Bulletin 983694-OE Printed 5-70
Cummins Engine Company, Inc.
Columbus, Indiana, U.S.A. 47201

Shop Manual

Cummins Diesel V-1710 Series

Foreword

Cummins Diesel Engines treated in this manual are 40 deg. "V" 12 cylinder, four-stroke cycle, high-speed, full-diesel engines.

The engine models covered in this manual can be identified as to design, breathing (if no letter "T," engine is naturally aspirated), cubic inch displacement, application and maximum rated horsepower by the following code:

Example: VTA-1710P700

V—Engine
T—Turbocharged
A—After cooled intake manifold
1710—Cubic inch displacement
P—Industrial application
700—Maximum rated horsepower

Other applications designations are:

B—Off-highway vehicle
C—Construction
P—Industrial
GS—Generator-Standby
GC—Generator-Prime Power
M—Marine

This unit rebuild manual was written for service personnel who repair or rebuild Cummins V-1710 series engines and units used thereon. The engines included under the basic series are naturally aspirated and turbocharged as listed on pages 5 and 6.

The Cummins V-1710 series engines described in this manual are improved models of the 5-1/2 inch bore engines with the following major improvements.

1. Internal (oil pan enclosed, cylinder block mounted) lubricating oil pump, suction line and discharge line to drillings in cylinder block.

2. Internal oil drillings, to and from cooler and filters, to eliminate periodic hose replacements.

3. Combination oil cooler and full flow oil filter assembly mounted directly to the cylinder block, for closer oil temperature control, improved filtering efficiency and freedom from hose problems.

4. Engine serial number nameplates for current production V-1710 series engines with internal lubricating oil pump have a suffix "3" in engine serial number.

Suffix "3" indicates the engine has a larger crankshaft, main bearing cap side bolts and improved one-piece rear cover and seal.

The above changes reduce maintenance costs, eliminate exterior lines and connections, and generally simplify engine servicing.

At the overhaul period this engine will be easy to disassemble, inspect, repair or rebuild and assemble. Instructions for each operation and for each unit on the engine are described in this manual, or referred to another Cummins Manual if the unit is used on several series of engines.

The manual is so arranged that each section essentially becomes a manual within itself, and if desired can be separated from the balance of the manual so each section can be used in separate areas of a shop.

For the convenience of those using tools calibrated in metric measurements, all wear limits and specifications have been converted to millimeters or other metric units.

Cummins Distributors have special tooling, trained personnel and genuine Cummins service parts for all phases of engine repair and rebuilding.

Cummins Engine Company, Inc.
Columbus, Indiana, U.S.A. 47201

Table of Contents

All information listed below and covered in this manual can be identified by the base manual bulletin number 983694. Assemblies not covered in this manual but covered in other manuals can be identified by their respective manual bulletin numbers. These consist of units common to several series of Cummins Engines.

Introduction

Engine Disassembly — Group 0

All Units 983694

Cylinder Block — Group 1

Cylinder Block . . . . Unit 101 983694
Cylinder Liners . . . . Unit 102 983694
Idler Gear . . . . Unit 103 983694
Crankshaft . . . . Unit 104 983694
Bearings . . . . Unit 105 983694
Vibration Damper . . . . Unit 106 983694
Counterbalancer . . . . Unit 107 . . . . . . None
Connecting Rod . . . . Unit 108 983694
Piston and Rings . . . . Unit 109 983694
Camshaft . . . . Unit 110 983694
Gear Cover . . . . Unit 111 983694
Rear Cover . . . . Unit 112 983694

Cylinder Head — Group 2

Cylinder head . . . . Unit 201 983694
Injector Sleeve . . . . Unit 202 983694
Valve Seat/Inserts . . . . . . Unit 203 983694
Valve Crosshead/Guides . . . Unit 204 983694
Valves, Guides, Springs . . . . Unit 205 983694

Rocker Lever — Group 3

Levers and Housing . . . . . . Unit 301 983694
Push Tube . . . . Unit 302 983694
Crankcase Breather . . . . . . Unit 303 983694
Cover . . . . Unit 304 983694

Tappets — Group 4

Cam Followers . . . . Unit 401 . . . . . . None
Tappets . . . . Unit 402 983694

Fuel Pump — Group 5

Fuel Pumps . . . . Unit 501 983535
Fuel Filters . . . . Unit 502 983535
Housing . . . . Unit 503 983535
Gear Pump/Damper . . . . . Unit 504 983535
Shut-down Valve . . . . Unit 505 983535
Front Cover . . . . Unit 506 983535
Governor Spring Pack . . . . Unit 507 983535
Pressure Regulator . . . . . . Unit 508 983535
Tanks and Line . . . . Unit 509 983535
Assembly . . . . Unit 510 983535
Calibration (Type R) . . . . . Unit 511 983505
Calibration (Type G) . . . . . Unit 511 983525
Auxiliary Equipment . . . . . Unit 512 983535

Injector — Group 6

Injectors . . . . Unit 601 983536
Lines/Connections . . . . . . Unit 602 983536

Lubricating System — Group 7

Oil Pan . . . . Unit 701 983694
Oil Lines . . . . Unit 702 983694
Dipstick . . . . Unit 703 983694
Filters . . . . Unit 704 983694
Cooler . . . . Unit 705 983694
Pump . . . . Unit 706 983694

Cooling System — Group 8

Water Pump . . . . Unit 801 983694
Fan Hub . . . . Unit 802 983694
Thermostats . . . . Unit 803 983694
Corrosion Resistor . . . . . . Unit 804 983694
Heat Exchanger . . . . Unit 805 983694
Raw (Sea) Water Pump . . . . Unit 806 983694
Radiator . . . . Unit 807 983694
Thermal Controls . . . . Unit 808 983694
Intercooler . . . . Unit 809 983694
Auxiliary Fan Drives . . . . . Unit 810 983538

Drive Unit — Group 9

Fuel Pump/Compressor . . . Unit 901 983694
Generator . . . . Unit 902 983694
Supercharger . . . . Unit 903 . . . . . . None

Intake Air System — Group 10

Air Cleaner/Piping . . . . . . Unit 1001 . . . 983694
Cold Starting . . . . Unit 1002 . . . 983694
Aneroid . . . . Unit 1003 . . . 983694

Index

Supercharger . . . . .Unit 1004 . . . . . None
Turbocharger (T-50) . . . . . .Unit 1005 983615
Turbocharger (VT-50) . . . . .Unit 1005 983681
Turbocharger (T-18A) . . . . .Unit 1005 983678

Exhaust System — Group 11

Manifolds . . . . .Unit 1101 983694
Mufflers/Piping . . . . .Unit 1102 983694
Auxiliary Equipment . . . . . .Unit 1103 983694

Air Equipment — Group 12

Compressor . . . . .Unit 1201 983542
Vacuum Pump . . . . .Unit 1202 983542
Starting . . . . .Unit 1203 983542

Electrical Equipment — Group 13

Starting Motor . . . . .Unit 1301 983694
Alternator/Generator . . . . . .Unit 1302 983694
Wiring Diagrams . . . . .Unit 1303 983444
Mag-tronic Ignition . . . . . . .Unit 1305 983694

Engine Assembly — Group 14

Assembly . . . . .Unit 1401 983694
Testing . . . . .Unit 1402 983694
Storage . . . . .Unit 1403 983694

Instruments and Controls — Group 15

Engine Safety Controls . . . . .Unit 1501 983694

Engine Adaptations — Group 16

Flywheel/Housings . . . . . . .Unit 1601 983694
Flywheel Drives . . . . .Unit 1602 983694
Mountings . . . . .Unit 1603 983694
Marine Gear . . . . .Unit 1605 983694

Wear Limits/Specifications — Group 18

V-1710 Series . . . . .Unit 1801 983694

Vehicle Braking — Group 20

Retarders . . . . .Unit 2002 983694

Power Generators — Group 21

Static Type . . . . .Unit 2101 983600
Brushless . . . . .Unit 2102 983679

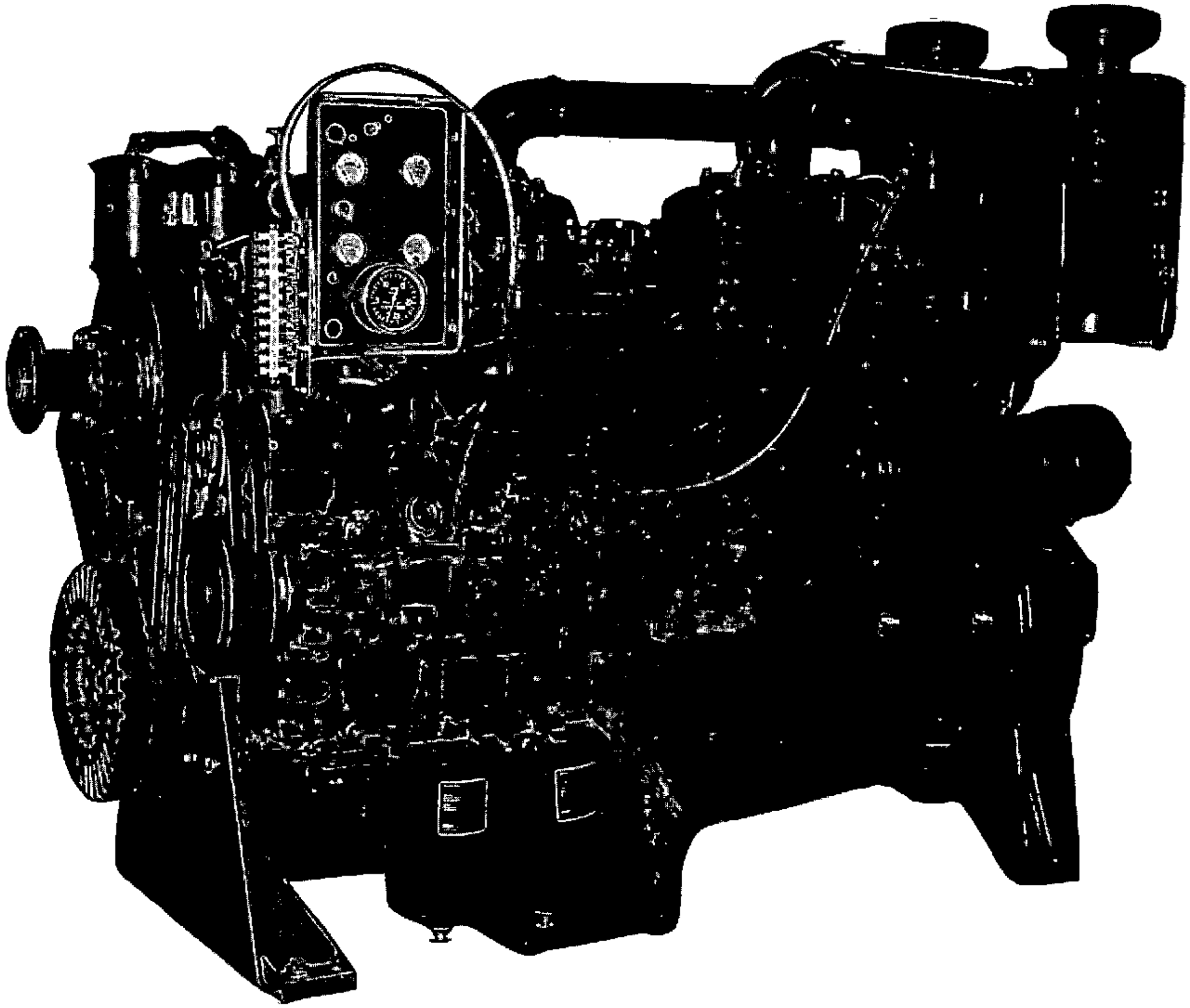


Table 1: Cummins V-1710 Naturally Aspirated Engines

Model	Bore & Stroke Inch [mm]	Displacement Cu. Inch [cu cm]	Sea Level Max. Torque @ RPM Ft.-Lts. [kg m]	Sea Level Max. HP @ RPM
V-1710-460	5-1/2 x 6 [139.7 x 152.4]	1710 [2802.9410]	1265 @ 1500	460 @ 2100
V-1710-500	5-1/2 x 6 [139.7 x 152.4]	1710 [2802.9410]	1440 @ 1600	500 @ 2100

1. Horsepower ratings (stated in U.S. values) established at 29.92 In./Hg. barometric pressure (sea level), 60 deg. F [15.5 deg. C] air intake temperature, dry air. Derate naturally aspirated engines 3% for each 1000 ft. [304.800 m] above sea level and 1% for each 10 deg. F [5.56 deg. C] rise in air temperature.

May be either C, P, PG, M, GS/GC or L according to application.

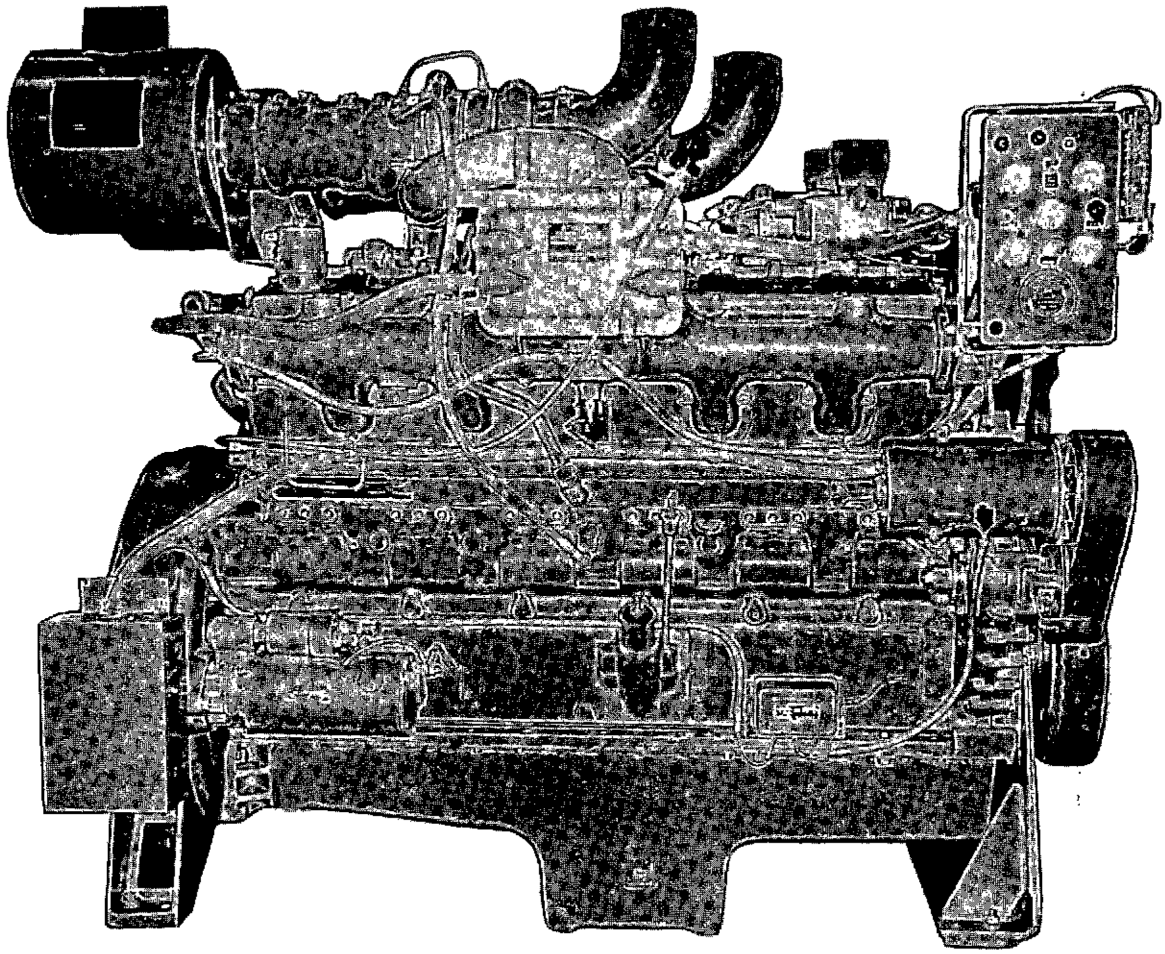


Table 2: Cummins V-1710 Turbocharged Engines

Model	Bore & Stroke, Inch [mm]	Displacement Cu. Inch [cu cm]	Max. Altitude Ft. [mm]	Max. Torque @ RPM Ft-Lbs. [kg m]	Max. HP @ RPM
VT-1710-635	5 1/2 x 6 [139.7 x 152.4]	1710 [2802.9410]	11,000 [3352.8000]	1750 @ 1500 [242.0250]	635 @ 2100
VTA-1710-700	5 1/2 x 6 [139.7 x 152.4]	1710 [2802.9410]	8,500 [2590.8000]	1920 @ 1500 [265.5360]	700 @ 2100
VTA-1710-800	5 1/2 x 6 [139.7 x 152.4]	1710 [2802.9410]	7,500 [2285.6000]	2200 @ 1550	800 @ 2100

1. Horsepower ratings (stated in U.S. values) established at 29.92 In./Hg. barometric pressure (sea level), 60 deg. F [15.5 deg. C] air temperature, dry air.
2. Turbocharged engines are derated 4% for each 1000 ft. [304.800 m] altitude above maximum altitude stated above and 1% for each 10 deg. F [5.56 deg. C] air temperature rise above 100 deg. F [37.8 deg. C].

May be either C, P, PG, GS/GC or L according to application.

Introduction

This manual covers all models, listed on preceding pages, built by Cummins Engine Company, Inc., Columbus, Indiana and its subsidiaries. These engines are used in many applications and have gained world wide recognition for their dependability and simplicity of operation, maintenance and repair.

The Manual And Its Arrangement

The V-1710 Shop Manual is written especially for service personnel overhauling the engines and components used thereon. The instructions are as brief as possible yet cover the essential operations necessary to completely disassemble, inspect, repair, assemble and test the complete engine.

Manual Sections

This manual is made up of several major sections each of which is numbered by group numbers, 0 through 21.

Major sections as listed in the Table of Contents are divided into sub-sections. For example, Group 1, which covers the cylinder block group, contains sub-sections 1 covering the cylinder block, 2 covering cylinder liners, 3 covering idler gear, etc. The Group number appears as a prefix to the section and page numbers on each individual page.

Unit Sections

Each unit contained within an engine group has been assigned a number so unit sections can be removed from the basic manual and taken to that area of the shop concerned with repair of the unit involved.

Note: If it is desired to remove pages or sections, bend manual back at beginning and end of section and pull out. The cover is glued in place and sections can be removed quite easily.

Many locations have already set up their parts departments utilizing the group and unit number; this provides a quick reference and a given location when a particular part or unit is required.

Page Numbers

Page numbers within the unit sub-section are numbered consecutively, starting with a new Page 1 at the beginning of each sub-section.

Table Numbers

Tables of dimensions, wear limits and torque values are numbered consecutively by group, section number and with a new Table 1 beginning at the front of each sub-section.

Illustration Numbers

Illustrations are numbered consecutively, beginning with group, section number and figure number at the beginning of each sub-section.

Location Of Information

Information regarding a particular part within a general group, such as a cylinder liner within the cylinder block group in which it is located, can best be located by using the Table of Contents. Under each Group is listed the units within the group and the group and unit number under which it appears. For example, the cylinder liner is a part of the Cylinder Block Group 1. Found under Group 1, the liner carries the unit number 102, as sub-section 2, to Group 1.

Parts Dimensions, Wear Limits And Torque Specifications

Parts dimensions are given in Tables within the Unit sub-section concerned with the part in question. Worn limits are also given in these tables throughout the manual. Torque specifications are within the text or tabulated the same as parts dimensions under the applicable unit sub-section.

At the end of the manual in Section 18, there is a complete tabulation of parts dimensions, worn limits and torque specifications. The experienced serviceman may prefer to work only from these condensed specifications, unless he is working with an unfamiliar part or unit.

Worn Limits

Worn limits as stated in this manual indicate that the part may be reused if it is at the worn limit. Discard only if it exceeds the worn limit. Of course, the reuse of any part is partially the responsibility of the person making the inspection, as it could well be damaged in an area not listed as a worn limit, thus making it unfit for further use.

Universal Units

Units such as fuel pumps, injectors, air compressors and turbochargers are also used on other models of Cummins Engines. These Group sections are in separate manuals and so written that they may be used with other engine shop manuals. These units are covered in full detail to make the information as useful and universally applicable as possible. Only a reference page to the proper separate manual appears in this Engine Shop Manual, refer to "Table of Contents."

Auxiliary Equipment

Units such as hydraulic governors, exhaust brakes, thermatic fans, etc. are sometimes used on Cummins Engines and in many cases are covered in this manual. In other cases, these special units are listed in the group in which they operate (hydraulic governors with Fuel Pump Group, etc.), but information is contained in separate manuals or must be obtained from the manufacturer.

Additional Information

Cummins Engine Company, Inc. is constantly improving its products and Cummins Distributors and Dealers are kept fully abreast of these improvements, and where possible the instructions to apply the improvements to engines already in service at the lowest possible cost to the engine owner. Information on improvements and changes is released and arranged using the group and unit number system so the Distributor or Dealer has a ready cross reference between this manual, new information and parts. Complete new products as released will be given unit numbers applying to the engine group within which it is used or if necessary a new group can be established.

Keep in close contact with the nearest Cummins Distributor or Dealer to remain current with the advances in design and release of new Cummins products.

Engine Disassembly Group

Unit removal is a simple operation; however, time and labor will be saved if the necessary steps are followed concerning unit removal. A few simple precautions are included in this manual that will help to prevent accidents and/or damage to the parts involved.

Unit Removal

Before disassembly of an engine, or any unit used on the engine, inspection of the over-all condition should be made and as much history as possible should be collected. These two items will provide clues to reasons for failure, if one occurred, and will furnish a great deal of information concerning necessary repair.

Inspection of each unit removed and tagging of electrical wires, bearing shell positions and other parts identification will help to insure correct assembly during the assembly operations.

Remove units and parts from cylinder block in the following order, paying particular attention to the precautions noted. Place removed parts and units (except electrical parts or those that could be damaged by steam cleaning) on a rack or cart for steam cleaning.

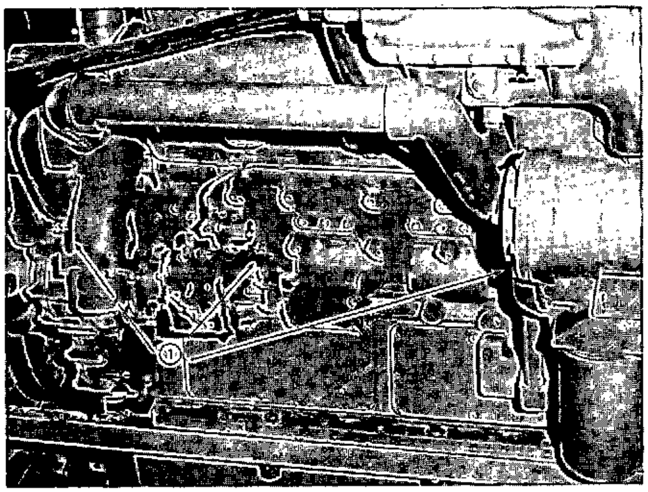


Fig. 0-1, V40033. Water drain points

Drain Water And Oil

1. Drain lubricating oil from oil pan, oil filters, oil cooler, hydraulic governor and air compressor.

2. Drain fuel from fuel pump, fuel filter(s), fuel lines and fuel pump float tank (if used).

3. Drain water from water pump, cylinder block (there are two drain cocks for each cylinder bank), radiator or heat exchanger, lubricating oil cooler housing, intercooler and expansion tank, as used. Fig. 0-1.

Note: Drain cocks on fuel pump side of block may be behind air compressor or fuel pump and oil filters.

4. Bleed compressed air system (when used).

Engine Serial Number Plate

Engine serial number nameplates for current production V-1710 series engines with internal lubricating oil pump have a suffix "3" in engine serial number.

Suffix "3" indicates the engine has a larger crankshaft, main bearing cap side bolts and improved one-piece rear cover and seal.

1. Location of engine serial number plate is shown in Fig. 0-2.

2. Always refer to engine serial number and model designation when ordering parts or assemblies.

3. If the camshafts, pistons and/or piston rings are changed from those shown on the serial number plate, the correct part numbers should be stamped on the plate. This information is often vital to fuel pump calibration and satisfactory engine performance.

Caution: Do not change engine serial number.

Electrical Connections

1. Disconnect and tag all wire leads from terminals of generator, cranking motor, cold-starting electrodes, fuel pump solenoid, regulator, remote controls, etc.

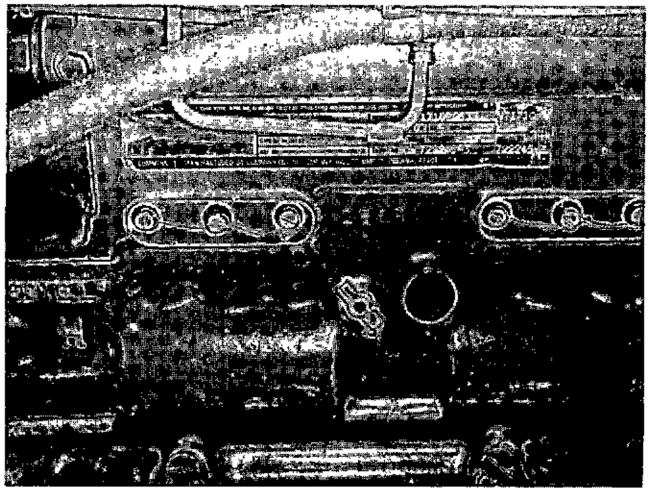


Fig. 0-2, V40079. Engine serial number plate

2. Remove all other electric controls.

Controls And Instruments

1. Disconnect and tag all wires at control panel and termination points. Fig. 0-3.

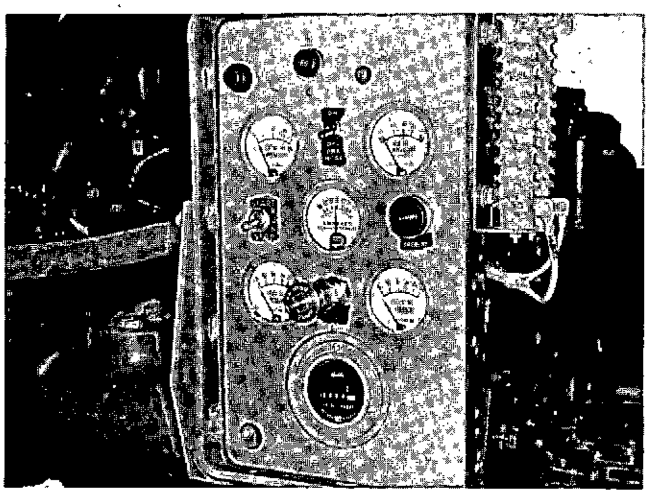


Fig. 0-3, V40083. Control panel

2. Disconnect and tag all hose and tubing at panel and termination points.

3. Remove nuts and bolts securing panel to mounting brackets; lift off panel.

4. Remove capscrews securing mounting brackets; lift off brackets.

Mechanical Controls; Water, Air, Oil And Fuel Connections

1. Remove mechanical control linkage. (Clutch, throttle linkage, etc.)

2. Remove radiator hose and discard.

3. Remove sea water inlet and outlet connections from sea water pump (when used).

4. Remove and tag all water hose from intercoolers and water tubing.

5. Remove and tag all air and oil lines and cover openings with tape.

6. Remove air cleaner hose, connections and crossover pipes to engine and cover intake ports with gummed tape or plates.

Caution: Cover inlet and outlet to turbocharger with plates or gummed paper to keep out foreign objects.

7. Remove tubing from air compressor (if used).

Cranking Motor

Electric

1. Remove capscrews and lockwashers securing cranking motor to flywheel housing. Fig. 0-4.

Fig. 0-4, V40036. Removing cranking motor

2. Move cranking motor toward front of engine to disengage from flywheel ring gear and clear flywheel housing; lift off cranking motor.

Air

1. Relieve pressure and disconnect air lines from source of supply and cranking motor.

2. Remove capscrews and lockwashers securing cranking motor to flywheel housing.

3. Slide cranking motor toward front of engine to disengage ring gear and clear flywheel housing; lift away starter.

Generator/Alternator

1. Remove capscrew, lockwasher and flatwasher securing adjusting bar to generator/alternator. Fig. 0-5.

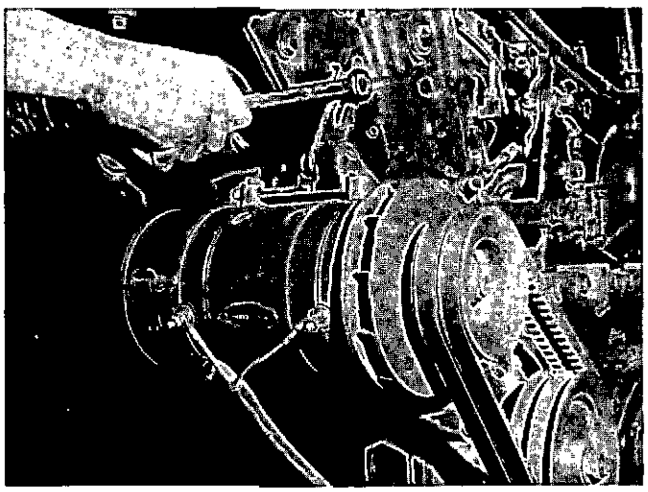


Fig. 0-5, V40037. Removing generator

2. Move generator/alternator in toward block and remove drive belts.

3. Remove generator/alternator from mounting blocks or bracket.

4. Remove capscrews and lockwashers securing bracket; remove bracket.

5. Remove capscrew and lockwasher securing adjusting bar; remove adjusting bar.

Steam Clean Engine Exterior

A portable fuel oil or electric-heated steam cleaner is very satisfactory for general use. In addition to actual time-saving effected by engine cleaning, inspections can be made more easily and accurately during disassembly if surfaces are clean.

Fan And Fan Hub

1. Remove fan, if used.

2. Loosen fan hub retainer nut behind fan bracket.

3. Loosen adjusting screw. Fig. 0-6. Disengage and remove belts.

4. Remove adjusting screw and retainer nut; lift fan hub from engine.

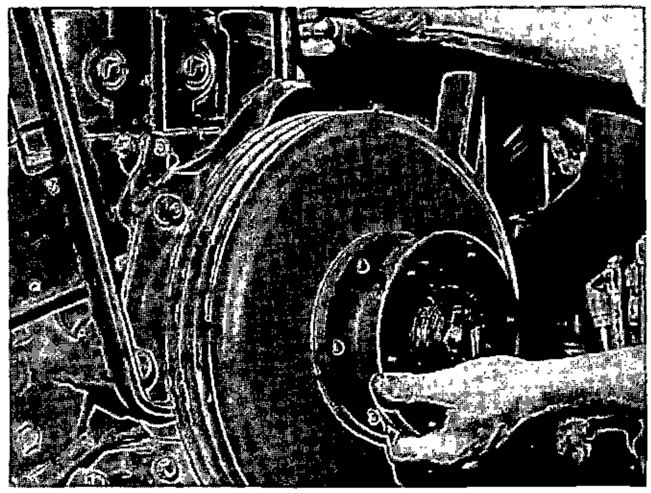


Fig. 0-6, V40038. Loosening fan hub adjusting screw

Mount Engine On Stand

1. The engine stand illustrated is designed so the engine may be mounted with all units in place. Blue prints of the stand are available upon request from Cummins Engine Company, Inc.

2. Lifting eyes are provided above the exhaust manifolds to lift engine into position.

3. Bolt engine in place on the stand, utilizing the holes in the cylinder block flange. Fig. 0-7.

Fuel Filter (Replaceable Element)

1. Remove capscrews and washers securing bracket to block; lift off bracket. Fig. 0-8.

2. Remove capscrew securing filters to filter head; remove filter cases and discard elements.

3. Remove all fuel lines, if not previously removed.

4. Remove capscrews and washers securing filter head to mounting bracket. Lift off filter head.

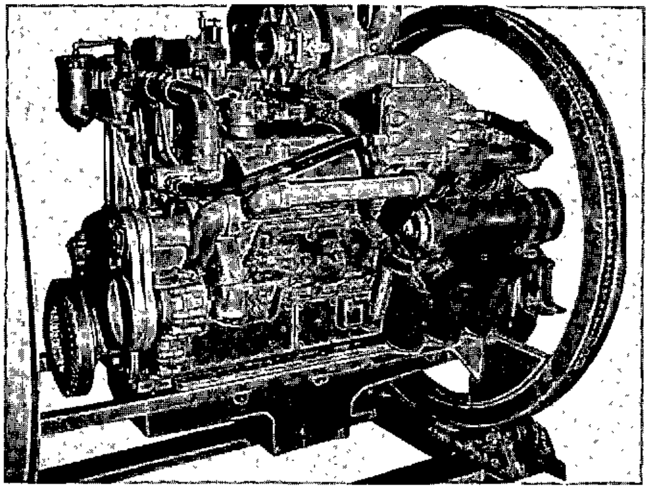


Fig. 0-7, V40039. Engine mounted on ST-412 Engine Stand

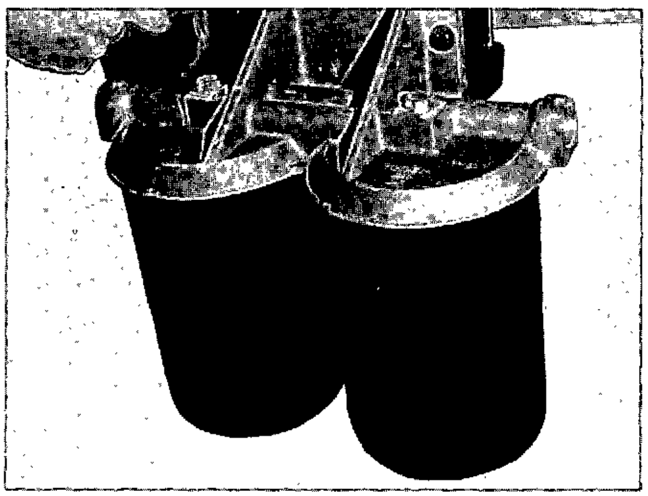


Fig. 0-8, V40084. Removing fuel filter bracket (replaceable type filter)

Fuel Filter (Throw-Away-Type Filter)

1. Remove all fuel lines, if not previously removed.

2. Remove combination case and element; discard.

3. Remove capscrews and lockwashers securing filter head to mounting bracket. Lift off filter head.

4. Remove capscrews and lockwashers securing bracket to block. Lift off bracket.

Expansion Tank

1. Loosen hose clamps and remove all hose from water inlet and outlet connections; lift off connections.

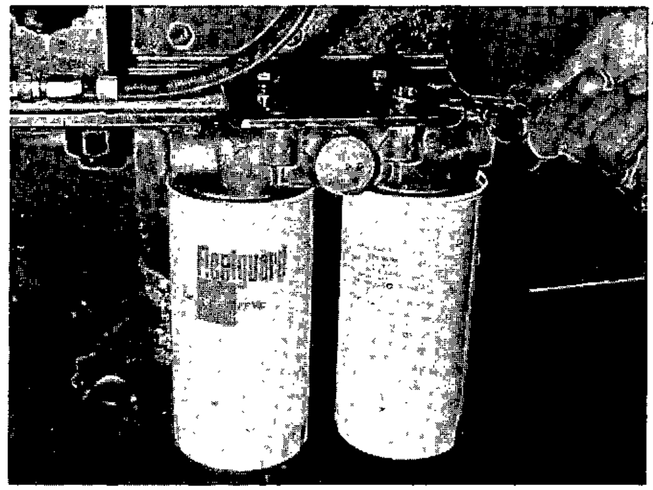


Fig. 0-9, V40041. Removing fuel filter head (throw-away type filter)

2. Disconnect water by-pass piping from thermostat housing and water pump connection.

3. Remove connections from expansion tank to heat exchanger and water pump.

4. Remove capscrews and lockwashers securing expansion tank to mounting brackets; lift off expansion tank.

Corrosion Resistors

1. Close shut-off valves in inlet and drain lines; remove plug from each resistor housing and drain coolant.

2. Disconnect inlet and outlet lines.

3. Remove capscrews and lockwashers securing corrosion resistor bracket, Fig. 0-10, to intake manifold or other location; remove corrosion resistor assembly.

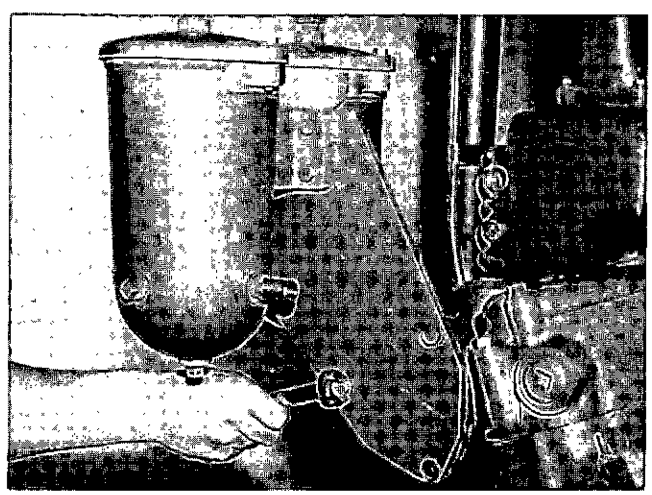


Fig. 0-10. V40042. Removing corrosion resistor bracket

Heat Exchanger

1. Disconnect raw water inlet and outlet connections between raw water pump and heat exchanger; lift off connections.

2. Disconnect engine coolant connections from heat exchanger and engine coolant pump.

3. Remove capscrews and lockwashers securing heat exchanger to mounting brackets; lift off heat exchanger.

4. Remove capscrews and lockwashers securing mounting bracket and braces to engine; lift off bracket and braces.

Lubricating Oil Filter (Full-Flow)

1. Remove drain plug from each filter case and drain filters.

2. Loosen capscrew at bottom center of each filter case; remove case and lift out element. Fig. 0-11.

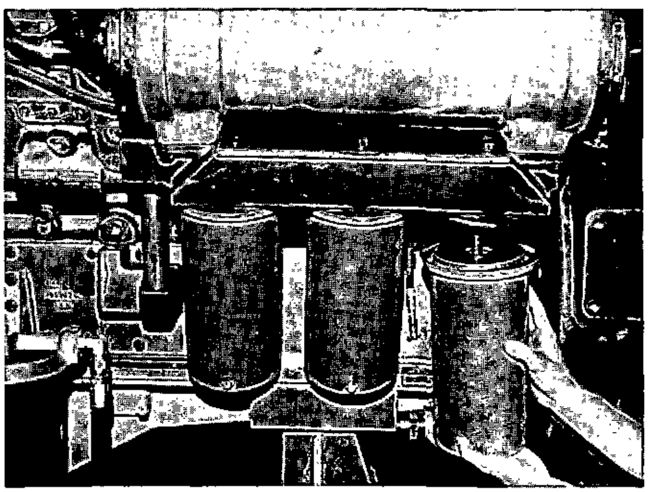


Fig. 0-11, V414202. Removing oil filter case

3. Inspect filter element for evidence of bearing materials which might indicate necessity for additional repair; each part should be checked as removed to get a full story of what may have caused a failure or how much repair will be required.

Lubricating Oil Cooler

1. Remove capscrews and lockwashers securing water inlet connection to front of cooler. Rotate to remove connection and water inlet tube from engine; separate connection and tube. Discard "O" rings.

2. Remove capscrews and lockwashers securing water outlet connection and tube to rear of cooler; separate connection and tube. Discard "O" rings.

3. The cooler is secured to the filter head with eight capscrews. Four of these capscrews are located inside the filter head. Fig. 0-12. Remove all capscrews to lift cooler from bracket. Discard gaskets.

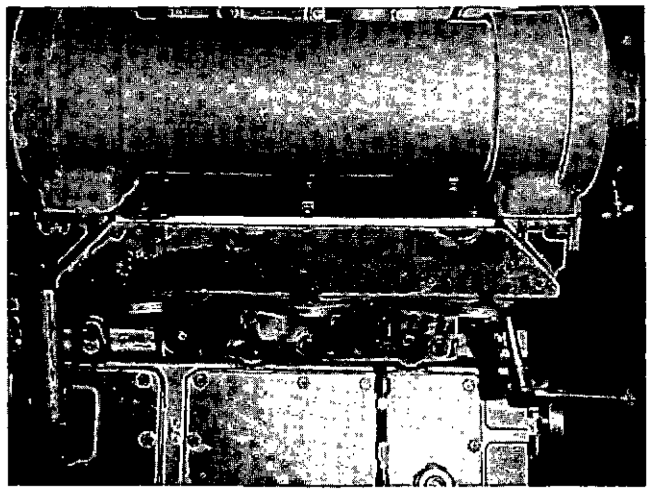


Fig. 0-12, V40044. Removing oil cooler

Lubricating Oil Filter Head

1. Remove capscrews and lockwashers securing filter head to bracket. Fig. 0-13.

2. Rotate head on supply transfer tube (front tube) to disengage drain tube (rear tube) from block. Continue to rotate head until it can be removed from supply transfer tube.

3. Remove tubes from filter head and discard "O" rings.

Lubricating Oil Cooler/Filter Bracket

Remove capscrews and lockwashers securing cooler/filter bracket to block. Fig. 0-14. Lift off bracket.

Remove Fuel Lines

Remove and tag all fuel lines and clamps. Tape all fuel openings in cylinder heads and fuel pump. Reference Fig. 0-15.

1. Fuel inlet from filter (1).

2. Fuel pump outlet (2).

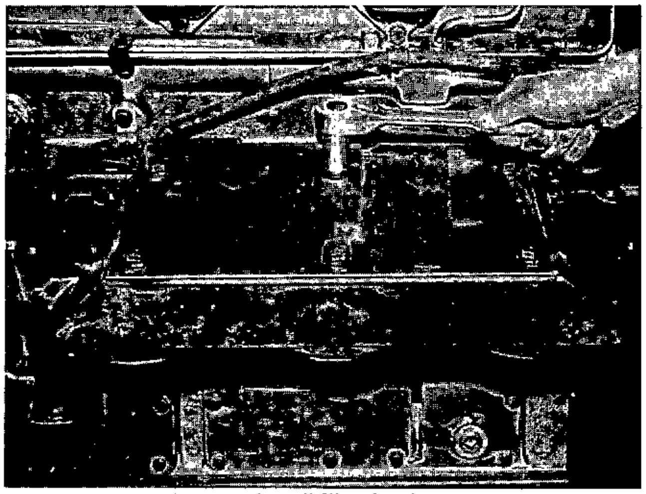


Fig. 0-13, V40045. Removing oil filter head

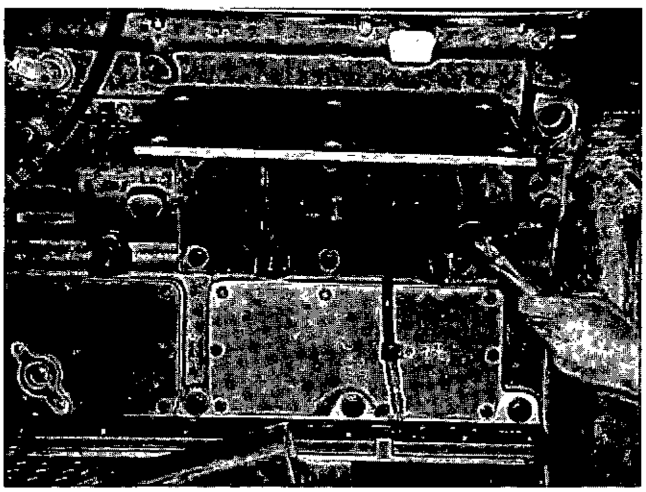


Fig. 0-14, V40081. Removing oil filter/cooler bracket

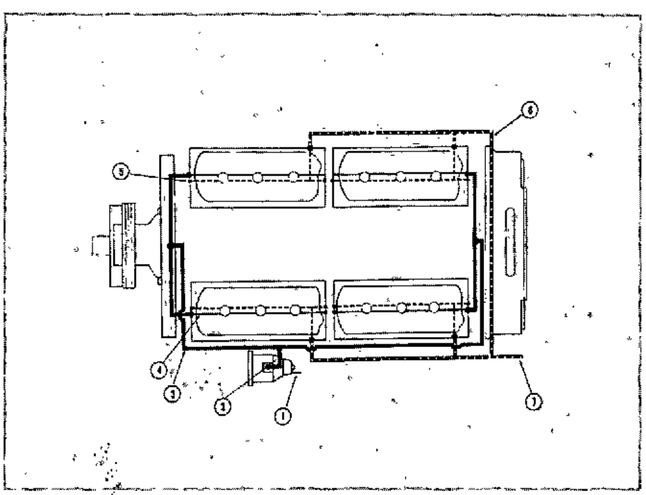


Fig. 0-15, V40047. Fuel lines and passages

3. Fuel supply lines (3).

4. Fuel drain lines (6).

5. Fuel return to tank (7).

6. Injector inlet (4) and drain (5) are drilled passages in cylinder head.

Torque Converter Cooler

The torque converter or accessory oil cooler, when used, is mounted on front of engine depending upon application.

1. Disconnect oil lines from cooler.

2. Disconnect water inlet and outlet connections.

3. Remove mounting hardware; lift off cooler.

4. Remove mounting bracket and braces.

Raw Water Pump

1. Loosen capscrews securing raw water pump to mounting bracket; slide pump toward engine and lift off drive belt.

2. Remove capscrews and lockwashers; lift off raw water pump.

Air Cleaners

Remove air cleaners from brackets; remove brackets from engine (when engine-mounted).

Turbochargers

1. Remove turbocharger oil drain lines if not previously removed.

2. Disconnect each turbocharger's piping from intake manifold connection.

3. Remove heat blankets or heat shields (when used).

4. Remove mounting stud nuts and/or capscrews (if used). Fig. 0-16. Lift turbochargers from engine.

Caution: Cover inlet and outlet ports with gummed paper to keep foreign objects out of turbochargers. Do not stuff rags into ports.

Balance Tube

An air balance tube between air intake manifolds of

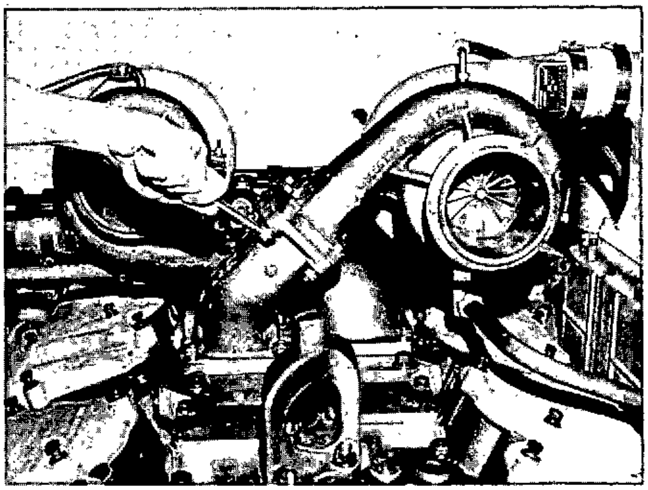


Fig. 0-16, V414186. Removing turbocharger

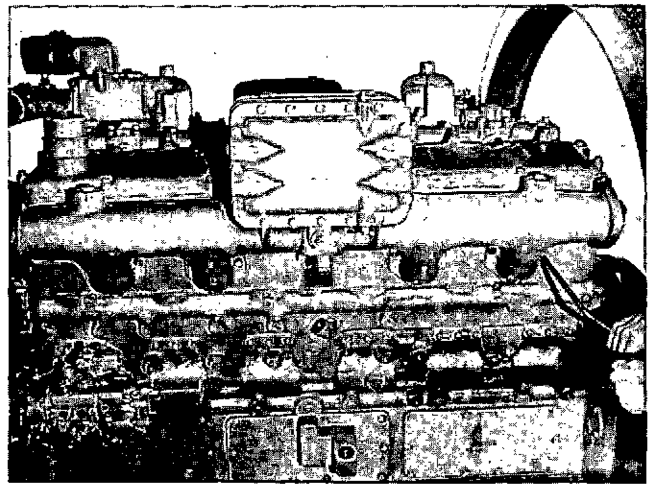


Fig. 0-17, V40050. Intercooler and air intake manifold

turbocharged engines is used to equalize air pressure in each manifold. It is installed at the flywheel end of intake manifolds.

1. Remove capscrews and lockwashers securing balance tube assembly to each intake manifold. Remove balance tube.

2. Remove gaskets and discard.

Intercoolers

1. Disconnect turbocharger air connections from intercoolers.

2. Disconnect and tag water supply and return lines from intercoolers and termination points, if not previously removed.

3. Remove capscrews, lockwashers and flatwashers securing intercooler covers to intake manifold; lift out intercoolers and discard gaskets.

Intake Manifolds

1. Remove capscrews, lockwashers and flatwashers, Fig. 0-17, securing manifolds to cylinder heads.

2. Lift manifolds from engine.

3. Remove and discard gaskets.

Water Pump

1. Remove capscrews and lockwashers from adjustable sheaves.

2. Loosen adjustable drive pulley sheaves and lift drive belts from pump pulley.

3. Remove air compressor water line, if used.

4. Remove capscrews and lockwashers securing water pump and valve and injector timing pointer to gear case cover. Fig. 0-18.

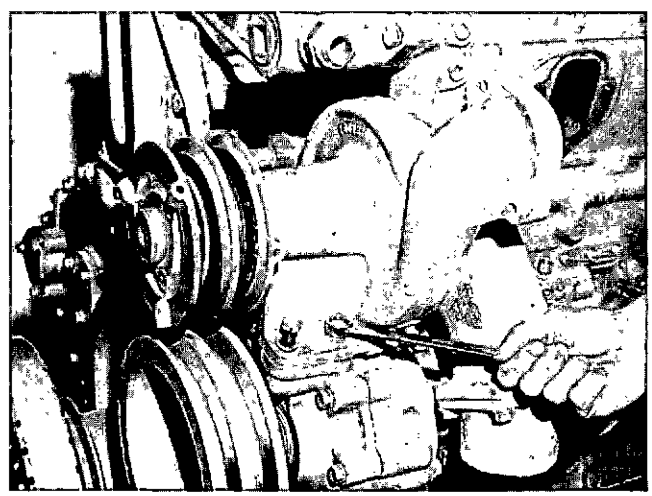


Fig. 0-18, V40051. Removing water pump mounting capscrews

5. Lift off water pump. Fig. 0-19.

Water Outlet Connections Or Thermostat And Thermostat Housings

1. If engine is equipped with torque converter cooler:

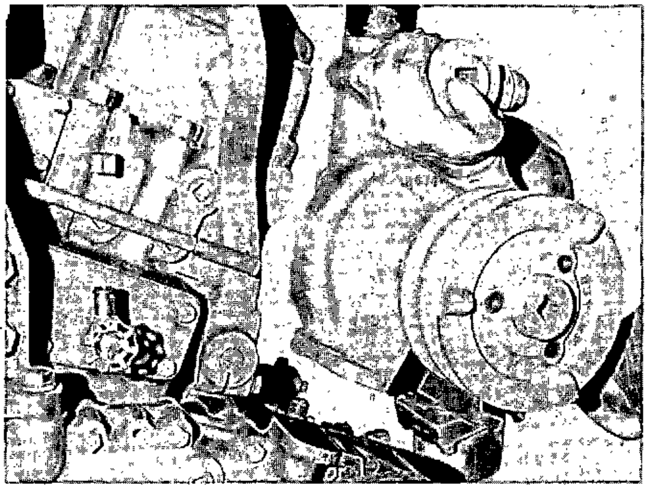


Fig 0-19, V40052. Removing water pump

a. Remove water connections from exhaust manifolds; remove gaskets and discard.

b. Thermostats are located in torque converter cooler inlet and outlet housings.

2. If engine is equipped with radiator or expansion tank:

a. Remove water outlet connection from thermostat housing.

b. Remove capscrews from thermostat housing. Fig. 0-20. Lift housing from exhaust manifold.

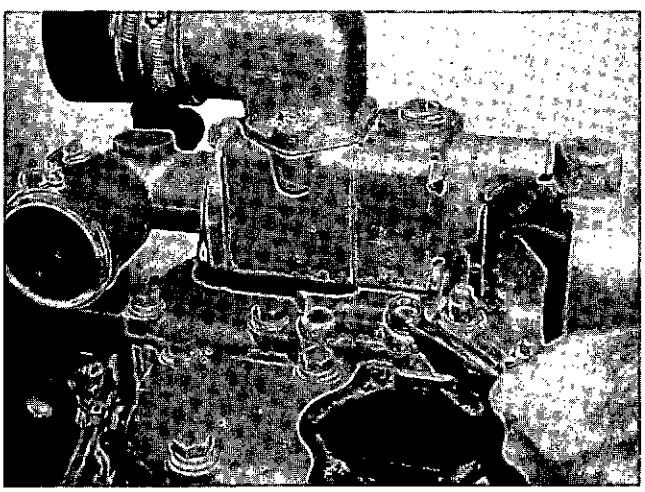


Fig. 0-20, V40053. Removing thermostat housing

Water Manifold (With Dry Exhaust)

1. Remove nuts and bolts securing heat shield clamps to water manifold; lift off clamps and install bolts and nuts on clamps.

2. Remove capscrews and lockwashers securing water manifolds to cylinder heads; lift off water manifold and discard gaskets.

3. Separate water manifold and discard "O" rings.

Exhaust Manifolds—Wet Type

1. Remove nuts and lockwashers holding the engine lifting brackets to manifolds; remove lifting brackets.

2. Remove manifold capscrews and/or stud nuts.

3. Using a chain hoist, carefully lift exhaust manifolds from engine to keep from bending studs. Fig. 0-21.

4. If manifold is stuck on gasket, use extreme caution in prying against cylinder head; discard gaskets.

5. If studs are removed, tag for reinstallation in engine assembly.

Caution: Never use a screwdriver or wedge between machined surfaces.

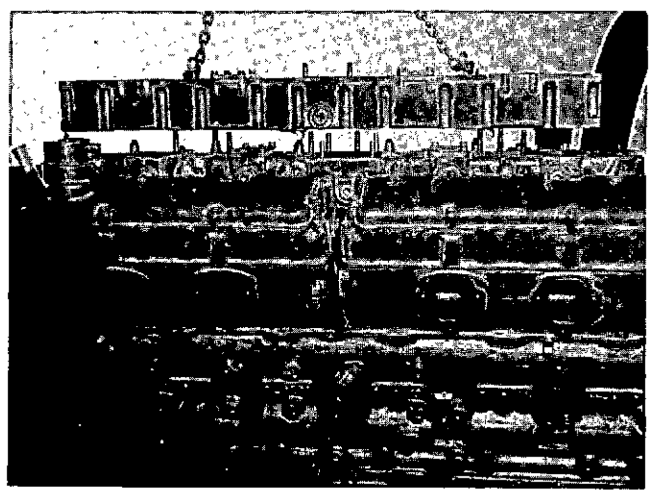


Fig. 0-21, V40054. Removing exhaust manifold

Exhaust Manifold—Dry Type

1. Remove nuts, lockwashers and bolts securing clamps on exhaust manifold; lift off clamps and install bolts and nuts to clamps.

2. Remove capscrews, lockwashers and flatwashers securing engine lifting bracket to exhaust manifolds; remove lifting bracket spacers.

3. Remove remaining capscrews, lockwashers and flatwashers securing exhaust manifold to head; lift off exhaust manifolds and remove lifting brackets. Discard gaskets.

Aneroid Control

1. If not previously removed, disconnect and tag fuel lines and air line from aneroid.

2. Remove capscrews and washers securing aneroid to bracket; lift off aneroid.

3. Remove capscrews and lockwashers securing bracket to block; lift off bracket.

Fuel Transfer Pump And Float Tank

1. Remove fuel lines, if not previously removed.

2. Remove capscrews and lockwashers securing fuel transfer pump to bracket. Lift off pump.

3. Remove capscrews and lockwashers securing bracket to engine. Lift off bracket.

4. Remove capscrews and lockwashers securing float tank and bracket to engine. Lift off float tank assembly.

Fuel Pump

1. Remove fuel supply line and return line.

2. Disconnect linkage to hydraulic governor, when used.

3. Remove capscrews and washers securing fuel pump to mounting flange or bracket.

4. Lift off fuel pump, Fig. 0-22, and drive coupling; discard gasket and drive buffer, if used.

Caution: Do not lose coupling retainer plate, if used, and rubber buffer from fuel pump end of air compressor.

Air Compressor

Cummins Gear Driven

1. Remove all water lines, if not previously removed.

2. Remove locknut and flatwasher securing water pump drive pulley on compressor crankshaft.

3. Using ST-647 Puller, remove pulley from compressor crankshaft. Fig. 0-23.

4. Remove drive key from compressor crankshaft.

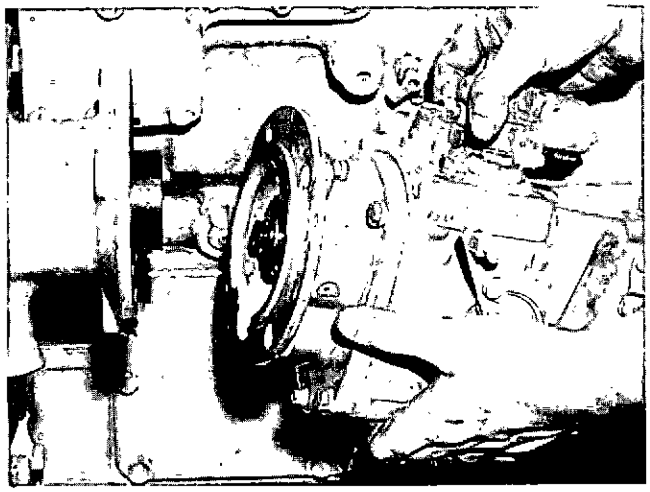


Fig. 0-22, V40055. Removing fuel pump

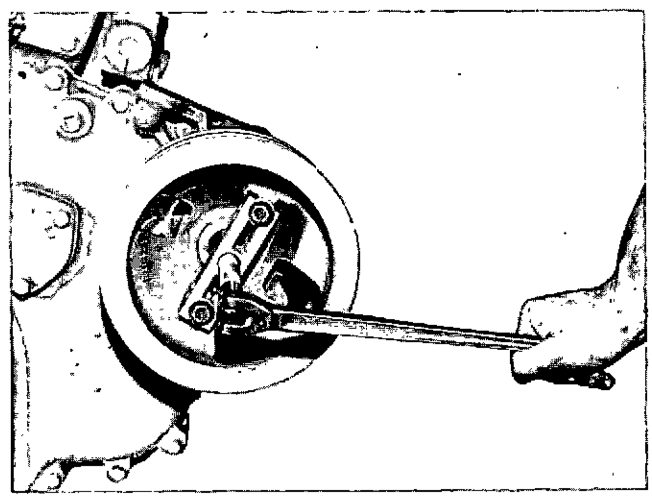


Fig. 0-23, V40056. Removing water pump drive pulley with ST-647

5. Remove oil slinger through oil seal in gear case cover.

6. Remove capscrews and lockwashers securing air compressor to gear case. Fig. 0-24.

7. Slide compressor rearward and remove from engine; discard gasket.

Coupling Driven

1. Disconnect air, water and oil lines if not previously removed.

2. Remove capscrews and lockwashers securing compressor to gear case.

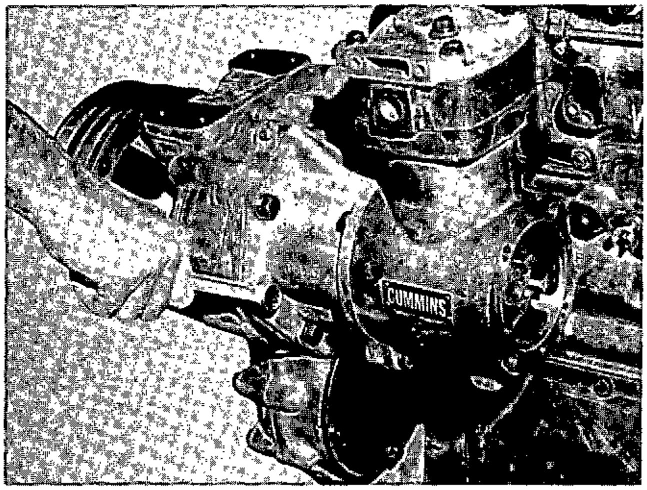


Fig. 0-24, V40057. Removing Cummins air compressor

3. Lift off compressor and discard gasket.

4. Remove coupling from accessory drive shaft.

Hydraulic Governor Drive

The shaft of the drive protrudes through gear case cover and mounts water pump drive pulley in front of gear case cover.

1. Remove hug nut and flatwasher securing water pump drive pulley on drive shaft.

2. Using ST-647 Puller, pull pulley from shaft and remove key.

3. Remove oil slinger from shaft.

4. Remove mounting capscrews and lockwashers.

5. Slide the drive unit back to disengage gears and remove from gear case.

Fuel Pump/Accessory Drive

1. Remove hug nut and flatwasher securing water pump drive pulley to drive shaft.

2. Using a suitable puller, remove pulley from shaft and remove key.

3. Remove oil slinger from shaft.

4. Remove capscrews and lockwashers; slide drive unit back to disengage gears and remove from gear case.

Generator or Auxiliary Drive Unit

1. Remove all auxiliary driven units, drive belts and brackets from engine.

2. If front drive pulley is used:

a. Remove hug nut securing pulley to shaft.

b. Using ST-647 Puller or equivalent, remove pulley from shaft (1, Fig. 0-25).

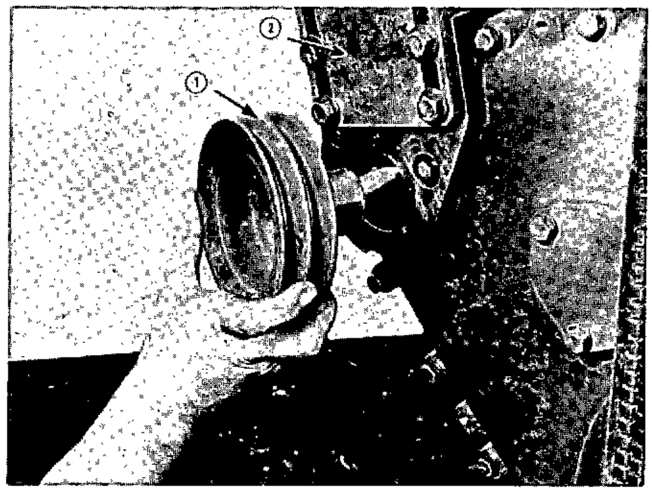


Fig. 0-25, V40058. Removing auxiliary drive pulley

c. Remove drive key from drive shaft.

3. Loosen capscrews and lockwashers securing drive to gear case; capscrews cannot be removed with pulley in place.

4. Disengage and remove drive assembly; discard gasket.

5. Remove brackets (2, Fig. 0-25), as used.

Fan Bracket

1. Remove capscrews and hardware securing compression release linkage to bracket.

2. Remove capscrews and lockwashers securing fan bracket to block and gear case cover. Lift off bracket. Fig. 0-26.

Vibration Damper, Crankshaft Drive Pulley And Crankshaft Flange

1. Remove lockwires (or bend up lockplates if used) and capscrews securing vibration damper; lift off damper. Fig. 0-27.

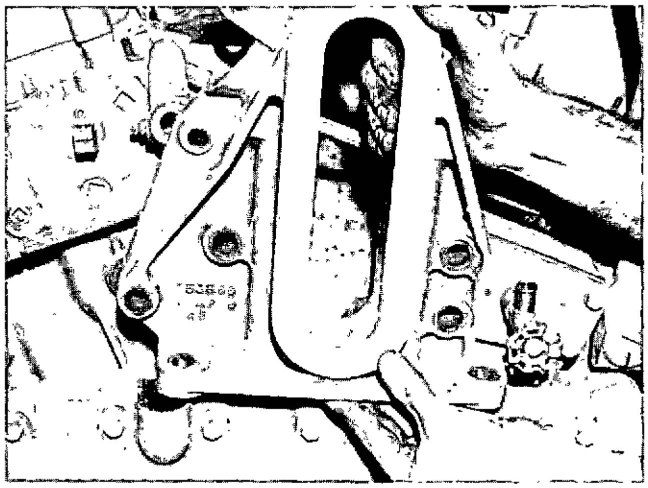


Fig. 0-26, V40059, Removing fan bracket

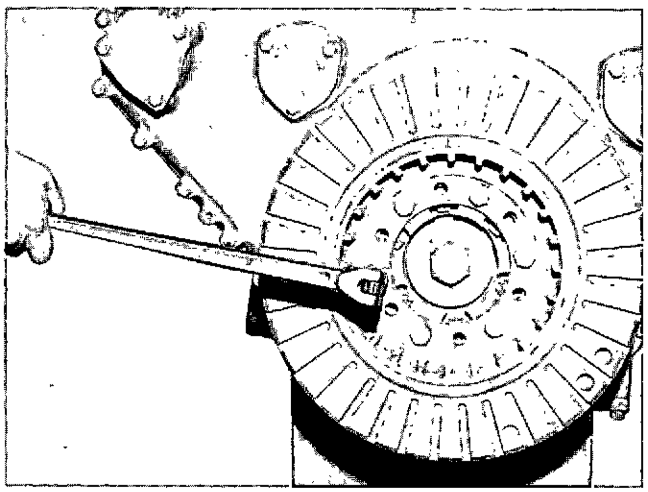


Fig. 0-27, V40060. Removing vibration damper

Caution: Do not hammer against damper to remove from pulley.

2. Remove capscrews securing adapter to crankshaft flange; lift off adapter.

3. Remove capscrew and washer securing flange to crankshaft.

4. Use ST-887 Crankshaft Flange Puller, or suitable puller, to pull flange from crankshaft. Fig. 0-28.

Gear Case Cover

1. Remove capscrews, lockwashers and flatwashers securing camshaft thrust plate to gear case cover; remove thrust plate and shims.

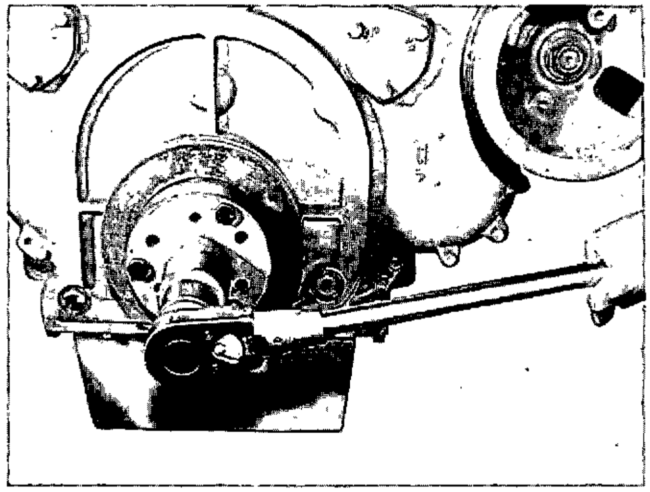


Fig. 0-28, V40061, Pulling crankahsft flange

Caution: Do not lose any of the shims used to regulate camshaft end clearance. They must be replaced during assembly.

2. Remove capscrews and lockwashers securing gear case cover to gear case and oil pan.

3. Insert two 3/8-16 guide studs 4 inch [101.6000 mm] long into top of gear case cover to prevent dropping cover during removal.

4. Insert three 3/8-16 capscrews 4 inch [101.6000 mm] long into holes provided in gear case. Fig. 0-29. By alternately turning capscrews the gear case cover will be pulled loose from its dowels. Remove pulley capscrews and slide gear case cover from studs. Remove guide studs.

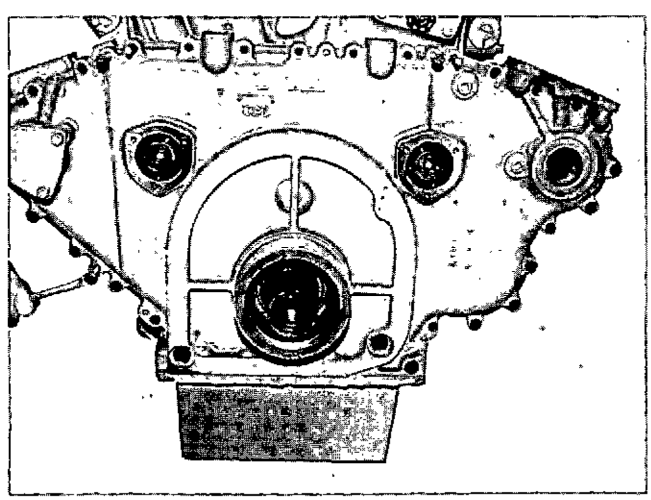


Fig. 0-29, V40062. Removing gear case cover

Piston-Cooling Oil Nozzles

All turbocharged engines are equipped with piston oil cooling. Oil is supplied to six oil nozzles on each side of the cylinder block through a full-length internal drilling.

Remove capscrew, lockwasher and flatwasher securing each nozzle flange to block and remove nozzles.

Note: No. 2 cylinder oil spray nozzle is located under cover plate as illustrated in (1, Fig. 0-30).

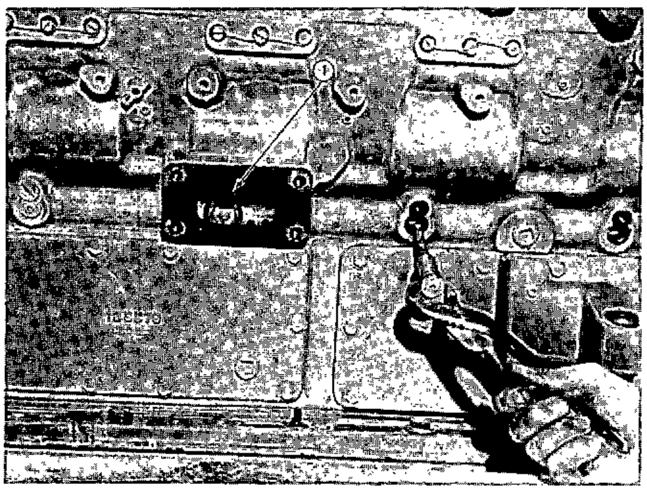


Fig. 0-30, V40066. Removing piston cooling nozzles

Crankcase Vent Tube

1. If used, remove vent tube from breather.

2. Remove tube clamp(s) from engine and lift assembly from engine.

Rocker Housings And Housing Covers

1. Remove capscrews, flatwashers and lockwashers from rocker housing covers; remove housing covers and discard gaskets. Tag covers by position as removed.

2. Remove capscrews from rocker housings.

3. Lift rocker housings from engine, Fig. 0-31, and discard gaskets.

4. Remove and discard "O" ring around each oil drilling restrictor in head.

Injectors

1. Remove hold-down capscrews.

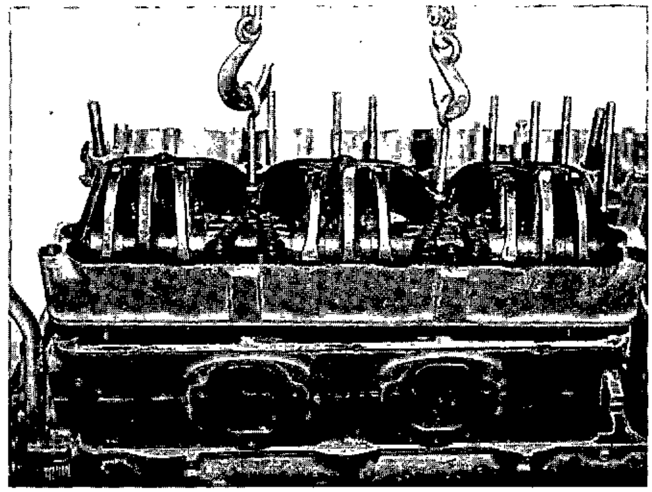


Fig. 0-31, V40063. Removing rocker arm housing

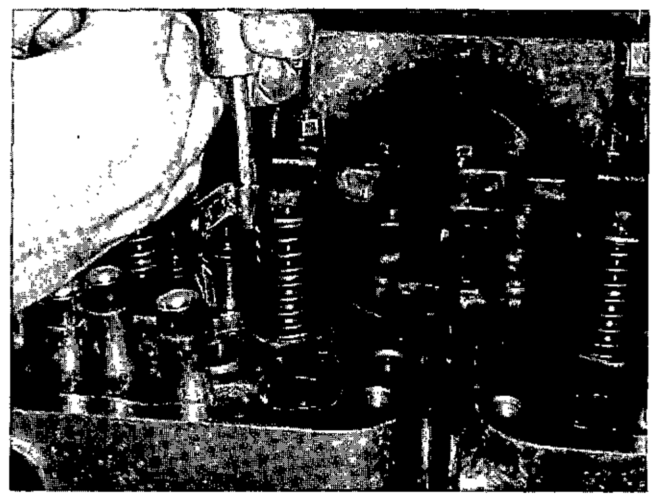


Fig. 0-32, V40080. Removing injector with ST-1147

2. Lift off hold down plate and remove injector link. Remove injector with ST-1147 Injector Puller. Fig. 0-32.

3. Place injectors in rack for protection. Tag and number by cylinder from which removed. Do not damage injector tip.

Push Tubes And Crossheads

1. Lift crossheads from crosshead guides.

2. Remove push tubes by lifting them from their tappets. Fig. 0-33.

Cylinder Heads

1. Remove cylinder head capscrews and washers.

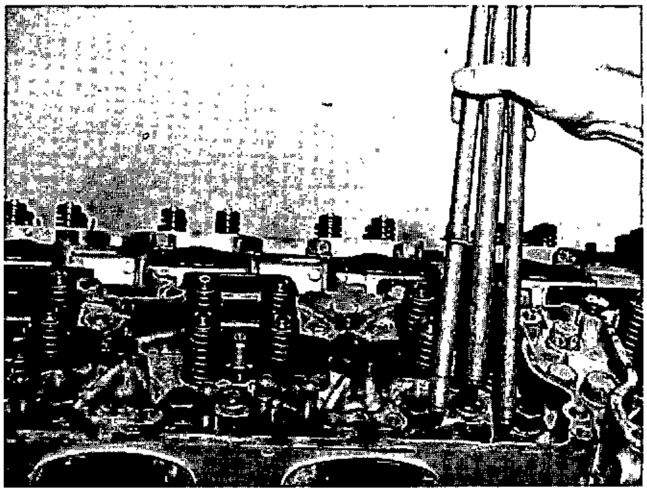


Fig. 0-33, V41499. Removing push tubes

Note: It is suggested that cylinder heads be tagged for position occupied on engine so they may be reinstalled in same position, thus saving time in making exhaust manifold alignment checks.

2. Install guide studs to aid in removal.

3. Using suitable hoist, lift cylinder heads from cylinder block. Fig. 0-34.

4. Remove head gaskets, grommets and grommet retainers; discard.

Valve And Injector Tappets

1. Remove lockwires, lockscrews and copper washers holding tappet guides; discard copper washers.

2. There is one guide for each tappet.

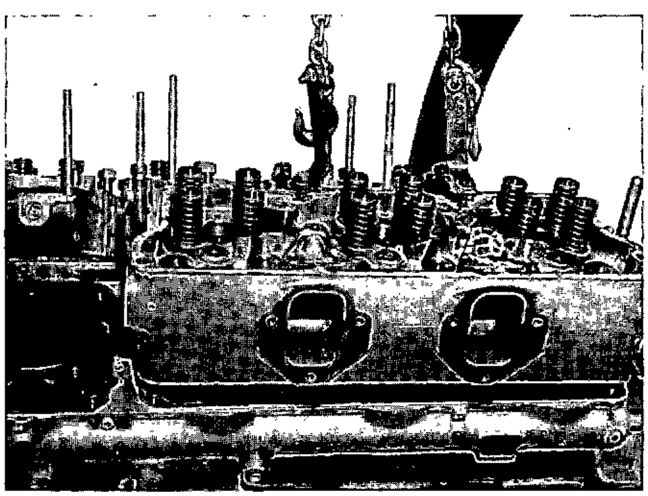


Fig. 0-34, V40065. Removing cylinder heads

3. Lift tappets from block with a long wire hook or equivalent.

Water Header Plates

1. Remove capscrews and lockwashers securing water header plates in "V" block; lift off plates and discard gaskets. Fig. 0-35.

2. Remove capscrews and lockwashers securing water passage cover plate to front of block; lift off cover and discard gasket.

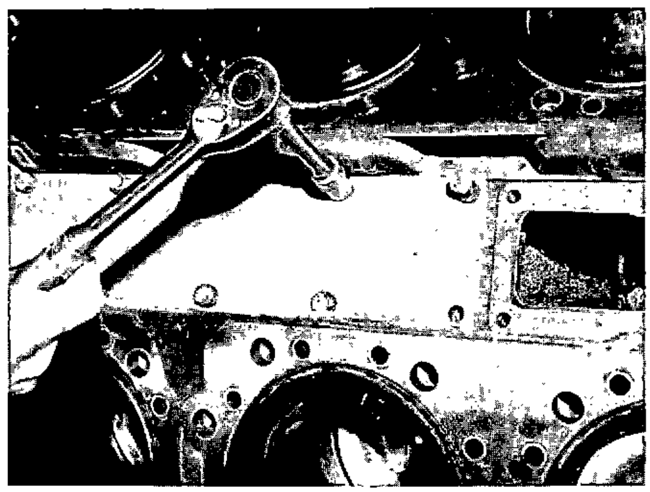


Fig. 0-35, V40067. Removing water header plates

Compression Release And Linkage

1. Remove capscrew and lockwasher securing compression release linkage controls to shafts; slide levers forward off shafts.

Note: Do not separate linkage unless rods and unibals are scribed for location.

2. Remove compression release shaft lockscrew and copper washer from each bank at rear of block.

3. Pull shafts from block.

Flywheel

1. Remove lockwires and capscrews securing flywheel to crankshaft flange.

Caution: On generator set or other engines using piston ring type rear cover, capscrews securing rear cover slinger assembly to back of flywheel must be removed so slinger remains in rear cover assembly. Failure to disconnect slinger will result in damage or breakage to slinger and oil seal rings.

2. Insert two 5/8-18 studs 7 inch [177.8000 mm] long through two capscrew holes in the flywheel 180 deg. apart and screw into crankshaft flange to support flywheel during removal.

3. In two holes provided, place two 1/2-13 capscrews 2-1/2 inch [63.5000 mm] long, threaded their entire length. Turn in capscrews alternately to pull flywheel from crankshaft dowels.

4. Using a suitable hoist, lift flywheel from guide studs. Fig. 0-36.

5. Remove gasket, if used, and discard.

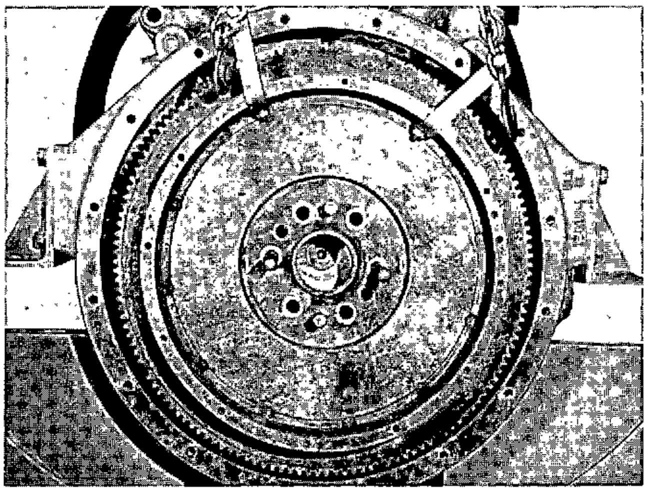


Fig. 0-36, V40068. Removing flywheel

Flywheel Housing Or Starter Mounting Plate

1. Remove mounting capscrews and lockwashers from block and oil pan.

2. Insert two 5/8-11 studs in block to guide flywheel housing during removal.

3. Drive housing from dowels by tapping on back side with a soft hammer or wooden block.

4. Using suitable hoist, lift housing from guide studs. Fig. 0-37.

5. Discard gaskets.

Center Idler Gear

1. Remove capscrew, lockwasher and retaining washer. Retaining washer is pinned to shaft.

2. Remove front thrust washer, gear and rear thrust washer from idler shaft. Fig. 0-38.

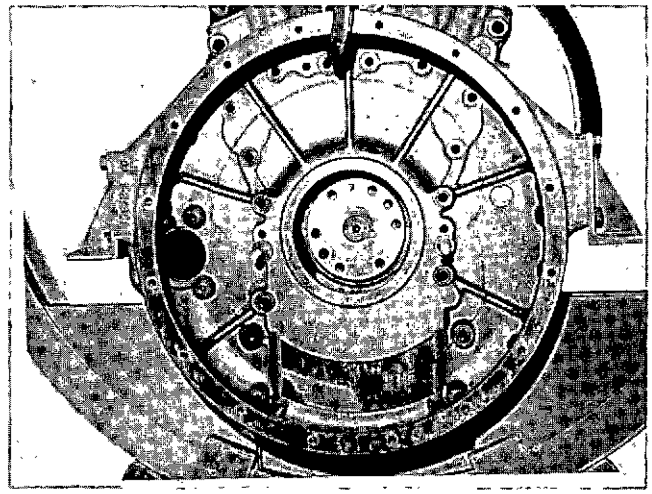


Fig. 0-37, V40069. Removing flywheel housing.

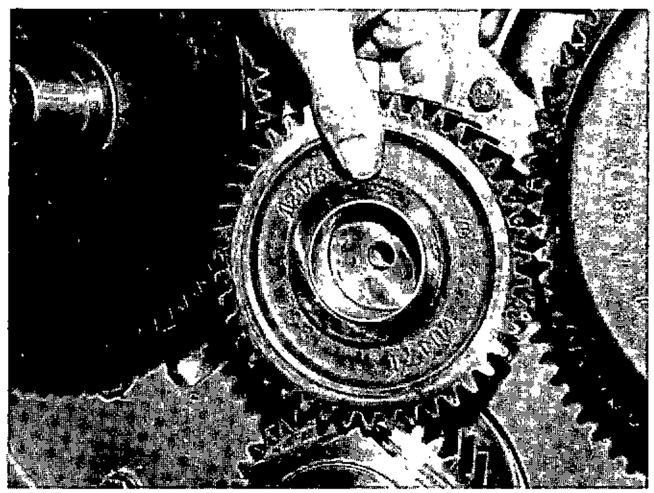


Fig. 0-38, V40070. Removing idler gear

Camshafts And Gears

1. Remove camshaft and gear from each bank of engine.

2. Lift and rotate slightly while pulling from block. Do not remove gears from camshafts. Tag camshafts to identify left-bank or right-bank camshaft.

Hand Hole Covers

1. Remove capscrews and lockwashers securing covers to block.

2. Remove covers and discard gaskets; tag each cover, or otherwise mark, to prevent confusion at assembly.

Rear Cover With Oil Seal Rings

1. Remove oil drain tubing assembly between cover housing and oil pan.

2. Remove capscrews and lockwashers securing cover to block.

3. Carefully pry cover from dowel pins; remove and discard gasket.

Caution: Cover assembly must be removed as a unit to prevent damage to slinger and oil seal rings.

Oil Pan

1. Remove capscrews, lockwashers and flatwashers, if used.

2. Separate oil pan from block assembly and discard gasket. Fig. 0-39.

3. Discard rubber packing seal between oil pan and rear cover plate.

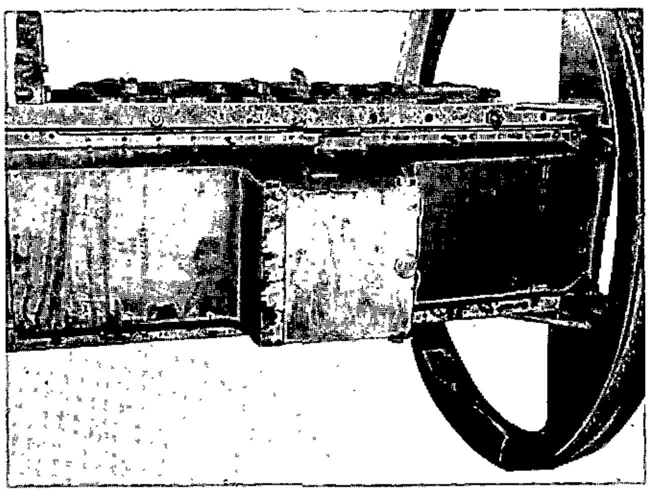


Fig. 0-39, V40072. Removing oil pan

Rear Cover (One-Piece)

1. If engine has "wet" flywheel housing, remove "O" ring.

2. Remove capscrews and lockwashers securing rear cover to block.

3. Carefully pull rear cover and seal from block.

Lubricating Oil Pump

The lubricating oil pump is mounted in oil pan at front end of engine and driven off the crankshaft gear; lubricating oil suction tube runs to screened flange in sump of oil pan.

1. Remove capscrews and lockplates securing suction tube brace to block.

2. Remove capscrews and lockplates securing suction tube to lubricating oil pump; discard gasket.

3. Remove capscrews and lockplates securing discharge connection to block. Rotate and remove connection from discharge tube.

4. Remove discharge tube from lubricating oil pump and discard "O" rings.

5. Remove capscrews and lockplates securing lubricating oil pump to block. Fig. 0-40. Lift off pump.

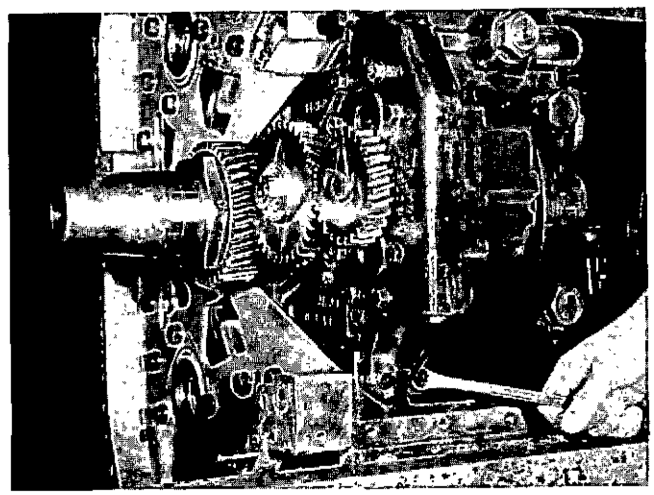


Fig. 0-40, V40073. Removing lubricating oil pump

Piston And Connecting Rod Assemblies

Note: Engines after Serial No. 664253 have rods with a thinner crank pin width which permits piston and rod to be removed through top of cylinder liner after rod bolts are removed. Remove liners from block with ST-777 Cylinder Liner Puller and ST-781 Puller Plate.

1. Clean all carbon from upper inside wall of each cylinder liner with ridge reamer and fine emery cloth or equivalent.

2. Remove connecting rod bolt nuts and washers; pull caps and bearing shells from connecting rods.

3. Tape rod bearing shells together and label each pair by cylinder number for later reference.

4. Using soft hammer drive rod bolts from rod.

5. Push connecting rod and piston assemblies from cylinder liners with wooden stick, holding pistons so they will not be dropped and damaged.

Caution: Do not mutilate inner walls of cylinder liners.

6. Reassemble each connecting rod cap to assembly as it is removed, the rod caps are not interchangeable. Label each assembly by cylinder number.

Note: Rods and caps are matched assemblies, as removed make sure parts are stamped, so they can be reassembled correctly. Phase 3 rods are to be stamped 1/4 inch [6.350 mm] either side of centerline of the bolt hole. If a new assembly is used, be sure to stamp before installing in engine.

7. Remove piston pin snap rings.

8. To facilitate removal of piston pins, first heat pistons in boiling water; then push pin from piston, using finger pressure or other suitable method. Do not drive or otherwise force pin from piston.

Cylinder Liners

Use ST-777 Puller with ST-781 Liner Puller Plate; or equivalent to pull cylinder liners. Discard "O" rings and "crevice seal" (as used).

Note: A liner that is difficult to remove or "frozen" may be removed from the cylinder block by turning the cam of ST-777 Liner Puller to provide a "jack screw action".

Connecting Rods, Pistons And Cylinder Liners

Note: Piston, rod and liner must be removed as an assembly in engines prior to Serial No. 664253.

1. Remove connection rod nut bolts, Fig. 0-41, washer, and lockplates (if used), loosen rod caps. Discard lockplates if used and install the new washer during assembly.

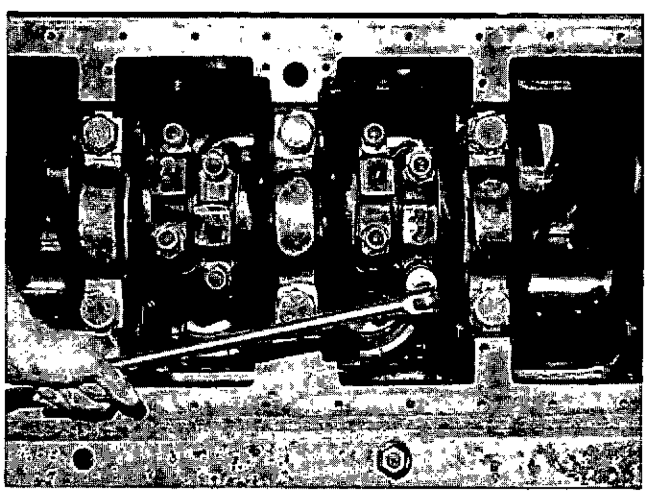


Fig. 0-41, V40074. Removing rod nuts

2. Lift off rod cap and remove bearing shell; roll upper bearing shell from rod.

3. Tape bearing shell halves together and mark cylinder number from which removed.

4. Push piston/rod assembly upward into liner. Assemble plate ST-414-5 over rod bolts.

5. With crankshaft at bottom of rod throw travel, position ST-414-1 Ram (1, Fig. 0-42) over rod journal.

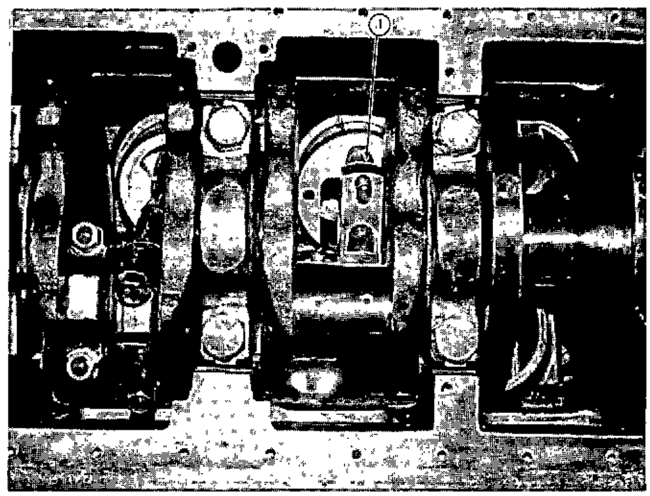


Fig. 0-42, V40075. Removing piston, rod and liner

6. Using a bar, turn crankshaft. The connecting rod throw will raise the ram and push piston/rod assembly and liner from block.

