SERIES 53
SERVICE MANUAL
DETROIT DIESEL ENGINES

DETROIT DIESEL ALLISON
DIVISION OF GENERAL MOTORS CORPORATION
DETROIT, MICHIGAN, 48228

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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.

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SCOPE AND USE OF THE MANUAL

This manual covers the basic Series 53 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 Series 53 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 sub-sections which contain complete maintenance and operating instructions for a specific sub-assembly on the engine. For example, Section 1, which covers the basic engine, contains sub-section 1.1 pertaining to the cylinder block, sub-section 1.2 covering the cylinder head, etc. The subjects and sections are listed in the Table of Contents on the preceding page. Pages are numbered consecutively, starting with a new Page 1 at the beginning of each sub-section. The illustrations are also numbered consecutively, beginning with a new Figure 1 at the start of each sub-section.

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 sub-assembly 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 sub-section 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 "Factory Engineered" replacement parts are available from authorized Detroit Diesel Service Outlets conveniently located within the United States, in Canada from the distribution organization of Diesel Division, General Motors of Canada Limited, and abroad through the sales and service outlets of General Motors Overseas Operations Divisions.

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 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 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 injected fuel has been burned.

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

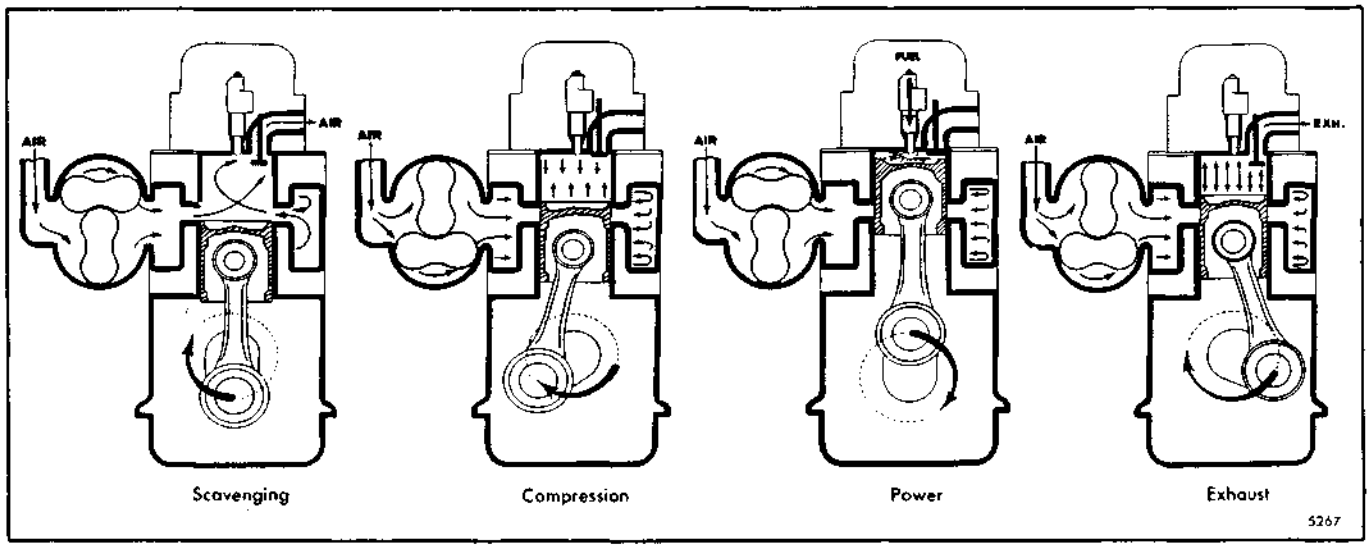


Fig. 1 - The Two Stroke Cycle

GENERAL DESCRIPTION

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

The In-line engines, including the inclined marine models, include standard accessories such as the blower, water pump, governor and fuel pump, which, on some models, may be located on either side of the engine regardless of the direction the crankshaft rotates. Further flexibility in meeting installation requirements is achieved with the cylinder head which can be installed to accommodate the exhaust manifold on either side of the engine.

The V-type engines use many In-line engine parts, including the 3-53 and 4-53 cylinder heads. The blower is mounted on top of the engine between the two banks of cylinders and is driven by the gear train. The governor is mounted on the rear end of the 6V-53 blower and on the front end of the 8V-53 blower.

The meaning of each digit in the model numbering system is shown in Figs. 2 and 3. 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 blower and exhaust manifold location on the In-line engines as viewed from the rear of the engine while the letter A or C designates the location of the oil cooler and starter on the V-type engines.

Each engine is equipped with an oil cooler (not required on certain two-cylinder models), full-flow oil filter, fuel oil strainer and fuel oil filter, an air cleaner or silencer, governor, heat exchanger and raw water pump or fan and radiator, and a starting motor.

Full pressure lubrication is supplied to all main, connecting rod and camshaft bearings and to other moving parts. A rotor-type pump on In-line or 6V engines or a gear-type pump on 8V engines draws oil from the oil pan through a screen and delivers it to the oil filter. From the filter, the oil flows to the oil cooler and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the camshaft bearings and up through the rocker arm assemblies; the remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft.

Coolant is circulated through the engine by a centrifugal-type water pump. Heat is removed from the coolant, which circulates in a closed system, by the heat exchanger or radiator. Control of the engine temperature is accomplished by thermostat(s) 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 manifold in the cylinder head(s) and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifold and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

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

Engine starting is provided by either a hydraulic or electric starting system. The electric starting motor is 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 or hydraulic type engine governor, depending upon the engine application.

5043-5101

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENTS * (see below)	DESIGN VARIATION	SPECIFIC MODEL NUMBER AND STARTER—BLOWER ARRANGEMENT

APPLICATION DESIGNATION

5042-5100	MARINE
5043-5100	FAN TO F/W—INDUSTRIAL
5044-5100	POWER-BASE
5045-5100	GENERATOR
5047-5100	FAN TO F/W—VEHICLE

DESIGN VARIATION

5043-5000	"N" ENGINE
5043-5100	2 VALVE HEAD
5043-5200	4 VALVE HEAD
5042-2302	TURBOCHARGER

STARTER—BLOWER ARRANGEMENT

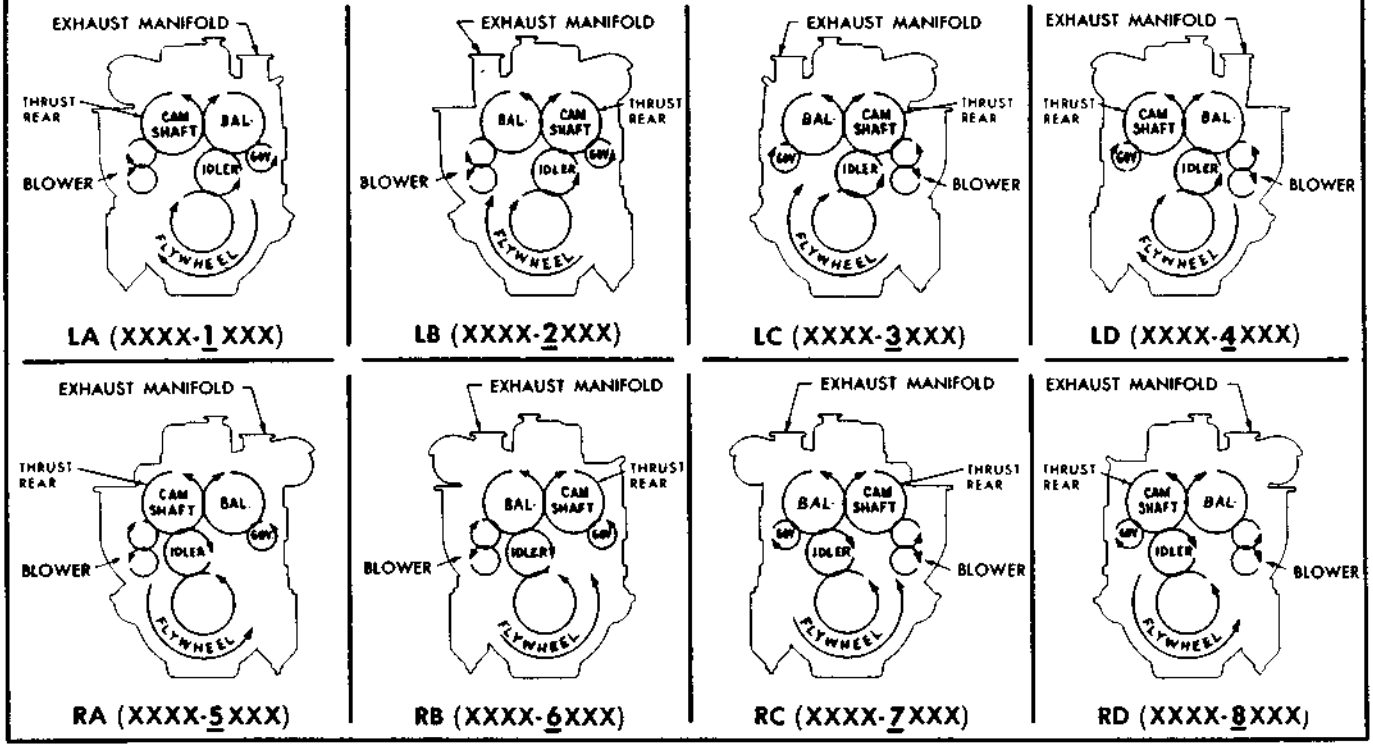
Odd number in last digit designates starter opposite blower.

Even number in last digit designates starter same side as blower.

*** 2, 3, 4-53 BASIC ENGINE ARRANGEMENTS**

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A-B-C-D designates location of exhaust manifold and blower as viewed from the flywheel end of the engine.



ALL ABOVE VIEWS FROM REAR (FLYWHEEL) END OF ENGINE

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Fig. 2 - In-line Engine Model Description, Rotation, and Accessory Arrangements

5 0 6 3 — 5 2 0 0

SERIES 53	NUMBER OF CYLINDERS	APPLICATION DESIGNATION	BASIC ENGINE ARRANGEMENT * (see below)	DESIGN VARIATION	SPECIFIC MODEL NUMBER

APPLICATION DESIGNATION

5062-3000 MARINE
5063-5200 FAN to F/W-INDUSTRIAL
5064-5200 POWER-BASE
5065-5200 GENERATOR
5067-5040 FAN to F/W VEHICLE
5082-5000 MARINE
5083-5000 FAN to F/W INDUSTRIAL
5087-5040 FAN to F/W VEHICLE

DESIGN VARIATION

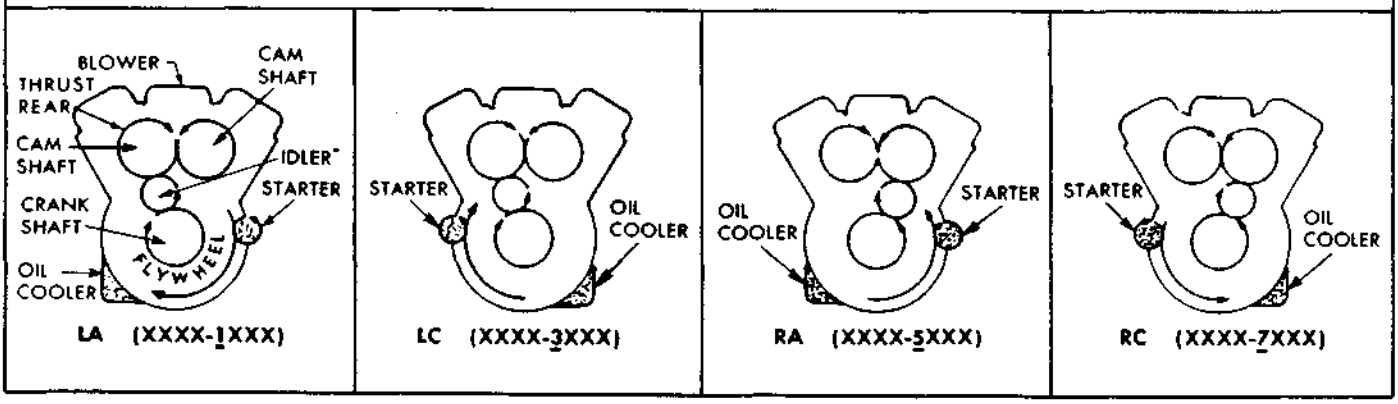
5062-3000 "N" ENGINE
5063-5200 4 VALVE HEAD

* BASIC ENGINE ARRANGEMENTS

Rotation: R-(right) and L-(left) designates rotation as viewed from the end of the engine opposite the flywheel.

Type: A and C designates location of starter and oil cooler as viewed from the flywheel end of the engine.

Cylinder Bank: Left and right cylinder banks are determined from the flywheel end of the engine.



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ALL ABOVE VIEWS FROM REAR FLYWHEEL END OF ENGINE

Fig. 3 - 6 and 8V Engine Model Description, Rotation and Accessory Arrangement

GENERAL SPECIFICATIONS

	2-53	3-53	4-53	6V-53	8V-53N
Type	2 Cycle	2 Cycle	2 Cycle	2 Cycle	2 Cycle
Number of Cylinders	2	3	4	6	8
Bore	3.875 in.	3.875 in.	3.875 in.	3.875 in.	3.875 in.
Stroke	4.5 in.	4.5 in.	4.5 in.	4.5 in.	4.5 in.
Compression Ratio (Nominal) (Standard Engines).	17 to 1	17 to 1	17 to 1	17 to 1	—
Compression Ratio (Nominal) ("N" Engines)	—	21 to 1	21 to 1	21 to 1	21 to 1
Total Displacement - Cubic Inches	106	159	212	318	424
Number of Main Bearings	3	4	5	4	5

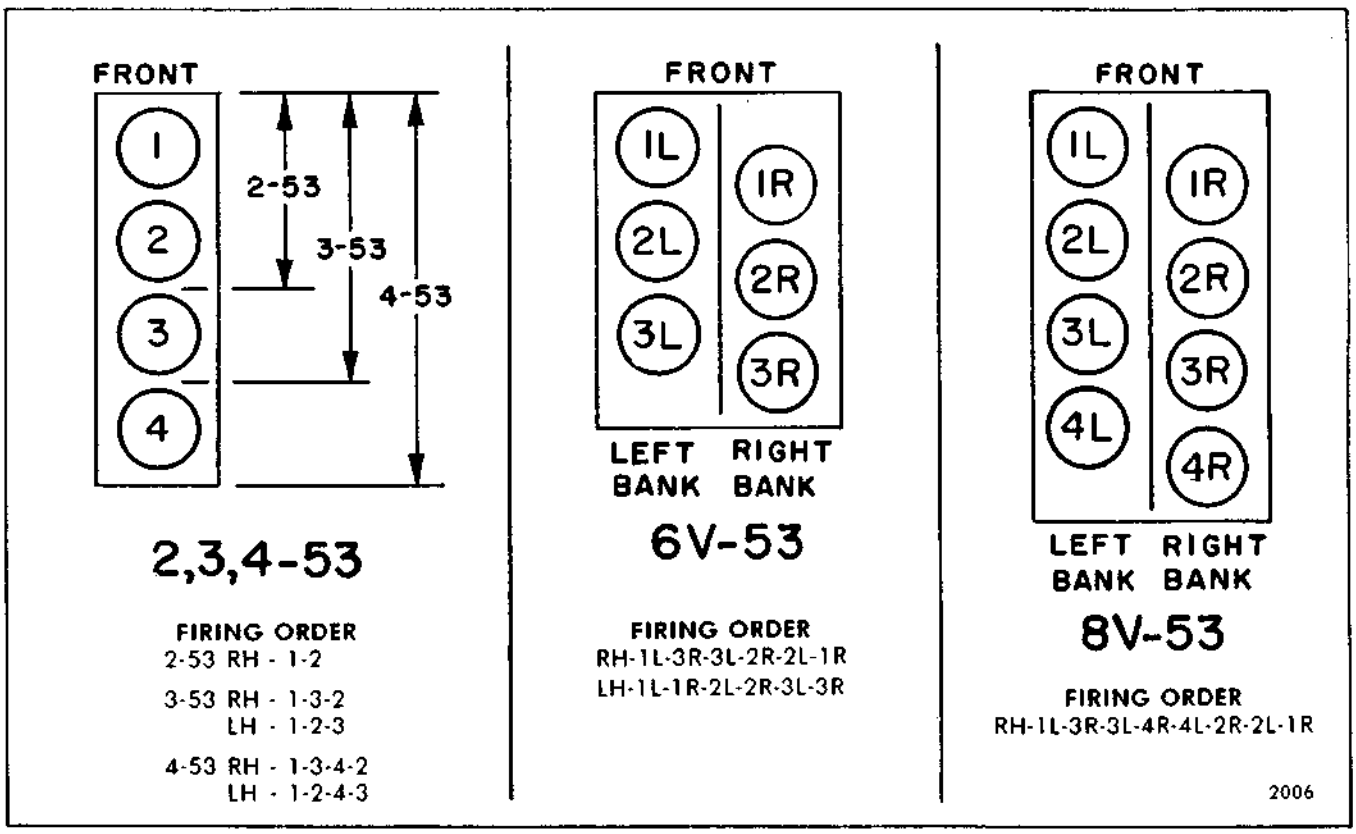


Fig. 4 - Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION PLATE

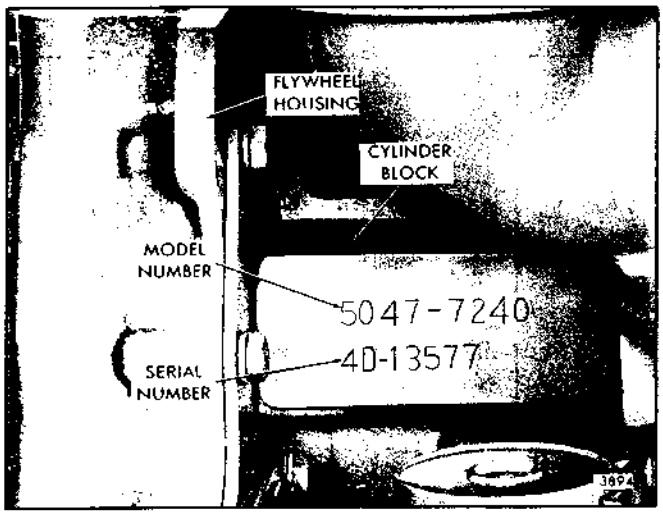


Fig. 5 - Typical Model and Serial Numbers as Stamped on Cylinder Block (In-Line Engine)

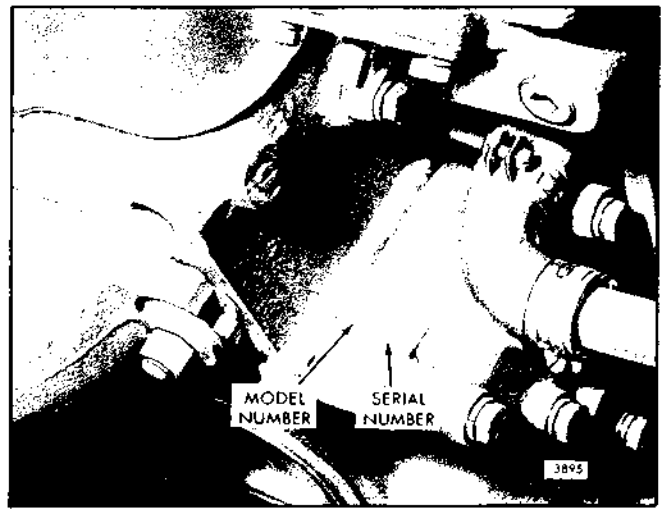


Fig. 6 - Typical Model and Serial Numbers as Stamped on Cylinder Block (6 and 8V Engines)

On the In-line engines, the model number and serial number are stamped on the right-hand side of the cylinder block in the upper rear corner (Fig. 5). The model number and serial number on the V-type engines are located on the top right-hand front corner of the cylinder block, as viewed from the rear of the engine (Fig. 6).

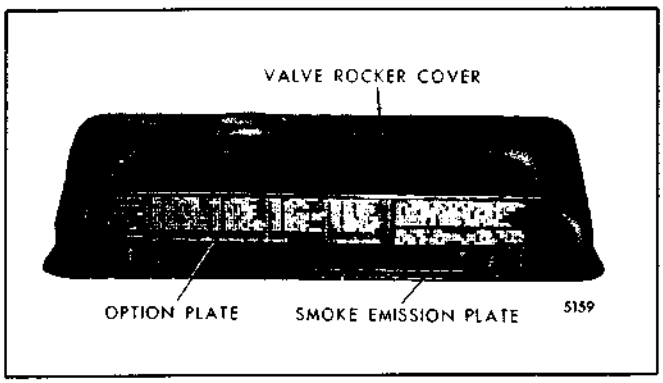


Fig. 7 - Option Plate

An option plate, attached to the valve rocker cover, is also stamped with the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 7). Where required, a smoke emission certification plate is installed next to the option plate.

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

All groups of parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

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

GENERAL PROCEDURES

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

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

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

DISASSEMBLY

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

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, 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 sub-assemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each sub-assembly 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 sub-assemblies.

Solvent Tank Cleaning

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

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

Rinsing Bath

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

Drying

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

Rust Preventive

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

INSPECTION

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

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

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

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

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

ASSEMBLY

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

Use of the proper equipment and tools 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.

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, in the case of vehicle application, by being bumped by another vehicle is minimized.

Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.

2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

3. 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.

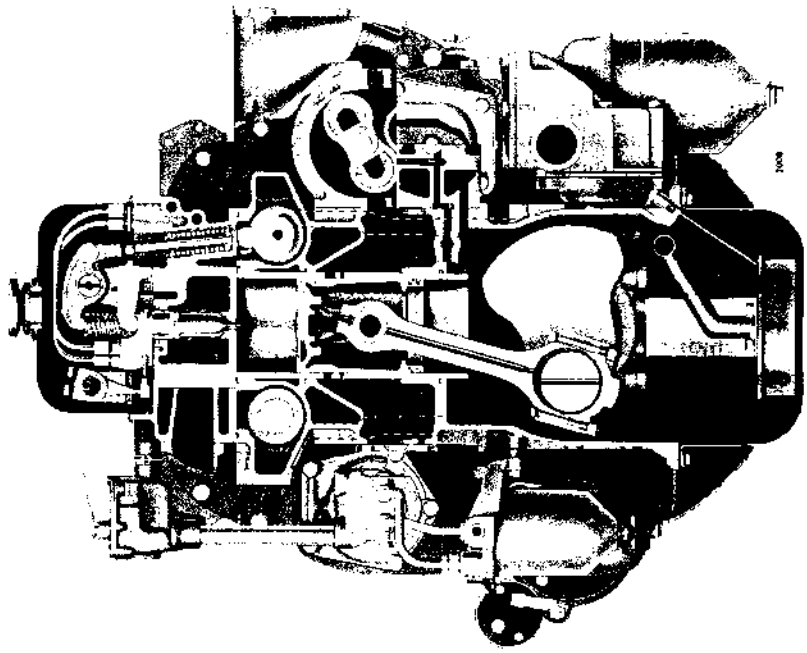
5. Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichlorethylene. However, while less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield, and apron.

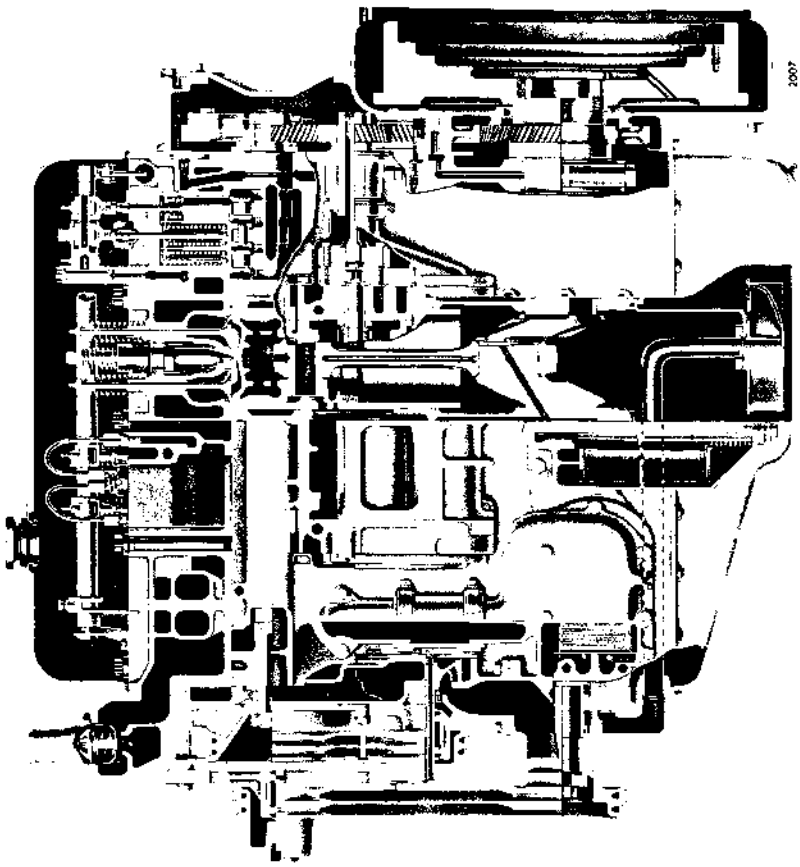
Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

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

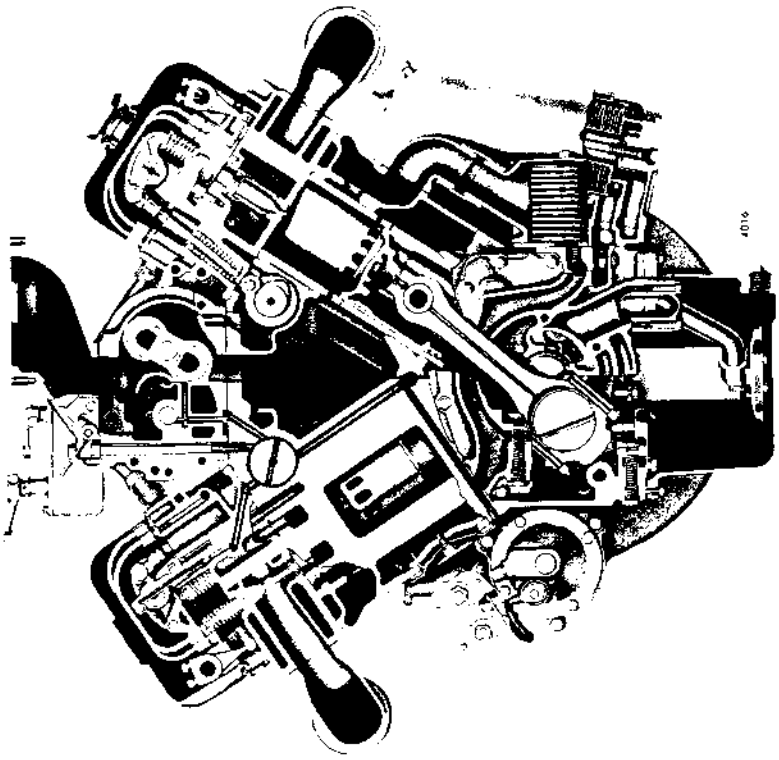
7. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

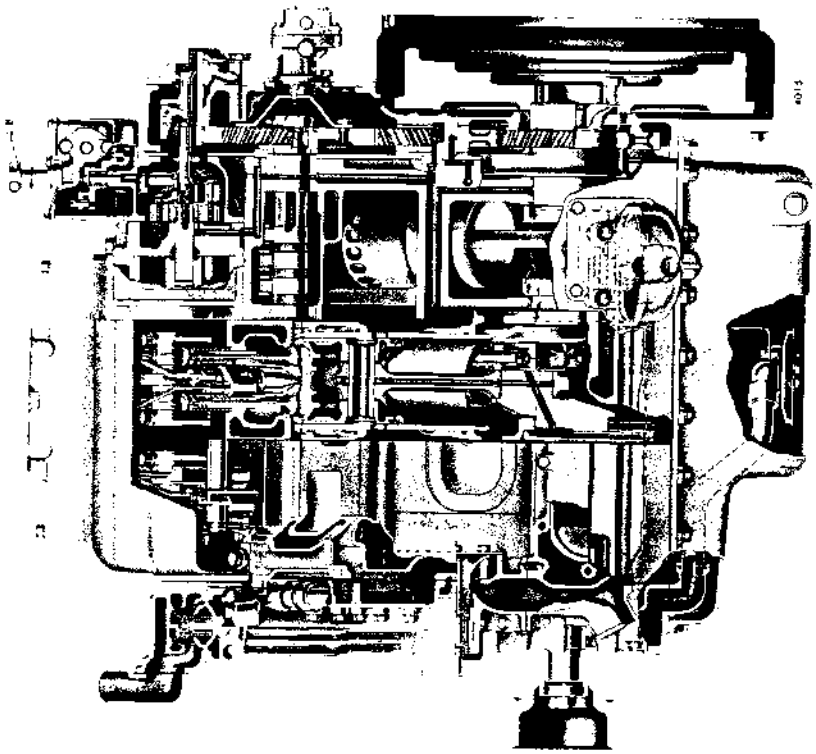
8. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing.



