 ± 010 projection
5152121 studs — drive to 1 00 ± 030 projection
5142549 plug — install **below finished surfaces**

(2) Plugs install flush to below top of finished surfaces of block

● Apply Loctite J-26558-92 pipe sealer or equivalent with teflon prior to installation

REV 9-77

12V-71 CYLINDER BLOCK PUGGING CHART
(6V-71 & 8V-71 SEE OPPOSITE SIDE)



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By Order of the Secretary of the Army:

JOHN A. WICKHAM, JR.
General, United States Army
Chief of Staff

Official***:***

R. L. DILWORTH
Brigadier General, United States Army
The Adjutant General

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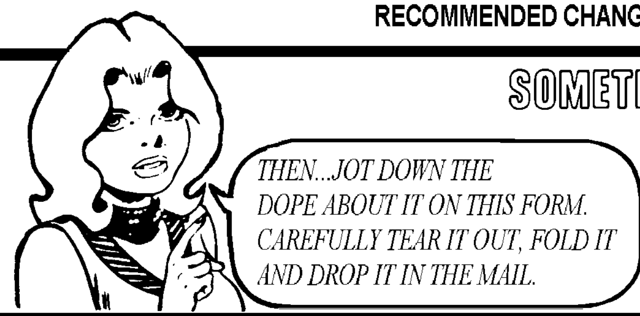

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The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 dekagram = 10 grams = .35 ounce
acres
1 hectogram = 10 dekagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47

1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	*To*	*Multiply by*	*To change*	*To*	*Multiply by*
inches	centimeters	2.540	ounce-inches	newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	newton-meters	1.356	metric tons	short tons	1.102
pound-inches	newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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