Note: A suitable block of hardwood may be used between the throw and rod to remove liners.

7. Replace bearing cap and nuts on same connecting rod from which removed. Bearing caps are not interchangeable.

Note: Engines after Serial No. 664253 have rods with a thinner crank pin width which permits piston and rod to be removed through top of cylinder liner after rod bolts are removed. Remove liners from block with ST-777 Cylinder Liner Puller and ST-781 Puller Plate.

8. Pressing on piston crown, push piston/rod assembly through bottom of liner.

9. Remove and discard crevice seal and "O" rings from liner.

10. Remove and discard piston pin snap rings.

11. Heat aluminum piston in hot water; push piston pin from piston.

Caution: Never drive piston pin from piston. Driving may distort piston and cause seizure of piston in cylinder liner.

12. Remove and discard piston rings.

Crankshaft And Main Bearing Shells

1. Remove side bolts and washers from each side of block securing main bearing caps to side of block, when used.

2. Bend back lockplates.

3. Remove each main bearing capscrew and discard lockplates.

4. With a small pry bar, loosen each main bearing cap. Fig. 0-43. When caps are free, lift caps from block. Keep capscrews in original position (tapped holes) in block.

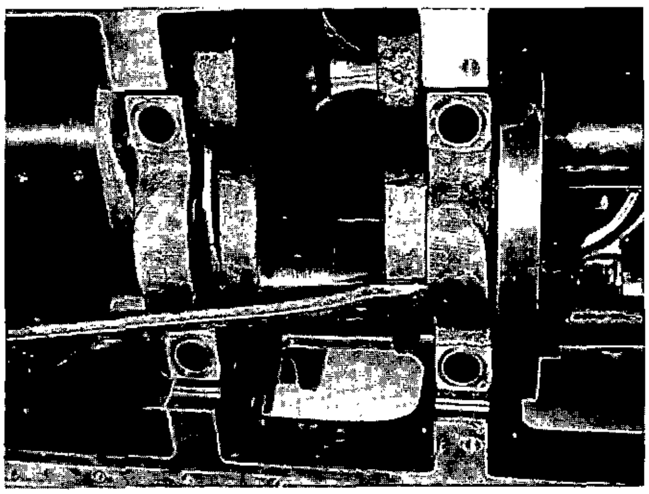


Fig. 0-43, V40076. Removing main bearing cap

Note: Service tool ST-1178 Main Bearing Cap Puller and ST-782-2 Slide Hammer may be used.

5. Remove thrust rings from each side of rear main bearing cap.

6. Remove lower main bearing shells from crankshaft or cap and remove upper thrust rings. Tag and tape thrust ring halves together to prevent damage.

7. Using a chain hoist with rubber-covered hooks to protect bearing surfaces, lift crankshaft from cylinder block. Fig. 0-44.

8. Remove upper main bearing shells.

Note: Replace main bearing caps in same position as removed. Main bearing caps are not interchangeable. Tape corresponding upper and lower main bearing shells together and number by position removed.

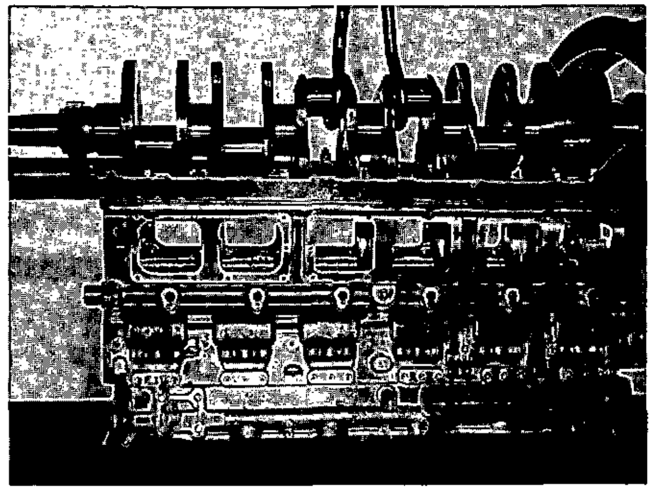


Fig. 0-44, V40077. Lifting crankshaft

Gear Case

1. Remove capscrews and lockwashers securing gear case to block.

2. Install two guide studs 6 inch [152.4000 mm] long through top of gear case into block to prevent gear case from falling during removal.

3. With a soft hammer, tap case alternately top and bottom, left and right, to drive from dowels.

4. Lift case from guide studs and remove studs from block. Discard gasket.

Steam Cleaning

1. Place parts in trays and clean with steam jet to remove exterior dirt, etc. Dry thoroughly with compressed air.

2. Cover plates, pipe plugs, etc. should be removed as applicable to facilitate cleaning of oil and water passages.

3. Do not steam clean the following:

a. Electrical components

b. Wiring

c. Injectors

d. Fuel pump

e. Belts and rubber hose

Glass Bead Cleaning

Glass bead cleaning has been proven most effective for pistons, valves, cylinder heads, etc. The nature and degree of treatment is controlled by the size of glass beads used, operating pressure and exposure time.

1. Bead size—for pistons and other similar parts, use U. S. sieve size No. 70. For general purpose cleaning use No. 60. It is not necessary to use U. S. sieve size No. 60 unless a heavier finish is desired.

2. Operating Pressure—90 PSI [5.4039 kg/sq cm] for pistons etc. for general cleaning, pressures from 90 to 125 psi [5.4039/8.7858 kg/sq cm] may be used.

3. Exposure Time—Do not expose the part being cleaned to the bead blast any longer than absolutely necessary. This is particularly true when cleaning soft material such as aluminum.

4. The only additional cleaning required is to wash with water or blow-off with compressed air.

Caution: Be sure all foreign material has been removed from parts before reassembling.

Removal Of Natural Gas Engine Components

Spark Plugs

1. Remove ignition harness wire from transformer terminal.

2. Remove screws securing transformer cover, retainer, spring and transformer ground wire to rocker cover; lift off cover.

3. Lift transformer, spring, spring retainer and cover assembly from the spark plug adapter tube.

4. Using a 13/16 inch [0.8125 mm] deep-well rubber insert spark plug socket, remove spark plug from adapter. Lift out spark plug and gasket.

Mag-tronic Ignition

Remove nuts, flatwashers, lockwashers and capscrews securing Mag-tronic to drive assembly.

Carburetor And Pressure Reduction Valve

1. Shut off main gas supply valve.

2. Remove air intake piping from carburetors.

3. Remove gas supply line from pressure reduction valves.

4. Remove throttle linkage and cross-shaft from carburetor.

5. Remove clamps securing pressure reduction valve to mounting bracket.

6. Remove capscrews and washers securing carburetors to intake manifolds; lift off carburetors and pressure.reduction valves and discard gaskets.

7. Separate carburetors and pressure reduction valves; remove pipe fittings.

Hydraulic Governor

1. Disconnect and tag electrical wiring from motor-driven head, if used.

2. Draw scribe mark on the governor terminal lever and governor terminal shaft to assist in assembly alignment.

3. Disconnect carburetor linkage from governor speed control lever. Do not remove lever from speed-adjusting shaft without first scribing position to assist in assembly alignment.

4. Remove stud nuts securing governor assembly to governor drive housing; lift off governor and discard gasket.

Cylinder Block Group

The cylinder block group consists of cylinder block, cylinder liners, idler gear, crankshaft, bearing shells, damper, connecting rods, pistons, rear cover, camshafts and gear cover. Cleaning, inspection and rebuilding of each part is described in this section.

Cylinder Block—Unit 101

Metric Measurement

Cummins Engines are used world wide; therefore, all applicable dimensions, temperatures, torque values, etc. are listed in both U.S. Metric Units of measurement. To aid in setting the two systems apart, [Metric Units] are always enclosed in brackets [].

Cleaning

1. Remove all pipe plugs from oil and water passages, etc.

2. Remove oil control valve:

a. Remove expansion plug from housing.

b. Discard plug, remove spring and by-pass disc.

Caution: Remove plug with care for assembly is spring loaded.

c. Do not remove housing from bore in block unless damaged.

3. Clean block by submerging in tank of cleaning solution heated to near boiling. Use Turko or Wyandotte "G" solvent or equivalent; follow manufacture recommendations as to use.

a. Circulate solvent to increase effectiveness.

b. To remove heavy deposits of lime, circulate acid-type cleaner.

Caution: The use of acid may be extremely dangerous to workmen and injurious to machinery. Never use in machine shop or near machinery subject to rusting. Always provide a tank of strong soda water as neutralizing agent.

Passages

1. Run rods with brushes or swabs through all oil passages.

Table 1-1-1: Cylinder Block Pipe Plug Torque

Plug Size	Minimum Ft-lb [kg m]		Maximum Ft-lb [kg m]	
1/8	5	[0.6915]	15	[2.0745]
1/4	30	[4.1490]	35	[4.8405]
3/8	35	[4.8405]	45	[6.2235]
1/2	45	[6.2235]	55	[7.6065]
3/4	60	[8.2980]	70	[9.6810]
1-1/4	75	[10.3725]	85	[11.7555]

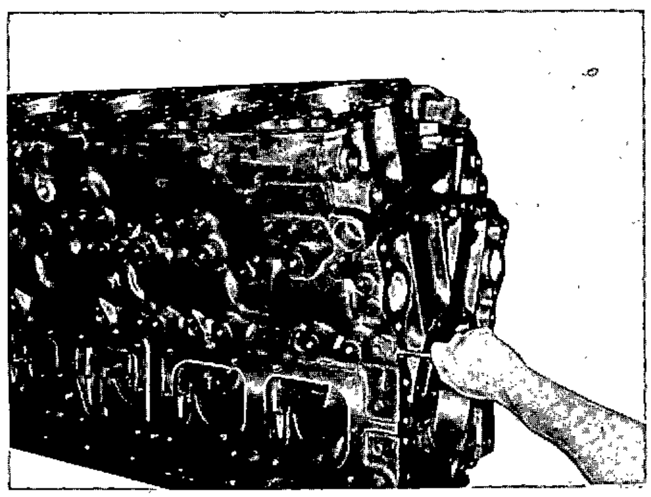


Fig. 1-1-1, V40166. Cleaning block oil passage

2. Replace all pipe plugs. Use "Teflon" sealing tape or "John Crane Lead Sealer, No. 2" on plugs to prevent leakage. Tighten plugs to values listed in Table 1-1-1.

Note: If additional machining is to be performed, oil passage cleaning and replacement of plugs should be done after all machining is completed.

Air Vent Hole

Clean hole (No. 1 cylinder left bank and No. 6 cylinder right bank) that opens into water header. Fig. 1-1-2.

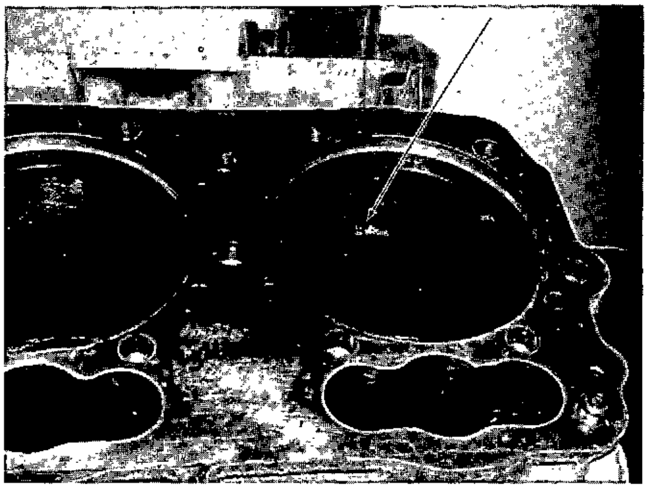


Fig. 1-1-2, V40120. Air bleed hole

Liner Bore

1. Scrape counterbore lightly to remove any scale.

2. Clean lower liner bore with sandpaper or sanding drum powered by an electric drill. Emery cloth may be used if bore contains ridges. Be sure to remove nicks or burrs that would damage liner packing rings as liner is installed.

Capscrew Holes

1. Blow all dirt or cleaning fluid from capscrew holes with an air jet. Fig. 1-1-3.

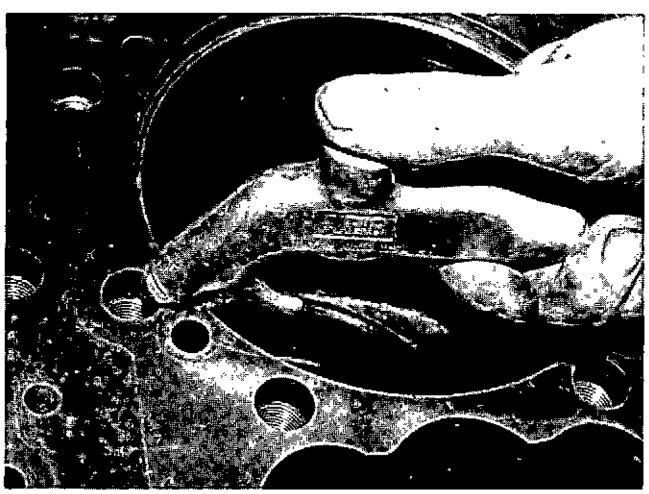


Fig. 1-1-3, V40121. Cleaning cylinder head capscrew hole

Caution: Any time air jets are in use, the workman must wear goggles or other protection.

2. Cylinder head capscrew holes in block are counterbored to prevent distorting and forcing liners out-of-round, when cylinder head capscrews are tightened. All dirt and oil must be removed from holes to prevent damaging block when capscrews are tightened.

Inspection

Before any part is discarded or used again a careful inspection must be performed. The inspection should include wearing surfaces and general over-all conditions. Cost of rebuilding an engine can be high or low, depending entirely upon intelligent inspection and use of proper standards.

Using Dye Penetrants To Locate Flaws

1. To successfully use dye penetrant method of locating cracks, porosity, leaks, etc. requires cleaning the part, penetrant application, developing the penetrant and inspection.

2. Clean suspected defective area with kerosene or other grease-removing cleaner.

3. Apply dye penetrant allowing time for it to dissolve or enter into the defect (usually about fifteen minutes); do not "force" dry. Remove all excess penetrant.

4. Apply developer so defect will stand out; cracks usually show up as a solid or dotted line; however, caution must be observed as this can be a non-damaging forging lap.

5. Porosity usually shows up as dots in local areas. The wider the area spreads, the larger the defect.

Corrosion

1. Corrosion most frequently occurs on portions of block nearest cylinder liners and is evidenced by pitting. Discard block if area cannot be cleaned, or if area is distorted.

2. In many cases the liner packing area in the block may be repaired by sleeving as outlined under "Parts Replacement and Repair" following, if pitting endangers the effectiveness of liner packing ring and crevice seals.

Camshaft Bushings

1. Use inside micrometers or dial bore gauge to gauge camshaft bushing inside diameter. Fig. 1-1-4. Mark bushings for replacement if worn larger than "Worn Limit" shown in Table 1-1-2.

2. If bushings have been badly chipped, scored or scratched, mark for replacement.

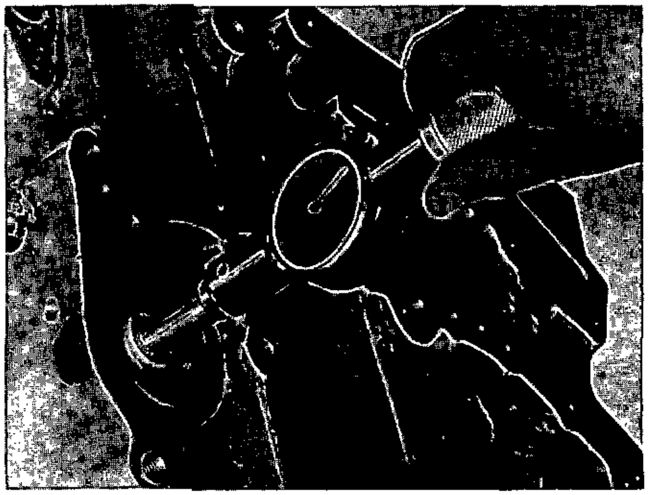


Fig. 1-1-4, V40102, Checking camshaft bushing inside diameter

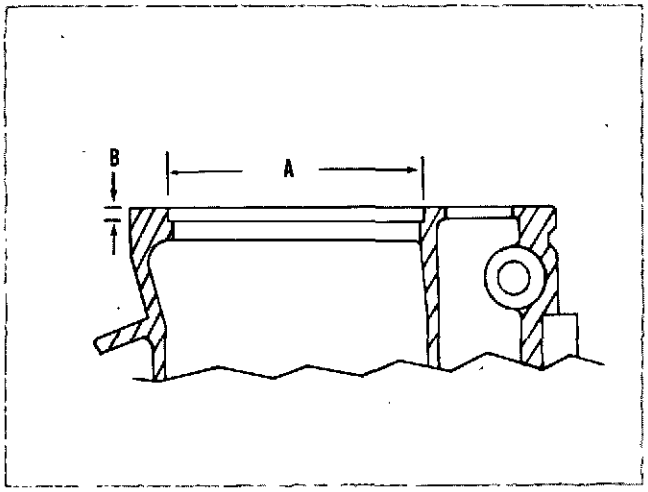


Fig. 1-1-5, V414207, Cylinder liner counterbore dimensions

Table 1-1-2: Camshaft Bushing Inside Diameter

New Dimension Minimum Inch	[mm]	Maximum Inch	[mm]	Worn Limit Inch	[mm]
2.1245	[53.9623]	2.1283	[54.0588]	2.1295	[54.0893]

3. If bushings have turned in block bore, check block bore size; see Table 1-1-3.

Table 1-1-3: Block Camshaft Bushing Bore

New Dimensions Minimum Inch	[mm]	Maximum Inch	[mm]	Worn Limit Inch	[mm]
2.2535	[57.2389]	2.2545	[57.2643]	2.2555	[57.2897]

4. Make certain oil passages between bushings and block oil holes are properly aligned. If bushing replacement is necessary, see "Parts Replacement and Repair" following.

Cylinder Liner Counterbore

1. Check upper liner counterbore diameter (Table 1-1-4) and remove burrs, dirt, etc., so liner will enter without distortion (Fig. 1-1-5).

Caution: Do not attempt to rework counterbore "A" diameter.

Table 1-1-4: Cylinder Liner Counterbore Diameter

New Dimensions Minimum Inch	[mm]	Maximum Inch	[mm]
6.5615	[166.6621]	6.5635	[166.7129]

2. The counterbore ledge must be smooth and perpendicular to the cylinder liner bore.

3. Check counterbore depth so installed liner will be assembled to correct protrusion and to determine if refinish of counterbore surface is necessary. Depth of counterbore on a new block is listed in Table 1-1-5.

Table 1-1-5: Cylinder Liner Counterbore Depth

New Dimensions Minimum Inch	[mm]	Maximum Inch	[mm]	Worn Limit Inch	[mm]
0.3500	[8.8900]	0.3510	[8.9154]	0.4110	[10.4394]

4. If worn to or beyond worn limit, the cylinder block must be replaced.

5. Installed cylinder liners must protrude 0.004/0.006 inch [0.1016/0.1524 mm] above block. To check for proper protrusion without installing a liner:

a. Measure liner flange outside bead with micrometer. Fig. 1-1-6. **Do not include bead on top of liner flange in taking measurement.**

Fig. 1-1-6, V40123. Checking liner flange height-outside head

b. Measure block counterbore depth with dial indicator depth gauge or ST-547 Gauge Block. Fig. 1-1-7. If ST-547 is used, "zero" indicator before taking measurement.

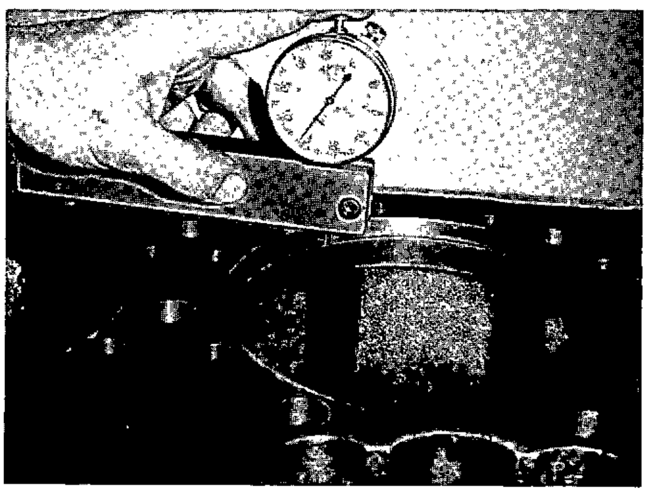


Fig. 1-1-7, V40124. Checking liner counterbore depth in block

c. Check depth at four equidistant locations. Ledge must not be "cupped" more than 0.0014 inch [0.0355 mm] Depth must not vary more than 0.001 inch [0.0254 mm] throughout counterbore circumference.

d. If dimensions do not meet standards of step "c" above, counterbore must be resurfaced. See "Parts Replacement and Repair."

e. Subtract counterbore depth from liner flange thickness to determine amount of shims and depth of counterbore cut that must be used to provide desired liner protrusion (see "5" above).

Note: If material to be removed will result in a counterbore depth exceeding worn limit in Table 1-1-5, block cannot be reused.

6. The most accurate method of checking protrusion is as follows:

a. Install liner and packing rings (see Group 14, for assembly) in block with proper number of liner shims beneath the flange.

b. Insert cylinder head capscrews into ST-1005 Cylinder Liner Hold-Down Tool Sleeve and screw capscrews into block so foot of ST-1005 rests upon cylinder liner "fire ring." Capscrews should be spaced around liner so even load will be applied.

c. Tighten capscrews to 50 ft-lb [6.9150 kg m] torque.

d. Use ST-547 Gauge Block and check liner protrusion above the cylinder block at four equidistant points outside the bead.

e. Add or remove shims from beneath the liner flange as needed to reach 0.004/0.006 inch [0.1016/0.1524 mm] protrusion.

f. With liner installed check for out-of-round as described under "Install Liner in Block," Group 14.

Cylinder Liner Lower Bore

1. Install a new cylinder liner in the block without packing rings or crevice seal. Fig. 1-1-8.

Note: Liner contact is permissible as long as it does not cause liner out-of-round.

2. Clearance between liner and block should be as listed in Table 1-1-6.

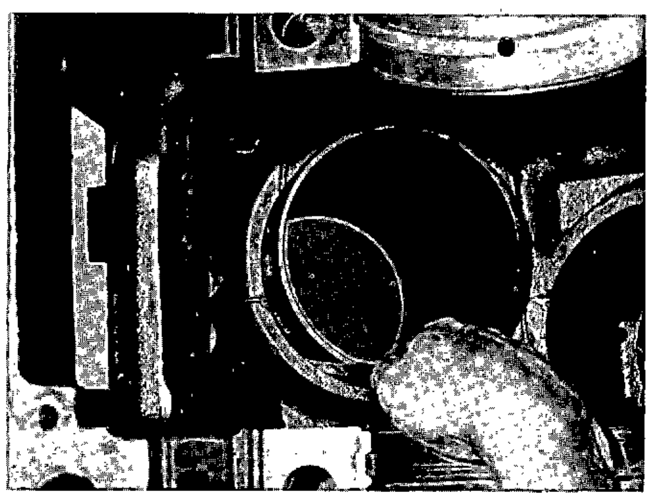


Fig. 1-1-8, V40125. Checking clearance between block and liner

Table 1-1-6: Liner-To-Block Clearance – Lower Bore

Minimum Inch	[mm]	Maximum Inch	[mm]
0.004	[0.1016]	0.008	[0.2032]

3. If clearances do not fall within above limits, recheck after counterboring.

Note: These limits do not apply with cylinder head installed and tightened to operating torque.

4. If clearance is not correct, check lower block packing ring bore inside diameter. See Table 1-1-7.

Table 1-1-7: Lower Liner Bore Inside Diameter

Minimum Inch	[mm]	Maximum Inch	[mm]
6.1240	[155.5496]	6.1260	[155.6004]

Check Lower Liner Bore Concentricity With ST-1082

If a piston seizure has occurred or after counterboring the cylinder block, it is a good practice to check the counterbore to lower cylinder liner bore concentricity. ST-1082 Concentricity Gauge may be used in combination with parts from ST-1081 Boring Tool. See Fig. 1-1-9.

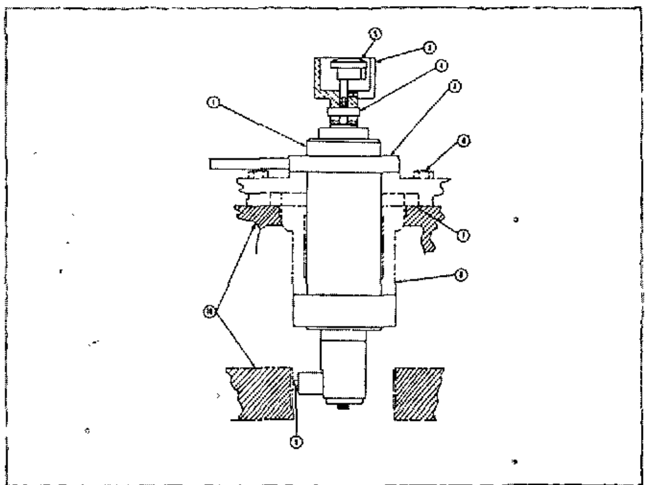


Fig. 1-1-9, V40152. ST-1082 Concentricity

Preparation Of Cylinder Block

1. Remove all carbon and scale from deck, counterbore and lower bore of block (10, Fig. 1-1-9).

2. Deck must be flat (remove all burrs and nicks) and clean.

Assembly Of Concentricity Gauge

1. Select all the proper components (ST-1076, ST-1082, ST-1081-30, ST-1031-31 and ST-1084-5) for V-1710 5-1/2 inch bore engines.

2. Install ST 1084-5 Bore Adapter (8, Fig. 1-1-9) onto ST-1082 Concentricity Gauge (1) (wipe all furnished surfaces clean).

3. Install ST-1076 Adapter Plate (7) onto concentricity gauge (1) with 3/4 inch recess toward bore adapter (8).

4. Engage ST-1081-31 locking nut (5) onto concentricity gauge (1) and tighten locking nut ST-1081-30 handle until concentricity gauge, bore adapter and adapter plate are one unit.

5. Rotate adjusting knob (4) counterclockwise until it bottoms out against indicator holder (3), then rotate adjusting knob clockwise one revolution.

6. Install dial indicator (2) into indicator holder (3) and adjust indicator gauge to zero.

Installation Of Concentricity Gauge

1. Rotate adjusting knob (4) counterclockwise until gauging finger (9) is fully retracted.

2. Install unit into cylinder block with hold-down holes matching holes in cylinder block.

3. Assemble hold-down capscrews (6) and washers (4 required) through adapter plate into cylinder block finger tight.

4. Torque the capscrews to 50/75 ft-lb [6.9150/10.3725 kg m].

Check Concentricity

1. Rotate adjusting knob clockwise until dial indicator reads 0.025 inch [0.6350 mm] on plus side of zero.

2. Rotate adjusting knob counterclockwise until dial indicator reads zero.

3. If zero is missed on first try go past zero and come back to zero as described in Steps 1 and 2.

4. Rotate shaft on concentricity gauge in clockwise direction with indicator holder slowly 360 deg.

5. The movement of indicator from zero is immediately apparent. New block should be concentric within 0.005 inch [0.1270 mm] total indicator reading.

Main Bearing Caps

1. Main bearing caps have an interference fit to block of 0.004/0.006 inch [0.1016/0.1524 mm].

2. Caps must fit in block with no perceptible clearance or "shake." Milled faces of cap must always rest on mating portion of block to prevent distortion during tightening.

3. Replacement caps, which must be machined to fit, are available as service parts; see "Parts Replacement and Repair".

4. Inspect main bearing side bolt holes for stripped or damaged threads. If damaged mark for repair.

Main Bearing Bore

1. Assemble main bearing caps, lockplates and capscrews to block in operating position. Fig. 1-1-10. Tighten capscrews to operating tension; see "Parts Replacement and Repair".

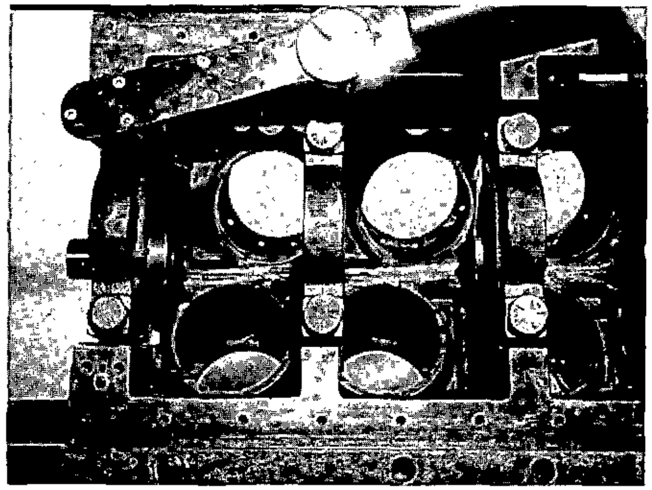


Fig. 1-1-10, V40126. Tightening main bearing capscrews

2. Gauge main bearing bore horizontally, vertically and diagonally with dial bore gauge or inside micrometers properly adjusted to standards, Fig. 1-1-11. See Table 1-1-8.

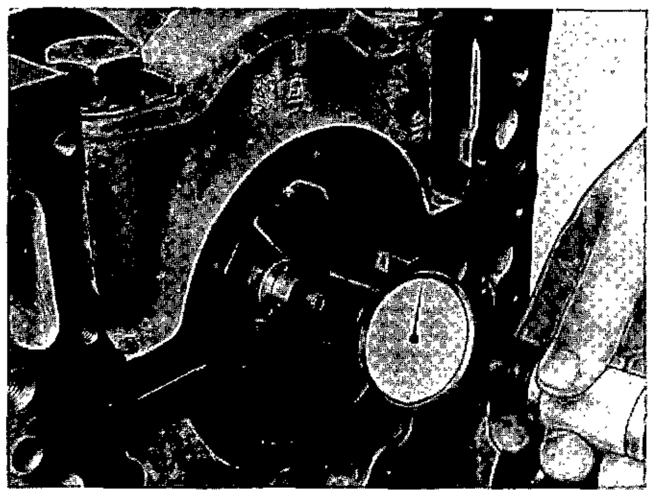


Fig. 1-1-11, V40103. Checking main bearing bore for out-of-round

Table 1-1-8: Main Bearing Bore Inch [mm]

Serial No. Suffix	New Dimensions Minimum	Maximum	Worn Limit
3	6.0950 [154.8130]	6.0960 [154.8384]	6.0965 [154.8511]

Note: Number "3" may appear as reference number on nameplate.

3. Check bore alignment with ST-1048 (Fig. 1-1-12) or ST-1177-15; bore is 6.0950 to 6.0960 inches [176.5300 to 176.6840 mm]. This closely ground checking ring will pass through all bores unless caps are not tightened to proper tension, burrs, etc., have not been removed, or caps are distorted. For installation of ST-1177 refer to Main Bearing Bore Reaming, Page 1-1-9.

4. *If it is definitely determined that a main bearing cap has* been distorted and is preventing checking bar from passing through bore, mark block for reaming.

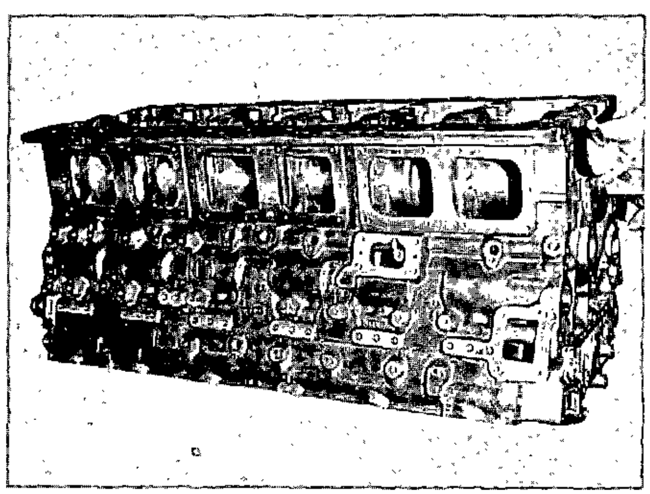


Fig. 1-1-12, V40104. Checking main bearing bore alignment

Water Passages

1. Check all water passages to make sure they are open.

2. Check for eroded water holes which may prevent proper seating of head gasket or grommet retainers.

3. Water holes not eroded more than 1/16 inch [1.5875 mm] from edge of hole can be "bushed"; see Parts Replacement and Repair"

4. Check for erosion within 1/32 to 3/32 inch [0.7937 to 2.3812 mm] from liner counterbore; if not more than 0.010 inch [0.2540 mm] deep block may be resurfaced.

Tappet Bores

1. Measure tappet bores with a small bore gauge, Fig. 1-1-13. See Table 1-1-9.

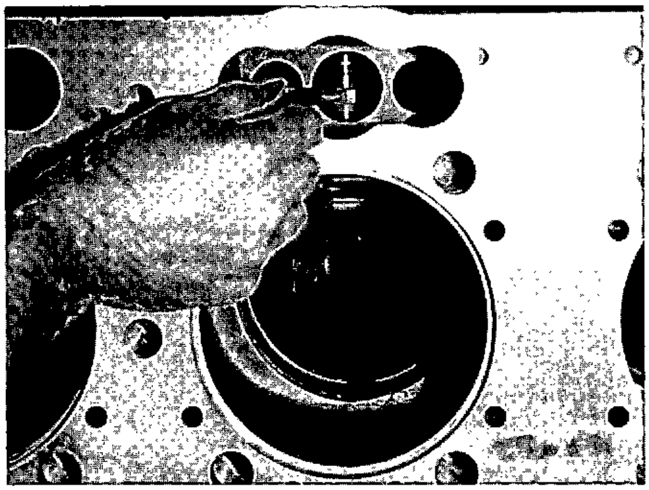


Fig. 1-1-13, V40127. Checking tappet bore inside diameter

Table 1-1-9: Tappet Bore Size

Tappet Location	New Dimension Minimum Inch [mm]	Maximum Inch [mm]	Worn Limit Inch [mm]
Injector	1.6245 [41.2623]	1.6255 [41.2877]	1.6270 [41.3258]
Valve	1.1870 [30.1498]	1.1880 [30.1752]	1.1895 [30.2133]

2. If worn beyond limit in Table 1-1-9 or out-of-round more than 0.0015 inch [0.0381 mm], replace block.

Idler Gear Shaft

Replace idler shaft, if worn smaller than 1.9965 inch [50.7111 mm].

1. Remove outer lockscrew from left side of ilder shaft boss; then remove setscrew which secures shaft in block.

2. Using a suitable puller, pull shaft from block.

3. Place new shaft in block bore and drive shaft in block until it seats on shoulder.

4. Install setscrew to secure idler shaft in block; install lockscrew in boss.

Parts Replacement and Repair

After a thorough inspection of cylinder block, bushings and main bearing caps, the decision must be made whether to install a new block assembly, replace bushings or caps and how much can be done to rebuild or recondition the reusable parts. The following instructions cover the operations that may be performed to make a reusable block ready for service.

All rebuilding should be done in well-equipped shops, and with experienced personnel, to obtain satisfactory service from the part being repaired.

Sleeve Camshaft Bushing Bore In Block

1. If camshaft bushing bore in block is damaged, first determine cause of damage and correct. Bore may then be repaired by installing sleeve.

2. Pilot boring bar in two good camshaft bushing bores either fore or aft of one being repaired.

3. Cut piece of 2-1/2 inch [63.5000 mm] O.D. seamless steel tubing with 1/8 inch [3.175 mm] wall to length of bore in block. Chamfer one end to facilitate installation.

4. Measure O.D. of tubing.

5. Perform boring operation. Bore must be 0.002/0.005 inch [0.0508/0.1270 mm] smaller than tubing O.D. to provide press fit.

6. Remove boring bar and carefully clean block to remove all shaving.

7. Apply a thin coat of Permatex to tubing O.D. and block bore I.D. to prevent galling during installation and to provide a tighter press fit.

8. Install tubing with short mandrel to prevent collapsing. Mandrel must have shoulder on drive end.

9. Pin sleeve with 1/16 inch—27NPTF x 1 inch Salsbury pipe plug or soft steel pipe plug through side wall of block or through camshaft bushing bore. Stake plug.

10. Reinstall boring bar and bore sleeve to 2.2535/2.2545 inch [57.2389/57.2643 mm] I.D. Remove bar and clean all shavings from block.

11. Install bushings.

Camshaft Bushing Replacement

1. Service tools are available for removal and installation of camshaft bushings. The tool consists of two parts: ST-782 Busing Driver and ST-785 Bushing Mandrel.

2. Camshaft bushings are two piece and must be located with space between to act as an oil passage.

3. Locate bushing on drive mandrel.

4. Drive in position so oil holes are open. Fig. 1-1-14.

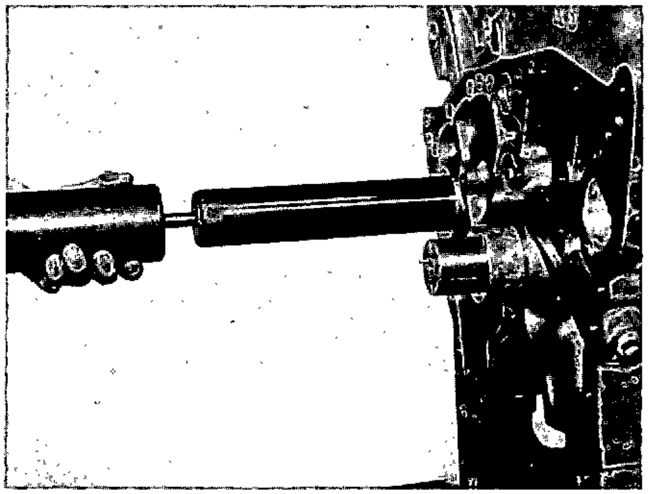


Fig. 1-1-14. V40128. Installing camshaft bushing

Main Bearing Cap Repair

Note: This procedure cannot be followed in off centered holes due to thin wall construction.

1. Drill out stripped or damaged threads with a 53/64 inch drill [0.8281 mm] to 1.000 to 1.150 inch [25.400 to 29.210 mm] deep.

2. Countersink 0.885 to 0.895 inch [22.4790 to 22.7330 mm] diameter by 86 deg. included angle.

3. Tap hole with 7/8-14 UNC-2B tap to 0.800 to 0.900 inch [20.3200 to 22.8600 mm] deep.

4. Install "Keensert" insert Cummins Part No. 203299.

5. Screw in insert finger tight, "Kees" (locking tanges) will automatically stop insert.

6. For proper engagement visually check insert, flush or below surface of cap.

7. Secure in position by driving "Kees" down flush with cap surface by lightly tapping on tool.

Main Bearing Cap Replacement

1. Semi-finished replacement main bearing caps are available for limited use in rebuild shops.

Note: The responsibility for use of semi-finished caps must be assumed by the engine owner or by the shop which performs the work.

2. Replacement main bearing caps have 0.003 inch [0.0762 mm] material in bore and 0.005 inch [0.1270 mm] excess in length (pilot dimension). Other dimensions are the same as finished main bearing caps.

3. A No. 7 new replacement cap does not have cap-to-block dowel holes and must be machined to block width.

4. Machine an equal amount of material from each end of semi-finished cap to provide 0.004 to 0.006 inch [0.1016 to 0.1524 mm] interference fit in block.

5. If the cap is a rear cap (No. 7):

a. Remove locating dowels from block.

b. Locate and machine cap so thrust faces of cap and block are flush. Use Prussian Blue on block surface to locate dowel holes in cap.

c. Remove cap.

d. Drill dowel holes. Fig. 1-1-15.

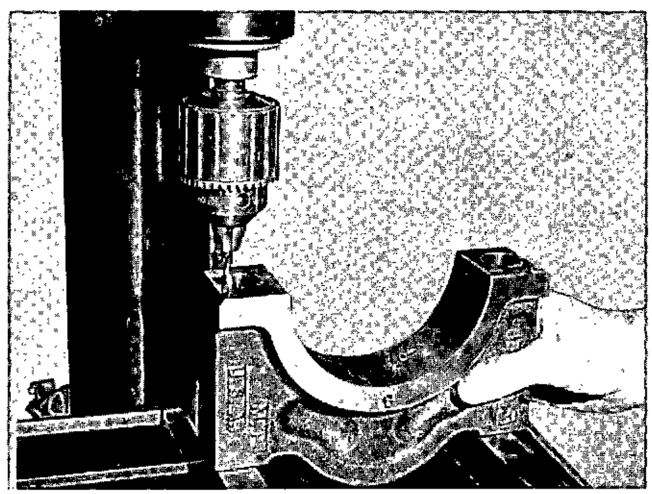


Fig. 1-1-15. V40129. Drilling dowel hole in rear main bearing cap

e. Reinstall cap and ream dowel holes to the smallest permissible oversize.

f. Install dowels in block.

6. Install all caps on block and ream bore as described in following paragraphs.

Main Bearing Bore Reaming With ST-1048

1. If main bearing bore was out of alignment or if

replacement cap has been installed, ream bore as follows.

Caution: Do not ream the main bearing bore indiscriminately. It should never be necessary to ream the main bore unless a cap has been distorted or replaced.

2. If bore must be reamed, first remove 0.002/0.003 inch [0.0508/0.0762 mm] stock from bottom milled surface of main bearing caps which are out of alignment. Remove stock by lapping or surface grinding.

Note: Omit this step if replacement caps are being used.

3. Lay Reaming Bar ST-1047 in block, so rear of bar is piloted in two good main bearing bores, in block. See Table 1-1-8.

4. Install all main bearing caps in block and tighten capscrews to operating tension, following steps shown in Table 1-1-10, in alternating steps from one capscrew to another on same journal.

5. Install and torque main bearing side capscrews on engines with serial number suffix "3" or reference number "3" on serial plate to following values.

a. Torque all right bank side capscrews to 70-75 ft-lbs [12.6810/13.3725 kg m].

b. Torque all left bank side capscrews to 70-75 ft-lbs [12.6810/13.3725 kg m].

c. Return to right bank and torque side capscrews to 135-145 ft-lbs [18.6705/20.0535 kg m].

d. Return to left bank and torque side capscrews to 135-145 ft-lbs [18.6705/20.0535 kg m].

6. Lubricate reamer cutters and bores in block with engine lubricating oil. This will prevent reaming oversize and will allow a better finish.

7. Use ST-219 Hand Driver to turn the reamer. Fig. 1-1-16. This driver is loosely pinned to prevent up and down or side thrust of reamer while it is being turned.

8. Run reamer through remaining main bearing bores without "backing up" or reversing.

9. Check bore with Checking Bar and measure bore diameter once again with dial bore gauge. See Fig's. 1-1-11 and 1-1-12, and "Main Bearing Bore."

10. Clean block thoroughly.

Reaming Main Bearing Bore With ST-1177

A new combination main bearing bore checking bar and boring tool has been designed for use in repair of engine cylinder blocks. The combination tool is used to perform

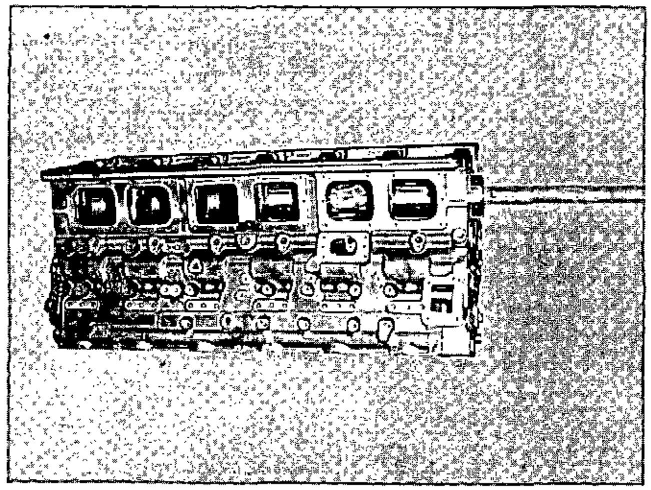


Fig. 1-1-16, V40107. Reaming main bearing bore

both the barring and checking functions. The one single new tool, ST-1177, will replace the tools currently being used. Parts will continue to be available for the "old-style" tools on special order.

1. Cylinder block should be cleaned, and block and ST-1177 Boring Tool allowed to stabilize to room temperature.

2. Remove all burrs and irregularities from pan ledge and each side of main bearing bores.

3. Install main bearing caps and torque all main bearing capscrews and side capscrews to required specifications.

4. Check bore diameter with a dial bore gauge. A damaged cap can be replaced with a semi-finished cap.

Assembly Of ST-1177 Boring Tool To Block

1. Remove two undamaged main bearing caps. Preferably one from each end of block. (No. 1 and 7) or as far apart as possible.

2. Insert proper centering rings, with oiler up, in two bores and tap top of centering ring with plastic hammer to seat.

3. Reinstall main bearing caps and torque to required specifications.

Caution: If centering ring must be installed in journals which have had the caps replaced by semi-finished caps, limit the torque to 10 ft-lbs.

4. Machine an equal amount of material from each end of semi-finished cap to provide 0.002 to 0.004 inch [0.0508 to 0.1016 mm] interference fit in block.

5. If cap is a rear cap:

a. Remove locating dowels from block.

b. Locate and machine cap so thrust faces of cap and block are flush. Use Prussian Blue on block surface to locate dowel holes in cap.

c. Remove cap.

d. Drill dowel holes.

e. Reinstall cap and ream dowel holes to smallest permissible oversize.

f. Install dowels in block.

6. Oil centering ring bores and boring bar.

7. Install boring bar (ST-1177-16) through centering rings rotating slowly. Bar should spin free.

8. Slide bar out one end until appropriate checking ring can be installed on bar.

9. Oil outside diameter of checking ring.

10. Using light finger pressure against checking ring on both sides of bar, push checking ring through each bore. Fig. 1-1-17. Bar must be turned during this check.

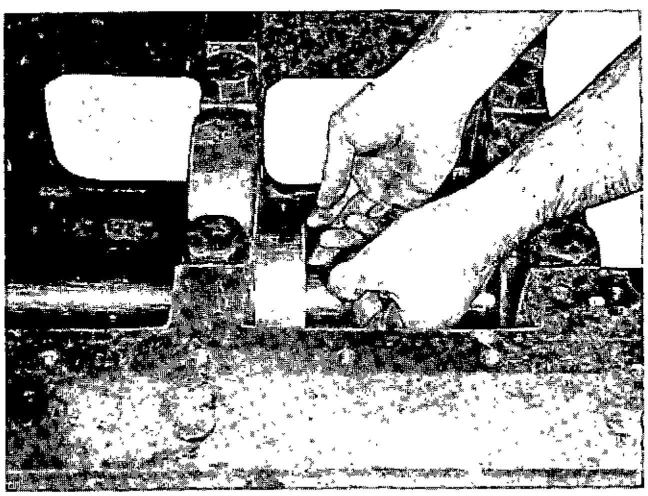


Fig. 1-1-17, V40187. Checking main bearing bore with ST-1177

a. Check bore for burrs if check ring will not pass through bore.

b. If checking ring will not pass through majority of bores, move centering rings to other bores and repeat procedure.

c. Mark bores to be salvaged.

Assemblying Micrometer Tool Bit Setting Gauge And Tool Bit

1. Place micrometer shaft (ST-1177-46) through bore of micrometer bracket (ST-1177-45) and thread into micrometer base (ST-1177-44). Tighten securely.

2. Tighten the socket head screw (ST-1177-29) in the micrometer bracket until the bracket is tight on the micrometer shaft; micrometer hole in micrometer bracket *must be in alignment with hole through micrometer shaft.*

3. Install centering ring (ST-1177-42) over micrometer shaft.

4. Install micrometer (ST-1177-43) in micrometer bracket.

a. Adjust micrometer thimble to value stamped on centering ring.

b. Hold micrometer spindle against centering ring and tighten socket head screw (ST-1177-48) in micrometer bracket. Check to see that micrometer spindle turns free.

5. Remove centering ring.

6. Install appropriate cutter holder over micrometer shaft.

7. Align tool bit hole in cutter holder with hole through micrometer shaft and tighten cutter holder socket head screws. Fig. 1-1-18. Keep even gaps between two halves of cutter holder.

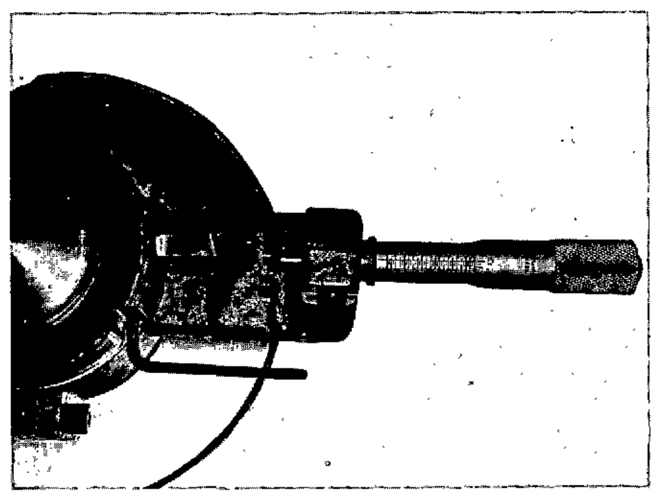


Fig. 1-1-18, V40188. Adjusting tool bit in cutter holder

8. Insert appropriate cutting bit in tool holder. Tool must be short enough that it does not extend into the bore of tool holder.

9. Loosen micrometer bracket socket head screw until micrometer bracket can be moved to center micrometer

spindle with point of tool bit.

10. With cutter key (ST-1177-49) adjust tool bit against micrometer spindle and tighten tool bit swivel pad screw in tool holder.

11. Back off micrometer and recheck tool bit set. Do not tighten micrometer spindle against tool bit point or carbide can be chipped. Do not sweep micrometer spindle across carbide cutter for it will chip cutting edge.

12. Back off micrometer and remove cutter holder from micrometer shaft.

Cutting Bores

1. Install bore feed assembly (ST-1177-17) in one end of boring bar and tighten socket head screw (ST-1177-32).

2. Install torsion bar (ST-1177-33), threaded end first, through bore feed assembly and thread tight into end hole of torsion bracket (ST-1177-34). The flats on bar can be used to tighten it into bracket.

3. Locate tapped hole in end of block and secure torsion bracket to block with suitable capscrew and washer.

4. Pull out on plastic knob of feed assembly until pin is free of slot and turn 1/4 turn. Fig. 1-1-19.

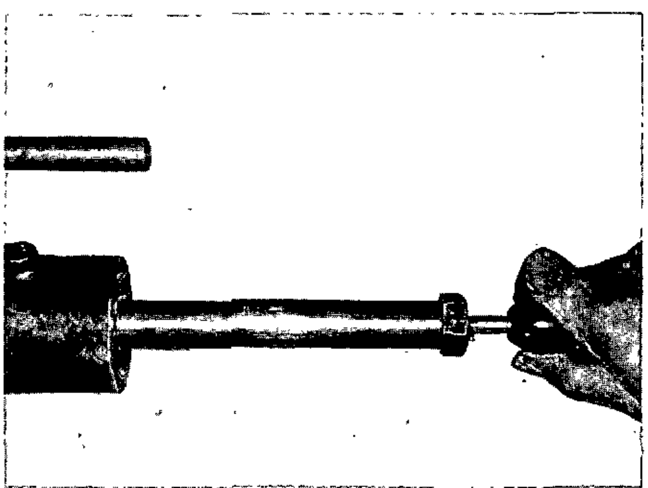


Fig. 1-1-19, V40189. Adjusting bore feed assembly

5. Pull complete feed assembly back to knob.

6. Tighten the wing nut in the feed assembly to secure it on torsion bar.

7. Install the square head set bolt in second threaded hole of torsion bracket end and tighten snug against cylinder block to stabilize torsion assembly.

8. Turn the plastic knob on drive assembly 1/4 turn until pin seats in groove.

9. Install adapter (ST-1177-31) in other end of boring bar with 1/2 inch end out. Lock with socket head screw (ST-1177-32).

10. Lock (ST-1177-27) swivel joint in a 1/2 inch drill's chuck. Note the drill's direction or rotation.

11. Install tool bit holder on boring bar, next to journal to be cut. When in operation, boring bar will feed toward feed assembly. Make sure tool bit cutting edge is turned in direction of drill's rotation.

12. With swivel joint on boring bar adapter, bore the journal. Fig. 1-1-20. Do not push on drill. **Allow feed assembly to regulate amount of cut.** Keep boring bar well lubricated during all boring operations.

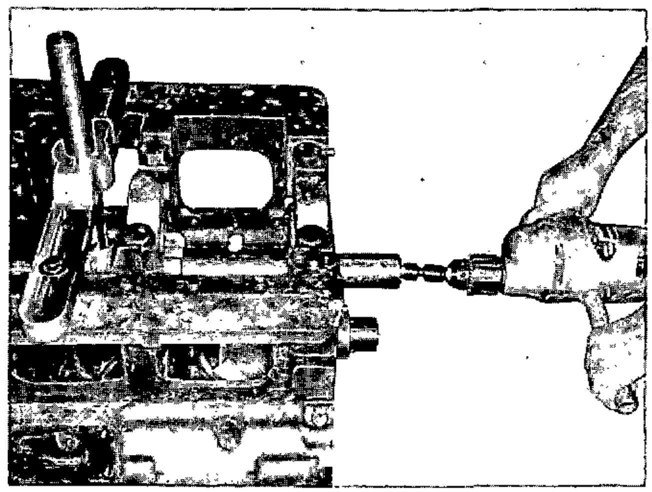


Fig. 1-1-20, V40190. Boring main bearing journal with ST-1177

13. Check size of bore with a dial bore gauge and alignment with checking ring.

14. Clean the block thoroughly.

Use Of Bridges

Bridges and bearings are intended for additional support of boring bar and are designed to compensate for any distortion of oil pan mounting surface. It is not necessary to use bridges if centering rings are located far enough apart.

1. Assemble bearing bar (ST-1177-22) on bearing (ST-1177-21) with hexagon head capscrew (ST-1177-23)

finger tight.

2. Slide bearing over boring bar at point where support is needed. Allow room for cutter holder, if next to journal being cut.

3. Lower line bore bridge (ST-1177-18) over bearing bar and secure to oil pan mounting surface with appropriate capscrews.

4. Tighten socket head screw (ST-1177-25) in bearing until bearing is snug on boring bar but do not restrict bar's turning capability.

5. Tighten hexagon head capscrew (ST-1177-25) in bearing bar and socket head capscrew (ST-1177-19) in bridge.

6. Turn boring bar to see that it rotates freely.

Table 1-1-10: Main Bearing Capscrew Tightening

Step	Ft-Lbs	[Kg m]
1. Tighten to	200/210	[27.6600/29.0430]
2. Advance to	410/420	[56.7030/58.0860]
3. Loosen	ALL	ALL
4. Tighten to	120/125	[16.5960/17.2875]
5. Advance	60 deg.	60 deg.

Sleeve Eroded Water Holes

The cylinder block surface around the water holes must be free of any erosion, pits, scratches or blemishes which are more than 0.003 inch [0.0762 mm] deep in the area 1/16 to 5/32 inch [1.5875 to 3.9674 mm] from edge of water holes. Repair as follows:

1. Insert hold-down adapter of ST-1010 into cylinder head capscrew hole. Fig. 1-1-21.

2. Position tool on head with reamer guide hole over water hole to be repaired.

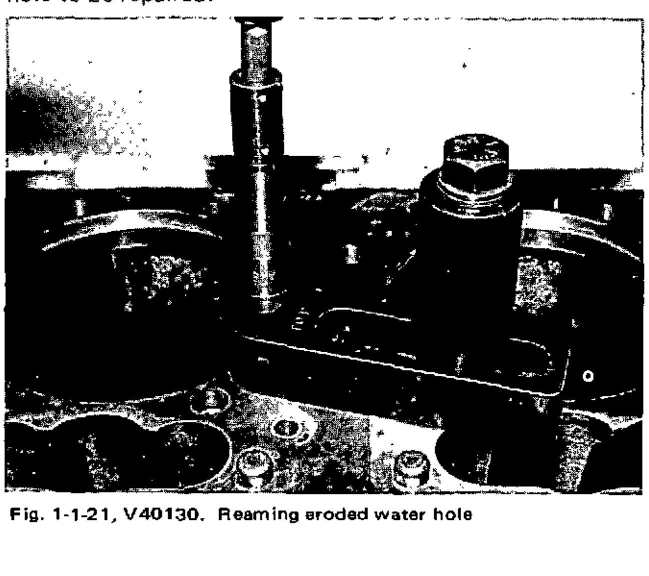


Fig. 1-1-21, V40130. Reaming eroded water hole

3. Insert tool hold-down knob into holder assembly and tighten down finger tight.

4. Insert locating pin into eroded hole and tighten hold-down knob.

5. To set depth of reamer assembly, insert assembly in guide. Place bushing between holder assembly and reamer adjustable stop collar. Insert 0.005 inch [0.1270 mm] feeler gauge between bushing and adjustable collar; tighten setscrew.

Caution: Take care not to use too large a reamer; avoid getting head gasket grommet over liner flange.

6. Attach drive adapter to half-inch drill chuck and place grooved end of drive adapter into reamer assembly.

7. Ream out eroded water hole until collar bottoms against tool.

8. Remove drill, reamer assembly, holder assembly and hold-down adapter.

9. Drive bushing into reamed hole with driver. Bushing should protrude about 0.003 to 0.005 inch [0.0762/0.1270 mm].

10. If block is to be resurfaced, see "Resurface Cylinder Block." If not to be resurfaced, file bushing flush with head, using a wide, flat mill file.

a. Be careful not to damage cylinder head surface when filing sleeves.

b. Thoroughly clean block water passages to remove all cuttings and filings.

11. If proper bushing is not available, heavy-wall copper tubing may be used. Tubing must provide 0.002 to 0.005 inch [0.0508 to 0.1270 mm] press fit. Overall length should be approximately 1/2 inch [12.7000 mm]; inside diameter must be 7/16 inch [1.1125 mm] to allow proper water flow through head.

Top Surface Refinishing

Under certain conditions, a cylinder block may be salvaged by removing a maximum of 0.010 inch [0.2540 mm] of material from the top surface.

1. Use either a milling machine or large surface grinder; locate block on main bearing pads, not on pan ledge.

2. Make light cuts of 0.001 to 0.003 inch [0.0254 to 0.0762 mm] deep, removing only enough material to make block usable.

3. Check distance from centerline (A, Fig. 1-1-22) of main bearing bore to top of block.

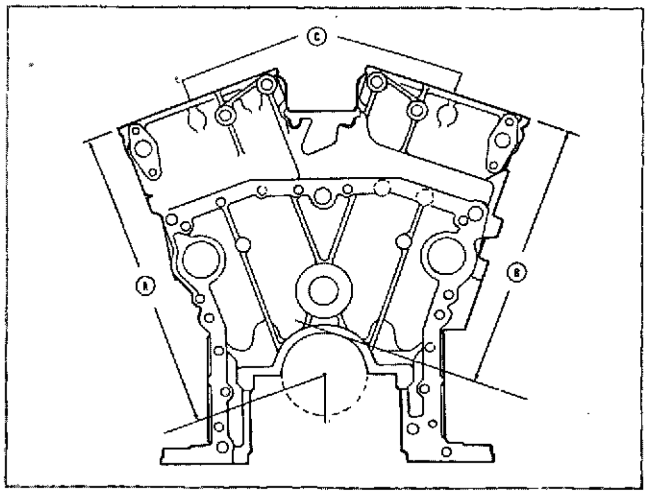


Fig. 1-1-22, V40106. Cylinder block height

a. Find this dimension by placing block, top down (C), on a flat surface plate and measuring from main bearing bore centerline to plate. Table 1-1-11.

b. An alternate method is to check distance (B) from installed main bearing bore alignment bar to top surface of block. Table 1-1-12.

c. Distance from head surface to main bearing bore centerline must not vary more than 0.002 inch [0.0508 mm] throughout length of block. Head surface flatness must not vary over 0.002 inch [0.0508 mm].

Table 1-1-11: Cylinder Block Height From Main Bearing Centerline (A, Fig. 1-1-18) Inch [mm]

New Dimensions Minimum	Maximum	Worn Limit
19.004 [482.7016]	19.006 [482.7524]	18.994 [482.4476]

Table 1-1-12: Cylinder Block Height From Alignment Bar (B, Fig. 1-1-18) Inch [mm]

Serial No. Suffix	New Dimensions Minimum	Maximum	Worn Limit
3	15.9565 [405.2697]	15.9580 [405.3332]	15.9457 [405.0207]

Note: Number "3" may appear as reference number on nameplate.

Note: Cummins Engine Company, Inc. assumes no responsibility for the success of this operation. It can be done only in a shop that is properly equipped.

4. Finish surfaces to 125 R.M.S.

5. Resurface counterbore to obtain proper liner protrusion.

Lower Liner Packing Ring Bore Repair

Cummins Engine Company, Inc. cannot assume responsibility for the success of the following repair operation. It is a job that can be done only in shops properly equipped for this type work and by trained personnel.

It is very important that dimensions given be duplicated. Depth and diameter dimensions must be held within tolerances given so liner packing rings and crevice seals will seal properly.

Installation Of Brass Sleeve Using Boring Bar

The O.D. of 163401 "brass" sleeve is approximately 0.012 inch [0.3048 mm] larger than recommended bore. This press fit is sufficient interference to hold sleeve in place.

Caution: The following instructions do not apply when ST-1081 or cast iron sleeve part No. 195778 are to be used.

1. Bore block as shown in Fig. 1-1-23 and to dimensions as follows:

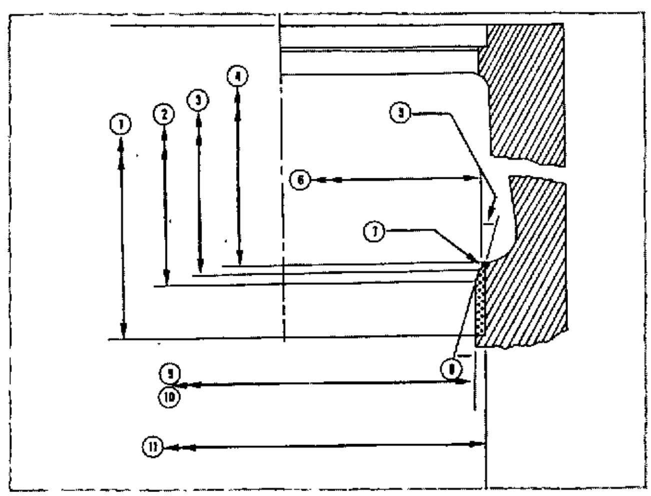


Fig. 1-1-23, V40108. Sleeve and block boring dimensions

a. Bottom of block bore (11) is 6.361 to 6.363 inch [161.5694 to 161.6202 mm] diameter, to block deck (1) is 8.565 to 8.585 inch [127.5510 to 228.0590 mm].

b. The 20 deg. chamfer (5) in block is 0.010 to 0.020 inch [0.2540 to 8.585 inch [127.5510 to 228.0590 mm].

2. Clean all chips from block.

3. Mix sealer of three parts glycerine to one part litharge to a smooth paste.

4. Wipe bore with a clean cloth and apply sealer.

5. Sleeve is larger than top bore. Place O.D. of sleeve against top of bench and press out-of-round just enough to push through bore.

6. Turn sleeve in cylinder bore so O.D. chamfer is down.

7. Provide a driver which closely pilots sleeve and with clearance flats on outside diameter.

8. Index driver so flats will allow it to pass through top bore and place driver on sleeve.

9. Turn so driver is on bottom and press sleeve over driver by using a wooden hammer handle or equivalent. This is slightly difficult due to limited space.

10. Coat O.D. of sleeve with sealer.

11. Position driver and sleeve in chamfered edge of bore.

12. Place driver extension in driver; make sure sleeve is centered in bore and tap lightly on extension to seat driver in sleeve and start sleeve into bore.

13. Drive sleeve into bore of block until it bottoms in bore with a heavy hammer or use a hydraulic ram.

14. Should driver stick in sleeve due to interference, a cylinder liner puller can be used to pull driver.

15. Bore sleeve inside diameter as shown in Fig. 1-1-23 and to dimensions as follows:

a. Bottom of sleeve (8) 20 deg. chamfer to (2) block deck 7.314 to 7.326 inch [185.7756 to 186.0804 mm].

b. Top of sleeve 20 deg. chamfer to (3) block deck is 7.265 to 7.285 inch [184.5310 to 185.0390 mm].

c. Bottom of sleeve (7) 0.040 to 0.060 inch [1.0160 to 1.5240 mm] radius to block (4) deck 7.187 inch [182.5498 mm] maximum.

d. Top of sleeve (7) radius is 0.040 to 0.060 inch [1.0160 to 1.5240 mm] (6) diameter 6.250 to 6.260 inch [158.7500 to 159.0040 mm].

e. Sleeve (9) bore diameter is 6.124 to 6.126 inch [155.5496 to 155.6004 mm] to a (10) depth of 8.850 to 8.875 inch [224.7900 to 225.4250 mm].

16. Remove boring bar from bore. Use fine emery cloth to break sharp corners in entrance of bore so rubber packing rings will not be damaged when liners are installed.

17. Clean bore thoroughly to remove all emery dust and boring chips. Blow dry with compressed air and coat machined surfaces with engine lubricating oil.

18. After boring and sleeve installation check alignment as described under "Cylinder Liner Lower Bore."

Installation Of Cast Iron Sleeve Using ST-1081 Boring Tool

Use ST-1081 Boring Tool as indicated in following steps when installing 195778 cast iron sleeve in lower bore of block.

Preparation Of Cylinder Block

1. Remove all carbon and scale from deck, counterbore and lower bore.

2. Deck must be flat (remove all burrs and nicks) and clean. Check edges of block for raised areas and remove with file.

Assembly Of Boring Tool

1. Select the proper service tool components (ST-1081, ST-1076, ST-1084, ST-1081-52).

2. Install ST-1084 Bore Adapter (8, Fig. 1-1-24) onto ST-1081 Boring Tool. (Clean all finished surfaces.)

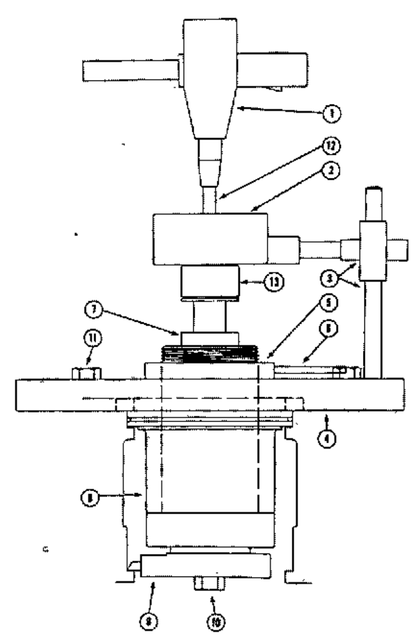


Fig. 1-1-24, V40153. ST-1081 Installed in block

3. Install ST-1076 Adapter Plate (4) onto boring tool with 3/4 inch recess toward bore adapter.

4. Engage retaining nut (5) onto boring tool and tighten retaining nut until boring tool, bore adapter and adapter plate are secure.

5. Install ST-1081-52 Tool Holder (9) into boring tool (7) and tighten in position with capscrew (10).

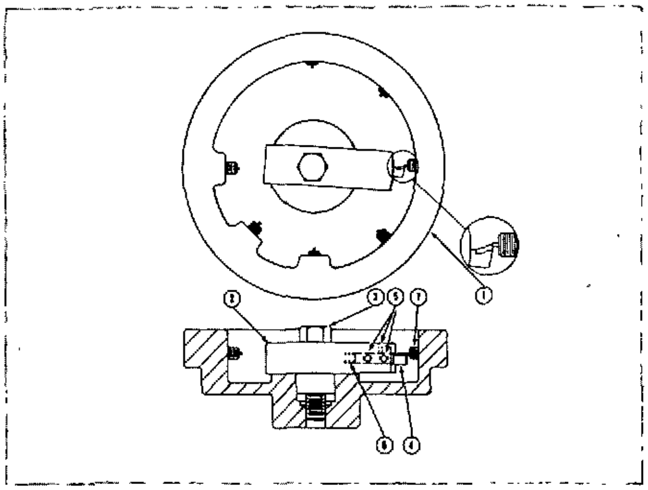


Fig. 1-1-25, V40154. Setting ST-1081 tool bit

Presetting Tool Bit

1. Loosen two setscrews (5, Fig. 1-1-25).

2. Install tool bit (4) into tool holder (2), being sure that spring (6) is in place.

3. Push in on tool bit until it bottoms on spring.

4. Lock one setscrew (5).

5. Place tool holder into ST-1081-59 Tool Bit Setting Gauge and fasten in place with capscrew (3) finger tight.

6. Position point of tool bit so it will engage setting nib.

Note: Proper nib will be indicated by stamped letters or numerals for particular engine.

7. Loosen setscrews (5) allowing point of tool bit to engage setting nib.

8. Tighten two setscrews (5) against tool bit.

9. Remove tool holder and tool bit from tool bit setting gauge.

10. They are now ready to install in boring tool.

Installation And Operation

1. Install assembled boring tool into cylinder block, allowing bore adapter (8, Fig. 1-1-24) to engage counterbore and holes in adapter plate to match mating holes on cylinder block.

2. Fasten adapter plate in place with four capscrews and washers (11).

3. Torque capscrews to 50-75 ft-lbs [6.9150/10.3725 kg m].

4. Install torque reaction bar (3) into adapter plate.

5. Install gear drive (2) onto boring tool with 1/2 inch square drive engaging boring tool and gear drive anchor arm engaged over the torque reaction bar.

6. Install drive adapter (12) into drill motor (1) and fasten in place.

7. Engage drive adapter and drill motor onto gear drive.

8. Be sure boring tool shaft is in maximum up position.

9. Turn on drill motor. Initial contact of tool bit with bore will be intermittent and care should be exercised at start of cut. While unit is rotating, apply a slight downward pressure until maximum depth of bore is complete.

10. Pull up on drive shaft of boring tool (turning clockwise) until drive shaft is in up position.

11. Repeat Steps 9 and 10 to be sure of a true hole.

12. Remove unit from cylinder block.

13. Sand paper rough edges from top and bottom of cut.

Caution: If tool bit is changed, be sure and reset new tool bit.

Installing Repair Sleeve Into Cylinder Block

1. Thoroughly clean bore area with compressed air.

2. Set sleeve (4, Fig. 1-1-26) 195778 on deck of cylinder block as shown in (5).

3. Push sleeve through upper bore.

4. Install sleeve driver into sleeve (6) when in position shown in (7).

5. Rest sleeve and sleeve driver as a unit in position to go into lower bore.

Note: I.D. chamfer of sleeve to be toward top of block.

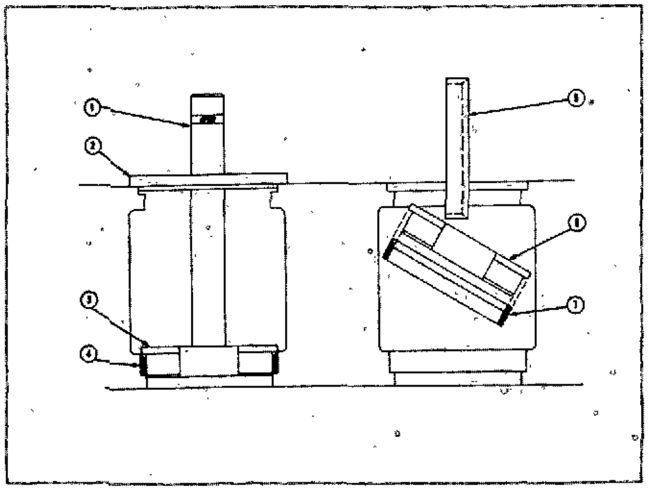


Fig. 1-1-26, V40155. Installation of 195778 sleeve

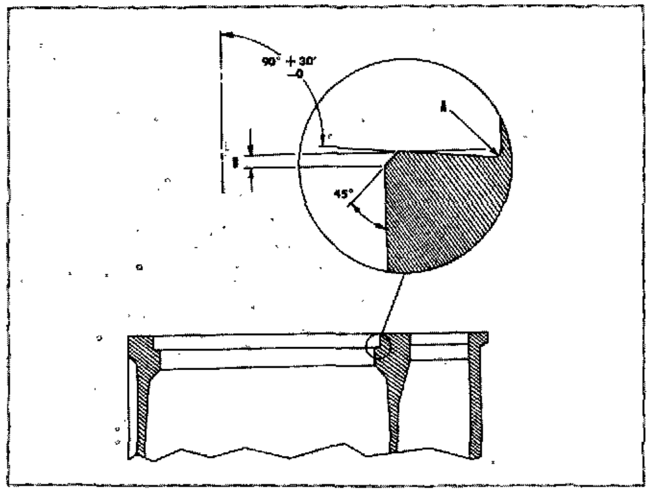


Fig. 1-1-27, N20147. Cylinder liner counterbore cross section

6. Insert sleeve driver handle into sleeve driver.

7. Install locator (2) over sleeve driver handle (1) and into counterbore.

8. Tap gently on sleeve driver handle until sleeve is located on starting radius of sleeve.

9. With heavy hammer drive sleeve into place.

Note: When sleeve is in correct position, the sleeve driver handle will become free for removal.

Cylinder Liner Counterbore

Resurface cylinder liner counterbore if block has been resurfaced, ledge is uneven or where liner protrusion is incorrect. ST-676 or ST-1059 Counterbore Tool with appropriate adapter plate can be used for this operation.

Counterboring With ST-676

1. Use ST-681 Adapter Plate.

2. Check counterbore tool bit before boring operation.

a. A correctly ground tool bit will leave counterbore surface completely flat or cupped to a 30-minute angle (the cup is preferred) with a 0.005 to 0.015 inch [0.1270 to 0.3810 mm] radius as shown in (A, Fig. 1-1-27).

b. A correctly ground tool bit is shown in Fig. 1-1-28. Point A is 0.008 to 0.012 inch [0.2032 to 0.3048 mm] radius; side surface must be ground flat to sharpen.

3. Position tool adapter in liner bore.

4. Tighten top and bottom locating pins by turning in

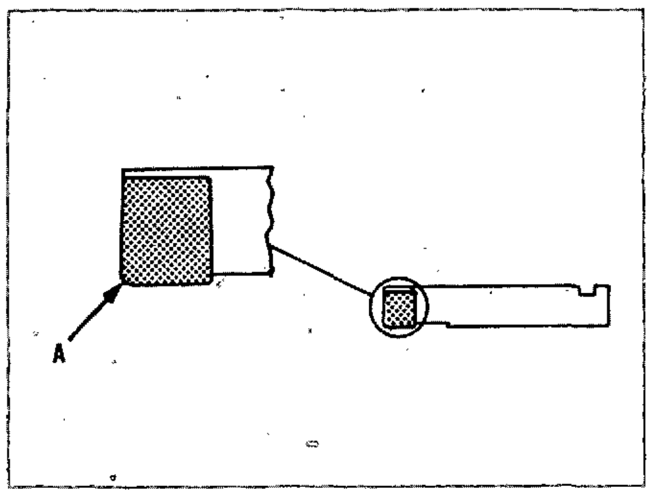


Fig. 1-1-28, N20148. Counterboring tool bit specifications

socket-head screws.

5. Set tool adjustable sleeve so blade just touches bottom of counterbore ledge. Use lubricating oil on cutter blades.

6. Turn in clockwise rotation with even pressure.

Caution: Never turn tool counterclockwise. Doing so will damage cutter blade.

7. Use a series of light cuts to clean up entire circumference of seat.

8. Check seat to determine if additional cuts are required.

Caution: Under no circumstances may inside diameter of ledge be lower than outside diameter. A ledge that droops toward center could contribute to cylinder liner breakage. Maximum counterbore depth after boring must not exceed limit given in Table 1-1-5.

9. Chamfer edge of counterbore ledge 45 degrees after counterboring. See (B, Fig. 1-1-27). Do not chamfer deeper than 0.013 to 0.024 inch [0.3302 to 0.6096 mm] to avoid reducing liner seating area.

10. Use shims to compensate for metal removed and to restore liner protrusion to 0.004 to 0.006 inch [0.1016 to 0.1524 mm]. Shims are available as shown in Table 1-1-13.

Note: Use as few shims as possible, i.e., use on thick shim in preference to two or more thinner shims. Never use shims thinner than those listed.

Table 1-1-13: Cylinder Liner Counterbore Shims

Thickness Inch	[mm]	Part No.
0.0063/0.007	[0.1600/0.1778]	143938
0.0072/0.0088	[0.1828/0.2235]	143939
0.0081/0.0099	[0.2057/0.2514]	143946
0.018/0.022	[0.4572/0.5588]	143947
0.028/0.034	[0.7112/0.8636]	143948
0.056/0.068	[1.4224/1.7272]	143949

Cylinder Head Capscrew Threads

Check cylinder head capscrew hole threads in block. If threads are damaged, block may be repaired by installing Heli-coil inserts.

1. Drill out old threads with 23/32 inch drill and to a depth of 1-7/8 inch [47.6250 mm] from the cylinder block top surface.

2. Tap drilled hole with tap contained in ST-476 to a depth of 1-3/4 inch [44.4500 mm]. ST-476 contains a tap and Heli-Coil inserting tool and may be purchased through Cummins Distributors.

3. Install insert, Cummins Part No. 102674, with inserting tool until it is 1/2 inch [12.7000 mm] below top surface. Break off insert tang using a punch and hammer, not an inserting tool.

Counterboring With ST-1059

1. To assemble counterboring tool.

a. Wipe all finished surfaces clean.

b. Install ST-1076 Adaqter Plate (2, Fig. 1-1-29) onto ST-1059 Driver Unit (1) with four capscrews (4) provided with unit.

c. Install ST-1065 Tool Holder (3) onto driver unit (1) allowing keyway in tool holder to engage over Woodruff Key.

d. Fasten tool holder (3) onto driver unit (1) with capscrew (5).

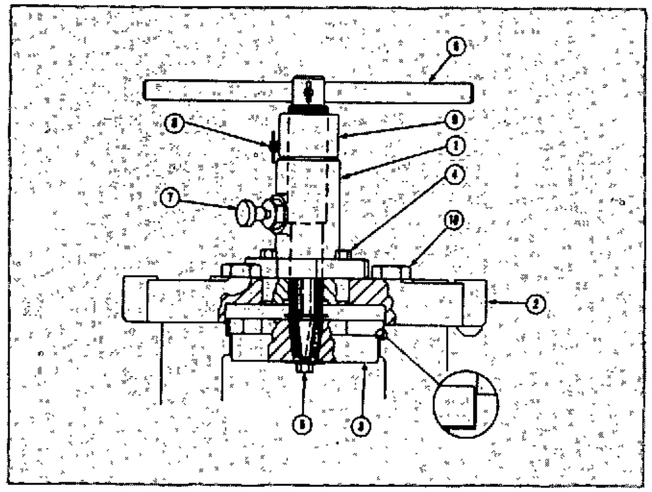


Fig. 1-1-29, V40156. ST-1059 Counter bore tool

2. Presetting tool bit Fig. 1-1-30 .

a. Loosen thumb screw (3, Fig. 1-1-30) and push adjusting pin (5) back into housing.

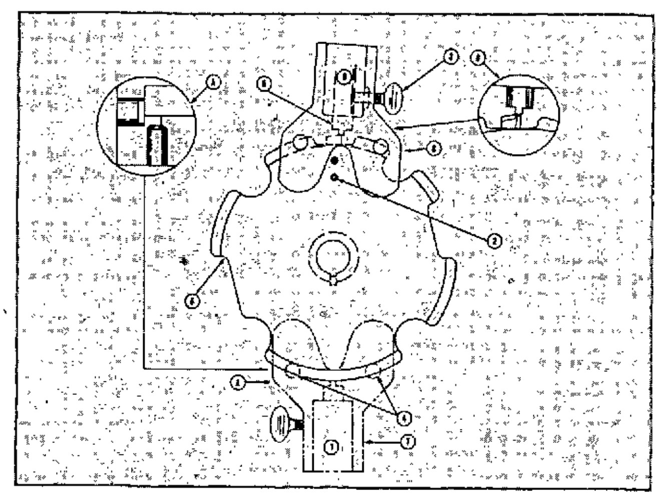


Fig. 1-1-30, V40157. ST-1081 Tool bit

b. Tighten thumb screw.

c. Place tool bit setting gauge (1) onto tool holder (6) in position No. 1 (7) with dowel pins (4), engaging smaller diameter of tool holder and holding locating surfaces of housing against flat surface of tool holder (see Section A).

d. While holding tool bit setting gauge in the above position, loosen thumb screw (3) allowing adjusting pin (5) to engage larger diameter of tool holder. See position No. 1 (7).

e. Tighten thumb screw (3).

f. Tool bit setting gauge is ready for use.

g. Install tool bit into tool holder as shown in Section B.

h. Set point of tool bit below larger diameter of tool holder and tighten one setscrew (2).

i. Place tool bit setting gauge in position No. 2 (8) with dowel pins engaging smaller diameter of tool holder and holding locating surfaces of housing against flat surface of tool holder (see Section B).

j. Position adjusting pin (5) over point of tool bit.

k. Loosen setscrews (2) allowing tool bit point to rest against locating point of adjusting pin.

l. Tighten setscrews (2).

3. Prepare block for counterboring.

a. Remove all carbon and scale from top of block and counterbore.

b. Top of block must be flat. (Remove all burrs and nicks.) Check edges of block for raised areas and remove with file.

4. Install counterboring tool.

a. Pull out on handle (6, Fig. 1-1-29) until plunger (7) will hold tool holder (3) in the up position.

b. Place unit on cylinder block with hold-down holes matching holes in cylinder block.

c. Hold onto handle (6) and pull out on plunger (7).

d. Slowly lower tool holder into counterbore.

e. Engage larger diameter of tool holder into counterbore and allow tool bit to rest on counterbore ledge.

f. Loosen locking screw (8) and rotate adjusting nut (9) in clockwise direction until tool bit clears counterbore ledge.

Note: Always rotate unit clockwise.

g. Tighten locking screw.

h. Assemble hold-down capscrews and washers (10) through adapter plate into cylinder block finger tight.

i. Torque four capscrews (4) to 50/75 ft-lbs [6.9150/10.3725 kg m].

Note: Tool holder must rotate freely.

5. To measure depth of counterbore:

a. Install depth gauge (4, Fig. 1-1-31) into gauging hole (2) of adapter plate (3).

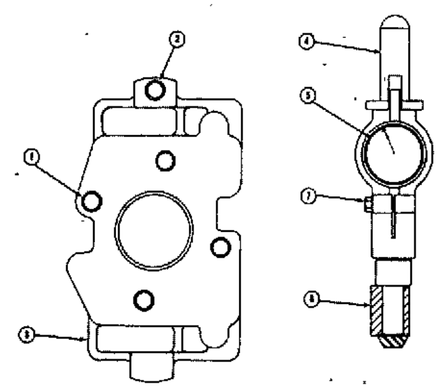


Fig. 1-1-31, V40158. Setting depth gauge

b. Loosen capscrew (7) and push down on dial indicator (5) to end of travel.

c. Pull dial indicator 0.010/0.020 inch [0.254/0.508 mm] off bottom, (end of travel).

d. Tighten capscrew (7).

e. Set dial indicator to zero.

f. Rotate tool holder until red indicator line matches red line on adapter plate.

g. Place depth gauge on four counterbore measuring holes (1).

h. The average of the four readings will be the present depth of counterbore.

i. See Table 1-1-5 for counterbore depth.

6. To operate counterboring tool:

a. Loosen locking screw (1, Fig. 1-1-32).

b. Rotate adjusting nut (2) in counterclockwise direction until tool bit is resting on lowest part of counterbore ledge and there is clearance between housing (3) and adjusting nut.

Note: The distance between housing and adjusting nut equals amount of material that will be removed from counterbore ledge.

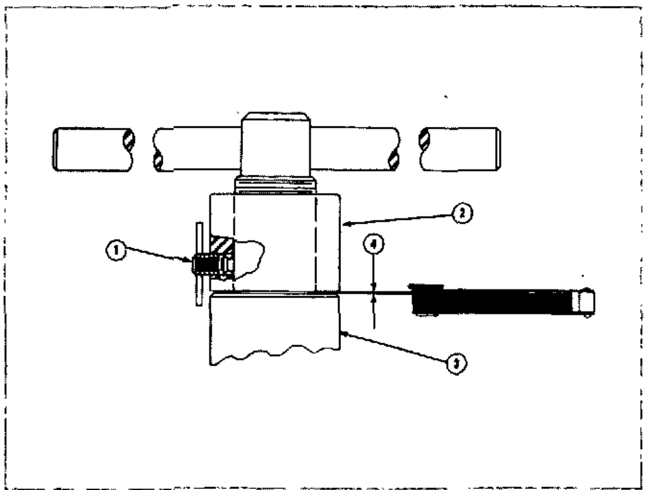


Fig. 1-1-32, V40159. Setting depth of cut

c. To set the depth of cut, place a feeler gauge of required thickness (4) between adjusting nut (2) and top of housing (3). For example, if 0.005 inch [0.1270 mm] of material is to be removed from counterbore ledge use 0.005 inch [0.1270 mm] feeler gauge. Make sure there is no grease or dirt between adjusting nut and top of housing.

d. Rotate adjusting nut until feeler gauge is just held between adjusting nut and top of housing.

e. Tighten locking screw (1).

f. Remove feeler gauge (4).

g. Hold down on handle applying more pressure on tool bit side and rotate handle in a clockwise direction until unit turns freely and is bottomed out between adjusting nut and top of housing.

h. Measure depth of counterbore as described in step 5.

i. Recondition counterbore as required.

Tool Bits

1. These tool bits are a select grade of carbide to give maximum tool-life and are accurately ground with precise angles on the cutting edge.

2. Never attempt to grind these tool bits without special equipment and instructions.

Note: A factory-resharpened tool bit replacement is available from:

B. K. Sweeney Mfg. Company
Denver, Colorado 80216
Phone - (303) 355-2355

Machining Lower Bore Entry Chamfer

If the lower bore or the lower bore entry chamfer is beyond the tolerances, pitted, or eroded, one of the following operations may be performed to salvage the cylinder block. Although these salvage operations are approved field practice, Cummins Engine Company, Inc. cannot accept responsibility for the success of the operation due to variations in equipment, materials, and workmanship.

If the erosion has occurred only on the entry chamfer and not in the packing ring sealing area, the chamfer may be "built up" by the use of a plastic steel compound such as Devcon Plastic Steel, Type "A." The manufacturer's directions should be followed for this salvage procedure. Check the chamfer depth after this operation and resurface the chamfer if beyond acceptable tolerances.

Preparation Of Cylinder Block

1. Remove all carbon and scale from top of block, counterbore and lower bore.

2. Top of block must be flat (remove all burrs and nicks) and clean. Check edges of block for raised areas and remove with file.

Assembly Of Boring Tool

1. Select the proper service tool components, (ST-1081, ST-1076, ST-1084, ST-1081-52).

2. Install ST-1084 Bore Adapter (8, Fig. 1-1-33) onto ST-1081 Boring Tool. (Wipe all finished surfaces clean.)

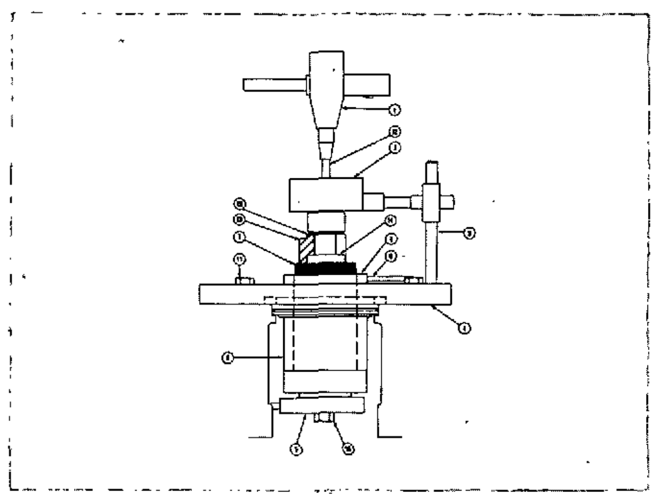


Fig. 1-1-33, V40160. Lower counterbore tool bit

3. Install ST-1076 Adapter Plate (4) onto boring tool with 3/4 inch recess toward bore adapter.

4. Engage retaining nut (5) onto boring tool and tighten retaining nut until boring tool, bore adapter and adapter plate are one unit.

5. Install ST-1081-52 Tool Holder (9) into boring tool (7) and tighten in position with capscrew (10).

6. Install ST-1096-2 Depth Spacer (13) onto end plate (14) between thrust washer (15).

Presetting Tool Bit

1. Loosen two setscrews (5, Fig. 1-1-34).

2. Install tool bit (4) into tool holder (2), being sure that spring (6) is in place.

3. Push in on tool bit until it "bottoms-out" on spring.

4. Lock one setscrew (5).

5. Position spacer (8) over locating diameter of tool holder.

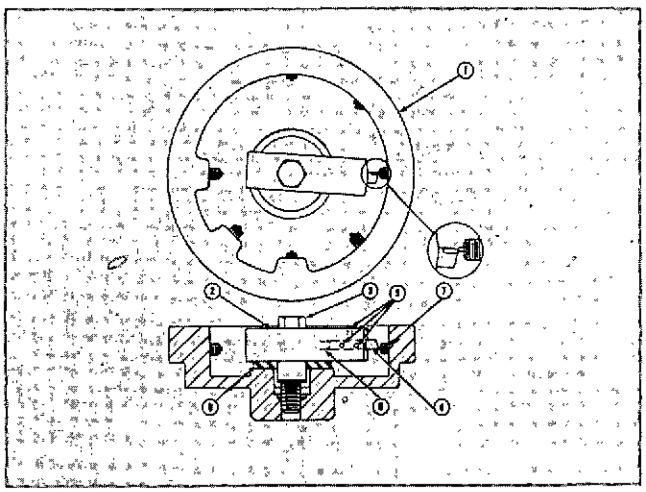


Fig. 1-1-34, V40161. Presetting tool bit

6. Place tool holder into tool bit setting gauge and fasten with 5/8 inch capscrew (3); tighten capscrew finger tight.

7. Position point of tool bit so it will engage setting nib and loosen setscrews (5) allowing point of tool bit to engage setting nib.