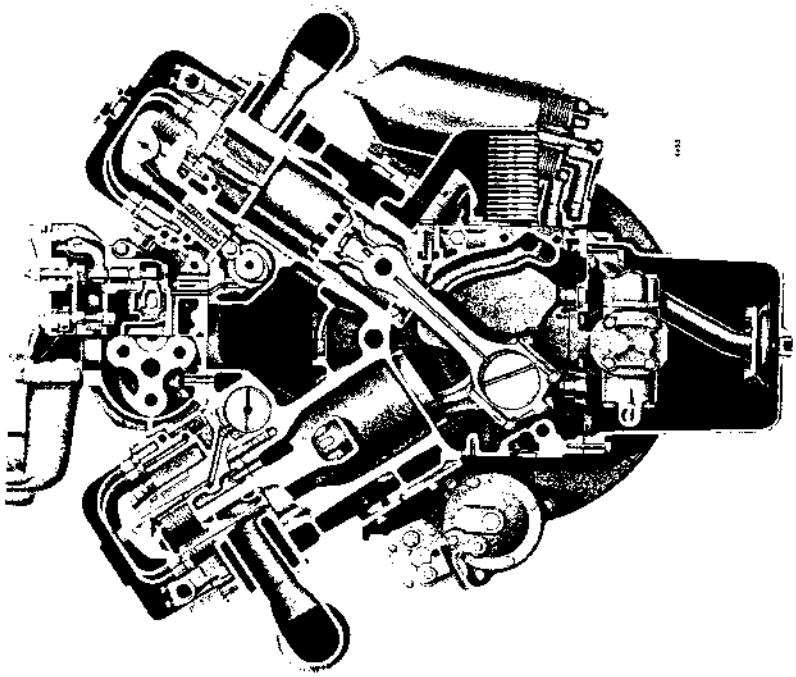


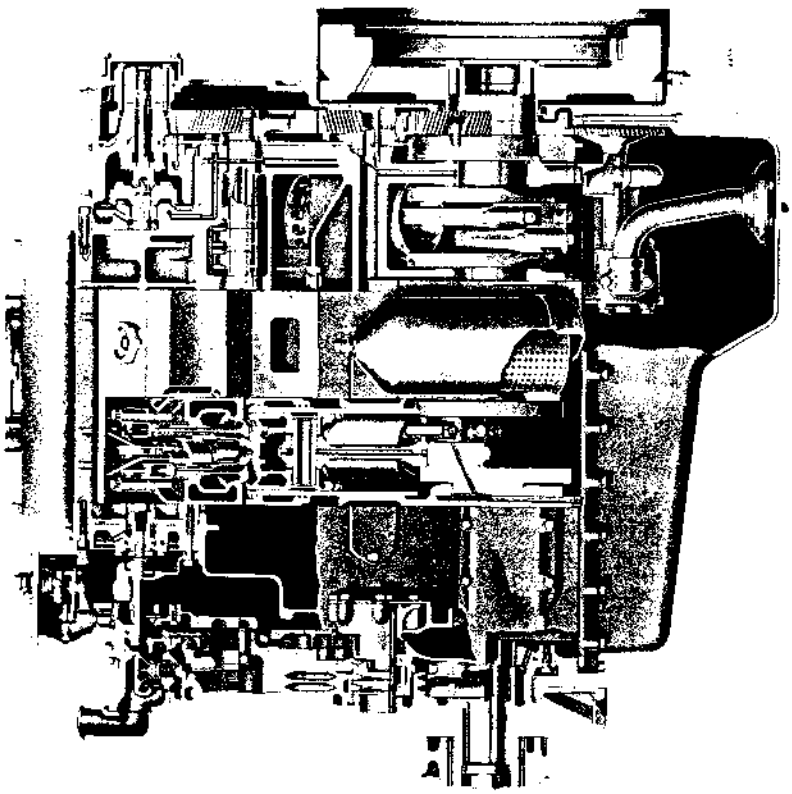
Cross Sections of a Typical In-Line Engine



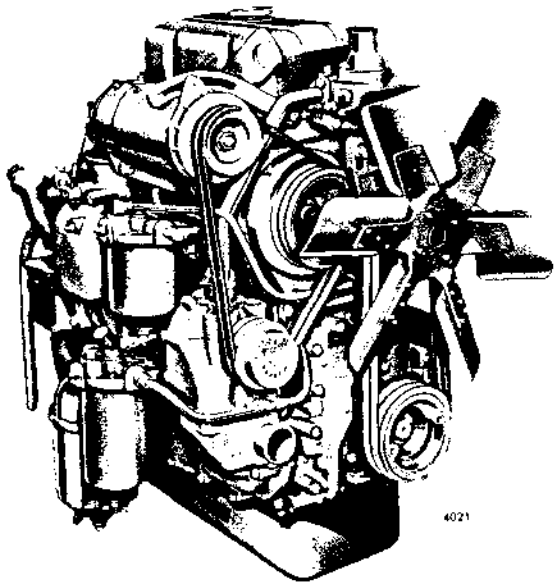


Cross Sections of a 6V-53 Engine

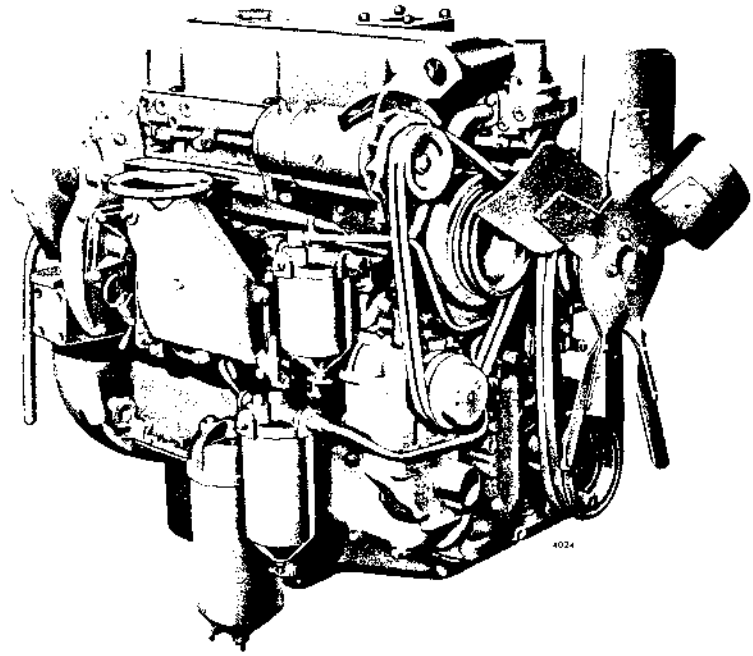




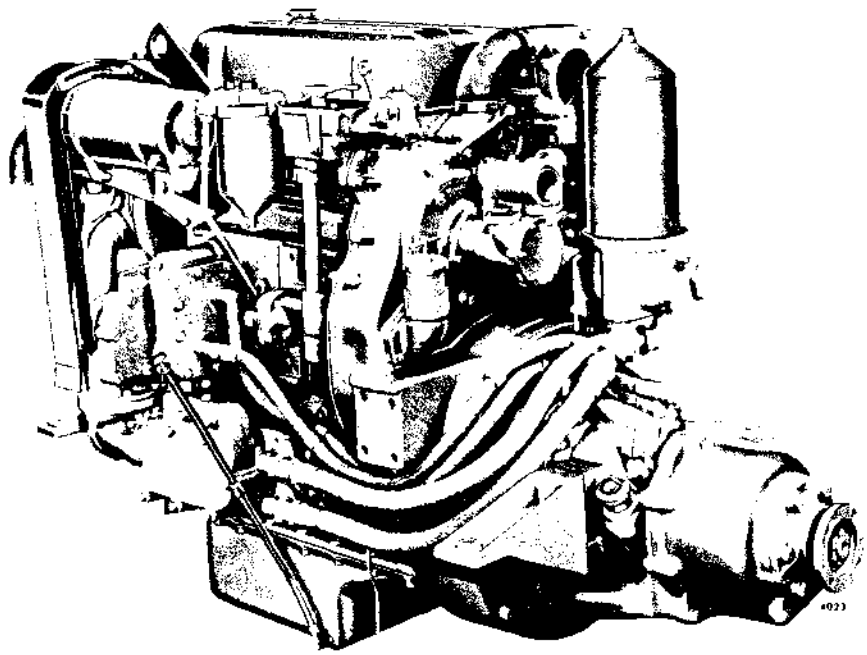
Cross Sections of an 8V-53 Engine



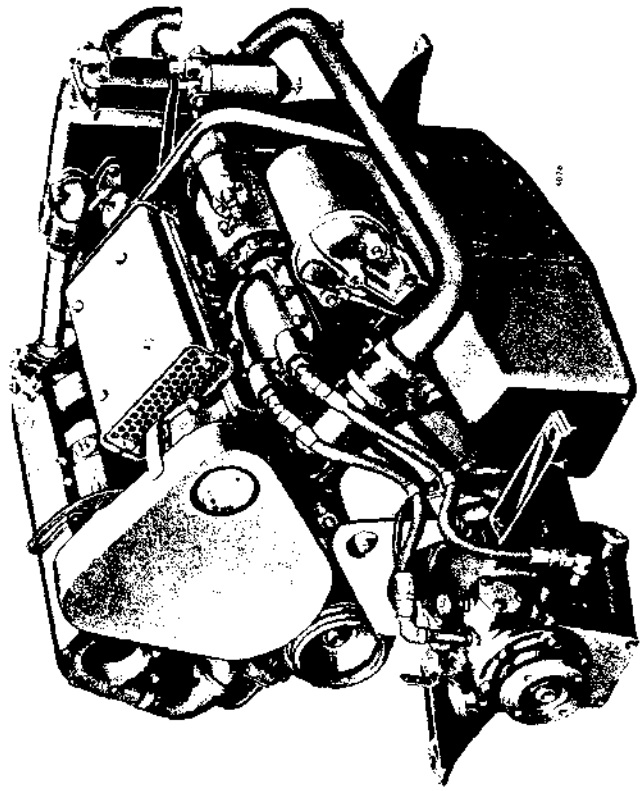
Typical Fan-to-Flywheel Unit (2-53)



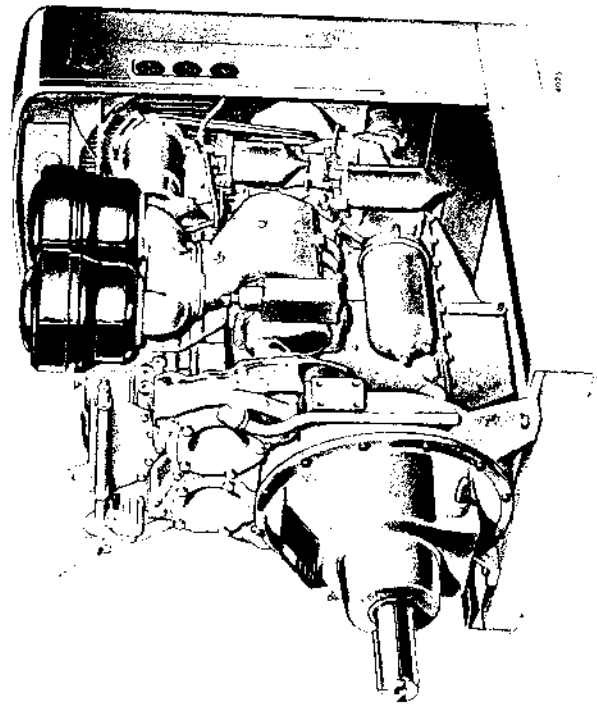
Typical Fan-to-Flywheel Unit (4-53)



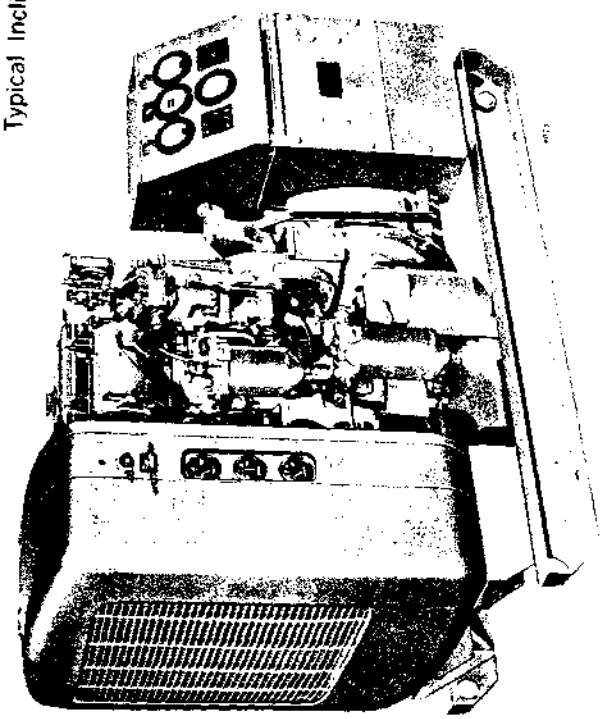
Typical Marine Propulsion Unit (3-53)



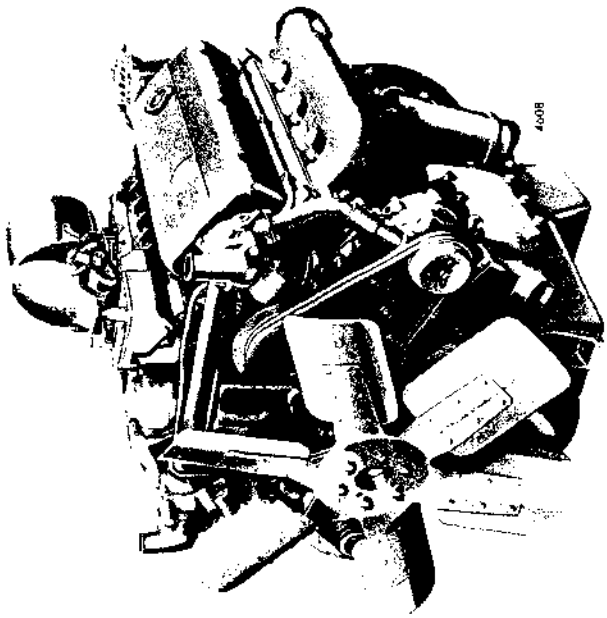
Typical Inclined Marine Propulsion Unit



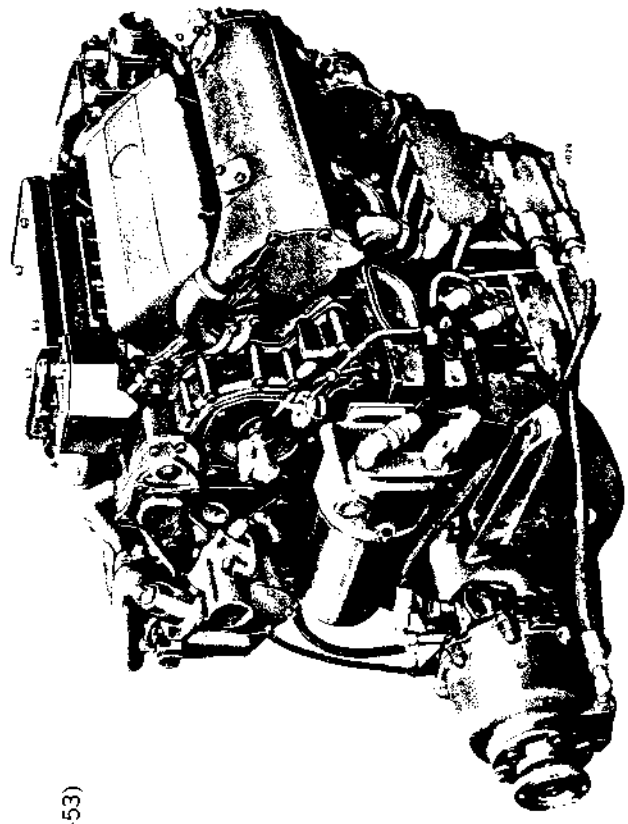
Typical Industrial Power Take-Off Unit



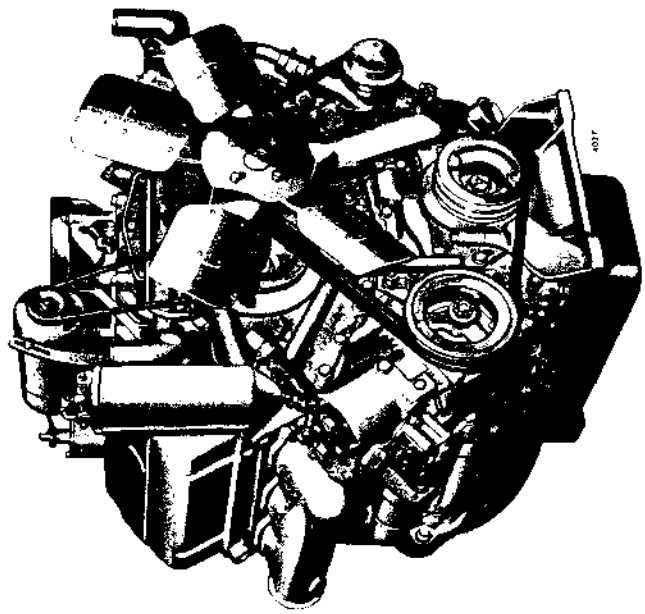
Typical Power Generator Unit



Typical Vehicle Unit (8V-53)



Typical Marine Propulsion Unit (6V-53)



Typical Fan-to-Flywheel Unit (6V-53)

SECTION 1

ENGINE (less major assemblies)

CONTENTS

CYLINDER BLOCK

The cylinder block (Figs. 1 and 2) 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. Cylinder blocks for the two, three and four cylinder In-Line engines are identical in design and dimensions except for length.

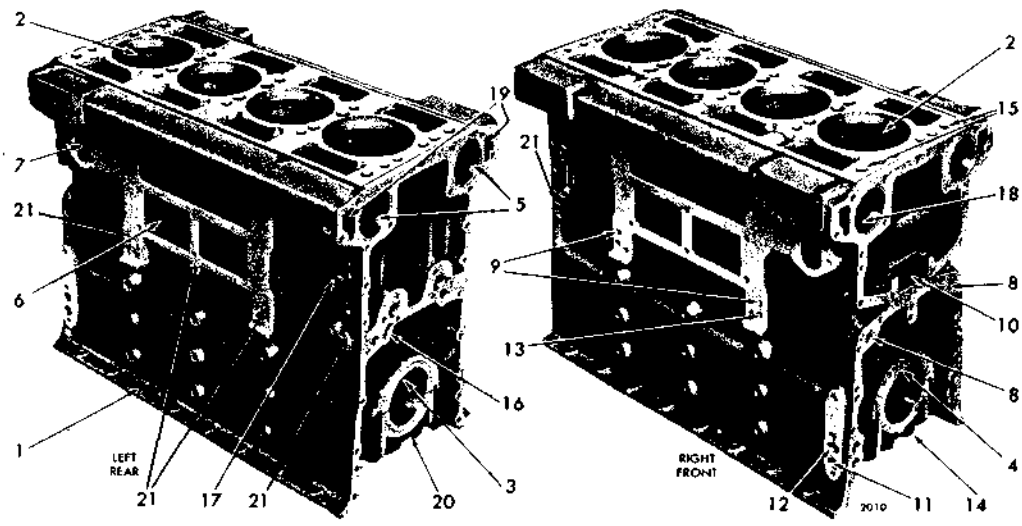
The block is bored to receive replaceable wet-type cylinder liners. On the In-Line and 6V cast iron cylinder blocks, a water jacket surrounds the upper half of each cylinder liner. On the 6V aluminum and the 8V cast iron cylinder blocks, a water jacket also surrounds the lower half of each cylinder liner. The water jacket and air box are sealed off by a seal ring compressed between the liner and a groove in the block (Figs. 3, 4 and 5).

An air box surrounding the lower half of the cylinder liners conducts the air from the blower to the air inlet ports in the cylinder liners. An opening in the side of the block opposite the blower on the In-Line engines and air box openings in both sides of the block on the V-type engines provide access to the air box and permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners.

The camshaft and balance shaft bores are located on opposite sides near the top of the In-Line engine block. On the V-type engine, the camshaft bores are located on the inner side of each cylinder bank near the top of the block.

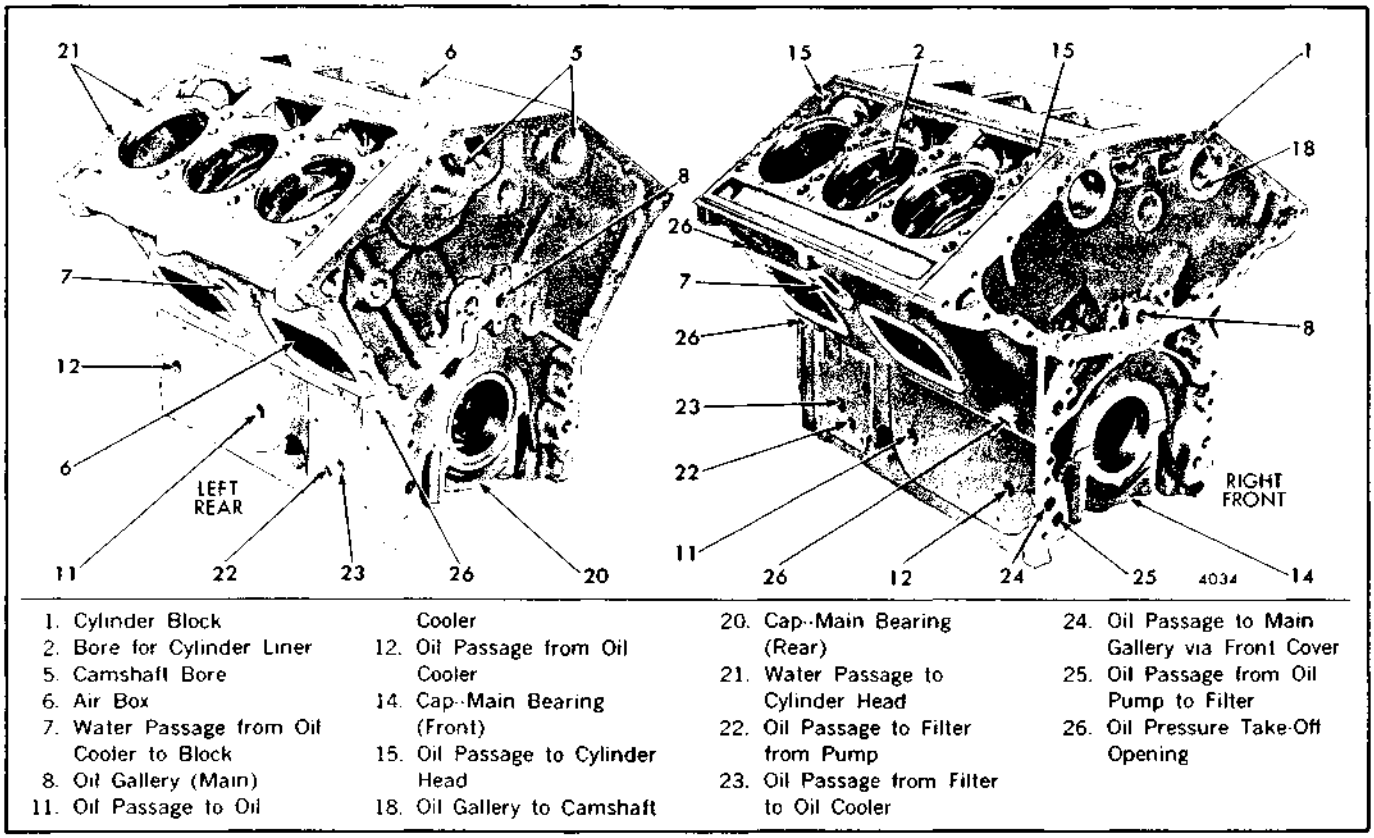
The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external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

The top surface of the In-Line block and each cylinder bank of the V-block 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 (Fig. 6). In addition, the V-type engine block is grooved around the air inlet opening, between the cylinder banks, to accommodate a blower-to-block seal ring.