Note: Proper nib will be indicated by stamped letters or numerals for particular engine.

8. Tighten two setscrews (5) against tool bit.

9. Remove tool holder and tool bit from tool bit setting gauge.

10. They are now ready to install in boring tool.

Installation And Operation

1. Install assembled boring tool into cylinder block, allowing bore adapter (8, Fig. 1-1-33) to engage counterbore and holes in adapter plate to match mating holes on cylinder block.

2. Fasten adapter plate in place with four capscrews and washers (11, Fig. 1-1-33).

3. Torque capscrews to 50 to 75 ft-lbs [6.915 to 10.3725 kg m].

4. Install torque reaction bar (3) into adapter plate.

5. Install gear drive (2) onto boring tool with 1/2 inch square drive engaging boring tool and gear driver anchor arm engaged over the torque reaction bar.

6. Install drive adapter (12) into drill motor (1) and fasten in place.

7. Engage drive adapter and drill motor onto gear drive.

8. Be sure boring tool shaft is in maximum up position.

9. Turn on drill motor. Initial contact of tool bit with chamfer will be intermittent and care should be exercised at start of cut. While unit is rotating, apply a slight downward pressure until maximum depth of chamfer is complete.

10. Remove unit from cylinder block.

11. Sand paper rough edges.

Caution: If tool bit is changed, be sure to reset new tool bit as described in Presetting Tool Bit.

Repairing Cylinder Liner Counterbore

ST-1168 Cylinder Liner Counterbore Salvage Tool will enable salvaging a block which has a damaged or cracked counterbore ledge. The bores can be enlarged and a new sleeve installed.

The new counterbore salvage sleeve, Part No. 202226 is a precision sleeve; no inside diameter cutting is required except cutting the counterbore ledge to depth. When installed 0.005 inch [0.1270 mm] to 0.010 inch [0.2540 mm] must be cut from the counterbore ledge to meet specifications.

Counterbore Salvage Procedure

The ST-1166 Magnetic Crack Detecting Tool may be used to determine the extent of cracks in the counterbore ledge.

Magnetic Inspection

1. Place the magnet straddling the area to be checked.

2. Fill the bulb 1/3 full of powder.

3. Spray powder lightly on area to be checked.

4. Gently blow off excess. Powder will remain in crack if present and show up as white line.

Preparing The Block

1. Steam clean block and remove all dowels from top of block.

2. Remove all burrs and high spots from top of block with a large mill file. Finish dress with a flat stone.

3. Remove all dents or burrs from the I.D. of counterbore, to be cut, with emery cloth. This I.D. is used to locate the tool.

Assembly Of The Tool

a. Assemble adapter plate (Detail 28) to the main body with four socket head screws (Detail 30). Fig. 1-1-35.

2. Assemble tool holder (Detail 15 or 39) on shaft of the main body (Detail 1) and secure with nut (Detail 33) and washer (Detail 34). Fig. 1-1-35.

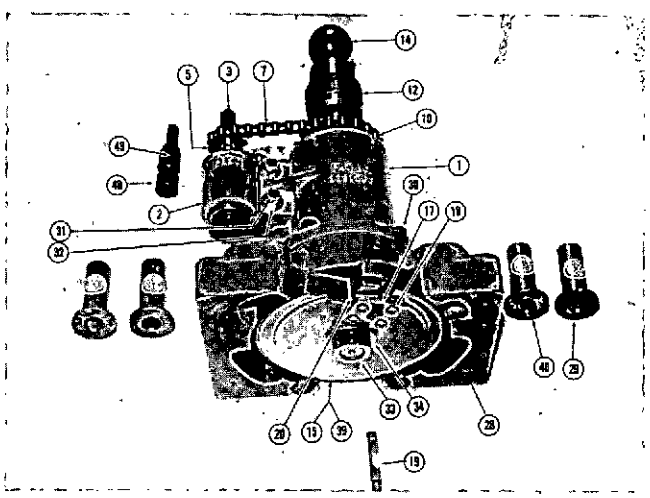


Fig. 1-1-35, V40172. ST-1168 Boring Tool

Machining The Block

1. Remove the cutting tool from the ST-1168 tool (Detail 15 or 39) holding plate. Fig. 1-1-36.

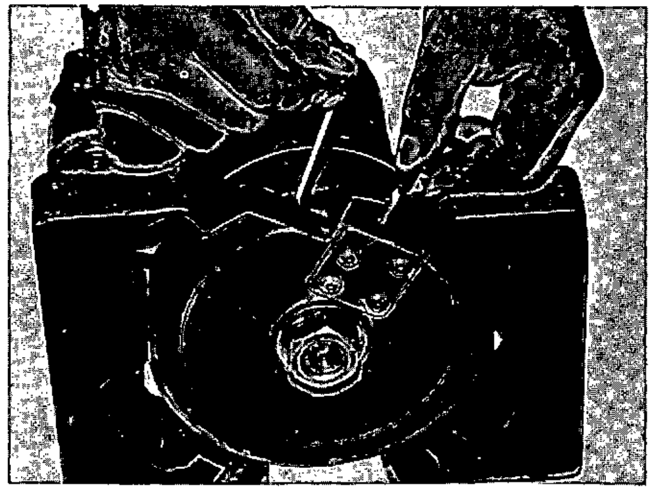


Fig. 1-1-36, V40173. Removing tool holder

2. Place the boring machine on the cylinder block above bore to be cut and hand start mounting capscrews. The capscrew spacers (Detail 29 or 40) must be on capscrews. Fig. 1-1-37.

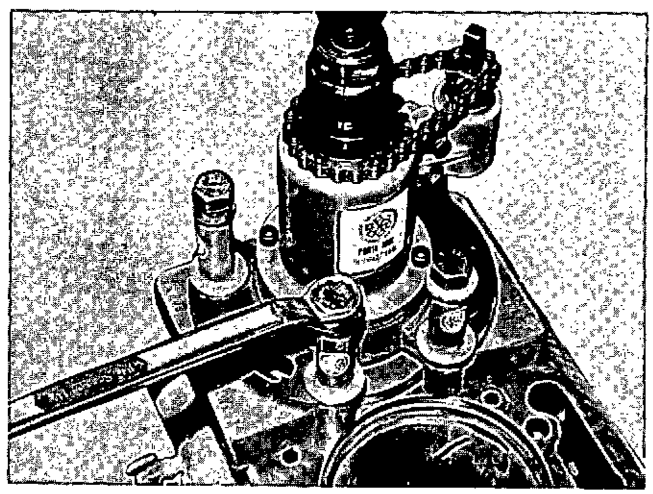


Fig. 1-1-37, V40174. Clamping tool to block

3. Lower tool holder into bore, Fig. 1-1-38, by pulling up on the orifice retractor knob (Detail 14), Fig. 1-1-35, while pushing down on set collar (Detail 12).

4. The tool holder lower diameter is used to center machine in the counterbore I.D. Push tool holder lower locating O.D. into I.D. of counterbore and tighten four mounting capscrews alternately to 25 to 35 ft-lbs [3.4575 to 4.1490 kg m].

5. Retract tool holder by pulling up on orifice retractor knob (Detail 14).

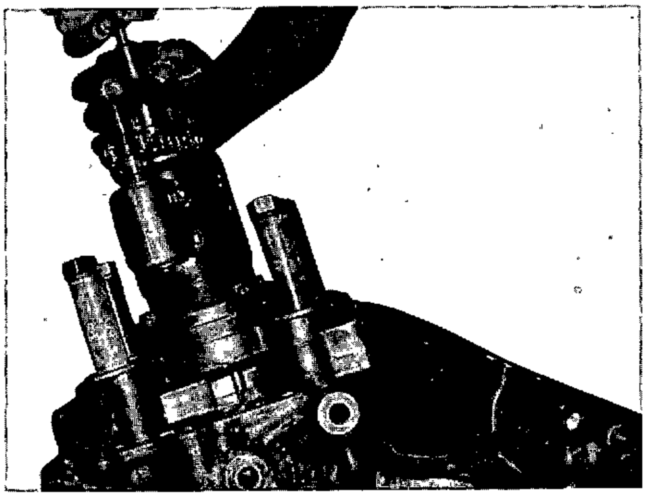


Fig. 1-1-38, V40191. Centering tool in counterbore

6. Loosen set screw (Detail 23) in back end of tool bit and push adjustable set pin (Detail 21) all the way in. Lock set screw. Fig. 1-1-39.

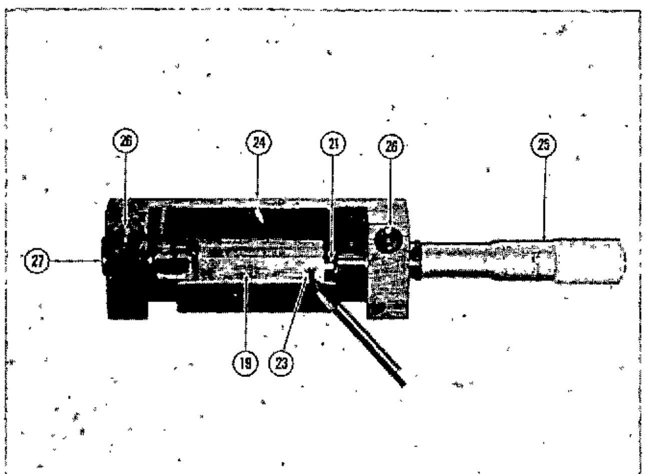


Fig. 1-1-39, V40176. Tool bit adjustment

7. Adjust micrometer (Detail 25) to 6.750 inch [171.4500 mm].

8. Place tool bit (Detail 19) in tool bit gauge as shown in Fig. 1-1-39 and hold firmly against stop and hardened pad (Detail 27).

9. Loosen tool bit set screw and allow adjustable set pin to come out against micrometer spindle. Lock set screw.

10. As a further check, back off thimble on micrometer and recheck tool bit length again.

11. Insert tool bit into tool holder and tighten tool holder lockscrew (Detail 20). The tool bit must be held all the way in against the tool holder.

12. Turn the tool holder until the tool bit recess is at the large opening in the ST-1168-28 adapter plate. Fig. 1-1-40.

13. Place a 0.004 inch [0.1016 mm] feeler gauge between block and tool bit and lower the tool bit onto feeler gauge by pulling up on retractor knob while pushing down on set collar. Fig. 1-1-37.

14. Loosen set collar set screw and back off collar counterclockwise until salvage sleeve can be placed between collar and boring machine main body as a depth indicator. Tighten set screw in set collar.

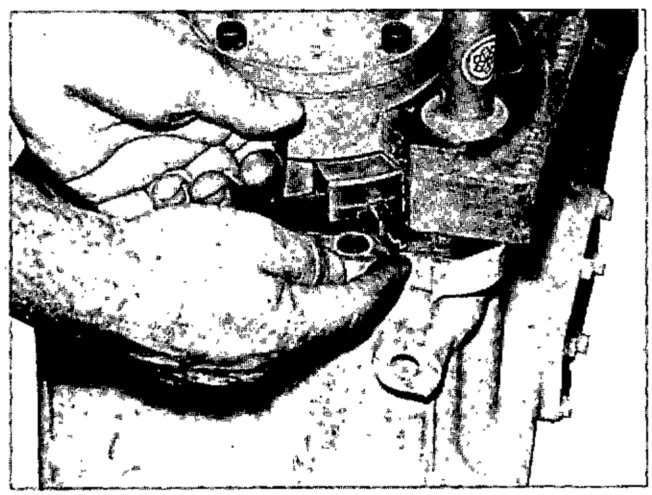


Fig. 1-1-40, V40177. Preparing to install tool bit

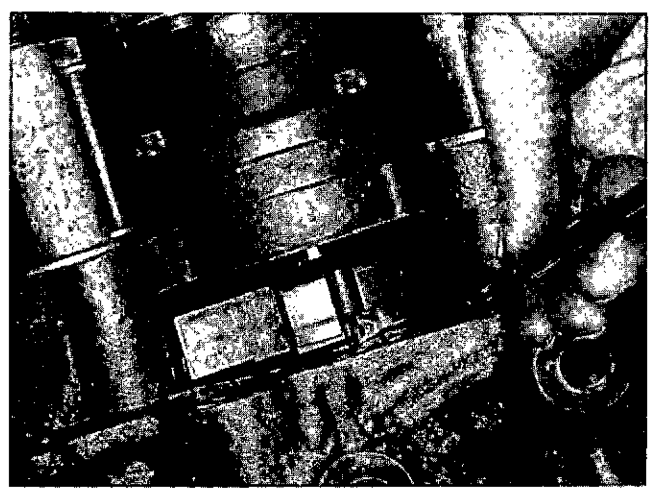


Fig. 1-1-41, V40192. Setting depth of tool cut

Note: This spaces the set collar to cut to a depth 0.004 inch [0.1016 mm] less than total height of salvage sleeve, to be used.

15. Remove feeler gauge from below tool bit.

16. Check the 1/2 inch drive flex adapter (Detail 48) in a 1/2 inch or 3/4 inch heavy duty (10 amperes or more) hand drill. Fig. 1-1-42.

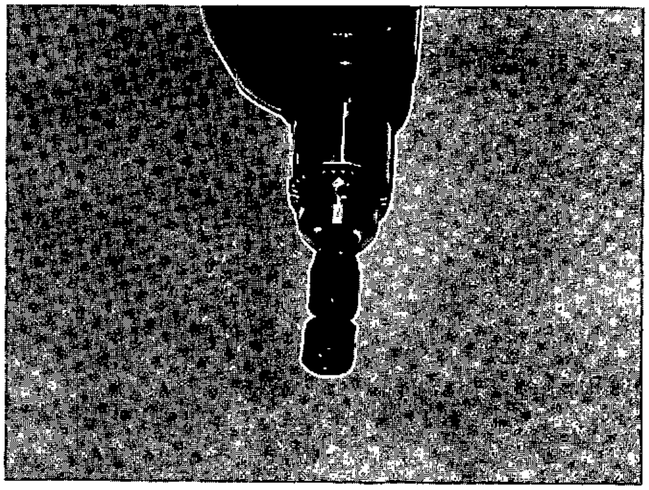


Fig. 1-1-42, V40179. Hand drill driver

Caution: Drills rated at less than 10 amperes may be overloaded and damage as a result.

17. With drill on half inch drive of boring tool (Detail 3), bore hole until the drill freewheels. About half way down during the cut, the tool bit begins cutting out the old counterbore ledge, operator should have a firm grip on the drill to be prepared for increased load on the drill from the added metal being cut. Stop immediately when drill freewheels.

18. Retract the tool holder by pulling up on the retractor knob. Remove the tool bit from the tool holder.

19. Clean away all shavings and deburr the bore I.D. with emery cloth.

Installing The Salvage Sleeve

1. Clean bore thoroughly with a nonpetroleum base solvent or cleaner.

2. Coat O.D. of sleeve lightly with Compound 40 Locktight and drive sleeve into bore with driver ST-1168-36-47 and a soft hammer until it bottoms (see Details 36 through 47). A solid sound can be heard when sleeve bottoms.

3. The sleeve will protrude above the top of block by 0.004 inch [0.1016 mm] and must be filed even with the top of block. Remove all burrs with emery cloth.

4. Check counterbore depth with ST-547 gauge block and cut to depth per normal procedures. The salvage sleeve is designed to be 0.005 inch [0.1270 mm], 0.010 inch [0.2540 mm] above required counterbore depth. Cut counterbore to depth listed in specifications, Group 18.

Installation Of Oil Control Valve

If oil control valve housing has been removed from bore, located between oil drillings in front center of block, when piston oil cooling is required install housing as follows:

1. Scribe a centerline on the boss perpendicular to the bored hole, using the capscrew holes as locators.

2. Align the scribe-line on the oil central valve housing; align the two (2) oil passage holes with those in cylinder block. Press housing into the bore until it is flush to 0.020 inch [0.508 mm] below the cylinder block face.

3. Insert oil control by-pass disc and spring into valve control housing.

4. Position expansion plug over spring and into bore.

5. Drive expansion plug into housing bore with ST-1053 plug driver until flush with housing surface. See Fig. 1-1-43.

6. On non-piston cooled cylinder blocks drive solid plug in bore flush to 0.010 inch [0.2540 mm] below surface of bore.

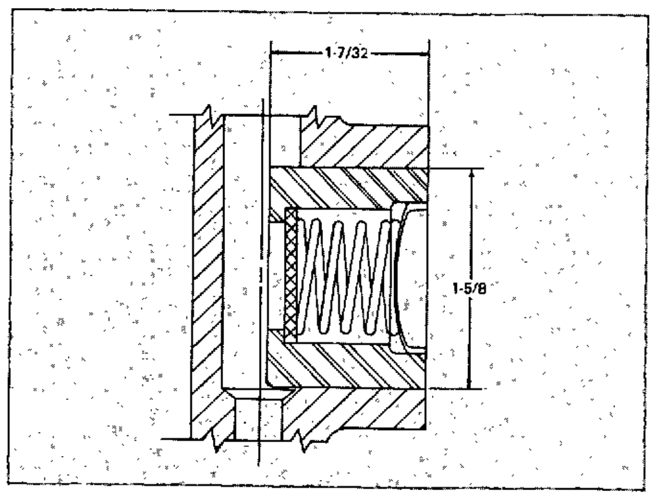


Fig. 1-1-43, V40180. Oil control valve installed

Cylinder Liners—102

Cleaning And Inspection

1. Remove rust and scale from liner exterior with wire brush or by similar cleaning operation.

2. Check for cracks in cylinder liners just under top flange, at bottom of liner, or above top seal ring groove. Check as follows:

a. Magnetize liner if magnetic equipment is available.

b. Pour magnetic solution over liner while it is still magnetized.

Note: Cast iron will not hold magnetism permanently.

c. If magnetic inspection cannot be performed, clean liner thoroughy.

d. Spray suspected area with dye penetrant.

e. Allow penetrant to dry for fifteen minutes. Do not "force" dry; remove excess dye.

f. Spray with developer and check for crack indications. See Page 1-1-2, "cracks."

3. Discard any liner with excessive corrosion or erosion and pits 1/16 inch [1.5875 mm] deep or more.

4. Check underside of liner flange for dents, pitting or fretting. Discard liner if any unevenness cannot be removed by lapping.

5. Check worn liners with dial bore gauge. Fig. 1-2-1. If liners are worn more than 0.004 inch [0.1016 mm] in excess of new liner maximum diameter, replace. See Table 1-2-1 for new liner dimensions.

Table 1-2-1: Std. Cylinder Liner Inside Diameter — Inch [mm]

Liner Material	New Dimensions Minimum	Maximum	Worn Limit
Cast Iron	5.4995 [139.6873]	5.5010 [139.7254]	5.5050 [139.8270]

Note: Dimensions at 60/70 deg. F [15.6/21.1 deg. C]; new liners with lubrite finish may be 0.0002/0.0006 inch [0.0050/0.0152 mm] smaller than indicated due to lubrite coating.

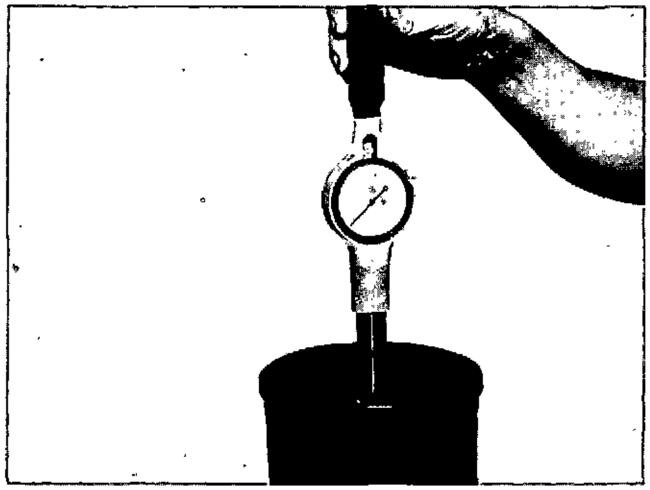


Fig. 1-2-1, V40131. Measuring liner bore

6. Mark liners to be reused for ridge cutting, boring or grinding and honing if worn less than above limits and otherwise undamaged in area (1, Fig. 1-2-2).

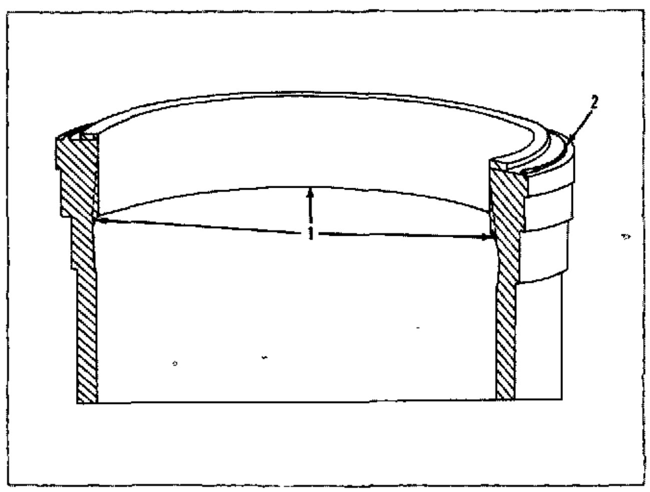


Fig. 1-2-2, N20151. Worn ridge in cylinder liners

Grind Cylinder Liners

Cylinder liners should not be reused without reboring or regrinding if they exceed worn limits; however, in most cases it is more economical to install new liners and keep all parts standard size.

1. Remove ridge at top of worn liners with a ridge cutter, or other means, to prevent damage to new rings.

2. Grind or bore liners to next standard oversize.

3. Finish hone liners to proper finish. See "Liner Honing."

Liner Honing

Honing operation described below is not designed to enlarge cylinder bore several thousandths [millimeters] for oversize pistons and rings. When honing oversize, both roughing and finishing stones are used. Recommendations given are specifically designed to put proper finish and geometric design in cylinder liner with a minimum of stock removal. For this reason, only one grit size is used and stones are used wet.

Walls can be straightened with 4 or 5 final passes through bore. Proper finish will be on walls due to fine grading of stone recommended. Visual inspection of liner honed, according to recommendations, will indicate importance of using equipment and procedures which give the operator maximum control of operation.

Initial Set-Up

1. Place cylinder liner in cylinder bore of a scrap block without packing rings or crevice seal. Upper liner bore in block should be relieved so liner will drop into place very easily.

2. Tap two water holes and assemble capscrews and soft washers to holes making sure soft washers are over liner flange, but do not extend into bore of liner. Tighten finger tight and make an initial check for distortion on the new fixture as follows:

a. Place dial gauge in cylinder liner about 1-1/2 inch [38.1000 mm] from top.

b. Watch gauge for movement while capscrews are tightened to secure liner.

c. Loosen capscrews and more dial bore gauge to another position in liner bore and repeat check while tightening capscrews.

d. If distortion is noted, remove liner and check for dirt *between flange and counterbore ledge. Also, check flatness* of counterbore ledge. If liner is seating evenly on ledge, distortion will be less than 0.0003 inch [0.0076 mm] and barely noticeable.

3. Assemble a Sunnen UN-60 Universal Honing Stand, or equivalent, to cylinder block. Use wooden blocks to adapt base to bore size; then use expanding foot to tighten base to stand in bore.

4. Assemble upper support arm to stand and attach drill handle to canvas loop.

5. Place a Sunnen AN-80 Quick Coupler, or equivalent, securely in drill chuck. Fig. 1-2-3.

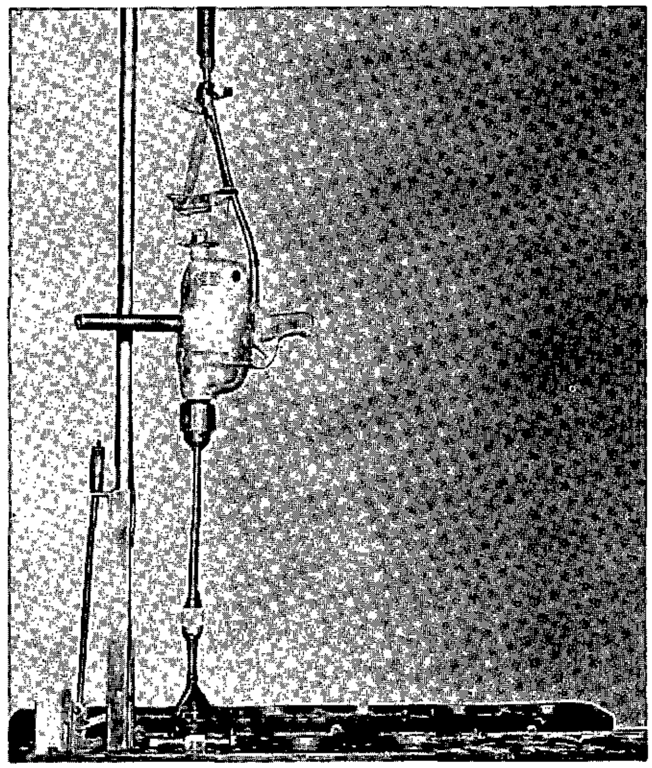


Fig. 1-2-3. V40132. Honing liner

6. When installing Sunnen AN-201 Coarse Finishing Stone Set, or equivalent, carefully note manufacturer's instructions concerning their assembly to a Sunnen AN-111 Cylinder Hone and suggested use. In a few instances, Cummins procedure differs with general procedures recommended by manufacturer. For instance, stones are used with honing oil in this procedure and are used as a 1-stone (or 1-step) procedure to get required finish with minimum stock removal. Finish and required procedures for Cummins will be discussed further at end of honing procedures.

7. Insert hone assembly into top of cylinder liner. Raise center pinion (knurled nut) assembly 1/4 inch [6.3500 mm] and turn counterclockwise (left) to expand stones to approximate bore size. Fig. 1-2-4. Push center pinion down until its inside gear engages outside gear on hone body. Attach hone to quick coupler.

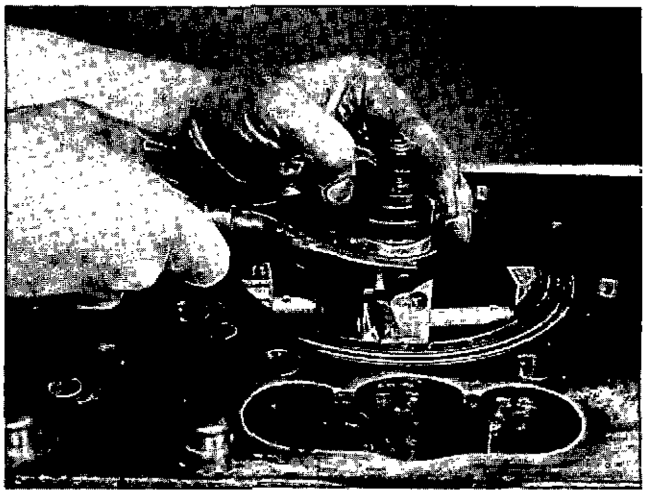


Fig. 1-2-4, V40133, Initial stone expansion

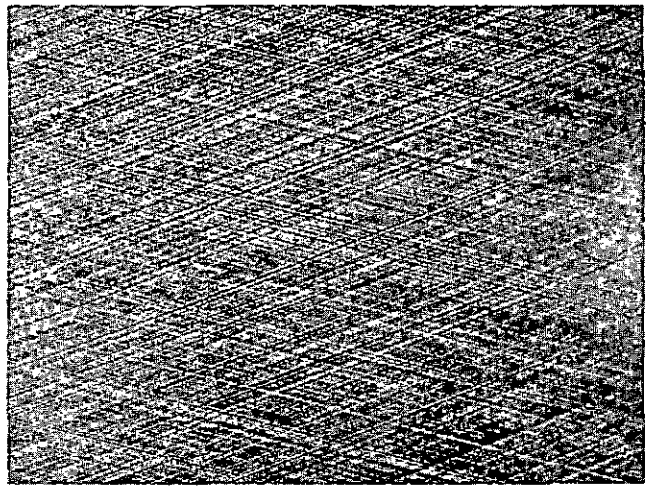


Fig. 1-2-5, N20153. Cylinder liner cross-hatch pattern

8. Swing upper support arm so drill and hone are approximately over center of liner bore. Adjust length of canvas strap attached to drill so hone hangs with ends of stones extending out of liner bore approximately 1 inch [25.4000 mm].

9. Adjust stroking stop (collar and wing screw) so stones will not extend more than 1 inch [25.400 mm] from bottom of cylinder liner at end of down stroke. Put enough down pressure on hone to make sure stones will not hit obstructions beneath liner during honing. Secure stop collar when setting is correct to clear stones.

10. Do not start drill motor. Practice stroke a few times for "feel" with stones expanded loosely in liner and not in actual contact with walls. Down stroke hits stop, but operator must stop stroke at top allowing stones to extend out top of bore 1/2 inch [12.7000 mm] to 1 inch [25.4000 mm]. Stroking speed required to produce a 35 deg. to 45 deg. crosshatch is approximately 50 strokes per minute. Fig. 1-2-5.

Note: It is very important to have 45 deg. crosshatch pattern to enable the piston rings to shear or peel the sharp ridge points during break-in. If pattern is nearly horizontal, some pattern engagement and tearing may occur. If pattern is vertical, this forms a path for blow-by.

11. Disconnect hone and remove from liner.

12. The edges and corners of new stones are very sharp. Tank a hand hone and slightly round all corners and edges to reduce tendency to crumble when stones are first used.

13. Re-check set-up and become familiar with hone mechanism and stroke. Check manufacturer's instructions packaged with components.

Honing Operation

1. Check liner in honing fixture to make sure it is secure.

2. Check liner with dial bore gauge to determine how wear pattern must be removed. In this case, assume that liner has a slight ring at top, 0.002 inch [0.0508 mm] wear and out-of-roundness in ring travel area. It tapers in at bottom of bore due to lack of wear in that area.

3. Assemble hone to liner bore. Expand stones to diameter of cylinder bore with quick-acting center pinion assembly (knurled nut) as described under "Set-Up."

4. Expand stones and guides firmly against cylinder walls by turning winged collar clockwise on top of pinion assembly. Do not tighten too tight.

5. Apply Sunnen Man-845 Honing Oil freely to stones, guides and cylinder walls with brush or oil can after attaching hone to Quick Coupler.

6. Grasp drill handles (Sioux No. 1560 Heavy Duty drill or equivalent with a 300 rpm no-load speed) firmly and turn on motor. Let extension handle contact vertical stand to absorb torque of motor. Use hand on handle (with switch) to keep drill and hone over center of liner.

7. Stroke as follows: Move to bottom of bore and bring hone up half-way in bore. Then go back to bottom of bore. On next upstroke come all the way to top (don't let stones extend more than 1/2 to 1 inch [12.7000 to 25.4000 mm] out top of bore) and return to bottom repeating double stroke in bottom of bore. After 6 to 8 strokes have been made to top of bore, double stroke both top and bottom of bore. This action removes stock faster at opposite ends of bore removing tapered condition of liner. The first honing cycle should last only 10 to 15 seconds; then shut off drill and check for results. At first it may be wise to remove hone and check with dial bore gauge to become familiar

with cutting speed of stones. Make a visual inspection of bore frequently and add oil to keep stones clean and cutting freely.

8. Apply oil and operate for anothe; 10 to 15-second cycle, if needed, double stroking either end that is smaller in diameter than ring area. This operation is designed to straighten wall of bore and remove carbon ring at top. Keep stones cutting by adjusting pressure with winged collar. A slight reduction in drill speed will be noted when stones are cutting. Torque action felt on drill handles also is a good indicator.

9. Thirty to forty seconds honing time can remove 0.001 to 0.002 inch [0.0254 to 0.0508 mm] from bore depending upon stone pressure. Straighten bore quickly by double stroking; then full stroke bore only enough to lay a uniform finish on the walls. The total honing time will usually run about 20 to 40 seconds to perform what is commonly called a deglazing operation.

10. After pattern is uniform, stop hone; adjust stones to a firm but light pressure. Apply oil and make 4 or 5 full-length strokes and shut drill off while continuing stroke. Double stroke in bottom if necessary to time actual stopping of hone rotation when hone is at top of bore. This preserves cross-hatch pattern, and puts true stone pattern (20 to 30 rms finish) on cylinder walls. Fig. 1-2-5.

11. Rms is a conventional abbreviation for root mean square, a mathematical term indicating the average irregularity of surface.

This slightly irregular surface on the cylinder liners is required so new piston rings and reworked liners will break in (or wear in) together.

It is also necessary to have basic honed pattern in liners to retain some oil in valleys as piston rings scrape away oil on liner walls. If walls were smooth, they would quickly run dry and score.

12. Remove hone from liner and remove liner from fixture.

13. Make a final check of bore size and make sure that carbon ring at top and thrust wear pattern are removed. Note angle of cross-hatch to check stroke speed. Refer to Table 1-2-1 for specifications concerning maximum bore size. Out-of-roundness should not exceed 0.0015 inch [0.0279 mm] except at assembly as noted under "Assembly Group 14." If stones have been kept wet, walls will show a uniform satin finish and will be of proper 20 to 30 rms finish. If a smooth, shiny finish is noted, it is probably due to lack of oil, or motoring hone too long in final honing cycle. As oil disappears from walls, stones tend to load and become dull. Honing oil keeps stones sharp and promotes true cutting action.

Cleaning

1. After liners are honed, they must be cleaned thoroughly with solvent, steam cleaner or hot soap and water. It is recommended that cleaning operation be ended by scrubbing bore with a bristle brush to remove as much honing debris as possible. Blow liners dry with compressed air.

2. Coat bore of liners generously with clean lubricating oil. If possible, let liners stand 5 or 10 minutes before next step.

3. Use white paper towels to wipe lubricating oil from liner bores. Note gray and even black residue that appears with oil on white towels. This is honing debris that remained on liner walls. Repeat application of lubricating oil and wipe off with white paper towels. If honing debris is still present, repeat lubricating oil treatment. Usually liners will appear clean on second application. Liners must be completely cleaned after honing. After soap and hot water treatment, liners will appear clean when a paper towel is wiped through dry bore. This is a false indication since lubricating oil treatment will remove additional abrasive material. We cannot be too emphatic about importance of thoroughly cleaning liners after honing.

Note: Always install new liner packing rings and crevice seals (as used) when assembling liner to engine.

Idler Gear—Unit 103

Inspection

1. Inspect idler gear bushing. Mark for replacement if I.D. is more than 2.002 inch [50.8508 mm].

2. Inspect idler gear for worn or cracked teeth. Mark for replacement as necessary.

3. Measure idler gear pin in block. Replace if O.D. is less than 1.9965 inch [50.7111 mm].

Replacement

1. If bushing must be replaced, press old bushing from gear and press in new bushing.

2. Place idler gear flat against face plate or back rest in lathe or in boring machine fixture. Center gear by clamping chuck jaws on precision drill rod resting on pitch diameter of gear.

3. Bore new bushing concentric with gear pitch diameter to 2.000 to 2.001 inch [50.8000 to 50.8254 mm].

Crankshaft—Unit 104

Disassembly

1. If crankshaft gear is chipped, cracked, broken or worn, remove lockplate and nut (if used).

2. Attach a circular-type puller, as illustrated in Fig. 1-4-1, behind the crankshaft gear.

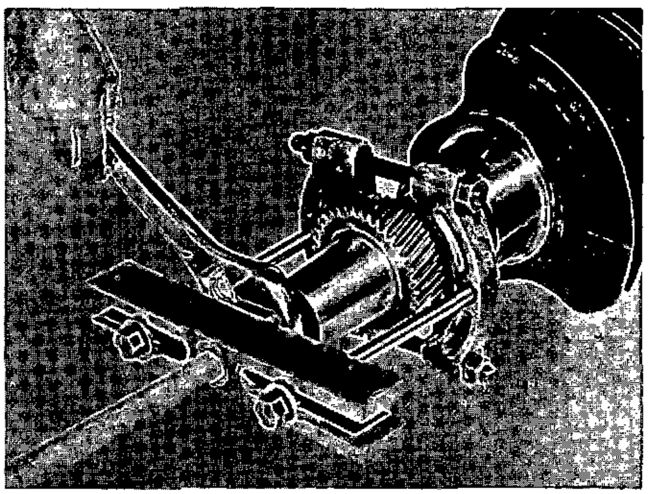


Fig. 1-4-1, V40142. Pulling crankshaft gear with ring-type puller

3. Apply 75 to 100 ft. lbs. [10.3725 to 13.8300 kg m] on puller screw.

4. Heat gear with heating torch – not a cutting torch – to 300 deg. to 400 deg. F [148.9 deg. to 204.4 deg. C]. The gear will expand, making it easier to pull.

5. Remove gear key.

6. If crankshaft gear condition is satisfactory, do not remove.

Cleaning And Inspection

1. Inspect crankshaft visually for scratches, nicks, cracks and obvious wear pattern.

2. Measure crankshaft journals with micrometers. See Fig. 1-4-2 or 1-4-5 and Table 1-4-1.

3. Check crankshaft for out-of-round condition.

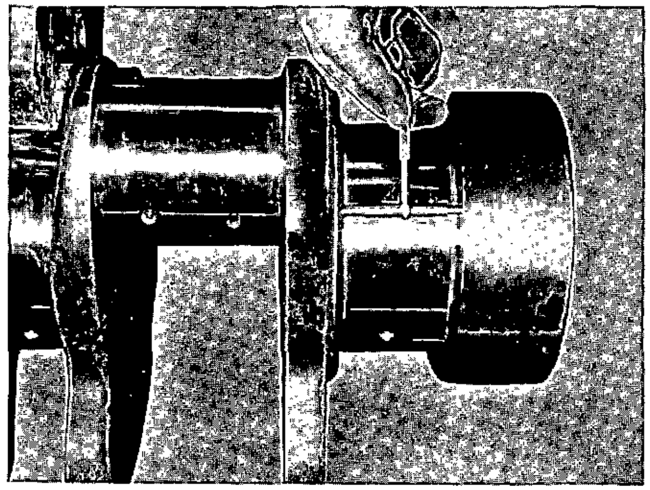


Fig. 1-4-2, V40170. Checking crankshaft flange for wear

Crankshafts should be reground if main bearing or crankpin journals are worn out-of-round more than 0.002 inch [0.0508 mm]. Fig. 1-4-5.

Clean Drillings In Crankshaft

1. Remove all pipe plugs.

2. Clean all drilled oil passages in crankshaft with a rod and rag as if cleaning a rifle barrel; flush to remove sludge. Fig. 1-4-3.

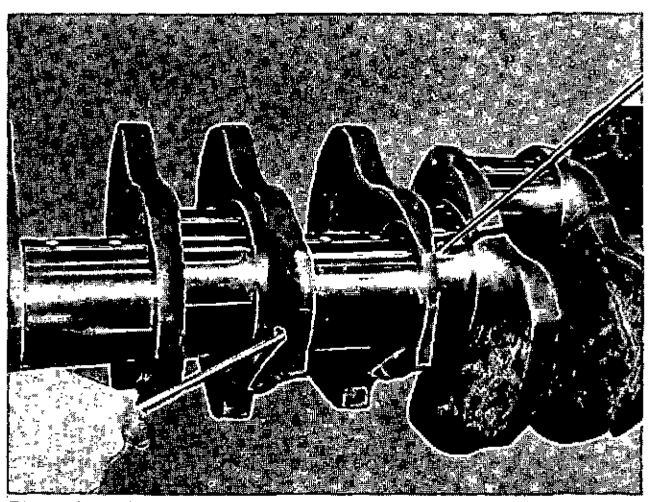


Fig. 1-4-3, V40141. Cleaning drilled oil passages

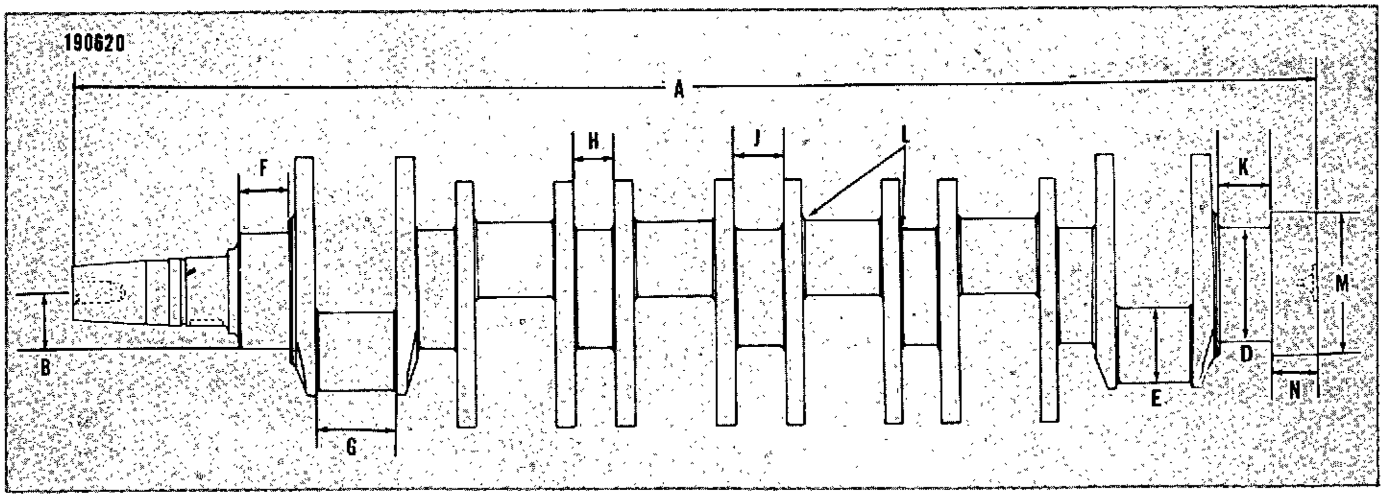


Fig. 1-4-4, V40181. Crankshaft dimension

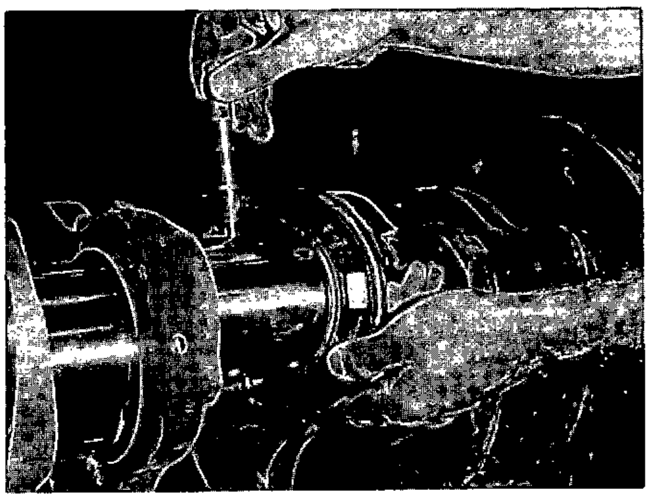


Fig. 1-4-5, V40144, Measuring crank pin journal

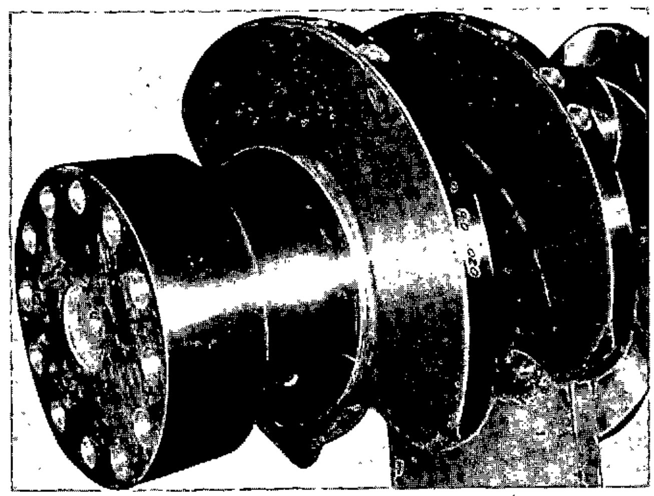


Fig. 1-4-6, V40182. Oversize thrust bearing size mark on crankshaft

3. Install and tighten plugs to 5 ft. lbs. [0.6915 kg m] torque.

4. Stake pipe plugs by making a 1/64 inch [0.3969 mm] indentation at outside diameter of threads with center punch.

Inspect Crankshaft Thrust Flange

1. Carefully examine crankshaft thrust flange at No. 7 main bearing. Fig. 1-4-2. If surface is scored or scratched, flange should be reground for oversize thrust rings.

2. Reground crankshafts or those used with oversized thrust rings should be marked so the correct thrust rings will be installed in their proper position. Fig. 1-4-6.

a. The marking should be stamped on the rear crankshaft counter weight.

b. Both the thrust ring size and ring location must be included in the stamping on crankshaft counter weight as shown in Fig. 1-4-6.

For example: front -- .0.010 inch [0.2540 mm] and rear -- 0.020 inch [0.5080 mm].

c. Measure for thrust flange wear by checking K dimension. Fig. 1-4-4.

d. If wear does not exceed 0.003 inch [0.0762 mm] at any one point, flange condition is acceptable.

e. If wear is 0.003 inch [0.0762 mm] or more, regrind

Table 1-4-1: Crankshaft Dimensions — Inch [mm]

Part No.	A	B	D	E	F	G	H	J	K	L	M	N
190620	63.355	2.995	5.7485	3.7485	2.560	4.048	1.990	2.490	2.700	0.175	7.248	2.495
	63.395	3.005	5.7500	3.7500	2.590	4.051	1.996	2.496	2.703	0.195	7.250	2.505
	[1607.9470]	[76.0730]	[146.0110]	[95.2119]	[63.6524]	[102.8192]	[50.5460]	[63.2460]	[68.5800]	[4.4450]	[184.0992]	[63.3730]
	[1610.2330]	[76.3270]	[146.5000]	[95.2500]	[63.7860]	[102.8954]	[51.0540]	[63.3984]	[68.6582]	[4.9530]	[184.1500]	[63.6270]

Note: Number "3" may appear as reference number on nameplate.

flange to restore flatness. If total wear and regrinding does not exceed 0.005 inch [0.1270 mm], standard thrust rings may be used.

f. If worn more than 0.005 inch [0.1270 mm], flange should be ground for 0.010 or 0.020 inch [0.2540 or 0.5080 mm] oversize thrust rings or built up by electric arc welding and reground to specifications. Mark as noted in a and b above.

g. Regrind must clean up a minimum of 90% of the thrust surface.

h. The regrind or resurfacing must result in maintaining installed crankshaft end clearance below 0.015 inch [0.3810 mm].

Magnetic Inspection

1. Wet complete surface with magnetic particle suspension before applying current.

2. Table 1-4-2 lists magnetizing currents that should be used.

3. Flow magnetic particle suspension over part in advance of placing part through coil. Turn current on coil and move coil full length of part.

Table 1-4-2: Magna-Flux Magnetization

Direction of Defect	Longitudinal	Circumferential
DC or rectified AC	1200 amps	3600-4000 amp turns
AC equipment	1400 amps	4200-4700 amp turns
Magnetizing Method	Head Shot	Coil Shot

Note: Ampere-turns is amperage flowing through coil multiplied by number of turns in coil; above is for 4-turn coil.

4. If shaft parts are within 2 or 3 inch [50.8000 or 76.2000 mm] of coil I.D., ample magnetism will be obtained if 3 shots of current are passed through coil while it is at each end and center of part length.

5. Limits of Acceptability.

a. Unless otherwise stated, limits of acceptability apply only to light slag or oxide stringers usually defined as inherent inclusions. Obvious cracks and circumferential or transverse defects are not acceptable.

b. Limits listed in following steps must be maintained within region "C" (Critical Region) shown in Fig. 1-4-7. Dimensional value of "C" is vertical distance measured downward from crankpin center-line and extending longitudinally for all crank webs between region "X" on crankpin and region "X" on main journal.

c. Indications located less than 1 inch [25.4000 mm] from major axis on centerline (1, Fig. 1-4-7) of adjacent web (measured circumferentially) must not exceed the following limits:

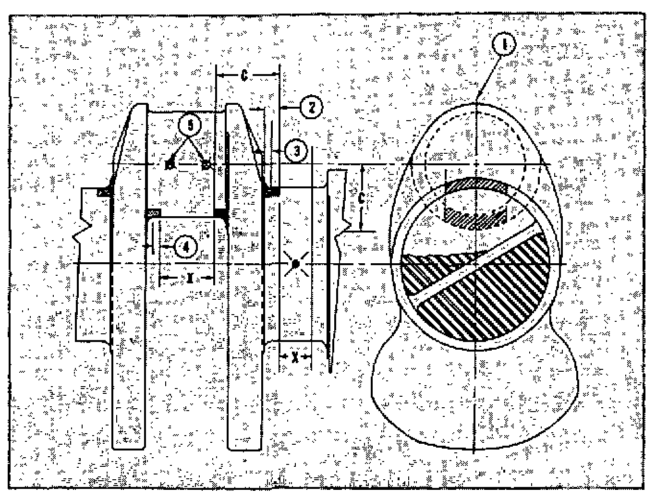


Fig. 1-4-7, V40145. Crankshaft magnetic inspection

(1) Light indications in or entering fillets (3) are acceptable if not more than 1/8 inch [3.1750 mm] long (open) (2) or 1/4 inch [6.3500 mm] long (subsurface).

(2) Light open indications on crankpin and main journal walls or bearing surface that extend closer than 1/8 inch [3.1750 mm] to fillets (4), but do not enter fillets, are acceptable if 3/8 inch [9.5250 mm] long or less. Light subsurface indications are acceptable.

d. Indications located more than 1 inch [25.4000 mm] from major axis or centerline (1) of adjacent web (measure circumferentially) must not exceed following limits:

(1) Light open indication in or entering fillets are acceptable if 3/8 inch [9.5250 mm] long or less. Light subsurface indications are acceptable.

(2) Light open indications on crankpin and main journal walls or bearing surfaces that extend closer than 1/8 inch [3.1750 mm] to fillet, but do not enter fillet, are acceptable if 1/2 inch [12.7000 mm] or less. Light subsurface indications are acceptable.

(3) Nicks on corners of webs are not acceptable. The part will be acceptable if nick can be removed by grinding a 3/32 inch [2.3812 mm] radius on corner.

(4) Imperfections on web periphery may be ground out to a depth of 3/32 [2.3812 mm] maximum using a 1/2 inch [12.7000 mm] minimum radius grinding wheel, provided balance limits are maintained.

(5) Light open indications that pass within 1/16 inch [1.5875 mm] of a crankpin hole (5) are acceptable if 3/4 inch [19.0500 mm] long or less and do not enter the oil hole chamfer or intersect the 45 deg. ± 10 deg. diagonal. Only those subsurface indications that lie closer than 1/16 inch [1.5875 mm] to surface (measured at the chamfer at a 45 deg. ± 10 deg. diagonal) are not acceptable. All other subsurface indications are acceptable.

e. Light open indications that enter the chamfer of any main bearing oil hole are acceptable if they are 1/8 inch *[12.7000 mm] or less. Subsurface indications ending in a* main bearing oil hole are acceptable.

f. Fine subsurface, salt and pepper type indications are permitted on upper and lower side of crankpins on trimming line.

g. Open longitudinal indications within region "X" which *are less than 1-1/2 inch [48.1000 mm] on main journals* and 1-1/8 inch [38.5750 mm] long on crankpins, are acceptable after sharp edges have been stoned 0.002/0.004 inch [0.0508/0.1016 mm] below the journal surface.

h. Longitudinal subsurface indications within the area "X" are acceptable.

i. Parallel open indications that meet the requirements of (s) and other requirements on length and frequency are acceptable.

j. Parallel subsurface indications are acceptable.

k. Indications that contain loose or foreign particles or voids left by such particles are not acceptable.

l. Not more than four open indications are to appear on any one journal or crankpin. Scattered small, open, or subsurface indications, six per crankpin, and eight per main bearing 3/16 inch [4.7625 mm] long or less, if not forming part of a long intermittent indication or entering an oil hole or fillet, will not be counted as indications in arriving at total number permitted. However, if in addition to showing maximum number of acceptable indications for the whole crankshaft the part also shows many widely scattered short indications, it will be rejected.

m. An inclusion which in intermittently open and subsurface shall be considered and measured as an open indication after the original indication is wiped off. The entire indication must first meet requirements for subsurface limits.

n. Open and subsurface indications on counterweights and crankthrow bevel outside the critical region are acceptable.

o. Open seams on web periphery that o. Seams or indications outside critical region that extend over crank web periphery but are not visible on crankpin, wall are acceptable.

p. Open seams on web periphery that show visual depth on crankpin wall may be removed from web periphery with a 1/2 inch [12.7000 mm] radius wheel, provided at least 1/16 inch [1.5875 mm] wall remains above crankpin fillet after repair and balance limits are maintained.

q. Indications due to weld defects are not acceptable in counterweight welds. Indications at corner may be ground out and blended to depth not exceeding 1/4 by 5/8 inch [6.3500 by 15.8750 mm] long.

r. Open longitudinal indications in flywheel and thrust flange fillets longer than 3/8 inch [9.5250 mm] are not acceptable.

s. Limits of indications on oil seal surface which, when wiped clean, do not show sharp edges, are acceptable.

6. After inspection where coil shot is used, give crankshaft head shot to put magnetic poles at ends of crank, not throws. The residual magnetic field should not exceed two units on the Magnaflux Field Indicator or equal.

Repair

Note: Atlas Crankshaft Corporation, a Division of Cummins *Engine Company, Inc. have facilities available to* recondition crankshaft to Cummins specifications.

Check Crankshaft Hardness Before Regrinding

1. All journals should be checked for hardness and must check within 40/50 Rockwell C.

2. If crankshaft journals check below 40 Rockwell C, the shaft should be hardened to a 0.090 inch [2.2860 mm] minimum depth and 45/50 Rockwell C before regrinding.

3. This check should also be performed after any bearing failure even though there was no seizure or crankshaft discoloration.

4. Soft crankshaft journals are more susceptible to high wear rate and breakage than those properly hardened.

Grind Crankshaft

1. If inspection shows crankshaft is worn to point where it must be reground and magnetic inspection shown it is suitable for regrinding, grind shaft to next standard undersize.

If crankshaft is sent out to a location other than the Factory for regrinding, make sure the regrind shop certifies that all crankshaft journals are hardened to 45/50 Rockwell C.

Caution: This operation must be performed by a shop with adequate equipment and fully trained personnel. Cummins Engine Company, Inc. will not be responsible for the results.

2. Connecting rod and main bearing shells are available in 0.010, 0.020, 0.030 and 0.040 inch [0.2540, 0.5080, 0.7620 and 1.0160 mm] oversizes.

3. If crankshaft thrust flange is worn, repair as outlined in "Inspect Crankshaft Thrust Flange" above.

Caution: Grind only the worn thrust face. Install oversize thrust rings on the wearing side only. Failure to do so will move operating position of crankshaft and cause extremely high wear.

4. Regrind crankshaft to undersize and hold to specifications shown in Fig. 1-4-3 as noted in the following steps.

5. Fillets add greatly to strength of crankshaft. Reducing fillet radii or undercutting subtracts materially from that strength. Conversely, if fillets are larger than those specified, bearing shells may be squeezed and will fail very quickly. Regrind fillets to values shown in Table 1-4-1.

6. Grind width of crankpin and main bearings to clean up basic face surfaces.

a. If there are deep interruptions such as "gouges" or "nicks" that do not extend into the fillets, smooth the edges with polishing paper.

b. A limit of 0.030 inch [0.7620 mm] over the maximum new crankshaft main bearing width specification, Table 1-4-1 shall apply in regrinding.

c. The pin wall heights of V12 cranks are not to be lowered to less than the minimum new crankshaft dimension of 0.001 inch [0.0254 mm] from the pin cheeks in regrinding and the pin bearing width is not to exceed 0.020 inch [0.5080 mm] over the maximum new crankshaft pin bearing width.

d. An attempt should be made to keep the pin wall heights as high as possible while still accomplishing the purposes for regrinding.

e. All fillet and bearing surfaces should have the same finish as a new crankshaft.

7. V-engine crankshafts may be ground "off stroke" only if the resulting stroke is shortened and not increased. A limit of 0.020 inch [0.5080 mm] under the mean stroke dimension shall apply. Table 1-4-2.

a. All pin bearings on all crankshafts must be reground to the degree of "off-stroke" required by the worst out-of-round pin bearing.

8. Maximum runout on thrust wall of Rear Main Bearings shall be 0.002 inch [0.0508 mm] T.I.R.

9. Gear-fit diameter is acceptable when 0.002 inch [0.0508 mm] total indicator runout is not exceeded in relation to adjacent main bearing.

10. Crankshafts with front oil seals may have the flange ground to a diameter not to exceed 0.010 inch [0.2540 mm] under the new crankshaft diameter after grinding and polishing.

11. The rear oil seal now rides on a wear sleeve on the crankshaft, Fig. 1-4-8. All crankshafts with rear flange of the design shown should have the wear sleeve replaced when a new rear cover seal is required.

12. Crankshaft must be dynamically balanced to 1 inch oz. [72.0080 g cm].

Chrome Plate Crankshaft

1. Hard chrome plating may be applied only to following crankshaft areas: gear-fit surface, rear oil seal surface and flywheel flange surface.

Caution: Plating of bearing journals in not acceptable.

2. Surfaces to be plated should be free from pits, tool marks, and all irregularities. Preserve all bevels, chamfers and radii. Remove pipe plugs.

3. If necessary, grind surfaces undersize before plating to

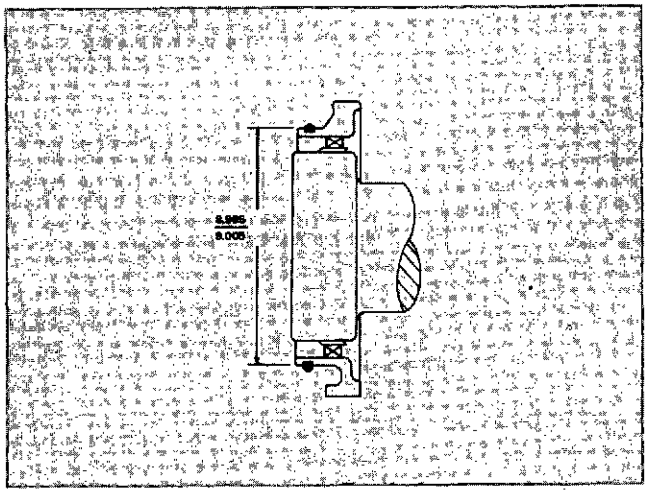


Fig. 1-4-8, V40184. Wear sleeve installed

produce minimum plating thickness of 0.002 to 0.015 inch [0.0508 to 0.3810 mm] when plated area is finished to standard diameter.

4. Chemically clean surfaces before plating.

Caution: Protect surfaces not being plated. Make certain drill passages are not contaminated with protective materials used.

5. Plating must be accomplished in a continuous operation. Double plating and spot plating are not acceptable.

6. After surfaces have been plated, heat at 375 deg. F [190.5 deg. C] for three hours to remove effects of hydrogen embrittlement.

7. Inspect plated surfaces.

a. Perform magnetic inspection as described above.

b. Check plate for firm bond to base metal, uniformity, freedom from frosty areas, pin holes, nodules, blisters and other defects.

c. Check drilled passages and unplated surfaces to make certain they are free of plating or protective materials.

d. Steam clean crankshaft.

e. Install and tighten pipe plugs 5 ft-lbs [0.6915 kg m] torque and stake in position.

Assembly

1. Install crankshaft gear, if removed.

Note: Check parts catalog for proper replacement gear.

a. Install key in shaft.

b. Heat gear with heating torch—not cutting torch—to 400 deg. F [204.4 deg. C];

Note: Apply a light even coat of Prussian Blue on bore of flange. Place flange on crankshaft nose turn (1/8) turn and pull straight off. Contact area should be full 360^{o} bluing contact at least 1/2 inch [12.7000 mm] wide at large end taper. Do not lap keyless crankshaft nose. Discard defective parts.

2. Lubricate crankshaft nose with Lubriplate and drive gear onto shaft with piece of tubing until it seats against shoulder.

3. Install lockplate and nut (if used).

Bearings—Unit 105

Main and connecting rod bearings are two-piece units containing an oil hole for lubrication. Thrust bearing "half-rings" are provided at the rear main bearing which then becomes a six-piece unit.

Inspect Bearing Shells

1. Gauge shell with ball point micrometer, dial indicator thickness gauge, or comparator, Fig. 1-5-1.

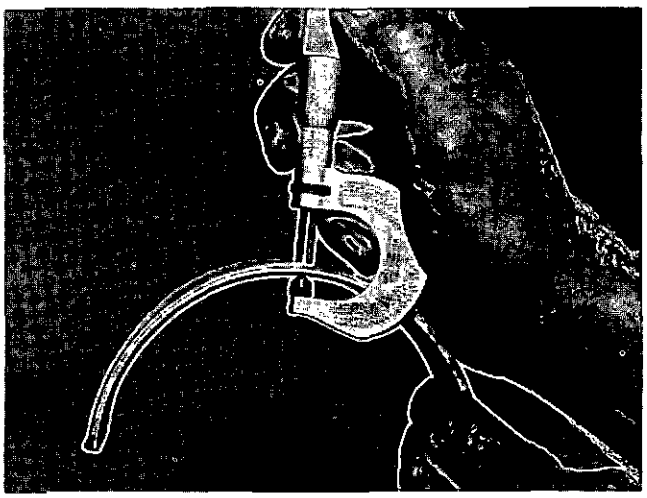


Fig. 1-5-1, V40112. Gauging bearing shell

Table 1-5-1: Bearing Shell Thickness — Standard - Inch [mm]

Bearing Shell	New Dimensions Minimum	Maximum	Worn Limit
Main	0.1705 [4.3307]	0.1712 [4.3561]	0.1692 [4.2976]
Conn. Rod	0.1245 [3.1623]	0.1250 [3.1750]	0.1232 [3.1292]

2. Discard shells that are worn more than dimensions shown in Table 1-5-1 or if chipped, flaked, or scored.

3. Total worn maximum oil clearance should not vary more than dimensions shown in Table 1-5-2 between adjacent main bearings.

Table 1-5-2: Journal Clearance — Inch [mm]

Bearing Shell	New Dimensions Minimum	Maximum	Worn Limit
Main	0.0026 [0.0660]	0.0065 [0.1651]	0.0100 [0.2540]
Conn. Rod	0.0020 [0.0508]	0.0050 [0.1270]	0.0085 [0.2159]

Caution: Under no circumstances should an attempt be made to scrape bearing shells, nor should they be lapped or filed to increase oil clearances.

4. A properly fitted bearing will appear dull gray after a reasonable period of service, indicating it is running on an oil film. Bright spots indicate metal-to-metal contact and black spots indicate excessive clearance.

Crankshaft Thrust Rings

1. The best measurement of wear on crankshaft thrust rings is the crankshaft end clearance check. See "Engine Assembly" Section 14.

2. Oversize thrust rings are available as indicated in Table 1-5-3.

3. At any time oversize thrust rings are used, be sure to use the same size (thickness) half-ring on both the upper and lower positions. Stamp crankshaft rear web indicating size used. See Page 1-4-1.

Table 1-5-3: Crankshaft Thrust Rings — Inch [mm]

Part No.	New Minimum	New Maximum	Worn Limit
180280	0.307 [7.7978]	0.317 [8.0518]	*
180281	0.317 [8.0518]	0.327 8.3058]	*
180282	0.327 [8.3058]	0.337 [8.5598]	*
*Use Following Crankshaft End Clearance:			
	0.0060 [0.1524]	0.0130 [0.3302]	0.0260 [0.6604]

Vibration Dampers—Unit 106

On engines where the vibrating forces are or could become harmful, vibration dampers are supplied.

V-1710 engines use rubber dampers, which are tuned to the engine's natural system frequency. These are made of metal units separated by rubber compound material. The dampers are designed to provide adequate protection for the engine when normal power transmitting components are connected in a suitable manner.

Cleaning

1. Rubber dampers should be cleaned in household detergent.

Caution: Use of solvent or degreasing compounds will cause deterioration of rubber.

Inspection

1. Inspect rubber damper for cracks, and inertia member for deterioration that will impair its effectiveness.

a. If the cavity depth (1, Fig. 1-6-1) exceeds 1/8 inch [0.1250 mm] all the way around, the damper must be considered failed.

b. If the cavity depth (2) exceeds 3/8 inch [0.3750 mm] all the way around the damper, the damper must be considered failed.

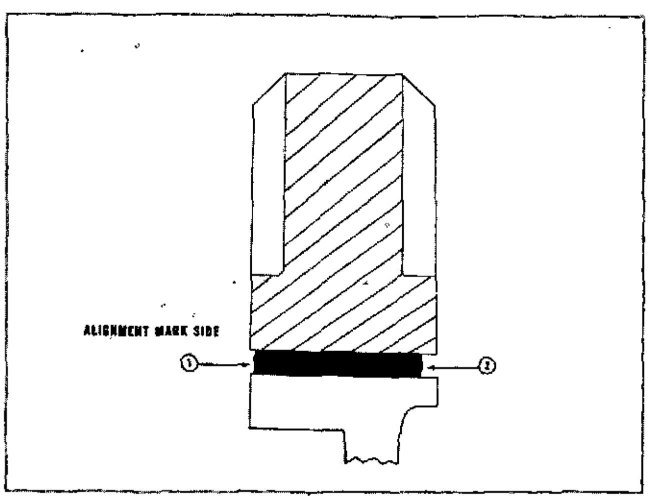


Fig. 1-6-1, V40165, Fail Damper

2. Check for alignment of index marks on damper hub and inertia member. (Fig. 1-6-2). If out of alignment more than 1/16 inch [1.5875 mm], discard damper.

3. Rubber vibration dampers that become damaged "wobble" during operation, indicating loss of effectiveness. Table 1-6-1 indicates limits as measured on inner ledge of inertia member. Such dampers must be discarded and replaced immediately.

Table 1-6-1: Damper Eccentricity and Wobble Limits – Inch [mm]

Serial No. Suffix	Part Number	Eccentricity	Wobble
3	193552	0.030 [0.7620]	0.030 [0.7620]
3	193553	0.030 [0.7620]	0.030 [0.7620]
3	193554	0.030 [0.7620]	0.030 [0.7620]

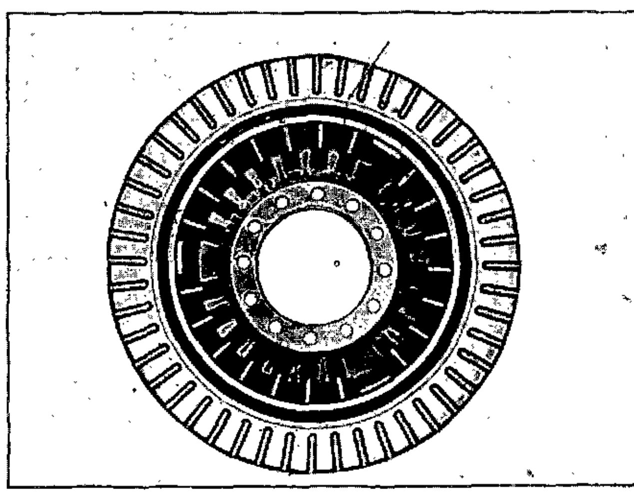


Fig. 1-6-2, V40167. Vibration damper alignment marks

Repair

Dampers are not subject to Field repair; therefore, if inspection shows them to be defective, install a new damper.

Vibration Damper Mounting Flange

1. Check damper mounting capscrew hole threads.

2. Maximum eccentricity of the mounting flange, measured on the outside diameter of the pilot, should not exceed 0.004 inch [0.1016 mm] total indicator reading.

3. Wobble of the flange, measured at 2-3/4 inch [69.8500 mm] radius, should not exceed 0.003 inch [0.0762 mm].

4. The above readings are to be taken after assembly on the engine.

Caution: Crankshaft must be kept to front or rear thrust limit while wobble is checked.

Connecting Rods—Unit 108

Inspection

1. Magnaflux all connecting rods, caps and bolts; discard if cracks are detected.

Note: Be sure rod and cap are kept mated at all times.

a. Check rods for cracks with 1800 ampere current AC equipment or 1500 ampere current DC or rectified AC equipment longitudinally between plates.

b. Check rods for cracks with 3000 to 3400 ampere-turns with AC equipment or 2600 to 2800 ampere-turns with DC or rectified AC equipment in a coil. Pay particular attention to shaded critical areas shown in Fig. 1-8-1.

Note: Ampere-turns is defined as the amperage flowing through the coil, multiplied by the number of turns in the coil. Most coils contain four turns and therefore only 700 amperes need to be applied with DC equipment, or 850 amperes with AC equipment.

c. Apply one and one-half percent wet solution while current is on. Make visual inspection after each application of current.

2. Assemble cap to rod and alternately tighten nuts to operating tension by Torque method as described in Table 1-8-1.

3. Check crankpin bore with a dial bore gauge or inside micrometers. Correct size is important to provide correct bearing crush. See Table 1-8-2 and (4, Fig. 1-8-1).

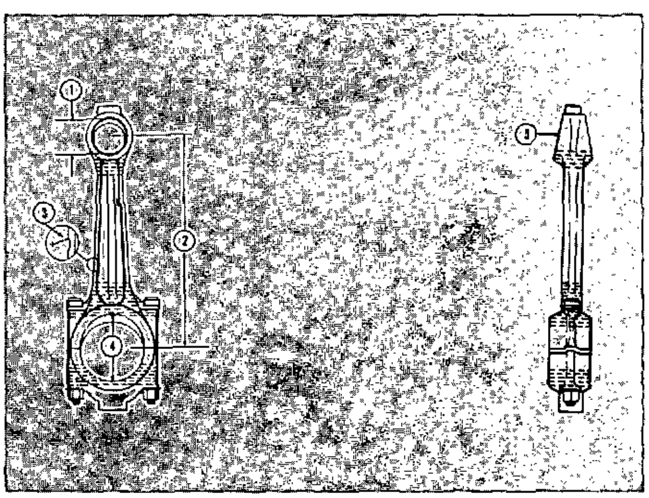


Fig. 1-8-1, V40114. Connecting rod specifications

Table 1-8-1: Template Tightening Connecting Rod Nuts

Tightening Sequence		Tightening Values Ft-Lb [kg m]
Step 1	Tighten to	70/80 [9.6810/11.0640]
Step 2	Advance to	140/150 [19.3620/20.7450]
Step 3	Loosen all	Completely
Step 4	Tighten to	70/80 [9.6810/11.0640]
Step 5	Advance to	140/150 [19.3620/20.7450]

4. Check piston pin bushing diameter with ST-205 plug gauge or with inside micrometers. See Table 1-8-2, Fig. 1-8-2 and (1, Fig. 1-8-1).

5. Use ST-561 Checking Fixture and Locating Mandrel to check rod alignment.

Note: Difference in reading should not exceed 0.015 inch [0.3810 mm].

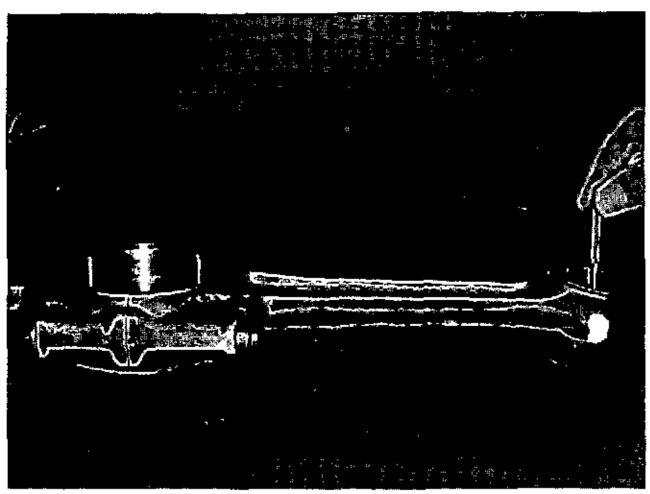


Fig. 1-8-2, V40185. Checking connecting rod piston pin bushing

Table 1-8-2: Connecting Rod Dimensions – Inch [mm]

Crankpin Bore New Dimensions Min.	Crankpin Bore New Dimensions Max.	Out-Of-Round Limit	Piston Pin Bushing New Dimensions Min.	Piston Pin Bushing New Dimensions Max.	Worn Limit
40.018 [101.6457]	4.0028 [101.6711]	0.0010 [0.0254]	2.0010 [50.8254]	2.0015 [50.8381]	2.0025 [50.8635]

6. Check connecting rod bolts, bolt holes and bolt pads.

a. *The bolt head must rest squarely on milled surfaces of rod.*

b. If connecting rod bolts have been tightened excessively, they may be permanently stretched in which case they must be discarded. Discard bolt if smallest diameter is less than 180.5400 inch [13.715 mm].

c. Check bolt pilot O.D. discard bolt if pilot is smaller than 0.6242 inch [15.8546 mm].

d. Discard all bolts and nuts that have distorted threads.

e. Check bolt hole diameter. If diameter exceeds 0.6249 inch [15.8724 mm].

f. Check bolt pad radius. See Page 1-8-1 for dimensions.

7. Inspect connecting rod bearing shells in same manner as main bearing shells. See Bearings in Unit 105 for shell *thickness and allowable wear.*

Calibrate Checking Fixture For Rod Size

1. Select a new rod that has been checked for correct absolute center to center (2, Fig. 1-8-1) length, 12 inch [304.8000 mm] between centers. (Production rods may vary from 11.998 to 12 inch [304.7492 to 304.8000 mm].

2. Assemble cap to rod as described in Table 1-8-1.

3. Insert piston pin, furnished in ST-563 mandrel set, in piston-pin bore.

4. Insert and tighten ("snug" only) expanding arbor ST-758 in crankpin bore. Locating pin must be down in cap on center line of rod.

5. Set rod in fixture. Fig. 1-8-3.

6. Move dial holder so dials indicate on piston pin.

7. Zero dial indicators.

8. Lift rod, arbor and pin assembly from fixture; turn horizontally 180 deg.; set back in fixture.

9. Readjust dial indicators to divide difference between first and second readings, fixture is now calibrated.

Check Rod Alignment

1. Measurements read directly from dial indicator indicate comparative length and misalignment of bores. Measurements apply with or without bushing installed.

2. Assemble ST-758 Mandrel in rod to be checked.

3. Set rod in fixture, be sure pin in mandrel is down and locked in position in center line of rod.

4. Take readings for length (compared to length set up in calibration of fixture) and misalignment of bores (difference in reading from one indicator to other).

5. Turn rod 180 deg. Total reading must not exceed 0.008 inch [0.2032 mm] when connecting rod, **does not contain bushing,** or 0.004 inch [0.1016 mm] **with bushing** installed and bored to size. This is combined plus and minus readings of indicator. Length must read $\pm$0.001 inch [$\pm$0.0254 mm] on gauges.

6. Measure rod twist with a feeler gauge between piston pin and dial holding plate. Fig. 1-8-4. When measuring connecting rod, twist in ST-561 and rod does not contain piston pin bushing, twist must not exceed 0.020 inch

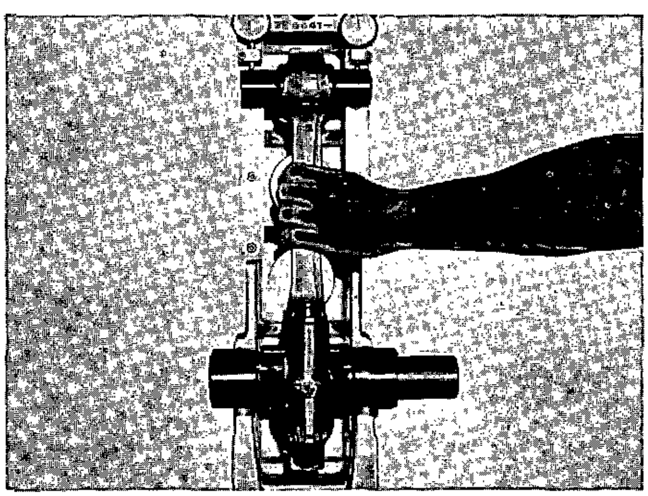


Fig. 1-8-3, V40138. Checking rod bore alignment

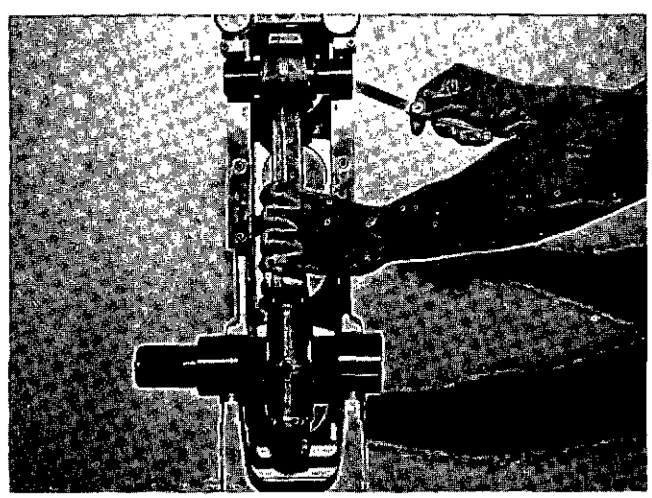


Fig. 1-8-4, V40139. Checking rod twist

[0.5080 mm]. Twist must not exceed 0.010 inch [0.2540 mm] with bushing in place and bored to size.

Check Centerline Of Rod

1. Attach a Starrett No. 196 indicator so it will contact the side milled surface of piston pin end of rod.

2. Slide crankshaft end of connecting rod sideways to contact ST-561 on same side as indicator gauge. See Step 1.

3. Zero indicator gauge on milled surface.

4. Turn rod 180 deg.; repeat all above checks.

Note: Difference in reading should not exceed 0.015 inch [0.3810 mm].

Repair Operations

Resize Crankpin Bore

Resize only if crankpin bore is outside limits given in Table 1-8-2.

1. Remove old piston pin bushing with ST-870 Mandrel and Block.

2. Install cap and tighten nuts by the Torque method. Table 1-8-1.

3. Recheck the rod length on ST-561 Checking Fixture. If rod length is 11.991 inch [304.5714 mm] or less, rod cannot be resized and must be discarded.

4. If rod is over 11.991 inch [304.5714 mm] in length, it is suitable for resizing crankpin bore.

5. Remove cap and surface grind or mill a maximum of 0.009 inch [0.2286 mm] stock from machined face of rod.

6. A maximum of 0.009 inch [0.2286 mm] stock may be machined from cap surface. Parts must be clamped securely during this operation to insure proper contact of entire mating surfaces after reassembly and proper alignment of bores for rod bolts. Bolt holes must remain perpendicular to machined mating faces.

a. Use surface plate and lapping compound to lap rod and cap mating surfaces. After grinding and lapping, "blue" surfaces; seating or flatness pattern must show a minimum 75% contact. Still-blued area must not be in area outside bolt centerline (area farthest from bore centerline); this area should indicate 100% seating. See Fig. 1-8-5.

b. Place mating rod and cap surfaces together and check closely for evidence of out of flat; see exaggerated example in Fig. 1-8-6.

7. The rod cap now must be reassembled to rod and tightened to operating tension by the Torque method. Table 1-8-1.

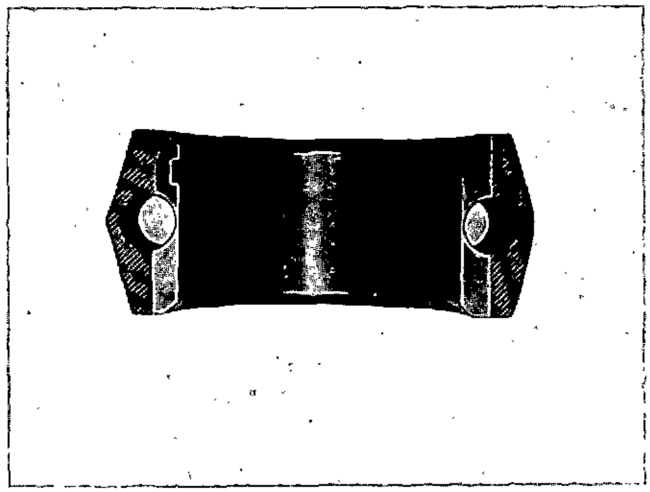


Fig. 1-8-5, N10188. Area of flatness

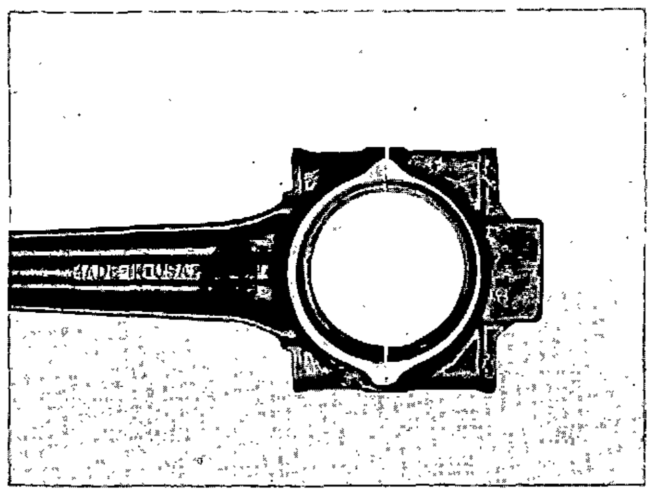


Fig. 1-8-6, N10189. Evidence of out-of-flat

Note: When placing rod in boring machine, place numbered side of rod in, if space bars are not used. Install rod with numbered side out, if space bars are used.

8. Line bore or grind the crankpin bore 4.0020 to 4.0025 inches [101.6508 to 101.6635 mm]. A fixture is required to maintain alignment of bores

Note: The above measurement is boring dimension before rod and cap separation.

9. Check alignment on ST-561. See "Check Rod Alignment" above.

Note: ST-294 Boring Machine is not suitable for this job. Use ST-526, a milling machine or cylinder grinder with a precision fixture.

10. *Finished surface must be to 63 micro-inch or better to* insure proper contact with connecting rod bearing shells.

11. Install and bore new heavy-wall piston pin bushing as *described under "Replace Piston Pin Bushing." Heavy-wall* special bushing must be used.

12. Bore piston pin bushing off-center to restore rod to original 11.998 to 12.000 inch [304.7492 to 304.8000 mm] length.

Restore Fillet

1. A dimension of 0.0800/0.0900 inch [2.0320/2.2860 *mm] (1, Fig. 1-8-7) fillet radius must be present at all* corners where rod is milled for bolt head.

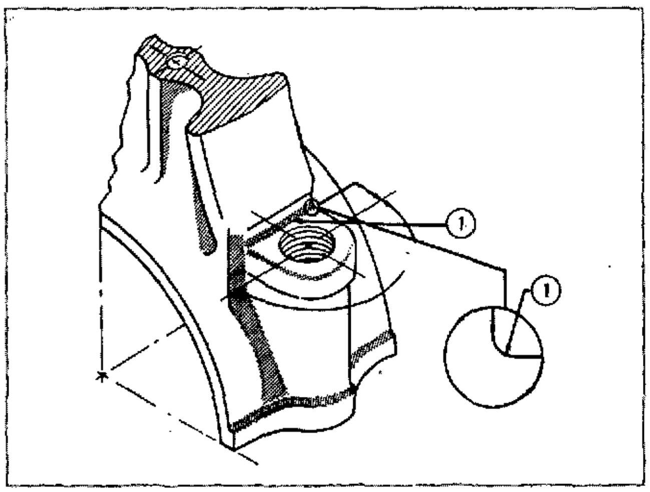


Fig. 1-8-7, V40114. Connecting rod radius specification

2. Remove nicks and dents which are less than 1/16 inch [1.5875 mm] deep by grinding or filing with a half-round file. Radius must be 1/2 inch [12.7000 mm] or more. Blend radii at ends of cut. Scrap rod if dents are deeper than 1/16 inch [1.5875 mm] (Fig. 1-8-1).

Chamfer Piston Pin Bore

1. ST-861 Chamfering Tool is used to chamfer tapered piston pin bushing bore, if not chamfered.

2. *Install proper bushing tool detail by use of flat-head* screw.

3. Set the guide screw holder in position; there are three notches, so guide screw will follow on face of bore.

4. Adjust tool bit until point just clears guide screw and tighten in position with two set screws.

5. Install unit into bore.

6. Adjust the guide screw (up or down) until tool bit just engages bore.

Note: A slight pressure is required against guide screw. To obtain this pressure, tighten set screw in end of holder against guide screw.

7. Insert drive ratchet and turn tool one complete turn to clean up edge of bore.

8. Loosen guide screw and again turn tool one or more complete turns to give a clean cut.

Note: Repeat until a uniform chamfer of 0.040 to 0.060 *inch [1.0160 to 1.5240 mm] depth is reached.*

9. Remove tool from bore, turn rod over and chamfer other side of bore.

10. With both sides chamfered, remove tool.

11. Use emery cloth to remove any sharp edges which may have been left on chamfer.

12. Wash rod which is ready for bushing installation.

Replace Piston Pin Bushing

1. To install standard size bushings in rods, on Detail 2 of ST-870 assemble Detail 5 sleeve, Piston Pin Bushing and Detail 6 guide sleeve. Fig. 1-8-8.

Caution: If one piece bushing is being used, be sure to line up oil hole in bushing and rod.

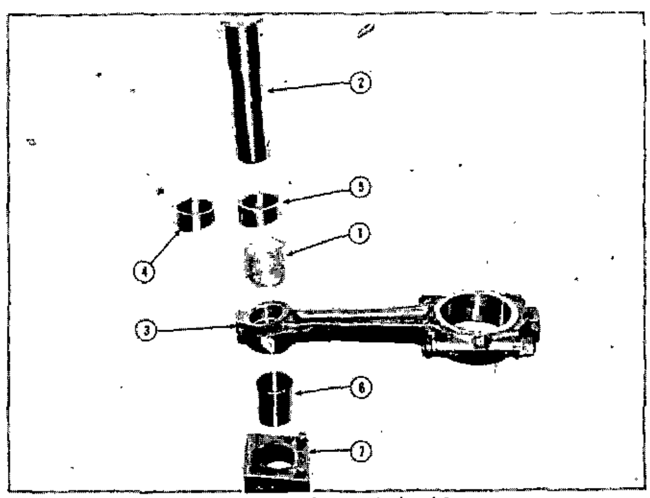


Fig. 1-8-8, V40171. Installing piston pin bushing

2. Place connecting rod on Detail 7 Block and support in horizontal position.

3. Assemble the mandrel with all components listed in Step "1" into the connecting rod bushing bore.

4. Line up mark on Detail 5 with middle of boss on rod.

5. Using an arbor press, push bushing into bore until Detail 5 contacts side of rod pin boss.

6. Remove assembly and place rod on Detail 7 Block so installed bushing half is down.

7. Using same tools less Detail 6 Guide Sleeve, press second half-bushing in the rod flush with rod surface.

8. To install thick-walled bushings in rods which have been resized at crank pin end, install in same manner as Step "1", except use smaller inside diameter Details 3, 9 and 10 instead of Details 2, 5 and 6.

Bore Rod Piston Pin Bushing

1. Fill lubricating holes with soap to keep out shavings.

2. Mount connecting rod in ST-526 Tobin-Arp Boring Machine. Fig. 1-8-9.

Note: Lower mandrel should have only the two horizontal blades in place to properly locate the side position of the piston pin end of rod.

3. See instruction booklet furnished with ST-526 for operating procedure.

4. Bore bushings to 2.001 to 2.0015 inch [50.8254 to 50.8381 mm] I.D. (1, Fig. 1-8-1). (Remove rod from ST-526 and check size with ST-205 Plug Gauge).

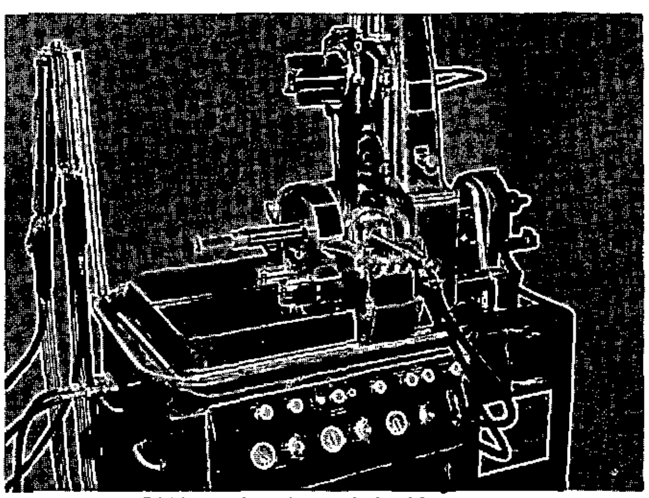


Fig. 1-8-9, V40116. Boring piston pin bushing

5. Remove sharp edges with a scraper.

6. Remove shavings and soap, wash in mineral spirits and dry with compressed air.

7. Check all dimensions on rebushed and rebored rods on ST-561 Checking Fixture as previously described.

Caution: All connecting rods used in an engine should have the same part number and weight code. Never attempt to interchange caps.

Piston and Piston Rings—Unit 109

Piston Rings

Normally, new piston rings are used at the rebuild period. New rings should be checked in the cylinder liner in which they are to be used to make sure the gaps are correct.