1. Cylinder Block
2. Bore for Cylinder Liner
3. Support--Upper Main Bearing (Rear)
4. Support--Upper Main Bearing (Front)
5. Bore--Cam or Balance Shaft
6. Air Box
7. Water Passage from Oil Cooler to Block
8. Oil Gallery (Main)
9. Oil Gallery (to Blower)
10. Oil Drain from Front Cover
11. Oil Passage to Oil Cooler
12. Oil Passage from Oil Cooler
13. Oil Drain from Blower
14. Cap--Main Bearing (Front)
15. Oil Passage to Cylinder Head (from Camshaft)
16. Oil Passage (Idler Gear Bearing)
17. Water Drain
18. Oil Gallery to Camshaft or Balance Shaft
19. Oil Drain from Cylinder Head
20. Cap--Main Bearing (Rear)
21. Oil Pressure Take-Off Opening

Fig. 1 - Cylinder Block (Four Cylinder Block Shown)



1. Cylinder Block
2. Bore for Cylinder Liner
5. Camshaft Bore
6. Air Box
7. Water Passage from Oil Cooler to Block
8. Oil Gallery (Main)
11. Oil Passage to Oil Cooler
12. Oil Passage from Oil Cooler
14. Cap--Main Bearing (Front)
15. Oil Passage to Cylinder Head
18. Oil Gallery to Camshaft
20. Cap--Main Bearing (Rear)
21. Water Passage to Cylinder Head
22. Oil Passage to Filter from Pump
23. Oil Passage from Filter to Oil Cooler
24. Oil Passage to Main Gallery via Front Cover
25. Oil Passage from Oil Pump to Filter
26. Oil Pressure Take-Off Opening

Fig. 2 - Cylinder Block (6V Cast Iron Cylinder Block Shown)

Each cylinder liner is retained in the block by a flange at its upper end, which seats in the counterbore in the block bore. An individual compression gasket is used at each cylinder.

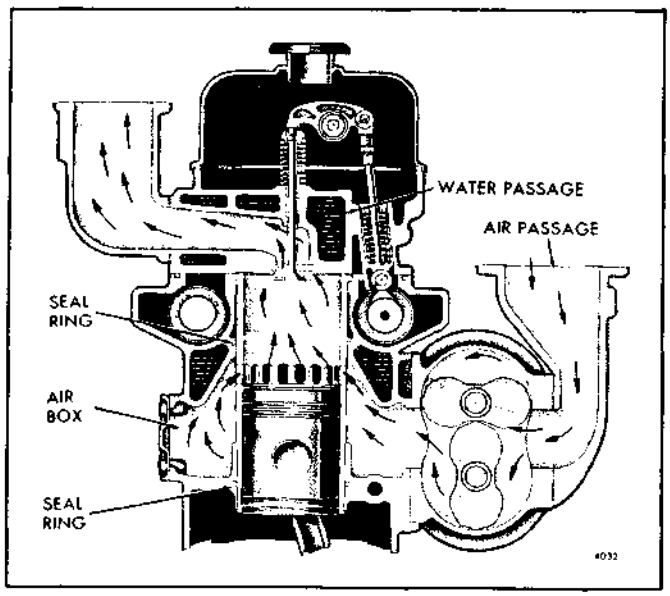


Fig. 3 - Air and Water Passages in In-Line Cylinder Block

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

The In-Line cylinder blocks were revised at the idler gear hub mounting pads, to increase the rigidity of the flywheel housing, by increasing two of the three 5/16 " - 18 bolt holes of each mounting pad to 3/8 " - 16 bolt holes (Fig. 7). The 3/8 " - 16 bolt holes were incorporated in engines beginning with serial numbers 2D-903, 3D-011 and 4D-103. Revised end plates, end plate-to-block gaskets and flywheel housing are required with the change in bolt sizes. Only the revised cylinder blocks are available for service.

The In-Line cylinder blocks have also been revised to improve the breathing characteristics and increase the flow of the lubricating oil returning from the cylinder head to the engine oil sump by the addition of two vertical oil passages directly under the camshaft and balance shaft at the front end of the cylinder block (Fig. 8). Cylinder blocks with the vertical oil passages

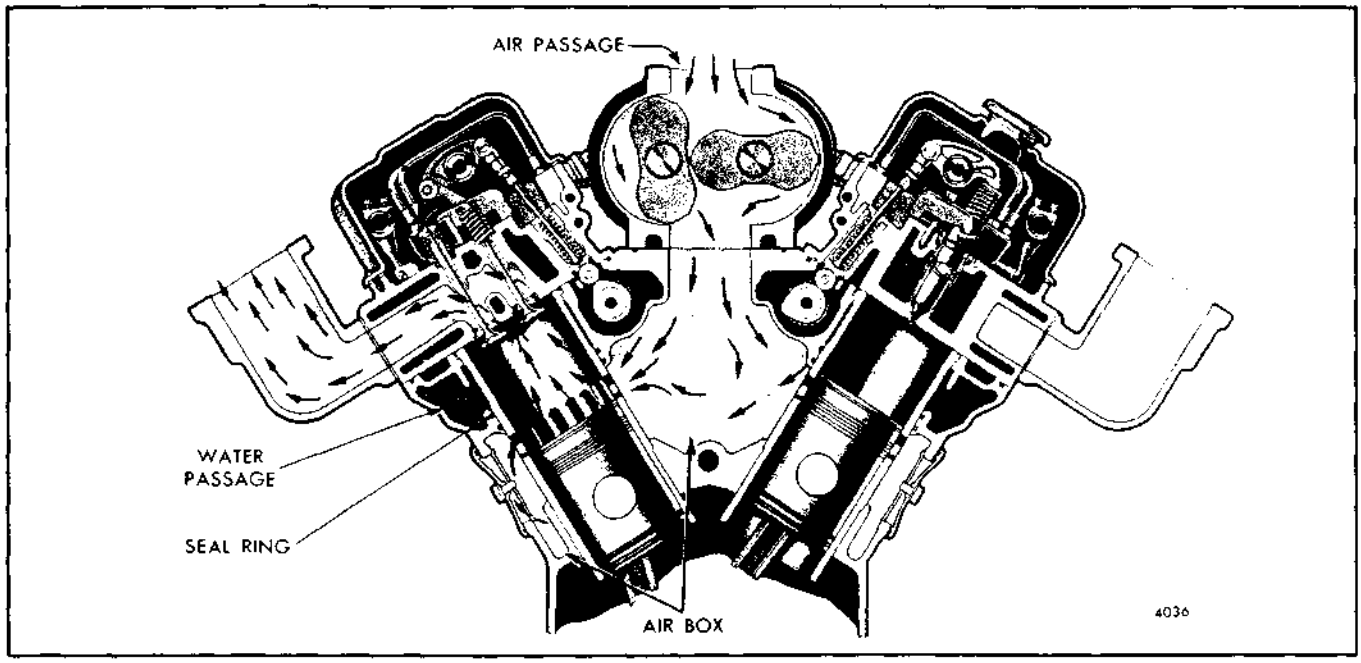


Fig. 4 - Air and Water Passages in 6V Cast Iron Cylinder Block

were used in engines beginning with serial numbers 2D-4010, 3D-117 and 4D-348.

The 8V cylinder block has been revised, effective with engine serial number 8D-2304, to provide improved scavenging and crankcase breathing by the addition of oil drains at the front corners of the cylinder block. The current 8V service cylinder block now incorporates an oil drain at each corner of the block.

New service replacement cylinder block assemblies include the main bearing caps, bolts and washers and the camshaft bearings (bushings). The dowels and the necessary plugs are also included.

Since the cylinder block is the main structural part of the engine, the various sub-assemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand (Fig. 9) 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 its base and disconnected from the transmission or other driven mechanism. 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 silencer or air cleaner and mounting bracket.

5. Remove the turbocharger, if used.

6. Remove the blower on In-Line engines.

7. Disconnect the exhaust piping and remove the exhaust manifold(s).

8. Disconnect the throttle controls.

9. Disconnect and remove the starting motor, battery-charging generator and other electrical equipment.

10. Remove the air compressor, if used.

11. Remove the radiator and fan guard or the heat exchanger and other related cooling system parts.

12. Remove the air box drain tubes and fittings.

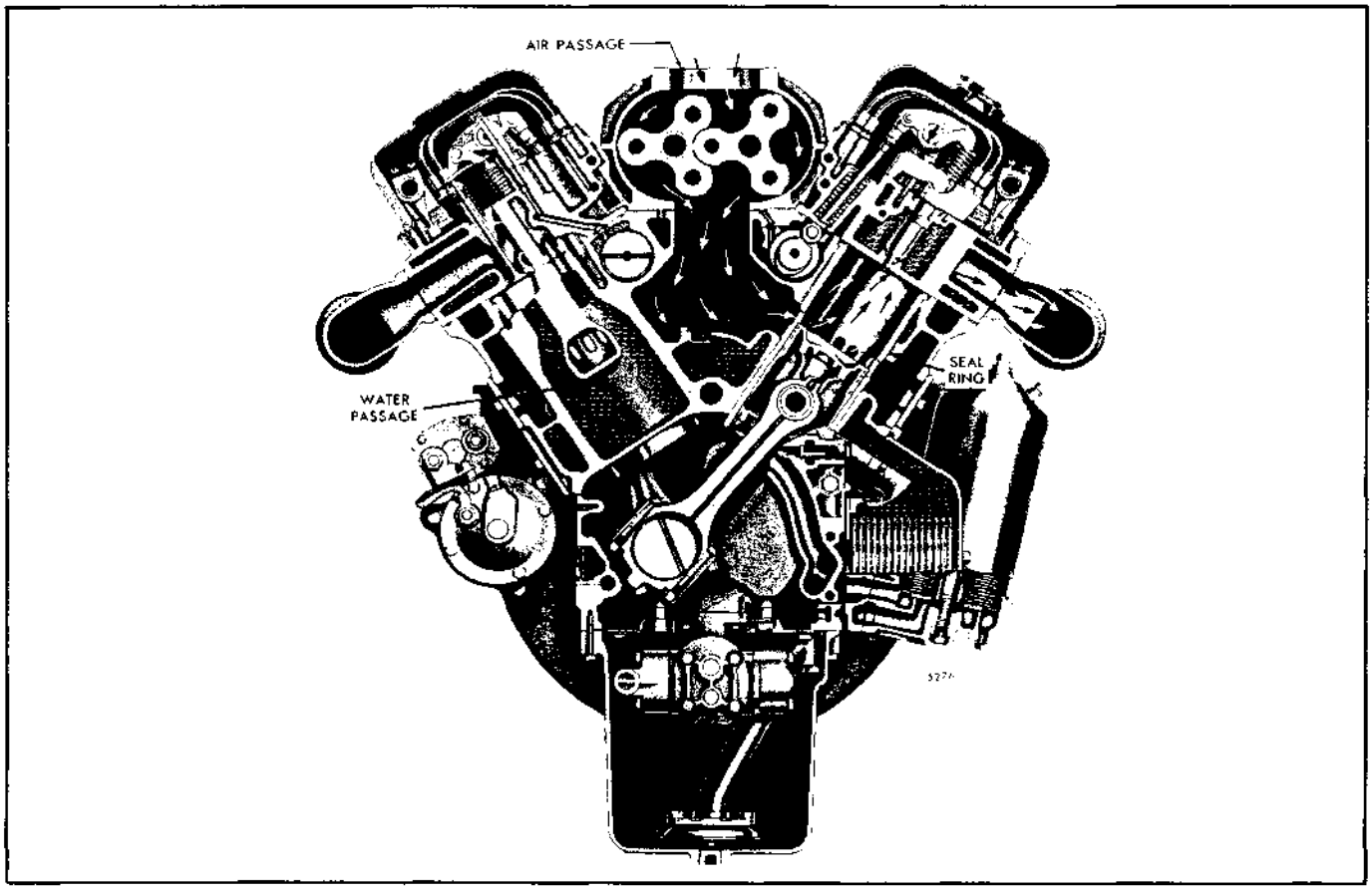


Fig. 5 - Air and Water Passages in 8V Cylinder Block

13. Remove the air box covers.

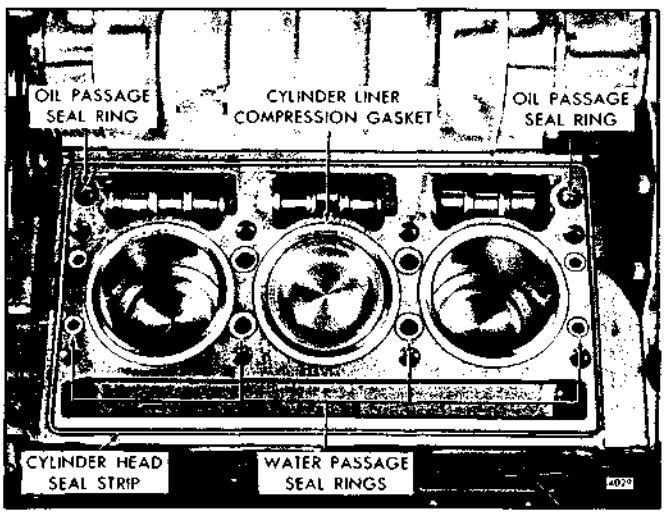


Fig. 6 - Cylinder Head Gaskets and Seals in Place on Cylinder Block

14. Disconnect any other lubricating oil lines, fuel lines or electrical connections.

15. Separate the engine from the transmission or other driven mechanism.

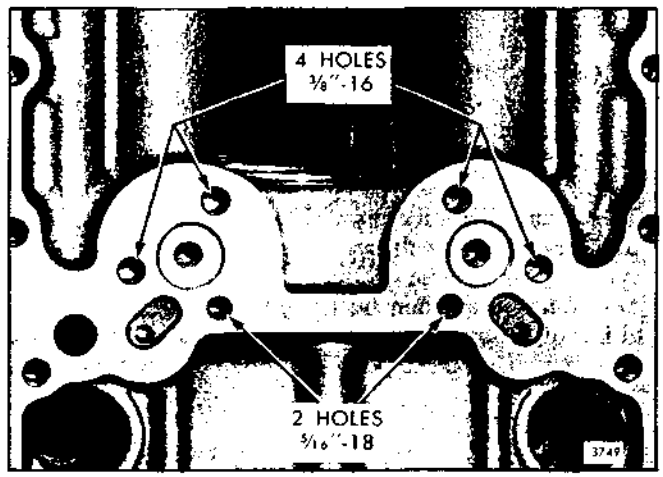


Fig. 7 - Location of the Four 3/8-16 Bolt Holes in Rear of Cylinder Block

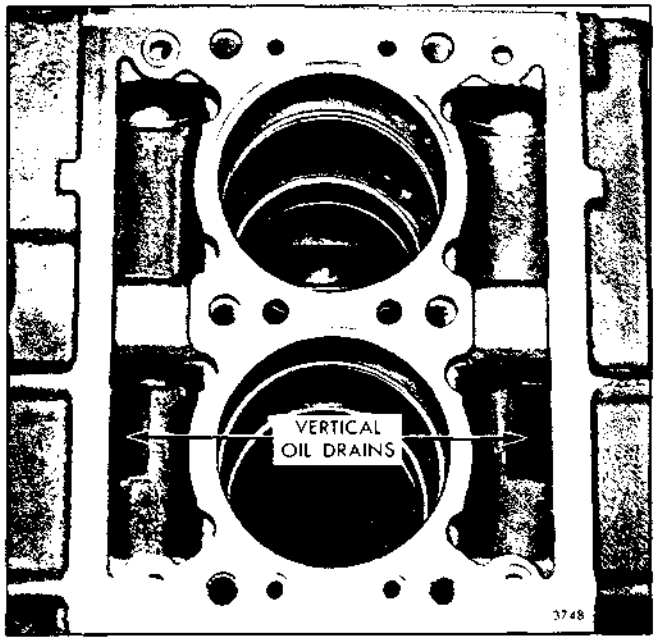


Fig. 8 - Vertical Oil Passages in Top of Cylinder Block

16. Remove the engine mounting bolts.

17. Use a chain hoist and suitable sling attached to the engine lifting brackets to lift the engine.

CAUTION: Do not lift a V-type engine by the webs in the air inlet opening at the top of the cylinder block.

18. Place the side of the cylinder block against the adaptor plate on the overhaul stand (Fig. 9). Use adaptor plate J 7622 (In-Line engine), J 8683 (6V engine) or J 21966 (8V engine) with overhaul stand J 6837-01.

19. Align the bolt holes in the adaptor plate with the holes in the cylinder block. Then install the 3/8 "-16 and 5/16 "-18 bolts, with a flat washer under the head of each bolt, and tighten them securely.

CAUTION: 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.

20. With the engine mounted on the overhaul stand, remove all of the remaining sub-assemblies and parts from the cylinder block.

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

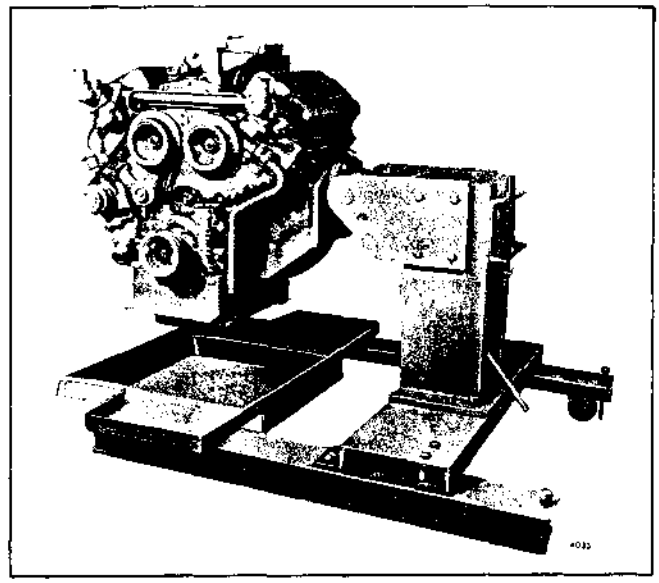


Fig. 9 - Engine Mounted on Overhaul Stand

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

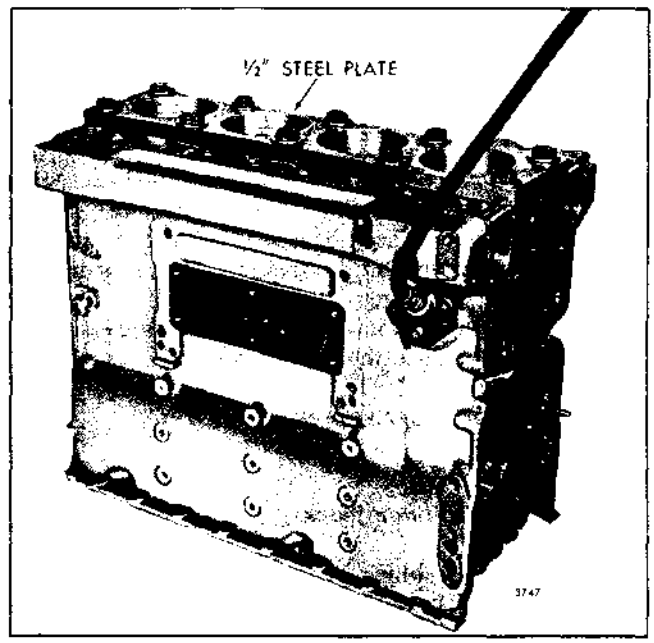


Fig. 10 - Cylinder Block Prepared for Pressure Test

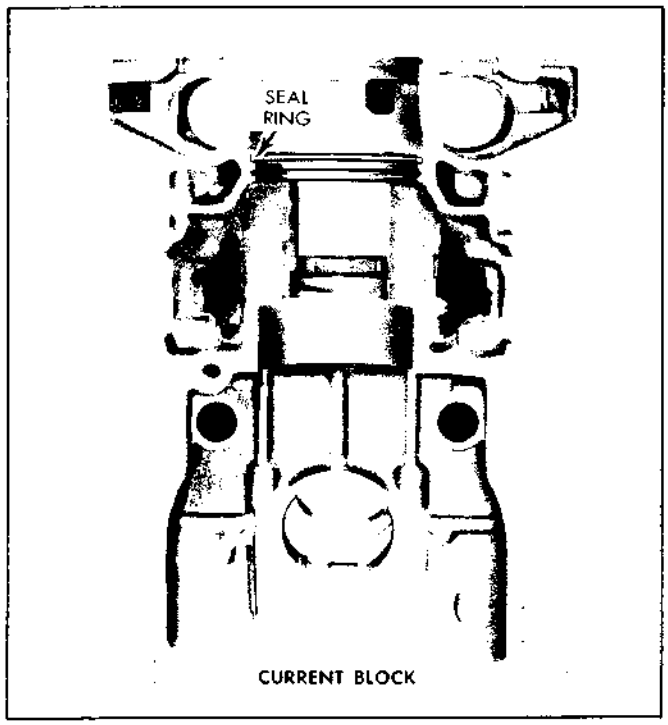


Fig. 11 - Location of Block Bore Seal Ring Groove

Clean Cylinder Block

1. Remove all of the plugs (except cup plugs) and scrape all old gasket material from the block.

2. Clean the block with live steam. Make sure the oil galleries, air box floor and air box drain openings are thoroughly cleaned. On former engines, jets machined in the camshaft and balance shaft bores (In-Line engines) and the camshaft bushing bores (6V engines) permit oil to be sprayed on the cam followers. Make sure they are not plugged. A .020 " wire may be used to clean the jets. Jets are not machined in the camshaft and balance shaft bushing bores in the current In-Line and 6V cylinder blocks. Oil is directed to the cam followers through small slots incorporated in the camshaft and balance shaft bearings.

3. Dry the block with compressed air.

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. In either method, it will be necessary to make a steel plate of 1/2 " stock to cover each cylinder bank of the block (Fig. 10). The plate(s) will adequately seal the top surface of the block when used with cylinder liner compression gaskets and water hole

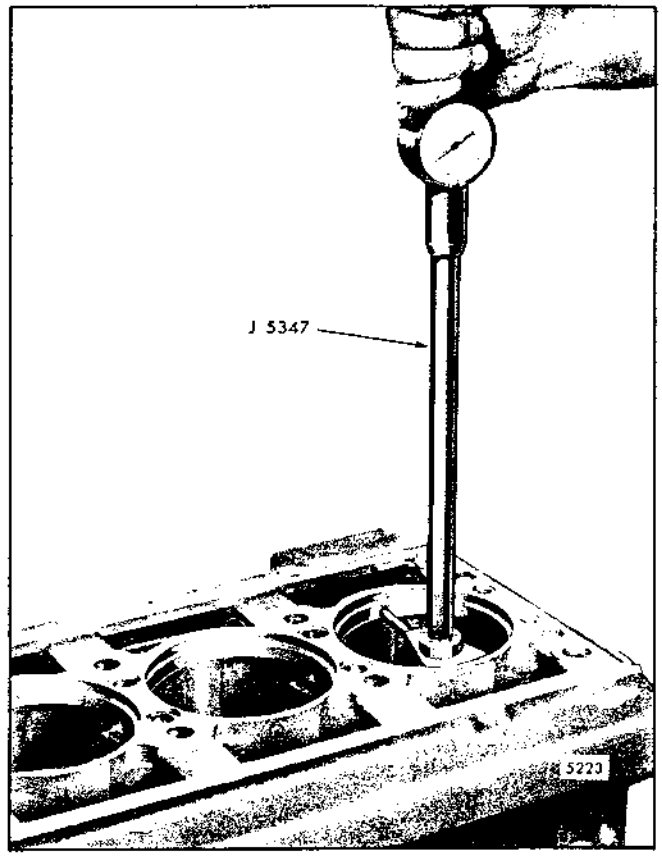


Fig. 12 - Checking Cylinder Block Bore with Tool J 5347

seal rings. It will also be necessary to use water hole cover plates and gaskets to seal the water inlet openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line so the water jacket can be pressurized.

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. Make sure the seal ring grooves in the cylinder bores of the block are clean. Then install new seal rings in the grooves (above the air inlet ports).

> **NOTE:** The current blocks have two seal ring grooves above the air inlet ports of each cylinder bore. Only one seal ring is required, however. Install the seal ring in the upper groove, if it is in good condition; if the upper groove is pitted or eroded, install the seal ring in the lower groove.

2. Apply a light coating of hydrogenated vegetable

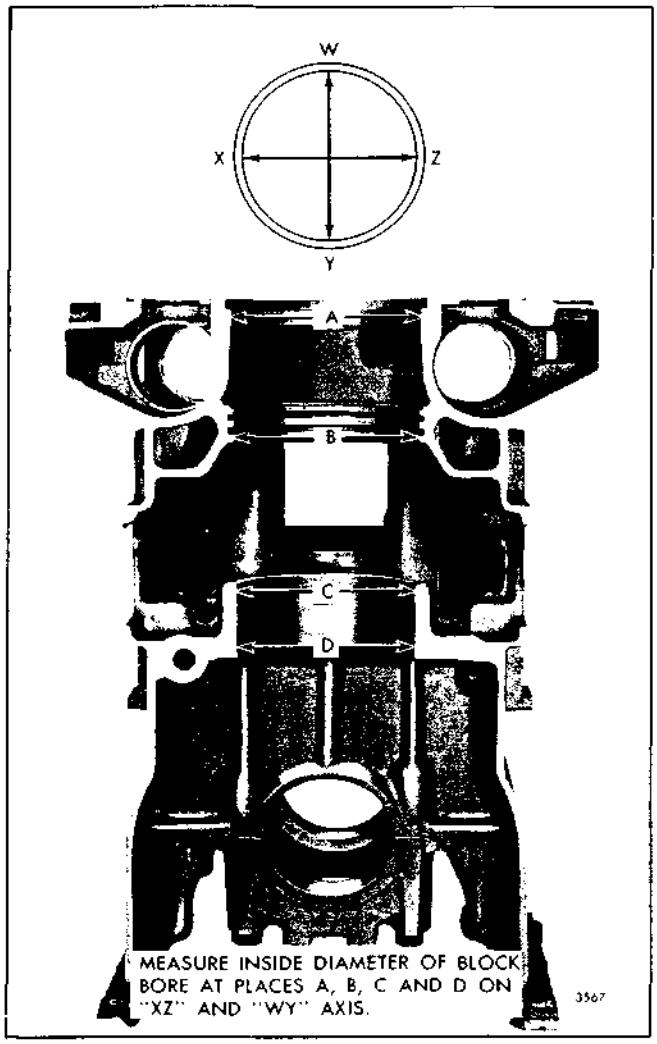


Fig. 13 - Block Bore Measurement Diagram

type shortening or permanent type antifreeze solution to the seal rings.

3. Slide the cylinder liners into the block, being careful not to roll or damage the seal rings. Install new compression gaskets and water hole seal rings in the counterbores in the top surface of the block.

4. Secure the plate(s) on the top of the block with 5/8 "-11 bolts and flat washers.

5. Install the water hole cover plates and gaskets on the sides of the block.

6. Immerse the cylinder block for twenty minutes in a tank of water heated to 180 ° - 200 ° F.

7. Attach an air line to the water hole cover plate and apply 60 psi air pressure to the water jackets and observe the water in the tank for bubbles which will

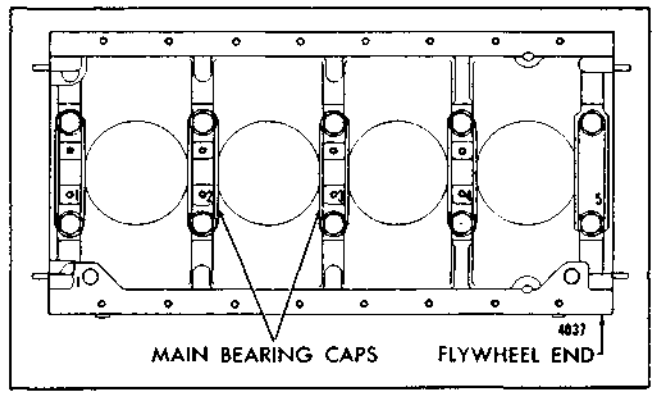


Fig. 14 - Typical Cylinder Block Markings

indicate cracks or leaks. A cracked cylinder block must be replaced by a new block.