1. Insert each ring in mating cylinder liner; position with head of a piston so it is seated squarely.

2. Seat ring in an unworn area of the liner.

3. Measure ring gap with a feeler gauge. Fig. 1-9-1. Gap should fall within limits given in Table 1-9-1.

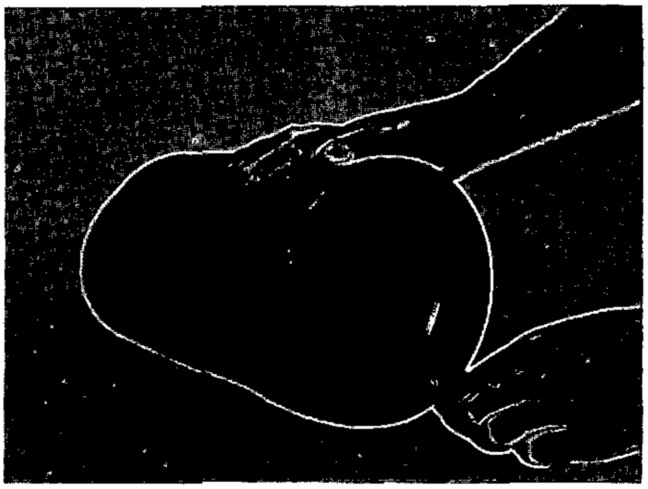


Fig. 1-9-1, V40135. Checking piston ring gap

Table 1-9-1: Piston Ring Gap — In New Or Reconditioned Liner

Ring Part No.	Minimum Inch [mm]	Maximum Inch [mm]
147670	0.017 [0.4318]	0.027 [0.6858]
132880	0.013 [0.3302]	0.023 [0.5842]
194610	0.010 [0.2540]	0.020 [0.5080]

4. If necessary, file or stone the ends of the rings to obtain the minimum gap.

Caution: Never file or stone chrome-plated rings and never use chrome-plated rings in chrome-plated cylinder liners.

5. Check current parts catalogs to make sure you use proper ring/piston combination.

Note: When used, chrome-plated compression ring is always installed in top piston ring groove.

Pistons

Cleaning And Inspection

1. Clean pistons in a solvent cleaning bath that will not attack aluminum or blast with a material that will not imbed in or remove metal (ground seed, etc.).

Caution: Piston skirts are coated with a plating that may blister if overheated. We recommend that water boiling point not be exceeded.

2. After cleaning, check top and second ring grooves with ST-560 Ring Groove Wear Gauge.

3. Shoulders of gauge must not touch ring groove lands if piston is to be reused. If shoulders touch, discard piston or mark piston for regrooving of the top groove.

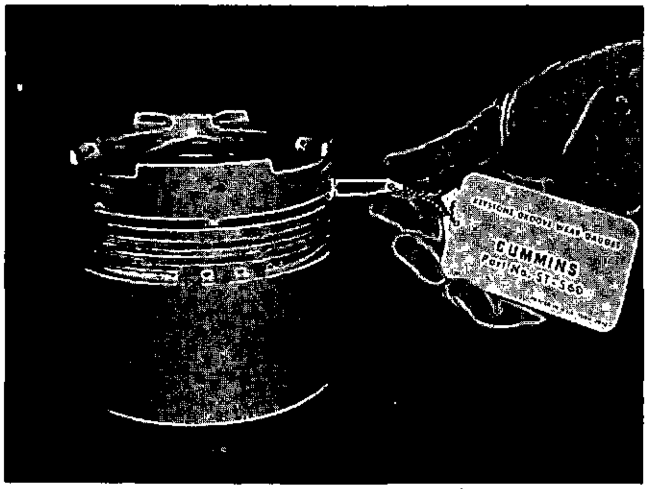


Fig. 1-9-2, V40142. Checking ring groove wear

4. If ST-560 is not available, check wear with a segment of a new ring and a feeler gauge.

a. Hold ring in groove, flush with land.

Table 1-9-2: Standard Piston Skirt Diameter at 70 deg. F. [21.1 deg. C] – Inch [mm]

Piston Part No.	* Gauge Point	New Dimension Minimum	Maximum	Wear Limit
175760	BC	5.4870 [139.3698]	5.4880 [139.3952]	5.4830 [139.2682]
199619	BC	5.4870 [139.3698]	5.4880 [139.3952]	5.4830 [139.2682]
195250	BC	5.4870 [139.3698]	5.4880 [139.3952]	5.4830 [139.2682]

*Refer to Fig. 1-9-3.

b. Insert 0.006 inch [0.1524 mm] feeler gauge.

c. If gauge enters groove without forcing or disengaging ring, wear is excessive and piston should not be used or should be marked for regrooving.

5. Measure piston skirt diameter with micrometer at right angle to piston pin bore (A, Fig. 1-9-3 for barrel-ground pistons), measure straight or tapered ground pistons at point B, 1 inch [25.400 mm] below ring groove and C, 1 inch [25.400 mm] above bottom of piston. Pistons should not be reused if worn more than indicated in Table 1-9-2 on this diameter.

6. Pistons should be checked at temperature of 70 to 90 deg. F [21.1 to 32.2 deg. C]; see Table 1-9-2.

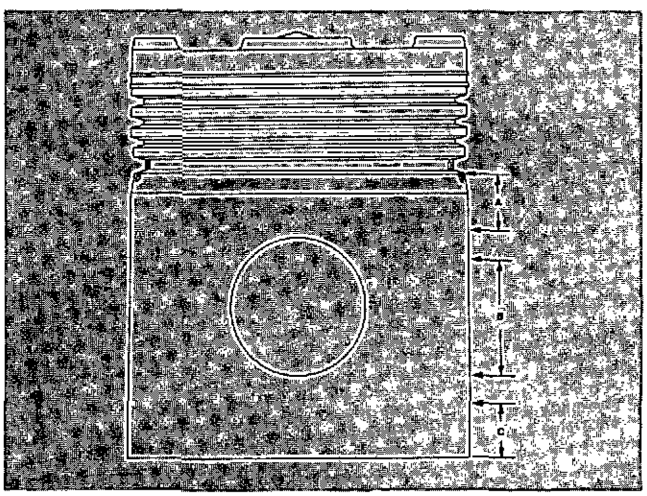


Fig. 1-9-3, N20171. Piston check points

Note: After measuring piston and comparing with liner inside diameter, piston-to-liner clearance may be computed if desired.

7. Piston pin bore checked at 70 deg. F [21.1 deg. C] should fall within limits shown in Table 1-9-3; add 0.0005 inch [0.0127 mm] per 10 deg. F [–12.2 deg. C] up to 90 deg. F [32.2 deg. C].

8. Check piston pin outside diameter with micrometers. Pins should not be reused if out-of-round more than 0.001 inch [0.0254 mm] or worn smaller than indicated in Table 1-9-4.

Caution: Reboring of piston pin bores and use of oversize pins is not practical because the misalignment that results from such practice will cause seizure of piston or failure of connecting rod bearings.

Table 1-9-3: Piston Pin Bore – Inch [mm]

New Dimensions Minimum	Maximum	Worn Limit
1.9985 [50.7619]	1.9989 [50.7720]	2.0000 [50.8000]

Table 1-9-4: Piston Pin Diameter – Inch [mm]

New Dimensions Minimum	Maximum	Worn Limit
1.9988 [50.7695]	1.9990 [50.7746]	1.9978 [50.7441]

Piston-To-Connecting Rod Assembly

1. Pistons are machined to a very close weight tolerance; therefore, as long as the same part number piston is used throughout the engine weight does not affect engine operation.

Note: Be sure rod and cap have cylinder number stamped on them before disassembly to prevent mixing parts.

2. Connecting rods have the weight "code letter" stamped on the rod cap and must be matched with other rods with same code letter.

3. Install one piston pin snap ring in piston pin bore. When 175760 or 199619 pistons are used in engine, 175755 *piston pin snap rings must be used. All others may use* 175755 or 61908.

4. Heat aluminum pistons in boiling water or in an oven,

not exceeding water boil temperature, and install pin through piston and connecting rod pin bores before piston cools.

5. At 70 deg. F [21.1 deg. C] the pin fit is 0.0001 to −0.0003 inch [0.0025 to −0.0076 mm] which prevents pin assembly unless piston is heated.

Caution: Never drive piston pin in pistons. Driving may cause distortion of the piston, causing piston seizure in the cylinder liner.

6. Secure pin with second snap ring at opposite end of pin bore.

Camshaft—Unit 110

Cleaning And Inspection

1. Steam clean camshaft assembly.

2. Check camshaft journals with micrometers. Fig. 1-10-1.

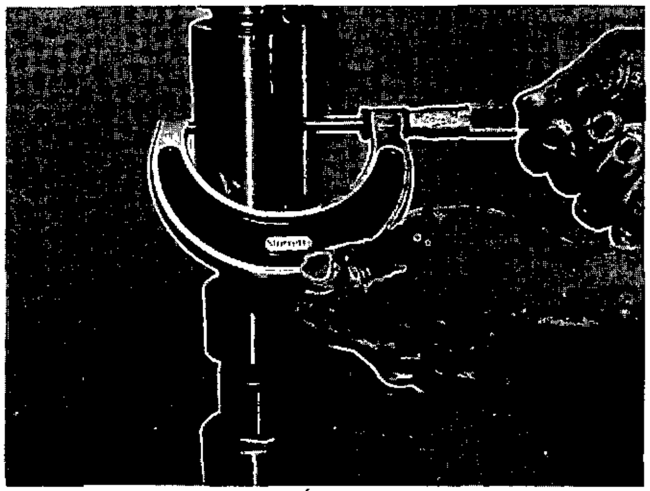


Fig. 1-10-1, V40134. Measuring camshaft journals

3. Replace camshaft if journals are worn beyond limits given in Table 1-10-1.

4. Replace camshafts that have scuffed, scored, or cracked injector or valve lobes. Check by magnetic inspection for possible cracks.

5. Cummins Engine Company, Inc. does not recommend regrinding of camshaft lobes.

Magnetic Inspection

These instructions apply to the magnetic particle inspection using "Magnaflux." The camshafts should be tested by the active or continuous method. That is, the whole surface must be wetted with the magnetic particle suspension before the magnetizing current is applied. Shafts must be magnetized by a single "shot" of current.

1500 amperes DC longitudinal magnetizing currents must be used for locating open seams and the presence of non-metallic inclusions; for detecting grinding checks a circular (coil) magnetizing current of 2000 amperes DC must be used.

Table 1-10-1: Camshaft Journal Diameter — Inch [mm]

New Dimensions Minimum	Maximum	Worn Limit
2.122 [53.8998]	2.123 [53.9242]	2.120 [53.8480]

Limits Of Acceptability For Injector Cam

1. Subsurface longitudinal indications:

1. None acceptable on nose.

b. Short longitudinal indications up to 5/8 inch [15.8750 mm] long are acceptable in the critical region on the cam surface, 1/2 inch [12.700 mm] before nose, and 3/8 inch [9.5250 mm] after nose.

c. Not more than two indications are allowable in the critical region of any one cam.

d. Light longitudinal indications not exceeding two in number are allowable outside of the critical regions.

e. Parallel indications must be separated by at least 1/16 inch [1.5875 mm] of metal.

2. Open longitudinal indications:

Open indications are not allowable except on the base circle. A maximum of two longitudinal open indications 1/4 inch [6.350 mm] long or less will be allowed on the base circle provided they are not closer together than 1/4 inch [6.350 mm] and are visible only as a tightly closed line when the surface is wiped clean. Open indications shall not be closer than 3/16 inch [4.7625 mm] to the edge of the cam.

3. Circumferential indications (lying at an angle greater than 15 deg. with the longitudinal centerline) are not allowable.

Limits Of Acceptability For Valve Cams

1. Subsurface longitudinal indications:

a. 1/8 inch [3.175 mm] indications are allowable on the nose.

b. Light longitudinal indications up to 1/2 of the cam width are allowable on the ramp.

c. Not more than two indications are allowable on the ramp or nose of any one cam.

d. Light longitudinal indications not exceeding two in number are allowable on the base circle of any one cam.

e. Parallel indications must be separated by at least 1/4 inch [6.350 mm] on the ramp and nose by 1/16 inch [1.5875 mm] on the base circle.

2. Open longitudinal indications:

Open indications are not allowable except on the base circle. A maximum of two longitudinal open indications 1/4 inch [6.350 mm] long or less will be allowed on the base circle provided they are not closer together than 1/4 inch [6.350 mm] and are visible only as a tightly closed line when the surface is wiped clean. Open indications should not extend closer than 3/16 inch [1.5875 mm] to the edge of the cam.

3. Circumferential indications (lying at an angle greater than 15 deg. with the longitudinal centerline) are not allowable.

Limits Of Acceptability For Bearing Surfaces

1. Subsurface indications are acceptable.

2. *Open indications:*

Four open longitudinal indications are permitted in each section of bearing provided not more than half of them extend the full width of the bearing. Edges of such indications are to be stoned, not to exceed 0.005 inch [0.127 mm] deep.

Gear

1. Remove gear if chipped, cracked or visibly worn. Gear is a press-fit on camshaft.

a. *Place camshaft in a press between V-blocks and press off gear.*

Caution: Never support gear on outer gear surface. Always support hub area with V-blocks or equivalent spacers.

Table 1-10-2: V-1710 Camshaft Key Tabulation

New Part No.	Old Part No.	Engine Model	Offset Inches [mm]	Assembly Instructions
200713	164428	VT12-635 & -700	.018 to .019 [0.4572 to 0.4826]	Arrow to Rear RB & LB
200707	138403	VT12-635 & -700	.011 to .012 [0.2794 to 0.3048]	Arrow to Rear RB
200723	190166		.025 to .026 [0.6350 to 0.6604]	Arrow to Rear LB
202600		VT12-635 & -700	.0385 to .0395 [0.9779 to 1.0033]	Arrow to Rear RB & LB
200723	190166	VT12-800	.025 to .026 [0.6350 to 0.6604]	Arrow to Front RB & LB
200707	138403	VT12-800	.011 to .012 [0.2794 to 0.3048]	Arrow to Front RB
200713	164428	VT12-800	.018 to .019 [0.4572 to 0.4826]	Arrow to Front LB
200722	183237	V12-500	.0055 to .0065 [0.1397 to 0.1651]	Arrow to Rear LB & RB
200712	164427	V12-500	.007 to .008 [0.1778 to 0.2032]	
	69550		*None*	

Note: For reasons of performance, V-1710 NA engines are normally advance timed, while VT-1710 engines are normally retard timed, relative to zero.

On V-1710 series LH engines, reverse arrow from that above for same timing effect.

Table 1-10-3: Camshaft Lobe Lift Measurements

Left Hand Engine	Right Hand Engine	Injection Spec. BTC	ATC	Valve Overlap	Exhaust Opens BBC	Intake Opens BTC	Exhaust Closes ATC	Intake Closes ABC	Valve Lobe Lift X	Inj. Lobe Lift
173350 (RB)	163930 (LB)	57° 44′	15°	90°	64°	36°	26°	40°	0.2835 Inch [7.2009 mm]	0.1170 Inch [2.9718 mm]
173340 (LB)	163880 (RB)	57° 44′	15°	90°	64°	36°	26°	40°	0.2835 Inch [7.2009 mm]	0.1170 Inch [2.9718 mm]

Note: The above lobe lift measurements are based on nominal values for checking camshafts not installed in engine and do not represent wear values.

b. Do not lose key.

c. Install key and coat camshaft gear hub area with Lubriplate Type 130-AA or equivalent. Refer to Table 1-10-2 for key position, for key marking see Fig. 1-10-2.

d. Heat gear to 400 deg. F [204.4 deg. C] in oven or with heating torch — not cutting torch — and press new gear onto shaft.

Caution: Always check timing when a new camshaft or gear is installed in an engine. See Section 14.

Note: Care must be taken to prevent gear breakage due to improper use of press and support bars.

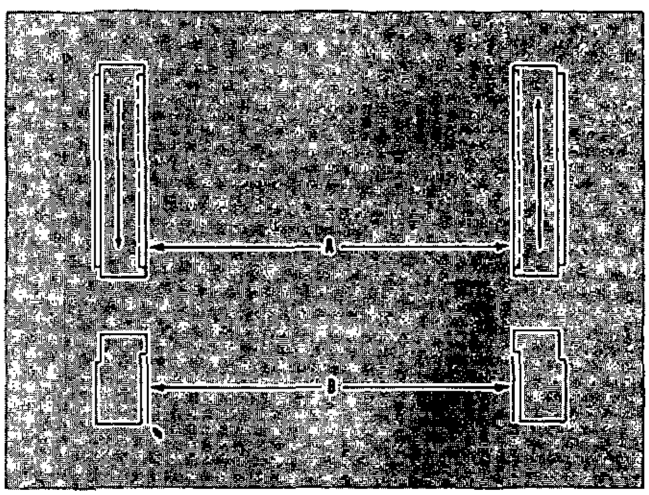


Fig. 1-10-2 N20174 Camshaft key markings

Gear Cover—Unit 111

Inspection

1. If not removed, remove all oil seals and bushings.

2. Check bushings and discard if rough or worn.

3. Check trunnion and/or bushing for wear; replaceable bushing is available to "rebuild" outside diameter of trunnion which was not originally equipped with bushing.

Parts Replacement And Repair

1. Press new bushing or bearings into cover as required.

2. Do not install oil seals until gear cover is to be assembled to engine; this prevents collection of dirt which could get into bearings, etc.

Gear Cover Trunnion

1. If gear trunnion on cover is to be "bushed," install as follows:

2. Machine gear case trunnion to 6.247 to 6.250 inch [158.6738 to 158.7500 mm] outer diameter. Fig. 1-11-1.

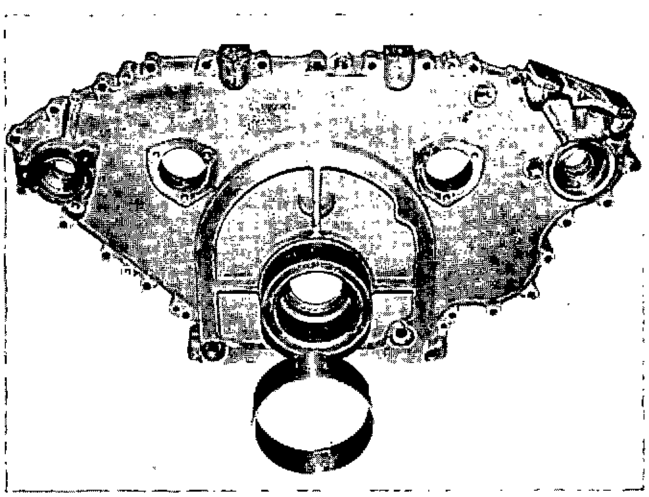


Fig. 1-11-1, V40151. Gear case cover and trunnion bushing

3. Press bushing (Part No. 161201) over machined trunnion with chamfered side of bushing toward gear case.

Fuel Pump Drive Bore (Bushing)

1. Inspect bushing for wear, install new bushing if worn larger than 1.5705 inch [39.8907 mm]. Be sure oil hole is indexed.

2. Undersize inside diameter bushings are available for use where air compressor crankshaft or fuel pump drive is worn or ground undersize. See Table 1-11-1. Shaft to bushing clearance should be maintained between 0.002 to 0.0075 inch [0.0508 to 0.1905 mm].

Table 1-11-1: Accessory Drive Bushing I.D. — Inch [mm]

Part No.	Size	New Minimum	New Maximum	Worn Limit
132770	Std.	1.565 [39.7510]	1.569 [39.8526]	1.5705 [39.8907]
132771	0.010 [0.2540]	1.555 [39.4970]	1.559 [39.5986]	1.5605 [39.6367]
132772	0.020 [0.5080]	1.545 [39.2430]	1.549 [39.3446]	1.5505 [39.3827]

Generator Drive Bore (Bushing)

1. Inspect bushing for wear, install new bushing if worn larger than 1.3205 inch [33.5407 mm].

2. Align oil holes and press in new bushing. New bushing inside diameter is 1.316 to 1.319 inch [33.4264 to 33.5026 mm] after assembly.

Camshaft Support

Cleaning And Inspection

1. Clean support in a solvent not harmful to aluminum.

2. Be sure oil drain holes are open.

3. Discard support if inside diameter is worn larger than 1.757 inch [44.6278 mm] out-of-round cracked or chipped. New dimensions are 1.751 to 1.754 inch [44.4754 to 44.5516 mm].

Rear Cover—Unit 112

Rear Cover

The rear cover is a unit subject to replacement of seals only. Damaged housings require replacement by a new assembly or installation of a "Heli-Coil" for stripped threads; these are the only items of repair.

Alignment during engine assembly is the biggest factor for proper performance of the rear cover unit. See Group 14.

Rear Cover (Piston Ring-Type)

Disassembly And Cleaning

1. Separate oil slinger assembly from oil slinger housing.

Caution: Carefully guide rings and slinger from housing to prevent damage to rings and housing.

2. Remove rings and springs from slinger; discard rings and springs.

3. Clean all parts in an approved solvent; dry with compressed air.

Inspection

1. Inspect housing for cracks or distortion.

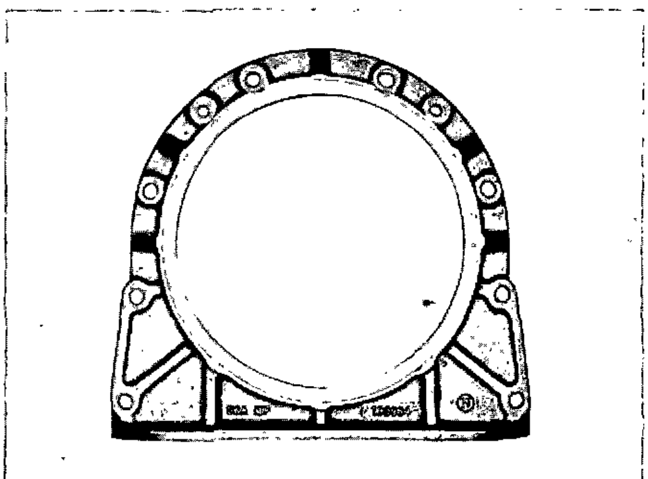


Fig. 1-12-1, V40168. Rear cover (oil seal type)

2. Check housing bore with a dial bore gauge for out-of-round and wear. Discard if out-of-round or worn larger than 8.504 inch [216.0016 mm]. New dimensions are 8.500 to 8.502 inch [215.9000 to 215.9508 mm].

3. Inspect slinger for groove wear and stripped threads; discard if worn or damaged.

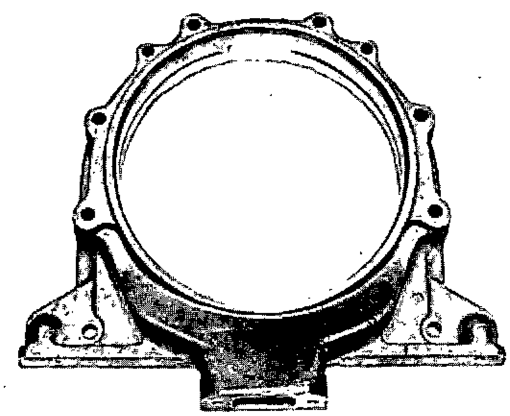


Fig. 1-12-2, V40150. Rear cover (piston ring type)

Cylinder Head Group

The cylinder head group covers the complete disassembly, inspection, repair and assembly of the cylinder head, guides, crossheads, valve seats, injector sleeves and valve springs.

Cylinder Head—Unit 201

Measurements

All dimensions in this group are listed in both U.S. and Metric units. The Metric units are enclosed in brackets [].

Disassembly

1. Remove exhaust manifold studs, if not previously removed, for ease in handling.

2. Steam clean complete head assembly and dry with compressed air.

3. Place cylinder head in ST-583 Head Holding Fixture or equivalent.

4. Remove valves and springs. Use ST-448 Valve Spring Compressor (1, Fig. 2-1-1) to compress valves springs. ST-448 may be used at bench or on installed engine.

Caution: If removing valve springs on an installed engine, be sure piston is up to support valves in cylinder. Replace springs before barring the engine or valve will drop into cylinder necessitating cylinder head removal to retrieve valve.

5. Screw stud (2) from ST-448 in rocker lever housing mounting capscrew hole.

6. Compress one valve spring at a time. Fig. 2-1-1. Tap valve head lightly to loosen; then remove half collets. A small magnet may be used as an aid in removing half collets.

7. Withdraw valves, valve springs and retainers (and valve spring guides, if used). Remove oil seals (if used) from intake valve guides on natural aspirated engines. Discard seals.

8. Remove pipe plugs from water passages.

9. Remove all pipe plugs from fuel passages in each cylinder head.

10. Remove and tag fuel inlet and drain fittings from each cylinder head as removed.

Inspection And Cleaning

Air Pressure Checking Cylinder Head

1. Install Injector Sleeve Holding Tool ST-384 or ST-923 or scrap injector cup assembly in each injector sleeve.

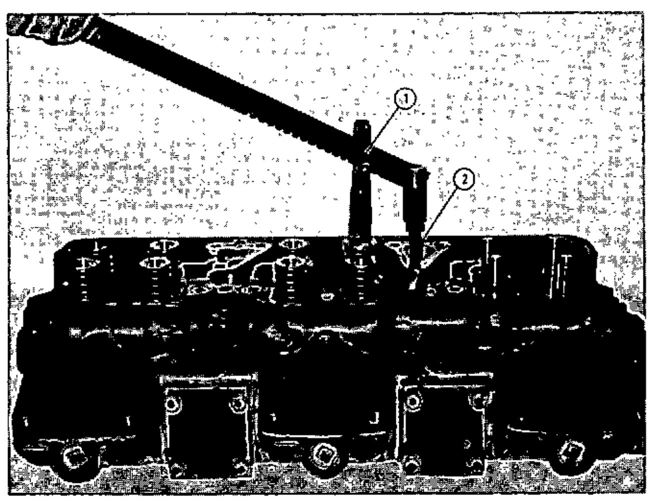


Fig. 2-1-1, V40201. Compressing valve springs with ST-448

2. Tighten sleeve holding tool to 10 to 12 ft-lb [1.3820 to 1.6584 kg m] to seal lower end of injector sleeve, Fig. 2-1-2, or install injectors and secure with capscrew to value as listed in Group 18.

3. Install ST-1012 Hydrostatic Tester or equivalent. Test cylinder head for leaks 30 to 40 psi air pressure within head. Submerge head in water and check for air bubbles originating at leaks past the injector sleeve, plugs, cracks or other flaws in the head assembly.

Water Test Cylinder Head

1. Install Injector Sleeve Holding Tool ST-384 or ST-923, or a scrap injector cup assembly in each injector sleeve. Fig. 2-1-2.

2. Tighten sleeve holding tool to 7 to 8 ft-lb [0.9861 to 1.1064 kg m] to seal lower end of injector sleeve, or install injectors and secure with capscrews torqued to same value as listed in Group 18.

3. Fill cylinder head with water and, if possible at 175 deg. to 200 deg. F [79.4 deg. to 93.3 deg. C]. Apply 75 to 85 psi [5.2732 to 5.9755 kg/sq cm] air pressure to head.

4. Open water outlet valve of test fixture; check for free water circulation through cylinder head. If restriction is evident, remove plugs and injector sleeves; clean water jackets of salt, lime or sludge as follows:

a. Remove all pipe plugs and the fuse plug from cylinder head.

b. Remove capscrews and lockwashers securing water header cover plates to head; remove plates and discard gaskets.

c. After steam cleaning and disassembly, submerge head in tank of cleaning solution heated to near boiling temperature. Use Turko or Wyandotte "G" solvent or equivalent; follow manufacturer's recommendations as to use.

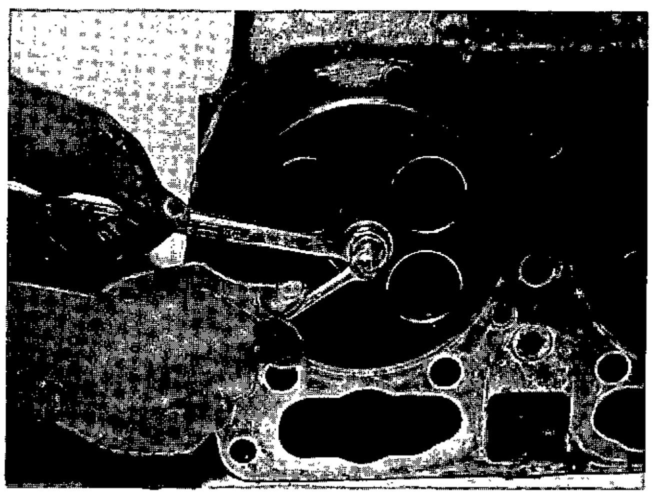


Fig. 2-1-2, V40204. Install injector sleeve holding tool ST-384

d. Circulate solvent to increase effectiveness on salt or lime deposits, grease, etc.

e. To remove heavy deposits of lime, use circulated acid-type cleaner.

Caution: The use of acid is extremely dangerous to workmen and injurious to machinery. Acid should never be used in machine shop or near any machine subject to rusting. Always provide a tank of strong soda water as a neutralizing agent.

5. Clean internal fuel passages with a tube type brush. Flush passages with solvent to remove dirt.

6. Check water passage running full length of head between valves for restriction. If plugged, open by rodding or drilling.

7. Check lubricating oil restrictor plug (1, Fig. 2-1-3) and lubricating oil passages to be sure they are open.

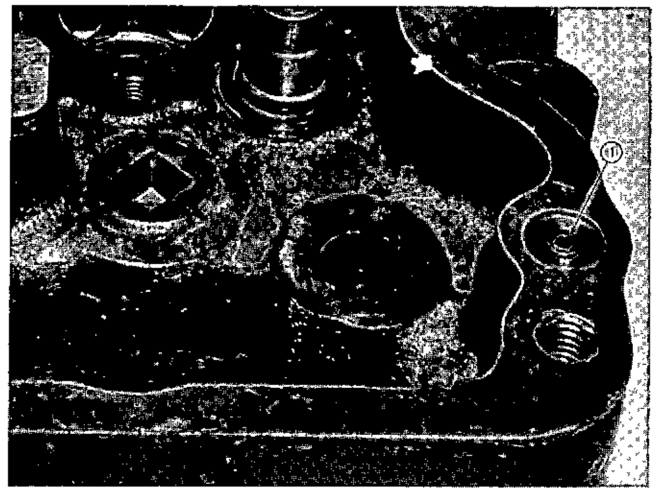


Fig. 2-1-3, V40202. Restrictor plug installed

8. After drying with compressed air, using orbital sander, sand cylinder head surface lightly, just enough to shine the finish. Fig. 2-1-12. This will allow a more complete inspection of mating surfaces.

Caution: Do not use disc sander. Serious damage could result in the sealing surface of the head.

9. Air test fuel line passage as follows:

a. Install "dummy" injectors in head (plugged fuel passages).

b. Block fuel outlet and attach an air pressure gauge.

c. Install air fittings in fuel inlets and apply air pressure of 90 to 100 psi [6.327 to 7.030 kg/sq cm].

d. Close air inlet valve and inspect passage for leaks.

e. Check air gauge, there must be no drop in pressure for 15 seconds; discard an unserviceable head.

10. Optional additional test to detect suspected weakness due to thin walls or porosity is as follows.

Hydraulic Pressure Test

Apply 500 psi [35.150 kg/sq cm] hydraulic pressure to fuel lines. No drop in pressure should occur in 15 seconds.

Air Test (Optional Method)

Apply air at 20 to 30 psi [1.4060 to 2.1090 kg/sq cm] to the passages to be checked. Maintain pressure for 30 seconds. Inspect for leaks during this time.

Note: Cylinder heads must be immersed in water while air pressure is applied. The leaks may be detected by bubbles of air rising to the surface of the water.

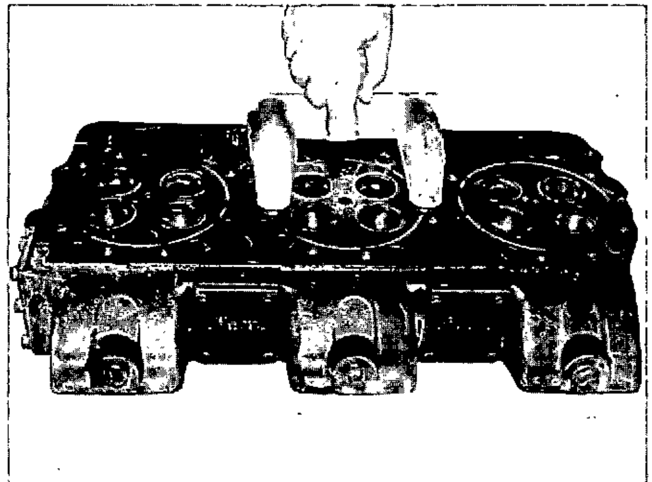


Fig. 2-1-4, V40245. Magnetic crack detection check with ST-1166

Magnetic Crack Detection

Inspect head for cracks using ST-1166 Magnetic Crack Detector in valve and injector port areas as follows.

1. Remove keeper bar from magnet poles.

2. Place magnet on area being inspected.

3. Spray a moderate amount of powder onto suspected area, blow off excess powder with low pressure air. Powder will remain in cracks, and will show as a white line.

Note: When dispensing powder, hold thumb partially over spray head to keep cap from blowing off.

Crosshead Guides

1. Check guide Outside Diameter with micrometers. Fig. 2-1-5. See Table 2-1-1 for worn replacement limits.

2. Check guide for straightness. It should be at right angles with milled surface of head. Replace if not straight.

3. Check crosshead guide protrusion above cylinder head. Protrusion should be 1.860 to 1.880 inch [47.2440 to 47.7520 mm].

Table 2-1-1: Crosshead Guide Dimensions — Inch [mm]

New Minimum	New Maximum	Worn Limit
0.4330 [10.9982]	0.4335 [11.0109]	0.4320 [10.9728]

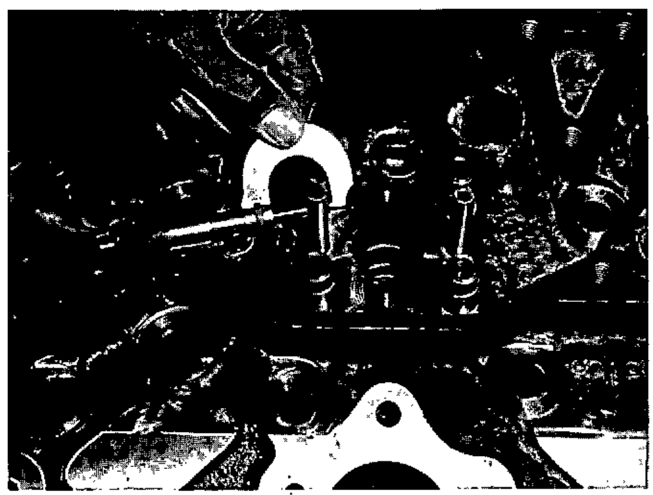


Fig. 2-1-5, V40215. Measure crosshead guide

Cylinder Head Fuse Plug

Cylinder heads are equipped with fuse plugs containing a metal-alloy center that melts if the engine is overheated.

1. Examine fuse plug for signs of overheating. (1, Fig. 2-1-6).

2. Install new plug if metal alloy has melted.

3. If fuse plug has melted, check carefully for further damage to head and engine.

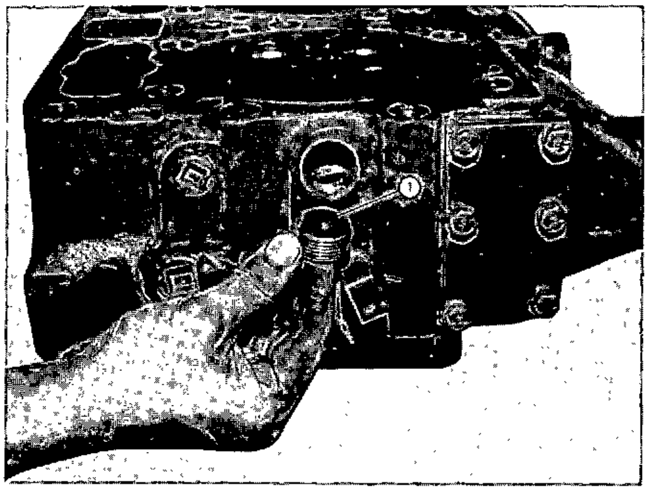


Fig. 2-1-6, V40216. Check fuse plug for overheating

Valve Seats

1. Check for loose valve seat inserts by lightly tapping head near inserts. A slight looseness may be found by tapping when head is cold and covered with film of oil.

2. If valve seat insert is loose enough to bounce or cannot be reground, mark for replacement. See VALVE SEAT INSERTS, Page 2-3-1.

3. If seat area width (1 or 2, Fig. 2-1-7) exceeds 0.125 inch [3.1750 mm] at any point and cannot be narrowed sufficiently, it is unlikely that seat can be successfully reground. See GRIND VALVE SEATS.

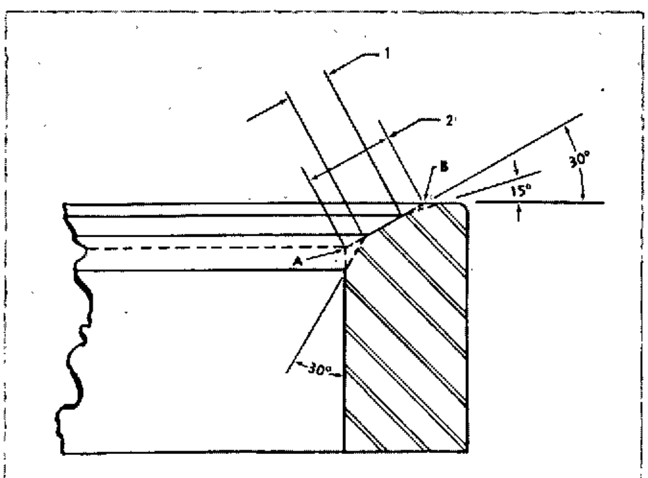


Fig. 2-1-7, N10228. Valve seat insert—cross section

Injector Sleeves

1. Note results of water test. Leaks indicate need for replacement.

2. Visually check sleeves which pass the water test for scratches on cup seat area and mark for replacement if seat area is scratched.

3. Lightly coat a new injector cup on injector body with Prussian Blue. Install in injector sleeve and torque injector into injector sleeve evenly to operating tension. Remove and check seat pattern. If indicated seat width does not show at least 0.060 inch [1.5240 mm] wide continuous contact, mark sleeve for replacement.

4. Check seat depth as follows:

a. Install injector assembly. Torque Nylock capscrews to 7 to 8 ft-lb [0.9681 to 1.1064 kg m].

b. Measure tip protrusion with dial indicator as shown in Fig. 2-1-8. Injector cup tip should protrude 0.040 to 0.055 inch [1.0160 to 1.3970 mm] beyond cylinder head milled surface. Maximum allowable protrusion is 0.065 inch [1.6510 mm].

c. See Unit 202 for sleeve replacement instructions.

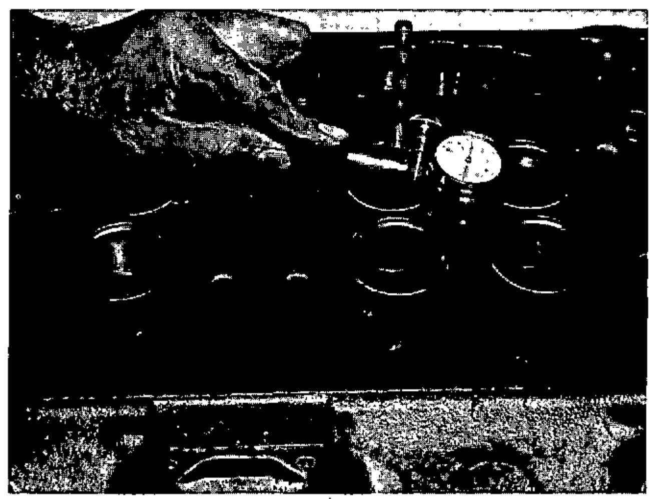


Fig. 2-1-8, V40217. Measure injector tip protrusion

ST-981 Injector Protrusion Checking Tool

1. Use ST-981 Injector Tip Protrusion Checking Tool to check injector seat depth as follows:

a. Place cylinder head on a flat metal surface.

Caution: Use care, to prevent damage to machined surface of cylinder head. Check must be made with valves removed so head seats flat on metal surface.

b. Loosen indicator clamping screw and raise indicator of ST-981 Protrusion Checking Tool.

c. Push plunger end of tool down against a flat metal surface until plunger is fully compressed up inside housing.

d. Lower dial indicator until maximum reading (plunger bottoms and hand movement stops) is obtained, then back off 0.010 inch [0.2540 mm] as indicated by hand movement; tighten indicator clamping capscrew.

e. Push plunger of tool against flat metal surface until plunger is fully depressed and set indicator to 0.0555/0.0605 inch [1.4097/1.5367 mm] reading on dial.

f. Insert checking tool into injector sleeve bore and press down until tool seats firmly on injector seat area in head (sleeve). Fig. 2-1-8.

g. With tool seated, indicator should read between 0.093 to 0.007 (mean point "0"), this provides 0.040 to 0.055 inch [1.0160 to 1.3970 mm] injector cup protrusion, if above steps on tool use are followed and seat is cut to proper depth.

Repair

Sleeve Eroded Water Holes

The cylinder head surfaces around the water holes must be free of any erosion, pits, scratches or blemishes which are more than 0.003 inch [0.0762 mm] deep in the area 1/16 to 5/32 inch [1.5875 to 3.9687 mm] from edge of water holes. Repair as follows:

1. Insert hold-down adapter of ST-1010 into injector sleeve.

2. Position tool (1, Fig. 2-1-9) on head with reamer guide hole over water hole to be repaired.

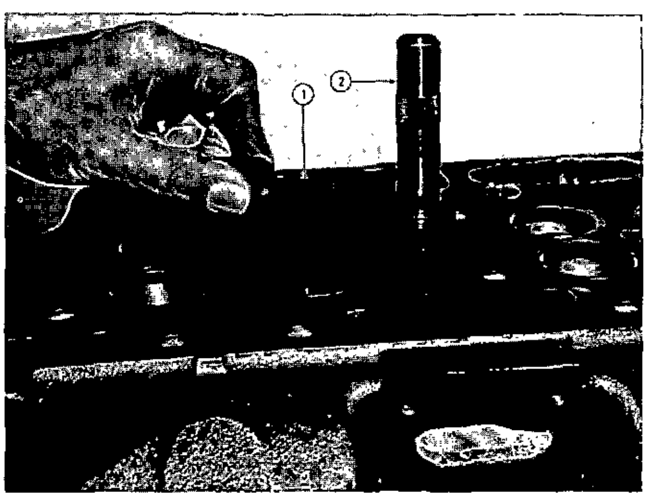


Fig. 2-1-9, V40218. Insert hold down knob

3. Insert tool hold-down knob into holder assembly and tighten finger tight.

4. Insert locating pin (2) into eroded hole and tighten hold-down knob.

5. To set depth of reamer assembly, insert assembly in guide. Place bushing (3, Fig. 2-1-10) between holder assembly and reamer adjustable stop collar (1). Insert 0.005 inch [0.1270 mm] feeler gauge (2) between bushing and adjustable collar; tighten set screw.

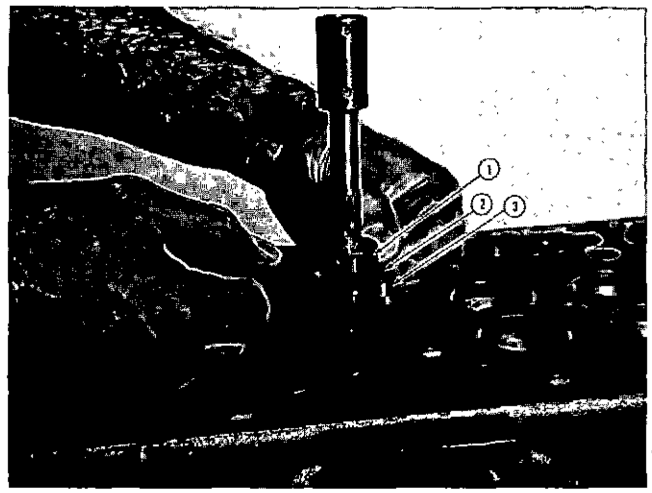


Fig. 2-1-10, V40219. Set reamer depth

Caution: Take care not to use too large a reamer.

Note: 9/16 and 5/8 inch [14.2875 and 15.8750 mm] diameter counterboring tools are available in kit. Select the proper counterbore tool needed.

6. Attach drive adapter to a drill chuck and place grooved end of drive adapter into reamer assembly.

7. Ream out eroded water hole until collar bottoms against tool.

8. Remove drill, reamer assembly, holder assembly and hold-down adapter. Clean hole thoroughly.

9. Drive bushing into reamed hole with driver. Fig. 2-1-11. Bushing should protrude about 0.003 to 0.005 inch [0.0762 to 0.1270 mm].

10. If proper bushing is not available, a heavy-wall copper tubing may be used. Tubing must provide 0.002 to 0.005 inch [0.0508 to 0.1270 mm] press fit. Overall length should be approximately 1/2 inch [12.7000 mm], inside diameter must be 7/16 inch [11.1125 mm] to allow proper water flow through head.

11. If head is to be resurfaced, see "Resurface Cylinder Head". If head is not to be resurfaced, file bushing flush with head, using a wide flat mill file.

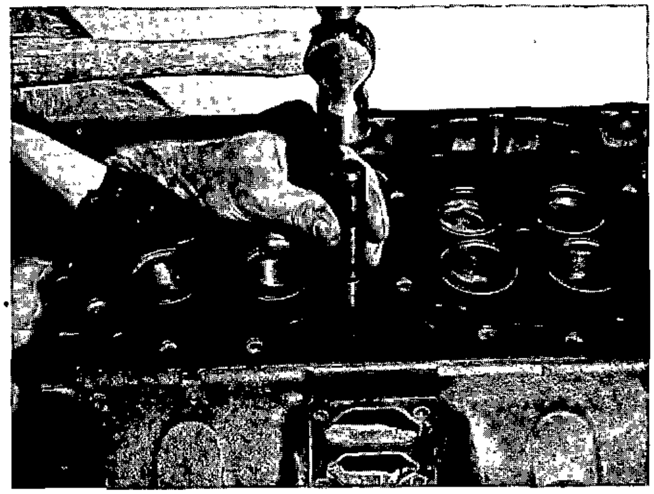


Fig. 2-1-11, V40220. Drive bushing into hole

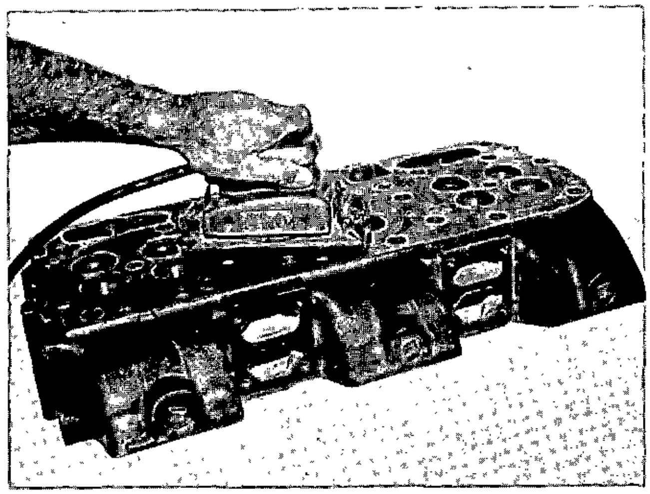


Fig. 2-1-12, V40221. Sand cylinder head

Resurface Cylinder Head

1. Resurface head if it has been scratched, etched or worn unevenly at point of contact with gasket sealing areas. Check erosion around water holes which could cause failure of head gasket to seal. If eroded, install bushings before *resurfacing head. See "Sleeve Eroded Water Holes."*

2. Remove 0.005 to 0.006 inch [0.1270 to 0.1524 mm] material at one time and no more than 0.030 inch [0.7620 mm] total. Table 2-1-3.

Table: 2-1-2: Head Height – Inch [mm]

New Minimum	New Maximum	Worn Limit
5.490 [139.4460]	5.510 [139.9540]	5.460 [138.6840]

3. Rework valve seat insert counterbore by removing amount of stock equal to that removed during head resurfacing operation. See Page 2-3-1.

4. Sand surface of cylinder head with an orbital sander. **Do not use a disc sander.** Do not allow the sander to tilt or rock, since this may result in rounding of the machined edges. Fig. 2-1-12.

5. After resurfacing:

a. Check head height; see Table 2-1-2 for head dimensions. Use micrometer or vernier calipers for accurate measurement. Fig. 2-1-13.

b. Check exhaust ports for flatness after head has been resurfaced. Ports should not be out of plane more than 0.003 inch [0.0762 mm].

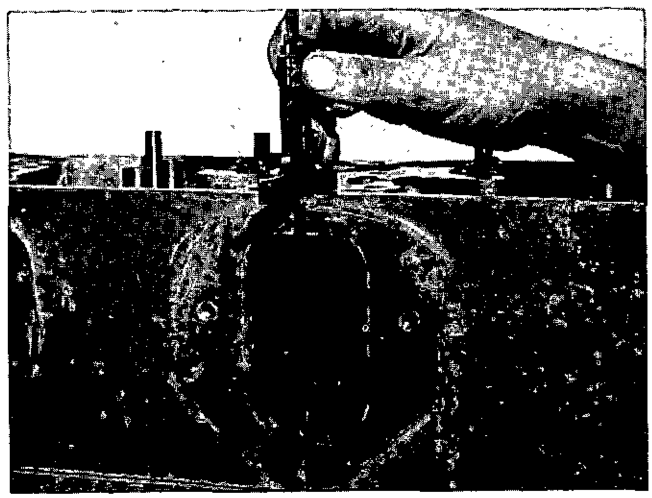


Fig. 2-1-13, V40222. Check cylinder head height

c. Install new injector sleeves to maintain correct injector tip protrusion. See Page 2-2-1.

d. Check over-all height of assembled valve springs to see if it is necessary to install spacers (1/16 inch [1.5875 mm] maximum) under springs to obtain correct assembled height.

Caution: Only 1/32 inch [0.7937 mm] spacer can be used if head has not been resurfaced.

Regroove Cylinder Head

Beaded cylinder liners, steel cylinder head gaskets and grooved cylinder heads are designed to operate in conjunction with each other.

If the cylinder head has been resurfaced, it will be necessary to cut grooves in the cylinder head over each cylinder liner sealing area. These grooves will assure a better seal between the cylinder head gasket and block during engine operation. Fig. 2-1-14. Use ST-597 or ST-913 Cylinder Head Grooving Tool to perform this operation.

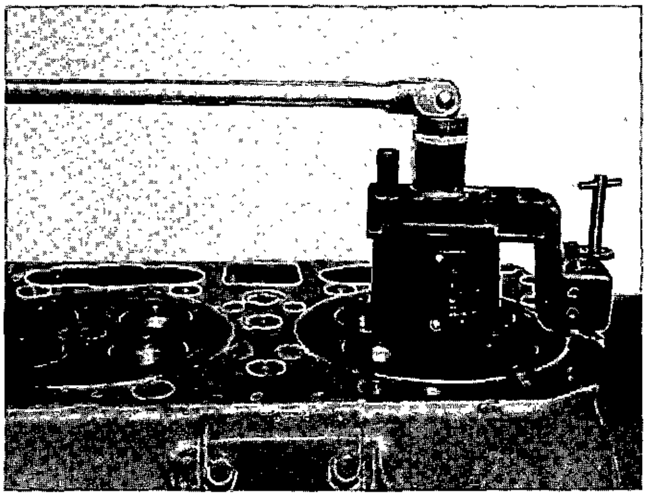


Fig. 2-1-14, V40223. Regroove cylinder head with ST-913

1. To use ST-597 grooving tool:

a. Place cylinder head in ST-583 Head Holding Fixture.

b. Select scrapped injector, preferably one with Class "O" plunger bore and injector cup. Cut off cup exposing plunger bore, maintaining cup seal area intact. Install reworked cup on injector body.

c. Install injector and cup in cylinder head and tighten mounting capscrews to 7 to 8 ft-lb [0.9681 to 1.1064 kg m] operating torque setting.

d. Select ST-597 spacer block for 5-1/2 inch [139.7000 mm] bore. Loosen two socket head screws in end of ST-597. Assemble spacer bwtween pilot pin and tool holder blocks. Distance from center of pilot pin to center of cutter should be 3.188 to 3.192 inch [80.9752 to 81.0768 mm].

e. Position largest pilot pin so it protrudes down in same direction as cutter and tighten assembly in place.

f. Turn cylinder head upside down on head holding fixture and install ST-597 pilot pin into injector bore.

g. Check position of stop in tool holder block to assure it will not contact water hole during grooving operation.

h. Set stop on tool so cutter protrudes 0.006 to 0.008 inch [0.1524 to 0.2032 mm] below stop. Rotate tool clockwise to cut groove. Do not rotate counterclockwise.

Caution: Do not attempt to cut deeper than cutter groove depth or cutter will break. Groove lands should be 0.010 to 0.015 inch [0.2540 to 0.3810 mm] wide and flush with head surface.

2. To use ST-913 grooving tool:

a. Place cylinder head in ST-583 Head Holding Fixture.

b. Check data plate on housing to determine in which hole the locating plug is to be placed.

c. Place tool holder into slot in housing with locating plug in proper hole and secure with 5/8 inch capscrew.

d. If tool has not been adjusted previously, adjust as follows:

(1) Place housing, with tool holder secured in place, on a surface plate or similar flat surface.

(2) Loosen setscrews holding tool adjusting screw and turn adjusting screw down until tool cutting bit touches surface plate.

(3) Remove grooving tool from surface plate and turn adjusting screw down three notches, or 60 deg., to lower cutting tool bit approximately 0.006 inch [0.1524 mm].

e. Install grooving tool on head by placing the locking screw in the injector holes and tighten hand tight. This locking screw can be used either with or without the injector sleeve.

Caution: Over-tightening of locking screw in head when injector sleeve has been removed may cause mutilation of the beads in the head.

f. Check head to assure cutting tool bit will not contact water hole during grooving operation.

g. Rotate grooving tool clockwise to cut groove. The tool bit is spring loaded in the tool holder and will ride over any "hard" spots on the head surface. It may take two or three revolutions to get a smooth even cut in the head. Fig. 2-1-14.

Injector Sleeve—Unit 202

Sleeve Removal

1. Remove worn sleeves (1, Fig. 2-2-1) used with cylindrical injectors with ST-1140 or ST-1153 Injector Sleeve Extractor (2). If puller is not available a "muffler sleeve cutting tool" may be used if extreme caution is observed to prevent damage to head surfaces.

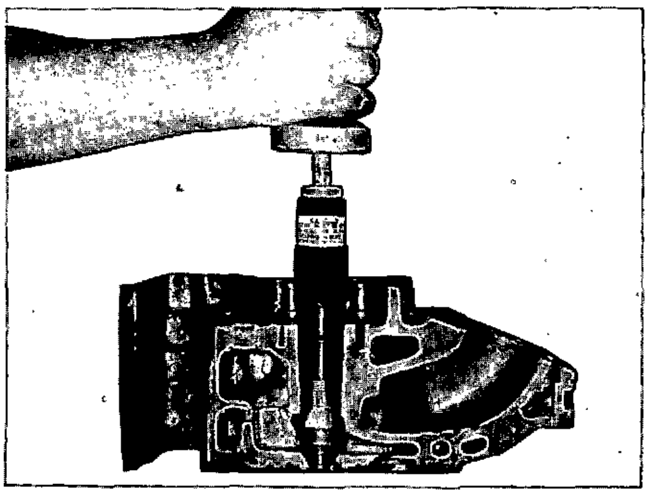


Fig. 2-2-1, V40246. Removing injector sleeve with ST-1153

2. Remove all foreign material from injector sleeve sealing area with a brass brush. Clean "O" ring groove to remove all foreign material that would prevent proper "O" ring sealing.

3. Clean thoroughly; and dry with compressed air.

Note: Avoid use of cleaning compounds containing ammonia which may react with the brass sleeve.

Bead Sleeve Seat In Head

Machine bead in sleeve seat area of head if mutilated or destroyed during cleaning. Fig. 2-2-2. This will provide an improved seal. See Table 2-2-1 for proper tools for machining sleeve seat in head.

1. Install seat cutter holder and position with pilot in a drill press. Refer to Table 2-2-1. Set drill press speed at not more than 75 rpm. Cutter may be turned by hand using a tap wrench.

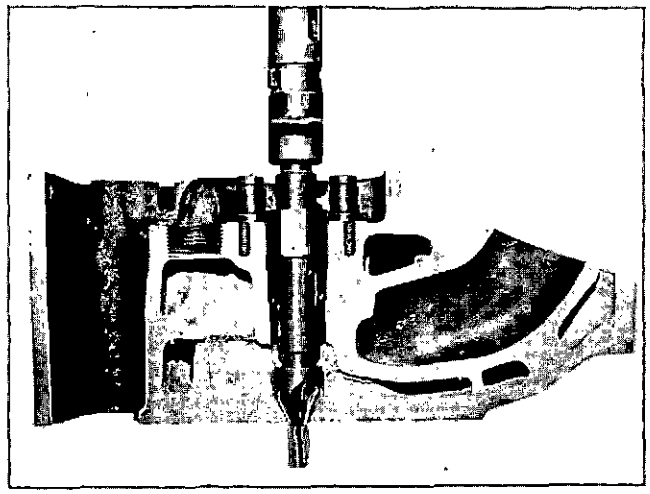


Fig. 2-2-2, V40225. Install bead cutting tool

Caution: Chattering may occur if drill press speed is over 75 rpm.

2. Place cylinder head on drill press table, allowing clearance for the end of the bead cutter to protrude below the head surface into a pilot. The pilot can be made by recessing a 1/2 inch [12.7000 mm] drill bushing in a plate which is centered below the drill spindle and secured in place.

3. Before starting drill press motor, insert cutter, adapter and pilot into injector bore to insure proper alignment.

4. Lift cutter, adapter and pilot, lubricate cutter with cutting oil and start cutting operation, applying a steady moderate pressure.

Caution: Do not cut more than 0.010 inch [0.2540 mm] deep.

5. When the proper depth has been obtained, allow the cutter to dwell for approximately 10 seconds to insure a good seat and clean grooves.

6. Remove bead cutter, adapter and pilot from drill press. Remove bead cutter from adapter and pilot, and install ST-824. This tool is needed to cut a 70 deg. angle relief chamfer at the top edge of the existing 60 deg. seat. Apply bluing at 60 deg. seat to aid in determining amount of 70 deg. cut needed.

7. Lubricate and install cutter, adapter and pilot; attach a

Table 2-2-1: Injector Sleeve Replacement Specificatiions

Tools for Machining Sleeve Seat in Head						Upper Sleeve Seating		Lower Sleeve Seat Sealing		Injector Seat Cutter
Bead Cutting Tool	30° Angle Cutter	70° Angle Cutter	Cutter Pilot	Sleeve Driver	Sleeve Holding Tool	Expanding Tool	Inch-I.D. Diameter	Angle Roller	Axial Force Applied to Roller	Seat Cutter
ST-788	ST-825	ST-824	ST-438-4	ST-632	ST-384	ST-880	1.145 inch 1.155 inch [29.0830 mm] [29.3370 mm]	ST-819	500/650 lb [226.7500/ 294.7750 kg]	ST-884

tap wrench to the adapter and rotate, applying even pressure. When the lower edge of the 70 deg. angle is approximately 1/8 inch [3.1750 mm] from the top bead, remove cutter, adapter and pilot.

8. Lubricate and install ST-825 Cutter, adapter and pilot. Attach a tap wrench to the adapter and rotate, applying a light even pressure. The ST-825 Cutter is used to cut a 30 deg. angle chamfer at the lower edge of the 60 deg. seat. When the upper end of the 30 deg. angle chamfer is approximately 9/64 inch [3.5718 mm] from the bottom bead, remove cutter, adapter and pilot.

9. Remove bluing from 60 deg. seat.

Sleeve Installation

1. Coat new "O" ring with clean engine lubricating oil; shake off excess.

2. Install "O" ring into groove provided in sealing area of injector sleeve bore.

Caution: Make sure sleeve seat at bottom of injector bore is free from oil, carbon or other foreign materials.

3. Using ST-632 Sleeve Driver, push new injector sleeve into bore of cylinder head until it bottoms in cylinder head. DO NOT STRIKE DRIVER WITH HAMMER DURING THIS STEP. Remove driver.

4. Install ST-384 injector sleeve holding tool; torque nut to 35 to 40 ft-lb [4.8405 to 5.5320 kg m]. Fig. 2-2-3.

5. Using ST-632 Sleeve Driver and hammer, strike ST-384 two moderate blows to insure that injector sleeve is seated properly in 60 deg. seat at bottom of injector bore; remove driver.

6. Retorque ST-384 Injector Sleeve Holding Tool to 35 to 40 ft-lbs [4.8405 to 5.5320 kg m].

7. Roll top 1/2 inch [12.7000 mm] area of sleeve with ST-880 Expanding Roller. Fig. 2-2-4.

a. Grind flats on top end of ST-880-7 Mandrel so that a socket and torque wrench can be used to turn mandrel in the roller.

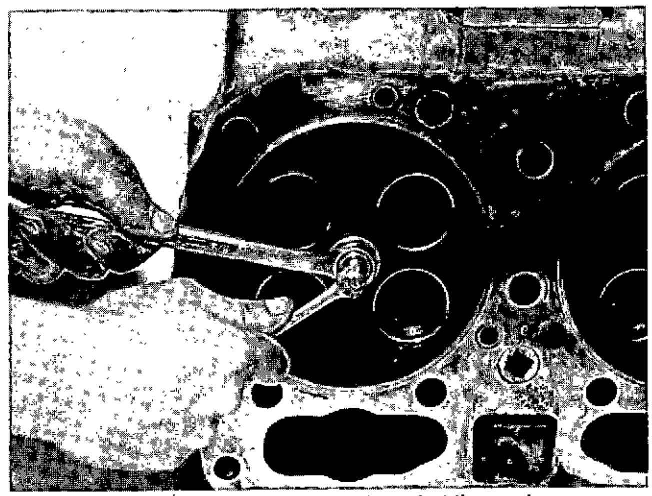


Fig. 2-2-3, V40204. Install injector sleeve holding tool

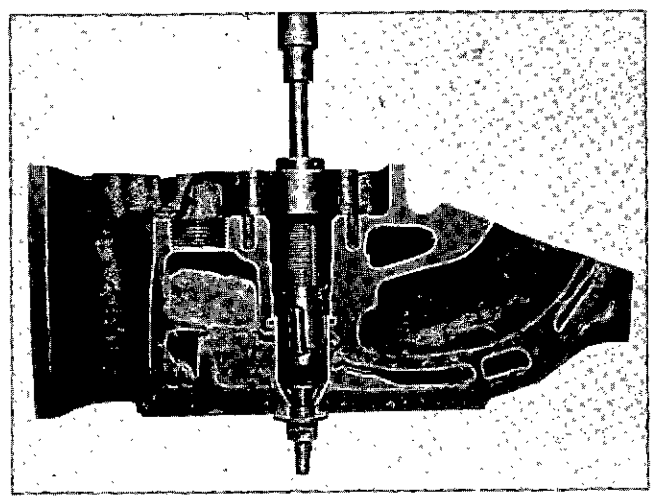


Fig. 2-2-4, V40227. Seal upper end of injector sleeve with ST-880

b. Lower ST-880 Expanding Roller into injector sleeve.

c. Use inch-lb [kg m] torque wrench to turn mandrel of ST-880; turn mandrel until a 75 inch-lb [0.8625 kg m] maximum torque reading is obtained on torque wrench.

Caution: Over rolling of injector sleeve will cause deformation of sleeve into "O" ring groove.

d. Remove ST-880 Expanding Roller and ST-384 Sleeve Holding tool.

Note: Do not roll lower area of injector sleeve.

8. Cut injector seat to provide proper injector seat and injector tip protrusion. Fig. 2-2-5. Use ST-884 Seating Cutter in a drill press with pilot, using a solid stream of good cutting oil to allow cutter to cut freely without grabbing, etc. Check tool bit to make sure it is ground to exact contours shown in Fig. 2-2-6 and Table 2-2-2.

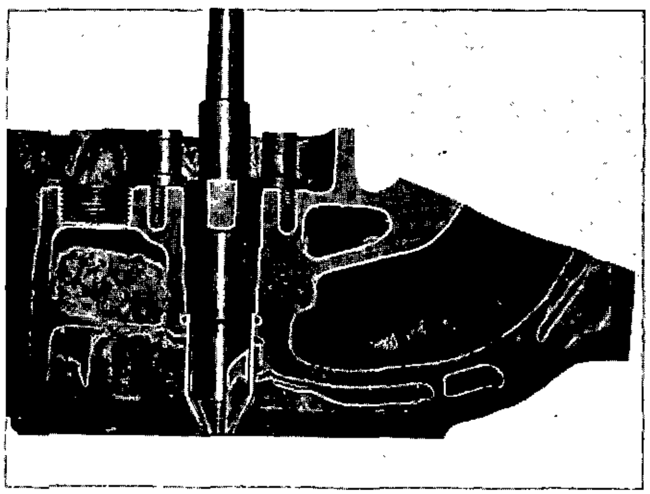


Fig. 2-2-5, V40229. Cut injector seat with ST-884

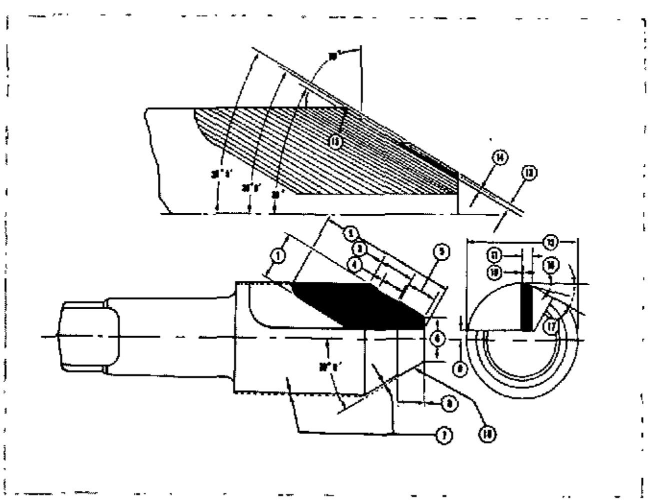


Fig. 2-2-6, N20213, ST-884 Injector seat cutter dimensions

9. To determine amount of cut, insert injector and measure tip protrusion. Depth of cut should provide 0.045 to 0.055 inch [1.0160 to 1.3970 mm] protrusion of injector cup tip beyond milled face of cylinder head. Maximum allowable injector cup tip protrusion is 0.065 inch [1.6510 mm].

10. Sleeve must "blue in" with Prussian Blue 360 deg. around injector seat when injector is installed in cylinder head. Bluing band must be 0.060 inch [1.1524 mm] minimum width.

Table 2-2-2: ST-884 Grinding Specifications

Item	Inch	[mm]	Item	Inch	[mm]
1.	0.375	[9.5250]	10.	*0.010	[0.2540]
2.	1.250	[31.7500]	11.	0.0937	[2.3812]
3.	0.3425	[8.6995]	12.	1.0615	[41.0210]
4.	0.226	[5.7404]		1.0635	[41.5290]
	0.236	[5.9944]	13.	0.0077	[0.1955]
5.	0.384	[9.7536]		0.0097	[0.2463]
	0.386	[9.8044]	14.	0.0015	[0.0381]
6.	0.375	[9.5250]		0.0025	[0.0635]
			15.	0.080 R	[2.0320] R
7.	0.020	[0.5080]		0.090 R	[2.2860] R
			16.	15 deg. Angle Relief	
8.	0.312	[7.9375]	17.	30 deg. Angle Relief	
9.	0.125	[3.1750]	*Land		

For use of table refer to Fig. 2-2-6.

Spark Plug Adapter

Removal Cleaning And Installation

1. Using ST-890 Adapter Wrench, Fig. 2-2-7, remove spark plug adapters from heads; remove and discard gaskets and "O" rings.

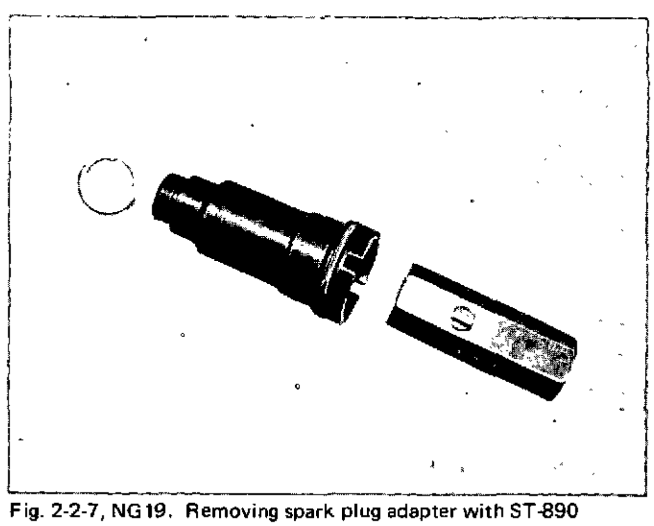


Fig. 2-2-7, NG19. Removing spark plug adapter with ST-890

2. Clean and lubricate spark plug adapter threads in the cylinder head by "chasing" with a 7/8-14 UNF tap or capscrew coated with lubricating oil.

Clean the machined "O" ring seating surface in the cylinder head with fine emery paper to remove scale build-up, etc., and to insure proper seating of the adapter "O" ring.

3. Using a ST-1142, clean up spark plug adapter seating areas. Fig. 2-2-8.

4. Clean threads and gasket seating area of the adapter.

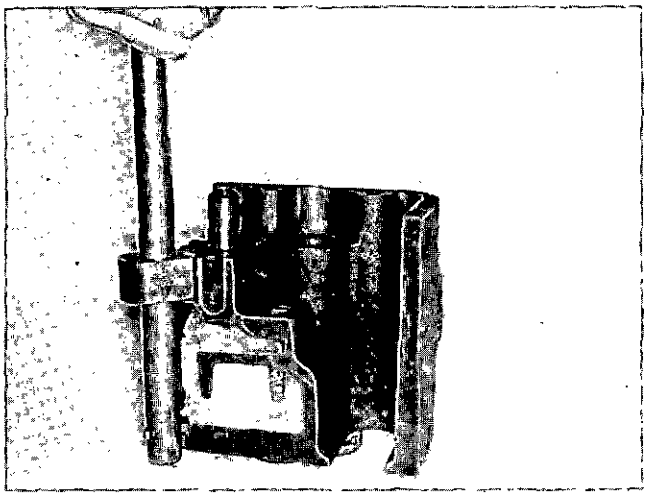


Fig. 2-2-8, NG30. Cleaning adapter seating area with ST-1142

5. Lubricate "O" rings and "O" ring seating areas in bores in heads with clean engine oil. Position new gaskets and "O" rings on spark plug adapters. Using ST-890 Wrench, screw adapters into cylinder heads and tighten to 70 to 80 ft-lb. [9.6810 to 11.0640 kg m].

Valve Seat Insert—Unit 203

Valve Seat Insert

The valve seat insert is used to provide a greater wear-resistant surface than the cylinder head material and to provide a new seat where seat is worn beyond regrind specifications.

1. Remove loose or excessively worn valve seat inserts, which were previously marked for replacement during cylinder head inspection, with an insert extracting tool or by striking insert sharply with a chisel, causing it to crack and release the press fit. Remove all inserts if head has been resurfaced. Fig. 2-3-1.

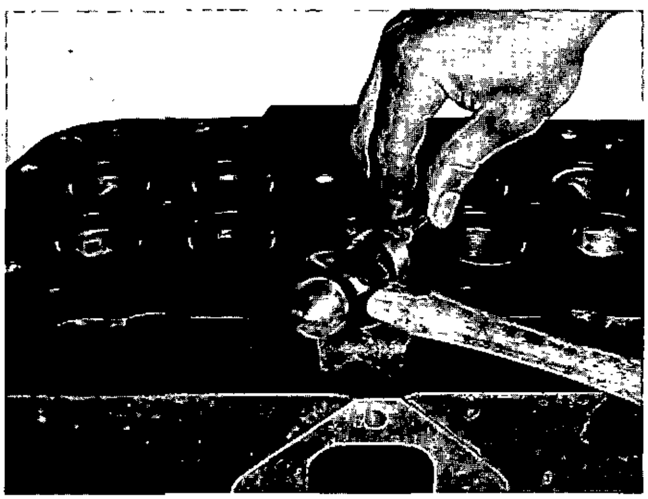


Fig. 2-3-1, V40231. Remove valve seat insert

Caution: Cover the valve seat with a shop rag to avoid injury from broken pieces of the seat.

2. Enlarge counterbore to next oversize. Most inserts are available in standard and oversizes as shown in Table 2-3-1.

Note: If head was resurfaced and inserts are to be reused, deepen counterbore only.

3. ST-257 Valve Seat Insert Tool, (1, Fig. 2-3-2) must be used to hold and drive cutters. ST-257 must be driven by an electric drill (3, Fig. 2-3-2).

4. ST-662 Cutter Set and ST-663 Valve Guide Mandrel Set are used with ST-257 when cutting valve seat insert counterbore. Select the proper size cutter (2), cutter drive (11), proper size tapered arbor for guide and insert it in valve stem guide.

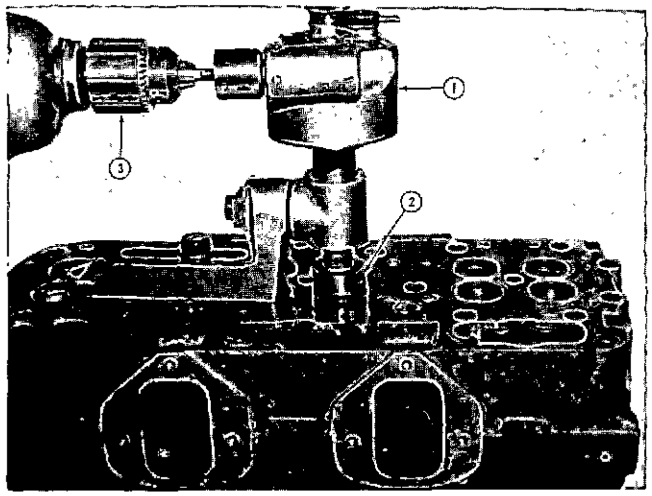


Fig. 2-3-2, V40232. Counterbore for valve seat insert

5. Always clamp the base as near to the seat being serviced as possible. Be sure everything is clamped tight before starting electric drill. See ST-257 instructions for further information on proper use of all tools in kit.

6. Cut counterbore 0.006 to 0.010 inch [0.1524 to 0.2540 mm] deeper than insert thickness to permit peening of head to hold insert. It is important to allow cutter to dwell for several revolutions upon reaching proper depth in order to insure a perfectly flat surface at the bottom for the insert to seat on. Remove ST-257 and remove all chips and dirt.

7. Install valve seat insert and peen around insert at least 4 or 5 places with the peening tool available as extra equipment in ST-257. A 1/4 inch [6.3500 mm] diameter round end punch may also be used.

Caution: Over-swagging around insert may crack cylinder head.

Grind Valve Seats

1. Use ST-685 Valve Grinding Kit (contains parts to grind valve seats on all Cummins engines) or tools of equal standards.

2. Check condition of grinding equipment.

a. Mandrels msust be straight and of proper size to fit in valve guide.

Table 2-3-1: Valve Seat Insert Specifications – Inch [mm]

Insert Part No.	ST Cutter	*Diameter	Oversize Depth	Insert O. D.	Cylinder Head I. D.	Insert Thickness
127930	ST-662	Std.	Std.	2.0025/2.0035 [50.8635/50.8889]	1.9995/2.0005 [50.7873/50.8127]	0.278/0.282 [7.0612/7.1628]
127935	ST-662	0.005 [0.1270]	Std.	2.0075/2.0085 [50.9905/51.0159]	2.0045/2.0055 [50.9143/50.9397]	0.278/0.282 [7.0612/7.1628]
127931	ST-662-1	0.010 [0.2540]	Std.	2.0125/2.0135 [51.1175/51.1429]	2.0095/2.0105 [51.0413/51.0667]	0.278/0.282 [7.0612/7.1628]
127932	ST-662-2	0.020 [0.5080]	0.005 [0.1270]	2.0225/2.0235 [51.3715/51.3969]	2.0195/2.0205 [51.2953/51.3207]	0.283/0.287 [7.1882/7.2898]
127933	ST-662-3	0.030 [0.7620]	0.010 [0.2540]	2.0325/2.0335 [51.6255/51.6509]	2.0295/2.0305 [51.5493/51.5747]	0.288/0.292 [7.3152/7.4168]
127934	ST-662-4	0.040 [1.0160]	0.015 [0.3810]	2.0425/2.0435 [51.8795/51.9049]	2.0395/2.0405 [51.8033/51.8287]	0.293/0.297 [7.4422/7.5438]

Caution: Be sure to measure insert before machining head or installing insert in head.

b. Bushings in grinder must be clean and must fit properly in guide mandrel.

c. Drive unit bearings must be in good condition.

3. Dress stone to 30 deg. from horizontal.

4. Grind valve seats, holding seating motor as nearly vertical as possible. Fig. 2-3-3. A severe angle will cause seat to be out-of-true depending upon amount of wear in grinder bearings, mandrel, bushings, etc., even though grinder has a universal joint.

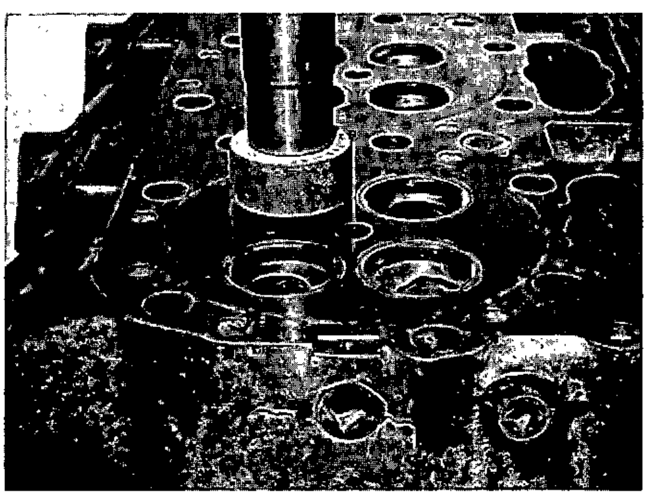


Fig. 2-3-3, V40210. Grind valve seat

5. Check valve seat width which should be 1/16 to 1/8 inch [1.5875 to 3.1750 mm]. See (1, Fig. 2-3-4).

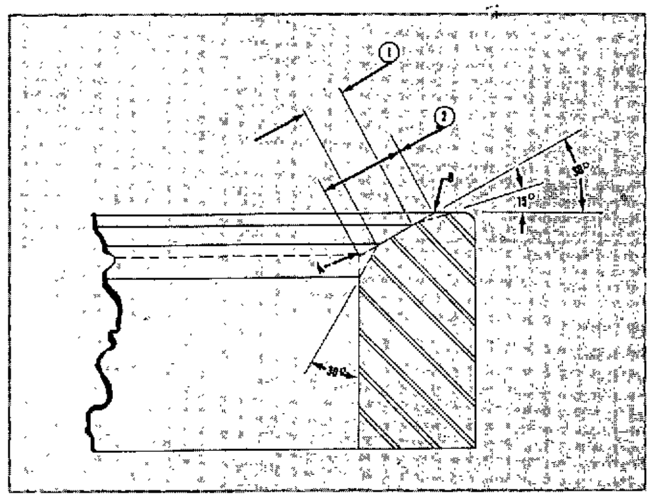


Fig. 2-3-4, N10228. Valve seat insert—cross sections

a. If seating area (2) is wider than 1/8 inch [3.1750 mm] maximum, stock can be removed from points "A" and "B" with specially dressed valve seat grinder stones.

b. Narrowing should not extend beyond chamfer on seat insert. Chamfer provides for peening metal.

6. Dress wheel for final finish.

7. Finish grind with light touches of stone against face.

8. Check valve seat concentricity with valve seat indicator as shown in Fig. 2-3-5.

a. Use valve guide as a center.

b. Total run out should not exceed 0.002 inch [0.0508 mm].

c. The gauge must be a perfect fit on pilot mandrel.

9. Check seat with mating valve as described on Page 2-5-3 to insure proper sealing.

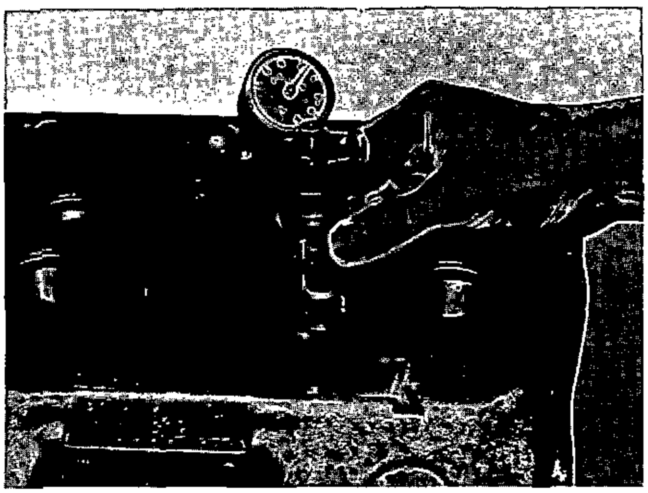


Fig. 2-3-5, V40233. Indicate valve seat insert face

Valve Crossheads and Guides Unit—204

Valve Crosshead Guides

Valve crossheads are used on engines with dual intake and exhaust valves so that both valves under the crosshead open and close at the same time.

1. Remove crosshead guides to be replaced, using ST-667 Puller which contains different-size collets for the various engine guides or dowels. Fig. 2-4-1. Clean holes thoroughly.

2. Press in new guides with ST-633 Crosshead Guide Mandrel. Fig. 2-4-2.

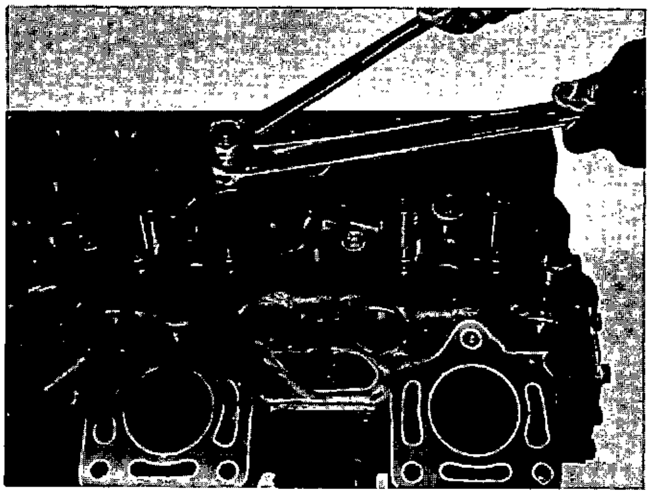


Fig. 2-4-1, V40234. Pull crosshead guide

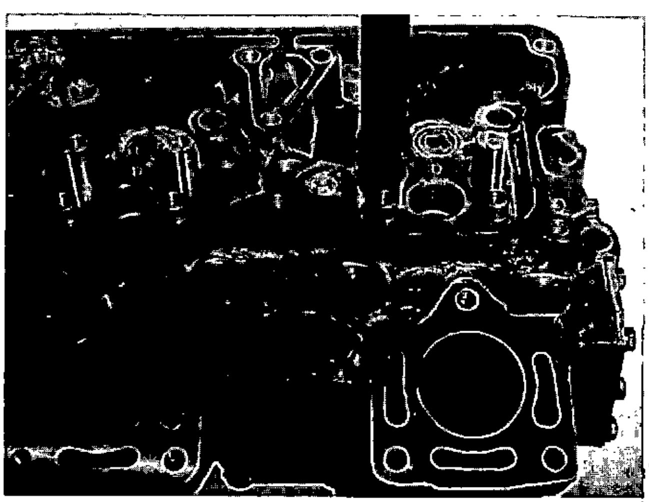


Fig. 2-4-2, V40235. Install crosshead guide

3. If mandrels are not available, press guides into head to obtain protrusion of 1.860 to 1.880 inch [47.2440 to 47.7520 mm].

4. Oversize crosshead guides may be installed as follows:

a. Drill guide bore in head to original depth with a 29/64 inch [11.5093 mm] drill.

b. Lubricate and ream bore with a 15/32 inch [11.9062 mm] reamer.

c. Consult latest Parts Catalog for oversize guide part number.

d. Install guide as stated in preceding paragraphs.

Crossheads

1. Clean crossheads.

2. Check for cracks with Magnaflux process.

3. With accurate micrometers, set a small bore gauge (such as Starret No. 829-D) 0.0002 inch [0.0050 mm] above worn replacement limit. Use as a "No-Go" gauge in crosshead bore (3, Fig. 2-4-3) to check for wear beyond worn replacement limits shown in Table 2-4-1. Check for out-of-round holes.

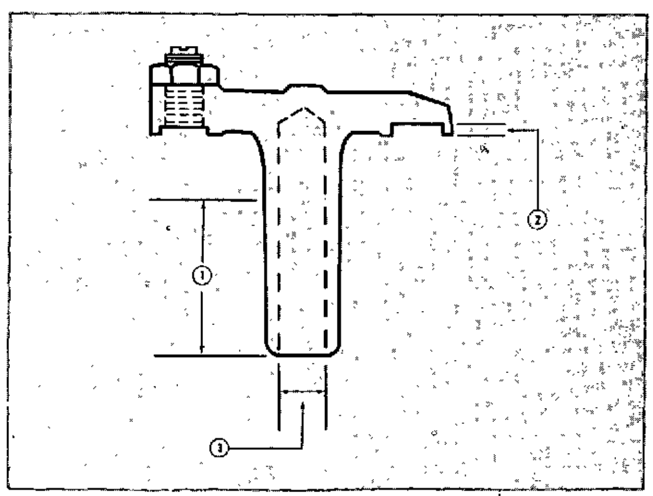


Fig. 2-4-3, V40236. Crosshead dimensions

4. Gauge hole at several points 90 deg. apart.

Table 2-4-1: Crosshead Stem Inside Diameter Inch [mm]

New Minimum		New Maximum		Worn Limit	
0.434	[11.0236]	0.436	[11.0744]	0.440	[11.1760]

Caution: Do not use a plug gauge for this operation.

5. Check reamed depth of crosshead bore (1, Fig. 2-4-3); it should be a minimum of 1.000 inch [25.4000 mm] in depth.

6. Check valve stem counterbore depth in underside of crosshead (2); dimensions should be 0.120 to 0.140 inch [3.0480 to 3.5560 mm].

7. Mark crossheads for replacement that exceed worn replacement limits.

8. Check for excessive wear on rocker lever and valve contact surfaces.

9. Check adjusting screw threads and nuts. Replace as necessary if threads or nuts show excessive wear.

Valves, Guides and Springs—Unit 205

Inspect Valves

1. Clean valves with a buffer and polish with crocus cloth.

2. Inspect, then discard if:

a. Heads are cupped, cracked, pitted or worn too thin to regrind within limits. Check valve head rim thickness. Discard valve if rim is less than 0.105 inch [2.6670 mm] (1, Fig. 2-5-1).

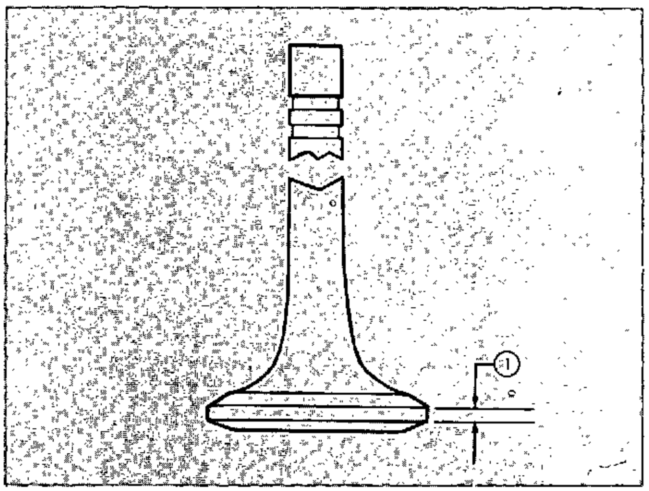


Fig. 2-5-1, N10231. Minimum valve head rim thickness

b. Stems, Fig. 2-5-2, are scored or worn beyond worn limits. New dimensions are 0.4500 to 0.4510 inch [11.4300 to 11.4554 mm].

c. Collet recesses are worn so new collets will not fit securely in recesses.

Grind Valves

Use ST-684 VAlve Grinding Kit or tools of equal standards.

1. Check valve grinder setting by using a new valve and an indicator gauge.

a. Chuck valve on guide area of stem. Fig. 2-5-3. Relieved portions on both ends of guide area are not necessarily concentric to guide area of stem.

b. Indicate on ground face of valve.

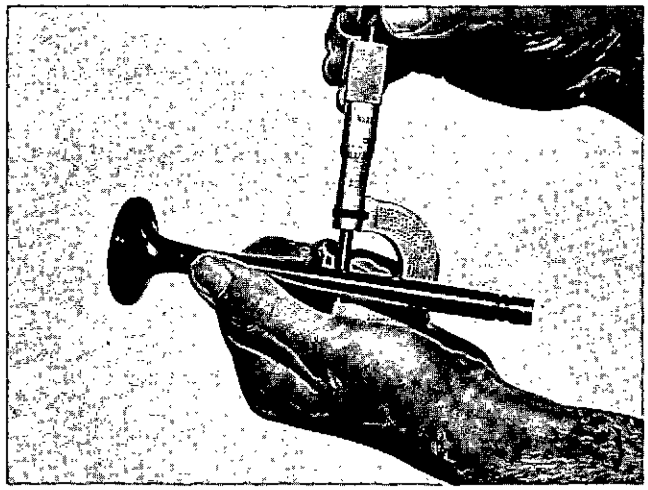


Fig. 2-5-2, V40237. Measure valve stem

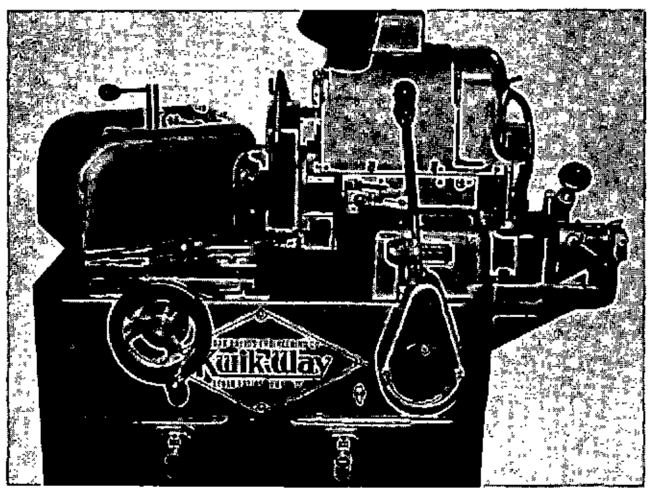


Fig. 2-5-3, N10230. Reface valve

c. Turn valve and mark high spot on head of valve.

d. Rechuck the valve 180 deg. from first position.

e. Repeat (b) and (c). If high spots are same for both (a) and (d) positions, valve is warped. If high spots occur in different positions, chuck is out of alignment. Runout should not exceed 0.001 inch [0.0254 mm].