8. Remove the block from the water tank. Then remove the plates, seals, gaskets and liners and blow out all of the passages in the block with compressed air.

9. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

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 equipment which it powers. However, it is necessary to remove the cylinder head(s), blower, oil cooler, air box covers and oil pan.

1. Prepare the block as outlined in Method "A". However, before installing the large sealing plate, fill the water jacket with a mixture of water and one gallon of permanent type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.

2. Install the plate(s) and water hole covers as outlined in Method "A".

3. Apply 60 psi 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 this 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.

5. After the pressure test is completed, remove the

plates and drain the water jacket. Then remove the liners and seal rings and blow out all of the passages in the block with compressed air.

6. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

1. Check the block bores as follows:

a. Make sure the seal ring grooves (Fig. 11) are thoroughly clean. Then inspect the grooves and lands for evidence of pitting and erosion. Two grooves are provided above the air inlet ports of each cylinder bore in the current block. The single groove formerly below the air inlet ports has been eliminated. However, a cylinder liner seal ring is required in the upper groove only. The lower groove (on the current block) is provided for the seal ring if inspection reveals extensive pitting or erosion along the upper land or inner surface of the upper groove. If both grooves are eroded to the extent that sealing is affected, then the block must be replaced.

b. Measure the entire bore of each cylinder with cylinder bore gage J 5347 (Fig. 12) which has a dial indicator calibrated in .0001 " increments. Use dial bore gage setting tool J 23059 to preset the cylinder bore gage to zero. Measure each block bore at the positions indicated in Fig. 13, on axis 90 ° apart. If the diameter does not exceed 4.5235 " at position "A", 4.4900 " at position "B" (and a sealing problem hasn't occured), or 4.3595 " at position "C" and "D", then the block may be reused. Also, the taper and out of round must not exceed .0015 ".

2. Check the top of the block for flatness with an accurate straight edge and a feeler gage. The top surface must not vary more than .003 " transversely and not over .005 " (2-53 engine), .006 " (3-53 or 6V engine) or .007 " (4-53 or 8V engine) longitudinally.

3. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth. The depth must be .300 " to .302 " 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 counterbores, when measured along the cylinder longitudinal centerline of the cylinder block.

4. Check the main bearing bores as follows:

a. Check the bore diameters with the main bearing caps in their original positions. Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Then install and tighten the bolts to the specified torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 3.251 " to 3.252 " (In-Line engine) or 3.751 " to 3.752 " (V-type engine). If the bores do not fall within these limits, the cylinder block must be rejected.

CAUTION: Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. Effective with engine serial numbers 6D-27030 and 8D-1155, a new hexagon head bolt and hardened steel washer are being used in place of the former 12-point flange type main bearing cap bolt.

NOTE: 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. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 14).

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

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. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened to the specified torque. If a main bearing bore is more

than .001 " out of alignment, the block must be line-bored 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 or a replacement bearing cap is used, the block must be line-bored. Install the bearing caps in their original positions (without the bearing cap stabilizers) and tighten the bolts to the specified torque (Section 1.0). Line-bore the block, but do not remove more than .001 " stock. After boring, all bores must be within the specified limits of 3.251 " to 3.252 " (In-Line block) or 3.751 " to 3.752 " (V-type block).

5. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .680 " from the cylinder block face.

The dowels used to retain the crankshaft thrust washers in the cylinder block and on the rear main bearing cap must extend .107 " to .117 " from the surface of the block or bearing cap.

6. Check all of the machined surfaces and threaded holes in the block. Remove nicks and burrs from the machined surfaces with a file. Clean-up damaged threads in tapped holes with a tap or install helical thread inserts.

7. 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 block on the overhaul stand.

2. If a new service replacement block is used, stamp the engine serial number and model number on the upper rear corner of the In-Line block or the top right-hand corner of the V-type block. Also stamp the position numbers on the main bearing caps (Fig. 14) and the position of the No. 1 bearing on the oil pan mounting flange of the block.

3. Install all of the required plugs and drain cocks. Use a good grade of sealing compound on the threads of the plugs and drain cocks. If a new service replacement block is used, make sure the top surface is plugged correctly to prevent low oil pressure or the accumulation of abnormal quantities of oil in the cylinder head.

4. Clean and inspect all of the engine parts and sub-assemblies 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 sub-assemblies are outlined in the following sections of this manual.

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

6. Install the air box covers and tighten the bolts. On In-Line engines, tighten the bolts to 12-16 lb-ft torque. On 6V engines when 1/4 " thick air box cover clamps are used, tighten the bolts to 8-10 lb-ft torque and when 3/8 " thick clamps are used, tighten the bolts to 10-15 lb-ft torque. On 8V engines, tighten the bolts to 13-17 lb-ft torque.

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 the RUN-IN procedure outlined in Section 13.2.1.

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

CYLINDER BLOCK END PLATES

A flat steel plate is bolted to the rear end of the cylinder block to provide a means of attaching the flywheel housing. At the time of a complete engine overhaul or of a cylinder block change, the cylinder block rear end plate must be removed and subsequently reinstalled.

Inspection

When the 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 end plate cleaned as outlined under *Clean Cylinder Block* in Section 1.1.

Check the surfaces of the end plate for nicks, dents, scratches or score marks; also make sure it is flat. Check the plug nuts in the end plate for cracks and damaged threads. If nicks or scratches on the sealing surfaces of the end plate are too deep to be cleaned up, or the plug nuts are damaged, replace the end plate 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.

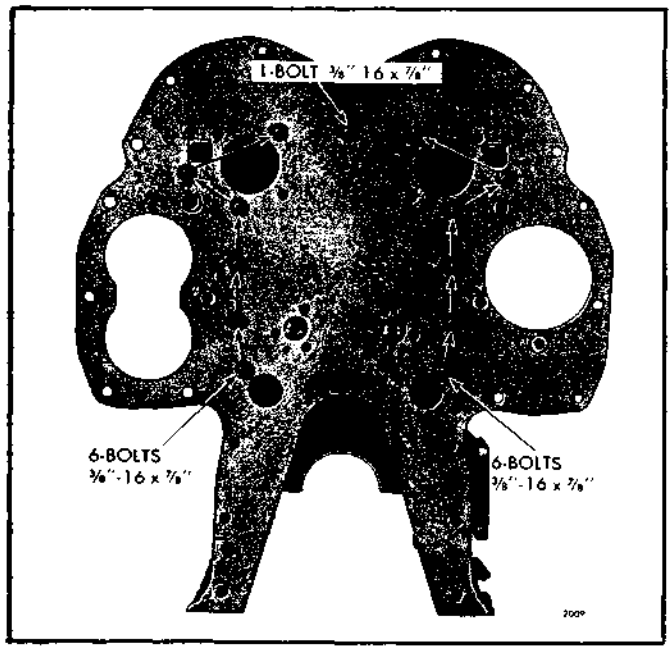


Fig. 1 - Cylinder Block Rear End Plate Mounting (In-Line Engine)

Install Cylinder Block Rear End Plate

1. Affix a new gasket to the end of the cylinder block (flywheel end), using a non-hardening gasket cement; also apply an even coating of gasket cement to the outer surface of the gasket next to the end plate.

On an 8V engine, a cylinder block to end plate (center) gasket is also used. Affix this gasket to the block over the idler gear hub mounting bolt holes.

NOTE: Remove the perforated sections from the current end plate gasket before installing the gasket on an engine built prior to 6D-6211.

2. Align the dowel pin holes in the end plate with the dowel pins in the cylinder block. Then start the end plate over the dowel pins and push it up against the cylinder block.

NOTE: When installing the end plate, the heads of the plug nuts at the top of the end plate on the In-line engine, or the two plug nuts in the side of the end plate on the V-type engine, should always face the forward end of the cylinder block.

3. On In-line engines, refer to Fig. 1 and install the

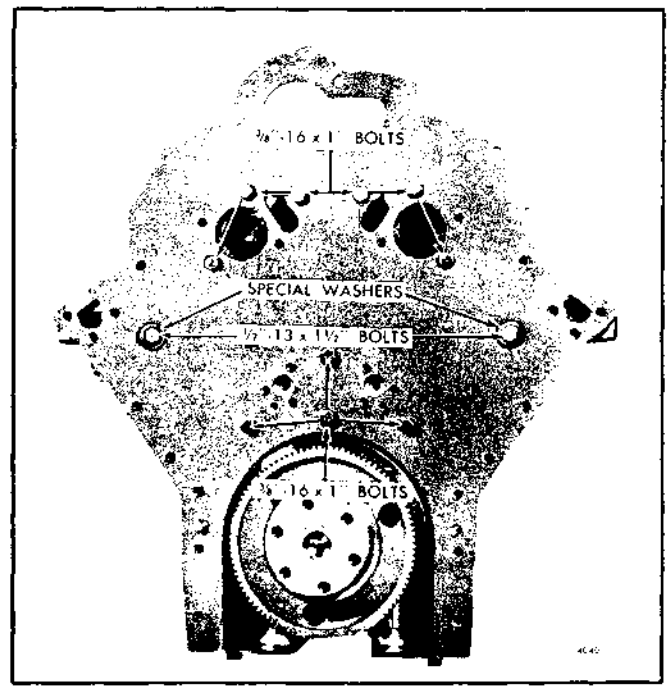


Fig. 2 - Cylinder Block Rear End Plate Mounting (V-Type Engine)

3/8 "-16 x 7/8 " bolts with lock washers. Tighten the bolts to 30-35 lb-ft torque.

NOTE: On In-line engines built prior to engine serial numbers 2D-903, 3D-011 and 4D-103, the top center end plate attaching bolt was 3/8 "-16 x 3/4 ". Do not use a longer bolt at this location on engines built prior to the above engine serial numbers.

4. On a V-type engine, refer to Fig. 2 for the location and install the 3/8 "-16 x 1 " bolts with lock washers. Also install the two special washers and two 1/2 "-13 x 1-1/2 " bolts as shown when the fuel pump is driven off the camshaft, or one special washer and bolt when the fuel pump is driven by the accessory gear. Tighten the 3/8 "-16 bolts to 30-35 lb-ft torque and the 1/2 "-13 bolts to 71-75 lb-ft torque.

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, condense and settle 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.

One drain tube is used on an In-line engine (Fig. 1) and two drain tubes are used on the 6V engines (Fig. 2) at the rear end of the cylinder block.

The 8V marine engines, effective with engine 8D-425, have one short and one long drain tube installed at the right front corner and one drain tube at each rear corner of the cylinder block. Effective with engine 8D-2304, marine engines have an oil drain tube at each corner of the cylinder block.

The 8V vehicle engines effective with 8D-425 have one short and one long drain tube installed at the right front corner and one drain tube at each rear corner of the cylinder block (Fig. 3). Industrial engines effective with 8D-435 have a short and a long drain tube installed at the right front corner and the left rear corner, as well as one drain tube at the left front corner and right rear corner; since they may operate

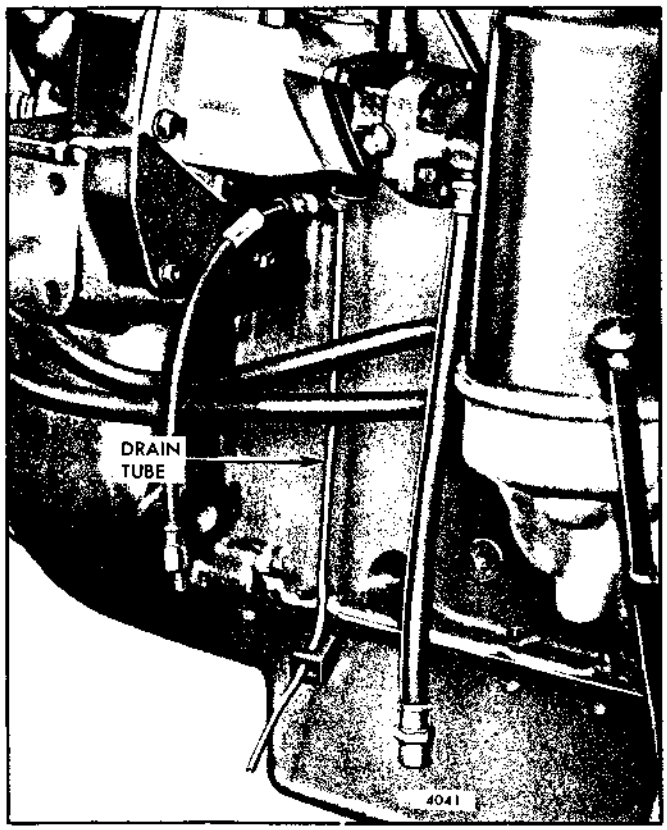


Fig. 1 - Air Box Drain Tube Mounting (In-Line Engines)

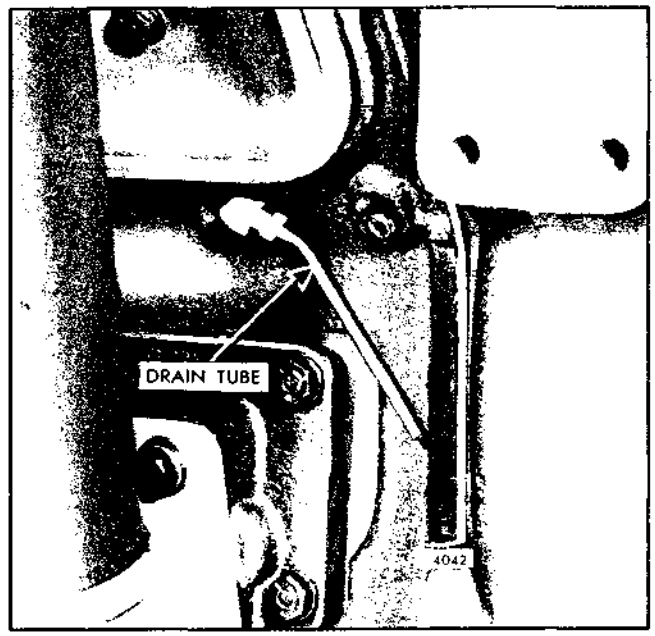


Fig. 2 - Air Box Drain Tube Mounting (6V Engine)

inclined in either direction. It is recommended that the additional drain tubes and fittings be installed on engines built prior to 8D-425

Inspection

During engine operation, a periodic check is recommended for air flow from the air box drain tubes. A partially plugged air box drain tube may allow air to escape and still cause liquid accumulation within the air box. This liquid accumulation can be seen by removing the cylinder block air box covers.

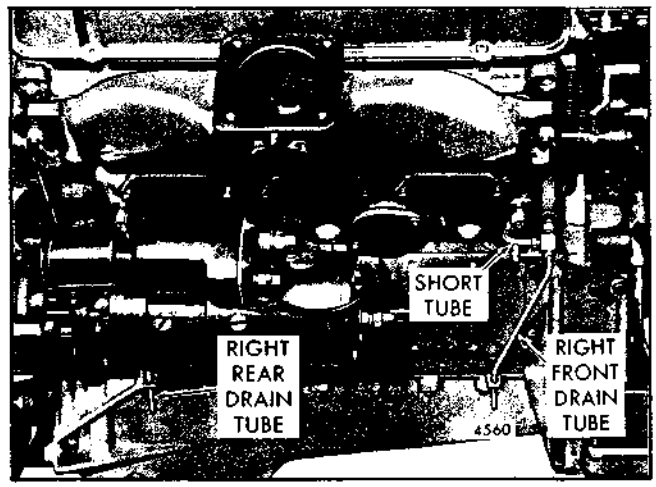


Fig. 3 - Air Box Drain Tube Mounting (8V Engine)

Remove the accumulation with rags or blow out with compressed air. If there is any sign of liquid accumulation or if there is no air flow from the air box drain tubes, remove the tubes and connectors and clean them thoroughly.

CYLINDER HEAD

The cylinder head (Fig. 1) is a one-piece casting. It may be removed from the engine as an assembly containing the cam followers, cam follower guides, rocker arms, exhaust valves and injectors. The head is securely held to the top of the cylinder block with bolts.

Located in the cylinder head are the exhaust valves, a fuel injector and three rocker arms for each cylinder. One rocker arm operates the injector plunger; the other two operate the exhaust valves. The rocker arms are operated by a camshaft through cam followers and push rods.

Exhaust valve inserts (valve seats), pressed into the cylinder head, permit accurate seating of the valves under varying conditions of temperature and materially prolong the life of the cylinder head. The inserts are ground to very close limits and their freedom from

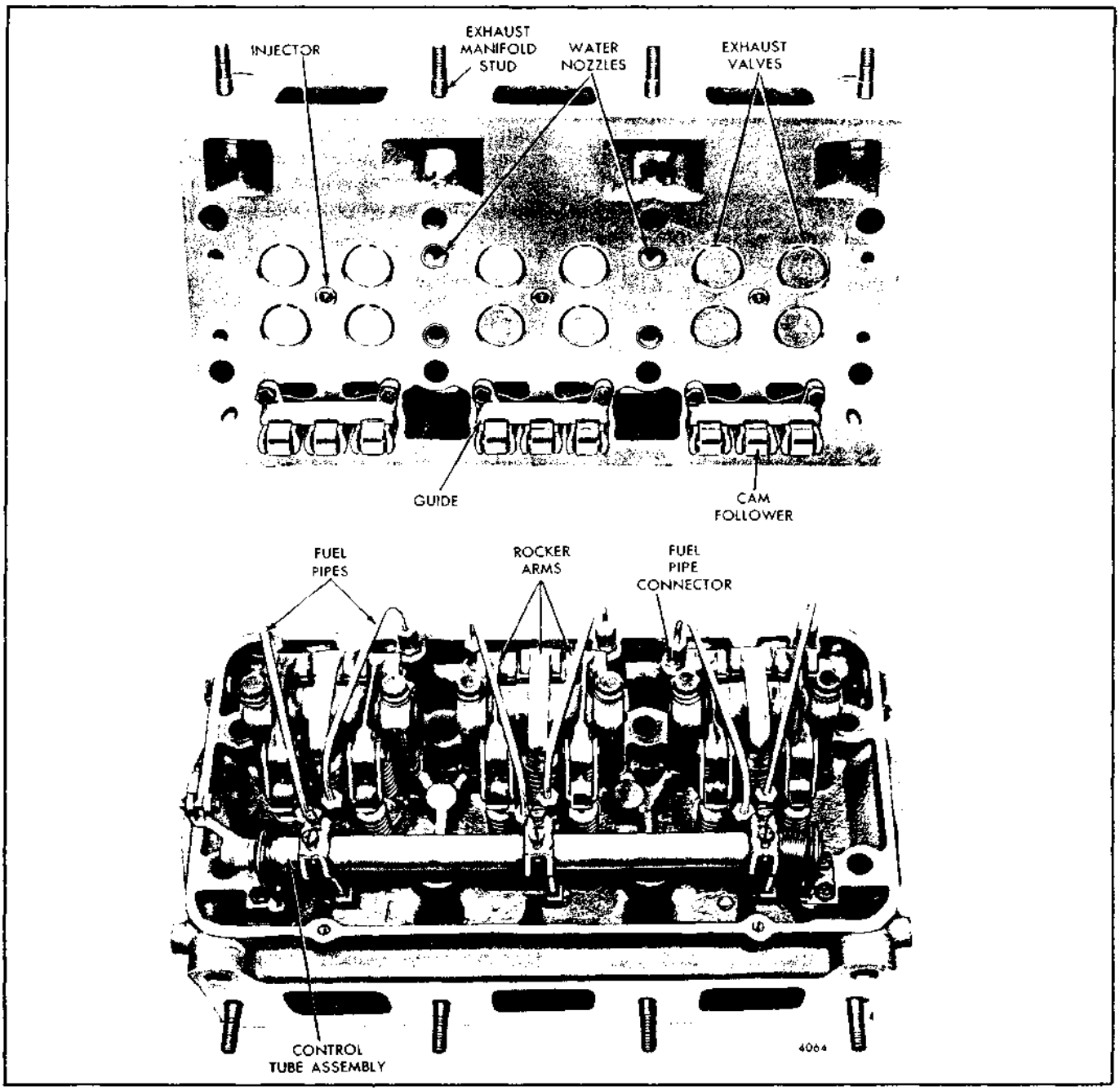


Fig. 1 - Typical Four-Valve Cylinder Head Assembly

warpage, under ordinary conditions, reduces valve reconditioning to a minimum.

To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube 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 flared lower end and sealed upper end prevent water leaks around the copper tube.

The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages, exhaust valve inserts and injector tubes are completely surrounded by cooling system water.

In addition to being surrounded by water, cooling of these areas is further assured by the use of double jet spray nozzles installed between each pair of cylinders in the water inlet ports of four valve cylinder heads. Nozzle holes are so positioned in the cylinder head that the comparatively cool water which enters the head is directed at high velocity against the sections of the head which are subjected to the greatest heat.

The coolant flow pattern is such on two-valve cylinder heads that nozzles are not required.

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 block and head are sealed with synthetic rubber seal rings which fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove in the block near the outer edge of the area covered by the cylinder head. When the cylinder head is pulled down, a positive leakproof metal-to-metal contact is assured between the head and block.

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

1. Removing and installing the pistons.

2. Removing and installing the cylinder liners.

3. Removing and installing the exhaust valves.

4. Removing and installing the valve guides.

5. Reconditioning the exhaust valves and valve seats.

6. Replacing the injector tubes.

7. Installing new cylinder head gaskets.

8. Removing and installing a camshaft.

Cylinder Head Maintenance

Engine temperatures should be maintained between 160° and 185°F. and the cooling system should be inspected daily and kept full at all times.

Unsuitable water in the cooling system may result in lime and scale formation which 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, a reliable non-corrosive scale remover should be used 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.

Adding cold water to a hot engine may result in head cracks. Water must be added slowly to a hot engine to avoid rapid cooling which will result in distortion and cracking of the cylinder head (and cylinder block).

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

The development of cracks in the cylinder head may be caused by abnormal operating conditions or through neglect of certain maintenance items. If this type of failure should occur, a careful inspection should be made to determine the cause so that a recurrence of the failure will be prevented.

Overtightening the injector clamp bolts may also result in head cracks. Always use a torque wrench to tighten the bolts to the specified torque.

Other conditions which may eventually result in head cracks are:

1. Excess fuel in the cylinders due to leaking injectors.

2. Oil pull-over due to an overfilled air cleaner sump, or improper viscosity oil in the air cleaner.

3. Neglected cylinder block air box drains which allow accumulated oil to be drawn into the cylinders.

Remove Cylinder Head

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

1. Disconnect the exhaust piping at the exhaust manifold.

2. Drain the cooling system.

3. Remove the air cleaner(s) or air silencer.

4. Disconnect the fuel lines at the cylinder head.

5. Remove the thermostat housing and the thermostat as an assembly.

6. Clean and remove the valve rocker cover.

7. Disconnect and remove the fuel rod between the governor and the injector control tube lever. Remove the fuel rod cover, if used.

8. Remove the exhaust manifold.

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

10. If the cylinder head is to be stripped for reconditioning of valves and valve seats or for a complete cylinder head overhaul, remove the fuel pipes and injectors at this time. Refer to Sections 2.1 or 2.1.1 for removal of the injectors.

11. Remove the cylinder head bolts. Then, lift the cylinder head off of the cylinder block, with lifter tool J 22062-01 (Fig. 2).

> **CAUTION:** When resting the cylinder head assembly on a bench, protect the cam follower rollers and the injector spray tips by resting the valve side of the head on 2" thick wood blocks.

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

Disassemble Cylinder Head

If a cylinder head is removed for inspection and possible repair or replacement, remove the following parts:

1. Fuel injectors, if not previously removed.

2. Fuel connectors.

3. Cam follower guides and cam followers.

4. Rocker arms, rocker arm shafts, brackets, push rods, push rod springs, spring seats and spring seat retainers.

5. Exhaust valves and valve springs.

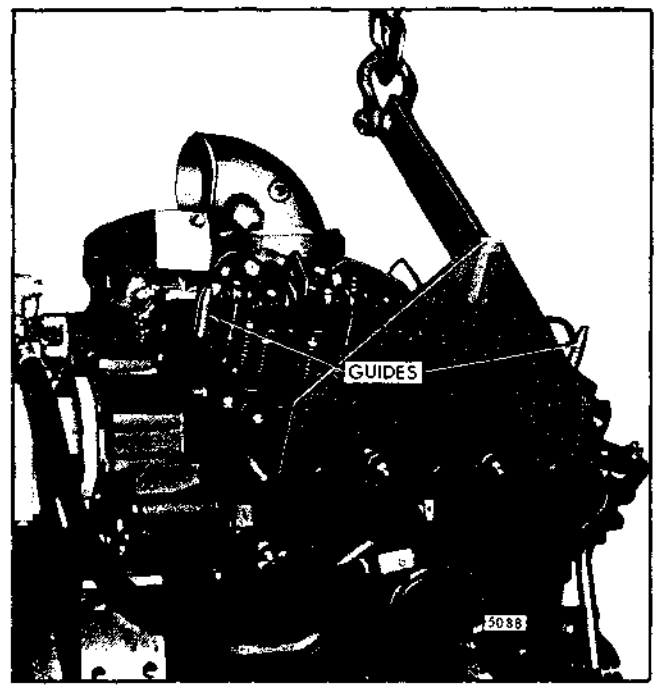


Fig. 2 - Lifting Cylinder Head Assembly Off Cylinder Block with Tool J 22062-01

The removal procedures to be followed, when removing the parts mentioned above, are covered in their respective sections of this manual.

Clean Cylinder Head

After the cylinder head has been stripped of all the component parts and all of the plugs (except cup plugs) have been removed, steam clean the head thoroughly.

Thoroughly clean a new service cylinder head to remove all of the rust preventive compound, particularly from the integral fuel manifolds, before the plugs are installed in the fuel manifolds and the head is mounted on the engine. A simple method of removing the rust preventive compound is to immerse the head in solvent, oleum or fuel oil; then, go over the head and through all of the openings with a soft bristle brush. A suitable brush for cleaning the fuel manifolds can be made by attaching a 1/8" brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

Inspect Cylinder Head

1. Check the cylinder head for leaks as follows:

   a. Seal off the water holes in the head with steel plates and suitable rubber gaskets held in place by bolts.

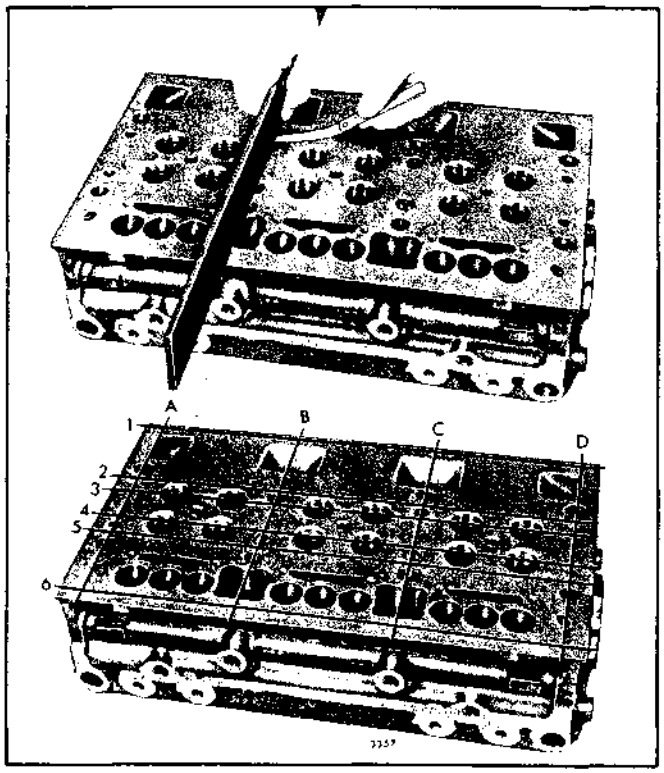


Fig. 3 - Checking Bottom Face of Cylinder Head for Warpage

b. Install dummy or scrap injectors to ensure 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 lb-ft torque.

c. Drill and tap into one of the water hole cover plates for an air hose connection and apply 80-100 psi air pressure to the water jacket. Then, immerse the head in a tank of water previously heated to 180-200°F. for twenty minutes to thoroughly heat the cylinder head. Observe the water in the tank for bubbles indicating cracks or leaks.

d. Remove the cylinder head from the tank and dry it with compressed air.

e. If inspection revealed cracks, replace the cylinder head.

f. Replace any leaking injector tubes as outlined in Section 2.1.4.

Over a prolonged period of operation, the cylinder head may assume a contour to match that of the cylinder block, which is normal. However, if the cylinder head is allowed to become overheated because of coolant loss, the resultant high temperatures cause stresses to occur in the casting which will affect the flatness of the head.

2. Check the bottom (fire deck) of the cylinder head for flatness as follows:

a. Use an accurate straightedge and feeler gage J 3172 to check for transverse warpage at each end and between all of the cylinders. Also, check for longitudinal warpage in six places as shown in Fig. 3. Maximum allowable warpage is given in the following chart:

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
2-53	.004"	.004"
3-53 & 6V-53	.005"	.004"
4-53 & 8V-53	.006"	.004"

b. The maximum allowable warpage limits should be used as a guide in determining the advisability of reinstalling the head on the engine or of refacing it. The number of times a cylinder head may be refaced will, of course, depend upon the amount of stock removed from the head during previous reworking operations.

c. If the cylinder head is to be refaced, remove the injector tubes prior to machining. Not over .020" of metal should be removed from the fire deck of the cylinder head. The distance from the top to the bottom (fire deck) of the cylinder head must not be less than 4.376", as shown in (Fig. 4). Stamp the amount of stock removed on the face of the fire deck near the outer edge of the head, in an area not used as a sealing surface.

d. After a cylinder head has been refaced and new injector tubes have been installed as outlined in Section 2.1.4, pressure check the cylinder head as outlined in Step 1.

3. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned

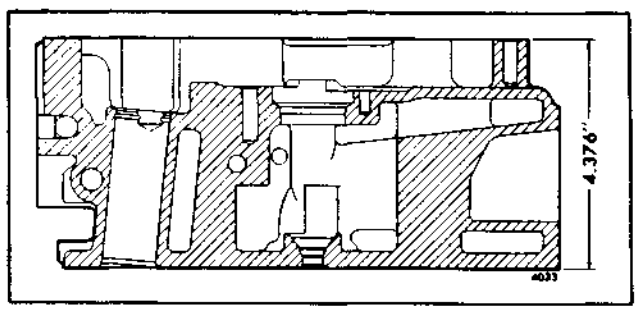


Fig. 4 - Minimum Distance Between Top and Bottom Faces of Cylinder Head

up with crocus cloth wet with fuel oil. If the bores are excessively scored or worn so that the cam follower-to-head clearance exceeds .006", replace the cylinder head.

4. Inspect the valve seat inserts for cracks or burning. Also, check the valve guides for scoring.

5. Check the water nozzles in a four-valve cylinder head to be sure they are not loose. Water nozzles are used only in the passages between the cylinders. If necessary, install or replace the water nozzles as follows:

a. Be sure the water inlet ports in the bottom of the head are clean and free of scale. The water holes may be cleaned up with a 5/8" diameter drill. Break the edges of the holes slightly.

b. If the water holes in the head have been enlarged by corrosion, use a wooden plug or other suitable tool to expand the nozzles so that they will remain tight after installation.

c. Press the nozzles in place with the outlet holes positioned as shown in Fig. 5. The angle between the outlet holes in the nozzle is 90°. Press the nozzles from flush to 1/32" below the bottom surface of the cylinder head.

6. Inspect the parts removed from the cylinder head before they are reinstalled in the old head or transferred to a new cylinder head.

Assemble Cylinder Head

New service cylinder heads include valve guides, valve seat inserts, water nozzles, injector tubes and the necessary plugs.

> **CAUTION:** When installing the plugs in the fuel manifolds, apply a small amount of sealant merchandized as a "dual purpose sealer" to the threads of the plugs only. Work the sealant into the threads and wipe off the excess with a clean, lint-free cloth so that the sealant will not be washed into the fuel system and result in damage to the injectors.

When a new cylinder head is to be used, remove the parts listed below from the old head and install them in the new head. If the old cylinder head is to be reused, install the parts in the old head prior to assembling the head on the cylinder block.

1. Exhaust manifold studs.

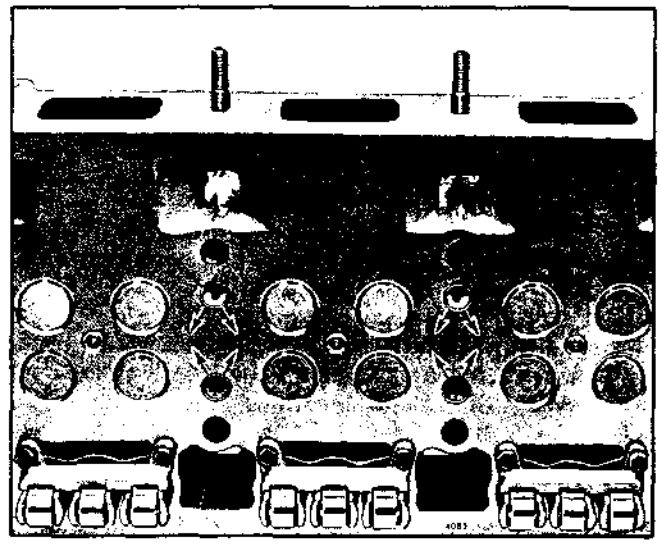


Fig. 5 - Correct Installation of Water Nozzles in Four-Valve Cylinder Head

2. Exhaust valves and springs (Section 1.2.2).

3. Install the fuel injectors at this time or after installing the cylinder head (Sections 2.1 or 2.1.1).

4. Cam followers, cam follower guides, push rod assemblies, rocker arm shafts and rocker arms; do not tighten the rocker arm bracket bolts at this time (Section 1.2.1).

5. Place new washers on the fuel connectors, then install the fuel connectors and tighten them to 20-28 lb-ft torque.

Pre-Installation Inspection

Perform the following inspections just prior to installing the cylinder head on the engine.

1. Check the cylinder liner flange height as outlined in Section 1.6.3.

2. Check to be sure the tops of the pistons are clean and free of foreign material.

3. Check to see that each push rod is threaded into the 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 tune-up.

4. Check to be sure that the groove and the counterbores in the top of the cylinder block are clean and smooth.

Install Cylinder Head

1. Install new cylinder head compression gaskets and seals as outlined below:

a. Place a new compression gasket on each cylinder liner.

b. Place new seal rings in the counterbores of the water and oil holes in the cylinder block.

c. Install a new oil seal in the milled groove in the cylinder block near the outer edge of the area covered by the cylinder head.

NOTE: Used water seals, oil seals and compression gaskets should *never* be used.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, use guide stud set J 9665. Install the guide studs in the end cylinder block bolt holes (Fig. 2).

3. Make a final visual check of all of the cylinder head gaskets and seals to ensure that they are in place just before the cylinder head is lowered onto the cylinder block. *This is a very important check.* Compression gaskets and seals which are jarred out of their proper position will lead to leaks and "blow-by" with resultant poor engine performance and damage to the engine.

4. Wipe the bottom of the cylinder head clean; then, lower the head on the block.

5. Lubricate the threads and the underside of each cylinder head bolt with a small quantity of International Compound No. 2, or equivalent. Then, install the bolts. On the In-line engines equipped with both six and twelve point cylinder head bolts, the twelve point bolts must be installed on the camshaft side of the head to eliminate possible interference between the governor control link and the cylinder head bolt.

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

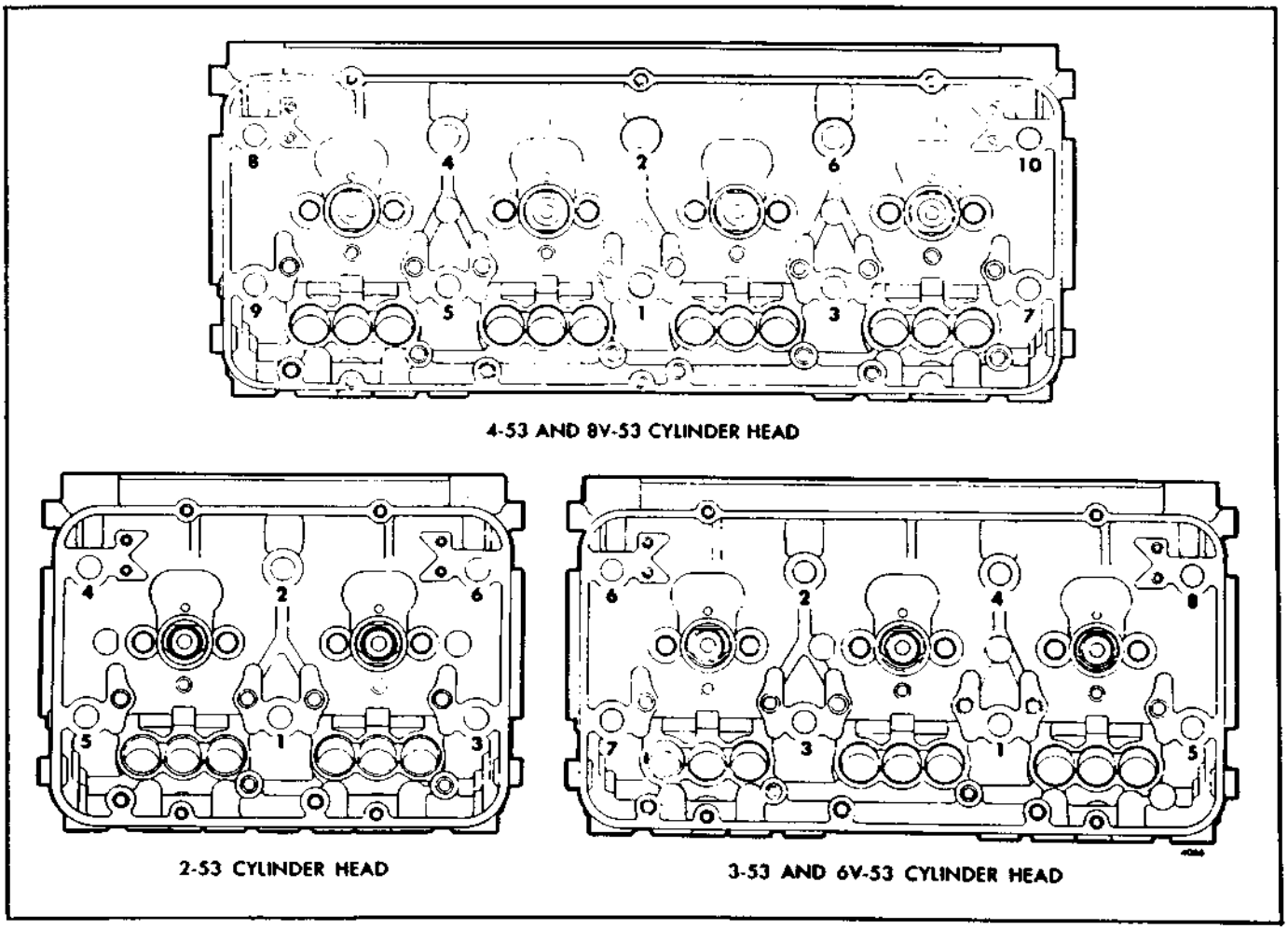


Fig. 6 - Sequence for Tightening Cylinder Head Bolts

6. The cylinder head must be gradually and uniformly drawn down against the gaskets and seals to ensure a good seal between the cylinder head and the block. Therefore, it is vitally important that the cylinder head be installed with the utmost care.

7. Then, begin on the camshaft side of the head to take up the tension in the cam follower springs by tightening the bolts lightly. Finally tighten the bolts to 170-180 lb-ft torque with a torque wrench, about one-half turn at a time, in the sequence shown in Fig. 6. Under no circumstances should the torque exceed the specified limits, otherwise the bolts may become stretched beyond their elastic limits.

8. Cover the oil drain holes in the cylinder head to prevent foreign objects from falling into the holes.

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

10. Tighten the rocker arm bracket bolts to 50-55 lb-ft torque.

CAUTION: 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 arm bracket bolts. Therefore, note the position of the exhaust valve bridge before, during and after tightening the bolts.

11. 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 torque.

CAUTION: 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.

12. Set the injector control tube assembly in place on the cylinder head and tighten the bolts, finger tight only. When positioning the injector control tube, be sure that 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 torque.

13. After tightening the bolts, revolve the tube and see if 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 with a soft hammer will remove any bind that exists. The injector racks *must* return to the no-fuel position freely by aid of the return spring only. *Do not* bend the return spring to bring about this condition.

14. Install the fuel rod and the fuel rod cover (if used).

15. Remove the covers from the drain holes in the head.

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

17. Install the thermostat housing and the thermostat.

18. Install the air cleaners.

19. Connect the fuel lines.

20. Fill the cooling system and check for leaks.

21. With the throttle in the OFF position, crank the engine over to be sure that all of the parts function freely.

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

23. Refer to Section 13.1 and start the engine. After starting the engine, check all fuel line connections to ensure that no fuel oil leaks into the cylinder head compartment to dilute the lubricating oil.

24. After the engine has been warmed up (to at least 160°F.), recheck the torque on the cylinder head bolts.

25. Recheck the exhaust valve clearance and the injector timing after the engine reaches normal operating temperature.

26. Examine all fuel oil, lubricating oil and water connections for possible leaks. Tighten the connections, if necessary.

27. Install the valve rocker cover, using a new gasket.

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

The rocker arms are operated by the 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 keep the follower rollers in line with the cams and serves as a retainer during assembly and disassembly.

A coil spring, located inside of each cam follower, is held in place in the cylinder head by a spring seat and spring seat retainer.

Several operations may be performed on the valve mechanism without removing the cylinder head from the cylinder block, while the head must be removed for certain other operations. The operations NOT requiring removal of the cylinder head are:

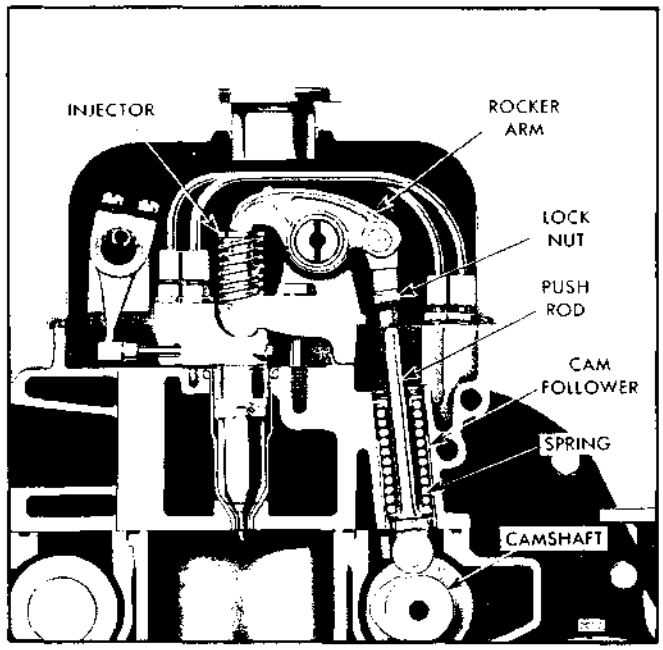


Fig. 1 - Injector Operating Mechanism (In-Line Engine Shown)

1. Adjusting valve clearance.

2. Removing and installing a valve spring.

3. Removing and installing a rocker arm.

4. Removing and installing a rocker arm shaft or shaft bracket.

5. Removing and installing an injector.

It is also possible, if occasion requires, to remove or replace a push rod, push rod spring, spring seats or cam follower without removing the cylinder head. These parts, however, are more easily changed from the lower side of the cylinder head when the head is off the engine. Both methods are covered in this Section.

To remove and install valves, valve guides, valve seat inserts and to recondition valves and valve seats, the cylinder head must be removed. Exhaust valves, guides and inserts are covered in Section 1.2.2.

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 oil passages in the cylinder block. Oil from this

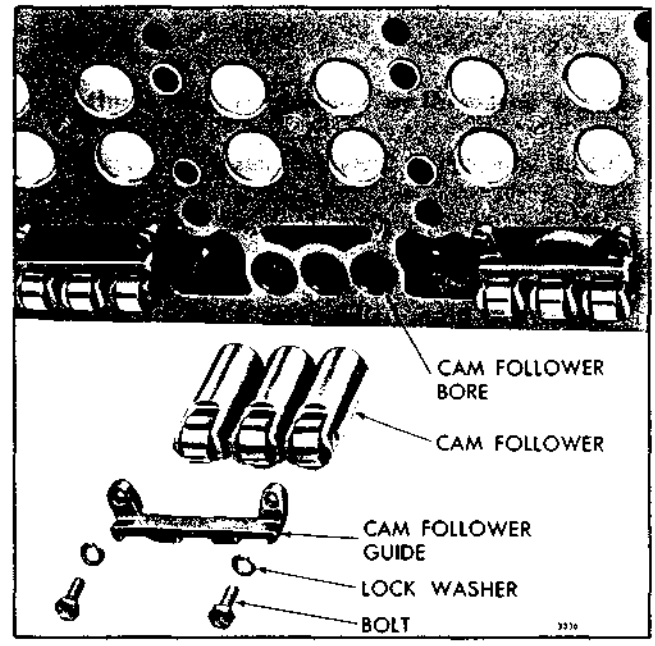


Fig. 2 - Cam Follower and Guide Location

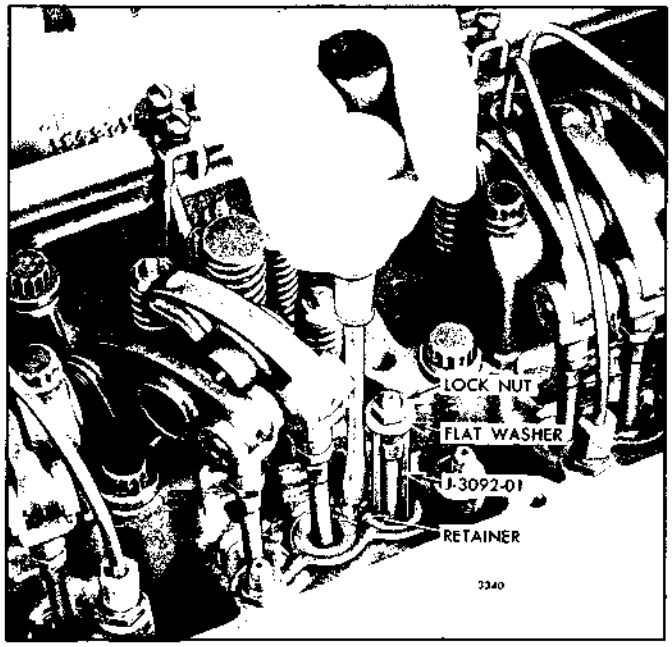


Fig. 3 - Removing Push Rod from Upper Side of Cylinder Head with Tool J 3092-01

longitudinal passage enters the drilled rocker arm shafts through the lower end of the drilled rocker shaft bracket bolts and lubricates the rocker arms.

Excess oil from the rocker arms lubricates the exhaust valves and cam followers. Additional cam follower lubrication is provided by oil from grooves in the camshaft bushing bores which is directed against the cam follower rollers.

Remove Rocker Arms and Rocker Arm Shaft

1. Clean and remove the valve rocker cover.

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

> **CAUTION:** 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. Bar the engine over in the direction of engine rotation or crank the engine with the starting motor to bring the push rod ends -- the outer ends -- of the injector and valve rocker arms in line horizontally.

> **CAUTION:** Left-hand turning engines should not be barred in the direction of rotation by use of a wrench on the crankshaft bolt, to avoid the possibility of loosening the bolt.

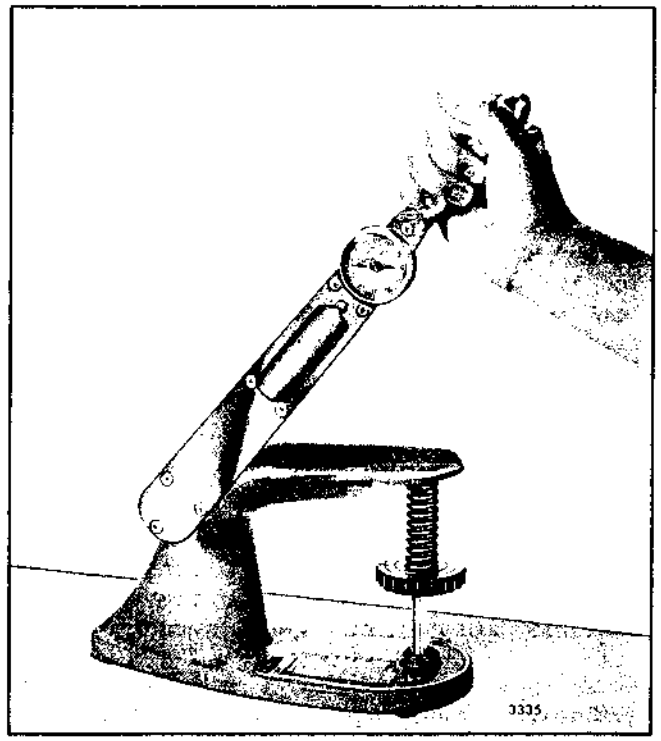


Fig. 4 - Testing Push Rod Spring

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

5. Loosen the lock nut at the upper end of the push rod, next to the clevis, and unscrew the rocker arm from the push rod.

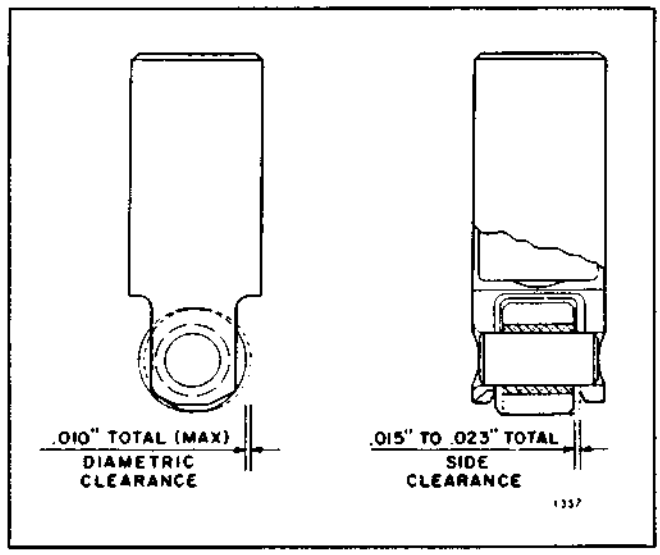


Fig. 5 - Cam Roller Wear and Clearance Diagram

Inspection

Wash the rocker arms, rocker arm shaft and brackets thoroughly in clean fuel oil and dry them with compressed air. Make certain that the oil passages in the rocker arms, rocker arm shaft and bracket bolts are open and clean.

Inspect all of the parts for excessive wear.

The maximum clearance between the rocker arm shaft and the injector rocker arm bushing or an exhaust valve rocker arm (which has no bushing) is .004 " with used parts.

Examine each rocker arm pallet (contact face) for wear or galling. Also check the contact surfaces of the exhaust valve bridge (four valve cylinder heads).

Remove Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)

With the cylinder head removed from the engine, remove the cam followers as follows:

1. Rest the cylinder head on its side and remove the two bolts and lock washers securing the cam follower guide to the bottom of the cylinder head (Fig. 2). Remove the guide.

2. Pull the cam followers from the bottom of the cylinder head.

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

4. Loosen the lock nuts at the upper end of the push rods and unscrew the push rods from the rocker arm clevises.

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

6. Remove the push rod lock nut, upper spring seat, spring and lower spring seat from each push rod for cleaning and inspection.

The push rod spring seat retainers remain in the cylinder head. If the head is to be changed, these retainers must be removed and installed in the new head.

Remove Cam Follower and Push Rod Assembly (Cylinder Head Not Removed from Engine)

A push rod, push rod spring, spring seats and cam follower may be removed from the top of the cylinder head by using tool J 3092-01 as shown in Fig. 3.

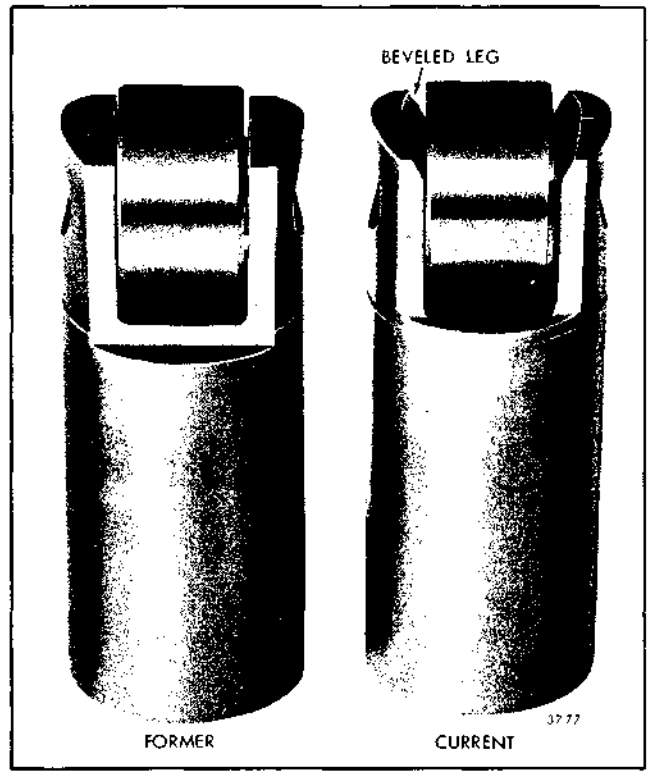


Fig. 6 - Former and Current Cam Followers

1. Clean and remove the valve rocker cover.

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

3. Remove the rocker arm brackets and rocker arm shaft as outlined in Steps 3 and 4 under *Remove Rocker Arms and Rocker Arm Shaft.*

4. Loosen the lock nut at the upper end of the push rod, next to the clevis, and unscrew the rocker arm from the push rod to be removed. Remove the lock nut from the push rod.