2. Check bearings of machine.

3. To avoid chatter and grind marks, use a proper grade grinding wheel such as Kwik-Way No. 8100.

4. Wet-grind valves to an exact 30 deg. angle from horizontal.

5. Valves and seats properly ground with precision equipment should not require lapping to effect an air-tight seal; however, a small amount of lapping is permissible if necessary in order to pass vacuum test described under "Testing Valve Seating" in following paragraphs.

6. Check rim thickness as shown in Fig. 2-5-1. If rim is less than 0.105 inch [2.6670 mm], valve is not suitable for use because of danger of burning and cupping.

7. Check valve in a guide and against a newly ground valve seat face. Pencil mark valve and drop into position; rotate valve 10 deg. A good seat will be indicated if all pencil marks are broken. Fig. 2-5-4. If pencil marks are not broken, valve seat tools need dressing or machine has not been properly adjusted; final check should be made with a vacuum testor. See "Testing Valve Seating."

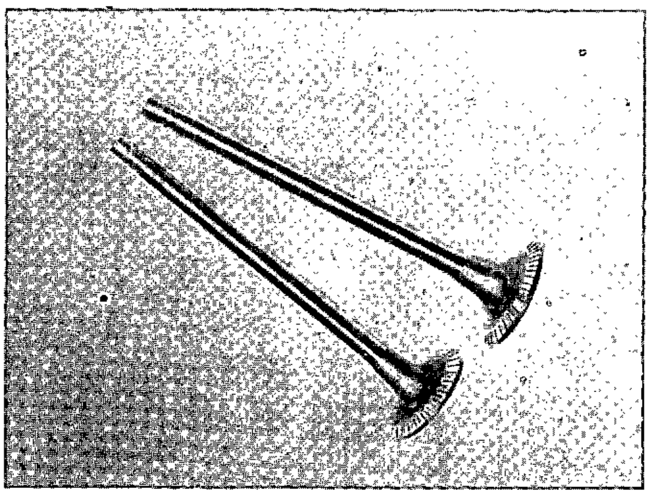


Fig. 2-5-4, N20217. Pencil marks on valves

8. Conditions of a good valve seat.

a. No grinding or reamer marks on seating surfaces and within guide.

b. Valve face a true 30 deg. angle.

c. Width of grind is within limits.

d. Guide-to-stem clearance is within limits as determined from dimensions of stem and guide.

Valve Guides

Inspect Guides

1. A plug gauge is not satisfactory to gauge worn guides. It will not detect an out-of-round hole. Instead, use a small bore gauge—Starrett No. 829-D, or similar (1, Fig. 2-5-5).

2. To use a small bore gauge, set it with accurate micrometers at 0.0002 inch [0.0050 mm] larger than worn replacement limit shown in Table 2-5-1. Then use bore gauge as a "No-Go" gauge. Fig. 2-5-5. Gauge the hole at several points crosswise and endwise of head.

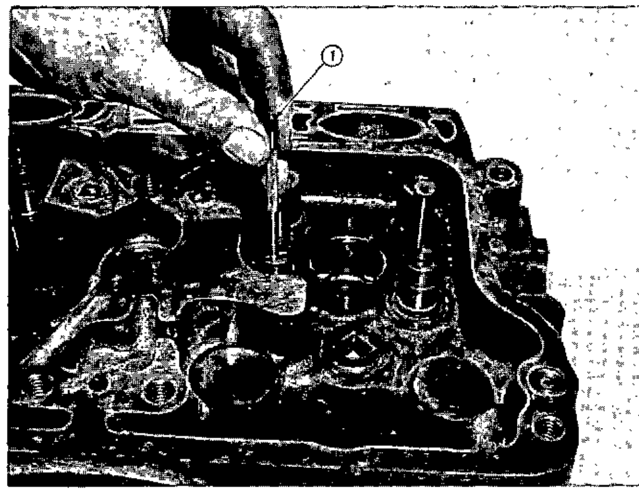


Fig. 2-5-5, V40238. Measuring valve guide

Table 2-5-1: Valve Guide Inside Diameter – Inch [mm]

New Minimum	New Maximum	Worn Limit
0.4525 [11.4935]	0.4532 [11.5112]	0.4550 [11.5570]

3. If old valve guides are worn beyond worn replacement limits shown in Table 2-5-1, mark replacement.

4. Inspect valve guides for chips, cracks or burrs; if damaged, mark for replacement.

5. Check valve guide protrusion. Protrusion should be 1.065 to 1.075 inch [27.0510 to 27.3050 mm] when guides use oil seals and 1.315 to 1.325 inch [33.4010 to 33.6550 mm] for guides without oil seals.

Replace Valve Guides

1. Drive out worn guides from underside of cylinder head.

2. Install new guides with arbor press and proper mandrel, ST-985 for guides using oil seals and ST-954 for guides without seals. Fig. 2-5-6.

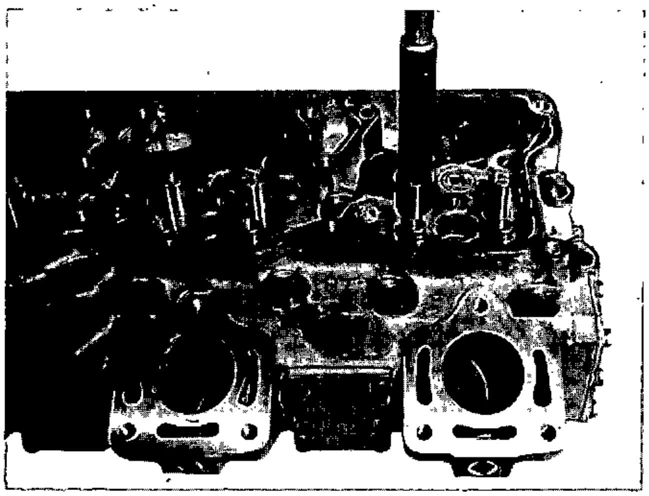


Fig. 2-5-6, V40211. Install valve guide with ST-714

3. If proper valve guide mandrels are not available, press guides into head to obtain 1.065 to 1.075 inch [27.0510 to 27.3050 mm] protrusion above head surface for guides with oil seals and 1.315 to 1.325 inch [33.4010 to 33.6550 mm] for guides without oil seals.

4. Most valve guides will not require reaming. Insert valve into guide and check for freedom of movement, or check guide with small bore gauge to determine if guide bore is too small.

Caution: Guides which have been through the "tuff-triding" process, identified by a dull gry appearance, are not to be reamed.

5. If reaming is necessary, proceed as follows:

a. Ream valve guide from bottom side of cylinder head, using a drill press and floating tool holder. Fig. 2-5-7. Use ST-646 Reamer only if valves will not go into guide freely.

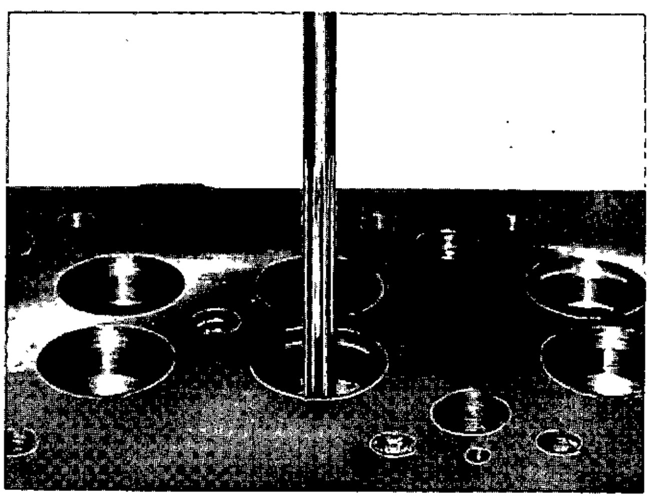


Fig. 2-5-7, V40212. Ream valve guide

Note: Use lubricating oil or soluble oil and water solution for good finish.

b. Ream valve guides with proper reamer to dimensions shown in Table 2-5-1.

Caution: Special care must be used to avoid breaking carbide tips. Sharpen tipped tools on a diamond-impregnated wheel.

Valve Springs

Weak valve springs may cause valve flutter which results in excessive wear on both valve and seat. Valve flutter interferes with valve timing and may cause valve to strike the piston head. Valve warping, cracking and breaking are the results of weak valve springs.

1. Test valve spring on spring tester that is capable of very accurate measurements of spring lengths by means of standards as listed in Group 18 and dial indicator gauge. Fig. 2-5-8.

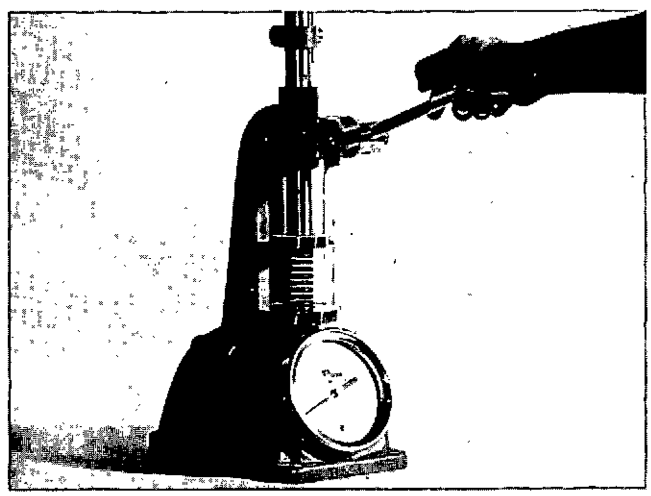


Fig. 2-5-8, V10214. Test valve spring tension

2. Spacers may be used under valve spring when insert and valve have been refaced to make valve spring check within load limit. Refer to Parts Catalog for specific spacer pertinent to engine model.

Note: A maximum of 1/16 inch [1.5875 mm] spacers may be used under valve spring when head has been resurfaced and valve and seat have been refaced.

3. If valve springs compress to dimension shown, at less than load indicated under "worn limits," valve springs should be discarded. Table 2-5-2.

Table 2-5-2: Valve Spring Data — Inch [mm], lb [kg]

Valve Spring Part Number	Approximate Free Length	Assemble Height	No. Coils	Wire Diameter	Working Length	Pounds Required To Compress New Minimum	New Maximum	Worn Limit
123932	3.230 [82.0420]	2.250 [57.1500]	11	0.1562 [3.9670]	1.765 [44.8310]	110 [49.8949	130 [58.9667]	105 [47.6270]
143907	2.890 [73.4060]	2.250 [57.1500]	10.5	0.162 [4.1148]	1.765 [44.8310]	108 [48.9880]	130 [58.9667]	105 [47.6270]
169703	2.664 [67.6650]	2.250 [57.1500]	9	0.177 [4.4958]	1.750 [44.4500]	139.2 [63.2410]	179 [81.1926]	135 [61.2346]

Caution: Do not mix valve springs of different lengths under the same crosshead.

Valve Guide Seal

Intake valve guide seals are not used on the natural aspirated engines. Some engines may still be using valve guide seals on the intake valve stem. It is recommended that seals be removed on all engines. No change in the valve guide on these engines is required, but new engines are using the 174213 guide.

Assembly and Testing–Unit 206

Assembly

Clean cylinder head, valves, springs, etc. before assembling. Check parts list to determine correct valve and piston combination.

1. Lubricate valve stem with clean SAE 30 lubricating oil and insert valves in valve guides.

2. Place cylinder head face down on a wooden bench or protective surface to prevent marring milled surface.

3. Assemble lower valve spring retainer on valve guides. Install valve guide oil seals on intake valve guides as follows, (if used):

a. Place plastic sleeve over valve stem.

b. Press seal into place over valve stem until seated on valve guide with ST-874.

c. Remove plastic sleeve.

4. Assemble springs.

Notes:

a. Use same part number spring with mating spring under same crosshead.

b. Reground valve heads seat deeper in cylinder head causing valve stem to protrude further above the guide. This allows valve spring to extend beyond length limits and causes weak spring action. Therefore, up to 1/16 inch [1.5875 mm] of spacers may be used to reduce valve spring length. See Table 2-5-2.

Caution: Too many spacers will cause the compressed spring to become a solid sleeve. See Table 2-5-2, "Valve Spring Data."

5. Assemble upper valve spring guide.

6. Use ST-448 Valve Spring Compressor to compress valve spring. Insert new half-collets.

Testing

Valve Seating

A vacuum tester to check valves and seats for leakage is available as ST-417. It consists of a vacuum pump, vacuum gauge and vacuum cup. Use with any 6-volt battery source or 110-volt electrical outlet as required. Fig. 2-6-1.

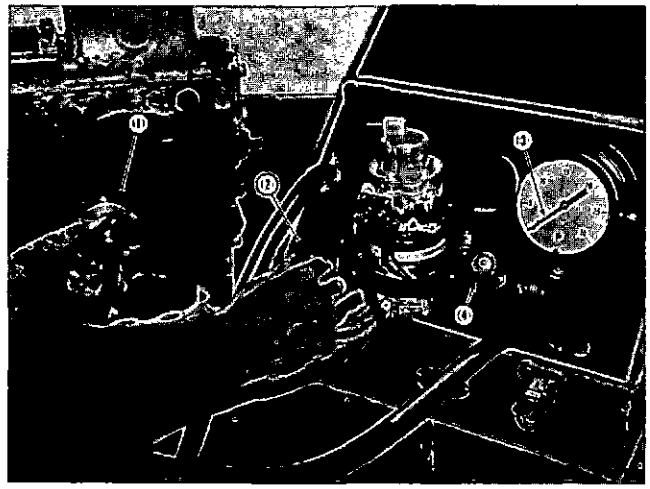


Fig. 2-6-1, V40239. Vacuum test valves for leaks

Caution: Never vacuum test cylinder head with injectors installed.

1. Valves and seats must be dry and clean.

2. Select proper vacuum cup (1, Fig. 2-6-1) for size valves to be tested. Cups are furnished with each tester so all engine models can be tested.

3. Place vacuum cup over valve head. "O" ring on cup should seat on flat surface of head surrounding valve. Grease can be applied to "O" ring for a better seal.

4. Turn hand shut-off valve to open position; hold push button (2) to operate vacuum pump.

5. Operate vacuum pump until hand on vacuum gauge (3) stops climbing at 18 to 25 inch-hg [0.6210 to 0.8625 kg/sq cm] as shown on dial.

6. Close shut-off valve (4); release push button to stop pump.

7. Time fall of gauge hand to test valve seat.

a. Begin timing as soon as hand reaches "18" on dial.

b. Stop timing when hand reaches "8." If elapsed time is less than ten seconds, valve seat seal is unsatisfactory.

8. Tap the stem end of the valve with a soft-faced mallet and retest.

9. If valve seat is unsatisfactory:

a. Check for leaking connections in tester; operate vacuum pump with suction cup against a clean window glass or any smooth flat surface; check for fall of indicator hand indicating loose connection.

b. Make sure valve and seat are not dirty.

10. Regrind valve and seat if necessary; however, it is possible to mistake leakage around the valve seat insert for valve seat leakage. If this type of leakage is suspected, apply grease around outside edge of insert to make a grease seal. Perform vacuum test and inspect the grease seal for a break indicating air leakage between wall of counterbore and valve seat insert. If leak around valve seat insert is found, correction is required before continuing with test.

Water Test

1. Replace all pipe plugs if not in place. Use sealing tape or lead sealer to prevent leakage. Torque plugs to values listed in Table 2-6-1.

Table 2-6-1: Cylinder Head Pipe Plug Torque ft-lb [kg m]

Plug Size	Minimum		Maximum	
1/8 inch	5	[0.6915]	10	[1.3830]
Fuse Plug	5	[0.6915]	10	[1.3830]
3/8 inch	35	[4.8405]	45	[6.2235]
1/2 inch	60	[8.2980]	70	[9.6810]
3/4 inch	65	[8.9895]	75	[10.3725]
1 inch	135	[18.6705]	145	[20.0535]

2. Install pipe plugs in fuel passages; seal with sealing tape or use liquid lead sealer to prevent leakage.

3. Install fuel inlet and drain fittings in same position, as removed, in each cylinder head.

4. Position water header plates with new gaskets; secure with lockwashers and capscrews to each head.

5. Install Injector Sleeve Holding Tool ST-384 or a scrap injector and cup assembly in each injector sleeve.

6. Tighten sleeve holding tool to 7 to 8 ft-lb [0.9861 to 1.1064 kg m] to seal lower end of injector sleeve, Fig. 2-6-2, or install injectors and secure with capscrews torqued to same value.

7. Test cylinder heads for leaks at 35 to 85 psi [2.4605 to 5.9755 kg/sq cm] and, if possible, at 175 deg. to 200 deg. F [79 deg. to 93 deg. C] water temperature. Check carefully around valve seats and injector sleeve seats for any cracks, even though such cracks might not show water leakage. This type crack is caused when injector capscrews are tightened beyond factory torque recommendation.

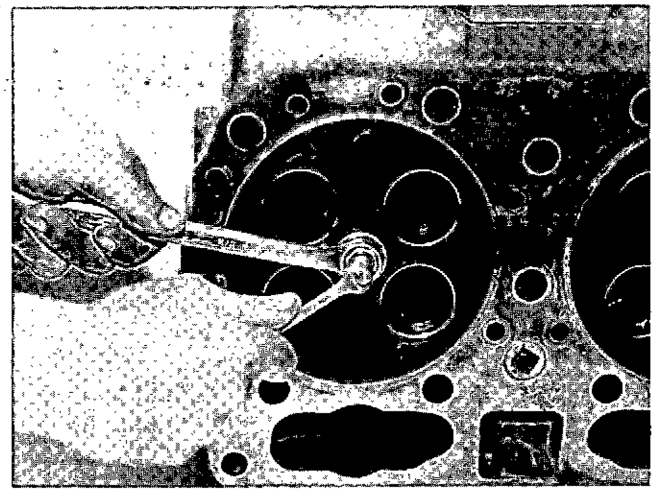


Fig. 2-6-2, V40204. Installing injector sleeve holding tool ST-384

Discard head, if cracked.

8. Open water outlet valve of test fixture; check for free water circulation through cylinder head. If restriction is evident, remove plugs and injector sleeves; clean water jackets of salt, lime or sludge.

Vent Holes

1. Cylinder heads contain vent or breather holes that must be open on naturally aspirated engines and plugged in rocker housing of turbocharger engines.

2. The vent hole of each cylinder head, in boss of head casting match those in rocker housing. (1, Fig. 2-6-3).

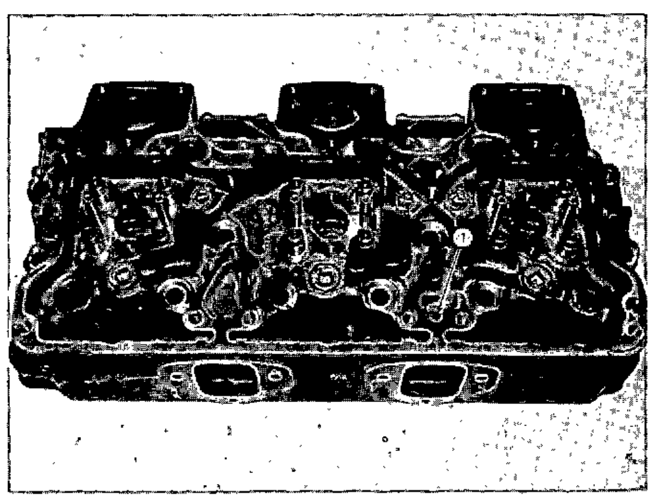


Fig. 2-6-3, V40240. Vent hole

Install Crossheads

1. Place crossheads over crosshead guides.

2. Assemble crosshead adjusting screw and locknut. Tighten finger tight against valve stem and move crosshead up and down to test for freedom of movement on guides.

3. It is a common practice to remove crossheads before installing heads on engine. It makes the task of installing heads much easier. See "Assembly Group 14" for crosshead adjustment instructions.

Rocker Lever Group

The rocker lever group consists of rocker levers, rocker lever shafts, push tubes, rocker lever covers, crankcase breathers and rocker lever housings.

Rocker Levers and Housing—Unit 301

Measurements

Dimensions in this group, where applicable, are listed in both U.S. and Metric units. The Metric units are enclosed in brackets [].

Rocker Lever Disassembly

1. Remove ventilator plug (on naturally aspirated engines) and 1/8 inch pipe (on turbocharged engines).

2. Remove pipe plug from end of rocker lever housing. Fig. 3-1-1.

3. Remove setscrew in bottom of housing that secures shaft.

4. Use a flat or drift punch to force out shaft and cup plug on other end of housing.

5. Locate shaft in a V-block, not a vise; remove pipe plug in end of shaft (if used).

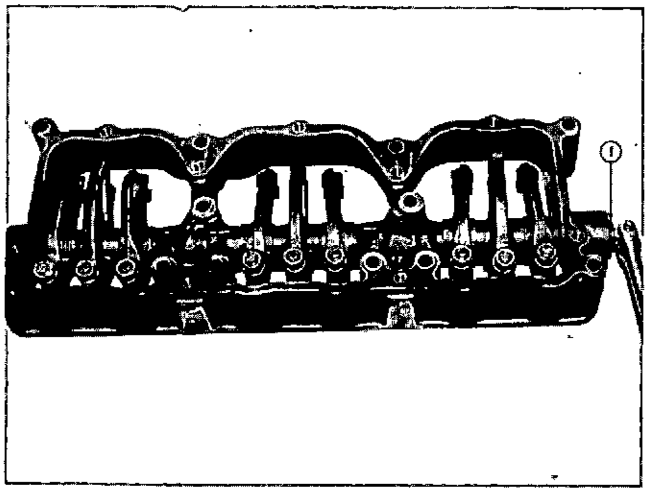


Fig. 3-1-1, V40302. Removing shaft retaining pipe plug

6. Remove rocker levers from housing. Tag rocker levers for correct position as removed to prevent confusion during assembly. Remove adjusting screw locknuts and adjusting screws from rocker levers.

Cleaning, Inspection And Repair

1. Clean all parts in cleaning solvent.

2. Blow out lubricating oil passages with compressed air.

3. Check for surface imperfections by magnetic inspection. Apply coil magnetization, amperage at 300 to 500 with residual Magnaglo. See Fig. 3-1-2 for most likely areas.

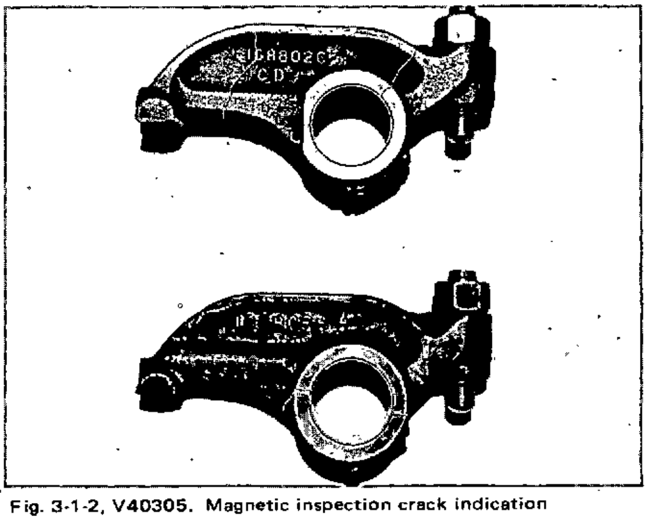


Fig. 3-1-2, V40305. Magnetic inspection crack indication

4. The ball end of rocker lever adjusting screw must be a true sphere. Test with 1/4 inch [6.3500 mm] radius gauge. Replace if flat at bottom or there is evidence of scratching or galling. Fig. 3-1-3.

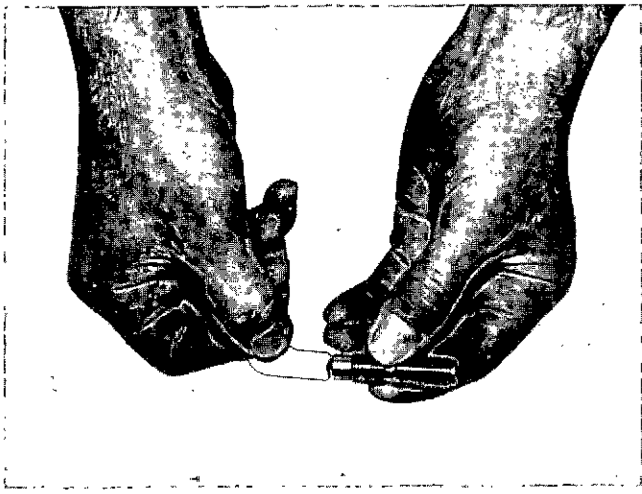


Fig. 3-1-3, N20305. Checking racker lever adjusting screw ball end

5. Examine injector rocker lever sockets for a true fit on injector links. Check sockets with a radius gauge or by observation of a small protrusion at bottom of socket. Pull and discard damaged or badly worn injector rocker lever sockets. If socket is broken, press out by drilling a small hole in lever above socket; after socket is removed, weld hole closed or install and stake a plug in hole.

6. Check rocker lever bushings for scratches, pitting or scoring. Check rocker lever bushing inside diameter with inside micrometers. Fig. 3-1-4. See Table 3-1-1 for bushing dimensions.

7. If bushing exceeds specifications given in Table 3-1-1, press out bushing with ST-691 mandrel and block. Clean lever thoroughly and dry with compressed air. See Parts Catalog for correct replacement bushing part numbers.

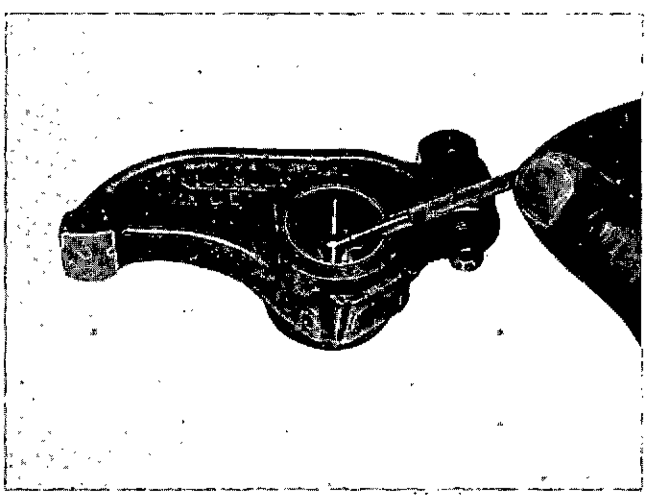


Fig. 3-1-4, V40306. Check rocker lever bushing for wear

Table 3-1-1: Rocker Lever Bushing Inside Diameter

Bushing Material	New Dimension Minimum Inch [mm]	Maximum Inch [mm]	Worn Limit Inch [mm]
Steel	1.1245 [28.5623]	1.1275 [28.6385]	1.1285 [28.6639]

8. Install new bushing with ST-691 and arbor press. Fig. 3-1-5.

a. On injector and exhaust valve levers, install bushings so oil holes to crosshead nose or injector link and adjusting screw are open for oil flow.

b. On intake valve levers, with oil drilling to crosshead nose end, install bushing so "nose" hole is closed and so "slot hole" is in line with adjusting screw oil hole.

Caution: Do not bore steel bushings.

9. Check intake and exhaust rocker lever-to-crosshead contact surfaces. If worn or damaged, grind to original contour or replace with new rocker lever.

10. Check rocker lever shaft for wear or scoring. If shaft has shoulders or ridges due to rocker lever action on shaft, replace with new rocker lever shaft. See Table 3-1-2 for shaft dimensions.

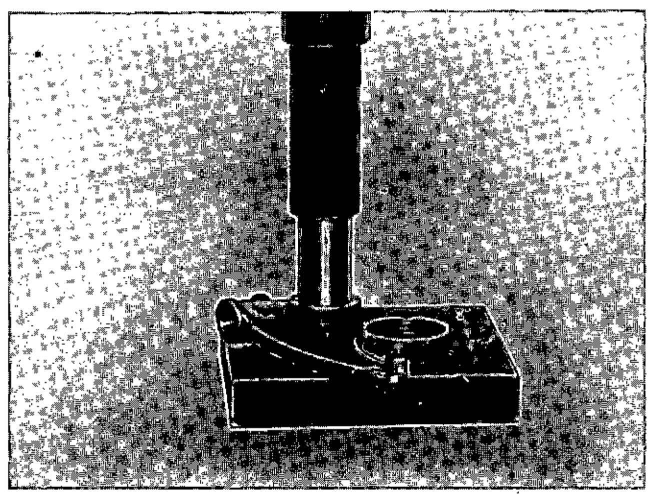


Fig. 3-1-5, N10304. Installing bushing with ST-691

Table 3-1-2: Rocker Lever Shaft Outside Diameter

New Dimensions Minimum Inch [mm]	Maximum Inch [mm]	Worn Limit Inch [mm]
1.1230 [28.5242]	1.1240 [28.5496]	1.1220 [28.4988]

11. Visually check surfaces which mate with adjacent levers. If galled, restore surfaces to original smoothness.

Rocker Lever Housing

Cleaning

After all rocker levers and plugs have been removed as described on Page 3-1-1, proceed as follows:

1. Clean rocker lever housing thoroughly in an approved solvent. Dry with compressed air.

2. Remove all gasket material from sealing surfaces.

Inspection

1. Visually inspect all capscrew and pipe plug holes for damaged threads.

2. Visually inspect for cracks, chips or breaks.

3. Check breather vent hole (1, Fig. 3-1-6) and rocker lever oil drilling (2) to make sure they are free of dirt or other deposits.

4. Check all sealing surfaces for damage.

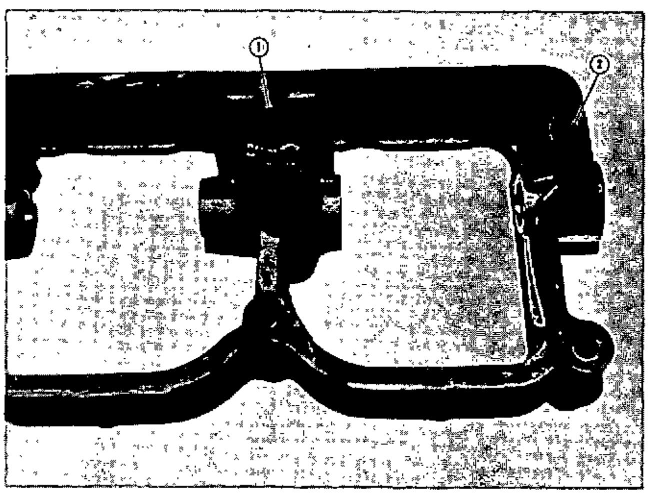


Fig. 3-1-6, V40311. Breather vent hole (bottom view)

5. Check rocker lever shaft bore inside diameter. Dimensions should be 1.1243 to 1.1251 inch [28.5772 to 28.5575 mm]. If for any reason lever shaft bore does not meet these dimensions, discard housing and replace.

6. If rocker lever housing cannot be salvaged, discard and replace with a new rocker lever housing. See Parts Catalog for correct part number.

Assembly

1. Rocker lever assembly is lubricated through oil holes in shaft and rocker lever housing which indexes with oil passage in cylinder head and block. See (2, Fig 3-1-6).

2. Install rocker lever socket in injector rocker levers (if removed).

3. Install adjusting screws and locknuts in rocker levers.

4. Coat rocker lever shaft with clean lubricating oil.

5. Start shaft into housing, install levers on shaft as shaft is pushed through housing. Fig. 3-1-7. See Parts Catalog for part numbers of intake and exhaust levers. See Fig. 3-1-7 for correct position of levers.

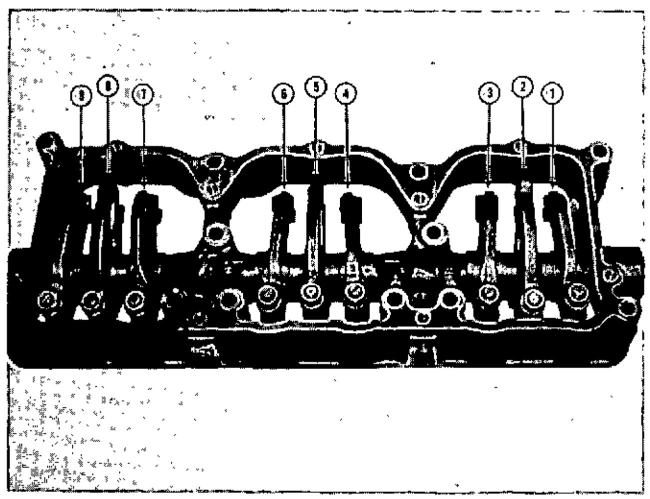


Fig. 3-1-7, V40303. Rocker lever assembly

a. Install exhaust (1), injector (2) and intake levers (3).

b. Install intake (4), injector (5) and exhaust levers (6).

c. Install intake (7), injector (8) and exhaust levers (9).

d. Coat expansion (cup) plug contact surface with Loctite Sealer. Install new expansion plug in rocker lever housing using ST-864 Driver.

Note: When using 191527 housing, use two (2) 175830 cup plugs. Use ST-1053 driver to install cup plugs. They should be flush to 0.010 inch [0.2540 mm] below surface.

6. Install pipe plug in end of rocker lever housing. Use sealing tape or Loctite to prevent oil leakage.

7. Check all levers for freedom of movement on shaft to

prevent galling.

8. Install and tighten shaft lockscrew.

9. On naturally aspirated engines, install breather vent plug to hole (1, Fig. 3-1-8). On turbocharged and Natural Gas engines install 1/8 inch pipe plug in all housings.

Caution: Levers can easily be installed in the wrong position; care must be used to install in correct position.

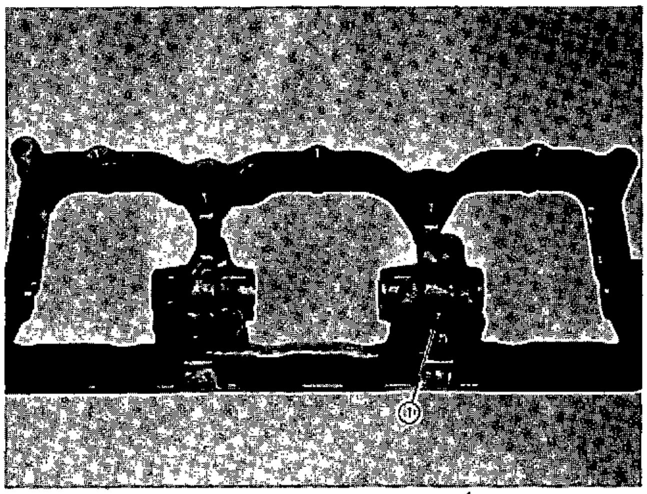


Fig. 3-1-8, V40307. Breather vent hole (top view)

Push Tubes—Unit 302

Each cylinder has an exhaust, injector, and intake push tube.

1. Clean push tubes in mineral spirits or an approved solvent.

2. Check injector and valve push tube ball end for wear with radius gauge. Fig. 3-2-1. Ball end diameter, intake (1, Fig. 3-2-2), injector (2) and exhaust push tube (3) is 0.623 to 0.625 inch [15.8242 to 15.8750 mm].

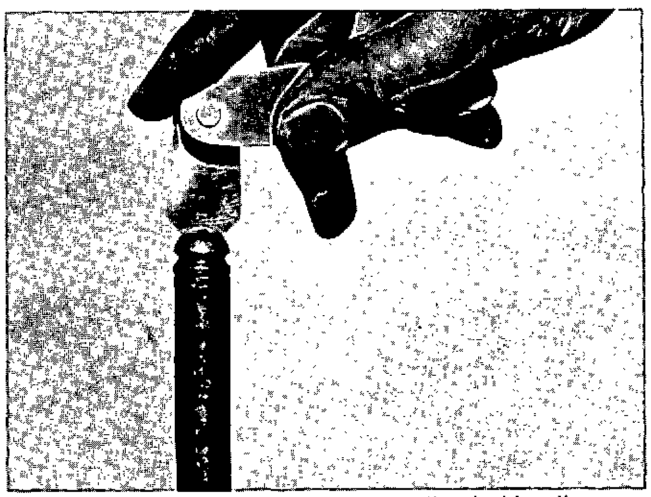


Fig. 3-2-1, N20309. Checking push tube ball end with radius gauge

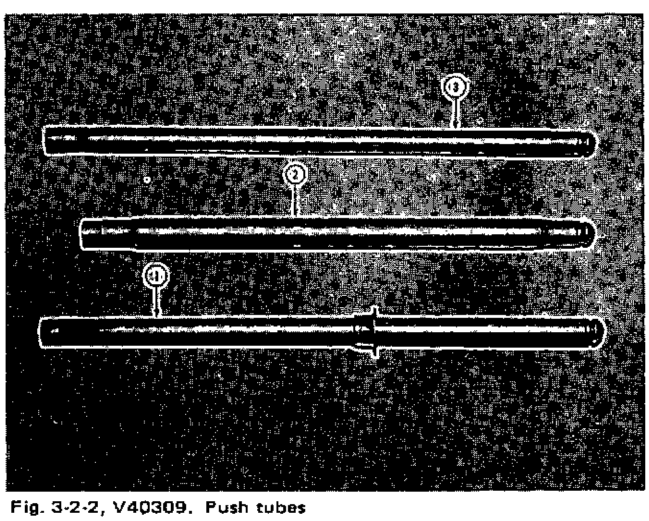


Fig. 3-2-2, V40309. Push tubes

3. Check socket of push tube with ball end of a new rocker lever adjusting screw, Fig. 3-2-3, or with a 1/2 inch [12.7000 mm] check ball which should "blue in" 80% of seat area; spherical inside diameter new is 0.5050 to 0.5200 inch [12.8270 to 13.2080 mm].

4. Extreme wear on either end of push tube will result in loss of lubricating oil pressure and may interfere with correct injector or valve adjustment.

5. Check push tubes to see if they are bent (out-of-round). Tubes should not be out-of-round more than 0.025 inch [0.6350 mm] when located in centers of socket and ball. Push tubes that are bent have usually had the adjusting screws over-torqued.

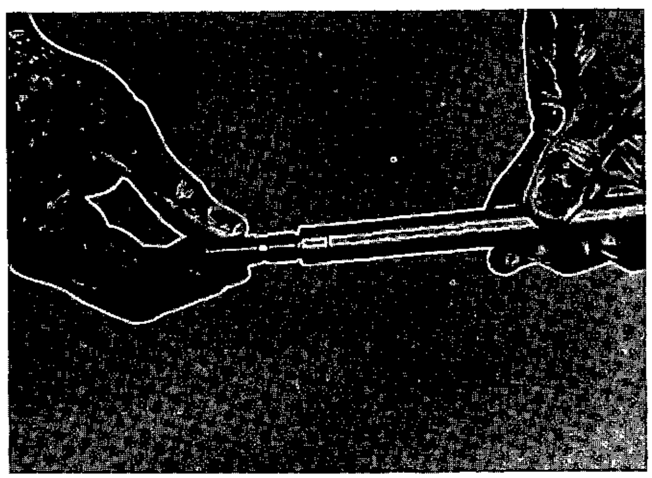


Fig. 3-2-3, N20310. Checking push tube socket with adjusting screw

6. Push tubes with worn balls should never be installed in new tappet sockets.

7. Push tubes which have become filled with lubricating oil should be drained by drilling a 1/16 inch hole in the tube 1 inch [25.4000 mm] above where tube contacts ball insert.

Crankcase Breather—Unit 303

Mesh Element Breather

The mesh element-type breather, Fig. 3-3-1, is used on all engines. The body is pressed into the cylinder head cover.

Disassembly

1. Remove wing nut (1, Fig. 3-3-1), flatwasher (2) and rubber washer (3) securing cover (4) and element assembly to breather.

2. Lift off cover, gasket (5), upper screen (6), mesh element (7) and lower screen (8) from body (9).

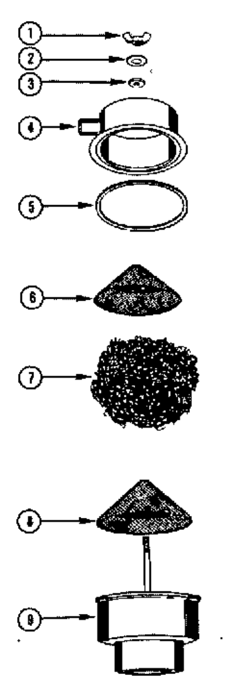


Fig. 3-3-1, V40310. Crankcase breather—mesh element

Cleaning And Inspection

1. Clean all parts in solvent. Use solvent that is not harmful to rubber. Clean mesh element and screens thoroughly.

2. Dry thoroughly with moisture-free compressed air.

3. Inspect rubber washers and gaskets; replace as necessary.

4. Inspect body for cracks, dents or breaks. Discard all unserviceable parts.

Assembly

1. Position lower screen (8, Fig. 3-3-1) into breather body (9).

2. Position new or cleaned element (7) and upper screen (6) over center screw in breather body.

3. Place cover (4) on body with gasket (5) in position.

4. Install rubber washer (3), flatwasher (2) and wing nut (1). Tighten securely.

Note: Paper element breathers are not recommended for V-1710 engines.

Rocker Lever Cover—Unit 304

Rocker Lever Covers

There are two types of rocker lever covers: plain type and *breather type. The type used depends on engine* application.

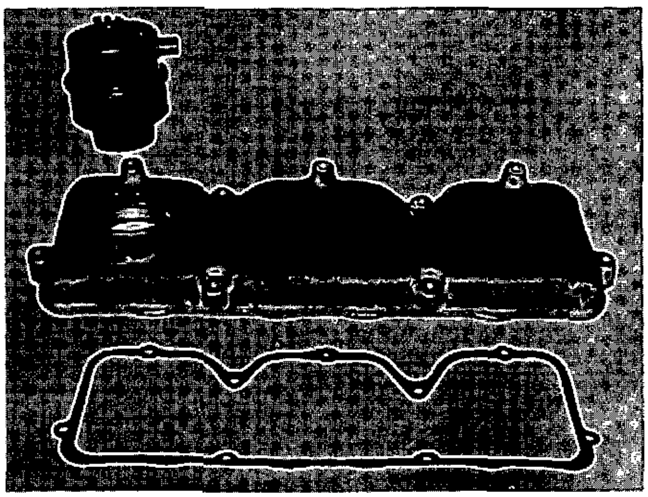


Fig. 3-4-1, V40308. Rocker lever cover assembly (breather type)

Cleaning And Inspection

1. Clean all parts in an approved cleaning solvent and dry with moisture-free compressed air.

2. Remove all gasket material from sealing edge of cover.

3. Inspect cover for cracks, dents and distorted sealing area; discard unserviceable parts. On breather-type covers, check closely around the press–fit area for cracks. Inspect for cracks around all capscrew holes.

4. If splits or cracks are found, install new covers.

Assembly

If a new breather-type cover is used, press in new or reconditioned breather body (breather must be pressed in straight). After installation of breather body, check closely for cracks around press-fit area.

Tappet Group

Tappets are used to transmit movement from the engine camshaft to the push tubes and rocker levers to actuate the injectors and valves. Tappet assembly is made up of a body containing a push tube seat, a roller and pin; the roller rides on the camshaft lobe.

Tappets–Unit 402

Measurements

All dimensions in this group, where applicable, are listed in both U.S. and Metric units. The Metric units are enclosed in brackets [].

Disassembly

1. Place 0.006 inch [0.1524 mm] shim (1, Fig. 4-2-1) between tappet (2, Fig. 4-2-2) and side of roller (3) to prevent springing fork when removing roller; press on end of pin (4) that is not lockwired (pinned).

2. Discard pin (4) and lockwire (5).

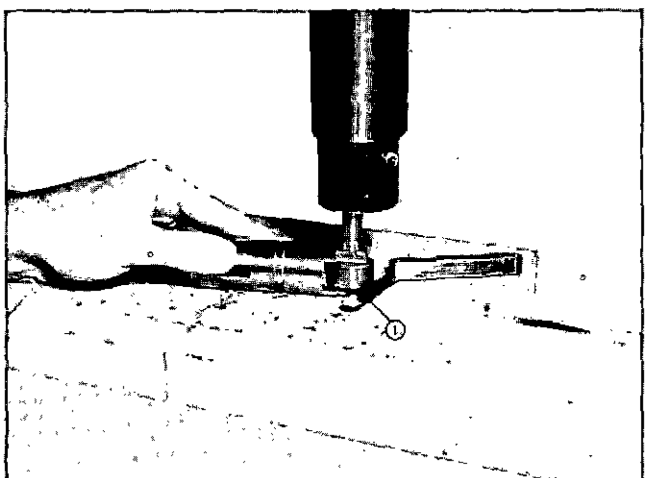


Fig. 4-2-1, N20402. Place shim between body and roller

Inspection

1. Check for scored, flaked or chipped rollers; discard damaged parts.

Note: If any of the conditions above exist, camshaft should be checked very closely for damage.

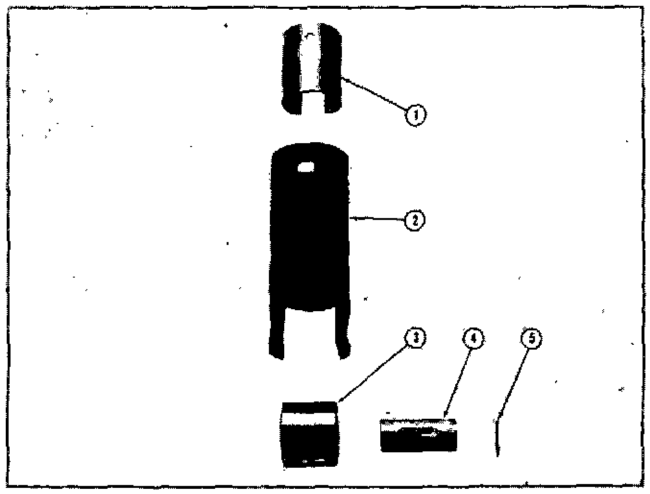


Fig. 4-2-2, N20404. Tappet assembly—exploded view

2. Measure tappet body outside diameter for wear; measure roller outside diameter and inside diameter for wear. Discard if worn beyond limits shown in Table 4-1-1.

3. Check tappet push tube seat by "bluing" corresponding new push tube on ball end and rotating in tappet; a full seat should be indicated. For best results keep push tube with mating tappet, especially if they are to be reused.

4. Check body pin holes and inspect holes for burrs before reassembly.

5. Check force required to move guide sleeve (1, Fig. 4-2-2) inside tappet, if greater than 70 inch-lb [0.8065 kg m], install new sleeve.

Assembly

1. Insert 0.006 inch [0.1524 mm] shim between side of roller (3, Fig. 4-2-2) and tappet (2); press pin (4) through tappet and roller with lockwire (5) in pin. Make sure lockwire seats in groove of tappet. See Fig. 4-2-3.

Table 4-2-1: Tappet Specifications – Inch [mm]

Assembly Or Part	New Minimum		New Maximum		Worn Limit	
Injector Tappet						
Body Inside Diameter	0.998	[25.3492]	1.007	[25.5778]	–	–
Body Outside Diameter	1.6225	[41.2115]	1.6235	[41.2369]	1.6215	[41.1861]
Roller Outside Diameter	1.1980	[30.4292]	1.2000	[30.4800]	1.1960	[30.3784]
Roller Inside Diameter	0.6280	[15.9512]	0.6290	[15.9766]	0.6300	[16.0020]
Roller Pin Outside Diameter	0.6243	[15.8572]	0.6247	[15.8673]	0.6233	[15.8318]
Roller Side Clearance	0.0080	[0.2032]	0.0200	[0.5080]	0.0250	[0.6350]
Roller Concentricity Assembled	–	–	0.0010	[0.0254]	–	–
Roller Squareness Assembled	–	–	0.0040	[0.1016]	–	–
Valve Tappet						
Body Inside Diameter	0.968	[24.5872]	0.978	[24.8412]	–	–
Body Outside Diameter	1.1850	[30.0990]	1.1860	[30.1244]	1.1840	[30.0763]
Roller Outside Diameter	1.0610	[26.9494]	1.0630	[27.0002]	1.0590	[26.8986]
Roller Inside Diameter	0.5030	[12.7762]	0.5040	[12.8016]	0.5050	[12.8270]
Roller Pin Outside Diameter	0.4995	[12.6873]	0.5000	[12.7000]	0.4985	[12.6619]
Roller Side Clearance	0.0080	[0.2032]	0.0220	[0.5588]	0.0270	[0.6858]
Roller Concentricity Assembled	–	–	0.0020	[0.0508]	–	–
Roller Squareness Assembled	–	–	0.0040	[0.1016]	–	–

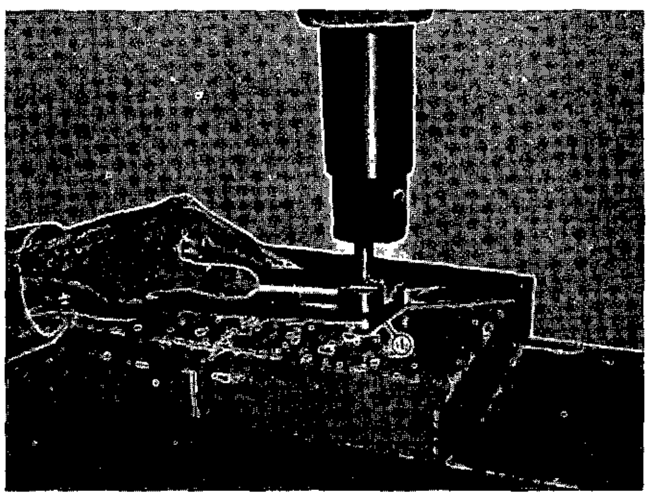


Fig. 4-2-3, N20402. Installing tappet roller pin

Caution: Lubricating oil passage in pin and tappet must index for adequate lubrication.

2. If removed, install steel sleeve (1, Fig. 4-2-2) in tappet by compressing and aligning guide slot in sleeve with slot in tappet body.

Caution: Make certain that any roller pins removed are replaced with identical pins. Use of incorrect pin and tappet combination will seal off lubricating oil drillings and lead to parts failure.

Inspection Of Assembled Tappet

Inspection of tappet assembly requires a surface plate, small V-block with clamp to hold tappet in position and an indicator calibrated in tenths of a thousandth inch or [mm] attached to a surface gauge.

1. Using a small wire, check indexing of pin and body lubricating oil passage.

2. Check freeness of roller by rotating two or three turns. If a "drag" is felt, the plating on pin has probably picked up during assembly, due to burrs or pin not being held square during assembly.

3. Stand small V-block on surface plate.

Note: Tools and parts must be clean to obtain a true check.

4. Stand tappet assembly on surface plate with roller up. Secure tappet in V-block with clamp. Fig. 4-2-4.

5. Using an indicator calibrated in tenths of a thousandth inch or [mm], check concentricity by rotating roller. Move indicator stand slightly and recheck. See Table 4-2-1 for dimensions.

Caution: Injector and valve tappet dimensions are not the same. Use correct dimensions when checking wear. Any parts that do not pass the checks must be disassembled. (Perform inspection during disassembly to determine the reason for rejection.) Reassemble tappets following "Assembly" and "Inspection of Tappet Assembly."

6. Using same indicator as in Step 5 above, check squareness of roller by sweeping indicator across diameter on one end of roller, then sweeping the other end. Rotate tappet roller 180 deg. and check again at roller ends by sweeping across the diameter. See Table 4-2-1 for dimensions. It is permissible and recommended to exert

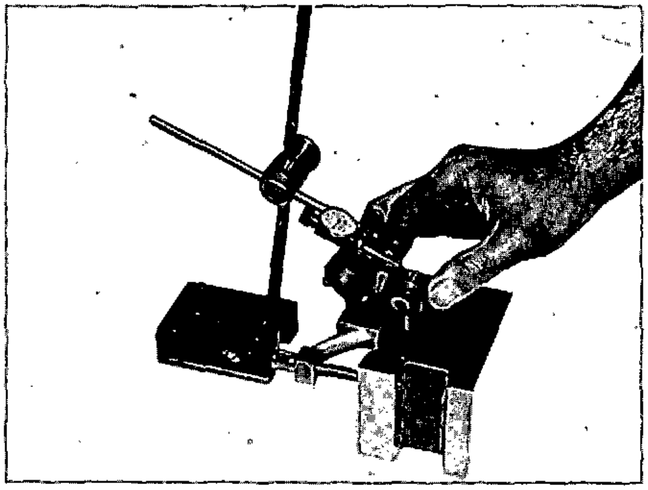


Fig. 4-2-4, N20405. Checking tappet roller concentricity

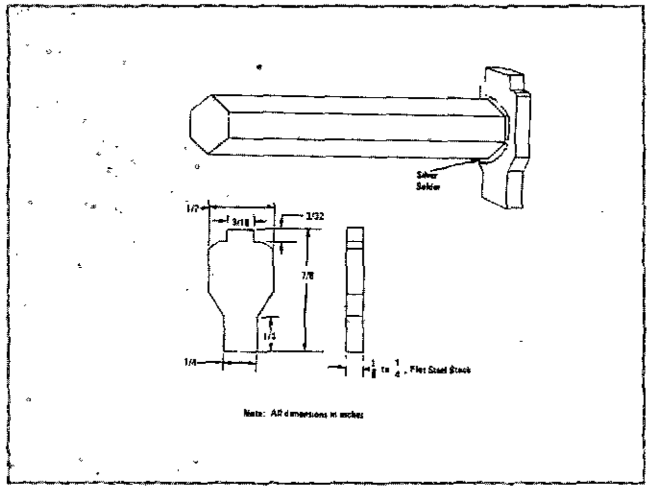


Fig. 4-2-5, V40316. Tappet torque tool

some downward pressure against roller when gauging to assure firm contact against roller pin.

Torquing Procedures

Due to recent changes in torque specifications, tappet inside diameters and guide sleeve interchangeability, it is necessary that specifications in Table 4-2-1 be followed.

1. Lubricate sleeve and tappet with clean S.A.E. 20 lubricating oil.

2. Assemble sleeve in tappet; align slots in normal operating position.

Note: Refer to parts catalog to determine correct sleeve and tappet combination.

3. Insert the torque tool into tappet sleeve.

a. Use the tool shown in Fig. 4-2-5 with Part No. 108156 Sleeve.

b. Use the tool shown in Fig. 4-2-6 with Part No. 195066 Sleeve.

c. Use the tool shown in Fig. 4-2-7 with Part No. 111689 Sleeve.

4. Boss on tool must fit in guide slot in sleeve.

Caution: Be sure the tool boss is inserted far enough in the slot to prevent its slipping out during torquing procedure. Also, be sure the tool is not cocked while in torquing position.

5. Using an inch-pound torque wrench, turn sleeve in both a

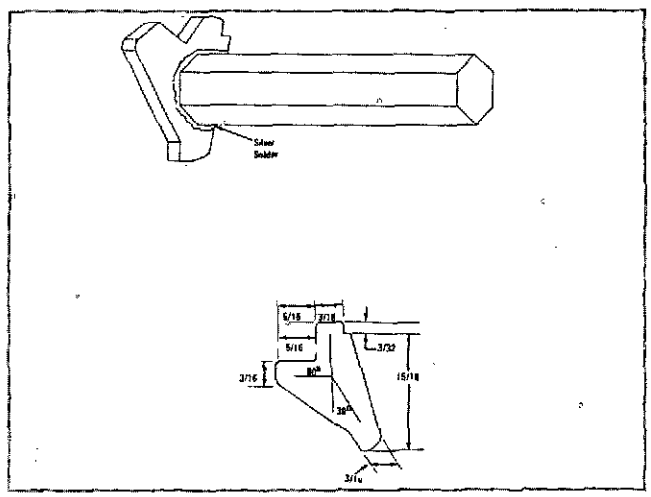


Fig. 4-2-6, V40317. Tappet torque tool

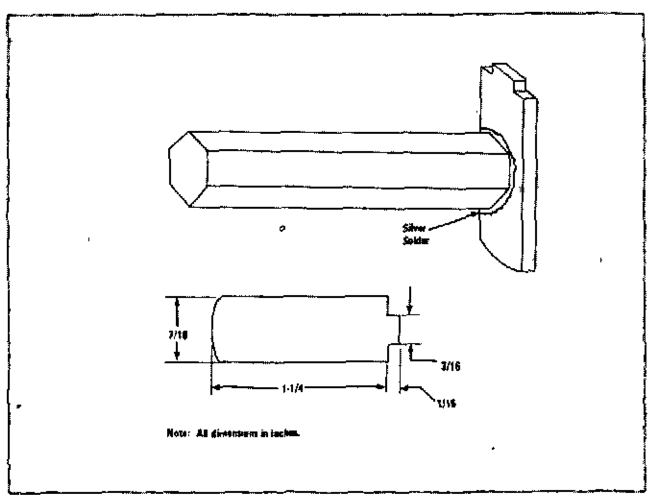


Fig. 4-2-7, V40318. Tappet torque tool

clockwise and counterclockwise direction. Torque must be as indicated in Table 4-2-2.

a. When checking torque on sleeve and tappet assemblies from an engine in service, the first torque reading may be high due to the break-a-way action.

b. If torque limits are not met after three different sleeves are tried in a tappet, replace the tappet.

Note: Do not bend the sleeve in an effort to raise or lower the torque values.

Table 4-2-2. Tappet I.D. and Sleeve Torque

Tappet I.D. (Inches) [mm]	Sleeve Part No.	Min. Torque (Inch Lbs) [kgm]	Max. Torque (Inch Lbs) [kgm]
0.968-0.978 [24.5872 to 24.8412]	108156	20 [0.230]	70 [0.805]
0.998-1.007 [25.3492 to 25.5778]	195066	20 [0.230]	70 [0.805
1.290-1.300 [32.7660 to 33.0200]	111689	15 [0.1725]	70 [0.805]

Fuel Systems Group

The PT fuel system is exclusively on Cummins Diesels; it was developed for Cummins Engines by the Cummins Engine Company, Inc. The identifying letters "PT" are an abbreviation for pump functions of supplying fuel pressure at the proper time "pressure-time".

PT Fuel Pump—Unit 500

Two models of PT fuel pumps are used: the PT (type G) and PT (type R). The PT (type G) indicates that fuel pressure regulation is a part of the governor function. The PT (type R) refers to fuel pressure regulation as a function of a regulator assembly. Repair of both pump models is described in Bulletin No. 983535 or revisions thereof, and applies to all Cummins Engines. Calibration of these pumps is different; therefore, this phase of repair and trouble-shooting is covered in separate manuals also.

1. Bulletin No. 983505 covers calibration of the PT (type R) pumps as used on Cummins engines.

2. Bulletin No. 983525 covers calibration of the PT (type G) pumps as used on Cummins engines.

Natural Gas Engines

Natural Gas Engines, carburetor adjustment and throttle travel settings are covered in Group 14, Unit 1402 and Bulletin No. 983645 or revisions thereof.

Manuals on all Cummins products may be purchased through a Cummins Distributor.

Injector Group

This group covers injectors, tubing and connections which carry fuel to and from the injectors.

Injectors and Connections—Unit 600

Injectors and connections are described, with all repair and calibration information covered, in Bulletin No. 983536 or reprints thereof. All Cummins injectors are covered in the single manual due to the similarity of design and function.

Manuals on all Cummins products may be purchased through a Cummins Distributor.

Lubricating System

Lubricating system group consists of oil pan, lines, dipstick, filters, coolers, oil pumps and pressure regulators.

Engine Oil Flow

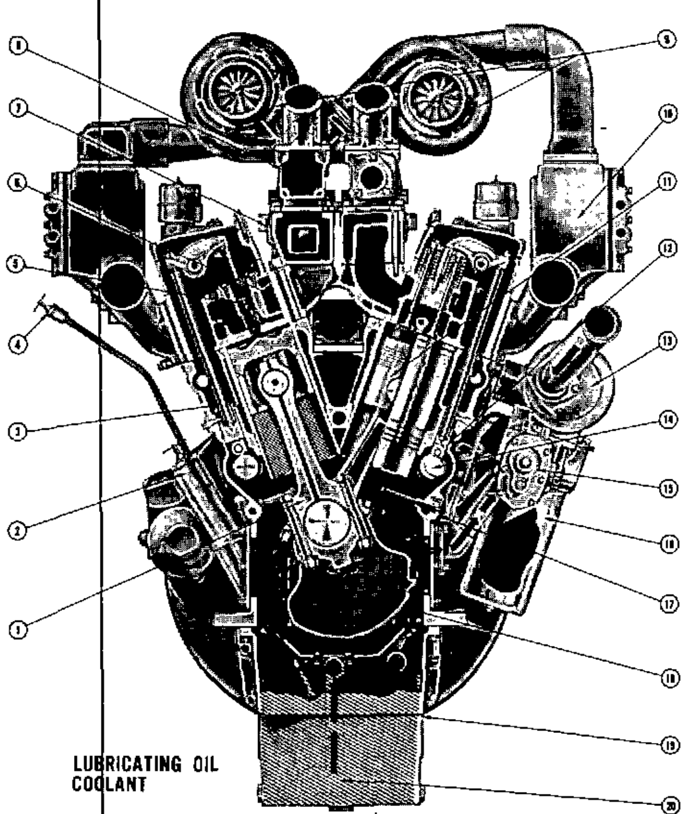
V-1710 Series engines are pressure lubricated by a gear-type lubricating oil pump. The lubricating oil pump is mounted on bottom of block, enclosed in the oil pan and driven by an idler gear from the crankshaft gear.

Oil, drawn from pan sump through a screen, is delivered to engine working components through oil lines and oil headers which are drilled the length of block. Drillings in block, cylinder head, crankshaft, connecting rods and rocker levers complete oil circulation passages. Fig. 7-0-1.

Oil circulation is from oil pan to pump and into cooler. The oil then flows to the oil filter and into oil header. Engines with oil-cooled pistons use headers to deliver oil to spray nozzles which direct oil to the pistons.

Main bearings receive oil from oil passages in block and connecting rod bearings are lubricated by oil drillings through the crankshaft.

Lubricating oil pressure is controlled by a pressure regulator



1. CONNECTING ROD
2. OIL FILLER
3. PUSH TUBE
4. OIL DIPSTICK
5. INJECTOR
6. COOLANT PASSAGE
7. EXHAUST MANIFOLD
8. THERMOSTAT HOUSING
9. T-50 TURBOCHARGER
10. INTER-COOLER/AIR INTAKE MANIFOLD
11. PISTON
12. TAPPET
13. OIL COOLER
14. CAMSHAFT
15. FUEL PUMP
16. FULL-FLOW OIL FILTER
17. PISTON-COOLING NOZZLE
18. OIL TO COOLER AND ENGINE
19. LUBRICATING OIL PAN
20. OIL SUCTION

Fig. 7-0-1, LWC 13. Oil flow—engine end view

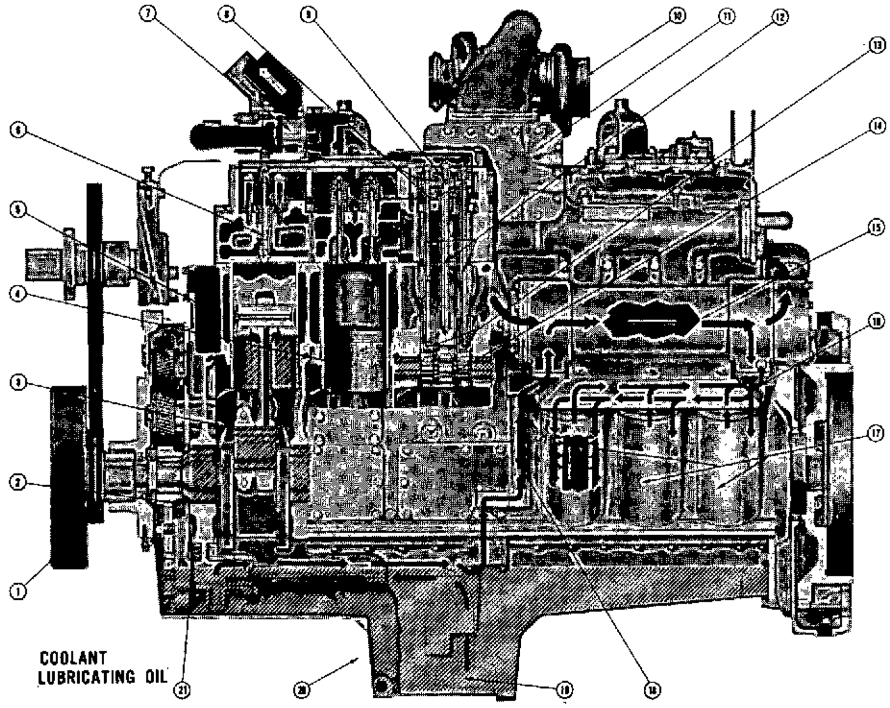


Fig. 7-0-2, LWC 14. Oil flow—engine side view

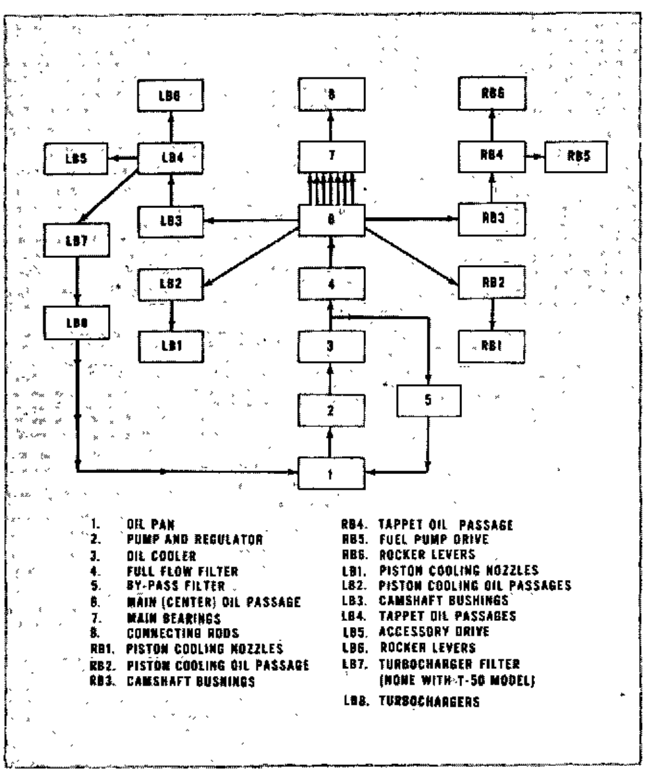


Fig. 7-0-3, V40730. Oil flow—schematic diagram

located in the oil pump. Operating pressure at governed speed is maintained between 50 and 90 psi [3.5154 and 6.3276 kg/sq cm].

Filters and screens are provided in lubricating oil system to remove foreign material from circulation and prevent damaging bearings or mating surfaces.

Maximum cleaning and filtration of the oil is achieved through use of both by-pass and full-flow lubricating oil filters. Full-flow filters are standard on all engines.

Some engines are equipped with special oil pans and by-pass filters for some applications, and others with auxiliary oil coolers to maintain closer oil temperature regulation.

The air compressor and turbocharger is lubricated from engine oil system. The turbocharger is also cooled by same lubricating oil used for lubrication.

Fuel pumps and injectors are lubricated by fuel oil, and most hydraulic governors, when used, use engine lubricating oil from a separate combination drive and oil sump.

Lubricating Oil Pan—Unit 701

Specifications

The extreme angular operation at which a vehicle is to be operated must be known and a lubrication system provided that is suitable for the maximum angle of operation. Engines for construction equipment must be equipped with the necessary components to permit at least 30 deg. vehicle angularity of operation. A scavenger lubricating oil pump is available to be used on engine applications where extremely high angularities are encountered. See Table 7-1-1 for oil pan capacities, sump location and permissible angularity.

Disassembly

1. Remove all gasket material from oil pan mating surfaces.

2. Remove damaged helicoil inserts (if used).

3. Remove pipe plug if necessary.

Cleaning And Inspection

1. Steam clean pan and all mounting parts.

2. Clean cast iron or steel pan in hot solvent tank.

Caution: Do not use solvent that will harm non-ferrous metal (aluminum, copper, brass, solder).

3. Visually check oil pan for cracks or, if a leak is suspected, check using dye penetrant.

a. Spray suspected area with dye penetrant.

b. Allow penetrant to dry for fifteen minutes. Do not "force dry"

c. Spray area with dye developer.

d. Check for crack indications.

4. Check helicoil inserts on aluminum oil pans. If lost or damaged mark for replacement.

5. Check all threaded holes for damaged threads.

Repair

1. Repair lost or damaged helicoil inserts.

a. Determine hole size; then use proper helicoil extraction tool to remove damaged helicoils. Recondition hole and insert new helicoil. Refer to Cummins Service Tool Catalog for proper helicoil tool.

b. Use starting and finishing tap for helicoil inserts for new or oversize holes in aluminum. When tapping aluminum, use fuel oil for lubricant to prevent tearing. Fig. 7-1-1.

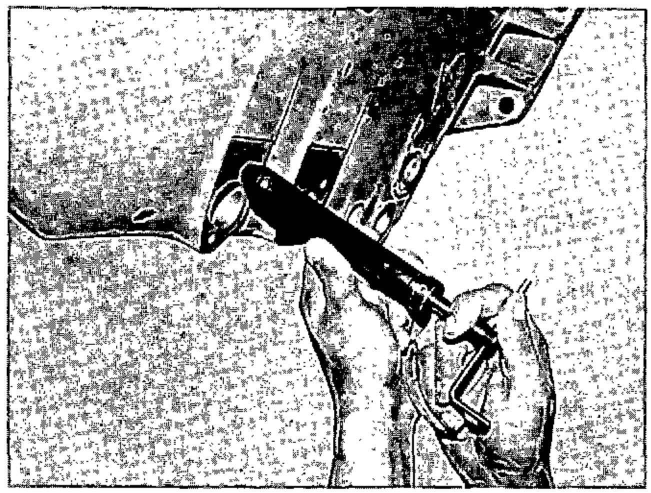


Fig. 7-1-1, V40731. Installing helicoil insert in oil pan

c. After inserting helicoil, bend starting end toward center then back toward side of hole to break off installation tip.

2. Repair small cracks in pan by welding. **Do Not Weld** finished surfaces.

3. Repair oil plug drain hole in aluminum or die cast oil pans when drain hole threads are damaged. Two oversize plugs are available to permit re-thread of oil pan drain holes at least twice.

a. Part No. 62117 Oil Pan Drain Plug; Size 1-1/4 inch x 12 thread.

(1) Enlarge damaged hole by drilling to 1 11/64 inch [29.7656 mm].

(2) Tap hole with a 1 1/4 inch x 12 tap. When tapping aluminum, use fuel oil for lubricant to prevent tearing of metal.

(3) Install new drain plug with a new copper gasket. Tighten to 60 to 70 ft-lb [8.2980 to 9.6810 kg m] torque.

Table 7-1-1: Oil Pan Capacity U.S. Gallons [Liters] and Maximum Operator Angularity

Part No.	Sump Location	Eng. Mtd. Tilt Angle	Capacity High	Low	Front Down	Front Up	Fuel Pump Side	Generator Side
181275	Center	0	18 [68.136]	16 [60.565]	30 deg.	35 deg.	35 deg.	35 deg.
196790	Front	0	18 [68.136]	16 [60.565]	30 deg.	35 deg.	35 deg.	35 deg.
*196789	Front	0	18 [68.136]	16 [60.565]	40 deg.	40 deg.	40 deg.	40 deg.
196793	Rear	0	18 [68.136]	16 [60.565]	30 deg.	35 deg.	35 deg.	35 deg.
196792	Rear	0	18 [68.136]	16 [60.565]	40 deg.	40 deg.	40 deg.	40 deg.
196794	Rear	8 deg.	28 [105.988]	26 [98.418]	30 deg.	50 deg.	45 deg.	45 deg.
198794	Rear	8 deg.	28 [105.988]	26 [98.418]	20 deg.	15 deg.	45 deg.	45 deg.

The maximum allowable down angles shown are based on the internal lubricating pump for engines rated at 2100 RPM or below. If engine speed ratings above 2100 RPM are used, the maximum allowable down angles must be reduced by 5 deg.

*When this front sump pan arrangement is used for crawler tractor type applications where 45 deg. angularity is required. The static oil level must be increased to 20 gal. [75.706 lit.] high and 18 gal. [68.136 lit.] low.

b. Part No. 120349 Oil Pan Drain Plug; Size 1 3/8 inch x 12 thread.

(1) Enlarge damaged hole by drilling 1 19/64 inch [32.9406 mm].

(2) Tap hole with a 1 3/8 inch x 12 tap. When tapping aluminum use fuel oil for lubricant to prevent tearing of metal.

(3) Install new drain plug with a new copper gasket. Tighten to 60 to 70 ft-lb [8.2980 to 9.6810 kg m] torque.

Assembly

1. Install pipe plugs to oil pan securely. **Do not overtighten.**

2. Apply new gasket to oil pan-to-block mating surface. Be sure mating surface is clean of all old gasket material before applying new gasket.

Table 7-1-2: Aluminum Oil Pan Plug Torques

Size	Torque — Ft-Lb	[Kg m]
1/8 inch	5/10	[0.6915/1.3830]
1/2 inch	20/25	[2.7660/3.4575]
1 inch x 18 with copper gasket	45/55	[6.2235/7.6065]
3/8 inch	20/25	[2.7660/3.4575]
1 inch	45/55	[6.2235/7.6065]

Use John Crane Plastic Lead Sealer Number 2, Crane Packing Co., Morton Groove, Illinois, or Teflon tape 0.003 inch [0.0762 mm] thick and wide enough to cover 5 full threads to obtain best seal.

Lubricating Oil Lines—Unit 702

Specifications

1. Hose used for lubricating oil or fuel should consist of a seamless synthetic rubber inner tube reinforced with fabric braiding and wire braiding, and covered with a synthetic rubber-impregnated oil-resistant fabric braid or rubber coating.

2. The minimum flexible hose sizes required for lubricating oil plumbing on Cummins engines are given in Table 7-2-1.

Table 7-2-1: Hose Size

Location	Minimum Hose Size
Turbo. Oil Supply	No. 6
By-pass Filter	See Unit 704

3. The hose should be capable of handling fluids ranging in temperature from −40 deg. to 300 deg. F. [−40 deg. to 148.9 deg. C] and be suitable for use with lubricating oil and/or fuel oil.

Caution: Since engine lube oil temperature may exceed 250 deg. F [121.1 deg. C] at full load operation and high ambients, hose meeting SAE specifications 100 R 1 and 100 R5 will not be adequate unless it is also capable of handling fluids within the temperature range as stated above.

4. Hose subject to high incidence of salt spray from road splash or on marine engines may require the use of corrosion-resistant wire braid or protective vapor-resistant wire braid or protective rubber covering, and should have brass hose fittings and adapters.

5. On those installations where there is high relative movement between parts connected by lube oil hose, such as filters mounted on frames and plumbed to the engine, consideration should be given to the use of premium-type hose material to avoid rubber fatigue which results in oil seepage and possible rupture of the hose liner.

6. Consideration should also be given to clamping of hose; that is, enough flexibility has to be provided to accommodate relative movement and at the same time clamps should be located as required to prevent chafing of the hose.

Cleaning

1. Clean all lubricating oil hose, inside and outside, in a tank of suitable solvent.

2. Dip hose in a hot-water tank and dry with compressed air, inside and outside.

3. Flush all flexible lubricating oil hose with a water solution containing a good grade soap cleaning compound at not more than 200 deg. F [93.3 deg. C]. Do not use steam.

Inspection

1. Inspect oil connections, flanges and tubing for cracks; reject if defective.

2. Inspect flexible hose for defects and deterioration. Reject hose that has become hard and brittle. Check for raised or swollen spots. Since flexible hose usually begins to deteriorate on the inside, the hose should be thoroughly checked for signs of internal collapse. If hose should collapse, lubricating oil flow would be seriously restricted.

Repair Old Style Fittings)

Replace defective or cracked hose and connections with new parts. Average life of flexible oil hose is 100,000 to 200,000 miles [160,900 to 321,000 km] or 3200 to 6400 hours depending upon amount of bend and temperature to which hose is subjected. For shops equipped to make up hose from bulk hose, follow steps below to insure proper fitting installation.

1. Cut hose to required length using a hacksaw.

2. Hose cut should be square within 5 deg.

3. Lay hose flat before cut is made.

4. Hose should not be crushed while sawing (crushed hose will permit nipple to pick up hose inner tube and block passage).

5. Place socket in jaws of a vise.

Note: Check all fittings to make sure of fit on mating part; see "Fittings" following.

6. Rotate hose counterclockwise while pushing it into socket.

7. Hold hose so it enters socket straight to prevent cocking of hose in socket.

8. Turn hose into socket until it bottoms.

9. Check hose to be sure it has bottomed and does not bell in from being pushed in too far.

10. Place socket and hose assembly in jaws of a vise. (Clamp on the socket).

11. Apply lubrication on nipple and inside of hose for ease of assembly using SAE 40 oil.

12. For Stratoflex Type 211 or Aeroquip Type 1503 hose, hand assembly tools are available for assembling nipple assemblies into hose and socket assembly. These tools have a pilot which makes assembling easier. A pilot should be used on hose sizes 4 through 12. Reference: Aeroquip Corp. Tool Kit No. 1597 SAE, for sizes 16 through 24 or Kit No. 1667 P.T.T. for Stratoflex Type 213 hose; nipple may be assembled to hose and socket assembly by turning nipple into socket using an appropriate wrench on the nipple hex.

13. For Stratoflex Type 211 or Aeroquip Type 1503, swivel nut and nipple can be easily assembled to socket and hose if nut and nipple assembly are first tightened on an adapter. With adapter-type assembly unit, a drill which closely corresponds to I.D. of fittings should be used as a pilot to start nipple into socket and base assembly. Adapters are not required for use with Stratoflex Type 213 hose.

14. Assemble nipple in socket and hose assembly.

15. On swivel assemblies there should be 1/32 to 1/16 inch [0.7937 to 1.5875 mm] clearance between nut and socket for Stratoflex 211 or Aeroquip Type 1503 hose. No clearance should be allowed for Stratoflex Type 213 hose.

16. Remove hose assembly from vise.

17. Inspect; no inner tube shavings are allowable.

Table 7-2-2: Hose Bends — Inch [mm]

Hose Size	Inside Dia.		Outside Dia.		Minimum Bend Radius	
4	3/16	[4.7625]	31/64	[12.3031]	2	[50.800]
5	1/4	[6.350]	35/64	[13.8906]	2-1/4	[57.150]
6	5/16	[7.9375]	39/64	[15.4781]	2-3/4	[69.850]
8	13/32	[10.3187]	47/64	[18.6531]	4-5/8	[117.475]
10	1/2	[12.700]	53/64	[21.0343]	5-1/2	[139.700]
12	5/8	[15.875]	61/64	[24.2093]	6-1/2	[165.100]
16	7/8	[22.225]	1-13/64	[30.5593]	7-3/8	[187.325]
20	1-1/8	[28.575]	1-31/64	[37.7031]	9	[228.600]
24	1-3/8	[34.925]	1-23/32	[43.6562]	11	[279.400]

Fittings

Fig. 7-2-1 illustrates different angle fittings (1 and 2) used on Cummins wire braid hose. Always check for correct mating parts. The bottom coupling (3) illustrates a universal unit to be used with either of the fittings shown. Failure to use proper combinations may cause air or fluid leaks.

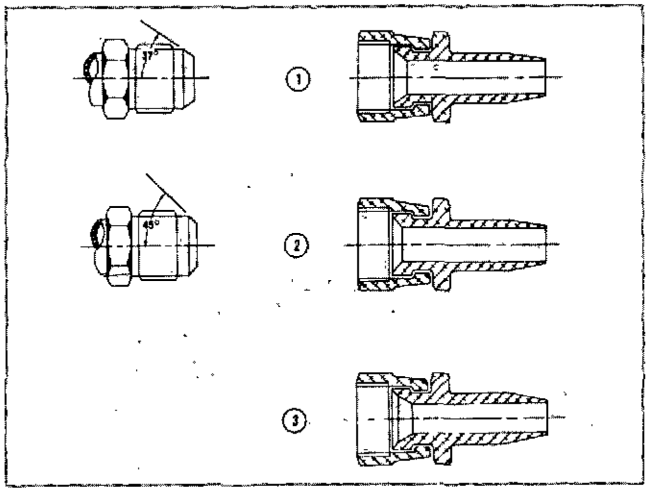


Fig. 7-2-1, N20725. Hose fittings

Repair (New Style Fittings)

New three piece swivel fittings were released replacing the two piece assembly, used with Stratoflex type 213 and 230 hose. See Fig. 7-2-2. For shops equipped to make up hose from bulk hose, follow steps below to insure proper fitting installation.

1. Place hose in vise and cut to desired length using fine tooth hacksaw or cut-off machine.

2. Place socket in vise and screw in hose counterclockwise.

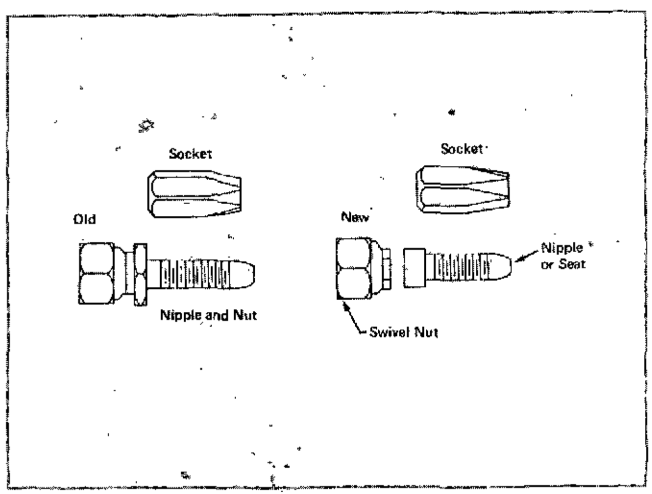


Fig. 7-2-2, V50708. Hose swivel fittings for Stratoflex 213 and 230 hose

3. Oil inside of hose and nipple (seat) threads liberally. Insert proper size assembly tool from ST-1160 Assembly Tool Kit into hose, working in and out until tool moves freely.

Note: ST-1160 Assembly Tool Kit, includes an assembly mandrel for each hose size 4, 5, 6, 8, 10, 12 and 16. In an emergency a brass fitting can be tightened in the swivel nut enough to enable turning the flare seat (nipple) into the hose and socket. ST-1160 cannot be used with old-style fittings nor can old-style hose assembly tools be used with new-style fittings. See Fig. 7-2-2.

4. Tighten nut and nipple (flare seat) on assembly tools with wrench.

5. Screw nipple into socket using wrench on hex of assembly tool. Leave 1/32 to 1/16 inch [0.7937 to 1.5275 mm] clearance between nut and socket so nut will swivel freely. Loosen tool from nut and remove.

6. For male pipe nipples screw nipple into socket using wrench on nipple hex, assembly tools are not required for installation of pipe nipple.

Caution: After assembly always look carefully inside fittings and hose for possible hose damage. This can be done with a flashlight. A cut in inside diamter of hose lining can plug hose bore when flow of fluid is sent through hose.

Lubricating Oil Dipstick—Unit 703

The dipstick supplied on each engine to check oil level has been calibrated for a certain oil level when used with a specific oil gauge tube and with engine in a certain position (angle of tilt sidways and fore and aft). Normally, a dipstick may be used for engine power angles +1 deg. from the angle specified for that particular dipstick. Too high an oil level will cause foaming, excessive oil temperature and power loss. Too low an oil level will result in oil pressure fluctuation and possible loss of oil pressure.

In the event a dipstick should be lost or damaged and a new dipstick is required:

1. If part number is known, from original engine parts list or from part number on old dipstick, replacement number should be used and recorded so further servicing problems will be avoided.

2. If it becomes necessary to mark a blank dipstick for use, see Table 7-3-1 for lengths available. Use straight or flexible dipstick, as required.

Table 7-3-1: Blank (Unmarked) Dipstick Length

Part Number	Inch	[mm]
131461	11-7/16	[290.5125]
131462	23-1/4	[590.550]
131463	47-11/16	[1211.2625]
161482	20-1/16	[508.0625]
161483	40-1/16	[1016.0625]
161484	60-1/16	[1524.0625]
197737	80-1/16	[2032.0625]

a. Determine oil pan part number; check high and low capacity. Table 7-1-1.

b. Place equipment where engine is in level or normal operating position.

c. Drain all oil from oil pan; drain both sumps, if engine is so equipped. Make sure all oil has drained from engine.

d. Fill oil pan with amount of oil indicated as low level in Table 7-1-1. Make sure oil goes into sump containing dipstick; allow sufficient time for oil to drain down into the pan. Where possible it is best to put clean oil directly into pan to get most accurate results.

e. Insert dipstick into dipstick tube until dipstick contacts bottom of pan. Measure distance dipstick protrudes above tube, remove dipstick and cut off end the same amount as measured protrusion (to bottom of cap).

f. Insert dipstick all the way into tube. Remove dipstick and mark low oil level indicated. Mark should be 0.010 inch [0.2540 mm] deep. Stamp (electric etch on spring steel) letter "L" immediately above mark (2, Fig. 7-3-1).

Caution: Do not use a chisel for marking, or stamp too deep. This may cause dipstick to break.

g. Cut excess length off dipstick leaving minimum of 1/2 inch [12.7000 mm] below low level mark.

h. Add amount of oil to pan to bring to high level as indicated in Table 7-1-1. Allow time for all oil to drain into pan.

i. Insert dipstick and withdraw; now mark oil level indicated. Stamp letter "H" immediately above mark (2).

j. Mark opposite side of dipstick (if desired) for running levels (1, Fig. 7-3-1). Running levels provide equivalent readings to static levels with engine running at low idle (550+25 RPM). Add running level marks with oil supply, low, as stated in Item d, mark as per Item f; for high level, as stated in Items h and i above.

Note: Running level readings require oil gauge tube with increased internal length and an internal drilled hole to provide for tube venting (if not originally equipped with running level markings).

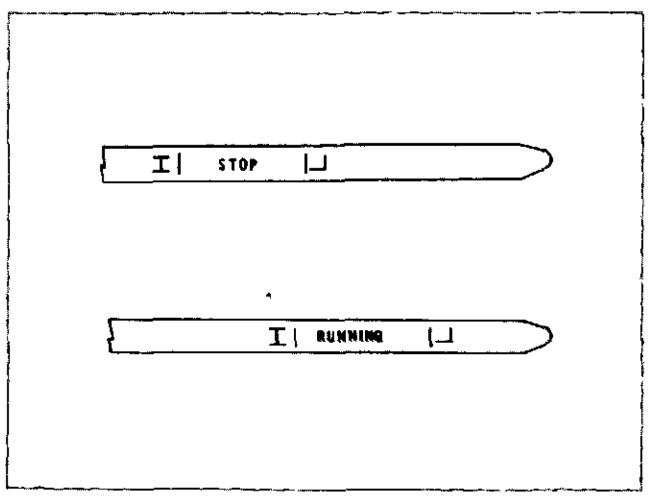


Fig. 7-3-1, V40726. Dipstick markings

Lubricating Oil Filters—Unit 704

Full-Flow Paper Element Filter

Disassembly

1. Remove drain plug from filter case and allow oil to drain.

2. Loosen and remove capscrew from filter head and remove filter case and element; remove seal ring and discard. Piston cooled engines have three filters; non-piston cooled have two filters.

3. Lift element from case; inspect element pleats for metal particles and discard. Fig. 7-4-1.

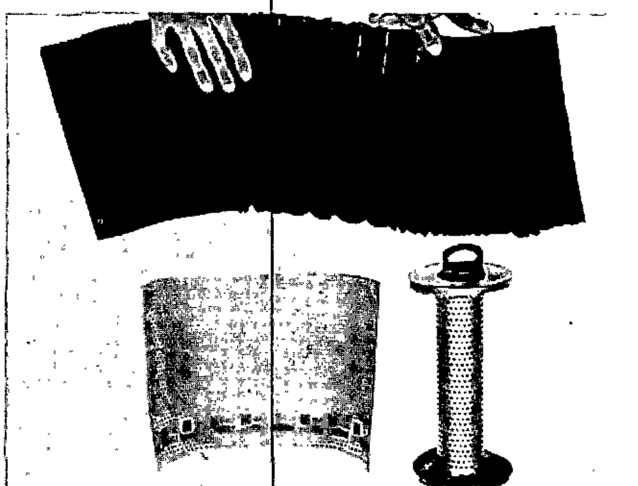


Fig. 7-4-1, V40727. Remove wrapper, inspect element pleats

Note: If metal is found in elements, an inspection should be made at once to find the source.

4. The filter by-pass valve normally requires no servicing; however, check to make sure the valve works freely. The valve is spring loaded and opens on a pressure differential. Fig. 7-4-2.

Cleaning and Inspection

1. Remove all pipe plugs and fittings from filter head. Fig. 7-4-2. Remove filter by-pass valve retainer (5), valve seat (4) and spring (3) from filter head (1), if necessary after Step 4 above.

Note: Housing (2) may remain in filter head.

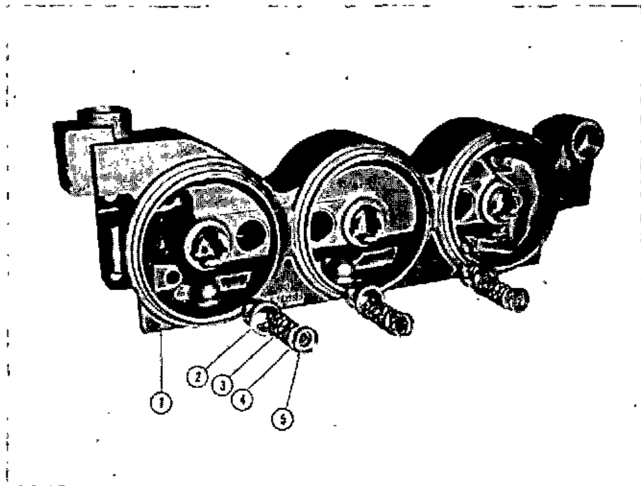


Fig. 7-4-2, V40725. By-pass valves—full-flow filter

2. Clean housing and case in approved cleaning solvent and dry with compressed air.

3. Remove snap ring from capscrew securing support, seal, washer and spring on capscrew in case.

4. Slide bolt from case; remove and discard copper washer and seal.

5. Inspect all parts for wear or distortion; discard and replace all damaged parts.

Assembly

1. Position new copper washer on capscrew.

2. Insert capscrew in filter case; slide spring, washer, new seal and support over capscrew; secure in position with snap ring on capscrew.