5. Install the remover J 3092-01, a flat washer and nut on the push rod (Fig. 3). Screw the nut down on the end of the push rod to compress the push rod spring.

6. Remove the retainer from the cylinder head with a screw driver or similar tool as shown in Fig. 3.

7. Unscrew the nut at the outer end of the push rod, thus releasing the spring.

8. Pull the push rod, spring, spring seats and cam follower out through the top of the cylinder head.

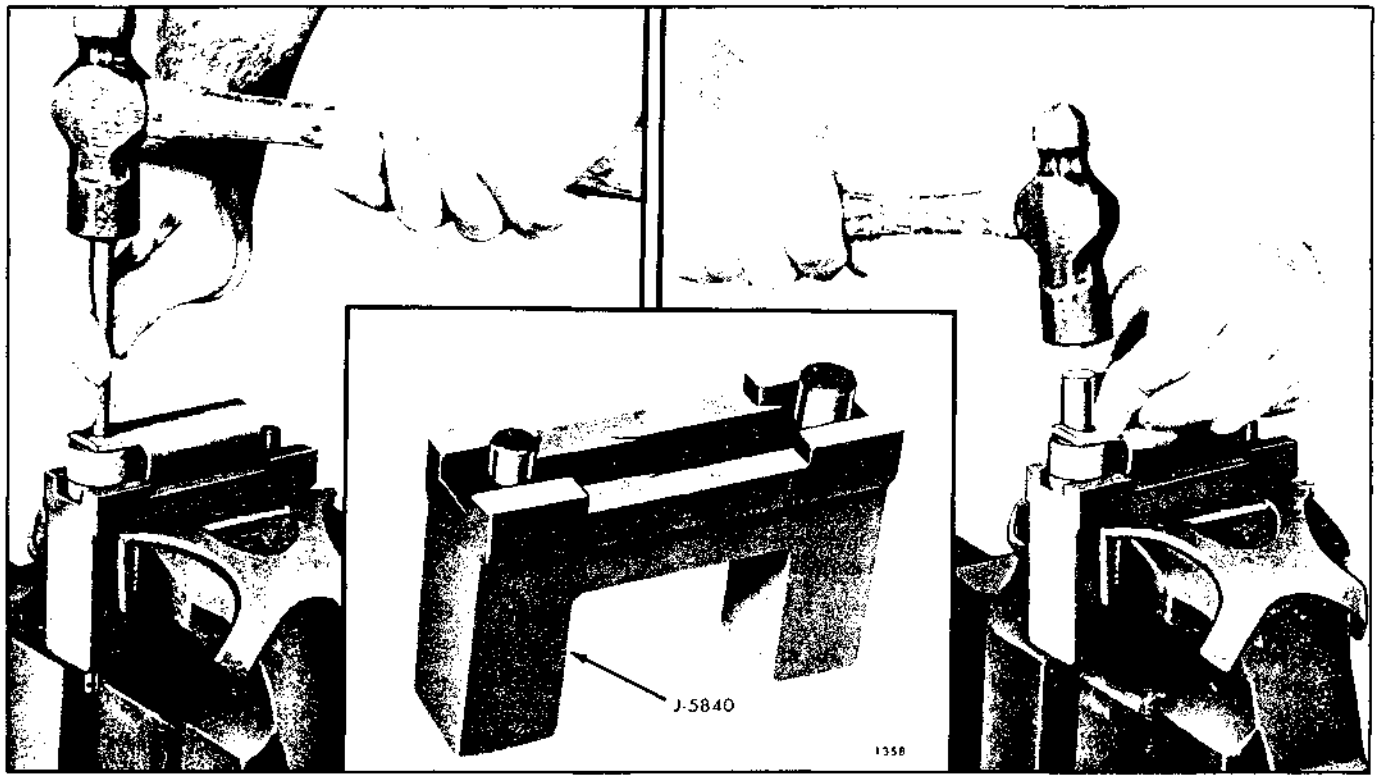


Fig. 7 - Removing or Installing Cam Follower Roller and Pin with Tool J 5840

Inspection

Proper cam follower inspection and service are necessary in obtaining continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, the cam followers, and their related parts, should be removed and inspected for excessive wear. This change in injector timing or exhaust valve clearance during engine operation can usually be detected by excessive noise at idle speed.

After the cam followers are removed, wash them with lubricating oil or Cindol 1705 and wipe dry. *Do not use fuel oil.* Fuel oil working its way in between the roller and bushing may cause scoring on the initial engine start-up since fuel oil does not provide adequate lubrication. Wash only the cam follower associated parts with fuel oil and dry them with compressed air.

Inspect the rounded end of the push rods for wear. Replace any push rod which is worn or bent.

The purpose of a push rod spring is to maintain a predetermined load on the cam follower to insure contact of the cam roller on the camshaft lobe at all times. Check the push rod spring load whenever the cam followers and related parts are removed for inspection.

The current push rod spring is made from .192 " diameter wire and was first used only in the injector cam follower position, effective with engines 2D-13453, 3D-3792, 4D-5323 and 6D-1077.

Effective with engines 2D-14188, 3D-6128, 4D-8549 and 6D-2709, the new spring is also used in the exhaust valve cam follower position. The former push rod spring was made from .177 " diameter wire.

Use spring tester J 9666 and an accurate torque wrench to check the push rod spring load (Fig. 4). Replace the current type spring when a load of less than 250 pounds will compress it to a length of 2-9/64 ". Replace the former type spring when a load of less than 172 pounds will compress it to a length of 2-1/8 ".

It is recommended that if one former type push rod spring requires replacement, all of the former type springs in either the injector or valve cam follower positions be replaced by the current type spring. A new design upper spring seat is required with the use of the current push rod spring.

Examine the cam follower bores in the cylinder head

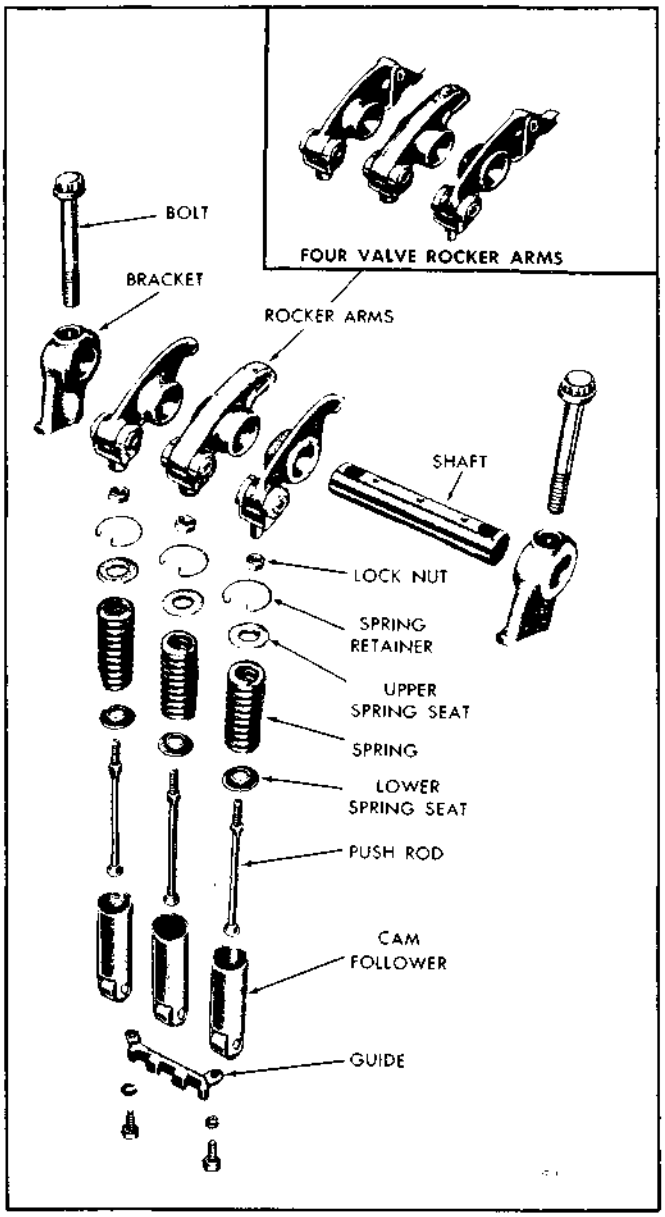


Fig. 8 - Valve and Injector Operating Mechanism Details and Relative Location of Parts

to make sure they are clean, smooth and free of score marks to permit proper functioning of the cam followers. Any existing score marks must be cleaned up.

Check the cam follower-to-cylinder head clearance. The clearance must not exceed .006 " with used parts. If replacement of a cam follower is necessary, use the correct type service cam follower to be assured that the cam roller will receive the proper lubrication.

The cam follower roller must turn smoothly and freely

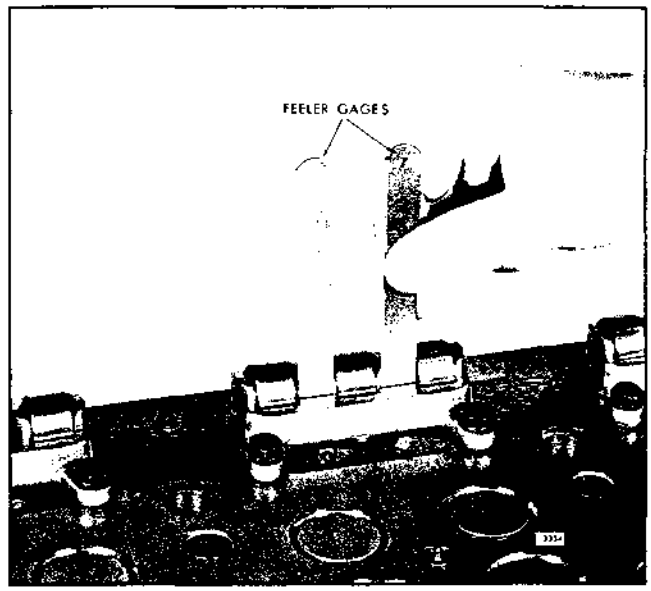


Fig. 9 - Checking the Clearance Between the Cam Follower Guide and Cam Follower Legs

on its pin and the roller must be free from flat spots or scuff marks. If the roller does not turn freely or has been scored or worn flat, then examine the cam on which it operates. If the cam is excessively worn or damaged, replace the camshaft.

Measure the total clearance between the roller bushing and pin, crosswise of the pin, as shown in Fig. 5 and, if the bushing is worn to the extent that more than

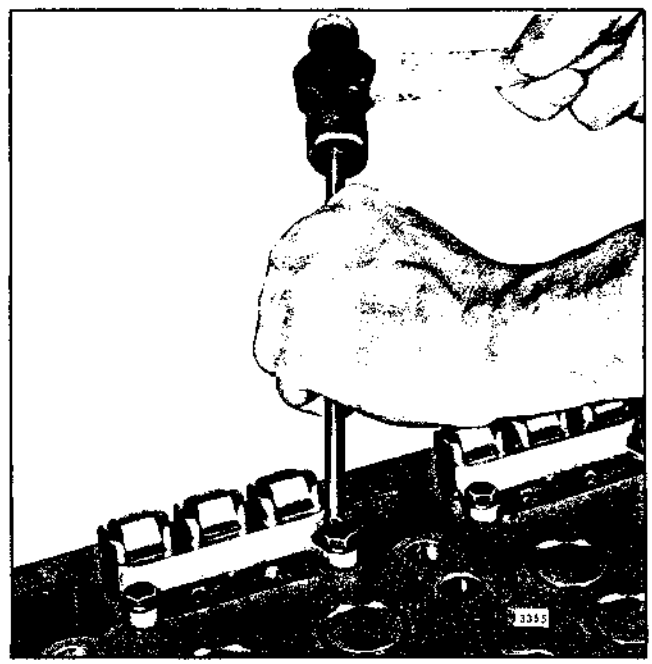


Fig. 10 - Adjusting Cam Follower Guide

.010 " diametric clearance exists, replace the cam follower assembly or install a new cam roller and pin, which are serviced as a set. Be sure the follower legs are beveled (Fig. 6) and check the total side clearance between the roller and follower; this clearance must not be less than .015 " nor more than .023 ".

Oversize roller and pin sets are available for service when required. However, DO NOT attempt to bore out the legs of a standard cam follower for an oversize roller and pin set. This cannot be over emphasized because of the extremely close manufacturing tolerances.

NOTE: Cam follower assemblies with the letter "S" stamped on the end of the roller, pin and on one leg of the cam follower body are equipped with oversize roller and pin sets.

Remove and Install Cam Follower Roller and Pin

1. Clamp fixture J 5840 securely in a vise as shown in Fig. 7 and place the cam follower in the groove in the top of the fixture with the follower pin resting on top of the corresponding 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 follower pin is seated on top of a spring-loaded plunger in the fixture body.

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

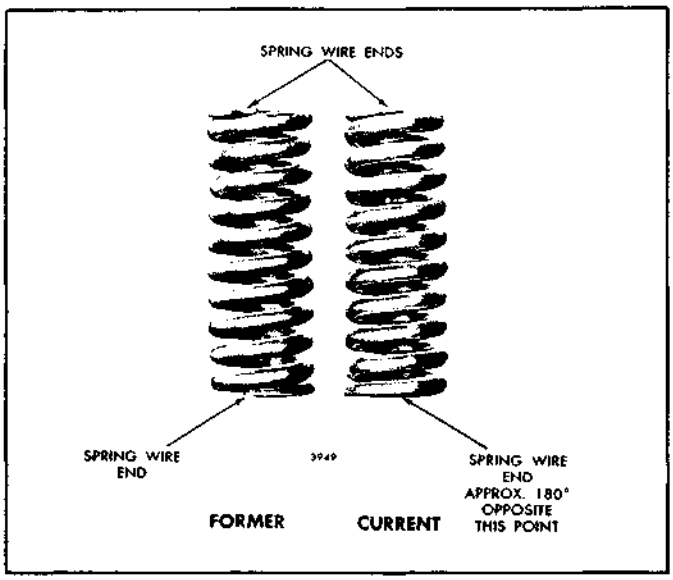


Fig. 11 - Push Rod Spring Identification

4. Prior to installing a new roller and pin, remove any burrs on the surfaces of the cam follower at the pin holes.

5. Position the follower body in the groove of the fixture with the proper size fixture plunger extending through the roller pin hole in one of the legs of the follower body.

6. Position the roller in the cam follower body (Fig. 7). The small plunger in the tool will align the roller with the pin holes in the follower body.

7. Align the pin with the hole in the follower body and carefully drive the pin into the body until the ends of the pin are centered in the legs of the body.

8. Check the side clearance between the roller and the follower body. This clearance must be .015 " to .023 ".

Install Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine)

1. Install a serrated lower spring seat on each push rod. If the engine being assembled was equipped with plain lower spring seats, replace them with serrated spring seats (Fig. 8).

2. Place the push rod springs (Fig. 11) on the push rods.

3. Install the proper upper spring seat on each push rod. The cup shaped spring seat used with the current type push rod spring may also be used with the former spring.

4. Install the spring seat retainer in the cylinder head. Then slide the push rod, lower spring seat, spring and upper spring seat as an assembly into the cam follower bore from the bottom of the cylinder head.

5. Screw the push rod lock nut down on the upper end of the push rod as far as possible. Then screw the push rod into the clevis until the end of the rod is flush with or above the inner side of the clevis.

6. Immerse the cam follower assemblies in clean Cindol 1705 (heated to 100 °-125 °F.) for at least one hour before placing them in the cylinder head, to ensure initial lubrication between the cam follower roller pins and the roller bushings. Rotate the cam follower roller during the soaking period to aid in purging any air from the bushing-roller area. The heated Cindol 1705 results in better penetration as it is less viscous than engine oil and flows more easily between the pin and roller bushing surfaces. After the cam follower is removed from the Cindol 1705, the cooling action of any trapped air in the pin and bushing area tends to pull the oil into the cavity.

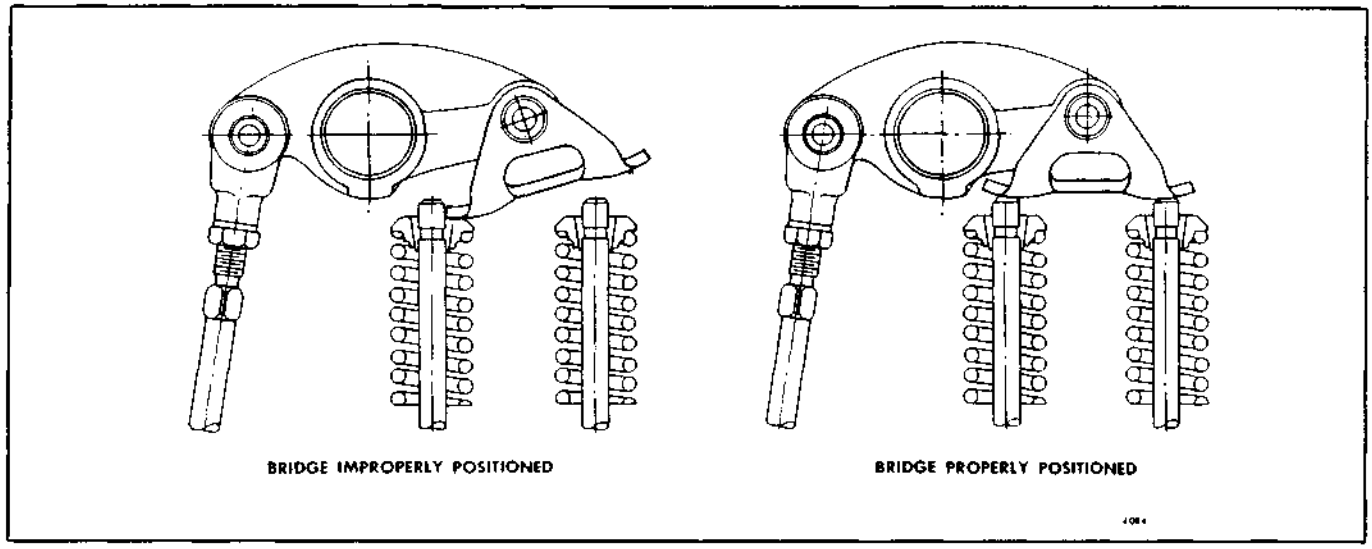


Fig. 12 - Relationship Between Exhaust Valve Bridge and Valve Stems

NOTE: Heat the Cindol 1705 in a small pail, with a screen insert. The screen insert will prevent the follower assemblies from touching the bottom of the pail during soaking, thus avoiding the possibility of contamination.

IMPORTANT: When installing a new cam follower assembly, wash it with clean lubricating oil or Cindol 1705 to remove the preservative.

7. Note the oil hole in the bottom of the cam follower. With this oil hole pointing away from the exhaust valves, slide the cam follower into position from the bottom of the head.

8. Attach the cam follower guide (Fig. 8) to the bottom of the cylinder head to hold the group of cam followers in place. Tighten the cam follower guide bolts to 12-15 lb-ft torque. Check to be sure there is at least .005 " clearance between the cam follower legs and the cam follower guide (Fig. 9). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 10). Then retighten the bolts to 12-15 lb-ft torque and recheck the clearance.

Install Cam Follower and Push Rod Assembly (Cylinder Head Not Removed from Engine)

1. Lubricate the cam follower as stated in Step 6 under *Install Cam Follower and Push Rod Assembly (Cylinder Head Removed from Engine).*

2. Note the oil hole in the bottom of the cam follower. With this hole pointing away from the exhaust valves, slide the cam follower into position.

3. Install a serrated lower spring seat on each push rod. If the engine being assembled was equipped with plain lower spring seats, replace them with serrated spring seats.

4. Place the push rod springs (Fig. 11) on the push rods.

5. Install the proper upper spring seat on each push rod. The cup shaped spring seat used with the current type push rod spring may also be used with the former spring.

6. Set the push rod, lower spring seat, spring and upper spring seat down in the cam follower.

7. Install a flat washer and nut on the push rod. Then place tool J 3092-01 on the push rod, between the flat washer and upper spring seat. Screw the nut down on the push rod until the spring is compressed sufficiently to permit the retainer to be installed. Partially collapse the retainer and install it in the cylinder head groove.

8. Remove the nut, flat washer and tool from the push rod.

9. Reinstall the nut on the push rod. Screw the nut down as far as possible on the push rod. Then screw the rocker arm clevis down on the push rod until the end of the push rod is flush with or above the inner side of the clevis.

NOTE: The injector rocker arm (the center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the

shaft on the valve rocker arms is longer on one side of the arm than on the other. The extended boss of the valve rocker arms must face the injector rocker arm.

Install Rocker Arms and Rocker Arm Shaft

1. Install the cylinder head, if removed, as outlined in Section 1.2.

2. Apply clean engine oil to the surface of the rocker arm shaft.

3. Install the rocker arms and rocker arm shaft by reversing the sequence of operations for removal. Tighten the rocker arm shaft bracket bolts to 50-55 lb-ft torque. After tightening the bolts, check for some side clearance to prevent bind between the rocker arms.

CAUTION: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the valve bridges are not resting on the ends of the valves when tightening the rocker arm shaft bracket bolts (Fig. 12). Therefore, note the position of the exhaust valve bridges before, during and after tightening the rocker arm shaft bracket bolts.

4. Align the fuel pipes and connect them to the injectors and the fuel connectors. Tighten the fuel pipe nuts to 12-15 lb-ft torque with socket J 8932-01.

CAUTION: 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.

5. Fill the cooling system.

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

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

8. Tune-up the engine, as outlined in Section 14, after the engine reaches normal operating temperature.

EXHAUST VALVES

Either two or four exhaust valves are provided for each cylinder, depending upon the engine model (Fig. 1). The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the rocker arm or the exhaust valve bridge.

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head. Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head. The exhaust valves and exhaust valve seat inserts are ground to a 30 ° 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.

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 leak-proof seating, valve stems must work freely and smoothly within the valve guides and the correct valve clearance (Section 14.1) must be maintained.

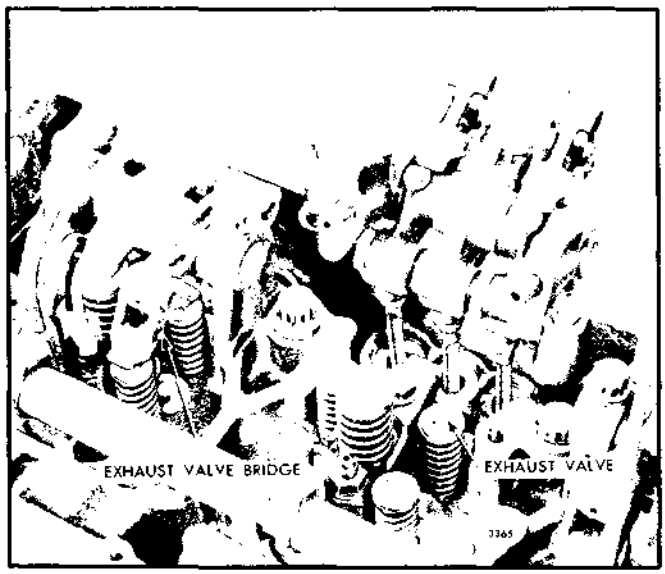


Fig. 1 - Location of Exhaust Valves

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

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

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

Lubricating oil and oil filters should be changed periodically to avoid 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 result in valves being held in the open position, being struck by the piston and becoming bent or broken.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors will have adverse effects upon combustion. Tightly adjusted valves will cause rapid pitting of the valve seats and a hotter running condition on the valve stems.

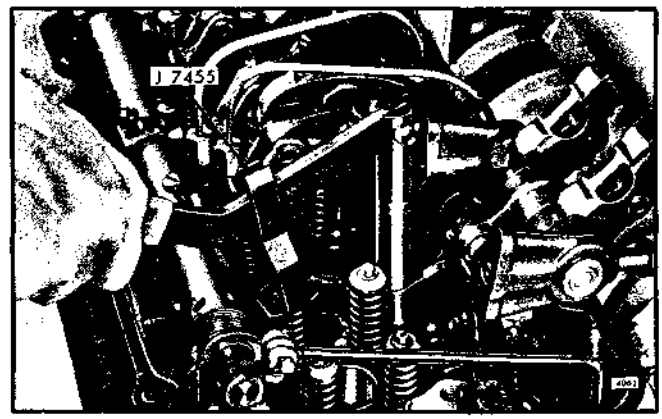


Fig. 2 - Removing Valve Spring

The cylinder head must first be removed before the exhaust valves, valve seat inserts or valve guides can be removed for replacement or reconditioning. However, the valve springs may be replaced without removing the cylinder head.

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.

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

> **CAUTION:** 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 and remove the brackets and shaft.

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

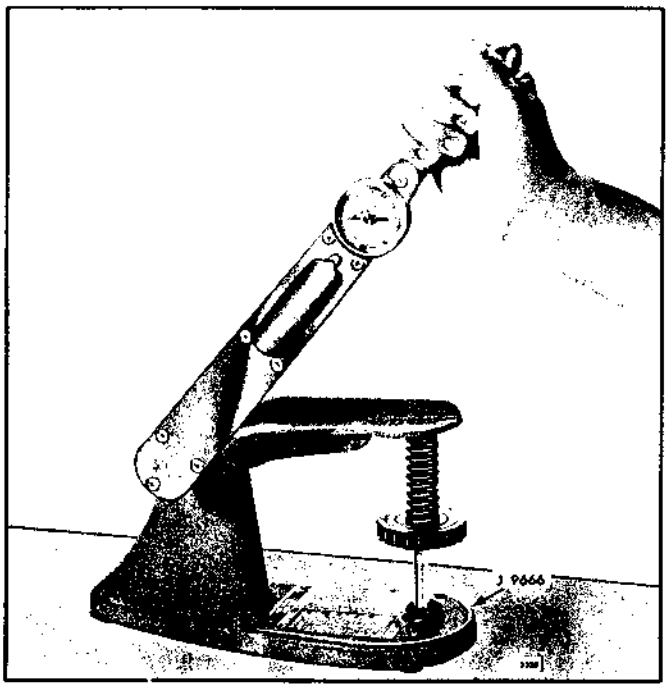


Fig. 3 - Testing Valve Spring

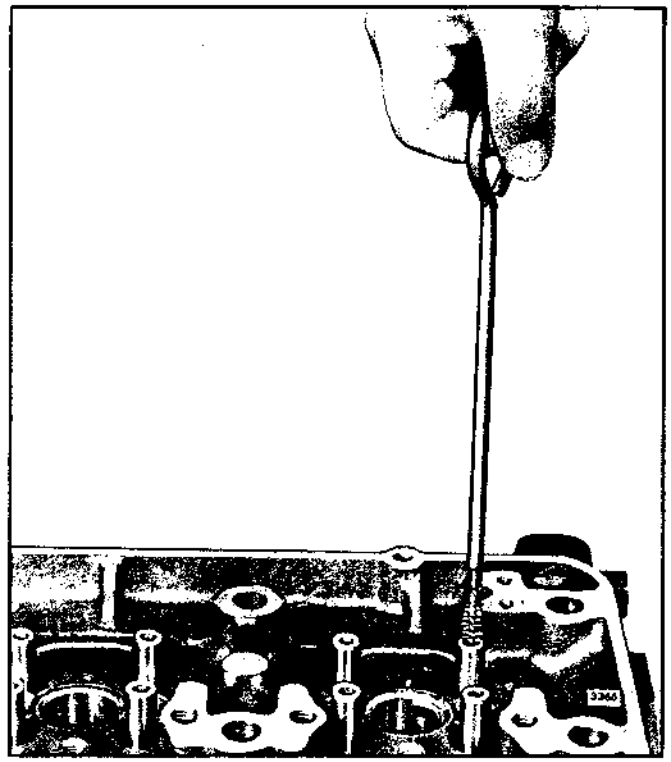


Fig. 4 - Cleaning Valve Guide

6. Thread the spring compressor tool into one of the rocker arm support bolt holes (Fig. 2). Then compress the spring and remove the two-piece valve lock.

7. 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:

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

2. Disconnect and remove the fuel pipes from the injectors and the fuel connectors.

> **CAUTION:** 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 and remove the brackets and the shaft.

4. Remove the fuel injector.

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

6. 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 re-installation in the same position. Then withdraw the valves from the cylinder head.

7. 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.

Check the springs with spring tester J 9666 and an accurate torque wrench. Replace a spring if a load of less than 33 pounds will compress a two valve cylinder head spring to 2.31 inches, or a load of less than 25 pounds will compress a four valve cylinder head spring to 1.93 inches. The difference in the load between a pair of four valve cylinder head springs must not exceed 6 pounds or the valve bridge will be unbalanced.

To eliminate exhaust valve spring surge, a new valve spring is used in the 6V-53 vehicle engines where the maximum speed rating has been increased from 2600 rpm to 2800 rpm. It is also used in the 6V-53 non-turbocharged engines. The change is effective with approximate engine serial number 6D-82217.

The new spring can be used only in engines built after engine serial number 6D-60776 that employ the present low lift camshaft, or older engines which have these camshafts installed.

> **NOTE:** The low lift camshaft which provides a maximum valve cam lobe lift of .276 " is stamped V7L at both ends.
>
> **CAUTION:** The use of the new spring with the former high-lift camshaft (.327 " valve cam lobe lift, stamped V7 or V at both ends) will cause the valve springs to bottom out, resulting in bent push rods and possible engine damage.

The new exhaust valve spring has a wire diameter of .148 "; the former exhaust valve spring has a wire diameter of .135 ".

For service replacement, change the new spring when a load of less than 25 lbs. will compress it to 1.93 " (installed length).

The new and former valve springs are interchangeable in an engine rated below 2800 rpm using a low-lift (V7L) camshaft. However, on any given valve bridge, it is recommended that both springs be the same.

When a former spring is replaced in an engine rated at 2800 rpm with a low lift (V7L) camshaft, all of the springs must be replaced with the new spring.

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

Carbon on the face of a valve indicates 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 light 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.

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.

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 inside diameter of the valve guides with brush J 5437 (two valve head) or brush J 7793 (four valve head) as shown in Fig. 4. This brush will remove all gum and carbon deposits from the valve guides.

Inspect the valve guides for fractures, scoring or excessive wear. Check the valve-to-guide clearance, since worn valve guides may eventually result in improper valve seat contact. If the clearance exceeds .006 " (two valve head) or .005 " (four valve head), replace the valve guides.

The current valve guides, which are not machined for use with oil seals, have a 45 ° chamfer at the upper end. They replace the former 15 ° chamfer valve guides for service.

Remove Exhaust Valve Guide

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

2. Drive the valve guide out of the cylinder head with valve guide remover J 6569 (two valve head) or J 7775 (four valve head) as shown in Fig. 5.

Install Exhaust Valve Guide

Turn the cylinder head right side up and install the valve guide as follows:

1. Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to the *Valve Guide Installing Tool* chart). Be sure to use the correct tool to avoid damage to the valve guide and to locate the valve guide to the proper dimension.

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. 6). Then press the guide in until the tool contacts the cylinder head (the bottom of the counterbore in the four valve cylinder head).

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

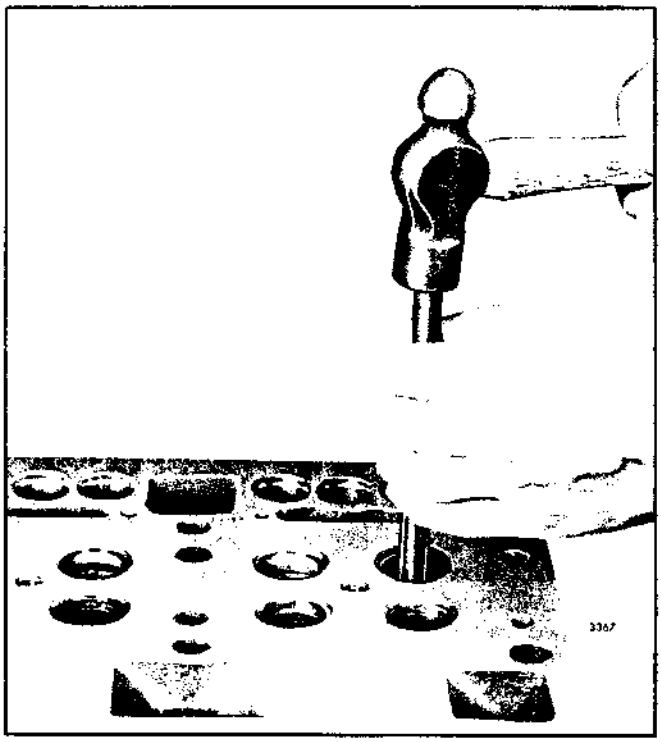


Fig. 5 - Removing Valve Guide

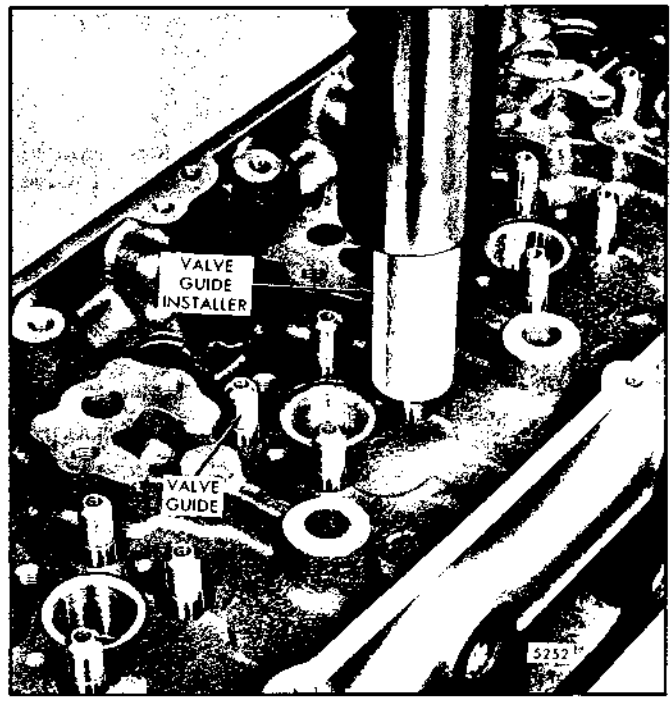


Fig. 6 - Installing Valve Guide

Tool No.	Cyl. Head	Valve Guide	Distance of Guide Below Top of Head
J 7560	2 Valve	15° Chamfer	.010"-.040"
J 7832	4 Valve	15° Chamfer	.010"-.040"
J 9756	2 Valve	45° Chamfer	.010"-.040"
J 9729	4 Valve	45° Chamfer	.010"-.040"
J 9730	4 Valve	*	.190"-.220"

*Machined for use with valve guide oil seal.

Valve Guide Installing Tools

Inspect Exhaust Valve Seat Insert

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

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 on a bench as shown in Fig. 7.

2. Place the collet of tool J 6974 (two valve head) or

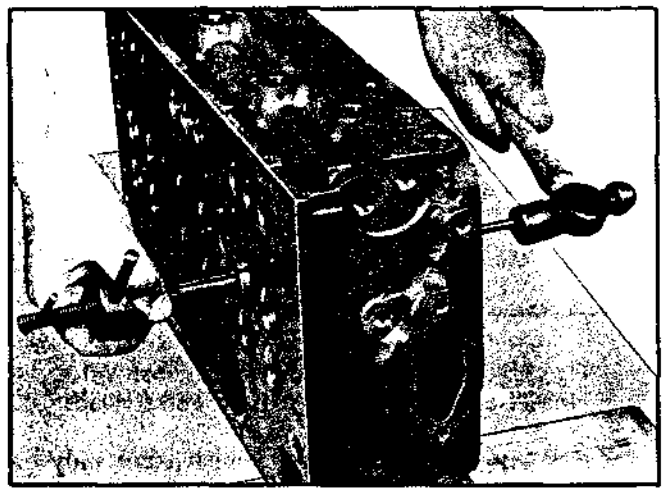


Fig. 7 - Removing Valve Seat Insert

J 7774 (four valve head) inside the valve 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 1/16 " away from its seat in the cylinder head.

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.

Install Exhaust Valve Seat Insert

1. Clean the valve seat insert counterbores in the 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 for cleanliness, concentricity, flatness and cracks. The counterbores in a two valve head have a diameter of 1.439 " to 1.440" and a depth of .294 " to .306 ". The counterbores in a four valve head have a diameter of 1.159 " to 1.160 " and a depth of .294 " to .306 " on former engines and a depth of .300 " to .312 " on current engines.

NOTE: Valve seat inserts which are .010 "

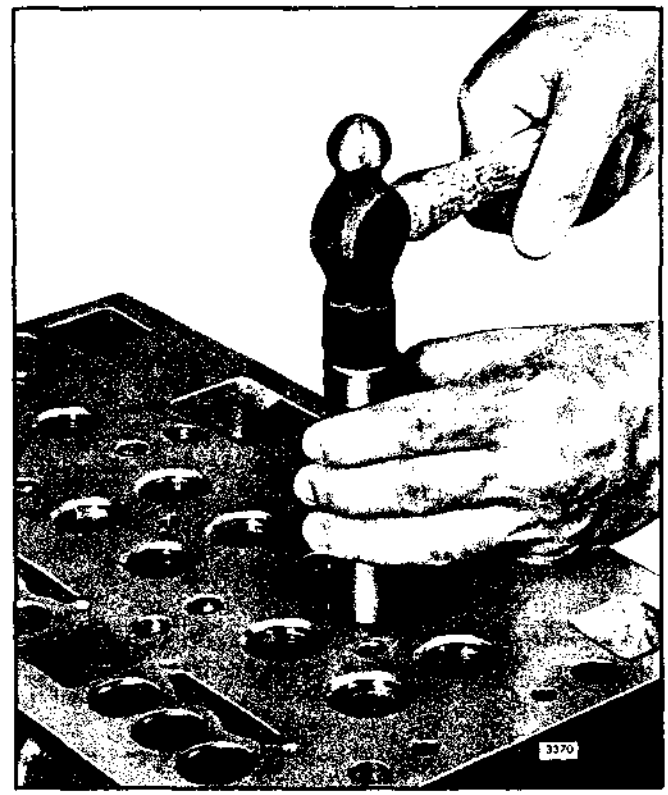


Fig. 8 - Installing Valve Seat Insert

oversize on the outside diameter are available, if required.

3. Immerse the cylinder head for at least 30 minutes in water heated to 180 °F. to 200 °F.

4. Rest the cylinder head, bottom side up, on a bench and place an insert in the counterbore--valve seat side up. This must be done quickly while the cylinder head is still hot and the insert is cold (room temperature). If the temperature of the two parts is allowed to become nearly the same, installation may become difficult and damage to the parts may result.

5. Drive the insert in place with installer J 6976 (two valve head) or J 7790 (four valve head) as shown in Fig. 8 until it seats solidly in the cylinder head.

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

Recondition Exhaust Valve and Valve Seat Insert

An exhaust valve which is to be reused may be refaced, if necessary (Fig. 9). To provide sufficient valve strength and spring tension, the edge of the

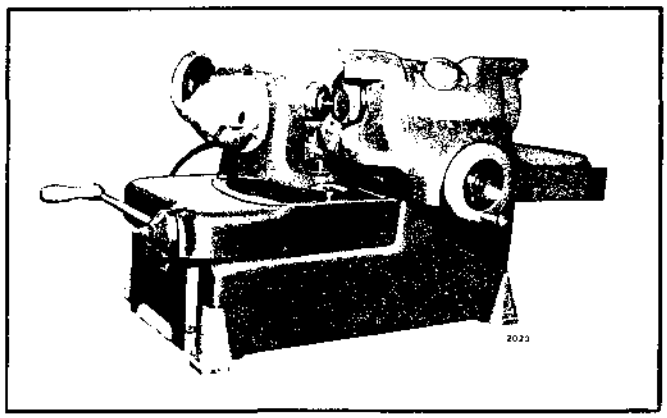


Fig. 9 - Refacing Exhaust Valve

valve at the valve head must not be less than 1/32 " in thickness and must still be within the specifications shown in Figs. 11 and 12 after refacing.

Before either a new or used valve is installed, examine the valve seat in the cylinder head for proper valve seating. The angle of the valve seat insert must be exactly the same as the angle of the valve face to provide proper seating of the valve. The proper angle for the seating face of both the valve and valve seat insert is 30 °.

When a new valve seat insert is installed or an old insert refaced, the work must be done with a grinding wheel (Fig. 10).

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method

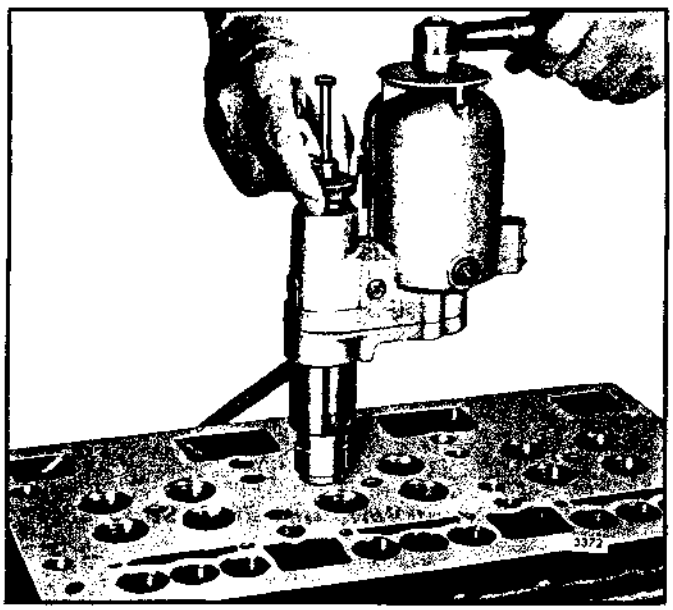


Fig. 10 - Grinding Valve Seat Insert

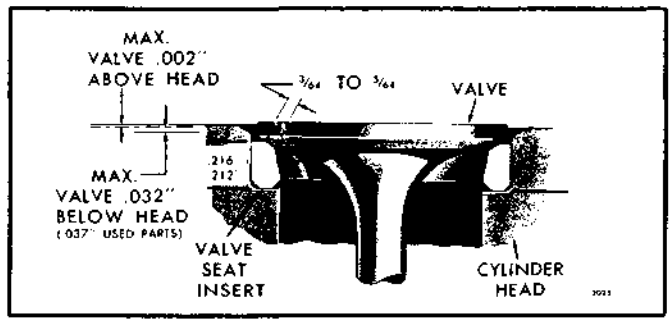


Fig. 11 - Relationship Between Exhaust Valve, Insert and Cylinder Head (Two Valve Head)

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.

To grind the valve seat inserts for a two valve cylinder head, use the following tools:

1. Grinder J 8165-1
2. Dial Gage J 8165-2
3. Pilot J 7659-1
4. Grinding Wheel (15 °) J 7924-1
5. Grinding Wheel (30 °) J 7924-2
6. Grinding Wheel (60 °) J 7924-3

To grind the valve seat inserts for a four valve cylinder head, use the following tools:

1. Grinder J 8165-1
2. Dial Gage J 8165-2
3. Pilot J 7792-1
4. Grinding Wheel (15 °) J 7792-2
5. Grinding Wheel (30 °) J 7792-3
6. Grinding Wheel (60 °) J 7792-4

Grind the valve seat inserts as follows:

1. First apply the 30 ° grinding wheel on the valve seat insert.

2. Use the 60 ° grinding wheel to open the throat of the insert.

3. Then grind the top surface with a 15 ° wheel to narrow the width of the seat from 3/64 " to 5/64 "

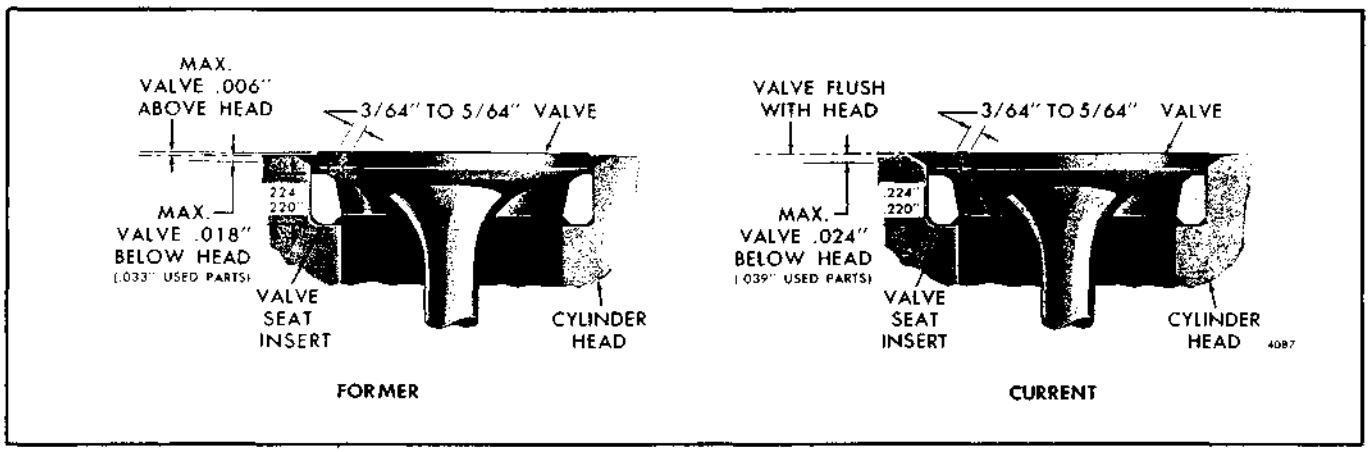


Fig. 12 - Relationship Between Exhaust Valve, Insert and Cylinder Head (Four Valve Head)

(Figs. 11 and 12). The 30 ° face of the insert may be adjusted relative to the center of the valve face with the 15 ° and 60 ° grinding wheels.

CAUTION: Do not permit the grinding wheel to contact the cylinder head when grinding the insert. If necessary, replace the insert.

The maximum amount that the exhaust valve should protrude beyond the cylinder head (when the valve is in the closed position), and still maintain the proper piston-to-valve clearance, is shown in Figs. 11 and 12. 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.

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. 13).

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. 14 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.

4. 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:

a. Apply a light coat of Prussian Blue or similar paste to the valve seat insert.

b. 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.

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

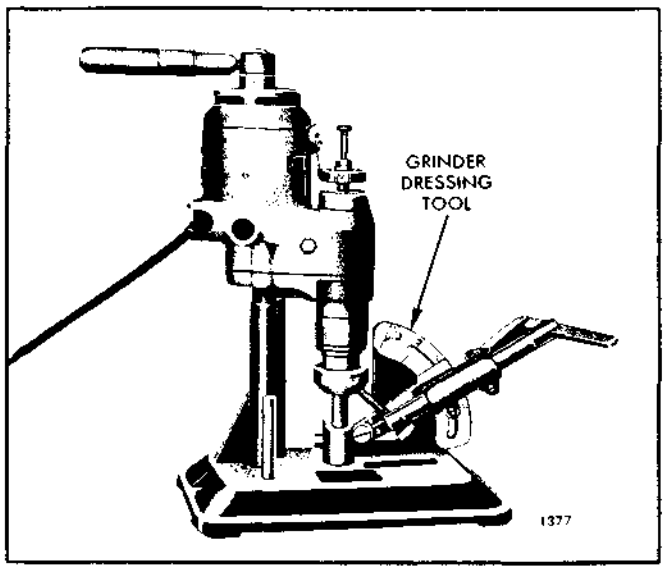


Fig. 13 - Grinding Wheel Dressing Tool of Set J 8165

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications shown in Figs. 11 and 12. Also, do not use "N" pistons with former four valve cylinder head assemblies unless the valves are flush with the cylinder head. If the valves are not flush, it may be necessary to regrind the valve seats so that

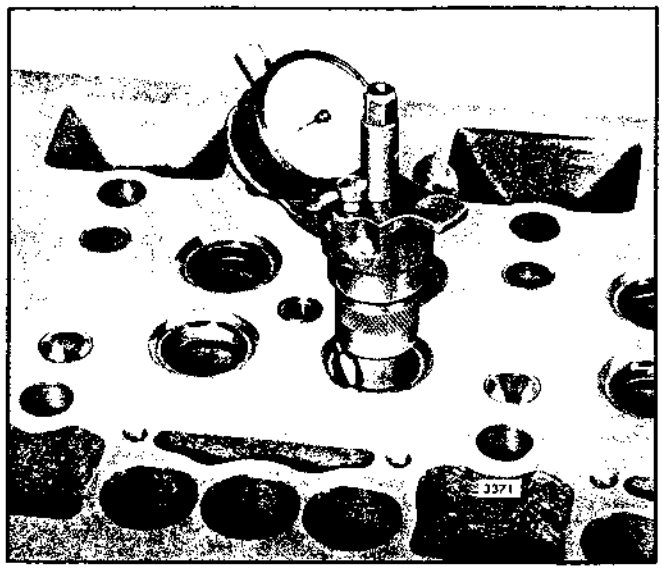


Fig. 14 - Checking Relative Concentricity of Valve Seat Insert with Relation to Valve Guide

the valves will be flush with the bottom surface of the cylinder head.

NOTE: The distance from the top of the four valve cylinder head to the bottom of the valve spring seat counterbore is 1-11/64 " in current design cylinder heads or 1-5/64 " in former design heads.

Be sure and install the correct parts in the four valve cylinder head. Current design cylinder heads are equipped with the thin valve spring seats (.060 ") and current design exhaust valves (Fig. 15). To facilitate replacement of a four valve head on an engine using the former exhaust valves, the proper quantity of the thick spring seats (.150 ") must be used.

Service cylinder heads are of the current design. The current thin valve spring seats (.060 ") are included with each cylinder head as a shipped loose item.

1. 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.

2. 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.

3. Install the valve spring seats.

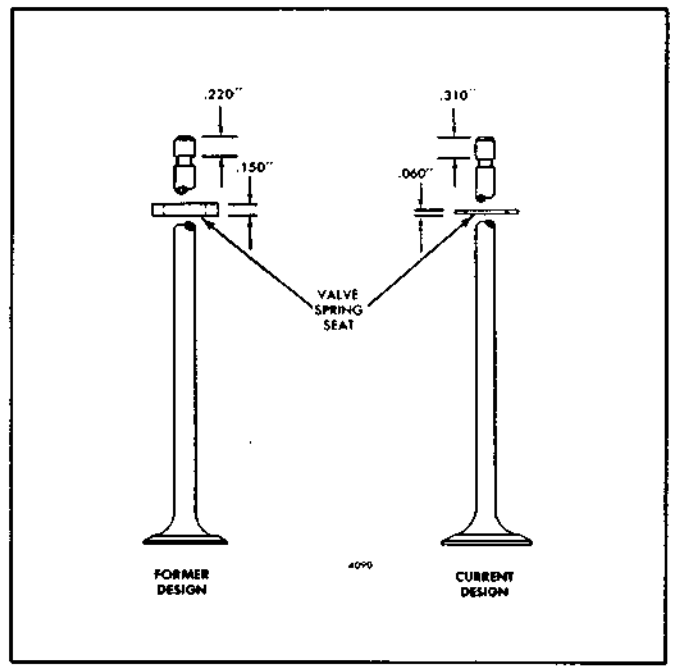


Fig. 15 - Former and Current Design Exhaust Valves (Four Valve Head)

4. 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.

5. Install the valve springs and valve spring caps.

6. Thread the valve spring compressor J 7455 into one of the rocker shaft bolt holes in the cylinder head (Fig. 2).

7. 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. Tap the end of the valve stem lightly with a plastic hammer to seat the valve locks.

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.

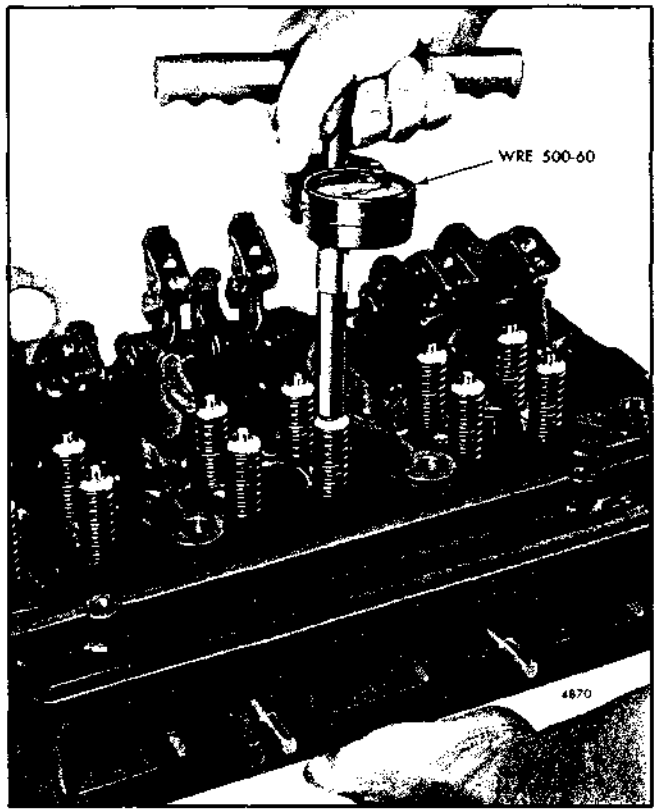


Fig. 16 - Checking Valve Opening Pressure with Gage WRE-500-60

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

9. Check the position of the exhaust valve (Fig. 11).

10. With the exhaust valves installed in the cylinder head, use spring checking gage WRE -500-60 and note the gage reading the moment the exhaust valve starts to open (Fig. 16). The minimum pressure required to start to open the exhaust valve must not be less than 33 pounds for a two valve cylinder head or 25 pounds for a four valve cylinder head.