3. Coat all plugs and fittings with sealing tape or lead sealer; install in filter head.

4. If removed, insert filter by-pass valve spring (large end first) in filter head; position relief valve in bore over spring and secure with retainer; press retainer in bore flush with head. Fig. 7-4-2.

5. Position new seal ring on filter head; slide new element with seals in place over capscrew and into filter case.

6. Position assembly to filter head and secure with

capscrew; tighten to 25 to 35 ft-lb [3.4575 to 4.8705 kg m].

By-Pass Filter

On most engines a by-pass filter is used in conjunction with a full-flow filter. Two Cummins Fleetguard 750 series by-pass filters are usually used on all turbocharged (and normally on all construction equipment) applications of V12 series engines.

Note: Never use a by-pass filter instead of a full-flow filter.

Disassembly

1. Remove clamping ring capscrew (1, Fig. 7-4-3) and lift off cover (2).

2. Unscrew upper support element hold-down assembly (3) and lift out hold-down assembly and element (4).

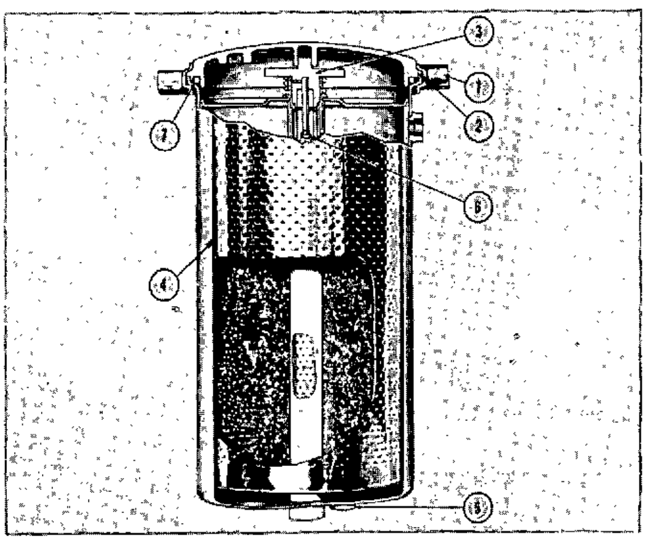


Fig. 7-4-3, V41908. Cross-section by-pass filter

Cleaning and Inspection

1. Clean housing and hold-down assembly in solvent.

2. Inspect hold-down assembly spring and seal. Replace if damaged.

3. Inspect drain plug (5) and connections. Replace if worn or damaged.

4. Check filter cover "O" ring (7). Replace if damaged.

5. Clean orifice (6) in upper support; this orifice is very important and controls amount of flow through the by-pass filter.

Assembly

1. Install new element

2. Replace upper support element hold-down assembly in filter and tighten down to stop.

3. Position "O" ring gasket on housing flange.

4. Install cover and clamping ring; tighten capscrew until clamping lugs come together.

Flow Characteristics And Specifications

With a 180 deg. F [82.2 deg. C] oil temperature and with engine at high idle, oil flow through the by-pass filters must be 3 minimum to 4 gal. per minute maximum [11.3560 to 15.1413 lit] (total flow through both filters) to insure maximum filtration and maintain adequate oil pressures.

Hose Size

1. The supply and drain lines should be No. 6 (5/16 inch [7.9375 mm] inside diameter) flexible hose up to 10 ft [3.048 m] in length. For lines over 10 ft [3.048 m], use No. 8 (13/32 inch [10.3187 mm] inside diameter). All fittings in by-pass circuit should be no less than 1/4 inch [6.350 mm] pipe size.

2. The return line should discharge below oil level in the oil pan to prevent foaming.

3. Supply line should be connected to oil circuit between oil pump and full-flow filter, Fig. 7-0-2..

Lubricating Oil Coolers—Unit 705

Engine Oil Cooler

Oil coolers shown in Fig. 7-5-1 are mounted on brackets secured to the cylinder block on the fuel pump side, near the flywheel housing.

Removal

1. Remove capscrews and lockwashers securing water supply and discharge connections, gaskets and lines; discard gaskets and "O" rings.

2. Remove capscrews and lockwashers securing oil cooler assembly to full-flow filter head; lift cooler from filter head; discard gaskets.

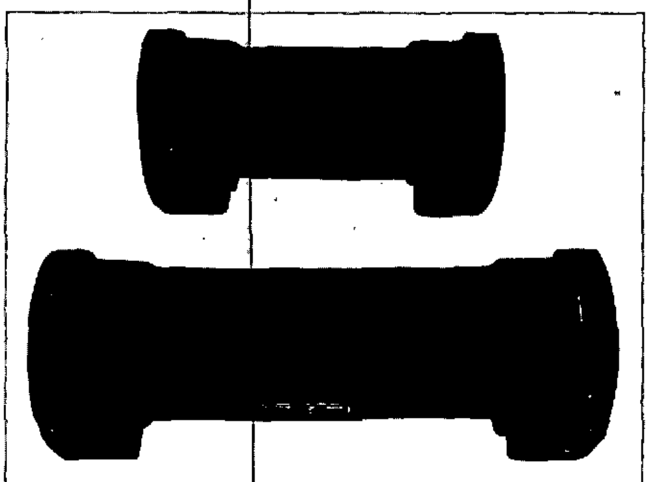


Fig. 7-5-1, V40732. Engine oil cooler assembly

Disassembly

1. Remove capscrews and lockwashers securing end cover plates to oil cooler; remove end cover plates; discard gaskets. Fig. 7-5-2.

Cleaning and Inspection

1. To prevent hardening and drying of foreign substances, clean cooler assembly immediately after removing end cover plates with approved cleaning solvent that will not harm non-ferrous metal.

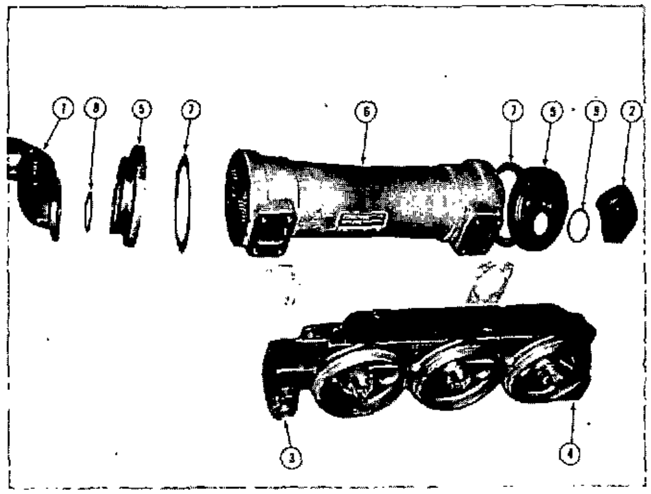


Fig. 7-5-2, V40815. Oil cooler end view, cover plate removed

2. Finish cleaning by blowing through core with compressed air.

3. Inspect core for corrosion or cracks where tubes are welded to end plates.

4. Clean connections and lines in approved cleaning solvent and inspect for cracks or damage.

5. Inspect lubricating oil cooler assemblies for leakage between oil and water passages.

a. Clamp cooler assembly in fixture and assemble air connection.

b. Place unit in water tank and apply 1 to 4 psi [0.07031 to 0.28124 kg/sq cm] air pressure to water side.

c. Inspect for air leaks, porosity in casting, etc.

d. Apply line air pressure, 35 to 40 psi 2.4607 to 2.8123 kg/sq cm] to oil side.

e. Inspect for air leaks as per step "c".

Repair

Repair damaged tubes by inserting a smaller O.D. tube inside damaged tube. Cut and flare ends; then solder securely. Do not restrict more than 5% of total number of tubes in this manner. If more than 5% of tubes are defective, discard cooler.

Caution: Do not damage adjacent tubes with heat while soldering.

Assembly

1. Assemble end cover plates (5, Fig. 7-5-2) to oil cooler housing (6) with new gaskets (7), lockwashers (8) and capscrews (9).

2. Mount oil cooler assembly to full-flow filter head with new gaskets, lockwashers and capscrews.

3. Assemble water supply and discharge connections and lines with new gaskets, "O" rings, lockwashers and capscrews.

Auxiliary Oil Cooler

Disassembly

1. Remove all flanges, hose and connections from oil cooler.

2. Remove cover plates from oil cooler and water cooler sections of oil cooler.

3. Remove core from housing if removable type.

Note: To prevent hardening and drying of foreign substances, clean core(s) as soon as possible after removal.

Cleaning (Oil Side)

1. Immerse the core in carbon tetrachloride or trichlorethylene or in other approved cleaning solvent. Let unit stand in solvent for several minutes. Force cleaner around tubes with hand rubber suction cup or with hand or motor-driven pump. Continue until clean.

Caution: This operation should be done in open air or in a well-ventilated room to avoid toxic effect of chemicals being used.

2. If oil passages are badly clogged, circulate an oakite or alkaline solution through the tubes. After cleaning, flush thoroughly with hot water.

Note: Flush inside of tubes with clean, light oil after both oil and water sides of cooler have been cleaned.

Cleaning (Water Side)

1. Immerse core of oil cooler in solution of one part muriatic acid and nine parts water after adding 1 lb. [0.4536 kg] of oxalic acid and 0.01 gal [0.0379 lit] of pyridene to each 5 gal. [18.925 lit] of solution.

2. Remove core when foaming and bubbling stops. This usually takes 30 to 60 seconds.

3. Immerse unit in a 5% solution of sodium carbonate. Remove when bubbling ceases and pressure flush with clean, warm water.

4. Clean inside of case thoroughly with steam, or solvent, or both.

Inspection and Repair

1. If leak occurs in a tube, repair by inserting a smaller O.D. copper tube inside the damaged tube.

2. Cut and flare ends of smaller tube and solder both ends securely.

3. Be careful not to damage adjacent tubes with torch flame.

4. Do not restrict more than 5% of total number of tubes in this manner. To do so would result in an undesirable increase in operating temperature, as well as considerable pressure drop.

Assembly and Testing

1. *Install oil cooler units in housing.*

2. Replace all old gaskets and "O" rings with new ones. Dip new gasket in light machine oil for 1 or 2 minutes before installing.

3. Assemble covers and mounting brackets with lockwashers and capscrews.

4. Seal core outlet.

5. Seal inlet with fitting designed for application of air hose and gauge.

6. Subject core to 35 to 40 psi [2.4607 to 2.8123 kg/sq cm] allowing only atmospheric pressure in the casting.

7. Permit unit to stand for 15 to 20 minutes; then check pressure gauge for pressure drop which will denote a tube or header leak.

8. To test case, seal coolant outlet and fill casing with water; then follow same procedure as in core test. A pressure drop on gauge will denote a casing leak.

9. If core is not intended for immediate use after repair and test, it should be prepared for storage.

a. Allow unit to drain thoroughly and blow out remaining liquid with air.

b. Flush light machine oil or soluble oil through tubes and drain off excess.

c. Seal all inlets and outlets to prevent entrance of dirt or foreign matter.

Lubricating Oil Pump—Unit 706

Standard, Mounted In Oil Pan (To Block)

The standard lubricating oil pump is shown in Fig. 7-6-1; (1) is pressure oil outlet, (2) regulator by-pass and (3) suction tube connecting point.

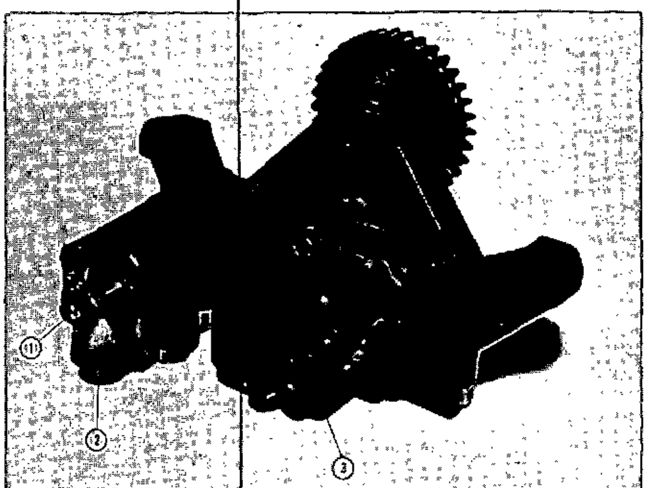


Fig. 7-6-1, V40728. Lubricating oil pump—assembled

Disassembly

1. Refer to Fig. 7-6-2; remove capscrews (35, 36, 18, 19) and lockplates (34) securing pump body (17) to cover (8).

2. Use ST-1115 Cover Puller or carefully drive cover (8) (with soft hammer or brass punch) from body (17) and remove gasket (15); shafts (12, 27) for idler gears serve as dowels.

3. Remove idler gears (14, 25) from shafts (12, 27); remove shafts from pump body (17); if worn, see Table 7-6-1.

4. Remove Huglock nut (1), retainer washer (2), intermediate drive gear (3) and thrust washer (7); press out shaft (10).

5. Press drive gear (37) from drive shaft (28).

6. Remove drive shaft assembly from body.

7. Press internal gear (26) from shaft (28), if shaft or gear is worn or damaged.

8. Remove plunger cap (32) and gasket (31); remove plunger (29) and spring (30) from body (17). Fig. 7-6-2.

Cleaning And Inspection

1. Wash all parts in cleaning solvent; dry with compressed air.

2. Check and replace bushings as required. See Table 7-6-1 for all worn limits.

3. If shafts are worn or scored, they must be replaced.

4. Replace cover, or body, if finished surfaces in gear pockets are scored or visibly worn.

5. The drive and idler gears must be replaced if worn or scored or damaged.

6. Check all hardware for worn or damaged threads; replace as necessary.

7. Thoroughly clean and lubricate all parts before assembly.

Assembly

1. Place plunger (29, Fig. 7-6-2) and spring (30) in body; secure with gasket (31) and cap (32).

2. Press internal drive (driven) gear (26) onto short end of drive shaft (28) until shaft extends through gear 1.020 to 1.040 inch [25.9080 to 26.4160 mm] if removed.

3. Install drive shaft assembly in pump body.

4. Press external drive gear (37) on drive shaft, leaving 0.061 to 0.063 inch [1.5494 to 1.6002 mm] end thrust.

5. Press in intermediate drive gear shaft (10) until it seats; mount thrust washer (7), intermediate gear (3), retainer washer (2) and Huglock nut (1). Torque Huglock nut (1) to 50 ft-lb [6.9150 kg m].

6. Place idler gears (14, 25) in pump body; install shafts first (12, 27), if removed; press shafts in until they protrude 0.860 to 0.890 inch [21.8440 to 22.6060 mm] above face of body.

7. Place gasket (15) on pump body (17); assemble cover (8) to body; press together, using pilot capscrews near each end to pilot gakset.

8. Secure cover to body with lockplates and capscrews.

Note: Check drive shaft for freeness.

9. Lock capscrews in position with lockplate tangs.

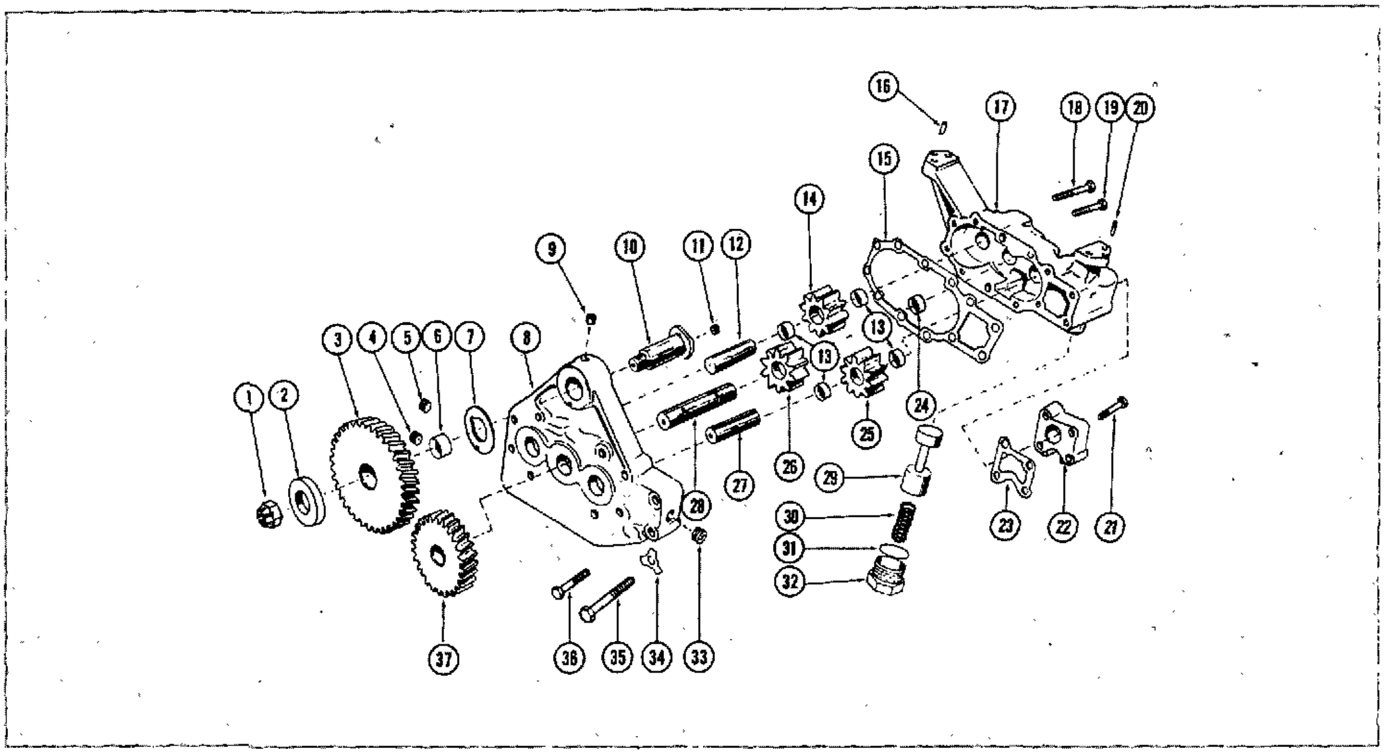


Fig. 7-6-2, V40729. Lubricating oil pump-exploded view

Tabel 7-6-1: V-1710 Lubricating Oil Pump Dimensions

Part Description	New Minimum Inch [mm]		New Maximum Inch [mm]		Worn Limit Inch [mm]	
Drive Idler Gear Bushing I.D.	0.9925	[25.2095]	0.9935	[25.2349]	0.9945	[25.2603]
Pump Drive Shaft Bushings I.D.	0.8767	[22.2681]	0.8777	[22.2935]	0.8787	[22.3189]
Pump Idler Gear Bushing I.D.	0.8800	[22.3520]	0.8805	[22.3647]	0.8815	[22.3901]
Drive Idler Shaft O.D.	0.9905	[25.1587]	0.9910	[25.1714]	0.9900	[25.1460]
Drive Shaft O.D.	0.8745	[22.2123]	0.8750	[22.2250]	0.8743	[22.2072]
Pump Idler Shaft O.D.	0.8775	[22.2885]	0.8780	[22.3012]	0.8770	[22.2758]
Drive Gear I.D.	0.8735	] 22.1869]	0.8740	[22.1996]	0.8741	[22.2021]
Driven Gear I.D.	0.8735	[22.1869]	0.8740	[22.1996]	0.8741	[22.2021]
Drive Idler Gear Thrust	0.001	[0.0254]	0.011	[0.2794]	0.013	[0.3302]
Drive Idler To Pump Drive Gear Backlash	0.006	[0.1524]	0.009	[0.2286]	0.012	[0.3048]
Driven Gear to Idler Gears Backlash	0.016	[0.4064]	0.020	[0.5080]	0.024	[0.6096]
Depth of Bushing in Drive Idler Gear	0.030	[0.7620]	0.040	[1.0160]	— —	— —
Depth of Bushing in Pump Cover	0.000	[0.000]	0.030	[0.7620]	— —	— —
Depth of Bushing in Pump Body	0.000	[0.000]	0.030	[0.7620]	— —	— —
Depth of Bushing in Idler Gears	0.000	[0.000]	0.020	[0.5080]	— —	— —
Protrusion of Idler Gear Shafts Above Pump Body to Cover Surface	0.860	[21.8440]	0.890	[22.6060]	— —	— —
Drive Gear to Cover Clearance	0.061	[15.4940]	0.063	[16.0020]	— —	— —
Driven Gear Location from Body of Drive Shaft	1.020	[25.9080]	1.040	[26.4160]	— —	— —
Thrust Washer Thickness	0.061	[1.5494]	0.063	[16.0020]	0.059	[1.4986]
Hug Nut Torque	50 ft-lb	[6.9150 kg m]	55 ft-lb	[7.6065 kg m]		

Scavenger Oil Pump

Disassembly

1. Remove capscrews (13, Fig. 7-6-3) and lockwashers (4) securing bracket to body. Tap bracket from body and discard gasket.

2. Slide driven gear (18) from shaft.

3. Support bracket and press drive shaft from external drive gear (1).

4. Remove shaft and internal drive gear (8) from bracket; press shaft from gear.

Cleaning and Inspection

1. Clean all parts in an approved cleaning solvent and dry with compressed air.

2. Check pump driven gear shaft outside diameter; if worn smaller than 0.7465 inch [18.9611 mm], pull from body and mark for replacement.

3. Remove bracket and body bushings if worn larger than 0.8765 inch [22.2631 mm].

4. Remove pump driven gear bushings if worn larger than 0.7515 inch [19.0881 mm].

5. Replace drive shaft if worn smaller than 0.8735 inch [22.1869 mm].

6. Discard any gear that is scored, chipped or shows excessive wear.

Repair

1. If driven gear bushings were removed, press new bushings into gear until 0.060 to 0.080 inch [1.5240 to 2.0320 mm] below surface. Bore bushings to 0.7500 to 0.7505 inch [19.0500 to 19.0627 mm] inside diameter.

2. If drive shaft bushings in bracket and body were removed, press new bushings into bracket and body until flush to 0.030 inch [0.7620 mm] below surface. Bore bushings to 0.875 to 0.8755 inch [22.2250 to 22.2377 mm] inside diameter.

Assembly

1. Press internal drive gear (8, Fig. 7-6-3) on shaft (9) from internal drilled oil line end, so shaft protrudes 0.970 to 0.980 inch [24.6380 to 24.8920 mm].

2. Press driven gear shaft (10) into body (11) so shaft protrudes 2 13/16 inch [71.4375 mm] above bottom finished surface of body.

3. Slide drive shaft assembly into bracket (3).

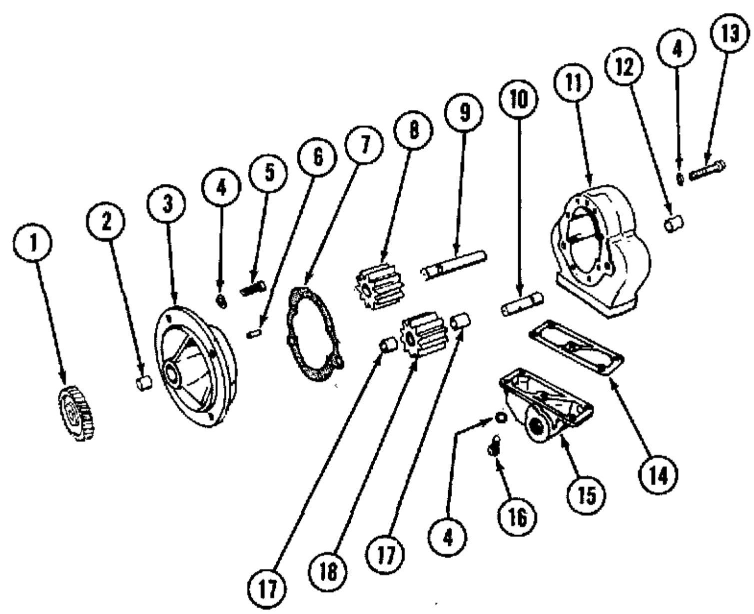


Fig. 7-6-3, V40734. Scavenger oil pump-exploded view

4. Press external driver gear (1) on shaft (9) until flush to 0.050 inch [1.2700 mm] shaft protrusion.

5. Slide driven gear (18) on shaft (10); assemble bracket (3) to body (11) using new gasket (7). Secure with lockwashers and capscrews. Check end clearance; it must be 0.002 to 0.004 inch [0.0508 to 0.1016 mm].

Cooling System Group

The cooling system group consists of the engine water pump, fan hub, thermostats, corrosion resistor, heat exchanger, sea or raw water pump, coolers, radiator and other thermo-controls.

Water Pump—Unit 801

Disassembly

1. Remove capscrews (21) Fig. 8-1-1, lockwashers (22), gasket (2) and cover (1) from water pump body.

2. Pull impeller (10) from shaft (7) with ST-647 puller.

3. Pull pulley sheave hub (12) from pump drive shaft (7).

4. Remove snap ring (11) from pulley end of body (6) and press out shaft spacer (23) and bearings (9).

5. Remove carbon face seal (4) from pump body (6); discard.

6. Press shaft (7) from bearings (9) and spacer (23); only if damaged remove retaining ring (8) from groove in shaft.

Cleaning

1. Clean all non-ferrous parts in Bendix carburetor cleaner or equivalent.

2. Immerse other parts in a solvent tank.

3. Make sure all traces of grease are removed.

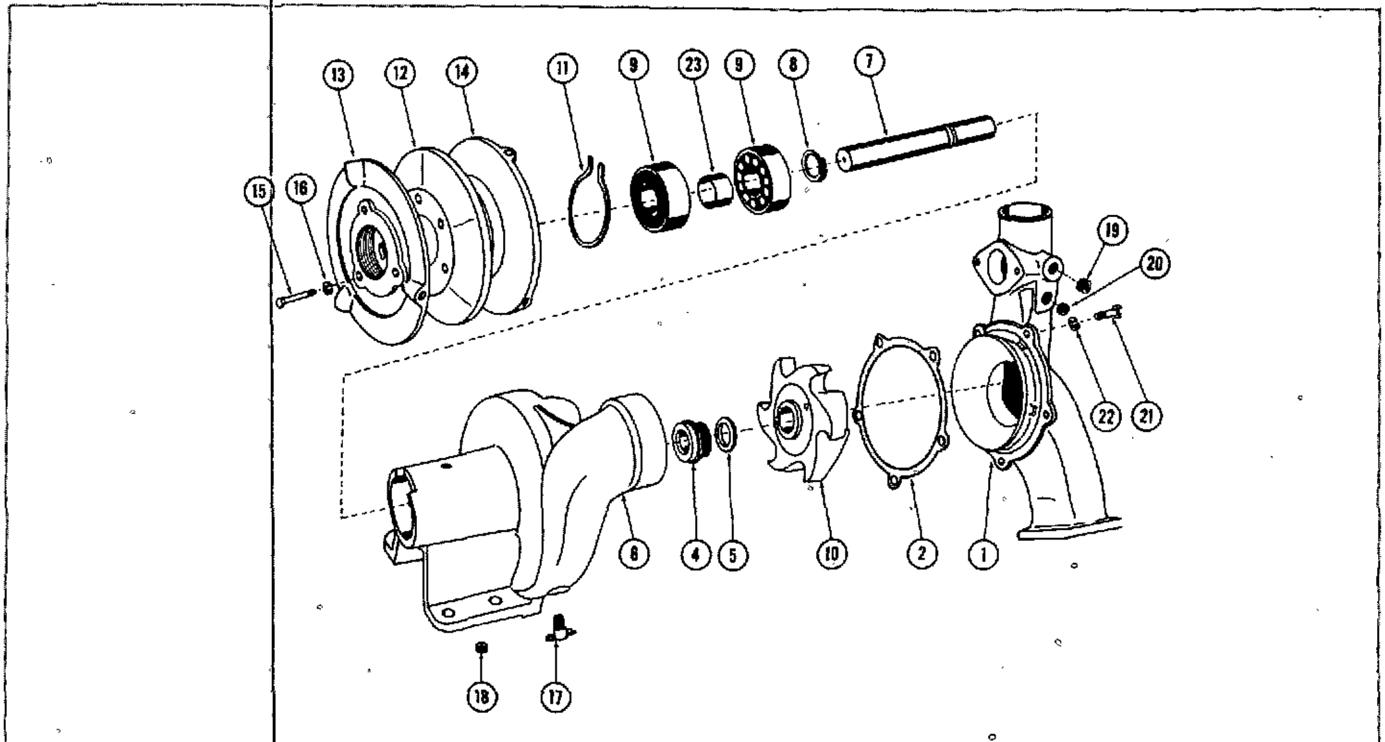


Fig. 8-1-1, V40810. Water pump — exploded view

Inspection

1. Inspect water pump bearing(s). Mark for replacement bearing(s) with rough or worn race(s) and damaged shield.

2. Inspect water pump impeller and cover. Mark for replacement if cracked or corroded to extent that it will interfere with circulation.

3. Measure impeller bore and shaft outer diameter. There must be a minimum of 0.0015 inch [0.0381 mm] press-fit between shaft and impeller; replace if necessary.

4. Inspect water pump mounting parts for cracks. Replace as necessary.

5. Examine carbon face seal carefully to make sure it is not cracked or chipped. Fig. 8-1-2. Usually it is best to install a new seal.

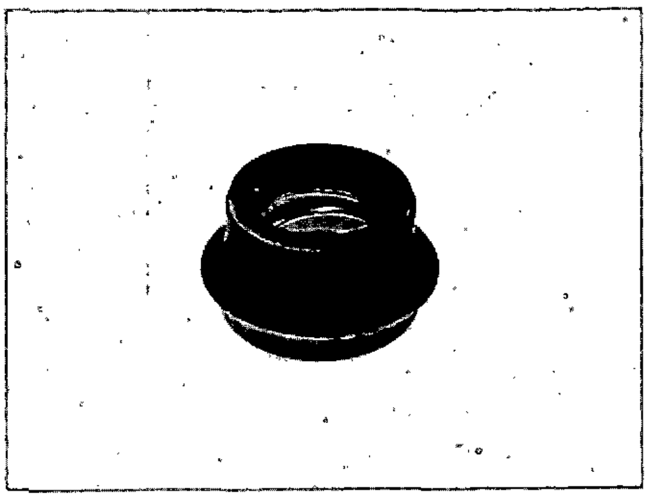


Fig. 8-1-2, V40811. Carbon face seal

6. Inspect metallic seat; if damaged, mark it for replacement.

Replacing Metallic Seat

The new seal assembly (metallic ring and rubber seat) is thicker than the former ceramic and film; therfore, for service usage it is necessary to machine stock from the old-style impeller ceramic seat surface to incorporate the new seal seat.

1. Strike damaged ceramic seat with a sharp tool perpendicular to axis of impeller.

2. Measure distance from ceramic seat surface to end of impeller bore. See Fig. 8-1-3.

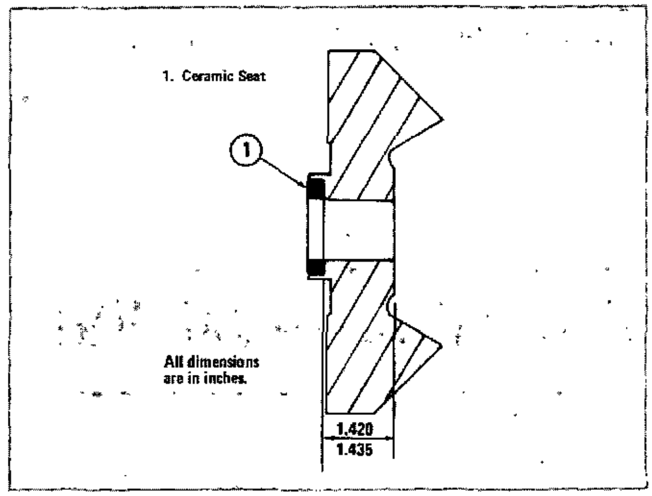


Fig. 8-1-3, V40822. Old style impeller

3. Machine the ceramic seat surface to the dimensions shown in Fig. 8-1-4. Only the "boss" which forms the old-style seat area is to be removed.

Caution: The machine surface must be square to the center line of the impeller bore within 0.002 inch [0.0508 mm] total indicator reading at a 0.75 inch [19.0500 mm] radius. All tool marks should be circumferential to the impeller bore. Radial tool marks may cause leakage.

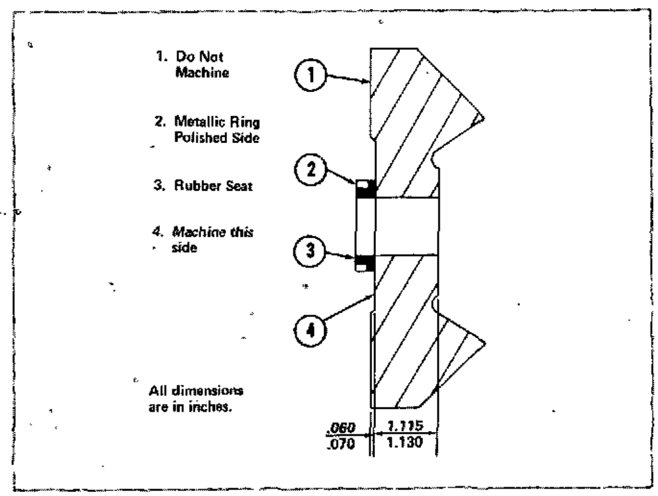


Fig. 8-1-4, V40823. Old style impeller conversion

Assembly

1. Place bearing retaining ring (8, Fig. 8-1-1) over long end of water pump drive shaft (7); press into first ring groove with a piece of tapered steel tubing.

2. Pack bearings (9) full of grease meeting specifications at

end of Group 18.

3. Press shielded bearing (9) with shielded side to retaining ring (8) over shaft until bearing seats against retaining ring. Bearings go on "long" end of shaft using the retainer ring as a guide point.

Note: Apply load to inner bearing race only.

4. Slide bearing spacer (23) over shaft (7). against bearing.

5. Place bearing (9) with open side to spacer, over water pump shaft and press into place.

6. Pack space between bearings 55 to 65% (0.84 to 0.99 oz. [23.8136 to 28.0660 G] full of grease meeting specifications in Group 18.

7. Press shaft and bearing assembly into water pump body (6).

8. Assemble large snap ring (11) to hold bearing and shaft in position.

9. Place rear adjustable sheave (14) on pulley hub (12); press pulley hub and sheave onto drive shaft until hub seats against bearing race. Support other end of shaft during pressing operation; mount front adjustable sheave (13). Turn water pump body assembly over and press in carbon face seal (4) with a section of 1 3/4 inch [44.4500 mm] inside diameter by 2 inch [50.8000 mm] outside diameter tubing until it seats.

10. Lubricate the inside diameter of the new rubber seat with a light coat of water soluable lubricant.

Caution: Do not allow any lubricant on the seal face of the metallic ring.

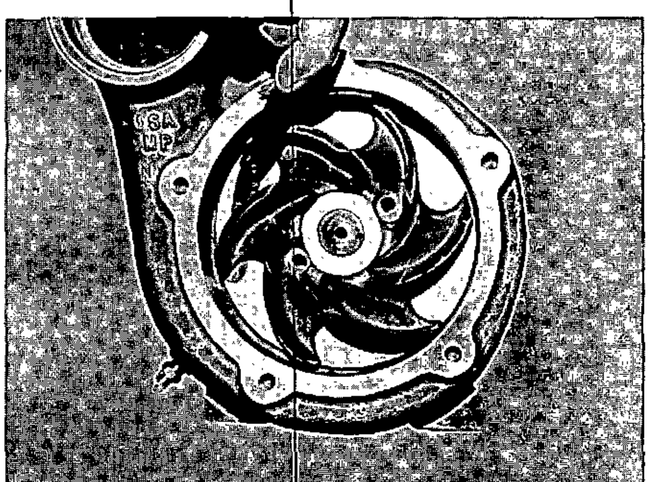


Fig. 8-1-5, V40812. Checking impeller clearance

11. Slide the seat assembly (rubber and metallic ring) over the water pump shaft until the polished side of the metallic ring bottoms against the carbon face of the pump seal.

12. Press impeller (10) onto shaft until there is 0.020 to 0.031 inch [0.5080 to 0.7874 mm] clearance between back of impeller and water pump body (6).

13. Install water pump cover (1) and new gasket (2) to water pump body (6). Check clearance between impeller vanes and cover Fig. 8-1-5; it should be 0.020 to 0.040 inch [0.5080 to 1.0160 mm].

Fan Hub—Unit 802

Fan

Check for bends, dents or cracks and replace if damaged.

Fan Hub

Disassembly

1. Remove capscrews and washers from fan plate (1, Fig. 8-2-1); remove plate, pilot (16) and gasket (2).

2. Remove cotter pin (15), nut (14) and washer (3).

3. Press shaft (12) from fan hub (4).

4. Remove seal (8) from hub.

5. Press bearings (7) and (13) from fan hub shaft.

6. Remove pulley (6) from hub if either part is damaged.

7. Remove grease plugs (5) from hub.

Inspection

1. Clean all parts in an approved cleaning solvent and dry with compressed air.

2. Inspect spindle bearing surface and inside diameter of bearing; it must be 0.000 to 0.001 inch [0.0000 to 0.0254 mm] press fit. Mark for replacement if rough or worn.

3. Discard seal and all other fan hub parts that are worn or defective and replace.

Assembly

1. Pack bearings with grease meeting specifications at end of Group 18. Press (do not drive) outer race of bearings into fan hub housing with cupped area up. Outer race must seat against shoulders provided in housing.

2. Press cone (inner race and rollers) of rear bearing onto fan hub spindle (12) against shoulder.

3. Pack bearing cones of both bearings with grease, working as much grease between inner race, rollers and cage as possible. Coat cup in housing (4) with grease.

4. Lower housing (4) and outer bearing race assembly down over fan spindle (12).

5. Press cone (inner race and rollers) of outer bearing on spindle (12). Be careful in assembly not to use too much force – only enough to slide assembly over spindle (12) is required.

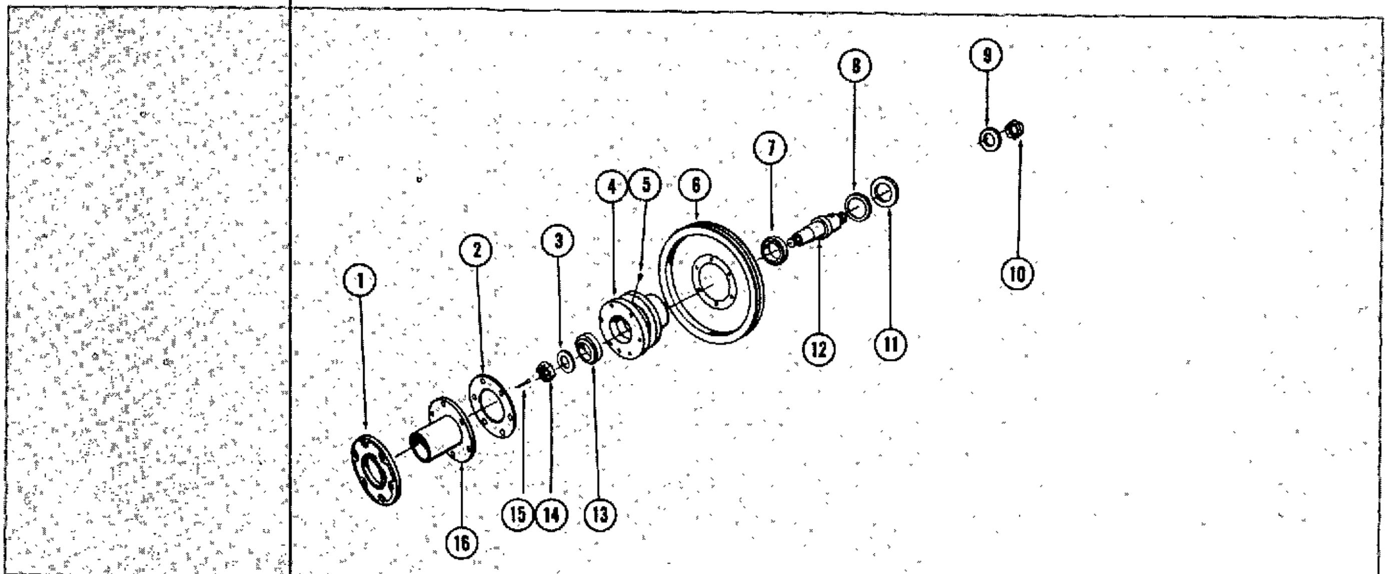


Fig. 8-2-1, V40813. Fan Hub assembly

6. Install washer (3).

7. Assemble slotted nut (14) to spindle (12).

8. Slowly rotate housing (4) around spindle (12) and at the same time tighten nut (14). Tighten until a small amount of "drag" is felt during rotation of housing.

Caution: Hub (4) must be rotated while nut (14) is being tightened. Failure to rotate hub will result in excessive end play.

9. Loosen nut (14) approximately 5 deg. to 30 deg. or one-half castellation if cotter pin is used.

10. Install cotter pin (15), but do not bend over.

11. Support fan hub assembly in a press by holding as near hub of pulley as possible. Apply sufficient force to nut end of shaft, to force cone against the nut which will give bearing clearance.

Caution: The force required to move inner cone against nut should never exceed that required to press cone on shaft.

12. Check housing (4) end clearance. It must be 0.001 to 0.007 inch [0.0254 to 0.1778 mm]. Hub must rotate freely. Loosen or tighten nut (14) if required and repeat Steps 9, 10, 11 and 12.

13. Bend cotter pin (15) and lock nut (14) in place.

14. Apply 0.2 to 0.3 oz. [5.6699 to 8.5049 g] of grease (Approximately 2 teaspoonfuls) to the rear bearing before installing grease. See Group 18 for grease specifications.

15. Press grease seal (8) into fan hub housing (4) with "open" side down facing bearing.

16. Apply 0.2 to 0.3 oz. [5.6699 to 8.5049 g] of grease to outer (front) bearing and assemble gasket (2) and fan hub (16).

17. Install fan bracket washer (9, 11) and locknut (10).

18. Fill hub cavity to 60 to 70% of capacity approximately 6 oz. [186.097 g] of grease.

19. After lubricating be sure to install both pipe plugs. Use of fittings will allow grease to be thrown out, due to rotative speed.

Caution: Do not grease hub excessively. Do not mix grades or brands of grease or bearing damage may result.

Thermostats—Unit 803

Thermostats are not subject to repair, but should be checked to make sure they are opening and closing at the proper temperatures. Engines should never be operated without thermostats which aid in the proper control of combustion chamber temperatures under all operating conditions.

Thermostat Housing

Disassembly

1. Remove mounting capscrews from water outlet connection (1, Fig. 8-3-1), discard gasket.

2. Remove capscrews from thermostat cover (5); discard gasket (3).

3. Remove thermostat (4).

4. Remove thermostat seal (6) from thermostat housing.

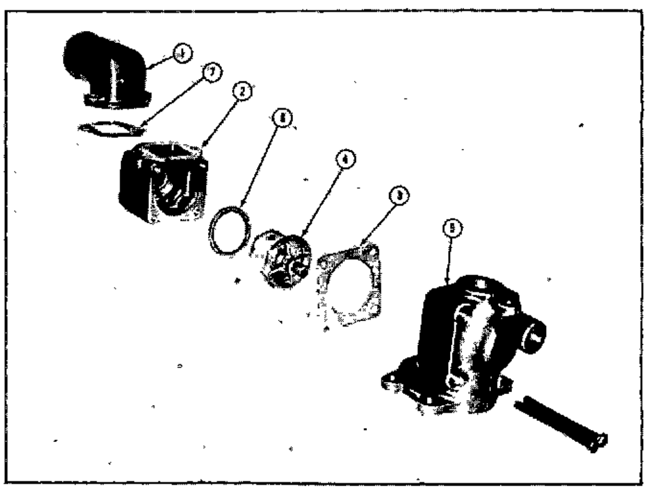


Fig. 8-3-1, V40814. Thermostat housing and seal—exploded view

Cleaning and Inspection

1. Using Turko or Wyandotte solvent, or equivalent, clean all parts to remove lime deposits and dry with compressed air.

2. Check thermostat to see if it opens and closes at the correct temperatures.

a. Immerse thermostat and thermometer (1, Fig. 8-3-2) in water.

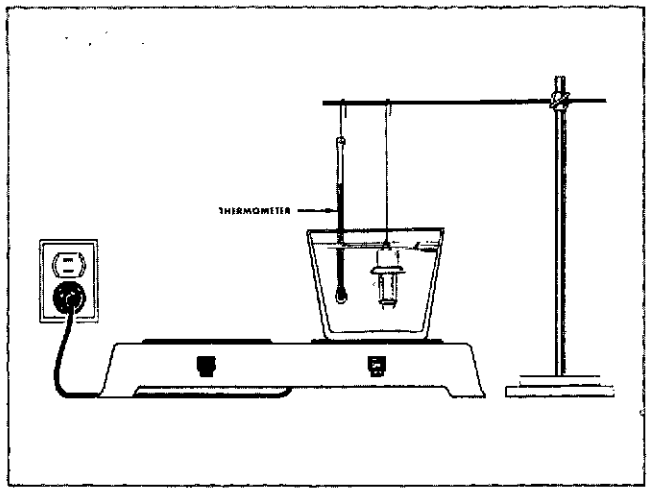


Fig. 8-3-2, N10809. Testing thermostat

b. Heat water to operating temperature and compare thermostat operation with thermometer.

c. Low-range thermostats start opening at 160 deg. F. [71.1 deg. C] and are fully open at 175 deg. F [79.4 deg. C].

d. Intermediate thermostats start opening at 175 deg. F [79.4 deg. C] and are fully open at 185 deg. F [85.0 deg. C].

e. High-range thermostats start opening at 180 deg. F [82.2 deg. C] and are fully open at 195 deg. F [90.6 deg. C].

3. Discard thermostat if it does not operate in correct range and replace with the same range thermostat as was originally installed.

Assembly

1. Use ST-953 Seal Mandrel and install new thermostat housing seal (6, Fig. 8-3-1) to insure proper thermostat operation.

2. Using new gasket (3), install new or tested thermostat (4) in thermostat housing (2) with vent hole at top. Failure to do so may result in air lock and insufficient coolant circulation.

3. Install thermostat cover (5), capscrews and lockwashers.

4. Install new gasket, water outlet connection, capscrews and lockwashers.

Corrosion Resistor—Unit 804

A corrosion resistor is effective only when properly maintained and when used with a cooling system that was new or properly cleaned before the resistor was installed. Use of a resistor on a used engine that has not been properly cleaned and flushed before installation reduces the resistor efficiency.

Disassembly

1. Remove capscrews (1, Fig. 8-4-1) and washers (2) from resistor cover (3). Remove cover gasket (4) and upper plate (5), discard gasket.

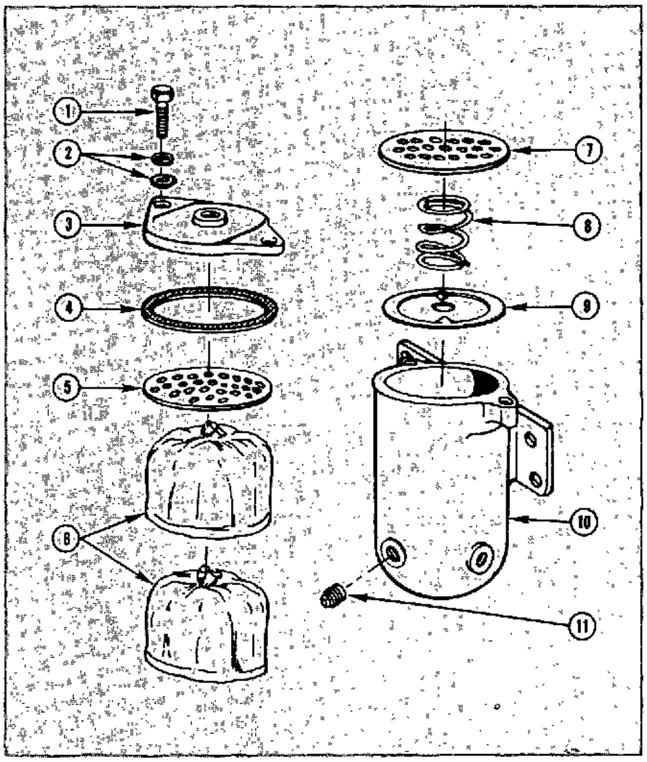


Fig. 8-4-1, V40815. Corrosion Resistor—exploded view

2. Lift elements (6) from resistor body (10; discard elements.

3. Lift out lower plate (7) and spring (8).

4. Remove drain plug (11) and sump plate (9) from body.

Inspection and Repair

1. Buff or polish upper and lower plates to remove scale and expose metal. Discard plates if more than 50% of metal surface cannot be exposed by polishing.

2. Clean all parts to remove deposit build up of scale . Inspect resistor body and cover for cracks or leaks.

3. Inspect spring for wear. Inspect drain plug and capscrews for thread wear. Replace as necessary.

Assembly

1. Install sump plate (9) in resistor body (10).

2. Install spring (8) on sump plate (9).

3. Install lower magnesium (flat) plate (7).

4. Remove transparent bag from new elements (6); install elements in body (10).

Note: Use chromate element only in V-1710 series engines.

5. Replace upper aluminum (concave) plate (5), gasket (4) and cover (3); secure cover to body (10) with capscrews (1) and washers (2).

6. Install drain plug (11).

Check Engine Coolant

Periodic tests of engine coolant should be made to insure frequency of corrosion resistor servicing or concentration of chromate is adequate to control corrosion for specific condition of operation.

When using plain water in a cooling system with a corrosion resistor (with chromate-type element) or when treating with chromate compounds, the concentration of effective inhibitor dissolved in the coolant can be measured by the color comparison method. Cummins Coolant Checking Kit ST-993 should be used for this check, Fig. 8-4-2.

Most commercially available antifreezes contain a coloring dye which renders the color comparison method ineffective. When colored antifreezes are present in the coolant, effective control of corrosion can be determined by inspecting the coolant for accumulation of reddish-brown or black, finely granulated dirt. A small

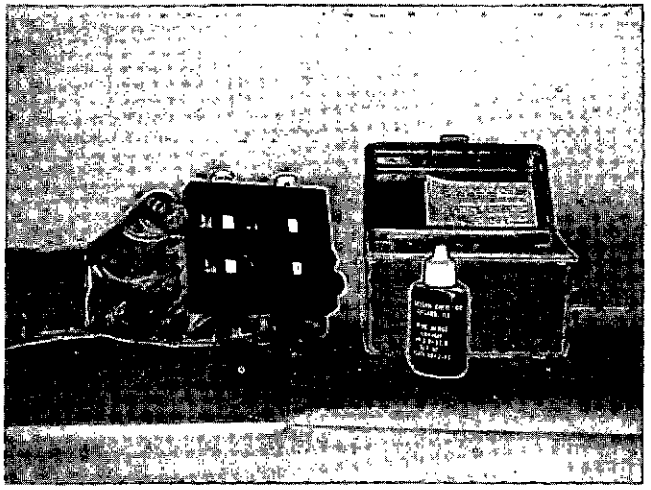


Fig. 8-4-2, N11946. Coolant checking kit ST-993

amount of corrosion produces significant quantities of these corrosion products; therefore, if corrosion resistor servicing is adjusted at the first indication of increased accumulation of these products, actual corrosion will be limited to a negligible amount.

Examine the sump of corrosion resistor for these "dirt" materials at time of servicing or inspect for them in a small sample of coolant drained from bottom of radiator after allowing coolant to settle.

Note: Check with antifreeze supplier to be certain chromate and antifreeze are compatible.

pH Value Test

1. Separate tubes marked "pH" are furnished in the ST-993 Test Kit, Fig. 8-4-2.

2. Add eight drops of pH reagent to tube and mix thoroughly.

3. Insert tube in comparator hole marked "pH".

4. Compare color of test sample with color standards on either side. Preferred range is 8.3 to 9.5.

5. Wash out test tubes after each test and keep reagent container caps in place.

Chromate Concentration Test

1. Draw a sample of coolant and pour into tube marked "Chromate". Dilute sample by 50% with clean water.

2. Insert sample into comparator hole marked "Chromate".

3. Compare color of test sample with color standards on either side. Preferred range is 100 to 150 gr per U.S. gal or 1700 to 2500 parts per million (ppm).

Note: This test is equivalent to 3500 to 5000 parts per million (ppm) of undiluted coolant.

4. Wash test tubes after each test.

Adjusting Coolant to Specifications

If the above tests indicate that the coolant is outside specifications, make an adjustment immediately to prevent corrosion.

If the Cummins Corrosion Resistor is used change element and run four to six hours; then check coolant again; in extreme cases it may be necessary to change element the second time. However, the latter condition may be due to larger coolant system than corrosion resistor was designed to treat; note reference on resistor label.

V-1710 Coolant Specifications

The V-1710 engine must have chromate protection at all times. Effective immediately, use only the standard chromate element with clear water or compatible antifreezes. Do not use the "PAF" or Borate element.

Make-Up Coolant Specifications

Where possible, it is recommended that a supply of make-up coolant be prepared to the following specifications, using soft water where possible and a compatible antifreeze. Chromate treatment of coolant assures constant level of concentration when coolant is added and requires no change in schedule of element replacement.

Chromate Concentration — NA_2CRO_4—3500 PPM

pH Value — 8 to 9.5

Alkalinity — 1500 PPM $CACO_3$
(Methal Orange Indicator)

Pre-charge chromates are available as Formula 2389, from Bird-Archer Co., 4337 North American St., Philadelphia, Pa.

Dearborn Compound 530 from, Dearborn Chemical Co., 14230 Ridge Road, Plymouth, Michigan.

Nalco 38 from, National Aluminate Corp., 6216 West 66th Place, Chicago, Illinois.

Note: Corrosion resistor element must continue to be used with pre-treated water.

Heat Exchanger—Unit 805

Disassembly

1. Remove all flanges, hose and connections from heat exchanger.

2. Remove cover plates from oil cooler and water cooler sections of heat exchanger.

3. Remove both oil and water cooling units, or core, from housing.

4. To prevent hardening and drying of foreign particles, clean core as soon as possible.

Cleaning (Water Side)

1. Immerse core in solution of one part muriatic acid and nine parts water after adding one lb. [7000 gr] of oxalic acid and 1-1/4 to 1-1/2 U.S. oz. [546.875 to 656.250 gr] of pyridene to each 5 U.S. gal. [18.925 lit] of solution.

2. Remove core when foaming and bubbling stops. This usually takes 30 to 60 seconds.

3. Immerse unit in a 5% solution of sodium carbonate. Remove when bubbling ceases and pressure flush with clean warm water.

4. Clean inside thoroughly with steam, or solvent, or both.

5. A usual practice is to take coolers to a radiator shop for cleaning. They are set up for this kind of work. The average shop is not.

Inspection and Repair

1. If leak occurs in a tube, repair by inserting a smaller O.D. copper tube inside of the damaged tube.

2. Cut and flare ends of smaller tube and solder both ends securely.

3. Be careful not to damage adjacent tubes with torch flame.

4. Do not restrict more than 5% of total number of tubes in this manner. To do so would result in an undesirable increase in operating temperature, as well as considerable pressure drop.

Assembly And Testing

1. Install cooler unit in heat exchanger housing.

2. Replace all old gaskets with new ones. Dip new gasket in light machine oil for 2 minutes before installing.

3. Assemble covers and mounting brackets with capscrews and lockwashers.

4. Replace disintegrated zinc plugs with new zinc plugs.

5. Seal core outlet and fill core with water.

6. Seal inlet with fitting designed for application of an air hose and gauge.

7. Subject core to specified pressure allowing only atmospheric pressure in the casing.

8. Permit unit to stand for 15 to 20 minutes; then check pressure gauge for pressure drop, which will denote a tube or header leak.

9. To test case, seal coolant outlet and seal casing fill with water; then follow same procedure as in the core test. A pressure drop on gauge will denote a casing leak.

10. If core is not intended for immediate use after repair and test, it should be prepared for storage.

a. Allow unit to drain thoroughly and blow out remaining liquid with air.

b. Flush light machine oil or soluble oil through tubes and drain off excess.

c. Seal all inlets and outlets to prevent entrance of dirt or foreign matter.

Testing Relief Valve

1. Attach air hose to heat exchanger through filler cap.

2. Pressurize exchanger to 7 psi [0.49217 kg/sq cm]; relief valve should open. If relief valve opens below 7 psi [0.49217 kg/sq cm] or fails to open at 7 psi [0.49217 kg/sq cm], mark for replacement.

Sea Water Pump—Unit 806

Disassembly

1. Remove oil drain plug (39, Fig. 8-6-1), oil filler plug (32) and both oil level plugs (39). Fig. 8-6-1.

2. Remove nut (38), lockwasher (37) and pulley from shaft (40).

3. Remove sleeve (36) from drive shaft (40).

4. Remove seal (34) from gear case (31).

5. Remove capscrews (19) and lockwashers (20) body (21) to gear case (31), lift gear case (31) from body (21) and discard gasket (30).

6. Remove dowels (33) from gear case (31) flange (as necessary).

7. Remove screws (2) and flexrings (3) end cover (4) to cam (8).

8. Remove screws (1), end cover (4) and gasket (5); discard gasket.

9. Remove spline seals (6) from impellers (7); discard seals.

10. Remove impellers (7).

11. Remove cam (8) from body (21).

12. Remove wear plates (9) from body (21).

13. Remove marcel washers (11) from shafts (23) and (40).

14. Remove ferrules (13) and washers (12) from shafts (23) and (40).

15. Remove "O" rings (14) from shafts (23) and (40); discard "O" rings.

16. Remove carbon seals (15) from adjacent to seal seats (16).

17. Remove seal seats (16) and seat gaskets (17) from body (21); discard gaskets.

18. Remove large key (25) from drive shaft (40).

19. Remove "O" ring (35) from drive shaft (40); discard "O" ring.

20. Remove bearing retainer ring (29) from driven shaft (23).

21. Remove gears (28) from shafts (23) and (40).

22. Remove slingers (18) from shafts (23) and (40).

23. Remove retainer rings (27) from body (21) for both shaft assemblies.

24. Remove shaft assemblies (23) and (40) from body (21).

25. Remove bearing seals (22) from shafts (23) and (40).

26. Remove small keys (24) from shafts (23) and (40).

27. Remove bearings (26) from shafts (23) and (40).

Cleaning and Inspection

1. Clean all non-ferrous parts in Bendix carburetor cleaner or equivalent. Make sure all traces of grease are removed.

2. Immerse other parts in solvent tank and remove all dirt and grease.

3. Inspect ball bearings and water seals. Mark for replacement if they are rough or worn.

4. Inspect impellers for wear or damage. Mark for replacement as necessary.

5. Inspect housing for cracks. Mark for replacement as necessary.

6. Inspect splines in shafts for wear and damage. Replace as necessary.

Assembly

1. Install bearings (26) onto lubricated shafts (23) and (40).

2. Install small keys (24) into shafts.

3. Install bearing seals (22) onto shafts (23) and (40) with lip facing toward bearing.

4. Position slingers (18) in drain area.

5. Lubricate bearing housings in body (21) and install shaft assemblies (23) and (40).

6. Install retaining rings (27) into body (21) for both shaft assemblies (23) and (40).

7. Position slingers (18) adjacent to shoulders on shafts (23) and (40).

8. Install gears (28) onto shaft (23) and (40) with hubs of gears adjacent to bearings (26).

9. Install bearing retaining ring (29) onto driven shaft (23).

10. Install "O" ring (35) over drive shaft (40).

11. Install large key (25) into drive shaft (40).

12. Lubricate seat gaskets (17) O.D. with water pump grease. Install seal gaskets (17) and seal seats (16) into body (40) with seal gaskets facing toward bearing.

13. Install carbon seals (15) with polished faces adjacent to seal seats (16).

14. Install lubricated "O" rings (14) on shafts (23) and (40).

15. Secure washers (12) to ferrules (13) with Fairprene No. 4, lining up convex dings in washers with slots in ferrules and install on shafts (23) and (40).

16. Install marcel washers (11) on shafts (23) and (40) lining up convex dings in marcel washers with concave dings in washers.

17. Install wear plates (9) into body (21).

18. Install cam (8) into body (21) with tapped holes facing outward.

19. Install impellers (7) into lubricated impeller bores.

20. Install spline seals (6) into impellers (7).

21. Install gasket (5) and end cover (4) with screws (1).

22. Assemble flexring (3) on screws (2) and install thru end cover (4) into cam (8).

23. Install aligning dowels (33) in gear case (31) flange (if removed).

24. Position gasket (30) on gear case (31) flange. Align gear case cover and install lockwashers (20) and capscrews (19).

25. Install seal (34) into gear case (31) with lip facing toward gear.

26. Install sleeve (36) on drive shaft (40) with "O" ring recess facing toward "O" ring (35).

27. Install pulley, washer (37) and nut (38) on shaft (40).

28. Install oil drain plug (39) oil filler plug (32) and both oil level plugs (39)).

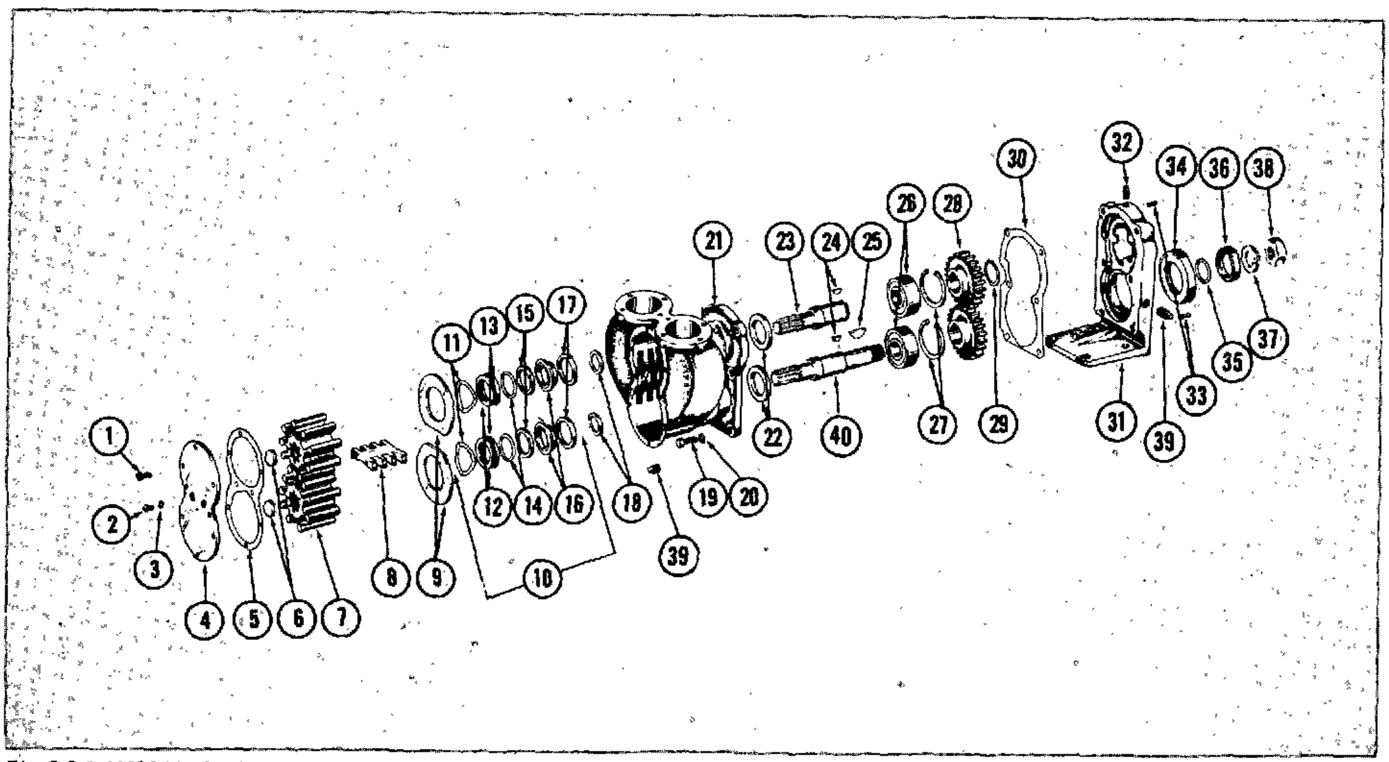


Fig. 8-6-1, V40816. Sea Water Pump — Exploded View

Radiator—Unit 807

Disassembly

1. To remove core assembly with headers, it will be necessary to remove the front screen guard and front screen guard spacers.

2. Remove bolts holding core section header casting to top and bottom tank. Then each core section may be removed from front of radiator assembly.

3. If it is necessary to service any other part of radiator assembly, remainder of assembly may be removed from unit without danger of damage to core.

4. The fan screen guard is disassembled by removing screws attaching it to fan shroud.

5. Remove bolts holding fan shroud to side members to disassemble fan shroud.

6. Overflow tube is removed by removing fitting in bottom of top tank and clips holding it to side member, then pulling it out of bottom of top tank.

7. Remove side members from top and bottom tanks, completing disassembly operation.

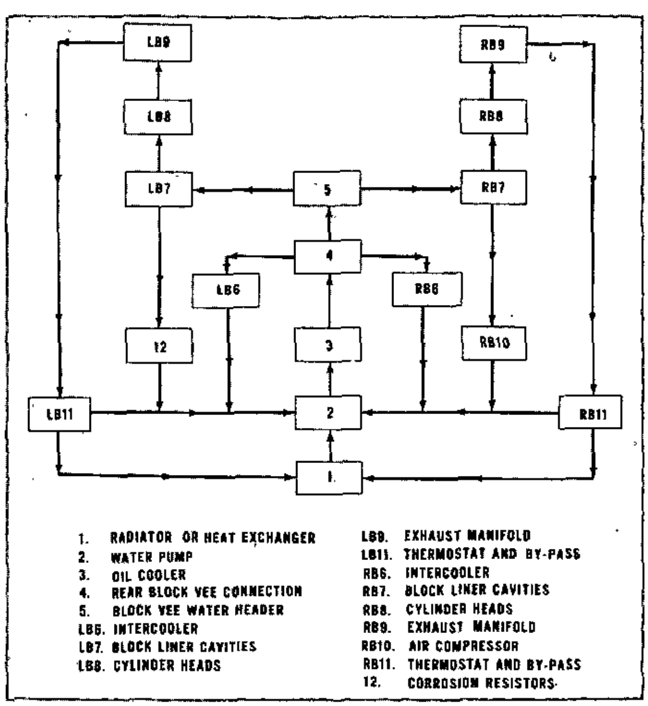


Fig. 8-7-1, V40817. Coolant flow — schematic diagram

Inspection And Rebuilding

1. Inspect radiator core for stoppage or leaks in same manner as described for the oil cooler (Group 7).

2. Do not use anti-leak compounds to stop core leaks. If split seams or solder breaks are found, have radiator repaired at qualified radiator repair shop.

3. To reassemble radiator, reverse disassembly procedure.

Caps

Radiator selection is normally based on a non-pressurized system; however, a pressure cap or valve set at approximately 4 to 7 psi [0.28124 to 0.49217 kg/sq cm] should be used, Table 8-7-1.

Caution: Before using higher pressure settings on cap, check radiator manufacturer.

Table 8-7-1: Radiator Caps

Part Number	Opening Pressure
69497	4 Psi [0.2812 kg/sq cm]
103624	4 Psi [0.2812 kg/sq cm]
119665	7 Psi [0.4922 kg/sq cm]

Hose

1. Hose must be able to withstand maximum pressure of system and at least 3 inch Hg [0.10359 kg/sq cm] suction vacuum.

2. Use hose conforming to SAE 20R1 Standards.

Operating Temperature

The cooling system should be designed and the necessary controls used to maintain engine coolant outlet temperature, at the radiator top tank, between 170 deg. F [76.7 deg. C] and 190 deg. F [87.8 deg. C] during normal operation. Under no operating condition should temperature be above 200 deg. F [93.3 deg. C] and for best operation do not allow temperature to drop below 160 deg. F [71.1 deg. C].

Coolant Piping

The circulation of the coolant is as important as the radiation ability of the radiator, since it is the coolant that brings the heat from the engine to the radiatr for transfer to the air. The rate of circulation is of course, basically dependent upon the capabilities of the engine water pump and the restrictions through the cylinder block and head, but the restriction can also be increased greatly and the circulation reduced, by small engine inlet and outlet connections, and by connections between engine and radiator which are too small. In addition to being sufficiently large, the hose and lines should be smooth and free from right angle bends, or sharp corners. Restriction at the coolant pump inlet should not exceed 3.00 inches Hg [0.10359 kg/sq cm].

To provide an adequate cooling system life, the rubber hose used should meet the requirements of SAE type 20 R1 hose. Hose clamps should be SAE type F or the equivalent.

The most desirable temperature for best engine operation is between 160 deg. F [71.1 deg. C] and 185 deg. F [85.0 deg. C]. Water out temperature of the engine should not be *allowed to exceed 200 deg. F [93.3 deg. C]. In order to* maintain this temperature, the engine cooling system must operate at top efficiency.

In addition to the standard engine cooling system components, auxiliary oil cooler may be used to control high temperature encountered in some applications.

1. A water type auxiliary oil cooler may be used where temperatures are not excessively high.

2. An air flow oil cooler – a coarse tube radiator – may be mounted in front of the engine radiator. This type cooler will reduce oil temperatures more than the water type.

Caution: Check with the cooler manufacturer for the proper installation procedure for your application.

When coolers for accessories are added in the engine coolant circuit that use engine water for cooling, they should be located so that the full flow of the water pump is circulating through the cooler at all times during engine operation, or located in the radiator bottom tank. Such coolers should be connected so that the by-pass water flows through them. In case it is desirable to locate such a cooler in the line between the radiator outlet and the water pump inlet, care must be taken to be sure that the pressure at the pump eye is not lowered to the point at which cavitation may occur and the water flash into steam.

Radiator bottom tank coolers are not considered satisfactory for vehicular applications where extensive operation of the engine occurs where no power requirements are present, such as on long downhill braking *operations. In such applications, since there is no engine* power output to generate heat, the temperature of the engine coolant is lowered, and the main-line thermostat closes, permitting only the recirculation from the thermostat to the water pump. Thus there is no circulation through the radiator to carry away the heat delivered to the heat exchanger. As a result, the coolant in the lower tank may be converted to steam with resultant pressure sufficient to cause loss of coolant through the pressure cap valve.

Regardless of the type of cooler used, always avoid sharp bends in piping or fittings. Be sure that all piping is of sufficient size to insure maximum cooling system efficiency.

Aeration And Afterboil

Air which becomes trapped in the cooling system during filling is vented through the radiator cap or overflow tube during engine operation. The resulting drop in coolant level causes the engine to overheat.

After a period of operation, abrupt shutdown causes sudden transfer of heat from the engine mass to the coolant. The coolant boils and steam forces part of the coolant out the overflow. The coolant level is then too low *to provide proper cooling.*

After aeration or afterboil, the drop in coolant level leaves an air space in the highest point in the cooling system.

Normal coolant circulation then traps additional air which reduces cooling efficiency. Both aeration and afterboil can be eliminated by using a radiator with a large top tank, or in a limited space, an auxiliary tank, to allow:

1. Purging of trapped air after initial fill.

2. Greater make-up coolant capacity.

3. Automatic deaeration.

4. Space for expansion of coolant and anti-freeze.

5. Space for surging and afterboil.

6. Greater pressure "head" over radiator.

Coolant Drawdown Test

The coolant drawdown should be determined as follows:

1. A transparent sight glass should be installed in the radiator inlet line.

2. The thermostat(s) must be opened by blocking to assure maximum water flow through the radiator.

3. The entire cooling system **including the expansion space** *should be filled with clean water. (The use of colored* coolants such as anti-freeze or treated water in this test will give a distorted reading.) Leave pressure cap off during drawdown test.

4. The coolant should be circulated through the radiator until no bubbles appear in the sight glass.

5. With the engine operating at maximum governed RPM, to provide maximum water pump delivery, the coolant should be drained from the system until the coolant passing through the sight glass first begins to show bubbles. Where these bubbles first appear is the point at which the system starts aerating. The number of quarts of coolant removed before the aeration begins is the amount of coolant drawdown. See Fig. 8-7-2.

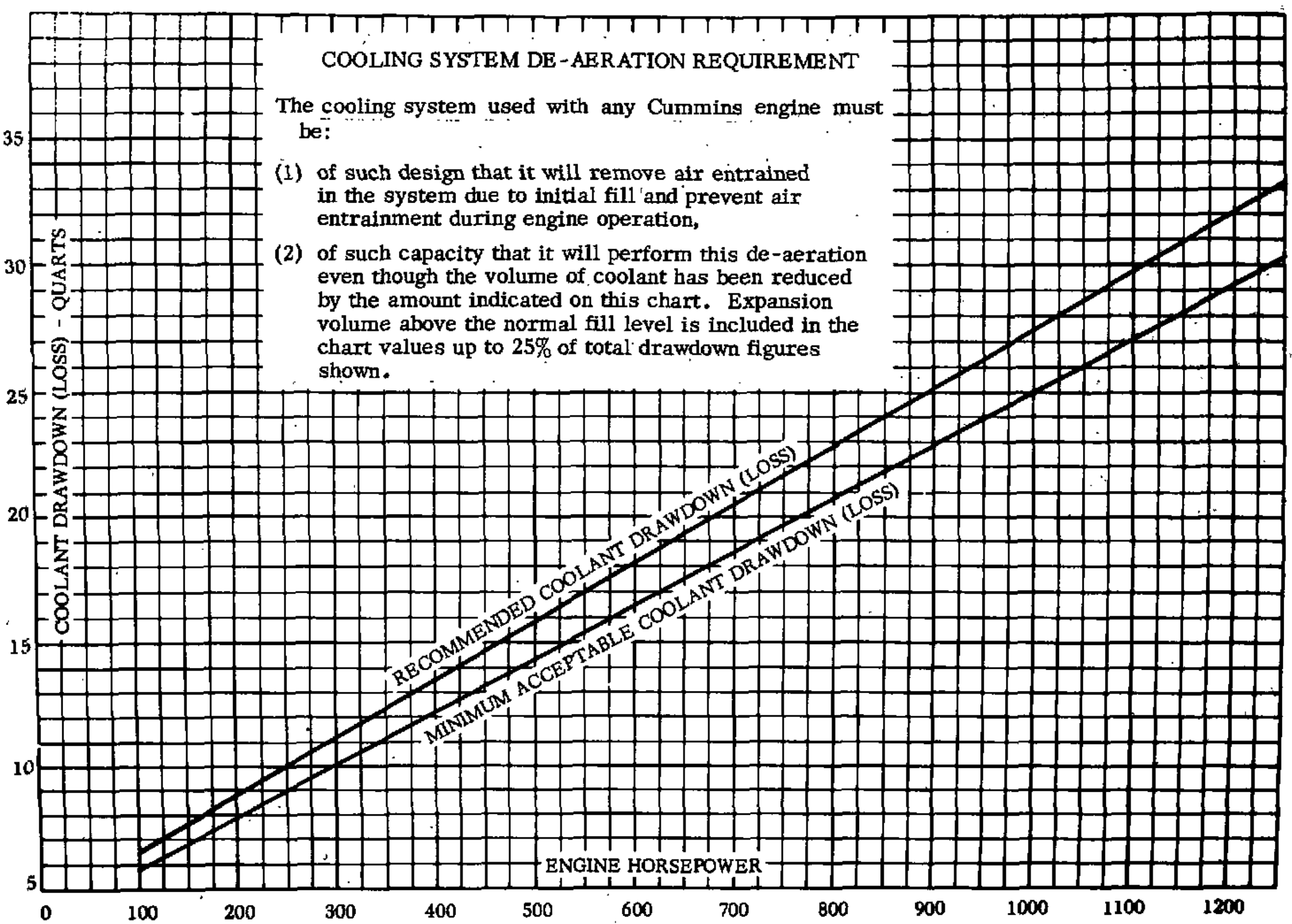


Fig. 8-7-2, V10810. Dearation requirements

Thermal Controls—Unit 808

1. Shutterstats and thermatic fans must be set to operate in same range as thermostat with which they are used Table 8-8-1 gives settings for shutterstats and thermatic fans used with thermostats.

2. All thermal controls should be so adjusted that coolant temperature is maintained as closely as possible between 160 deg. F [71.1 deg. C] to 190 deg. F [87.8 deg. C].

Shutterstat Location

The shutterstat may be located in engine water outlet on either side of thermostat or in radiator bottom tank. Location in radiator top tank is acceptable if control is always in water flow and not placed in expansion area. When placed in radiator top or bottom tanks, it must be located in an area of high coolant velocity to assure quick response.

Shutterstat Setting

The desired shutter control settings in terms of radiator top tank temperature are shown in Table 8-8-1. The values in the table are in terms of radiator top tank temperature and are applicable to both a location in the engine water outlet or the engine water inlet piping.

Water Temperature Gauge

1. The sensing unit of the water temperature gauge (1, Fig. 8-8-1) must be located on engine side of thermostat so bulb is in water flow.

2. Warning light switches should not be set higher than 200 deg. F [93.3 deg. C] and the sensing bulb located as described for the gauge bulb.

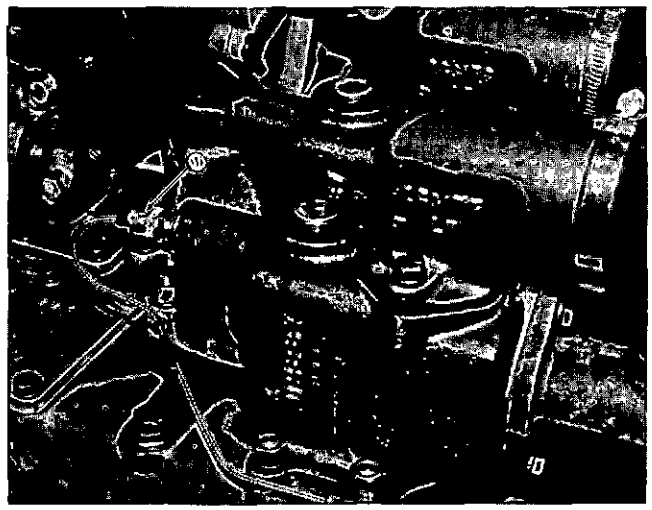


Fig. 8-8-1, V40818. Temperature gauge bulb location

Table 8-8-1: Thermal Control Settings

Control Used	Setting With 160 deg/175 deg F [71.1 deg/79.4 deg C] Thermostat	Thermostat	Setting With 170 deg/185 deg F [76.7 deg/85.0 deg C] Thermostat		Setting With 180 deg/195 deg F [82.2 deg/90.6 deg C] Thermostat	
	Open	Close	Open	Close	Open	Close
Thermatic Fan	185 deg F [85.0 deg C]	170 deg F [76.7 deg C]	190 deg F [87.8 deg C]	182 deg F [83.3 deg C]	Not Used	
Shutterstat	180 deg F [82.2 deg C]	172 deg F [77.8 deg C]	185 deg F [85.0 deg C]	177 deg F [80.6 deg C]	195 deg F [90.6 deg C]	187 deg F [86.1 deg C]
Modulating Fan Lockup	185 deg F [85.0 deg C]		190 deg F [87.8 deg C]		Not Used	
Modulating Shutters Open	175 deg F [79.4 deg C]		190 deg F [87.8 deg C]		195 deg F [90.6 deg C]	

Intercooler—Unit 809

Disassembly

1. Remove capscrews and lockwashers securing air connection (1, Fig. 8-9-1) to cooler housing (air intake manifold); lift off connection and discard gasket (2).

2. Remove water lines, supply and discharge, from intercooler.

3. Remove capscrews, lockwashers and flatwashers securing element covers (3) to cooler housing; lift off covers and discard gaskets (4).

4. Remove stabilizing screws, lockwashers and locknuts securing element to cooler housing (air intake manifold). Remove element (5) from cooler housing (air intake manifold). Remove and discard gakset (6).

Cleaning And Inspection

1. Clean all parts with an approved cleaning solvent and dry with compressed air; remove all gasket material.

2. Clean elements in a solvent not harmful to copper and dry by blowing through cores with compressed air.

3. Inspect element for corrosion, bent core fins and breaks where tubes are welded to end plates.

4. Inspect body and covers for breaks and distortion; mark for repair or replacement as necessary.

5. Inspect sealing surfaces of housing, covers and connections, screws and nuts; discard all damaged parts.

Repair

1. Repair all header leaks in element by soldering.

2. Weld all cracks or breaks of connections, covers and body.

Assembly

1. Install stabilizing screws in cooler housing from the inside threaded end of screw (slotted), must protrude through top side of housing.

2. Install lockwashers and jam nuts on screws, all the way down and finger tight.

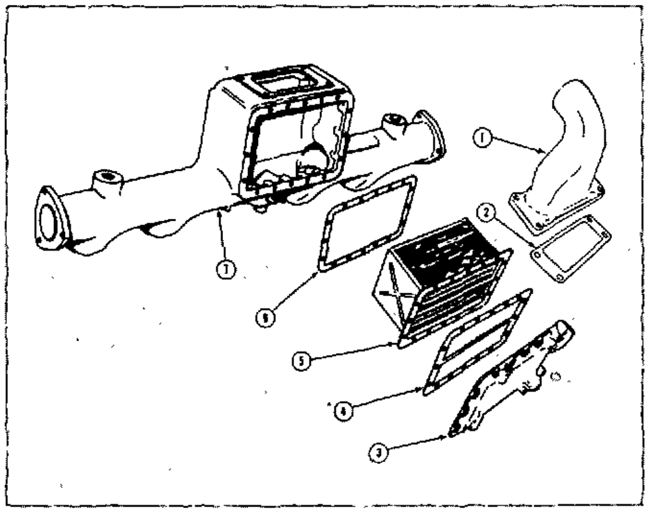


Fig. 8-9-1, V40819. Intake manifold with inter-cooler

3. Install guide pins in center hole on each side of core opening in intake manifold.

4. Install inner gasket (6, Fig. 8-9-1) over guide pins and next to manifold intercooler opening (1).

5. Carefully install intercooler (5) over guide pins into opening in intake manifold. Be careful not to damage fins on the cooler as it is inserted into manifold. Make sure intercooler goes all the way in and that the back side is resting on support pads in back side of intercooler opening in the intake manifold.

6. Install outer gasket (4) over the guide pins and next to intercooler. This gasket has two port sections which direct water circulation through cooler unit.

7. Install cover (3) over guide pins and against gasket. Install mounting capscrews, lockwashers and flatwashers starting each capscrew a few turns by hand and making sure that both gaskets, intercooler flange, and intercooler cover mounting holes are properly aligned with mounting holes in intake manifold. Remove and replace guide pins with mounting capscrews.

8. Tighten mounting capscrews. Use a tightening pattern which will pull cover down evenly. Failure to do this could result in cracking cover or it could result in gasket leakage. Tighten mounting capscrews in 15 ft-lb [2.0745 kg m] increments to 30 to 35 ft-lb [4.1490 to 4.8405 kg m].

9. Using a medium size screw driver, adjust stabilizer screws down until screw heads are firmly seated on top of

intercooler tank rim inside manifold, Fig. 8-9-2. While holding screw with screw driver, tighten locknuts using a suitable hand tool.

10. Install water lines, supply and discharge on intercooler cover.

11. Position air inlet connection with new gasket to cooler housing (air intake manifold); secure with flatwashers, lockwashers and capscrews.

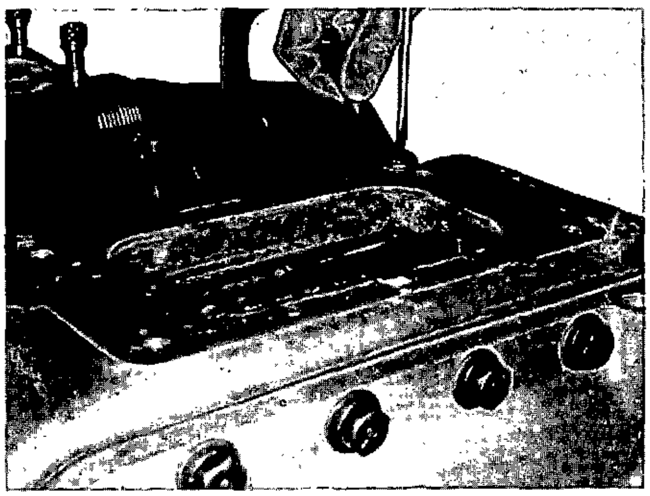


Fig. 8-9-2, V40824. Adjusting stabilizer screws

Drive Unit Group

The drive unit is used to transmit power from the engine crankshaft, through the camshaft gear, to drive a compressor, fuel pump, water pump or other assemblies. Usually, repair consists of replacement of oil seals, bearings or bushings only.

Fuel Pump Drive–Unit 901

Ball Bearings

Since ball bearings are so extensively used in drive units, it is well to review some of the general rules concerning their use and handling.

1. Ball bearings should be installed or removed from housing with an arbor press, using the right size and type of mandrel or plate. Pressing should be done on the race that is press fit. When the bearing is being pressed into a housing, the force should always be applied to the outer ring.

2. Work with clean tools in clean surroundings.

3. Remove all outside dirt from housing before exposing bearings.

4. Handle with clean, dry hands.

5. Treat a used bearing as carefully as a new one.

6. Use clean solvents and flushing oils.

7. Lay bearings on clean paper.

8. Protect disassembled bearings from dirt and moisture.

9. Wipe bearings with clean, lint-free cloth.

10. Keep bearings wrapped in oil-proof paper when not in use.

11. Clean inside of housing before replacing bearings.

12. Install new bearings as removed from the packing, without washing.

13. Keep bearing lubricants clean when applying and in covered containers when not in use.

14. Pack used and washed bearings with ball bearing grease before installation.

15. Do not take new bearings apart (unless two-piece assembly where each part is installed separately).

16. Never press against separators.

17. Never pound on a bearing or race.

18. Do not spin bearings before cleaning. Do not spin by force of air. Hold both races while drying with clean, compressed air.

19. The following types of defects cause bearings to be rejected for further use:

a. Broken or cracked race.

b. Dented shields or seals.

c. Cracked or broken separators.

d. Flaked areas on balls, rollers or raceways.

e. Broken or cracked balls or rollers.

f. Bearings that have been overheated. These bearings are generally darkened to a brownish-blue or blue-black color.

g. Bearings whose raceways are indented or "brinelled" by impressing balls or rollers into the races.

20. Dirt causes ball bearings to fail.

Oil Seals

1. When an oil seal fails it must be replaced with a new seal.

2. Oil seals are easily ruined by allowing shaft to turn against the sealing lip during installation, or by leaving keys in shaft.

3. The sealing lip must always compress with pressure.

4. The effectiveness of the seal depends on surface where seal seats. Always check hub sleeve surface for wear and replace sleeve if necessary before installing new seal.

5. Immediately beofre installing seals, always lubricate with clean SAE 30 lubricating oil.

Bores In Housing

1. Ball bearings must not turn in housing retaining bore. If old bearing has turned and ruined housing, both bearing and housing must be scrapped.

2. Bore of housing must be clean before pressing bearing in place.

Thrust Washers

In installation of thrust washers on accessory drives, the thrust side of washers are to be installed away from housing. The thrust side is identified by grooves. The steel backing against the cast iron housing will reduce the posibility of the thrust washers' turning.

Improper installation of these washers will result in excessive wear and increased end play, which causes early failure of the accessory drive assembly.

Drive Pulleys

Inspection

1. Check for cracks and chips in hub, web and groove areas.

2. Check for wear in grooves and wear sleeve. If wear on sleeve is visible, replace as outlined below.

3. On two-piece pulleys, check for stripped or distorted threads on sheave and in capscrew holes. Discard parts as necessary.

4. Check mounting hardware; discard if damaged.

Repair

1. Remove worn wear sleeve by splitting with chisel. Do not damage pulley hub.

2. Press new sleeve (1, Fig. 9-1-1) onto pulley hub (2) with mandrel. Consult latest Parts Catalog for correct pulley/sleeve combination. Some pulleys have longer hubs and therefore require different sleeves.

Caution: Wear sleeve is special material and is closely machined to insure proper sealing. Resurfacing of this part is not practical.

Fuel Pump/Water Pump/Compressor Drive

The drive housing may mount either a fuel pump only, an air compressor and a fuel pump or fuel pump and hydraulic governor drive.

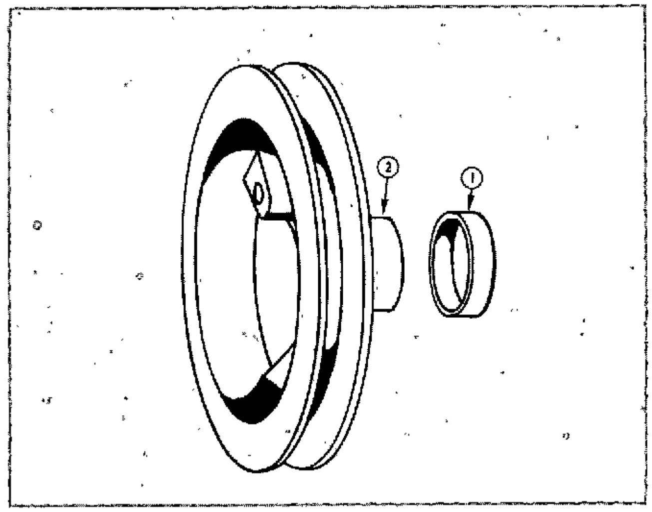


Fig. 9-1-1, V10908. Pulley and sleeve

Disassembly (Splined Coupling)

1. Remove drive shaft locknut (11, Fig. 9-1-2); using suitable puller, pull coupling (10) from shaft, lift out drive key.