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

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

13. Perform a complete engine tune-up.

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 flanged edge of the cover.

An option plate is inserted in a retainer (Fig. 1) attached to the cover on each In-Line engine and to one of the covers on a V-type engine.

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

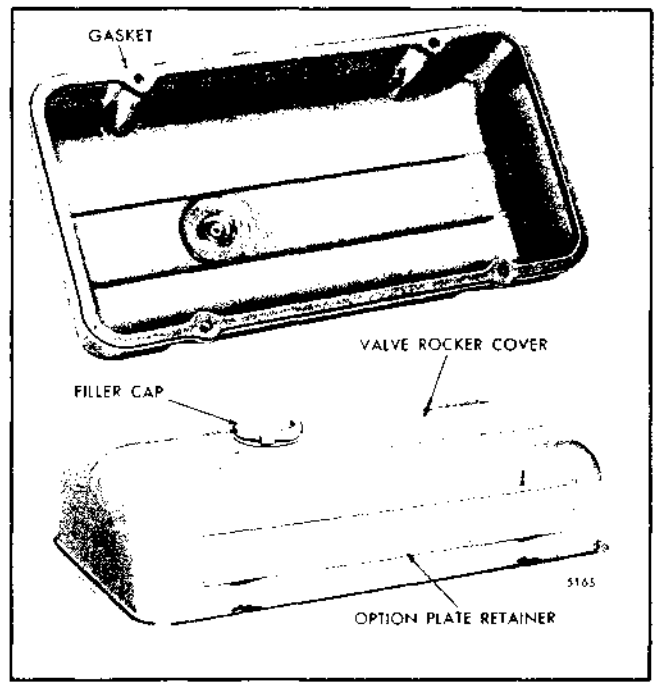


Fig. 1 - Typical Valve Rocker Cover Assembly

Remove and Install Valve Rocker Cover

Clean the cover before removing it fron. the engine to avoid dust or dirt from entering the valve mechanism. Then remove the valve cover screws and lift the cover straight up from the cylinder head. Use a new gasket when installing the valve rocker cover.

CRANKSHAFT

The crankshaft (Figs. 1 and 2) for the Series 53 engine is a one-piece steel forging, heat-treated to ensure strength and durability. All main and connecting rod bearing journal and oil seal surfaces are induction hardened.

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

The crankshaft end thrust 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.

On certain 4-53 and 6V-53 engines, a crankshaft with splines at the front end is used. These engines use a splined crankshaft pulley and pulley mounting components.

On In-Line and 6V engines, six tapped holes are provided in the rear end of the crankshaft for attaching the flywheel.

On the 8V engine, two dowels are provided in the rear end of the crankshaft for locating the flywheel and six tapped holes are provided for attaching the flywheel. One hole is unequally spaced so that the flywheel can be attached in only one position.

In-line engine main bearing journals are 3 " in diameter and the connecting rod journals are 2-1/2 " in diameter. On the V-type engine the main bearing journals are 3-1/2 " in diameter and the connecting rod journals are 2-3/4 " in diameter.

Effective with 8V engine serial number 8D-149, the 2.878 " diameter position at the front of the crankshaft serves as a journal for the outboard bearing (bushing type). A spacer (sleeve) is used on the 2.5000 " diameter position to provide a replaceable contact surface for the front oil seal which is located in the outboard bearing support assembly. Prior to engine 8D-149, the 2.878 " diameter position served as a contact surface for the front oil seal assembled in the front cover.

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 brackets

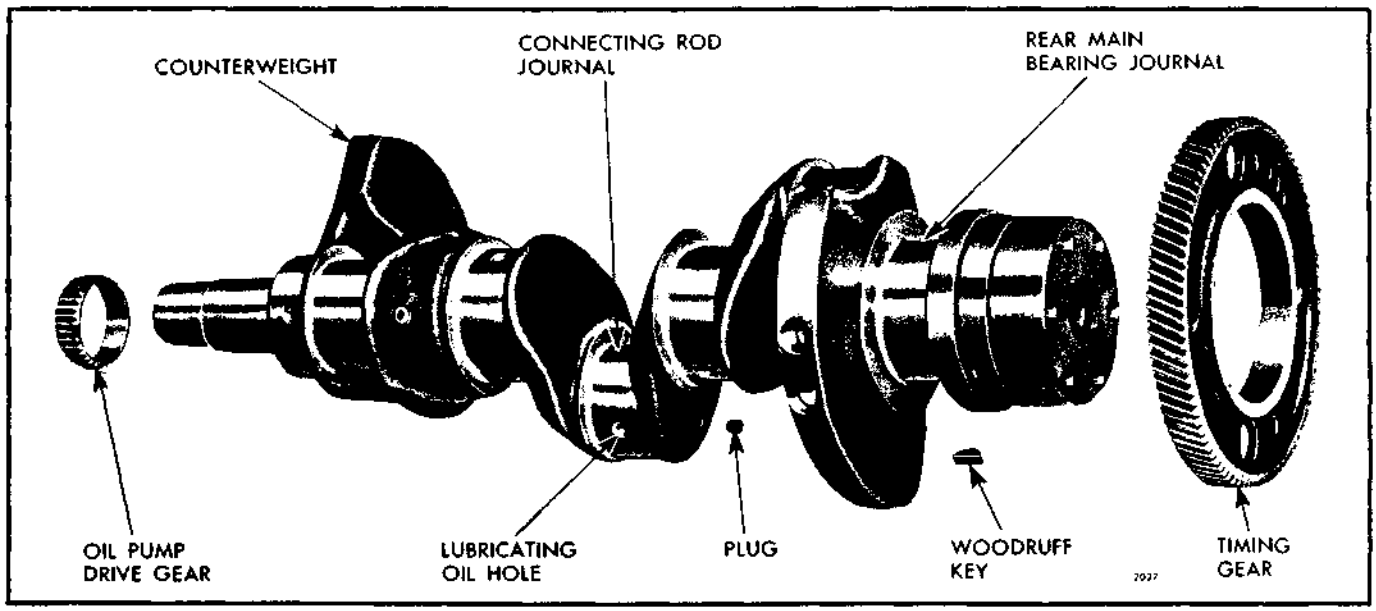


Fig. 1 - Crankshaft Details and Relative Location of Parts (Three Cylinder In-Line Engine Crankshaft Shown)

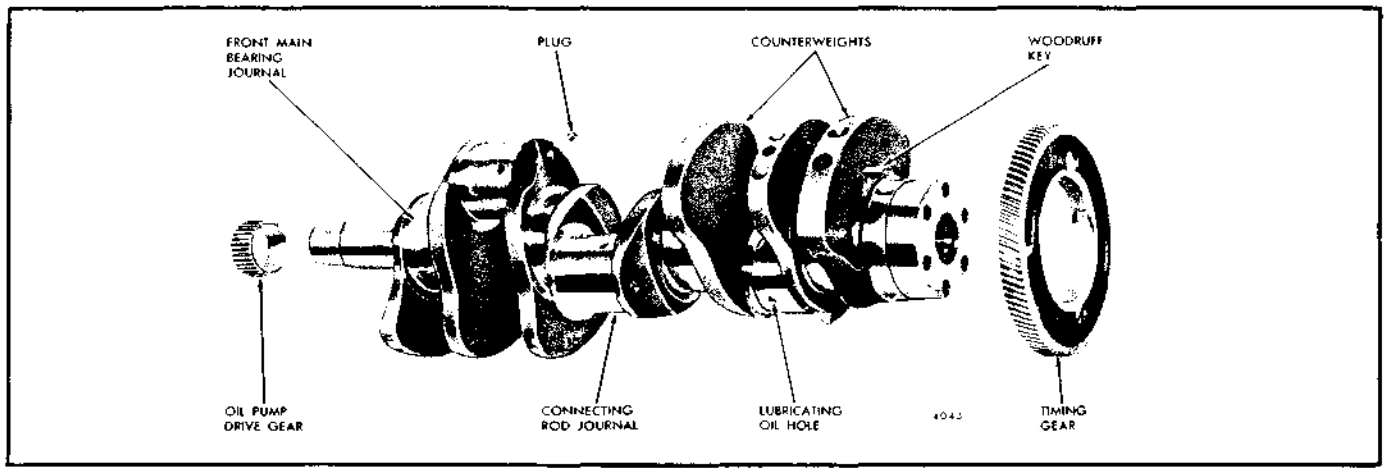


Fig. 2 - Crankshaft Details and Relative Location of Parts (6V-53 Engine Crankshaft Shown)

at each end of the engine, remove the engine from its base.

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 oil pump inlet pipe and screen.

9. Remove the flywheel and flywheel housing.

10. Remove the crankshaft pulley.

11. Remove the front engine support, if used.

12. Remove the engine lower front cover and oil pump assembly.

13. Remove the cylinder head(s).

14. On the V-type engines, remove the main bearing cap stabilizers.

15. Remove the connecting rod bearing caps.

16. Remove the main bearing caps.

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

18. Remove the pistons, connecting rods and liners.

19. Remove the crankshaft, including the timing gear (Fig. 3).

20. Refer to Section 1.7.5 for removal of the crankshaft timing gear and Section 4.1 for the procedure covering removal of the oil pump drive gear.

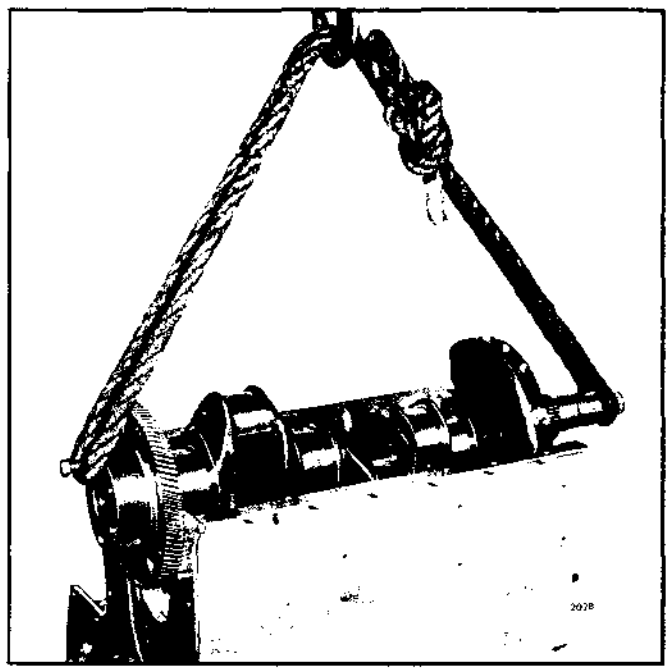


Fig. 3 - Lifting or Lowering Crankshaft from/into Cylinder Block

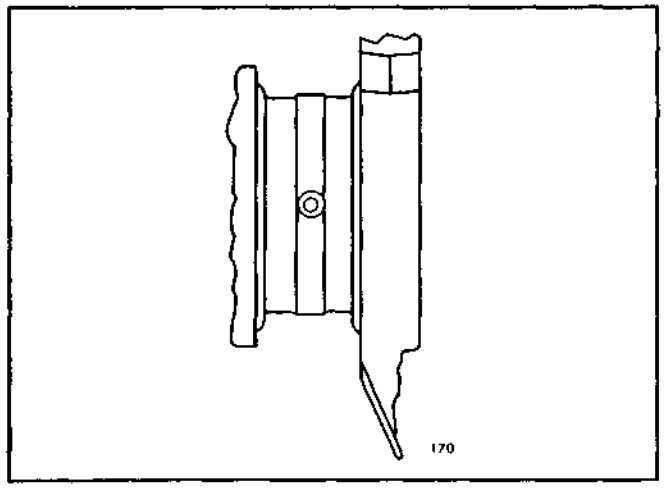


Fig. 4 - Typical Ridging of Crankshaft

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 plugs.

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

If the crankshaft has been subjected to excessive overheating, the heat treatment will be destroyed and a new crankshaft should be installed.

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. 4). 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 front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

Slight ridges on the crankshaft oil seal contact surfaces 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 seals may be repositioned in the flywheel housing and front cover 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.

On an 8V engine, check the crankshaft dowel extension. The dowels should 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 or in a lathe and check the alignment at the adjacent intermediate main journals with a dial indicator.

On 2, 3 and 4 cylinder in-line and 6V-53 crankshafts, the maximum runout on the intermediate journals must not exceed .002 " total indicator reading.

On an 8V-53 crankshaft, the maximum runout at the No. 2 and 4 journals must not exceed .002 "; the maximum runout at No. 3 journal must not exceed .004 " and the maximum runout on the outboard journal must not exceed .001 ".

On the 6V and 8V-53 crankshafts, when the runout on the adjacent journals is in opposite directions, the sum must not exceed .003 " total indicator reading. When the runout on the adjacent journals is in the same direction, the difference must not exceed .003 " total indicator reading. When high spots of runout on the adjacent journals are at right angles to each other, the sum must not exceed .004 " total indicator reading, or .002 " on each journal. If the runout limit is greater than given above, the crankshaft must be replaced.

Measure all of the main and connecting rod bearing

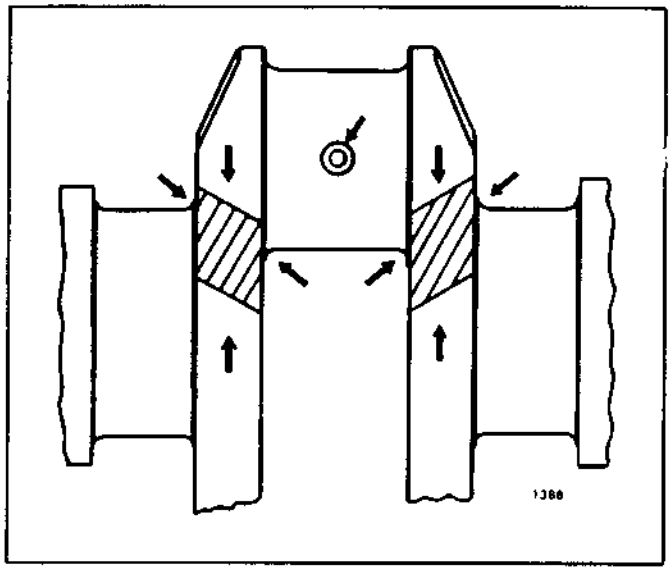


Fig. 5 - Critical Crankshaft Loading Zones

journals. 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 journal-to-bearing shell clearance (with new shells) exceeds .0045 " (In-line engine) or .0041 " (V-type engine), or the main bearing journal-to-bearing shell clearance (with new shells) exceeds .0040 " (In-line and V type engines), the crankshaft must be reground. Also, if the journal taper or out-of-round is greater than .003 ", the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .002 ".

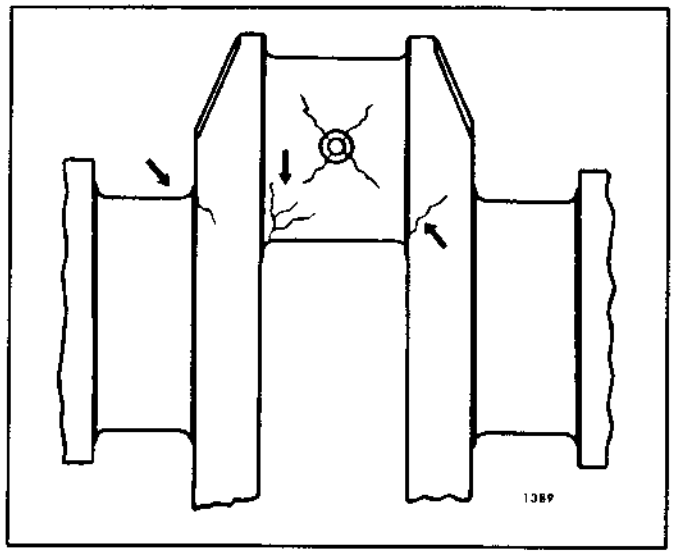


Fig. 6 - Crankshaft Fatigue Cracks

Inspection for Cracks

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

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

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

Fluorescent Penetrant Method: This is a method which may be used on *non-magnetic* materials such as stainless steel, aluminum and plastics. A highly fluorescent liquid penetrant is applied to the part. Then, the excess penetrant is wiped off and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by

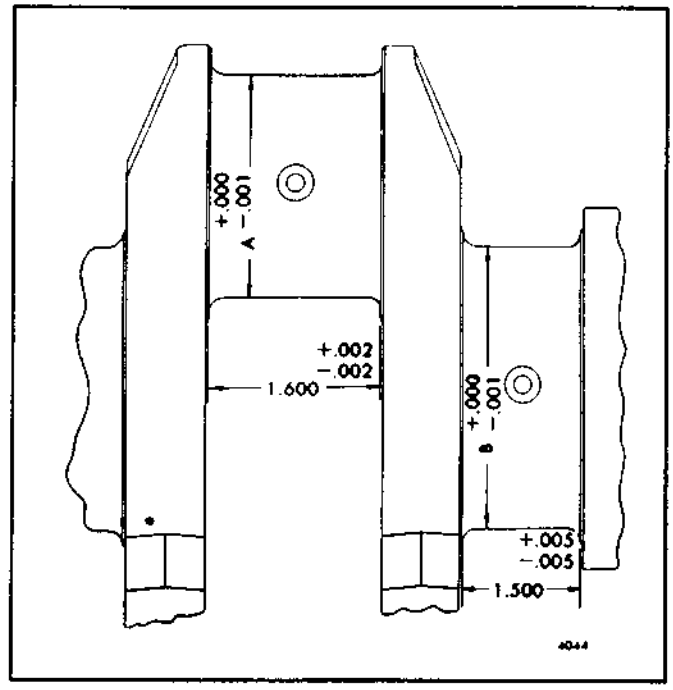


Fig. 7 - Dimensions of Crankshaft Journals - In-line Engine

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 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, however, sustain most of the load (Fig. 5).

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

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

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

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

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration,

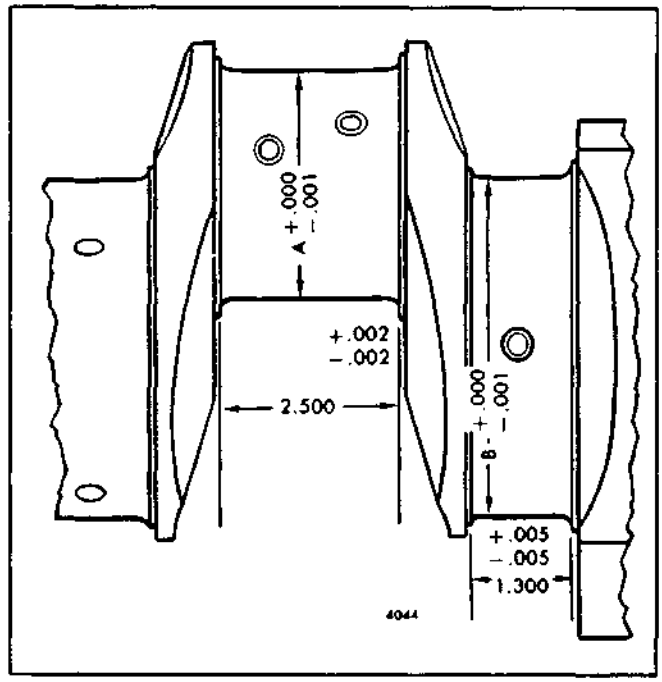


Fig. 8 - Dimensions of Crankshaft Journals - V-Type Engine

referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 5.

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

A loose, damaged or defective vibration damper, 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

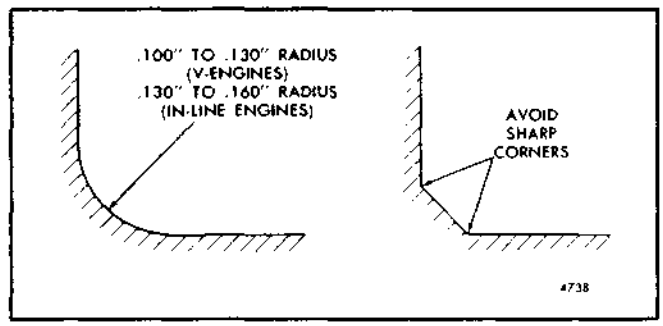


Fig. 9 - Crankshaft Journal Fillets

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

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, .002 ", .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 1 and Figs. 7 or 8 and determine the size to which the journals are to be reground.

Measurement of the crankshaft journals, and comparison of these measurements to the diameters required for various undersize bearings shown in Figs. 7 or 8 and Table 1, will determine the size to which the crankshaft journals must be reground.

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.

Bearing Size	Conn. Rod Journal Dia.	Main Bearing Journal Dia.
In-Line Engines		
Standard	2.500"	3.000"
.002" Undersize	2.500"	3.000"
.010" Undersize	2.490"	2.990"
.020" Undersize	2.480"	2.980"
.030" Undersize	2.470"	2.970"
V-Engines		
Standard	2.750"	3.500"
.002" Undersize	2.750"	3.500"
.010" Undersize	2.740"	3.490"
.020" Undersize	2.730"	3.480"
.030" Undersize	2.720"	3.470"

TABLE 1

3. All journal fillets on the In-line crankshafts must have a .130 " to .160 " radius and on the 6V and 8V crankshafts, a .100 " to .130 " radius between the crank cheek and the journal, and must not have any sharp grind marks (Fig. 9). The fillet must blend smoothly into the journal and the crank cheek, and must be free of scratches. The radius may be checked with a fillet gage.

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

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

6. If the thrust surfaces of the crankshaft are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .130 " to .160 " radius on the In-line crankshaft and .100 " to .130 " radius on the 6V and 8V engines between each thrust surface and the bearing journal (Fig. 9).

7. Stone the edge of all oil holes in the journal surfaces 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.

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to

Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	.1190"	.1220"
.005" Oversize	.1255"	.1270"
.010" Oversize	.1300"	.1320"

TABLE 2

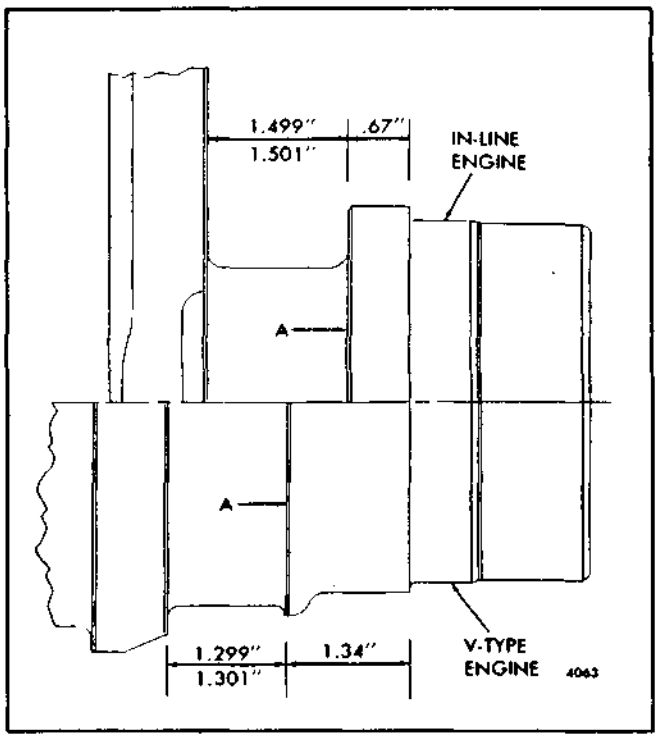


Fig. 10 - Standard Dimensions at Rear Main Bearing Thrust Washers--In-Line and V-Type Engines

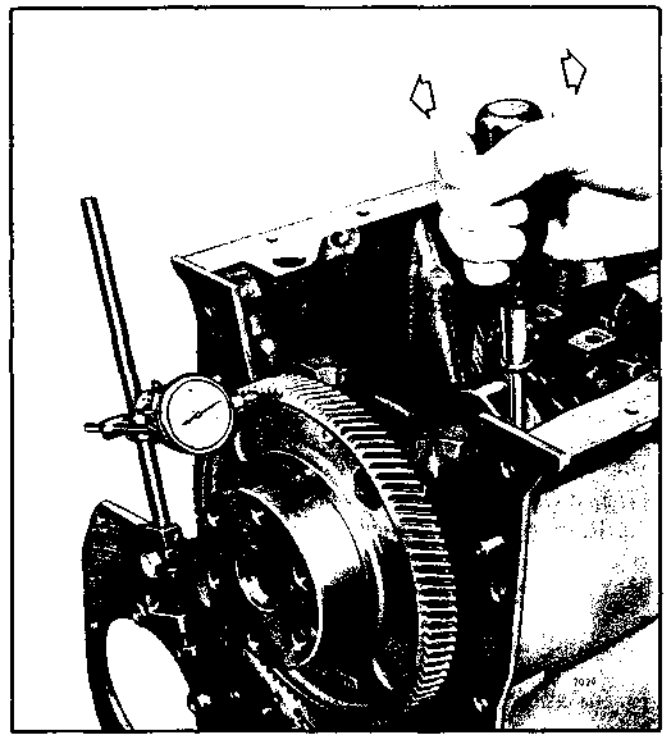


Fig. 11 - Checking Crankshaft End Play

remove the rust preventive, blow out the oil passages with compressed air and install the plugs. Then, install the crankshaft as follows:

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

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

2. Install the upper *grooved* 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.

3. Apply clean engine oil to all crankshaft 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 washers 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. 10 and Table 2.

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. Lubricate the bolt threads and bolt head contact surfaces with a small quantity of International Compound No. 2, or equivalent. Install the bearing caps and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly.

6. Draw the bearing cap bolts uniformly tight, starting with the center cap and working alternately toward both ends of the block, to 120-130 lb-ft torque. On a V-type engine, tighten the stabilizer to cylinder block bolts to 46-50 lb-ft torque. Rotate the crankshaft to make sure that it rotates freely.

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 (Fig. 11) with a pry bar. 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 should be .004 " to .011 " 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 head(s) (refer to Section 1.2).

10. Install the flywheel housing (Section 1.5), then install the flywheel.

11. Install the crankshaft lower engine front cover and the lubricating oil pump assembly on In-line and 6V engines or the engine front cover and outboard bearing support on 8V engines (Section 1.3.5).

12. Install the engine front support, if used.

13. Install the crankshaft pulley (Section 1.3.7).

14. Install the oil pump inlet pipe and screen on In-line and 6V engines; on the 8V engine, install the lubricating oil pump, inlet pipe and screen assembly (Section 4.1).

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

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

17. Install all of the accessories that were removed.

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

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

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