2. Remove clamping washer (9) and thrust washer (8) from coupling end of shaft (2).

3. Press shaft and gear assembly from housing (6).

4. Press shaft (2) from gear (1) and remove keys (16) from shaft.

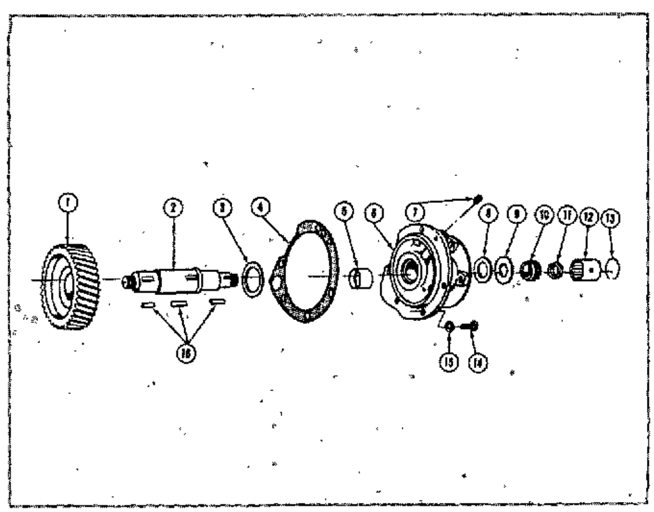


Fig. 9-1-2, V40909 Fuel pump/water pump/compressor drive

Cleaning And Inspection

1. Clean all parts in an approved cleaning solvent. Dry thoroughly.

2. Check gear and coupling for chipped, cracked or worn teeth.

3. Check shaft for wear, damaged keyways or damaged threads.

4. Inspect bushing for wear; replace if damaged.

5. Check support for cracks, breaks or rough mating surfaces.

6. Replace all parts not satisfactory for reuse.

Assembly (Splined Coupling)

1. Install key (16, Fig. 9-1-2) in center key slot of shaft and press drive gear (1) on shaft (2) from pulley end until gear seats against shoulder.

2. Slip on large thrust washer (3) with thrust face toward gear (1). Install shaft (2) through housing and bushing.

3. Turn over assembly; slip on small thrust washer (8) (face away from housing) and clamp washer (9). Install coupling key (16).

4. Press on coupling (10), hub end toward clamping washer (9), until coupling seats against clamping washer, and secure with locknut (11).

Disassembly (Buffer Drive)

1. Remove capscrew, using suitable puller, pull coupling from shaft, lift out drive key.

2. Remove clamping washer (9) and thrust washer (8) from coupling end of shaft.

3. Press shaft and gear assembly from housing (6).

4. Press shaft (2) from gear (1) and remove keys (16) from shaft.

Assembly (Buffer Drive)

1. Install key (16, Fig. 9-1-2) in center key slot of shaft and press drive gear (1) on shaft (2) from pulley end until gear seats against shoulder.

2. Slip on large thrust washer (3) with thrust face toward gear (1). Install shaft (2) through housing and bushing.

3. Turn over assembly; slip on small thrust washer (8) (face away from housing) and clamp washer 9). Install coupling key (16).

4. Press on coupling (10), hub end toward clamping washer (9), until coupling seats against clamping washer, and secure with capscrew.

Fuel Pump/Hydraulic Governor Drive

The fuel pump/hydraulic governor drive is used whenever a hydraulic governor is needed for a particular engine application. The governor mounts on top of housing and fuel pump is coupled to rear of housing.

Disassembly

1. Remove governor drive assembly from governor reservoir. Remove and discard gasket.

2. Remove snap ring (11, Fig. 9-1-3), ball key and collar (13).

3. Press on shaft (12) opposite gear end to separate all units from housing (14).

4. Remove capscrews (4) and lockwashers (5) and separate driver gear (2) and support assembly (3) from reservoir (21).

5. Remove drain plug, dipstick, vent plug and elbow from reservoir.

6. Remove shaft locknut (22) and washer (23) from drive shaft (31).

7. Use ST-528 puller to remove coupling (24), spacer (25) and governor drive gear (26).

8. Press on small end of shaft to remove shaft from support (3).

9. Press on large end of shaft to remove drive gear (2). Remove keys (32) from shaft keyway.

10. Remove snap ring (27) from support. Invert support and press out rear bearing (28) and oil seal (29). Discard oil seal.

Cleaning And Inspection

1. Clean all parts in approved cleaning solvent and dry thoroughly with clean, compressed air.

2. Check bearing for worn race or rough action. Mark for replacement as necessary.

3. Check gears for chipped or broken teeth or uneven wear. Mark for replacement as necessary.

4. Check governor shaft housing oil holes. Make certain

they are open.

5. Inspect support and reservoir for cracks, breaks, or rough mating surfaces. Mark for replacement as necessary.

Assembly

1. Lubricate outside of oil seal (29, Fig. 9-1-3) and press into support from large end. Open end of seal must be down. Check to see that oil holes in housing are open.

2. Invert support. Coat outside of rear bearing with lubricant and press bearing (28) into support to shoulder. Insert snap ring (27), flat side down.

3. Lubricate large end of shaft. Place key (32) in shaft (31) and press shaft into gear (2) against shoulder. Place flat side, not beveled side, of gear hub against shoulder.

4. Press shaft into inner race of front bearing (1) until bearing is against gear hub.

Note: Outer race of two-piece front bearing is installed in gear case cover.

5. Press small end of shaft assembly into large end of support. First, coat shaft with lubricant so oil seal will not be damaged.

6. Lubricate shaft and press governor drive gear (26) onto small end against bearing in housing.

7. Insert key (30); then press on coupling (24). Shoulder of coupling goes against gear unless a spacer (25) is used.

8. Install flatwasher (23) and shaft locknut (22).

9. Place reservoir (21) in vise with governor drive studs (17) up. Install dipstick, vent plug, weatherhead fitting and drain plug.

10. On governors with 2:1 gear ratio:

a. Install shaft (12) in housing (14) with splined end up.

b. Drop collar (13) into housing.

c. Lubricate ball key and insert in drive shaft; install snap ring (11).

d. Line up ball key with collar (13), invert assembly and press on gear (9). Allow 0.003 to 0.006 inch [0.0762 to 0.1524 mm] end play. Check with feeler gauge.

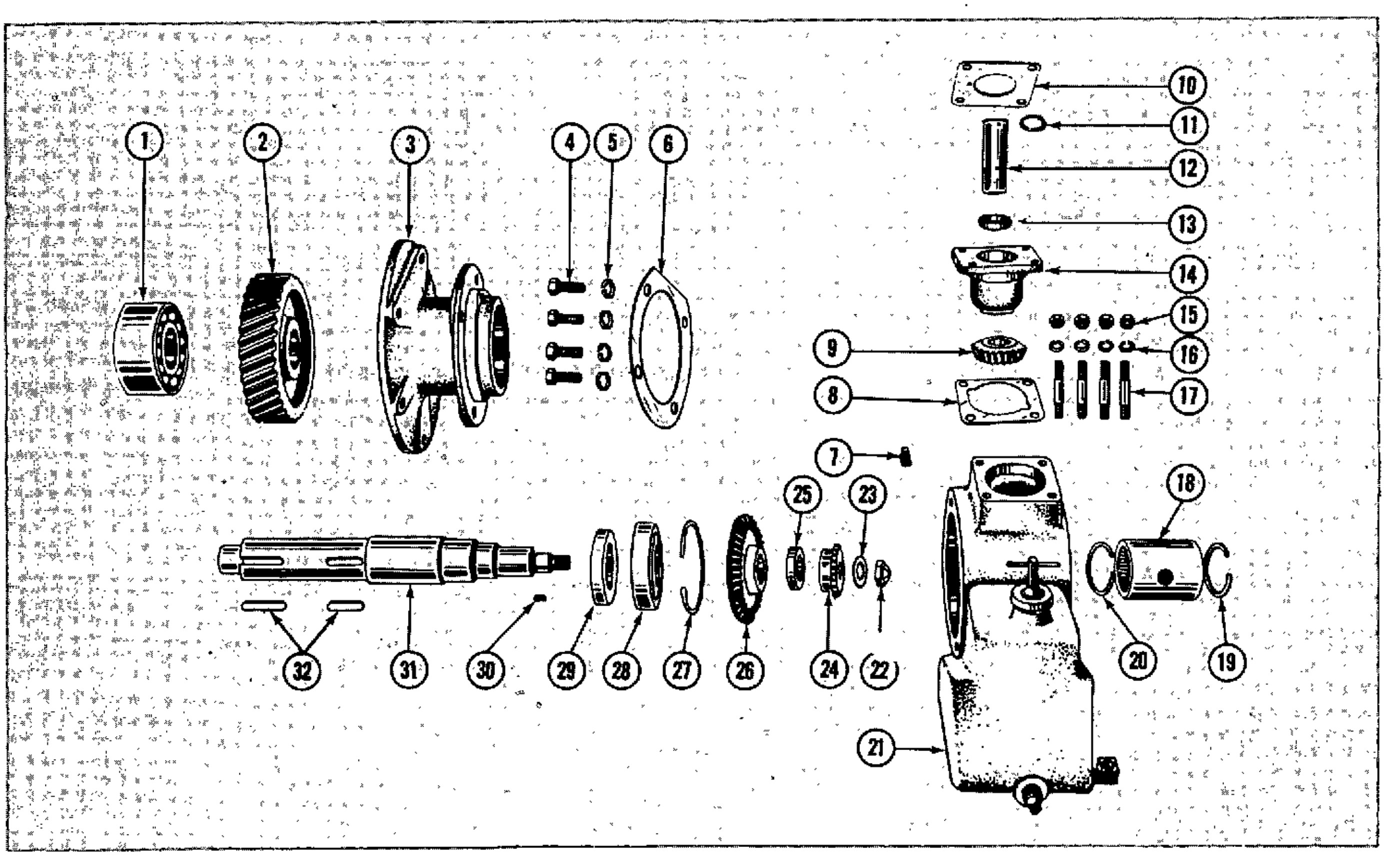


Fig. 9-1-3, N10907. Fuel pump/hydraulic governor drive

11. On governor with 3:1 gear ratio:

a. Press governor two-piece drive shaft (12) into washer flush with bottom side. Note relief in washer to start shaft.

b. Press shaft assembly into cylinder until shoulder on shaft is flush with end of cylinder.

c. Slide this assembly into governor drive housing (14) so flatwasher rests on bronze bushing.

d. Invert assembly and install ball key, collared washer (13) and snap ring (11).

e. Press on end of cylinder until flat washer is against bronze bushing.

f. Press gear into position allowing 0.003 to 0.006 inch [0.0762 to 0.1524 mm] end play. Check with feeler gauge.

12. Position gaskets (6) on housing (3) and install assembly to serial number side of reservoir (21), secure with four lockwashers and capscrews. Large oil hole in housing must be at top.

13. Position governor drive assembly with new gasket (8) over studs (17) onto reservoir (21), secure with lockwashers (16) and studnuts (15).

Generator Auxiliary Drive—Unit 902

The generator/auxiliary drive is used to drive the generator plus other auxiliary units as required.

There are two basic variations of this drive – a stub shaft and through shaft. Both drives are disassembled, inspected and assembled in the same manner.

Disassembly

1. Remove locknut (1, Fig. 9-2-1), flatwasher (2), and copper washer (3) from shaft (11).

2. Use suitable pulley puller; remove pulley (4) and key (13) if not previously removed.

3. Remove oil seal (5) from support (8); discard seal.

4. Remove spacer (6) and thrust washer (7) from shaft.

5. Remove shaft (11) and gear (12) assembly from support; remove large thrust washer (10).

Cleaning And Inspection

1. Wash all parts in an approved cleaning solvent and dry with compressed air.

2. Inspect drive gear (12, Fig. 9-2-1) for broken or worn teeth; replace if needed.

3. Inspect bushing inside diameter 1.316 to 1.319 inch [33.4264 to 33.5026 mm], if worn larger than 1.3205 inch [33.7947 mm] replace bushing.

4. Inspect shaft bushing area; new O.D. is 1.3115 to 1.3120 inch [33.3121 to 33.3248 mm], if worn smaller than 1.3110 inch [33.2994 mm] replace shaft.

5. Replace with new parts as needed.

Assembly

1. Install key (13, Fig. 9-2-1) in shaft (11) and press drive gear onto shaft against shoulder of shaft.

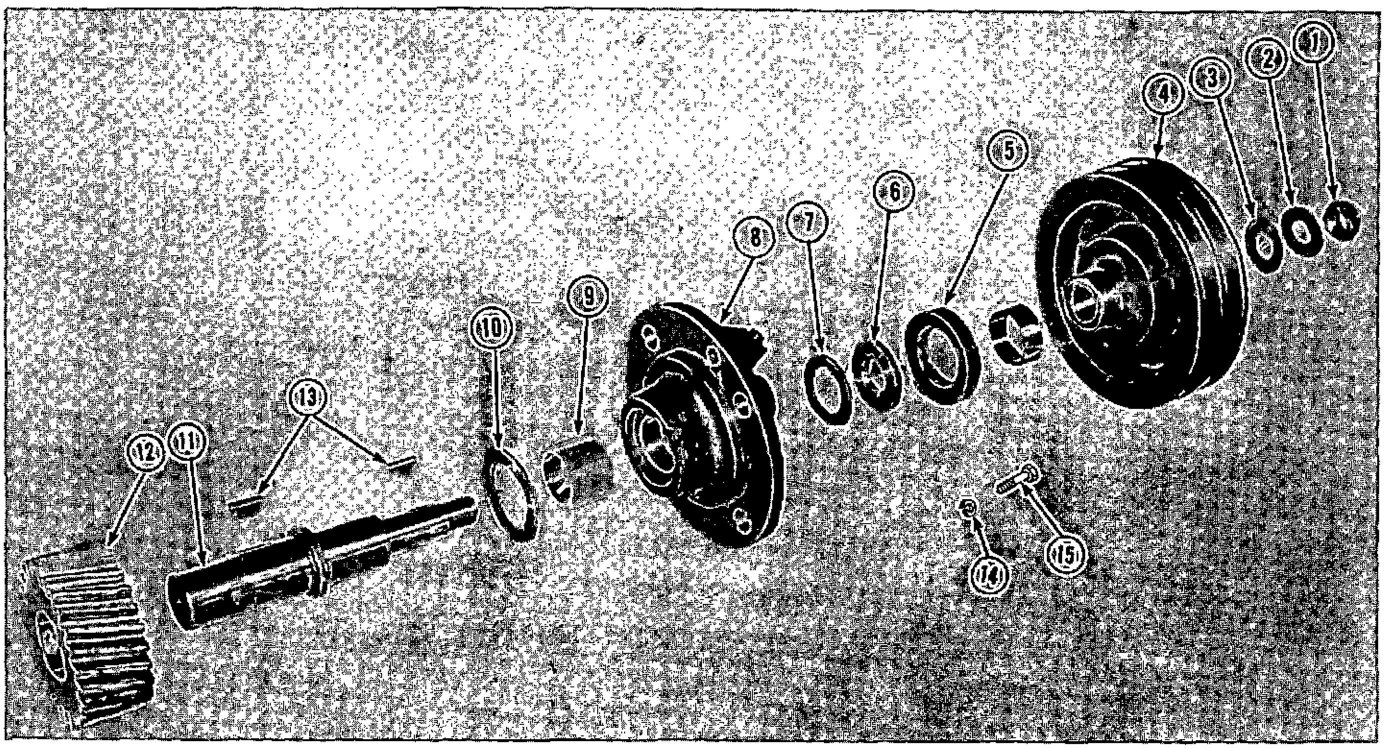


Fig. 9-2-1, V40811. Generator/auxiliary drive

2. Press bushing (9) into support (8) if bushing needs replaced.

3. Place thrust washer (10) onto shaft with thrust washer face toward gear. Lubricate shaft with clean lubricating oil at bushing area of shaft, then place shaft and gear assembly in support.

4. Turn upside down, put in press; support on gear end of shaft.

5. Install small thrust washer (7) (face up). Install spacer (6) with chamfered side down.

6. Lubricate oil seal lips with clean lubricating oil and install seal (5) in support (8).

7. Install drive key (13) in shaft (11). Install capscrews (15) and lockwashers (14) in drive housing.

8. Lubricate shaft and press pulley (4) on shaft (11). Maintain 0.002 to 0.007 inch [0.0508 to 0.1778 mm] end play. If pulley is not used, install spacer Part No. 139253.

9. Install copper washer (3), flatwasher (2) and locknut (1) on shaft. Tighten locknut.

Intake Air System Group

The intake air system group consists of air cleaners, piping, cold-starting aids, aneroids and turbochargers. The turbochargers are covered in separate manuals due to the fact that they may be used on several different series of engines.

Air Cleaners and Piping—Unit 1001

Oil Bath Type

Disassembly

1. If not previously removed, loosen hose clamps and remove hose connection securing intake pipe to cleaner.

2. Loosen bolts and nuts holding mounting straps together and remove straps.

3. Remove rain shield from cleaner.

4. Loosen wing nuts (1, Fig. 10-1-1) and remove oil cup (2) from cleaner (3).

5. Loosen clamp ring securing tray screen (1, Fig. 10-1-2) to cleaner and remove screen.

Cleaning And Inspection

This method of cleaning requires a drum, large enough to completely contain the air cleaner, and a source of air pressure. Any good commercial solvent may be used.

1. Steam clean exterior of cleaner to remove any large dirt concentrations.

2. Remove air cleaner oil cup.

3. Clamp hose with air line adapter to air cleaner outlet.

4. Submerge air cleaner in solvent.

5. Introduce air into unit at 3 to 5 psi [0.2109 to 0.3515 kg/sq cm] and leave in washer 10 to 20 minutes.

6. Remove cleaner from solvent and steam clean or dry unit thoroughly to remove all traces of solvent.

Caution: Failure to remove solvent may cause engine to overspeed until all solvent is sucked from cleaner.

7. If air cleaner is to be stored, dip in lubricating oil to prevent rusting of screens. If the screens cannot be

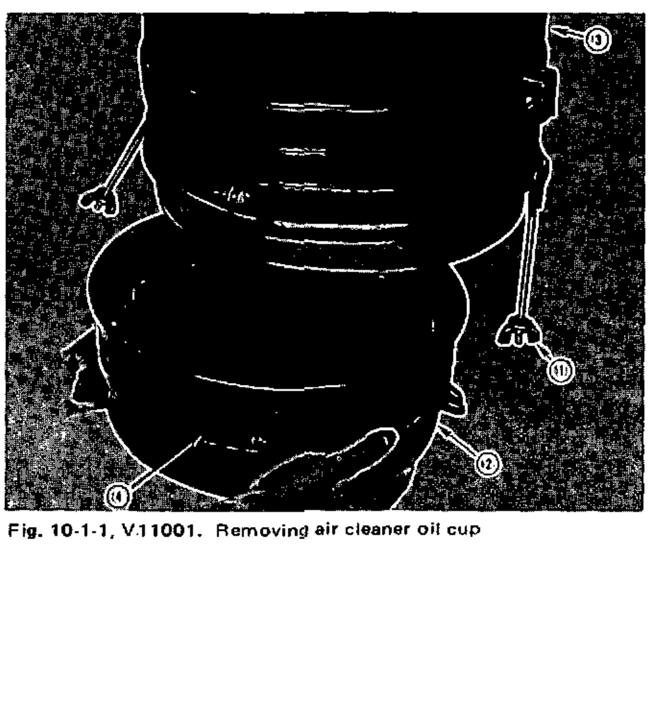


Fig. 10-1-1, V11001. Removing air cleaner oil cup

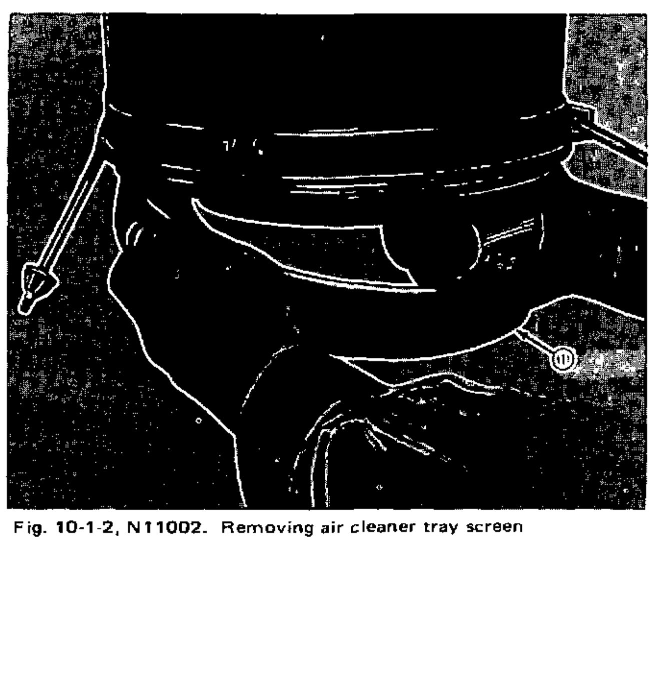


Fig. 10-1-2, N11002. Removing air cleaner tray screen thoroughly cleaned at this time or if the body has been pierced or otherwise severely damaged, replace the air cleaner.

8. Clean all hose, clamps and piping. Inspect for cracks or other damage.

9. Replace if defective.

Assembly

1. Assemble tray screen (1, Fig. 10-1-2) to cleaner and secure with clamp ring.

2. Assemble oil cup (2, Fig. 10-1-1) to cleaner and secure with wing nuts (1).

3. Assemble mounting straps to cleaner and secure with bolts and nuts.

4. Install rain shield.

5. Position hose connection over air intake pipe and secure to opening in cleaner with hose clamps.

Note: Fill oil cup to level indicated by bead (4, Fig. 10-1-1) on its side with clean, fresh oil before operating engine. An oil of the same grade as that in the crankcase should be used in the cleaner; however, in extremely cold weather a lighter grade may be necessary. Detergent or additive oils may be used as long as foaming is not encountered. **Never use crankcase drainings.**

Dry Type

Disassembly

1. Loosen wing nut (1, Fig. 10-1-3) securing bottom cover (2) to cleaner housing (3). Remove cover.

2. Pull element (6) down from center bolt (4).

3. Remove gasket (5) from outlet end (7) of housing.

Cleaning And Inspection

1. Clean element with compressed air. Do not hold jet too close, to avoid tearing element.

2. Wipe out cleaner housing with clean cloth.

3. Inspect gasket. Discard if not reusable.

Assembly

1. Install gasket (5, Fig. 10-1-3) at outlet end (7) of cleaner housing (3).

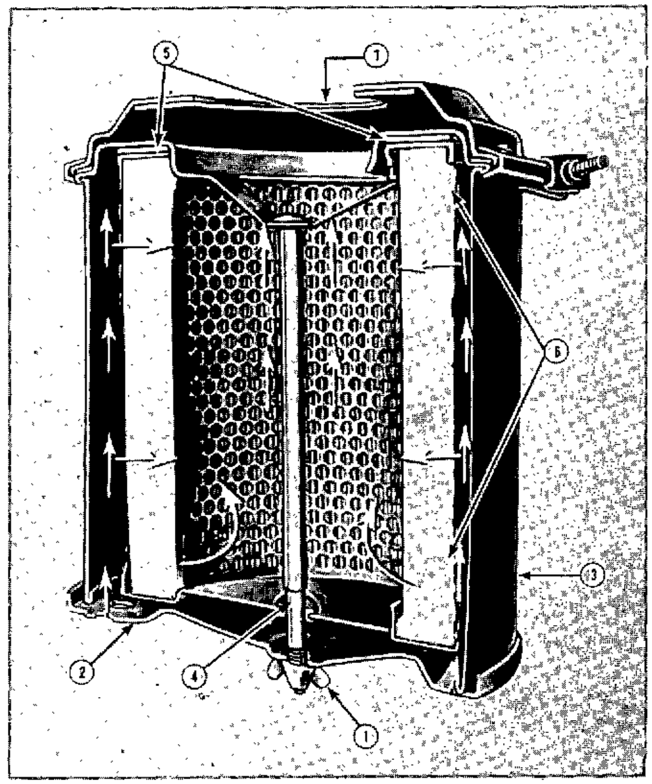


Fig. 10-1-3, N11003. Air cleaner—dry type

2. Install new or cleaned element (6) over center bolt (4), making certain it seats on gasket (5).

3. Install bottom cover (2) and secure with wing nut (1).

Composite And Cyclonic Dry Type

Disassembly

Before disassembly, wipe dirt from cover and upper portion of air cleaner.

1. On composite type, loosen clamps and remove top cover (1, Fig. 10-1-4).

2. Remove dust cup (2, Fig. 10-1-4) (1, Fig. 10-1-5) from bottom of cleaner.

3. Unscrew wing bolt (3, Fig. 10-1-4) (2, Fig. 10-1-5) holding element in position; on composite type remove element carefully so loose dirt does not fall back into chamber.

Cleaning

1. Empty dust cup.

2. A considerable amount of dust can be dislodged by

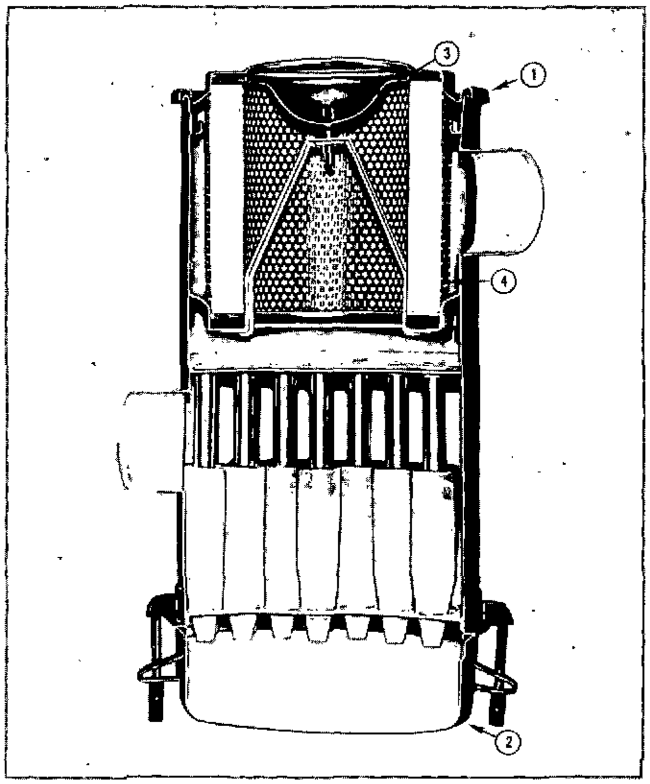


Fig. 10-1-4, N11004. Composite dry type air cleaner

Fig. 10-1-5, N11005. Cyclonic dry type air cleaner

slapping the side or bottom ring of the element with the palm of the hand or a soft hammer. However, most elements are discarded at the overhaul period.

Caution: Do not bang bottom rim of element against any hard surface.

3. Use compressed air to blow out element from clean-air side.

Caution: Air pressure should not be more than 100 psi [7.0310 kg/sq cm] to avoid rupturing element. Do not concentrate air pressure in one spot.

4. Wash filter with any good, non-sudsing household detergent and warm water (120 deg. to 140 deg. F [49 deg. to 60 deg. C]). Rinse with maximum 40 psi [2.8120 kg/sq cm] water pressure until drain water is clean. Dry with compressed air.

5. With filter element and dust cup removed, inspect tubes by looking through them at a bright light. Dust deposits can be removed with a stiff fiber brush.

Inspection

1. Inspect cover gasket for wear; replace if necessary.

2. Inspect element (4, Fig. 10-1-4) (3, Fig. 10-1-5) after cleaning to be sure there are no holes in filter paper.

3. Check gasket washer under the wing bolt for wear; replace if necessary.

Assembly

1. Install element (4, Fig. 10-1-4) (3, Fig. 10-1-5) into position.

2. Be sure gasket washer (4, Fig. 10-1-5) is in place under wing bolt (3, Fig. 10-1-4) (2, Fig. 10-1-5) before tightening.

3. Install cover (1, Fig. 10-1-4).

4. Install dust cap (2, Fig. 10-1-4) (1, Fig. 10-1-5).

Cartridge-Type Air Cleaner

Disassembly

1. Loosen wing nuts (4, Fig. 10-1-6) on air cleaner housing (5) to remove pre-cleaner panel equipped with dust bin (1). To remove pre-cleaner panel equipped with exhaust aspirator (2) loosen "U" bolt clamp securing pre-cleaner to aspirator tubing.

2. To remove dirty Pamic cartridge (3), insert fingers in cartridge opening using a "bowling-ball grip." Loosen all

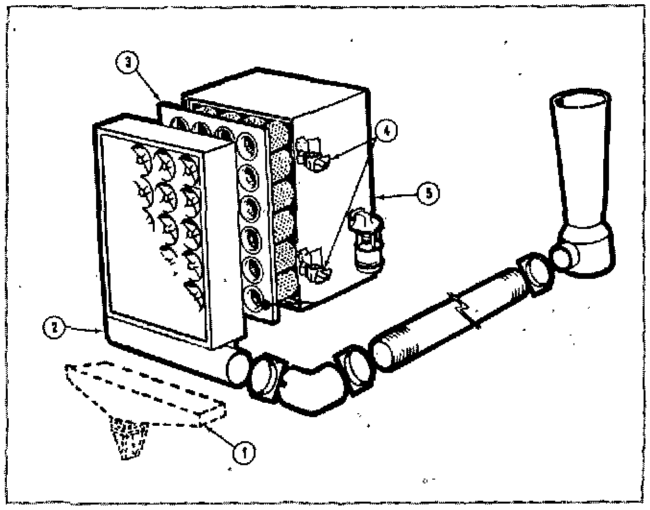


Fig. 10-1-6, N21026. Cartridge type air cleaner

four corners of cartridge, one at a time, by pulling straight out.

With larger cartridge, it may be necessary to break seal along edges of cartridge. After seal has been broken, pull the cartridge straight out and slightly up so cartridge will clear sealing frame and edges of air cleaner housing.

Cleaning And Inspection

1. Clean pre-cleaner openings of all soot, oil film and any other objects that may have become lodged in openings.

a. Remove any dust or dirt that may be in lower portion of pre-cleaner and aspirator tubing. Inspect inside of air cleaner housing to be sure it is free of all foreign material.

b. Pre-cleaners with dump valve in dust bin automatically expell dust and water while engine is running. During engine operation the dust bin is under a slight vacuum utilizing the engines pulsing action to open and close the dump valve. The dump valve also expells dirt and water whenever engine is shut down.

2. Inspect dirty cartridge for soot or oil. If there is soot inside Pamic tubes, check for leaks in engine exhaust system, exhaust "blow back" into air intake and exhaust from other equipment. If cartridge appears "oily," check for fumes escaping from crankcase breather. Excessive oil mist shortens life of any dry-type cartridge. Trouble-shooting before new cartridge is placed in the air cleaner can appreciably lengthen cartridge life.

3. It is not recommended to clean and reuse cartridge. Considerable laboratory testing shows that shaking, washing, rapping or blowing out with compressed air can cause cracks or ruptures in paper filter cartridges, which would permit wear-causing dirt particles to enter engine. If a failure occurs, there is no way of discovering it until cartridge is changed again.

4. Repeated tests have also shown that fine particles that penetrate deep into pores of filter paper cannot be removed by any method of cleaning. When returned to service, life expectancy (even if no failure occurs) of a paper cartridge will be only a fraction of original service life.

5. Inspect clamps and flexible hose or tubing to be sure all fittings are air tight on cleaners with exhaust aspirators.

Assembly

1. Inspect new filter cartridge for shipping damage before installing.

2. To install a new cartridge, hold cartridge (3, Fig. 10-1-6) in same manner as when removing from housing (5). Insert clean cartridge into housing; avoid hitting cartridge tubes against sealing flange on edges of air cleaning housing.

3. The cleaner requires no separate gaskets for seals; therefore, care must be taken when inserting cartridge to insure a proper seat within air cleaner housing. Firmly press all edges and corners of cartridge with fingers to effect a positive air seal against sealing flange of housing. Under no circumstances should cartridge be pounded or pressed in center to effect a seal.

4. Replace pre-cleaner panel (2) and tighten wing nuts (4). On pre-cleaner with exhaust aspirator, assemble aspirator tube to pre-cleaner panel and tighten "U" bolt.

5. Care should be taken to keep leaves, rags or side curtains from obstructing cleaner face. Obstructing air intake can result in reverse exhaust flow through bleed line and damage to cartridge.

Cleaner Restriction Indicator

1. The best method to indicate change periods for any dry-type air cleaner is by use of a restriction indicator such as shown in Fig. 10-1-7.

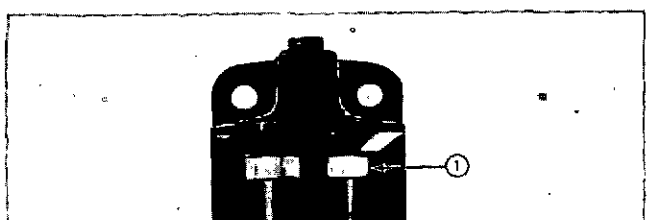


Fig. 10-1-7, CGS20. Air cleaner restriction indicator

2. The restriction indicator signals when to change cartridges. The red flag (1, Fig. 10-1-7) in window gradually rises as cartridge loads with dirt. Do not change cartridge until flag reaches top and locks in position. When locked, flag will remain up after engine is shut down. Change cartridge when flag locks at top. After changing cartridge, reset indicator by pushing re-set button (2). Push button all the way in firmly; then release. If button sticks, repeat pushing slowly.

3. A second method is utilization of a vacuum gauge and warning light that performs the same function as described in Step 1 and 2. Components for vacuum gauge include electrical source (1, Fig. 10-1-8) air piping (2), vacuum switch (3) and red warning light (4).

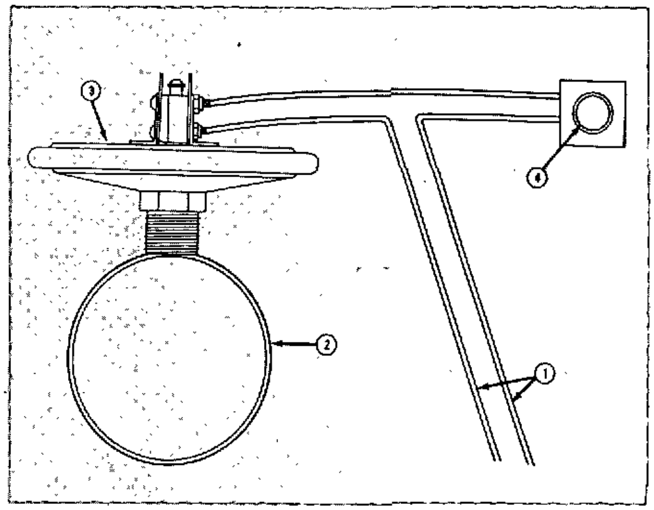


Fig. 10-1-8, N21905. Air cleaner restriction vacuum switch diagram

Air Cleaner And Piping Installation Recommendations

The required function of an air induction system is to supply clean, dry air to the engine without excessive restriction and a temperature at which the engine will operate efficiently.

Because dirt is the basic source of wear in liners, pistons, rings and valves, the effectiveness of the air cleaner and induction piping in preventing dirt entry into the engine has a considerable effect on engine life and maintenance costs. Control of the intake air temperature is required to obtain optimum power, together with maintenance and fuel economy. In order to accomplish these objectives, it is necessary to consider the following factors when designing and installing the air induction system.

Operating Restrictions

The over-all system design should provide minimum intake restriction to maintain adequate air flow to the engine for good combustion. In order to provide satisfactory engine performance and adequate air cleaner service life, the maximum total intake system restriction with a clean filter should not exceed the limits in Table 10-1-1.

Table 10-1-1: Total Intake Restriction Limits

Cleaner	Restriction Inch/Water	Water [mm]
Oil Bath	15	[381.000]
Dry Type (Normal Duty)	10	[254.000]
Dry Type (Medium Duty)	12	[304.800]
Dry Type (Heavy Duty)	15	[381.000]

The initial restriction of air flow through the air cleaner and piping system should be measured in the following manner. The vacuum measuring device, perferably a water-filled manometer, should be connected to the air induction system at right angles to air flow and flush with inside of induction system wall. This type of connection is made to ensure that only static flow is measured.

1. On naturally aspirated engines, the vacuum manometer should be connected to side of intake manifold near middle of manifold. A reading directly opposite a port location will give a faulty reading. If a plug is not provided in the manifold intake area, make reading as close to engine as possible in intake piping. The engine should be at normal operating temperature and at governed speed when vacuum reading is taken.

2. On turbocharged engines, the vacuum manometer should be connected to air intake pipe, one to two pipe diameters upstream from turbocharger inlet, in a straight section of pipe. The engine should be at normal operating temperature and at governed speed. Turbocharged engines should be under full load with time provided to allow the turbocharger to reach maximum speed when restriction is measured. (High idle, no-load readings on turbocharged engines are not satisfactory.)

3. Due to effect of restriction on engine performance, a maximum of 25 inches of water [635.0000 mm] has been established for dry-type cleaners as the service limit when cleaning or replacement is required and restriction measured as in Step 1 and 2 above. If the restriction is measured at the air cleaner body outlet, the restriction should not exceed 20 inches of water [508.0000 mm].

4. For oil bath cleaners, no maximum service limit can be established, since the service period is based on the amount of dirt in the air cleaner oil cup rather than its restriction.

5. The design of the induction system, including snorkels, should include adequate size of tubing and a minimum of bends to minimize total restriction.

6. The use of oversized oil bath cleaners would not be an

acceptable way to reduce over-all system restriction if the efficiency of the cleaner were reduced below 98%.

Piping

The piping between the cleaner and the engine should provide lifetime sealing against dirt without frequent maintenance or periodic replacement. A piping system composed of rigid tubing, hump hose or molded rubber elbows and "T" bolt clamps is highly recommended because these components have proven in the field to give the engine maximum protection with a minimum of maintenance. It is felt the use of these components represents an ideal system and any variation must be carefully evaluated as to its effect on the system and the increased maintenance involved. Always locate rubber hose connections away from high heat areas to obtain longer life.

Cold-Starting Aids—Unit 1002

Preheater

Due to the lower compression ratio of turbocharged engines, they may not start unaided below 40 deg. to 45 deg. F [4 deg. to 6 deg. C]. For this reason, the glow plug cold-starting aid is supplied as standard on these engines.

This aid uses engine fuel which is pressurized by a hand pump and atomized in a nozzle in the intake system. The atomized spray is ignited by the glowing coil of the glow plug and provides sufficient heat for combustion of fuel in the cylinders. Dependable starting down to −25 deg. F [−32 deg. C] can be obtained. A spray nozzle pressure of 50 to 100 psi [3.5155 to 7.0310 kg/sq cm] is required. Care must be exercised in pumping to provide only the pressure actually needed since, during cranking or low-speed operation, it is possible, by using excessive spray nozzle pressure, to have excessive fire in the intake manifold which will reduce the oxygen level to such a point that the engine will not fire and the preheater fire will go out.

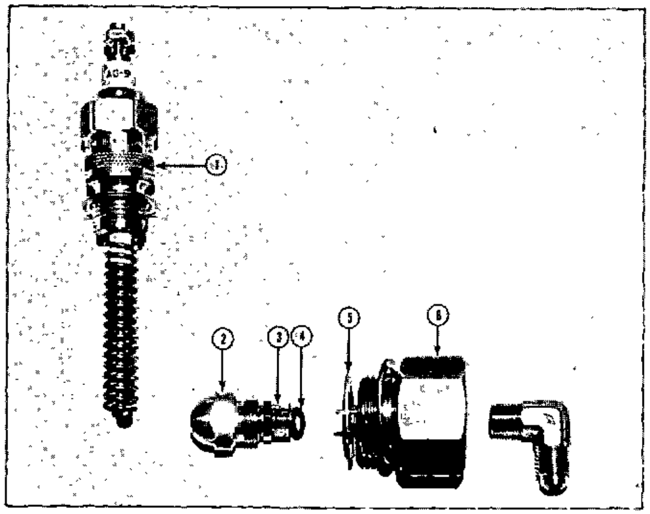


Fig. 10-2-1, N21019. Glow plug/preheater adapter/spray nozzle

By checking glow plug system prior to starting, battery strength will be conserved in case a malfunction occurs. An inspection hole is provided for visual observation of glow plug. To check, remove inspection plug and turn switch on; glow plug should become red hot in 15 to 20 seconds. Operate priming pump and check to see if a flame is produced. Then reinstall plug.

It is preferred that fuel supply be obtained from fuel tank. If this is impractical due to length of lines or cost, supply may be taken from pipe plug in bottom of fuel pump housing closest to throttle lever side or by a connection in engine fuel supply line. However, these methods are not desirable due to possible deterioration of hand pump seals which may allow air to be pulled into engine fuel system causing low power and erratic operation.

Disassembly

1. Remove preheater adapter (6, Fig. 10-2-1) from intake manifold.

2. Remove nozzle (2) and clamping washer (5) from adapter (6).

3. Remove glow plug (1) from intake manifold.

Cleaning And Inspection

1. Clean adapter and nozzle with Bendix carburetor cleaner, or equivalent. Be sure nozzle screen (3, Fig. 10-2-1) and spray holes are open and clean. Check "O" ring (4) for damage.

2. Check glow plug on 6-volt or 12-volt source, as applicable.

Caution: 6 and 12-volt plugs are not interchangeable.

Assembly

1. Assemble clamp washer (5, Fig. 10-2-1) and nozzle (2) to adapter (6).

2. Tighten nozzle to 15 to 20 ft-lb [2.0745 to 2.7660 kg m] and bend washer over one of hexagonal sides of nozzle.

3. Install assembled adapter in intake manifold.

Note: Preheater priming pump, Fig. 10-2-2, switches and resistor are located at the instrument panel and are to be checked during engine starting.

Preheater Priming Pump

Disassembly

1. Remove priming pump from instrument panel.

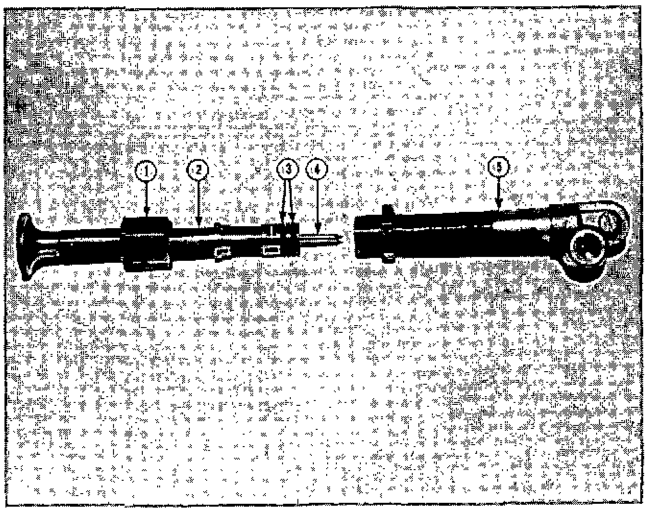


Fig. 10-2-2, N21020. Preheater priming pump

2. Remove plunger shaft (2, Fig. 10-2-2) by removing the lock seal nut (1).

3. Remove "O" rings (3).

Cleaning

Clean all parts in Bendix Carburetor cleaner or equivalent. Dry with compressed air. Check plunger point (4, Fig. 10-2-2) for damage.

Assembly

1. Assemble "O" rings (3, Fig. 10-2-2) on the plunger (2).

2. Lubricate "O" rings with light machine oil and allow excess oil to drain off.

3. Assemble shaft in pump body (5) and tighten seal nut (1) and test plunger for freedom of movement.

Ether-Starting Aids

The glow plug system supplies heat to the cylinders so *compression temperatures are sufficient to ignite fuel.* Ether-starting fluids allow combustion with a lower cylinder temperature since it is a more volatile fuel. A pressurized spray can or a rag wet with ether will usually provide quick starting as low as −10 deg. F [−23 deg. C]. Below this temperature, some means of injecting a carbureted ether vapor directly into the intake manifold is necessary. Table 10-2-1 lists approved cold-starting aids.

Table 10-2-1: Approved Cold-Starting Aids

Name	Manufactured by	Cummins	Mfr.	Remarks
Cummins	Cummins Engine Company, Inc.	99043-93		Diethyl ether. Spray may be directed toward air intake. Pressurized can.
Cummins (Chevron)	Cummins Engine Company, Inc.	43150		Uses 7 cc or 17 cc Chevron gelatin capsule. Gravity feed. Must not be used on turbocharged engines.
Chevron Capsule Primer	Chevron Oil Co.	SK-3713-B	Model L-13, S-12 or S-11	Pressure introduces fluid from 7 cc or 17 cc Chevron capsule into intake manifold.
Chevron Pressure Primer	Chevron Oil Co.	159383	Model 500	5/7-1/2 cc capsules.
Chevron Pressure Primer	Chevron Oil Co.	44357	9037	Chevron Pressure Primer Cartridge charged metal capsule, 10 cc.
*Ampco-*Sinclair	*Automotive & Marine* Products Corp. or Sinclair Refining Co.		*B-100*	*Uses air pressure to introduce special carbureted* mixture from metering chamber into intake manifold.
Start Pilot	Start Pilot Corporation		956-A	Double-action hand pump introduces a carbureted spray of special fluid into intake manifold.
Turner Quick Start	Turner Corporation Sycamore, Illinois		LP-1256-3 LP-1256-1	Push/pull control introduces a metered carbureted spray of special fluid into intake manifold.

Caution: Ether compound starting aids must never be used with the glow plug flame-thrower type cold-starting aid.

Turner "Quick Start" Starting Aid

The Turner "Quick Start" cold starting aid, approved for optional use on Cummins Engines, has been released based upon starting aid capabilities to −25 deg. F [−31.6 deg. C]. The valve meters and injects 5cc of starting fuel at each actuation. Fig. 10-2-3.

Electric valves meter and inject 1.5cc of starting fuel at each actuation, these are available as Part No's. 187208 (12 volt) and 187209 (24 volt). Fig. 10-2-4.

Caution: Do not attempt to use "Turner" or other ether compound type starting aids near heat, open flame or on engines equipped with glow plug system.

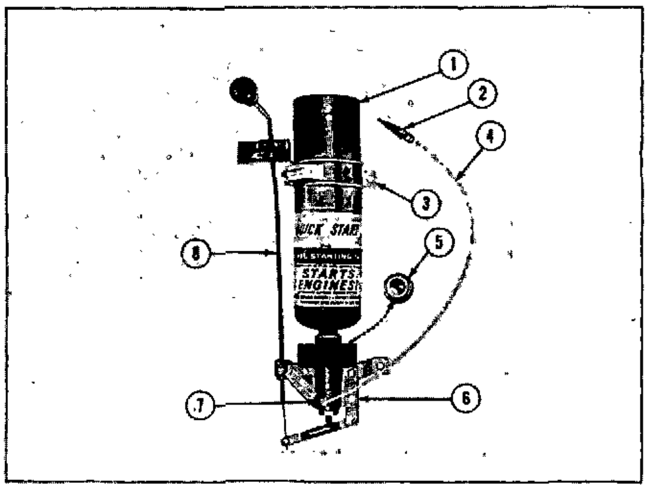


Fig. 10-2-3, V11011. Manual valve with fuel cylinder mounted

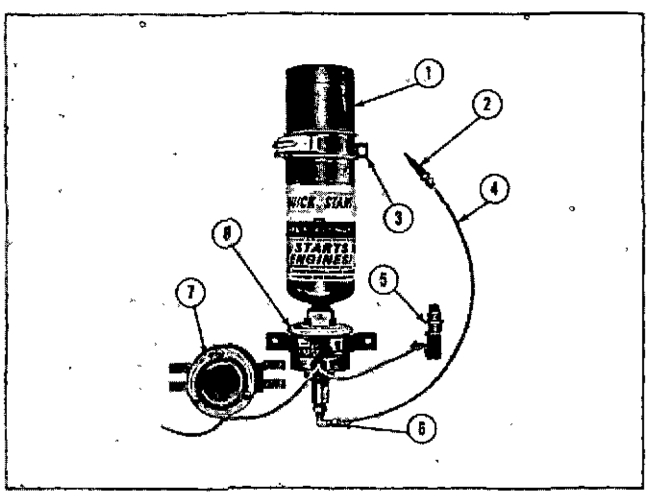


Fig. 10-2-4, V11012. Electric valve with fuel cylinder mounted

Manually Operated Valve

The manually operated valve, Part No. 191019, illustrated in Fig. 10-2-3 includes valve body assembly (6), 90 deg. elbow (7), cap (5), clamp (3) and Nylon tube (4). Fuel cylinder (1), atomizer-fitting (2) and pull control (8) must be ordered separately from parts catalog.

Standard pull or throttle control cables can be used, instead of the cables listed in parts catalog to actuate the manual valve, if desired.

1. Pull out cable knob 2 to 3 seconds to fill chamber.

2. Push in cable knob allowing 2 to 3 seconds to empty chamber.

3. At below zero temperatures, repeat Steps 1 and 2.

4. Wait 3 seconds and engage starter. Use only for starting.

Electrically Operated Valve

The electrically operated valve, Part No. 187208 or 187209, illustrated in Fig. 10-2-4 includes valve body (8), 90 deg. elbow (6), clamp (3), cap (not shown), push button switch (5), thermostat (7) and Nylon tube (4). The thermostat (7) is mounted on the engine exhaust manifold and cuts out the valve by sensing manifold heat when the engine is running. See parts catalog for fuel cylinder (1) and fuel atomizer fittings (2). These fittings must be ordered separately, as required.

The electrically operated valve should be wired as shown in Fig. 10-2-5.

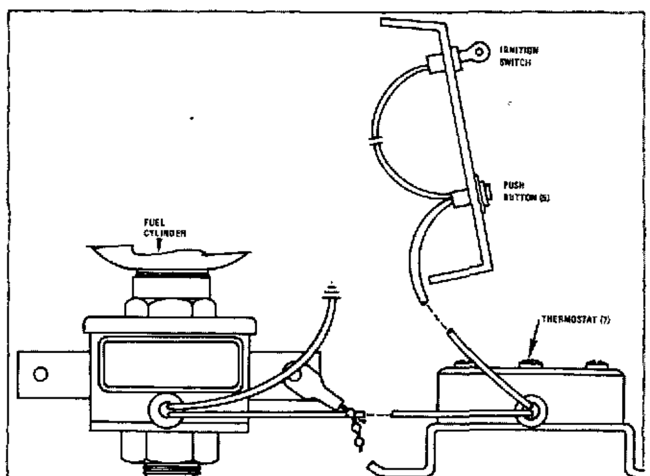


Fig. 10-2-5, V11013. Wiring diagram

Installation Recommendations

The atomizer fittings must be mounted in the engine air intake manifold or inlet connection to provide an equal distribution of starting fuel to each cylinder. The atomizer holes are 180 deg. apart and must be mounted so the fuel spray is injected the "long way" of the manifold. If incorrectly installed, the spary goes crosswise of the manifold.

The "V" type engines require two atomizer fittings, one in each intake manifold. A tee fitting, Part No. 187211, is available for use in connecting more than one atomizer in series.

Aneroid Control—Unit 1003

The aneroid control, Fig. 10-3-1, is a fuel by-pass system that responds to engine air manifold pressure. The aneroid limits fuel manifold pressure when the air manifold pressure is below a preset value. When accelerating the turbocharged engine from speeds below normal operating speed range to approximately 1400 rpm, air manifold pressure is not sufficient for complete combustion unless fuel delivery is reduced to maintain a suitable air-fuel ratio.

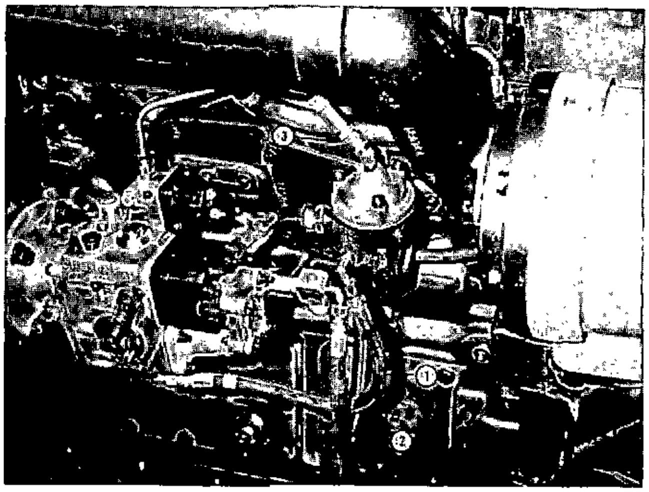


Fig. 10-3-1, V41020. Aneroid control and fuel flow

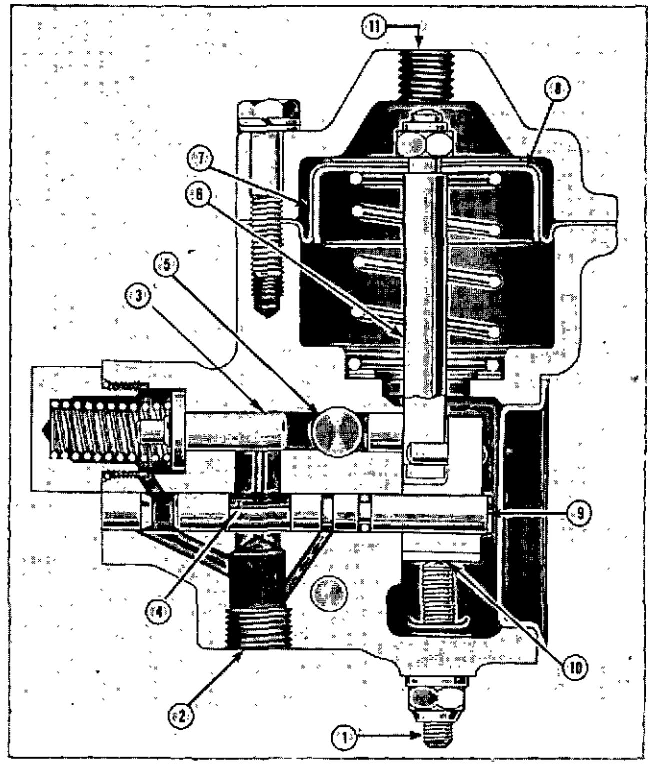


Fig. 10-3-2, N11023. Aneroid control — cross section

Fuel Flow

Fuel from the outlet side of the fuel pump governor barrel on PT (type G) fuel pumps or inlet side of PT (type R) (pressure regulator type) fuel pumps enters aneroid check valve area (5, Fig. 10-3-2). The check valve (3) prevents aneroid from by-passing fuel at engine cranking speeds. For speeds above cranking, fuel pressure forces check valve open, allowing fuel to flow to valve port (4) of shaft (9).

Shaft (9) and its bore from the by-pass valve. This shaft and bore allow passage or restriction of fuel flow in a similar manner as the throttle shaft and sleeve in the PT fuel pump. Fuel allowed to pass through by-pass valve is returned (2) to suction side (inlet fitting) of PT gear pump. The by-passed fuel reduces fuel pump out-put of fuel (manifold pressure) to engine.

The shaft and sleeve are by-passing fuel when tail (10) of lever, is resting against adjusting screw (1). The amount of fuel by-passed is adjusted by this screw (protrudes from bottom of aneriod). The lever arm connected to piston (8) by actuating shaft (6) rotates shaft, closing valve port. The lever is rotated by action of air intake manifold pressure (11) against piston and diaphragm (7), moving actuating shaft downward against resisting spring force.

Checks Before Adjustment

All aneroid controls are available with preset diaphragm spring travel adjustment; the fuel rate screw is the only adjustment required. Proper adjustment of the aneroid control for best performance requires the following checks:

1. Check fuel pump calibration and turbocharger operation before adjusting aneroid fuel rate screw.

2. Check aneroid settings by observing smoke during acceleration period.

Piping Installation

1. All turbocharged engines with an aneroid should have the aneroid inlet line (No. 5 hose) (1, Fig. 10-3-1) connected at bottom of fuel pump at outboard fitting (nearest throttle shaft side of pump body). The return line (No. 5 hose) (2) connects at fuel pump inlet connection.

2. Some PT (type R) (pressure regulator type) fuel pumps are piped from gear pump pressure tap to aneroid and need not be changed over unless so desired.

Standard Settings

1. Before attempting to check or set an aneroid control, check fuel pump settings by fuel manifold pressure or fuel rate; fuel rate is most accurate and should be used whenever possible.

2. If connected, disconnect line (3, Fig. 10-3-1) from aneroid control to engine intake manifold at the aneroid. Use a blunt instrument such as eraser end of a pencil and hold aneroid piston down against stop.

Note: A tool for this job may be made by tapping the inside diameter of a hose fitting or a pipe plug and adding a capscrew to hold piston down. Screw tool into aneroid diaphragm housing and turn down capscrew against piston screw, as necessary. This will free both hands for use.

3. Check fuel manifold pressure on engine with ST-435 Pressure Gauge. Fig. 10-3-3: Accelerate engine from idle to full throttle and record maximum pressure indicated on ST-435 Gauge.

4. If necessary, make adjustments to bring fuel pump pressure to proper limits, reference Bulletins 983505 or 983525.

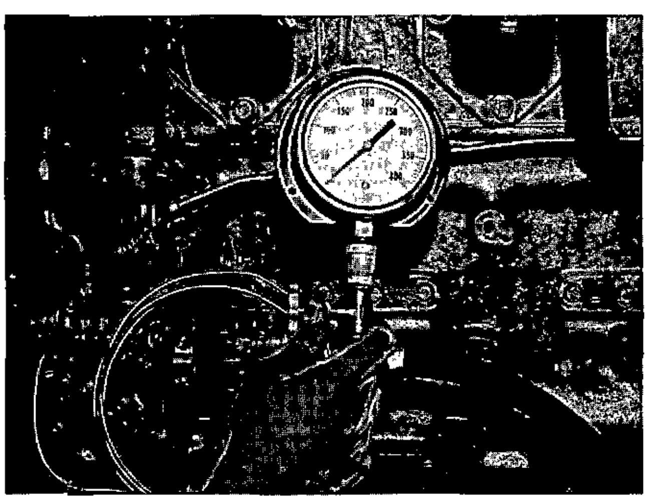


Fig. 10-3-3, V41021. Checking fuel manifold pressure

5. If possible, measure engine fuel rate, using ST-502 Flow Tank and a dynamometer. The fuel rate adjustment is more accurate than fuel manifold pressure check. For correct fuel rate values, see Bulletin 983505 or 983525.

6. After fuel pump is calibrated, check engine intake air manifold pressure with a mercury manometer. Compare readings with Table 10-3-1.

Table 10-3-1: Intake Manifold Pressure

Engine Model	Turbo Model	Rating HP @ RPM	Manifold Pressure Wet Exhaust	Manifold Pressure Dry Exhaust
VT-1710	T-50	635 @ 2100	29/35	33/39
VTA-1710	T-50	700 @ 2100	30/38	34/42
VTA-1710	T-18A	800 @ 2100	36/42	38/44
VTA-1710	VT-50	800 @ 2100 Loco	39/45	– –
VTA-1710	VT-50	800 @ 2100 Marine	35/41	– –
VTA-1710	T-50	730 @ 1800 Gen Set	36/42	– –
VTA-1710	T-50	630 @ 1500 Gen Set	30/36	– –

7. Remove tool or release piston so aneroid becomes fully operative. Start engine and warm up thoroughly. Accelerate engine from idle to full throttle and check fuel manifold pressure with ST-435 Pressure Gauge.

8. Fuel manifold pressure should fall within limits shown in Table 10-3-2. Adjust to proper value by turning aneroid control fuel screw in or out.

Alternate Adjustment Methods

1. The aneroid may be adjusted in the Field by observing acceleration smoke density if pressure gauges are not available. Fuel screw should be turned in two to two and one-half turns after contact with lever. Observe density of acceleration smoke. If smoke is too dark, back out screw until acceleration smoke becomes an acceptable density and engine performance is satisfactory, but do not back away from contact with lever. If screw is backed out too far and acceleration smoke becomes very light, engine acceleration will be slow.

2. If the engine is on a dynamometer and can be loaded for fuel rate measurement in pounds per hour, the aneroid fuel screw should be adjusted using engine fuel rate and horsepower output as the guiding values. See Table 10-3-2.

Special Settings

The fuel manifold pressure and fuel rate initial settings with intake manifold-to-aneroid line disconnected are listed in Table 10-3-2. These are settings for equipment where

Table 10-3-2: Aneroid Control Settings

Engine Model	Rated HP @ RPM	Aneroid BM	Code Letter	Piston Spring	No Air Engine Settings HP @ RPM	Fuel Press. PSI	Fuel Rate Lb/Hr	Screw Turns**	Remarks*
VTA-1710-C700	700 @ 2100	70220	FD	115086	470 @ 2000	100	186	3/4	Factory Setting
VTA-1710-C800	800 @ 2100	70220	FD	115086	600 @ 2000	100	228	3/4	Factory Setting
VTA-1710-C700	700 @ 2100	70220	FD	115086	310 @ 2000	63	140	– –	7000 ft Altitude Setting
VTA-1710-C800	800 @ 2100	70220	FD	115086	400 @ 2000	63	165	– –	7000 ft Altitude Setting

* Standard with governor controlled PT Pump – connect dump line to old pressure regulator cavity using 139473 plug.
** Screw turns after contact – fuel pressure is ± 5 psi (± 0.3515 kg/sq cm)

smoke density (particularly during acceleration) must not exceed Ringlemann No. 2.

On other types of operation that are not subject to smoke regulations, the operator may desire higher settings for additional power during acceleration. This may be accomplished by setting initial fuel rate approximately 15% more than the value listed in Table 10-3-2. This will, in turn, result in increased smoke density during acceleration.

This 15% increase refers only to initial fuel rate in Table 10-3-2, and not maximum fuel rate of an engine under load as listed in Fuel Pump Manuals 983505 and 983525. **Maximum fuel rate of the engine must never be exceeded.**

The 15% increase in initial fuel setting noted in preceding paragraph cannot be used in high-altitude operation because under that condition smoke density would be too great. The initial fuel setting should never be set high enough to cause excessive or "black-out" acceleration smoke.

Where an engine owner requires a special setting, he must be responsible for expense of adjustment and results.

Final Settings And Hook-Up

1. Connect line from diaphragm housing of aneroid to air intake manifold if it hasn't been connected.

2. Fill aneroid with **clean** engine lubricating oil. Fig. 10-3-4.

3. Check breather by reverse flushing with compressed air, reinstall aneroid breather (1, Fig. 10-3-5).

4. Start engine and check idle speed; in most cases, it will have to be adjusted upward after aneroid is installed. Make idle adjustments with fuel pump governor idle screw, **not with throttle adjusting screws.**

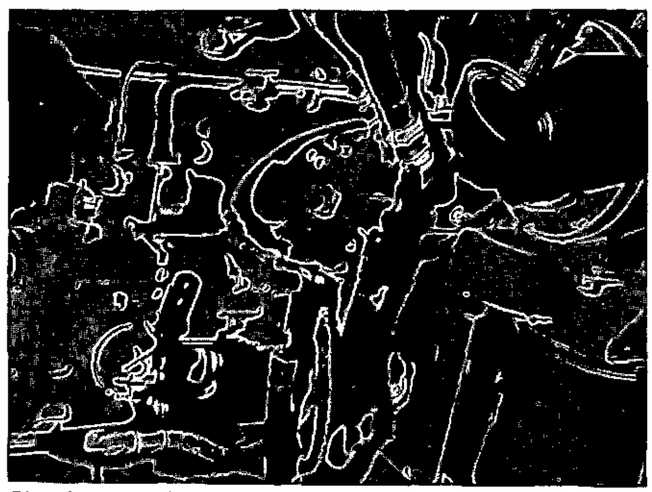


Fig. 10-3-4, V41022. Filling aneroid with lubricating oil

5. Check engine operation with aneroid connected. If smoke is excessive after 15 seconds of full throttle operation, aneroid is not at fault. Check fuel system and turbocharger before readjusting aneroid control.

6. If hard starting is encountered, check aneroid pressure valve for sticking open. If valve sticks closed, excessive smoke will result. When engine is stopped, check valve should be all the way in.

7. Always depress aneroid control piston as described under "Standard Settings" when checking fuel manifold pressure unless check is being made for setting as described in Step 7 under "Standard Settings."

Note: If desired, the aneroid may be disconnected while checking, instead of depressing piston.

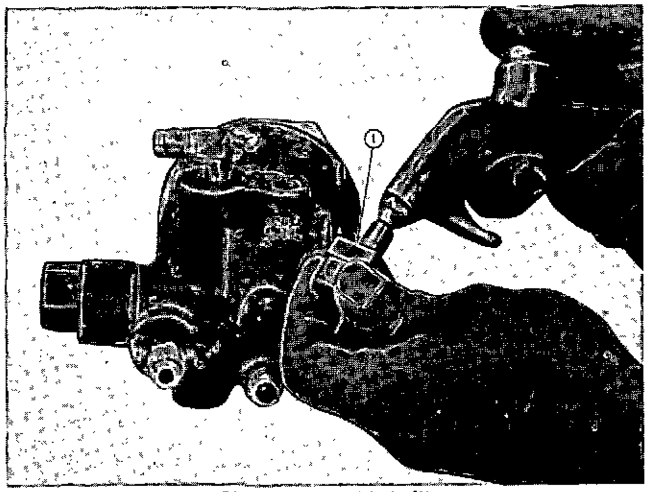


Fig. 10-3-5, N11021 Cleaning aneroid air filter

8. Keep aneroid control cavity filled with **clean** engine lubricating oil.

9. If diaphragm in aneroid needs to be replaced, do not change Factory preset spring and shim combination.

Repair

If aneroid cannot be properly adjusted as described above; disassemble and check for ruptured diaphragm, stuck by-pass valve, worn shaft or other defects.

1. When diaphragm is ruptured the aneroid will by-pass fuel causing loss of power and hard starting.

a. Remove air inlet connection from cover.

b. Remove capscrews and washers and lift off cover.

c. Remove nut and washer from shaft.

d. Replace damaged diaphragm and reassemble aneroid.

2. To replace sticking by-pass valve plunger:

a. Remove retaining ring, "O" ring and spring.

b. Remove plunger and check for burrs or other damage.

c. Inspect housing bore for damage.

d. If housing bore is satisfactory, install new or lapped plunger and reassemble.

3. If throttling shaft is worn, the aneroid will by-pass excessive fuel causing a loss of power; replace complete aneroid assembly.

Turbochargers—Unit 1005

Either of three Turbochargers may be used on V-1710 Series Turbocharged engines.

1. The T-50 Turbocharger is covered in Bulletin No. 983615.

2. The VT-50 Turbocharger is covered in Bulletin No. 983681.

3. The T-18A Turbocharger is covered in Bulletin No. 983678.

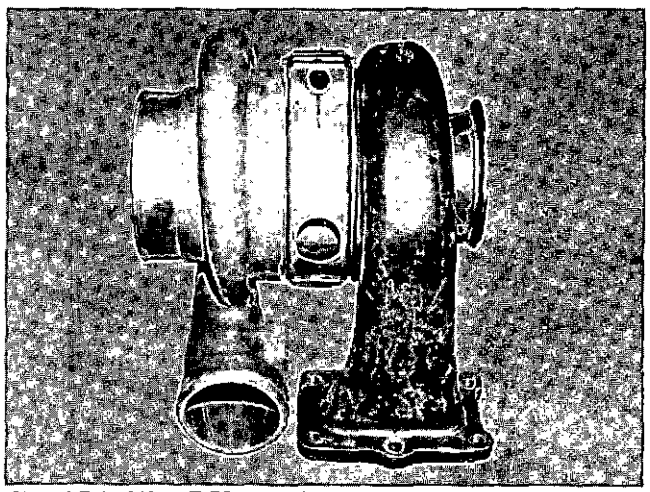


Fig. 10-5-1, T176. T-50 turbocharger

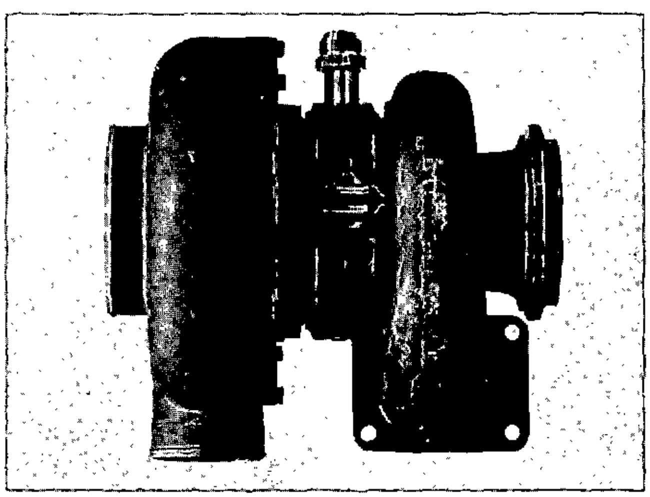


Fig. 10-5-2, T3100. VT-50 turbocharger

4. Copies of the manuals may be obtained or ordered through Cummins Distributors

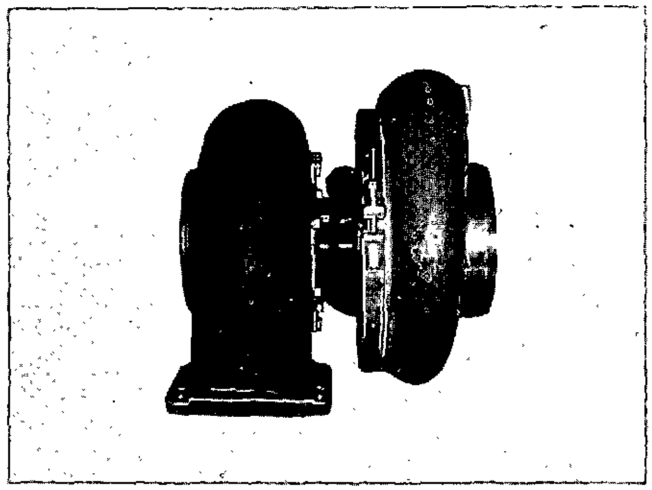


Fig. 10-5-3, TA48. T-18A turbocharger

Exhaust System Group

The exhaust system group consists of engine exhaust manifolds, piping and mufflers or silencers. Auxiliary equipment (such as exhaust brakes, aspirators and pyrometers) and instructions for its use and application are also covered.

Manifolds—Unit 1101

Exhaust Manifold (Dry Type)

Cleaning And Inspection

1. Steam clean manifold.

2. Inspect exhaust manifold for cracks and distortions; discard defective parts.

3. When ordering replacement parts, order same part as presently used. Manifolds are made of different materials and the rate of expansion may cause cracking if incorrect manifold combinations are used.

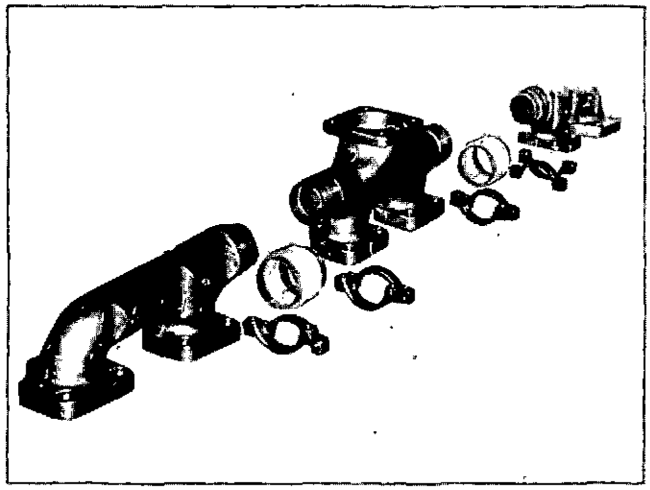


Fig. 11-1-1, V41101. Dry manifold

Exhaust Manifolds (Wet Type)

Cleaning And Inspection

1. The exhaust manifold is a combination water header and water-cooled exhaust manifold. Water test at 30 to 80 psi [2.1090 to 5.6240 kg/sq cm].

2. Remove inspection plate from exhaust manifold and discard gasket.

3. Inspect manifold for cracks and distortions.

4. Replace manifold if necessary.

5. Steam clean manifold and soak in acid tank to remove salt and lime deposits.

6. Position inspection plate with new gasket to exhaust manifold; secure with lockwashers and capscrews.

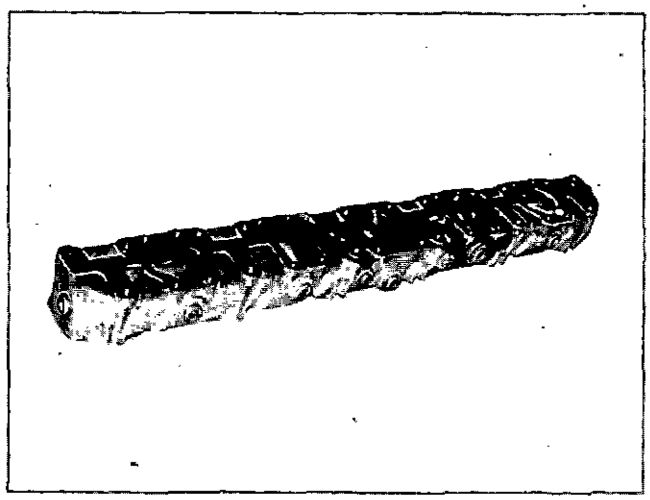


Fig. 11-1-2, V41102. Wet manifold

Caution: Do not run engine without coolant in water-cooled exhaust manifold.

Mufflers and Piping—Unit 1102

System Restrictions (Back Pressure)

1. When engine pistons must act against a back pressure in exhaust system to expel exhaust gas, usable output of engine is lowered; since air-fuel ratio will be reduced because of incomplete scavenging of cylinders, fuel economy is reduced and exhaust temperatures will increase. Although turbocharged engines are affected to a lesser degree than naturally aspirated engines due to positive pressure in intake manifold, it is essential exhaust system for all engines be designed to offer least possible restriction to exhaust flow.

2. High pressure indicates restrictions caused by foreign objects, excessive bends or small sizes of piping. The lowest pressure obtainable is desired.

3. If exhaust back pressure exceeds those values listed in step 9, early engine failure and poor performance may be expected.

4. The point of measurement must be as close as possible to the manifold or turbocharger outlet flange (1, Fig. 11-2-1) in an area of uniform flow such as a straight section of pipe at least one pipe diameter from any changes in flow area or flow direction.

5. Where it is impossible to locate the point of measurement in a straight section, it is permissible to measure on the side of a bend where flow is uniform and equivalent to flow along the centerline. Do not measure on inside or outside radius of bend as flow is not uniform at these points.

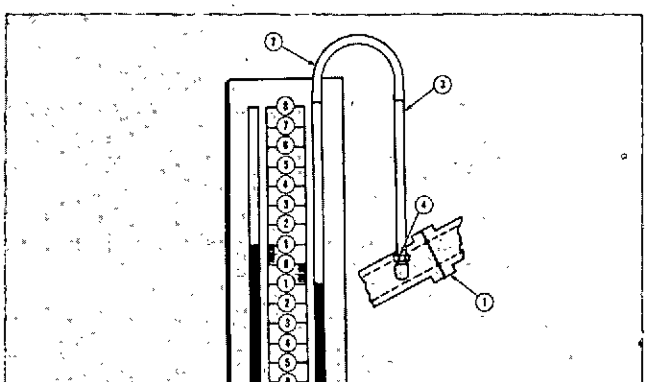


Fig. 11-2-1, V11101. Measuring back pressure

6. At the point selected, weld a 1/8 inch [3.1750 mm] pipe coupling to the exhaust tubing. Drill through tubing with a 1/8 inch [3.1750 mm] drill. Remove all burrs. Mount 90 deg. Weatherhead fitting (4) to coupling. Then use 3 ft [0.9144 m] of 1/8 inch [3.1750 mm] inside diameter copper tubing (3) plug 10 ft [3.0480 m] of 3/16 inch [4.7625 mm] inside diameter soft rubber hose (2) to manometer. (See Note.) The manometer may be mercury filled or water filled.

Note: It is important that line to manometer be as specified to minimize variation in reading due to a standing wave phenomenon which occurs in manometer line. A change in length or material of this line can significantly change reading obtained.

7. Start engine and operate until oil temperature reaches 140 deg. F [60 deg. C].

8. Take back-pressure readings when engine is developing its maximum horsepower at maximum engine speed.

9. Add reading of mercury in both columns for final figure. Fig. 11-2-1. Example: If mercury is 1 inch [25.4000 mm] high in left column and 1 inch [25.4000 mm] low in right column, you have 2 inch [50.8000 mm] of pressure. If the mercury is 1 inch [25.4000 mm] high in the right column and 1 inch [25.4000 mm] low in the left column, you have 2 inch [50.8000 mm] of vacuum. Maximum permissible back pressures are:

a. 1.5 inch [38.1000 mm] Hg. or 20 inch [50.8000 cm] of water for all naturally aspirated engines.

b. 2.0 inch [50.8000 mm] Hg. or 27 inch [68.5800 cm] of water for all turbocharged engines.

Exhaust Piping

Piping Design

If back pressure reading is too high, check entire exhaust system from exhaust manifold to end of exhaust pipe. If one or more of the following conditions are present in exhaust system, they must be eliminated.

a. Right angles (90 deg.) or sharp bends in exhaust pipe. If it is necessary to bend exhaust pipe, use gentle sweeping curves.

b. Small exhaust pipe diameters. The diameter of pipe throughout the exhaust system must not be smaller than diameter of exhaust manifold outlet flange.

c. Restrictions or stoppages in muffler device. Remove anything in the muffler that retards an easy passage of exhaust.

d. Small diameter pipes aft of muffler.

Flexibility

1. Provisions should be made for relative movement between exhaust piping and engine so no damaging stresses will be imposed on exhaust system components because of engine mounting flexibility or thermal growth.

2. The most common methods of obtaining flexibility are through the use of flexible (tubing spiral or bellows type) or special ball joint tube connections. The use of these components is necessary in the tubing between any components where either relative motion or thermal growth will subject components to excessive stresses.

Turbocharger Restrictions

1. Due to thermal expansion of turbocharger, it cannot be rigidly restrained and certain limitations in the connection of piping must be observed.

2. A minimum of 1 ft [30.4800 cm] of flexible connection or two ball joints must be provided within the first 4 ft [1.2192 m] of exhaust piping on turbocharged engines to allow for thermal growth without overstressing engine or turbocharger components.

3. No more than 4 ft [1.2192 m] of unsupported exhaust tubing or flexible connections should be attached to turbocharger to avoid overstressing the components.

Exhaust Pipe Size

1. The exhaust pipe size required to stay within back pressure limitations will depend upon the volume of flow, temperature of the gas, length of piping and number and angle of bends in the system. As a guide for preliminary design work and pilot installations, Table 11-2-1 gives the pipe diameter which field experience has shown to be adequate for most installations. Since restriction in mufflers varies considerably and routing of piping will effect restriction, the use of larger diameter piping may be required to stay within recommended limits.

2. A small increase in diameter can significantly reduce back pressure imposed by piping since back pressure imposed on a system by the exhaust pipe varies directly as the length and inversely as the 5th power of the diameter.

3. As a guide in the design of the system, exhaust gas flow for any engine will be approximately three times the engine's air intake consumption.

Table 11-2-1: Exhaust Pipe Size

Engine Model	Pipe Diameter Inch [mm]
V-1710 Naturally Aspirated and Turbocharged	Acceptable 4 [101.6000] Recommended 5 [127.000]

Supports

1. Many ways exist to accomplish desired flexibility while still adequately supporting the piping and other components in the system. To reduce the loading imposed on exhaust manifold, it is desirable to support long lengths of piping to the engine package or directly mounted component. However, flexibility must still be maintained through design of the support and/or use of flexible connections.

2. Many installations do not require exhaust components other than piping. In general, these use short lengths of tubing or pipe mounted directly to the manifold. Since permissible load depends upon the type of manifold used and relative overhang, no single restriction on maximum length or weight of unsupported tubing can be made to cover all applications. As a guide in design, it is recommended that no more than 4 ft [1.2192 m] of unsupported exhaust tubing (approximately 16-gauge wall) should be attached to the manifold. If it is necessary to exceed this, Cummins Engine Company, Inc. should be consulted and a mutually acceptable design worked out.

Muffler Location

1. Industry experience and laboratory tests have indicated that location of the muffler in the system has a very definite influence on both silencing capability of the muffler and back pressure imposed on the system. The importance of the position of the muffler becomes more critical as the system is extended in length.

2. In an exhaust system, sound or "standing" waves are set up and kept in vibration by exhaust impulses from the engine. These waves are independent of exhaust gas flow but are related to system length, temperature of gases and frequency of engine exhaust slugs. The sound pressure standing wave has a node or several nodes or regions of minimum pressure change, and corresponding anti-nodes or regions of maximum pressure change.

3. If a muffler is located at the pressure node, it does less silencing and causes a higher restriction, while a muffler located at pressure anti-node does greater silencing and imposes less restriction. The equations following have been derived to locate the muffler in the exhaust system near optimum location for best performance. Final location for best noise suppression and back pressure reduction should be determined by test.

4. The following formulae are given as guidelines toward optimum muffler location. Designs of necessity must be modified from values shown within expense, economic and physical limits.

a. The best calculated muffler locations for V type engines (Dual System) are as follows:

Preferred	1	$d = \frac{4L-5}{5}$
Acceptable	2	$d = \frac{2L-5}{5}$
Permissible	3	$d = \frac{3L-10}{5}$

b. Where "d" is the distance in feet from the right or left bank exhaust flange, as indicated by the subscript, to the center of the muffler, "L" is the total system length in feet from the right or left bank as indicated by the subscript.

c. The pair of equations to be used will generally be detected by space available for muffler in a particular installation. For example, cab-size mounted mufflers require use of 1 or 2 as stated in step a above.

Balance Tubes

Balance tube between dual systems can provide additional muffling. The equation for determining best or worst location for such a tube is the same as for muffler location above. The balance tube will decrease loudness by approximately 20% when properly located and when no mufflers are used. The percentage of reduction decreases with increased muffling.

Noise Isolation

Attention must be given to adequate silencing of the engine, since unnecessary noise is often objectionable. The degree of silencing required will vary with application, and since the engine will operate most efficiently with a minimum restriction in exhaust system, an effort should be made to avoid silencing engine by adding back pressure to a degree further than dictated by the application. Silencer manufacturers should be contacted for detail recommendations.

Moisture Exclusion

The exhaust system outlet should be designed to prevent entrance of moisture which might enter the engine or collect in the system thereby restricting the exhaust flow or causing deterioration of the system due to rust. The use of a commercial-type rain cap or a right-angle bend can be used on vertical exhaust systems, while a bevel cut on underneath side of pipe is normally sufficient with horizontal piping. In some installations it may be necessary to add small drain holes in piping.

Heat Radiation

In some cases, as in a marine engine room, it may be desirable to limit heat radiation from the exhaust system. An exhaust system for this type of installation should be insulated or water cooled. A cool exhaust system also reduces any fire hazard. When required for a particular installation, a heat shield that encloses the turbocharger casing is available to reduce heat radiated from this source.

Auxiliary Equipment—Unit 1103

Aspirators

Exhaust aspirators may be used to scavenge certain air-cleaning systems. The back pressure added due to restriction imposed by reduced area of the throat must be considered so back pressure limitation for engine model involved will not be exceeded. Experience indicates that when an aspirator is added to an existing system, back pressure limitations are almost always exceeded, and it is usually necessary to completely redesign the entire system. A check valve in aspirator line from air cleaner is frequently required to prevent exhaust gases from traveling to the cleaner during portions of operating cycle.

Pyrometers

An exhaust pyrometer (a device which indicates temperature of exhaust gases through use of a thermo-pyrometer) will consist of a single thermocouple in the exhaust piping to indicate temperature of total exhaust gas output of engine. The reading is given on a dial that is usually calibrated in color bands — green for normal operation, red for operation at excessive high temperatures. The pyrometer will indicate excessive exhaust temperatures before, and independent of, any coolant temperature change. Such excessive temperatures can be the result of lugging or overfueling, which in turn may be caused by a plugged air filter, high altitude operation or malfunction of exhaust system. The purpose of an exhaust pyrometer in an automotive installation is to promote engine life and fuel economy. It should **not** be used to set fuel rate or measure horsepower due to the number of factors which influence accuracy of the readings.

Air Equipment Group

The air equipment group consists of Cummins air compressors, check valve, vacuum pump and piping; it also includes the air-actuated cranking motors, which ary sometimes used on Cummins engines.

Air Compressor—Unit 1201

Cummins air compressor and the compact Cummins air compressor are used on all models of Cummins Engines and are completely covered from a servicing standpoint in Bulletin No. 983542.

Optional units, such as Bendix-Westinghouse, Wagner and others are covered by publications available from the manufacturer or his authorized service station.

Cummins two cylinder air compressor is used optionally on some models of Cummins Engines and are completely covered from a servicing stand point in Bulletin No. 983542 and Supplement 983547.

Vacuum Pump—Unit 1202

Cummins vacuum pump is an adaption of the compact Cummins air compressor and this unit is also covered in Bulletin No. 983542.

Air Cranking Motor—Unit 1203

Air cranking motor servicing is covered by the manufacturer or his authorized service station; however, basic suggestions for good operation and installation are covered in Bulletin No. 983542.

Electrical Equipment Group

The principle function of the Electrical System on Cummins Diesel Engines is that of cranking or starting and operating electrical accessories as required by the unit being powered. All Cummins Engines electrical wiring diagrams are contained in one manual, Bulletin No. 983444.

Cranking Motor—Unit 1301

The three basic cranking systems used on Cummins engines are electric, air and hydraulic. The selection of the type of system to be used is generally dependent upon the operator's preference or such factors as cost, weight or special operating requirements. Each system, when properly designed for engine and operating conditions, will perform satisfactorily.

Electrical Cranking System

This unit includes:

Electric Cables and Connections
Ground Connections
Cranking Motor
Series-Parallel Switch
Batteries

The information contained in this section is limited to a brief description of the function and operation of electric units used on Cummins engines and to simple tests and adjustments that can be made without special equipment.

Repair of electric units should be done in manufacturers' service stations. Their stations are well equipped and well distributed.

If this service is not available, further specific information can be obtained as follows:

Delco-Remy Equipment

Electrical Equipment Operation and Maintenance Handbook DR-324-1 or -2, -3, -4 and Test Specifications DR-324-S-1 may be purchased from the nearest United Motor Service Station, or the Service Dept., Delco-Remy Division, General Motors Corp., Anderson, Indiana.

Leece-Neville Equipment

Operation and adjustment information may be obtained from the nearest Leece-Neville distributor or the Service Dept. of the Leece-Neville Co., 5109 Hamilton Ave., Cleveland 14, Ohio.

Electric Cables And Connections

Electric current traveling through a wire may be compared to water flowing through a hose or pipe. Voltage in the electric circuit is like pressure behind water in the hose. Water pressure is lost if it is allowed to leak or if hose diameter is so small that it offers resistance to flow. This loss of water pressure compares with loss of electric pressure, or voltage, because of poor connection or conductors of insufficient capacity.

Battery Cables

Starter circuit resistance can have a significant effect on performance of the system to satisfactorily start engine. increase in the circuit resistance, due to cable and connection deterioration, will reduce cranking speed and starter cranking torque and result in more difficult engine starting, even with batteries of good capacity.

The total resistance of the circuit must not exceed "maximum circuit resistance" shown in Table 13-1-1. Resistance reduces electric current and cranking effort. The low-voltage high-amperage current in the cranking motor circuit requires heavy-duty cables and good connections. Battery cable size is based on total cable length (over to starter and back to battery).

Ground Connections

In engine applications a common ground connection is sometimes used. This system uses the metal of the unit as one side of the electric circuit and, as such, makes all metal that lies between electric unit and battery or generator an electric conductor. Fig. 13-1-1 and 13-1-2. Therefore, it is advisable to make all ground connections to the same solid metal member.

An occasion may arise when the battery is grounded to one

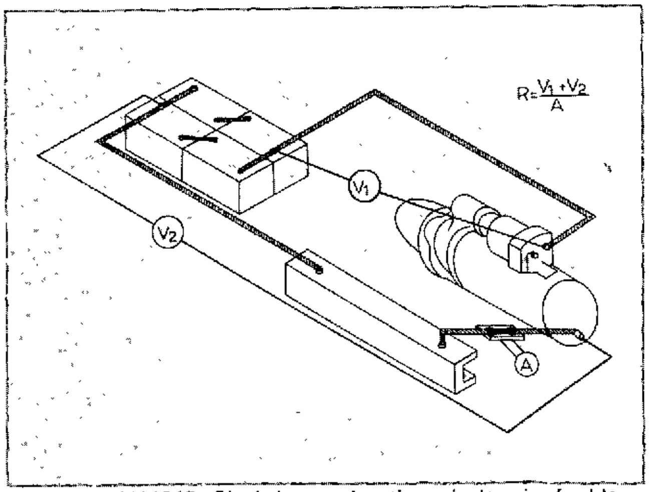


Fig. 13-1-1, V11313. Single battery location—single pair of cables with frame ground return

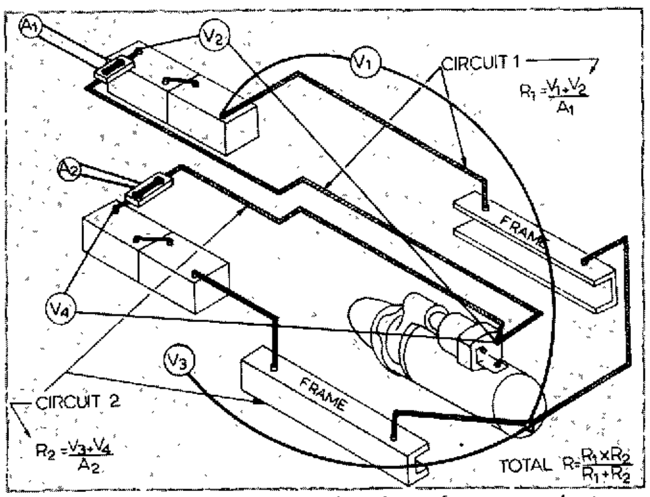


Fig. 13-1-2, N11314. Two battery location — frame ground return

beam of the frame and it is necessary to make ground connections to a second beam or section of the superstructure which is jointed to the first. This can be done safely if you first bolt and sweat-solder a flexible, heavy metal strap between the two beams to bridge the joint. This has the effect of making the jointed member a part of the beam which grounds the battery. All metal joints in the circuit should be treated in this manner. This will also hold true for instrument ground connections in the cab, on the instrument panel, etc.

Many engines and cabs are installed on rubber or other flexible mountings. These mountings, in themselves, provide practically no electric connection to the frame. Even a solid-type engine mounting in which the flywheel housing is bolted directly to the frame makes a poor electric connection. All ground connections from any electric unit should be made to the same solid or bridged metal member to which the battery itself is grounded. Fig's. 13-1-3, 13-1-4 and 13-1-5.

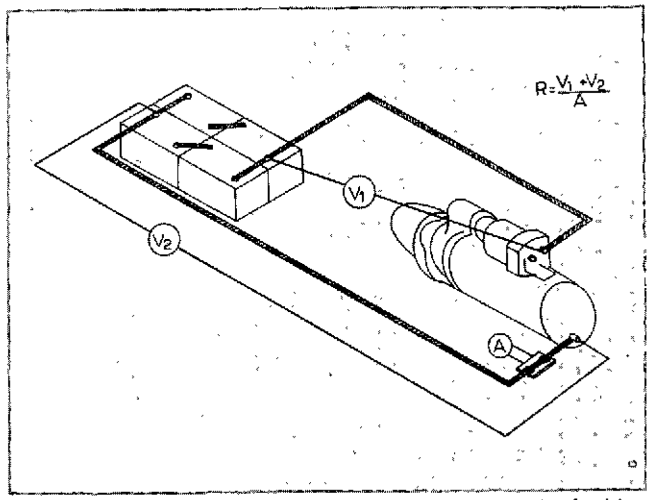


Fig. 13-1-3, N11315. Single battery location — single pair of cables

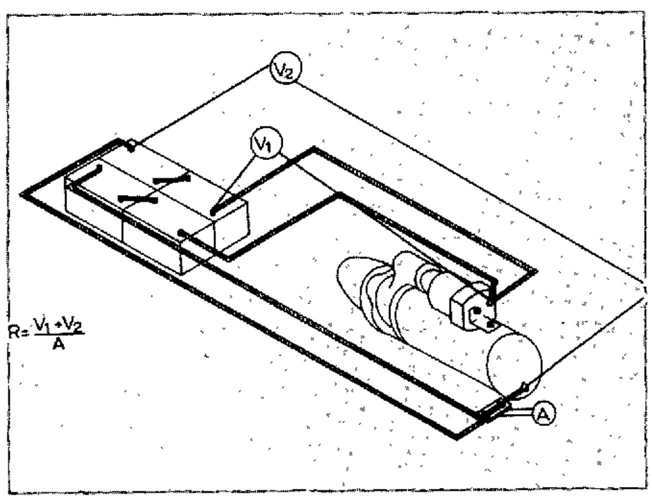


Fig. 13-1-4, N11316. Single battery location — parallel cables

Never install a battery or electric connection in a dirt stream or where excessive dirt, oil or corrosion will collect. Dirt, oil and corrosion act as an effective resistor, taking away current needed for engine cranking. Never attach ground wires to a rusty, greasy or dirty surface.

Regardless of where magnetic switches, cut-out relays and other control units are mounted, a separate ground wire should be run from the proper terminal or designated part of the unit to the same solid metal member grounding the battery. Whenever possible, make ground connections directly to the battery's grounding bolt. This will provide a dependable ground return circuit and permit unretarded passage of current to allow units to function as they are intended.

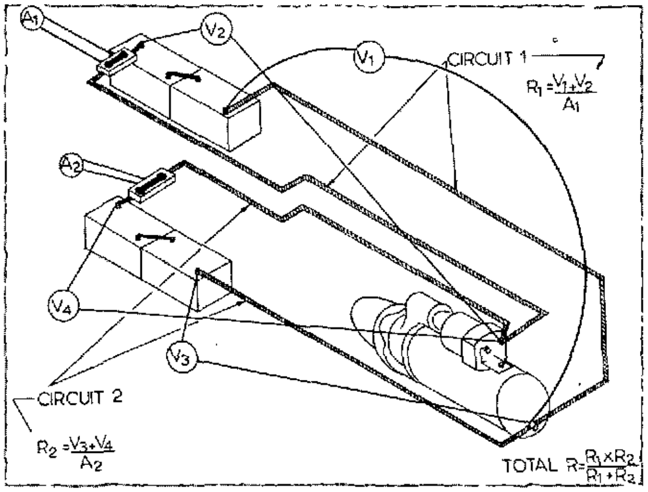


Fig. 13-1-5, N11317. Two battery locations — two pair of battery cables

The sketches shown here indicate the proper method of grounding certain units. They are not complete wiring diagrams, and under no circumstances should they be used as such.

To make a good electric connection between a cable terminal and the frame, clean and scrape metal surfaces until they are bright; then tin these surfaces to prevent rust and corrosion. To make a dependable, permanent joint, sweat-solder cable and frame after they are bolted together.

The heavy cables used to make ground connections from the battery, cranking motor or engine should not swing. A single bolt connection as shown in Fig. 13-1-6 is unreliable. The surface of frame at the joint is not tinned and, in addition, the heavy cable can swing back and forth to loosen connection. Loose connections leave a space between cable terminal and frame, which may allow the entrance of dirt or moisture to form rust or corrosion.

Recommended ground connections and methods of preventing cable swing are shown in Fig. 13-1-7. The surface of the frame at the connection is tinned to prevent rust and corrosion.

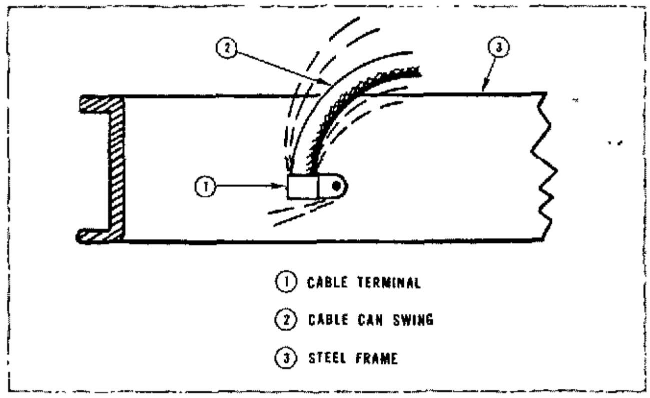


Fig. 13-1-6, V11301. Unreliable ground cable

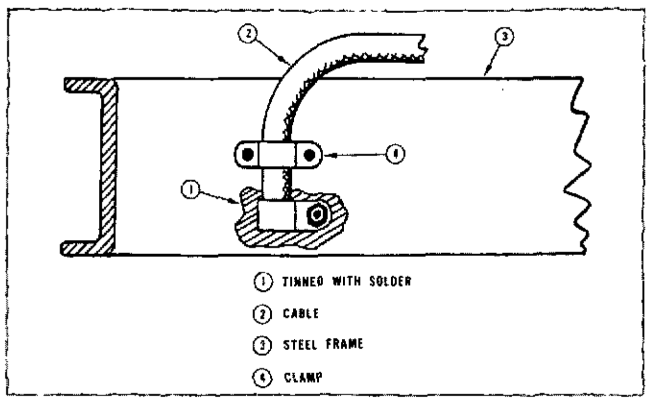


Fig. 13-1-7, V11302. Reliable ground cable

Table 13-1-1: Cable Sizes — Total Length Allowable in Cranking Motor Circuit Using Cable Sizes Indicated

		B and S Gauge and Length							
Circuit Voltage	**Maximum Circuit Resistance**	**No. 00 Ft**	**[m]**	**No. 000 Ft**	**[m]**	**No. 0000 Or Two No. 0 Ft**	**[m]**	**Two No. 00 Ft**	**[m]**
12-V	0.0012 Ohm	To 12	[3.6576]	12/16	[3.6576/4.8660]	16/20	[4.8660/6.0960]	20/25	[6.0960/7.6200]
12-V High Output Starting Motor	0.00075 Ohm	To 7	[2.1336]	7/9	[2.1336/2.7432]	9/12	[2.7432/3.6576]	12/14	[3.6576/4.2672]
24-V to 32-V	0.002 Ohm	To 20	[6.096]	20/27	[6.096/8.2296]	27/35	[8.2296/10.668]	35/45	[10.668/13.716]

Note: Two strands of No. 0 cable may be used in place of one No. 0000 cable provided all connections are carefully made. This is to insure that current in each parallel cable will be equal. The cross sectional circular mil area of No. 0000 cable is double that of No. 0 cable.

Cranking Motors

The cranking motor used on a Cummins engine is a special overload motor capable of delivering high horsepower. In order to obtain this power, it is necessary to build the cranking motor with a minimum of resistance so a large current will be taken through it. The cranking motor should be used for short periods only (15 seconds maximum) to avoid the possibility of failure due to overheating.

The cranking motors available for Cummins engines are of the 12, 24 or 30-32 volt series. The voltage rating must be selected to be compatible with engine cranking requirements as well as system voltage.

For a given engine, the cranking load will remain the same, irrespective of the system voltage; therefore, the same total battery energy will be required whether using 12, 24 or 30-volt systems. In other words, the same number and size of batteries is generally required with any system, although the system ampere hour rating would be different, since this depends not only on the number and size of batteries, but also the manner in which they are inter-connected to produce the system voltage. The lower voltage system will have a higher current draw for a given cranking load, making the over-all circuit design and circuit resistance more critical with a 12-volt system than with a 24 or 30-volt arrangement for the same engine.

Cleaning

All parts should be cleaned after disassembly. Do not clean the armature or fields in degreasing tank; compounds used in this type of cleaner may cause damage to insulation material.

1. If the commutator is dirty, it may be cleaned with a strip of No. 00 sandpaper.

Caution: Never use emery cloth to clean commutator.

2. All dust must be blown from cranking motor after commutator has been cleaned.

3. If commutator is rough, out-of-round, or has high mica, remove cranking motor from engine and disassemble. Turn the commutator down in a lathe, removing only sufficient material to true-up the commutator and remove roughness and high mica. Undercut the mica.

4. Replace worn brushes. If brushes wear rapidly, check for incorrect brush spring tension and roughness or high mica on the commutator.

Lubrication

1. All bearings provided with hinge cap or ball-type oilers should have 8 to 10 drops of light engine oil every 400 hours.

2. On units so equipped, keep grease cups filled with medium cup grease. Turn down one turn every 400 hours for proper lubrication.

3. Oil plugs should be removed every 6 months and the reservoir packed with graphite grease. On tractor, marine and stationary applications, lubricate at every unit rebuild.

4. Do not lubricate excessively, since excessive oiling may cause oil and grease to gum on the commutator and reduce the cranking ability of motor. Never oil commutator.

5. On some models, oil wicks are used for lubrication of the center or drive-end bearing. The wick is saturated with oil before assembly. When the cranking motor is removed from engine, oil wick should be saturated with oil before unit is reinstalled.

6. All oilless-type bushings should be supplied with a few drops of light engine oil whenever disassembled.

7. Lubricate cranking motor drives with a few drops of light engine oil during installation. Avoid excessive oiling.

Cranking Motor Controls

1. Because of high current flow from battery to cranking motor during cranking, a positive means of connecting and disconnecting battery and cranking motor must be used. The switch used must have contacts of adequate size to carry current without burning. A manually operated switch mounted on the floor board or cranking motor frame is the simplest type.

2. Some applications with Bendix drive use a magnetic switch — a small electromagnet — which, when energized, draws in a plunger and causes a contact disc to make contact between two terminals to complete the circuit from battery to cranking motor. The magnetic switch winding is usually energized by a push button.

3. Some applications with the overrunning clutch, or Dyer-type drive, use a somewhat larger magnetic switch called a solenoid switch. Here, the plunger not only thrusts against a contact disc to close the battery-to-cranking motor circuit, but is also linked to the shift lever so the drive pinion is shifted into mesh with the flywheel teeth by the solenoid action. The solenoid switch is usually actuated by a push button.

4. Cummins engines require a comparatively high voltage to assure adequate cranking. The series-parallel system is designed to provide a means of connecting two batteries in series to provide increased voltage for cranking, and reconnecting the two batteries in parallel for normal operation of electrical equipment after starting has been accomplished.

Cranking Motor Drives

Friction Clutch-Type Bendix Drive

1. This type of drive functions in much the same manner as other Bendix drives except it uses a series of spring-loaded clutch plates which slip momentarily during the shock of engagement to relieve shock and prevent it from being carried back through cranking motor. The slipping stops as engagement is completed so cranking torque is transmitted from cranking motor armature through drive pinion to flywheel ring gear.

2. The pinion of the Bendix drive is mounted on a threaded sleeve that matches internal threads in the pinion. When armature revolves, carrying threaded sleeve with it, inertia of pinion does not allow it to pick up speed as rapidly as the armature. The result is that the threaded sleeve turns within the pinion, moving the pinion endwise and into mesh with ring gear teeth so cranking is accomplished. The spring-loaded clutch takes up the sudden shock of meshing. When the engine begins to operate, the flywheel drives the pinion at a higher speed than the threaded shaft is revolving. This causes pinion to be turned relative to threaded shaft and in such a direction that the pinion is disengaged from ring gear teeth.

Overrunning Clutch Drive — Roller Type

1. The overrunning clutch is designed to provide positive meshing and disengagement of drive pinion and flywheel ring gear. It uses a shift lever that slides the clutch and drive pinion assembly along armature shaft so it can be meshed and disengaged as required. The clutch transmits cranking torque from cranking motor to engine flywheel but permits drive pinion to overrun, or run faster than, the armature after engine is started. This protects armature from excessive speed during brief interval that the drive pinion remains in mesh.

2. The overrunning clutch consists of a shell and sleeve assembly that is splined internally to match splines on armature shaft. Thus, both the shell and sleeve assembly and armature shaft must turn together. A pinion and collar assembly fits loosely into shell, and the collar is in contact with four matched steel rollers that are assembled into notches cut in the inner face of shell. These notches taper inward slightly so there is less room in the end away from rollers than in the end with rollers. The rollers are spring-loaded by small plungers.

3. When shift lever is operated, clutch assembly is moved endways along armature shaft so pinion meshes with flywheel ring gear. If teeth should butt instead of mesh, clutch spring compresses so pinion is spring-loaded against ring gear teeth. When armature begins to rotate, meshing takes place at once. Completion of shift lever movement closes cranking motor switch so armature begins to rotate. This rotates shell and sleeve assembly, causing rollers to jam tightly in smaller sections of shell notches. The rollers jam between pinion collar and shell so pinion is forced to rotate with armature and crank engine.

4. When engine begins to operate, it attempts to drive cranking motor armature, through the pinion, faster than armature is rotating. This causes pinion to rotate with respect to the shell so it overruns shell and armature. The rollers are turned back toward larger section of shell notches where they are free, and thus permit the pinion to overrun. This protects armature until automatic controls take over so the shift lever is released, causing shift lever spring to pull overrunning clutch drive pinion out of mesh from engine flywheel ring gear. This shift lever movement also opens cranking motor switch so armature stops rotating.

5. The overrunning clutch pinion requires the same ring gear as the Bendix pinion.

Overrunning Clutch Drive — Sprag Type

A heavy-duty sprag clutch has been designed to replace the heavy-duty six-roll clutch and some applications using Dyer and Bendix clutch-type drives. The pinion operates on a spiral-splined sleeve making it possible to mesh with flywheel ring gear more frequently even with butt-tooth engagements.

Many small sprags replace the rolls that distribute load or stress around points on a shell of uniform cross section. Much higher cranking loads can be carried with this construction.

In addition to the above features, a pinion block is incorporated to prevent closing of solenoid contacts and spinning meshes with ring gear on butt-tooth engagements that are not relieved by spiral movement of pinion. A second cranking attempt, however, is always successful.

Overrunning Clutch Drive — Positork Type

Positork starter drives provide protection in starting high-speed engines from damage caused by prolonged and high-speed overrun of drive pinion after engine has started. When starting switch is closed, starter drive moves forward (electrically, pneumatically, hydraulically or manually) to engage teeth of flywheel ring gear. If pinion tooth is obstructed in forward travel by tooth of flywheel ring gear, shifting mechanism continues to move against spring load, automatically rotating pinion until pinion tooth lines up with ring gear tooth space. Pinion tooth then enters tooth space and after predetermined depth of engagement, starting motor begins to rotate drive, cranking engine. When engine fires and runs, it begins to turn pinion faster than starting motor drives it. At this point, dentil clutch teeth allow opposing pinion dentil teeth to overrun them. At predetermined speed, dentil teeth are separated by action of centrifugally actuated weights in pinion area. There is no further contact between driving and driven members of starter drive during overrun position of starting cycle.

Separation of dentil teeth during prolonged highspeed overrun insures against damage to the starter, starter drive and flywheel ring gear.

Checking An Improperly Operating Cranking Motor

1. If cranking motor does not develop rated torque and cranks engine slowly or not at all, some indication of the source of trouble may be gathered by turning on the lights and attempting to crank.

a. If lights go out as cranking motor switch is closed, it is probable that a poor connection exists at battery terminals or elsewhere in the circuit.

b. If lights dim considerably, but still burn, it is likely that the battery is run down. Or, possibly there is some mechanical trouble either in the cranking motor or in the engine that makes it difficult for cranking to take place, and an excessively high current drain on the battery consequently results.

c. If lights do not dim, it indicates there is no current flowing to cranking motor, due either to cranking motor or cranking motor switch being open.

2. The preceding checks give only an approximate idea of the source of trouble, so in an emergency it might be possible to effect a temporary repair to allow temporary operation. To make a systematic analysis of the cranking motor system, the first step would be to check battery specific gravity. Then the battery connections and cables should be checked, along with cranking motor switch.

3. If all these are in order, remove cover band and inspect brushes and commutator. The brushes should form good contact with commutator and commutator must be reasonably clean and smooth. If it is not, it should be cleaned or turned down in a lathe. If there are burned bars on commutator, it may indicate open-circuited armature coils which will prevent proper cranking.

4. If leads have been thrown out of armature slots, indication is that the overrunning clutch caused armature to spit at excessive speed due either to a defective clutch or to the fact that the operator was using improper starting procedure. If the operator opens the throttle too wide on initial starting, or keeps starter pedal depressed too long after the starting has been accomplished, the overrunning clutch may overheat and partially bind so armature is spun at excessive speeds. In addition to damaging the armature, the overrunning clutch also will be ruined by such abuse. Evidence of excessive overrunning of clutch is failing of bearings, depositing of bearing material on armature shaft and a smooth face in collar on side closest to pinion.

5. Tight, dirty and worn bearings, bent shaft or loose pole shoe screws which allow armature to drag will reduce armature speed or prevent armature from turning.

6. If brushes, brush spring tension, commutator, etc., all appear in good condition, it will be necessary to remove the cranking motor for further tests.

Ground Connections Of Cranking Motors

In cases where recommended two-wire system is not used on cranking motor circuit, ground wire should go directly from positive terminal to steel frame members and be grounded as shown in Fig. 13-1-7. The motor mounting surface should not be used for ground circuit since pads on flywheel housing must carry this current to the frame, and they may have paint or other highly resistant material on them.

Series-Parallel Switch

The series-parallel switch makes it possible to use two 12-volt batteries which are connected in parallel for normal operating conditions after engine is started, but which are connected in series by means of series-parallel switch to provide 24 volts for cranking motor. Likewise, two 6-volt batteries can be connected either in parallel or in series to provide a 6 or 12-volt system.

The switch incorporates a heavy copper contact disk and heavy tungsten-faced main terminals, which resist effects of arcs that occur when circuits are broken. The main cranking current is carried through these contacts and terminals. In addition, there are contacts in the terminal plate assembly which complete the parallel connections between batteries for normal operation and also complete the connections that energize cranking motor solenoid in cranking position.

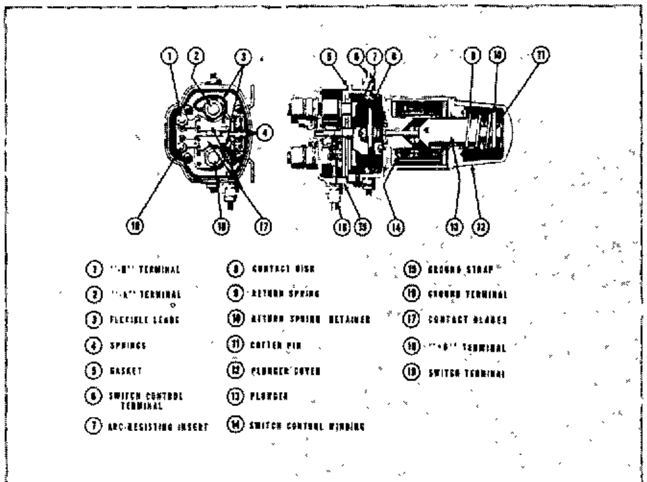


Fig. 13-1-8, V11303. Series parallel switch — cross section

After cranking has been accomplished and the series-parallel switch is released, the two batteries again become connected in parallel to provide 12-volt operation of equipment. In mechanically operated switch a quick-break mechanism, consisting of a pair of triggers and a cam, causes contact disk to be snapped away from stationary contacts very quickly so there is a very small amount of arcing.

Due to high voltage of starting circuit and great amount of power available from the two batteries, it is essential that every precaution be taken to avoid short circuits or grounds. All wires should be of sufficient size to carry the electrical load to which they are subjected without overheating. Stranded wire and cable should be used throughout to reduce the possibility of breakage because of vibration. All connections should be clean and tight and all terminal clips should be soldered to wires or cables. Only rosin flux should be used to solder electrical connections. All wires should be adequately insulated and supported at enough points to prevent movement and consequent chafing through insulation. It is desirable that all terminals and clips, which are ordinarily left exposed, be protected by insulation. Thus, rubber boots, rubber tape or friction tape and shellac should be applied to cover all exposed terminals and clips. This will prevent accidental grounding of an exposed terminal which could cause serious damage to the system.

Matching Flywheel Ring Gears And Cranking Motors

Figure 13-1-9 illustrates the importance of matching drive pinion and flywheel ring gear teeth properly. The left view shown the action of an overrunning clutch or Bendix pinion as it engages with the correct type of ring gear. However, if a Dyer drive is used with a ring gear for an overrunning clutch or Bendix drive (center view), difficulty is likely to be encountered in engagement. In this case, when the teeth butt, the pinion must move back and up as shown by the arrows before engagement can take place. It must be remembered that, with the Dyer drive cranking motor, pinion movement for engagement is in one direction while pinion movement during cranking is in opposite direction.

The action of a Dyer drive pinion engaging with a Dyer drive-type ring gear after teeth butt is shown at the right in Fig. 13-1-9. It will be noted that the chamfer on ring gear teeth used in connection with a Dyer drive cranking motor must be the reverse of the chamfer on a ring gear used with an overrunning clutch or Bendix drive. If the wrong type of gear is used, repeated attempts will be required for engagement, and burring of teeth is likely to occur. The same trouble will result from mismatching pinion and ring gears due to a change of rotation of engine or of cranking motor.

There is one exception to the above rule. Delco-Remy enclosed shift lever design cranking motor with Sprag Clutch can be used with either Bendix or Dyer-type flywheel ring gear. Pinion gears on these cranking motors are Bendix type, but tests have proved that they will engage also with Dyer-type ring gears without damage to gear teeth. This is due to the type of engagement action peculiar to the Sprag Clutch used in this class of cranking motors.

Batteries

Battery Specifications

1. The batteries listed in Table 13-1-2 are the minimum capacities that must be provided to crank engines at minimum engine temperatures expected. Battery capacities are given in ampere-hours.

2. Minimum battery capacities are based on engines with no externally connected parasitic loads (such as torque converters, hydraulic pumps, etc.). Any parasitic load that is coupled during cranking must be determined at lowest starting temperature so an equivalent increase can be made to the minimum battery capacity. Cable circuit resistance

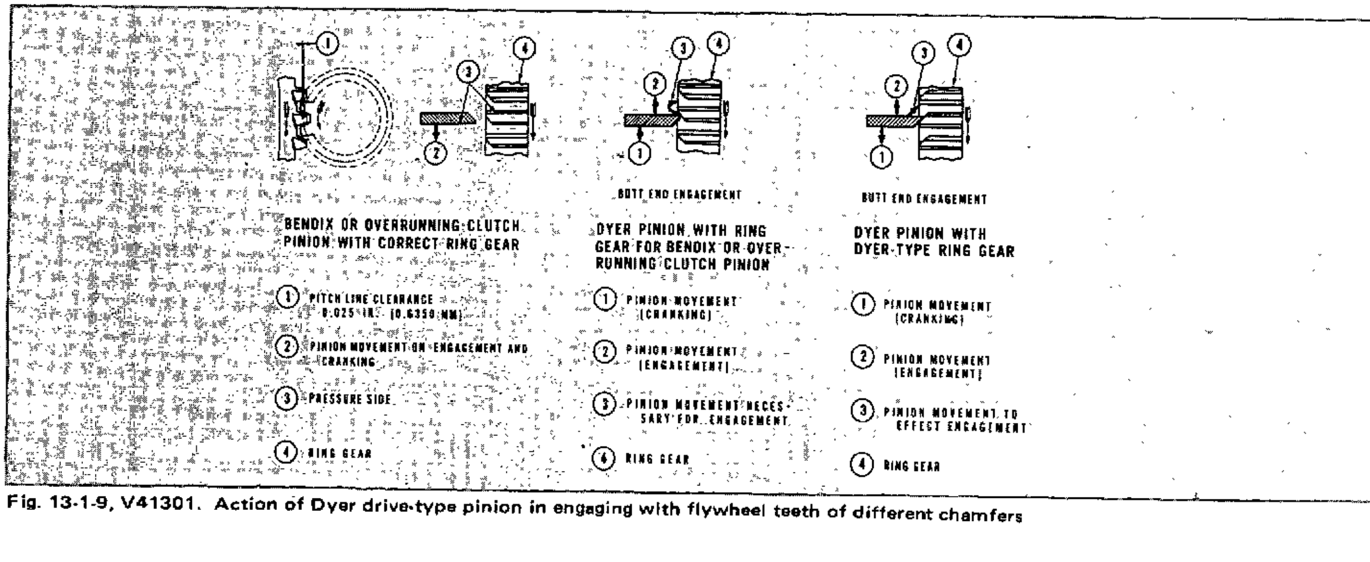


Fig. 13-1-9, V41301. Action of Dyer drive-type pinion in engaging with flywheel teeth of different chamfers

Table 13-1-2: Minimum Battery Capacity in Ampere Hours

Cummins Engine Series	Engine Displ. Cu. Inch [cc]	Winter Climate 0° F [−18° C[Minimum Engine Temperature*			Mild Climate 32° F [0° C] Minimum Engine Temperature*		
		12V.	**24V.**	**30V.**	**12V.**	**24V.**	**30V.**
V-1710	1710 [28,021.9410]		400	340		260	260

*"Minimum engine temperature" ist the temperature of the engine rather than the lowest night-time temperature. As an example; during a night when the temperature drops to −10° F [−23° C] for only a few hours, the minimum engine temperature would probably be no less than 0° F [−18° C]. An engine and battery would have to be cold soaked with no shelter at −10° F [−23° C] for 6-10 hours for the engine lubricating oil and battery to reach −10° F [−23° C]. All minimum capacities for batteries are based upon using Cummins recommended lubricating oils which are SAE 10W for winter climate and SAE 20 for mild and warm climates.

Table 13-1-3: Ampere Hour Capacity Ratings of Battery Systems

System Voltage	**Battery Connections**			
12 Volt	Two — 6-Volt Batt. in series	Four — 6-Volt Batt. in series parallel	One — 12-Volt Batt.	Two — 12-Volt Batt. in parallel
24 Volt	Four — 6-Volt Batt. in series	Eight — 6-Volt Batt. in series parallel	Two — 12-Volt Batt. in series	Four — 12-Volt Batt. in series parallel
30 Volt	Five — 6-Volt Batt. in series	Ten — 6-Volt Batt. in series parallel		
*Battery AABM Group Size	Total ampere hour system rating at the indicated voltage			
3H	130	260		
4H	150	300		
5D	165	330		
7D	200	400		
9D	340	680		
4D			150	300
6D			165	330
8G			175	
8D			200	400

* Association of American Battery Manufacturers

must not exceed Cummins limits. Battery cable size is based on total cable length (over to starter and back to battery).

Select the battery system from Table 13-1-3 that will give the required ampere-hour capacity as indicated in Table 13-1-2. In most cases more than one system is listed in Table 13-1-3 that will meet Table 13-1-2 requirements so extra consideration can be given to space requirements, ease of making connections and costs.

In order to obtain optimum battery service life and dependable engine starting, the battery capacity to be provided should not be less than recommended in Table 13-1-2. Accessories or drive lines which cause additional cranking load must be considered and the battery capacity shall be increased by the amount required to crank these accessories above the engine requirement which is listed in the table.

Allowing batteries to be completely discharged repeatedly will significantly reduce their service life.

U. S. 6TN And U. S. 8T Batteries

For military applications and especially for temperatures below 0 deg. F [−17.6 deg. C] (down to −65 deg. F [−53.8 deg. C]) the use of U. S. 6TN (100 AH at 12 volts) and U. S. 8T (200 AH at 12 volts) batteries is recommended. The characteristic feature of these batteries is the use of more but thinner plates per cell than comparable commercial batteries. This results in higher available energy at very low temperatures.

Starter Circuit Resistance Measurement Procedure

Battery circuit resistance can be determined from current and voltage measurements taken while cranking an engine. Cable resistance equals total cable circuit voltage drop divided by the current flowing.

The instruments required are a low-voltage DC voltmeter and a high-current ammeter. The voltmeter should have a scale so one to three volts can be read accurately. The voltmeter should have long leads so they will reach from battery to starting motor. The ammeter should have a scale so 500 to 1500 amperes can be accurately read. High currents are commonly measured by using a calibrated ammeter shunt with a meter to sense current flowing through the shunt. The shunt is a calibrated resistance capable of carrying high currents. The meter then senses current flowing through the shunt in terms of amperes.

Installations Having One Battery Location

1. Insert ammeter shunt in cable circuit so total starting motor current passes through the shunt. The length of added cable, if required in order to install meter shunt, must be kept at a minimum. All connections must be clean and tight. Fig's. 13-1-1, 13-1-2 or 13-1-3.

2. Disconnect wire going to fuel solenoid valve so engine does not start during these tests.

3. Measure voltage drop from positive battery post to its respective post on starting motor while cranking engine. To prevent damage to voltmeter, one voltmeter lead should not be connected until engine has begun to crank and should again be disconnected before starting motor has been disengaged. Both voltage and current readings should be taken simultaneously approximately two seconds after engine has begun to crank. Since high current flows during cranking, readings should be taken quickly and cranking kept to a minimum to avoid cable heating. Excessive cranking will cause calculated resistance to be high.

4. Measure the voltage from negative battery post to its respective terminal on starting motor while cranking the engine. As in Step 3, one voltmeter lead should not be connected until after the engine begins to crank and should again be disconnected before the starting motor is disengaged. Voltmeter and ammeter readings should be taken simultaneously approximately two seconds after the engine begins to crank.

5. Calculate total cable circuit resistance by adding the two voltmeter readings and dividing this sum by the average of the two current readings.

Installations Having Two Battery Locations

In installations where batteries are in two locations and where each set of batteries has its own separate circuit to the starting motor, the above procedure should be used for each set of batteries (as shown in Fig. 13-1-4 or 13-1-5). In this case the ammeter shunt should be installed in such a manner to read battery current rather than total starting motor current. The cable circuit resistance for each set of batteries should be calculated individually. After total cable resistance for each set of batteries has been determined, total equivalent circuit resistance can be obtained by the following equation:

$$\text{Total Resistance } R_e = \frac{R_1 \times R_2}{R_1 + R_2}$$

It is important in systems having two battery locations that each set of batteries supplies approximately the same amount of current to the starting motor. If current supplied by one set of batteries differs from the other by more than 30%, it is an indication that one set of batteries is in poor condition or that the resistance of one set of cables is greater than the other. In either case, this condition should be corrected.

Maximum Resistance Limits

Total cable resistance should not exceed that shown in Table 13-1-1. Since cable resistance to a large degree limits a starting motor's cranking performance and maximum torque, it is quite important to keep cable resistance within the published resistance limits shown. Poor connections or use of a frame ground are common causes of excessive circuit resistance.

The battery-charging generator or alternator selection is, for the most part, dependent upon the end users' requirements and preference. However, in the interest of avoiding unnecessary problems, it is important that certain precautions be taken before the selection is finalized.

Alternator and Generator—Unit 1302

The battery-charging generator or alternator selection is, for the most part, dependent upon the end users' requirements and preference. However, in the interest of avoiding unnecessary problems, it is important that certain precautions be taken before the selection is finalized.

The charging system must have sufficient capacity to sustain the operating load requirements and at the same time recharge the batteries sufficiently for subsequent engine starts.

The speed ratio of the generator or alternator should be reviewed to insure that the necessary charging rate is obtained and the maximum operating speed is within the limits established by the manufacturer for safe operation and long life. To provide maximum generator voltage regulator life, generator speed ratio shall be selected so the regulator does not cut in within plus or minus 50 RPM of engine idle at either hot or cold generator performance curve condition. This is necessary to prevent failure of the regulator cut-out relay which will tend to cut-in and out with resultant arcing and eventual failure.

Alternator

Self-rectifying AC generators are designed and constructed to give long periods of trouble-free service with a minimum amount of maintenance. The rotor is mounted on ball bearings, and each bearing has a grease reservoir which eliminates the need for periodic lubrication. Only two brushes are required to carry current through two slip rings to field coils which are wound on four-pole rotor. The brushes are extra long and under normal operating conditions will provide long periods of service.

The stator windings are assembled on the inside of a laminated core that forms the generator frame. Six rectifier diodes are mounted in the slip ring end frame and are connected to the stator windings through connectors mounted internally in two nylon holders, or a separately mounted rectifier; they act to change the alternator AC voltage to a DC voltage which appears at the "BAT" terminal on the alternator.

Even though the alternator is constructed to give long periods of trouble-free service, a regular inspection procedure should be followed to obtain maximum life from alternator.

Many mechanics who have learned proper procedures for installation, operation and adjustment of DC generators have encountered some trouble with AC systems. Following is a list of important rules — mostly don'ts — which must be observed with alternators and regulators. Failure to observe these precautions will result in serious damage to the electrical equipment.

1. Do not install either an alternator or a regulator without checking the manufacturer's specifications and confirming that they are matched for each other as to type, polarity and part numbers.

2. When installing a battery, always make absolutely sure that the ground polarity of battery and ground polarity of alternator are the same.

3. When connecting a booster battery, be sure to connect the negative battery terminals together and the positive battery terminals together.

4. When connecting a charger to battery, connect charger positive lead to battery positive terminal and charger negative lead to battery negative terminal.

5. Never operate an alternator on open circuit. Make absolutely certain all connections in the circuit are secure.

6. Do not short across or ground any of the terminals on the alternator or regulator.

7. Do not attempt to polarize the alternator. This procedure will almost certainly ruin the diodes.

For additional information on alternators, contact the Delco-Remy or Leece-Neville distributor.

Inspection

The frequency of inspection is determined largely by the type of operating conditions. High-speed operation, high temperatures and dust and dirt all increase the wear of brushes, slip rings and bearings.

At regular intervals, inspect terminals for corrosion and loose connections, and wiring for frayed insulation. Check mounting bolts for tightness, and belt for alignment, proper tension and wear. Because of higher load capacity and higher inertia of heavy rotor used in AC generators, proper belt tension is more critical than on DC generators to prevent slippage and wear. A cog belt is recommended for the most satisfactory service. The slip rings and brushes can be inspected through the end frame assembly. If slip rings are dirty, they should be cleaned with 400-grain or finer polishing cloth. Never use emery cloth to clean slip rings. Hold polishing cloth against slip rings with alternator in operation, and blow away all dust after the cleaning operation. If they are rough or out-of-round, alternator must be removed and disassembled so slip rings can be trued in a lathe.

If brushes are worn close to holder, alternator must be removed and disassembled so brushes can be replaced.

Noisy Alternator

Noise from an AC generator may be caused by worn or dirty bearings, loose mounting bolts, loose drive pulley or a defective diode or rectifier.

Lubrication

Under normal conditions, the alternator will not require lubrication between engine overhaul periods. The grease reservoir in each frame provides an adequate supply of lubricant for long periods of operation.

Output Check

To check alternator on test bench, make electrical connections as shown in Fig. 13-2-1, operate at specified speed and check for rated output. Adjust the load rheostat, if necessary, to obtain desired output.

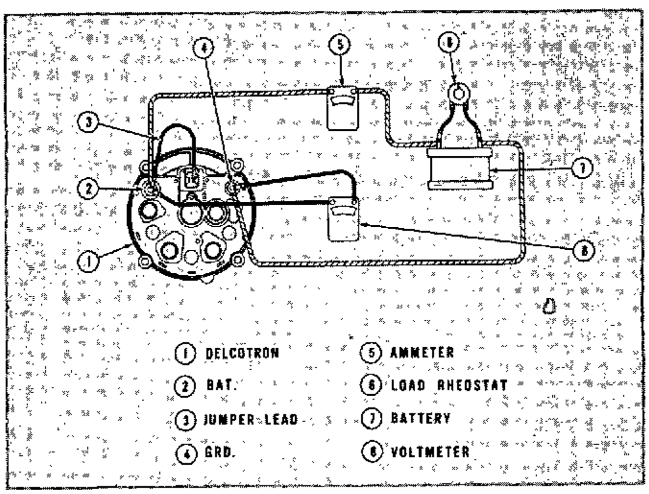


Fig. 13-2-1, V11304. Bench test of alternator output

Caution: On negative ground alternator connect negative battery post to alternator frame, and on positive ground alternator connect positive battery post to alternatur frame.

Generator

The shunt generator converts mechanical energy to electrical energy and supplies current for electrical equipment by replacing electricity consumed from the battery.

The shunt generator requires external current regulation in the form of a current regulator, voltage regulator and cut-off relay, which control generator output under all operating conditions.

Cleaning

Clean the generator thoroughly of all grease and dust. Do not clean armature and field in a degreasing tank, as this damages the insulation.

Commutator

1. If the commutator is dirty, it may be cleaned with a strip of No. 00 sandpaper held against it with a piece of soft wood while the generator is operated. Blow out dust. Never use emery cloth since emery may imbed and wear the brushes rapidly.

2. If the commutator is rough, out-of-round or has high mica, it must be turned down in a lathe and the mica undercut.

Lubrication

1. The oil reservoir in commutator end of generator should be kept filled with light engine oil to the overflow hole. This usually requires the addition of 8 to 10 drops of oil every 200 hours.

2. Generators with grease cups should have the grease cups turned down one turn every 200 hours. Keep grease cups filled with medium cup grease. Do not lubricate excessively since this might allow oil or grease to get on the commutator where it would gum and burn, thus reducing generator output.

3. Under normal operating conditions, sealed generators will not require additional lubrication between overhaul periods.

Connections

1. Check connections and wiring in generator-to-regulator-to-battery circuit. Check pulley nut to be sure it is tight.

2. Make sure the mounting bolts are tight.

3. All generator installations should be checked carefully to make sure they are properly grounded to the engine block.

The generator mounting pads and mounting surfaces of the bracket and generator frame should be free of paint, oil, grease or any material resistant to electric current. To further complete the ground circuit, the engine should be grounded to the same frame member used to ground the battery by means of a separate metal strap. This procedure must be followed on third-brush-type generators having only one armature terminal, since the positive brushes on these generators are grounded to the generator frames.

Checking And Adjusting Output

1. The output of the shunt generator is dependent upon both the setting of the current regulator and the voltage regulator.

2. Normally, if the generator is checked with an accurate ammeter and a fully charged battery is in the circuit, the proper voltage will be developed. Never set output above specified setting as this will result in generator failure.

Checking Inoperative Generator

If generator is not performing according to specifications and the tests outlined in the section on regulators have disclosed that the generator is definitely at fault, it may be checked as follows to determine location of trouble in generator.

No Output

When no output can be obtainea trom generator, remove cover band and check for sticking brushes, gummed or burned commutator or other causes of poor contact between commutator and brushes. If cause of trouble is not readily apparent, remove generator from engine and send to a Cummins distributor or a generator service station for further tests and repairs.

Excessive Generator Output

Excessive generator output is usually due to either (a) a grounded field circuit or (b) a shorted field. Check terminal insulation and, if trouble cannot be corrected there, send generator to a Cummins distributor or a generator service station.

Unsteady Or Low Output

This condition may result in any generator form:

1. Sticking brushes, low brush spring tension, or other condition which prevents good contact between brushes and commutator.

2. Commutator that is rough, out-of-round, dirty or burned. Dirt in slots or high mica also cause low or unsteady output. With these conditions, commutator should be turned down in lathe and mica undercut for carbon brushes. Burned bars, of course, indicate an open-circuit armature and corrections outlined above should be made.

Noisy Generator

This condition may be caused by loose mounting or drive coupling. Worn or dirty bearings may also cause noise. Brushes improperly seated may cause noise that can be eliminated by properly seating them with a brush-seating stone. A bent brush holder may cause noise and requires replacement as it is difficult to properly realign a holder.

Polarizing The Generator

1. Battery-charging DC generators must be polarized prior to starting an engine to prevent major damage to the electrical system. Normally, polarization is performed when:

a. The generator has not been polarized before.

b. Generator is removed from the engine to be repaired and then reinstalled.

c. The generator is used on a negative ground system and polarized for use on a positive ground system, or vice versa.

2. Polarization can be checked or performed as follows:

a. Insulate one brush from commutator of generator.

b. Disconnect lead from FIELD terminal of regulator.

c. Momentarily touch FIELD lead to BATTERY terminal on regulator. If there is a small spark, reconnect FIELD lead to regulator and remove insulation from between brush and commutator. The generator is now polarized.

d. If there is no spark, reconnect FIELD lead to regulator and proceed to Step E.

Caution: Never operate generator with field circuits (connected and "A" terminal lead disconnected (open-circuit operation), since this would allow a high voltage to build up within generator which would damage fields and armature.

e. Momentarily connect an external jumper between the BATTERY and ARMATURE terminals of regulator. The generator is now polarized.

f. Remove insulation from between brush and commutator.

Regulator Controls

Three separate magnetic switches must be used with shunt generator to provide complete control at all times. These are (1) cut-out relay, (2) voltage regulator and (3) current regulator.

Cut-Out Relay

1. The cut-out relay closes circuit between generator and battery when generator voltage has built up to a value sufficient to force a charge into battery.

2. The cut-out relay opens circuit when generator slows or stops and current begins to flow back from battery into generator.

3. The basic wiring diagram for a one-terminal, third-brush current-controlled generator used with a cut-out relay is shown in Fig. 13-2-2. Equipment that requires low generator output, such as shovels and power units, will sometimes have this type of generator and cut-out relay.

4. This type of equipment will give satisfactory service provided the G+B– terminal in the relay is properly grounded to the same frame member used to ground battery, as shown in Fig. 13-2-2, and provided the generator is used only for battery charging.

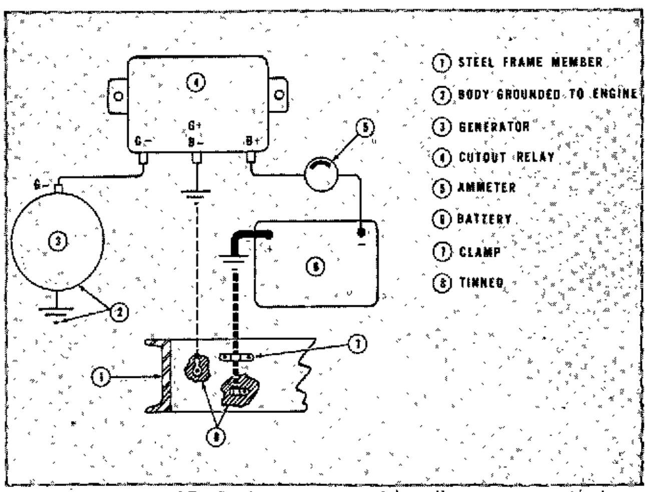


Fig. 13-2-2, N11305. Basic generator wiring diagram cut-out relay

Voltage Regulator

1. The voltage regulator prevents line voltage from exceeding a predetermined value thus protects battery and other electrical units in system from high voltage.

2. One characteristic of batteries is that, as either the specific gravity or the charging rate increases, other conditions being the same, battery terminal voltage increases. If terminal voltage is held constant as battery comes up to charge (specific gravity increases), charging rate will be reduced. The voltage regulator performs this job of holding voltage constant, and it consequently protects the electrical system from high voltage and the battery from overcharge.

Current Regulator

The current regulator limits generator output to a safe value. It is, in effect, a current-limiting device that operates when generator output has increased to its safe maximum and prevents generator from exceeding this value.

Regulator Operating Voltages

1. Regulators are factory adjusted according to the system in which they work.

2. For use in nominal 12-volt system, the regulator is adjusted to properly charged (under normal conditions) 6-cell batteries.

3. Because either 15-cell or 16-cell batteries may be used in 32-volt systems, particular attention must be given to application of regulators in a 32-volt system. These regulators are stamped "15 cell" or "16 cell" to indicate they have been factory adjusted for use with a battery having the specified number of cells. To use a regulator stamped "15 cell" with a 16-cell battery would result in a weak-charged battery and, conversely, a "16 cell" regulator would cause overcharging of a 15-cell battery.

Current And Voltage Regulator Connections

The basic diagram for Leece-Neville equipment, shown in Fig. 13-2-3, includes connection of the so-called "universal" regulator. For satisfactory operation, steel base of regulator must be grounded as shown because these regulators have small doughnut-type rubber shock mounts bonded to the base and depend entirely on this ground strap and capscrews to ground unit.

Wires shown as "A" and "B" in Fig. 13-2-4 indicate alternate connections necessary for recommended two-wire system.

Some large voltage regulation control units have cast aluminum bases and covers. These units are not grounded through their bases, but by separate wires from insulated terminals. This would be indicated on the unit wiring diagram.

Generator Cut-In

It is advisable to check cut-in point of generator regulator at idling speed. On engines equipped with low cut-in-type generator regulator, ammeter will indicate some value of charging when electric load is off. On other generator regulator systems, ammeter will read "O." In either case,

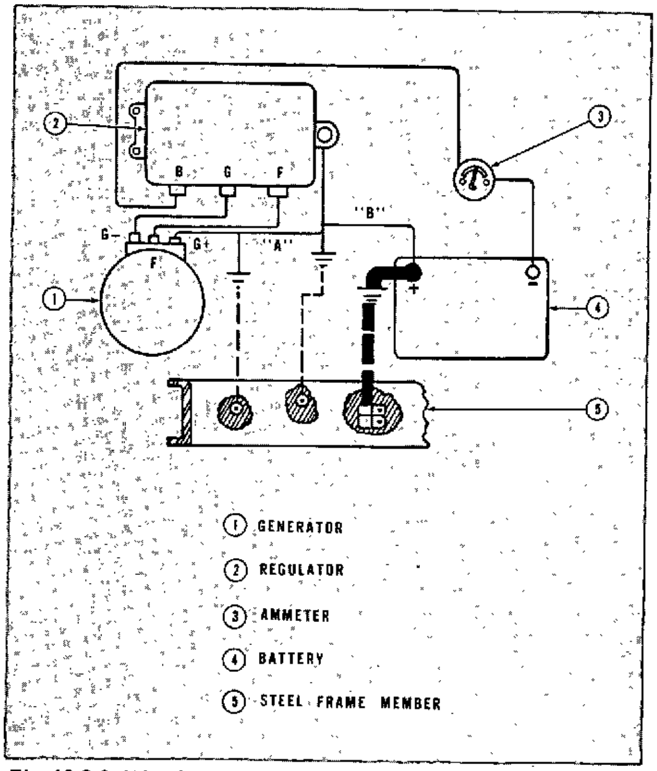


Fig. 13-2-3, N11306. Basic Leece-Neville generator wiring diagram

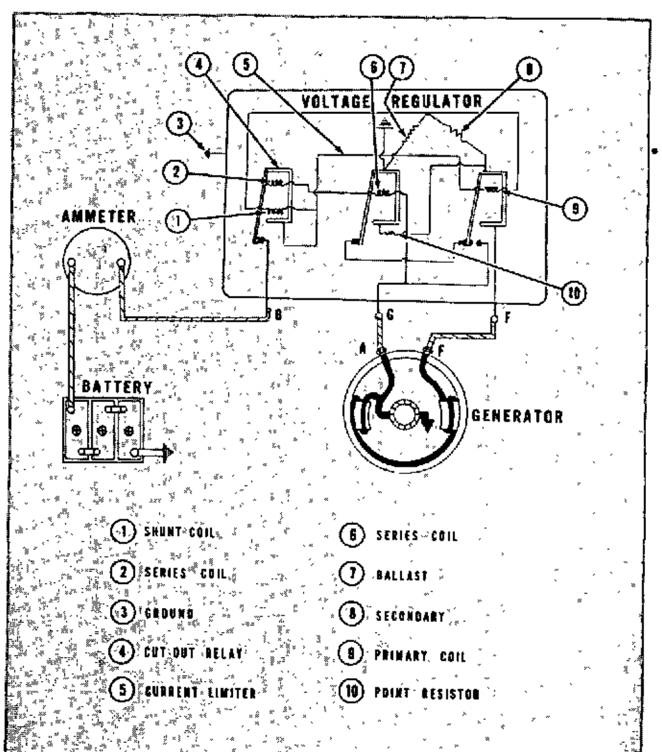


Fig. 13-2-4, N21301. Leece-Neville current and voltage regulator wiring circuit

ammeter will remain steady. Erratic movement of ammeter indicates that the regulator relay is cutting in and out frequently and this will cause an electric arc at these connections. If arcing continues, points will eventually weld together, which will leave circuit closed at all times. This will cause an overcharge into the battery during operation and a discharge through the generator when engine is stopped, eventually burning up generator and regulator. To overcome this condition, it will be necessary to increase engine idling speed until ammeter remains almost constant. Ammeter movement may indicate a loose connection.

Tests, Repairs And Adjustments

Complete instructions for testing, repairing and adjusting electrical equipment used on Cummins engines are available at moderate cost from manufacturers of the electrical equipment. Order the material from the United Motors Service or Leece-Neville distributor.

Mag–tronic Ignition–Unit 1305

Ignition System

The American Bosch Mag-tronic Ignition System currently used on Cummins Natural Gas Engines is a self-contained, self-powered, low tension, low fire hazard, electronic system specifically designed to meet the ignition demand and reliability requirements of high speed spark ignited engines.

The Mag-tronic Ignition System always includes an ignition generator, a wiring harness and one ignition transformer for each spark plug. The system may also include one or more safety switch adapters, and or circuit isolator.

All Cummins Natural Gas Engines are supplied with the Mag-tronic ignition system and as previously stated, it being self-powered, requires no external voltage and permanent damage can result from external voltage being applied to it.

The GV12 Mag-tronic has two ground leads identified as "P" and "N" with those letters on the connector, Fig. 13-5-1. The purpose of the leads is to ground, or short out the ignition system, and stop the engine. Should they at any time be grounded, or shorted to any part of the engine ground, the engine will not start or continue to operate. The two leads of the GV12 Mag-tronic cannot be joined one to the other to form a single ground lead without utilizing the safety switch adapter or circuit isolator.

Regardless of the number or types of switches, the ignition circuit of the Natural Gas Engines must be wired "Open To Run." The closing to ground of one or more switches, in the event of engine mal-function, will ground the circuit and stop the engine. Closing the start-stop switch will ground and stop the engine. The ignition circuit must be open from "P" lead from "N" lead and ground, for the engine to start or operate properly.

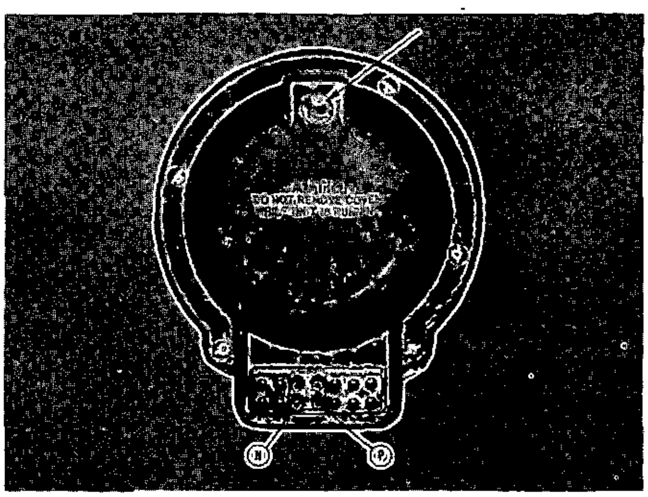


Fig. 13-5-1, NG25. Rear view Mag-tronic 12 cylinder

Trouble shooting for a grounded condition can be accomplished with an Ohmmeter, or a battery powered test light. Testing should be made with the wiring harness disconnected from the Mag-tronic and connections made from "P" and "N" receptacles in the wiring harness, to engine ground. Proceed to test each switch until the ground is located and corrected.

If the installation contains a safety switch adapter Bosch No. 101, this switch contains a storage capacitor which should be discharged by connecting a short lead of 14 gauge wire from ground to switch (center) post of the adapter. This discharge of the capacitor is necessary to prevent damage to testing instruments.

The Mag-tronic generators are all driven at crankshaft speed and the timing rotor reduced to one half crankshaft speed. The GV12 Mag-tronic rotates counterclockwise when viewing the drive coupling. The Mag-tronic generator requires a minimum engine cranking speed of 150 RPM to produce adequate firing to the spark plugs for starting. The voltage produced at the "P" and "N" terminals at cranking speed should be a minimum of 90 to maximum 110 V.D.C. and can be checked with an accurate D.C. voltmeter of 0 to 150 V.D.C. range. The voltage registered at the "P" and "N" lead should slowly dissipate through the voltmeter and will indicate the ability of the capacitor to retain its charge. A good capacitor will require 30 seconds or more to discharge. Voltage produced in the primary connections of the Mag-tronic generator with engine running will indicate approximately 50 V.D.C. on the voltmeter because of the extremely rapid firing pulse. Accurate checking of this voltage must be made on an oscilloscope, however, field checking with a D.C. voltmeter should indicate a minimum of 40 V.D.C.

Spark Plugs

Cleaning And Inspection

1. Clean electrode with a wire brush to remove all carbon and ash deposits.

2. Inspect spark plug for burned electrodes, cracked

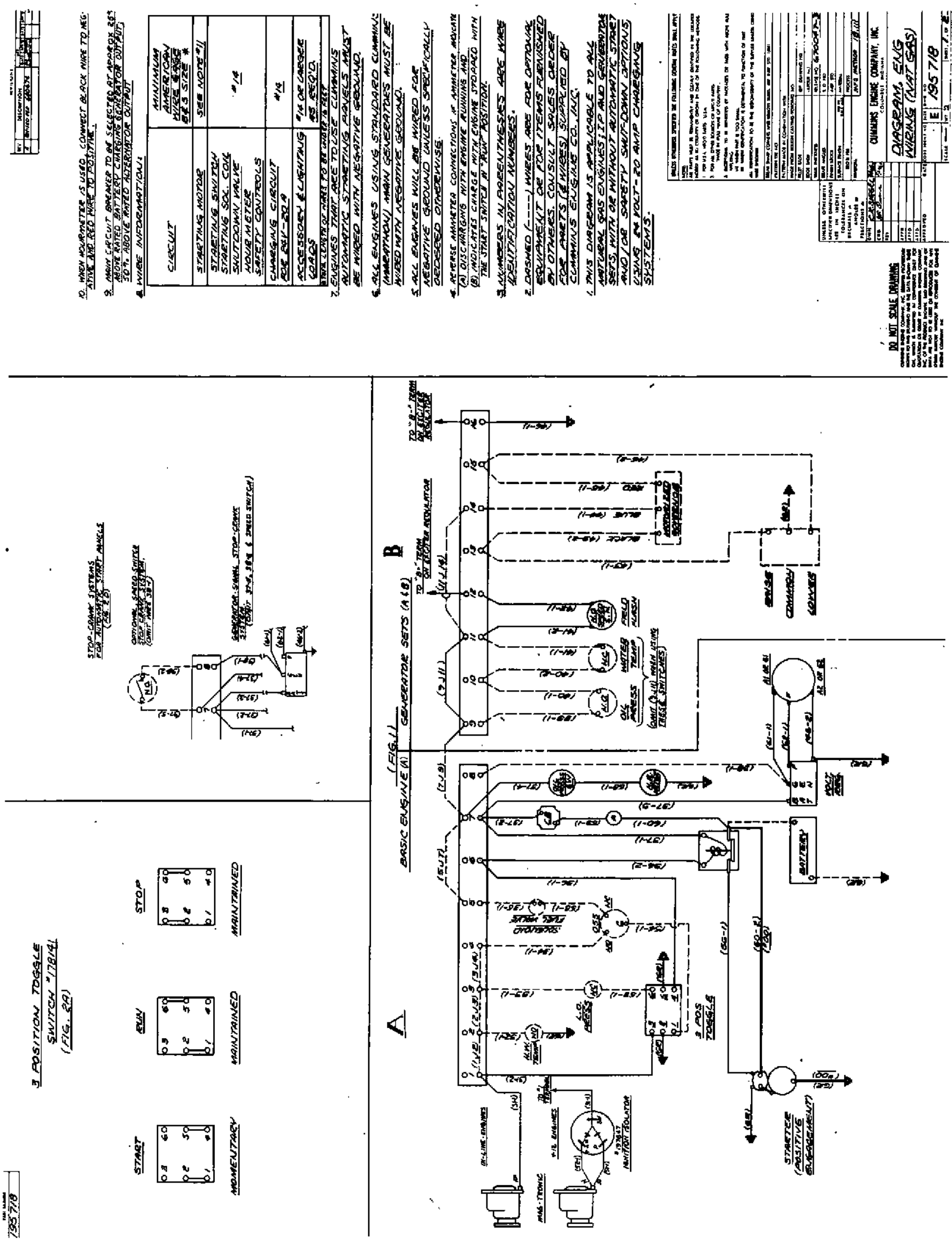


Fig. 13-5-2, CGB39. Wiring diagram

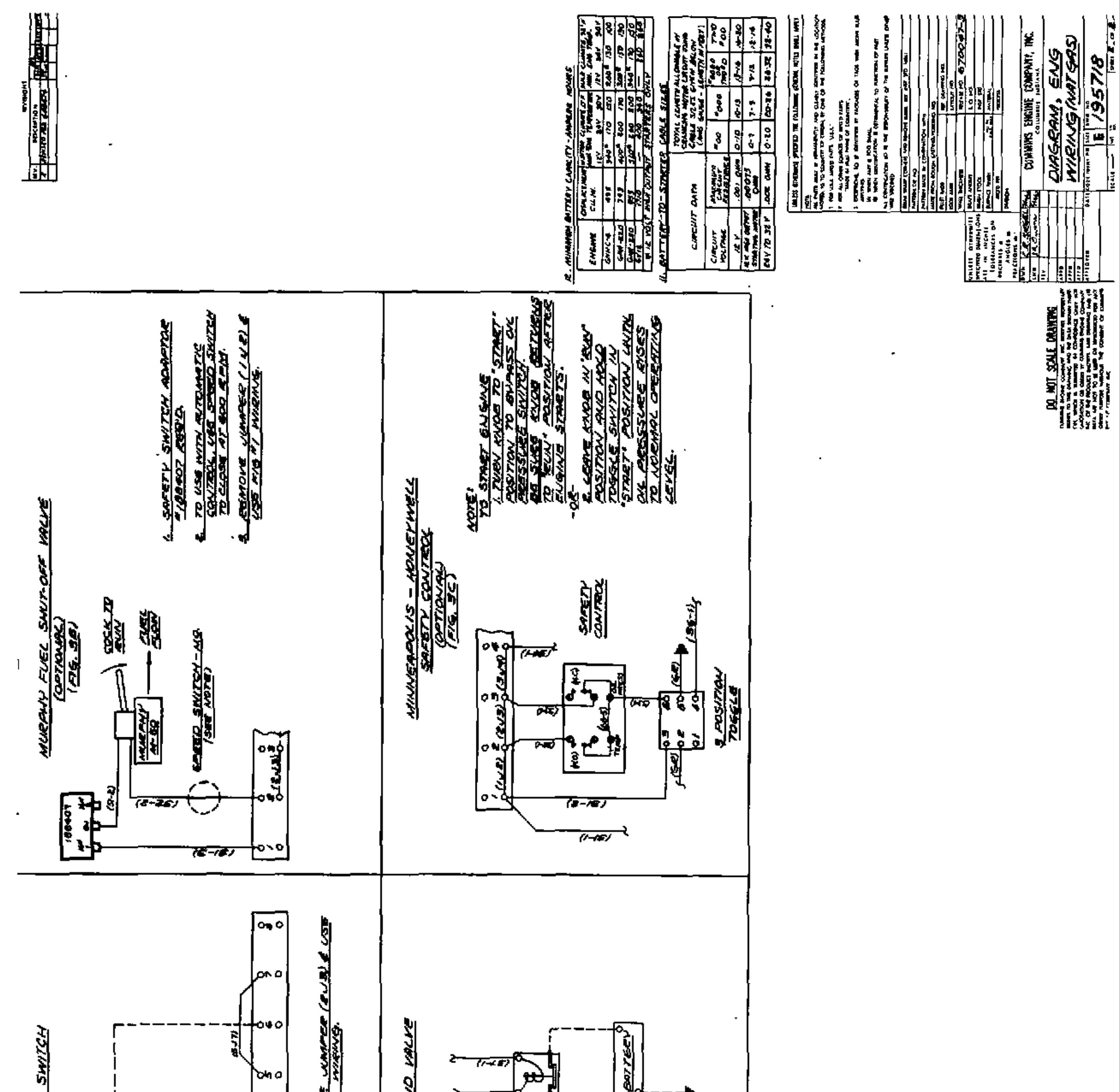


Fig. 13-5-2, CGB40. Wiring diagram

porcelain and stripped or crossed threads. Replace if defective.

3. Check spark plug gap and adjust. It should be 0.018 inch [0.4572 mm].

Ignition Transformer

The ignition transformers are mounted directly on the spark plugs and must be removed for inspection. Visual inspection should be made for cracks, broken or otherwise damaged terminals and deteriorated wiring. Electrical continuity can be checked with an Ohmmeter and the following values should be obtained; resistance from the positive terminal or black wire, to high tension connecting spring or spark plug contacting spring should be 4,500 to 5,500 Ohms. Resistance from both low tension terminals, or black to white wires should be 0.2 to 0.3 Ohms. Any values not within listed range would indicate a faulty transformer and should be replaced.

Engine Assembly Group

The engine assembly section covers assembly of all units and subassemblies to the cylinder block as well as adjustments prior to engine testing. For the convenience of those who store their engines during the winter months or for other reasons, engine storage is also described.

Assembly—All Units 1401

Dimensions, torque values, temperatures, etc., are given in U. S. and, where applicable, metric measurement. The metric values are enclosed in brackets [] to set them apart.

Dirt, of one form or another, remains the major cause of engine failures. The unit rebuild and assembly sections of a shop should be arranged so they can be cleaned easily and kept clean at all times. Paint, lighting and shop arrangement will help to keep the shop looking clean and orderly. No day is so rushed that some time cannot be profitably spent in shop cleaning.

The next problem is to keep dirt out of the shop. If units are cleaned thoroughly before they are brought into the unit rebuild departments, there will be less dirt to take out.

Engine assembly as described in this group is performed with the assumption units have been rebuilt or repaired and are ready to go together to complete the engine. During assembly operations it is important to closely inspect each unit to make sure something has not been overlooked during rebuilding or repair. Plugs should be checked for tightness, parts kept clean, openings covered, machined surfaces protected and all parts brought to the assembly area to save time and unnecessary labor.

Application of any type lubricant should be performed from covered containers and with clean fingers, it so applied, to prevent building dirt into the engine. The engine owner and operator have every right to expect good service from their rebuilt engine. Many operations described in the following instructions apply to engines which may differ slightly from the one illustrated; therefore, review each operation and make sure it applies directly to the engine being assembled.

The steps of engine assembly described in this manual may not always be ideal from the serviceman's standpoint; where conditions require a difference in assembly sequence it is permissible to do so providing all steps and precautions are observed and results are satisfactory.

Mount Block To Engine Stand

1. Mount V-1710 cylinder block to ST-412 Engine Stand using bolts through the cylinder block oil pan flange.

2. ST-412 Engine Stand for V-1710 engines is available from Cummins Engine Company, Inc. only upon special order; however, blue prints of the stand can be furnished upon request through a Cummins Distributor. Size of the stand and manufacturing time usually make it more economical to build the stand at the shop location. Fig. 0-7, Group 0.

Crankshaft

1. Be sure crankshaft, main bearing shells and block main bearing bore are clean.

2. Place all upper main bearing shells in position in block; locate in place with tang (1, Fig. 14-1-1).

Note: Upper shells have oil holes (2) in center that align with oil passages in block leading to oil header.

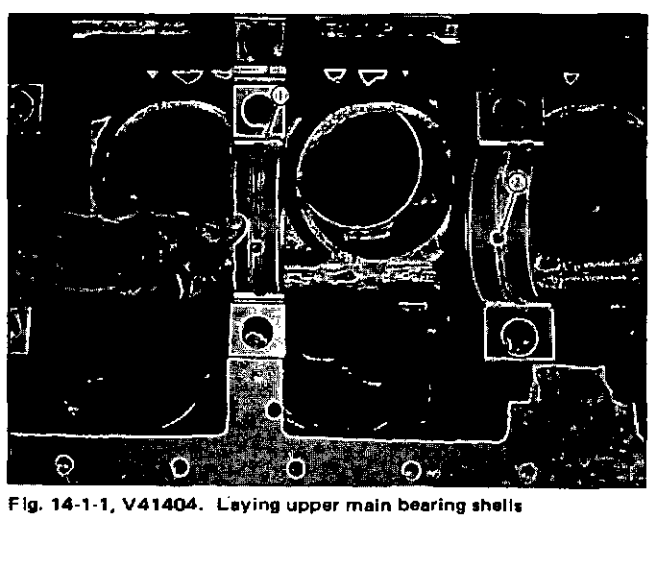


Fig. 14-1-1, V41404. Laying upper main bearing shells

3. Lubricate crankshaft journals and upper main bearing shells with a thin coat of clean engine lubricating oil.

Caution: Reground crankshafts or those using oversize thrust rings should have markings stamped on the rear crankshaft counterweight. Fig. 14-1-2. Both the thrust ring size and ring location should be in the stamping; for example: front–0.010 inch [0.2540 mm] and rear–0.020 inch [0.5080 mm]. Make sure the same sizes are used in pairs, upper and lower. See "Crankshaft – Unit 104."

4. With a chain hoist and hooks protected by rubber hose, carefully lower crankshaft into position. Fig. 0-44.

5. Slide upper thrust rings in position around No. 7 journal. Fig. 14-1-3. Lower thrust rings are dowelled to main bearing caps and hold upper rings in position.

Note: Thrust rings are available in 0.010 inch [0.2540 mm] and 0.020 inch [0.5080 mm] oversizes for reconditioned crankshafts.

6. Place lower main bearing shells in caps and engage locating tangs. Lubricate with a thin coat of clean engine lubricating oil.

7. Install main bearing caps so numbers on caps and block match (Fig. 14-1-4) and are adjacent. On No. 7 cap, be sure to locate thrust rings over dowels before locating cap to block.

Caution: The cylinder block is precision machined for the cap to fit into its correct position. Never file caps to reduce bearing clearance.

8. Install new lockplate (base "L" of lockplate down over cap to outside wall of engine). Lubricate lockplates and capscrew threads with clean engine lubricating oil.

Never use any other lubricant.

Caution: All main bearing capscrews on right bank (fuel pump side) except No. 7 are dowel fit.

9. With a torque wrench, tighten each capscrew in alternate steps as noted in Steps 1 through 4 of Table 14-1-1. Fig. 14-1-5.

10. Mark position after Step 4 in Table 14-1-1 by scribing pencil lines on capscrew head and cap. Advance each capscrew an additional 60 deg. (one hex) in 30 deg. increments; see Step. 5, Table 14-1-1. This is operating tension.

Caution: Do not use soft or distorted lockplates.

11. Test crankshaft for free turning. **Operation must be free enough so it can be hand cranked easily.**

12. Attach a dial indicator gauge securely to cylinder block with contact point of gauge resting on crankshaft flange and face.

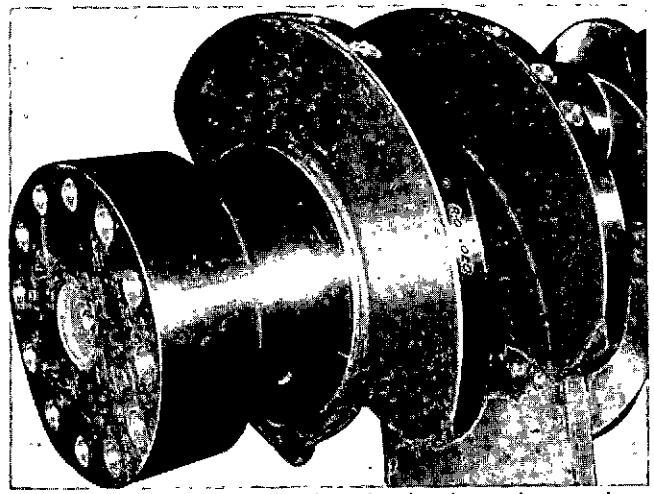


Fig. 14-1-2, V40182. Oversize thrust bearing size mark on crankshaft

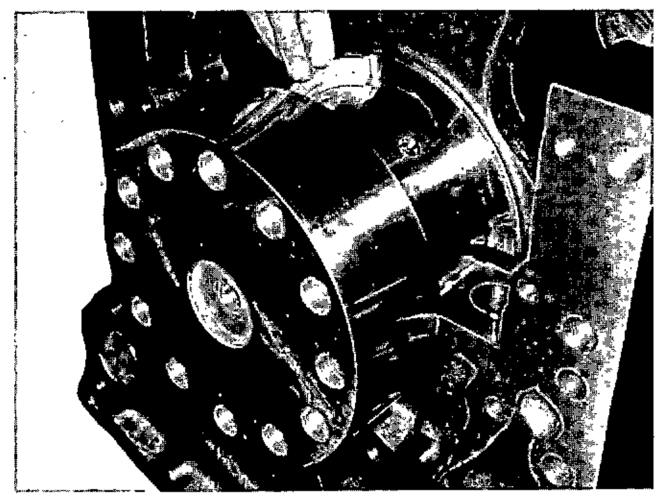


Fig. 14-1-3, V414214. Install thrust half-rings

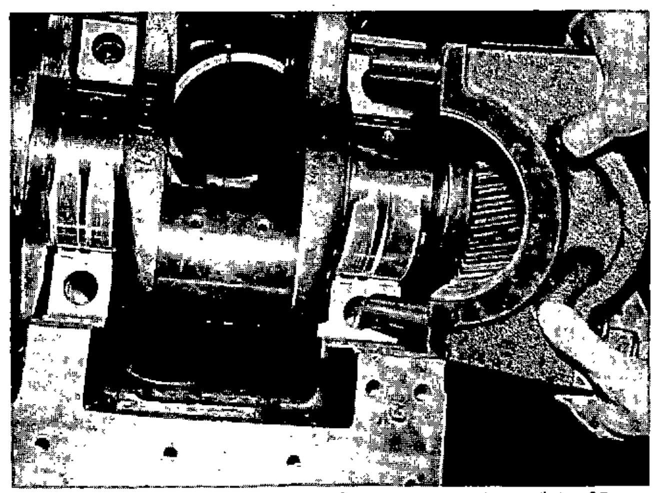


Fig. 14-1-4, V414107. Match numbers on cap with numbers on block

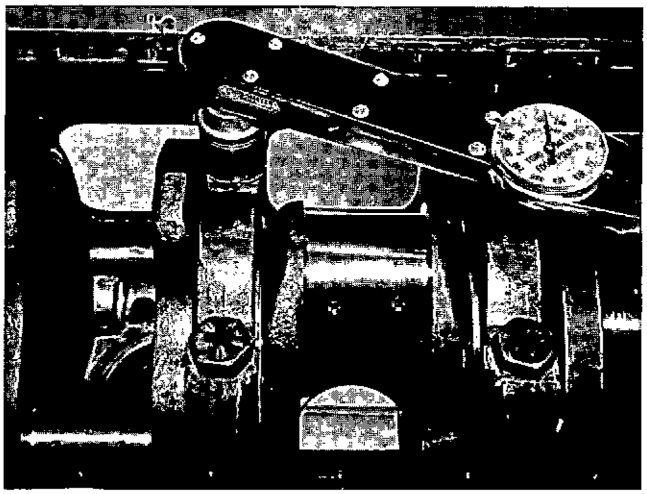


Fig. 14-1-5, V414108. Tighten main bearing capscrews

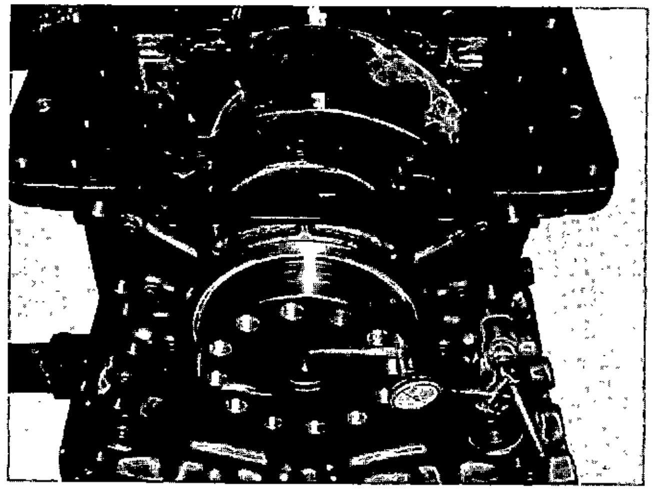


Fig. 14-1-6, V414215. Crankshaft end clearance check

Table 14-1-1: Main Bearing Capscrew Tightening Ft-Lb [kg m]

Step	Reading
1. Tighten to	200/210 [27.6600/29.0430]
2. Advance to	410/420 [56.7030/58.0860]
3. Loosen	All Capscrews
4. Tighten to	120/125 [16.5960/17.2875]
5. Advance	60°

13. Pry crankshaft toward front of engine, taking up all end play, and set gauge at "O." **The crankshaft must move freely.**

14. Pry crankshaft toward rear of engine. The gauge should indicate 0.006 to 0.013 inch [0.1524 to 0.3302 mm] end clearance for a new engine, or an engine with new crankshaft and new bearings. Fig. 14-1-6.

15. If end clearance is less than stated in Step 14, loosen capscrews slightly and shift crankshaft toward front of engine, then toward rear of engine. If capscrews have been loosened, retighten as described above. Recheck end clearance.

Caution: When an engine is being rebuilt, always bring crankshaft end clearance to 0.006 to 0.013 inch [0.1524 to 0.3302 mm] by using standard new parts or by using oversize thrust rings and a reconditioned crankshaft.

16. Bend an ear of each lockplate against the main bearing capscrew to lock it in place.

Installing Main Bearing Side Capscrews

1. Install and torque main bearing side capscrews on engines (Fig. 14-1-7) with serial number suffix "3" or reference "3" to following values.

a. Torque all right bank side capscrews to 70 to 75 ft-lb [12.6810 to 13.3725 kg m].

b. Torque all left bank side capscrews to 70 to 75 ft-lb [12.6810 to 13.3725 kg m].

c. Return to right bank and torque side capscrews to 135 to 145 ft-lb [18.6705 to 20.0535 kg m].

d. Return to left bank and torque side capscrews to 135 to 145 ft-lb [18.6705 to 20.0535 kg m].

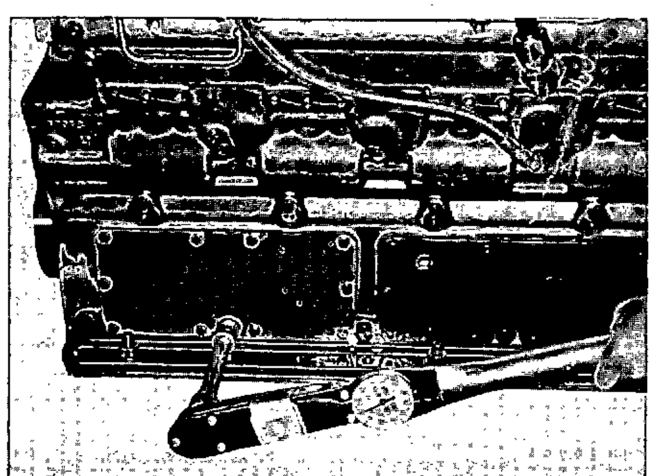


Fig. 14-1-7, V40242. Torquing side capscrew

Main Bearing Replacement — Crankshaft In Place

If crankshaft has not been removed from engine, it is possible to install new main bearings by the following procedure.

1. Remove only every other main bearing cap and lower shell at one time.

Caution: Never leave crankshaft unsupported.

2. Turn crankshaft until drilled hole in main bearing journal is visible.

3. Insert a 7/32 inch [5.5562 mm] by 1/2 inch [12.7000 mm] pin with a head 3/32 inch [2.3812 mm] thick into drilled hole of shaft. Fig. 14-1-8.

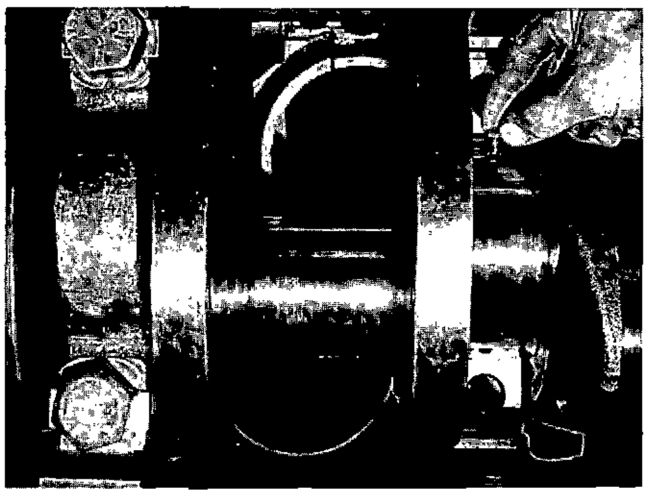


Fig. 14-1-8, V414110. Installing pin for turning out main bearing shell

4. Roll pin against shell on side opposite locating tang. Shell will turn out as crank is rotated.

5. Carefully clean oil passages in crankshaft and cylinder block.

6. Lay new shell in proper position on journal so locating tang will fit into recess in block when crankshaft is turned.

7. Use pin, only if necessary, and rotate to turn shell into position.

Caution: Be very careful not to damage bearing shell.

8. Replace lower shell and cap with locating tang in recess of cap.

9. Install a new lockplate and tighten capscrews as previously described.

10. Check for free turning of crankshaft.

11. If necessary, replace remaining shells in same manner. If *bearings have had considerable service, it is recommended* all be replaced so 0.002 inch [0.0508 mm] maximum variation in oil clearance between adjacent main bearings and journals is not exceeded.

12. Check crankshaft end clearance as previously described.

Rear Cover

Two types are used on V-1710 engines.

One Piece

1. *Dowels in cylinder block and dowel holes in cover plate* must be located before permanent assembly of the one-piece rear cover to cylinder block.

2. To locate rear cover for doweling to cylinder block:

a. Screw two flywheel guide studs into crankshaft.

b. Slide ST-1093 over guide studs on crankshaft, then install rear cover over tool. Fig. 14-1-9.

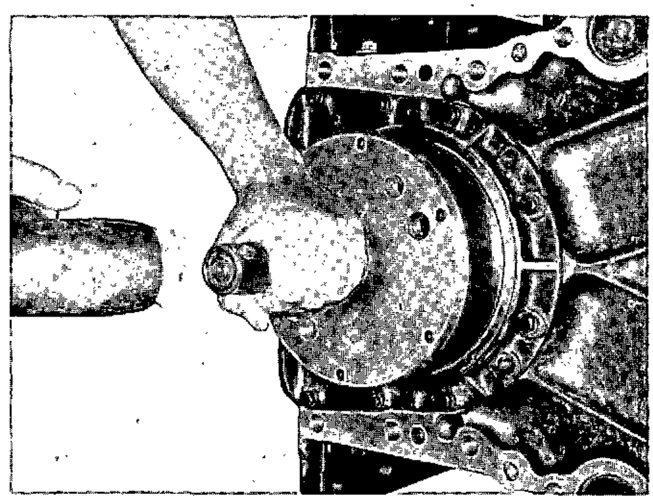


Fig. 14-1-9, V414216. Using ST-1093 Wear Ring and Oil Seal Driver

c. Bring rear cover flush with bottom of block to alignment of 0.004 inch [0.1016 mm], tighten in place and dowel.

d. Remove ST-1093 Driver and remove rear cover.

3. Apply gasket bonding adhesive on gasket surface of cylinder block and install rear cover plate cylinder block gasket. Extreme care must be taken to avoid dripping gasket adhesive onto crankshaft.

4. Install rear cover to block; secure loosely with capscrews and lockwashers.

5. Position wear sleeve on ST-1093 Seal and Sleeve Driver with outside chamfered edge down and inside chamfered edge up; then install alignment stud to crankshaft. Slip tool over studs and drive sleeve onto crankshaft.

6. Wash seal in clean engine lubricating oil. This may be done by dipping or by using a small brush.

7. Position seal on ST-1093 seal and sleeve driver. Slip tool over alignment studs and drive seal into rear cover. Remove studs.

8. Tighten and torque capscrews to 29 to 31 ft-lb [4.0107 to 4.2873 kg m].

9. If wet-type clutch rear cover is being used, lubricate new "O" ring and roll into groove on outside rear cover. Fig. 14-1-10.

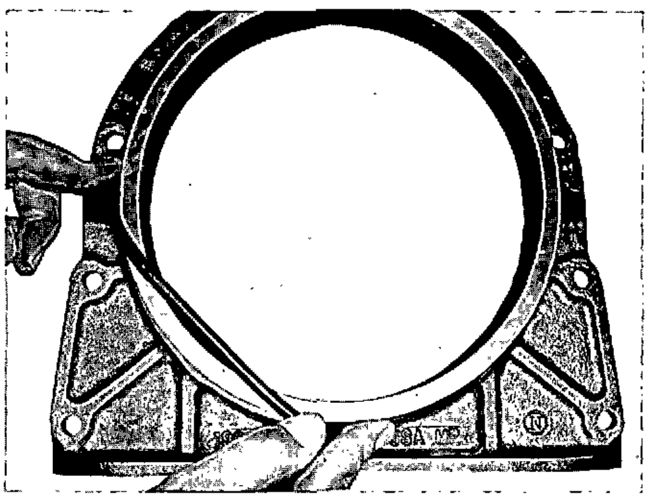


Fig. 14-1-10, V414217. Install rear cover "O" ring for wet-type clutch

Caution: Check for twisted ring by using mold mark on "O" ring as a guide; straighten as required.

Piston Ring-Type

For assembly procedure see Page 14-1-31.

Cylinder Liners, Pistons And Connecting Rods

Make sure liner counterbore and lower packing ring area in block have been thoroughly cleaned. Dirt or scale on these surfaces will cause distortion of liner and result in failure. Refer to "Cylinder Block" Group 1.

Note: On engines after Serial No. 664253 liners may be installed in block and then Piston and Rod Assembly through top of liner. Follow procedure as outlined below for liner installation, piston and rod assembly and installation.

Check Cylinder Liner Protrusion

Before installing cylinder liners, make sure liner protrusion above the cylinder block is correct; this is very important to obtain satisfactory head gasket sealing of the combustion chamber.

1. Inspect cylinder liner counterbore.

a. Check upper liner counterbore diameter at four equidistant points, Fig. 14-1-11. Counterbore dimensions of a new cylinder block are listed in Table 14-1-2.

Caution: Do not attempt to rework counterbore I.D.

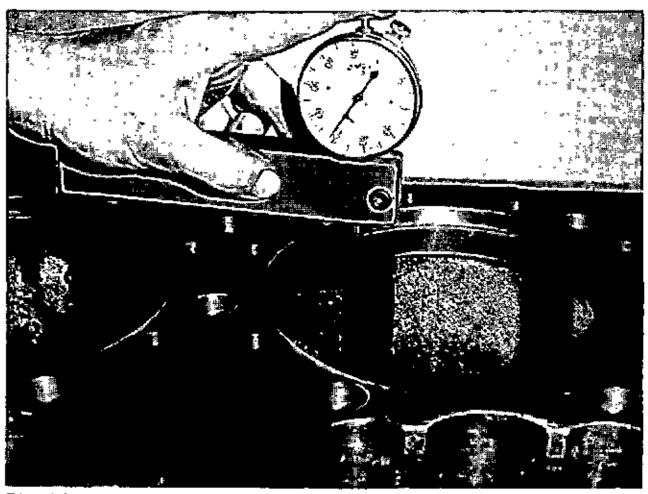


Fig. 14-1-11, V40124. Check liner counterbore depth

Table 14-1-2: Liner Counterbore

A Dimension Counterbore I.D. Inch [mm]	B Dimension Depth Inch [mm]
6.5615/6.5635 [166.6621/166.7129]	0.350/0.351 [8.8900/8.9154]

b. The counterbore ledge must be smooth and perpendicular or cupped slightly in relation to cylinder liner bore.

c. An installed cylinder liner must protrude 0.004 to 0.006

inch [0.1016 to 0.1524 mm] above milled surface of cylinder block.

2. The most accurate method of checking protrusion is as follows:

a. Install liner and packing rings in block with proper number of liner shims beneath the flange, if known. Refer to "Install Liner in Block" following.

b. Place ST-1005 Cylinder Hold-Down Tool Sleeve on cylinder block so foot of tool rests upon cylinder liner "fire ring." Secure tool to block with four capscrews; space capscrews so even load will be applied. Fig. 14-1-12.

c. Tighten capscrews to 50 ft-lb [6.9150 kg m] torque.

d. Use ST-547 Gauge Block and check liner protrusion above the cylinder block at four equidistant points outside the bead. Fig. 14-1-12.

e. Add or remove shims from beneath the liner flange to reach 0.004 to 0.006 inch [0.1016 to 0.1524 mm] protrusion; see Table 1-1-13 in "Cylinder Block Group" for listing of available shims.

f. With liner installed, check for out-of-roundness as described under "Install Liner in Block" following and shown in Fig. 14-1-13. See limits in Step 4 of "Install Liner in Block."

3. To check protrusion without actually pressing in liner, perform the following steps:

a. Measure liner flange with micrometer. Do not include bead on top of liner flange in taking measurement.

b. Measure counterbore depth with dial indicator depth gauge or ST-547 Gauge Block. If ST-547 is used, "zero" indicator before taking measurement.

c. Check depth at four or more locations. Ledge must not be "cupped" more than 0.0014 inch [0.0355 mm] and must never slope inward. Depth must not vary more than 0.001 inch [0.0254 mm] throughout counterbore circumference.

d. If dimensions do not meet standards as outlined in (c) above, counterbore must be reworked. See "Cylinder Block Group 2." Calculate depth of cut that will be necessary in order that a standard shim may be used to provide the desired 0.004 to 0.006 inch [0.1016 to 0.1524 mm] liner protrusion. Normally, a 0.007 to 0.009 inch [0.1778 to 0.2286 mm] cut will be adequate to recondition counterbore circumference.

Note: If the material to be removed will result in a counterbore depth exceeding the maximum listed in Group 18, it is recommended that the block not be reused.

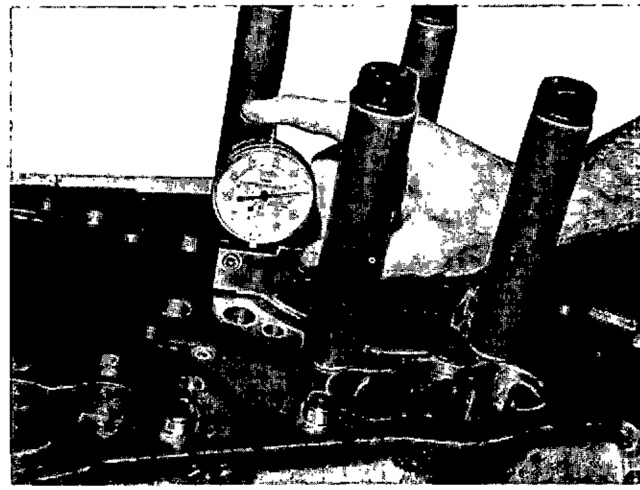


Fig. 14-1-12, V414114. Checking protrusion using ST-1005

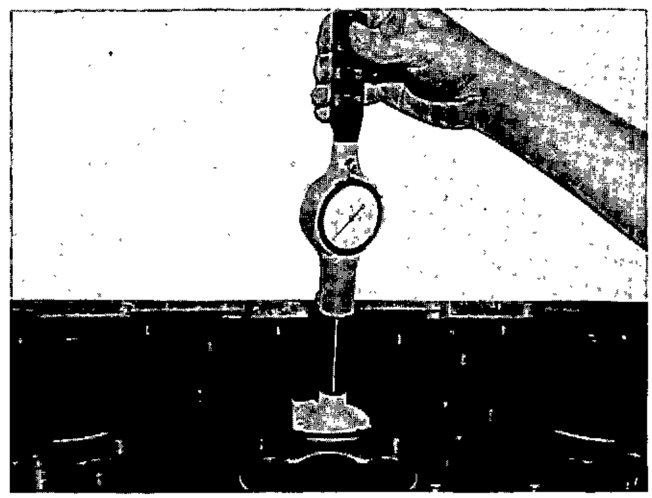


Fig. 14-1-13, V414116. Checking liner out-of-round without ST-1005

e. Check for variations in protrusion under each cylinder head. Variation cannot exceed 0.001 inch [0.0254 mm].

Assemble Connecting Rods And Pistons

1. Insert one snap ring in piston pin bore. When 175760 or 175770 piston is used in an engine, 175755 piston pin snap rings must be used. All other pistons may use 175755 or 61908 snap rings. Heat piston in boiling water or an oven at 220 deg. F [104.4 deg. C] for 5 minutes.

Caution: Do not overheat.

2. Support connecting rod upright and position piston over rod, aligning piston pin bore in rod with bore in piston.

3. Insert piston pin through piston and rod by hand; lock

pin in place with second snap ring. Fig. 14-1-14.

4. Assemble rings to pistons with word "top" at top with ST-763. Chrome ring is "top" compression ring when used.

Caution: Be sure to use type of ring specified for piston. Never use a chrome-plated piston ring in a chrome-plated liner.

Install Piston/Rod Assembly In Liner

1. Lubricate pistons, rings and cylinder liners with clean lubricating oil.

2. Using a standard band-type ring compressor to compress rings, insert piston and rod assembly in liner from bottom of liner. Fig. 14-1-15.

3. Assemble packing rings (1 and 2, Fig. 14-1-16) and crevice seals (3).

Note: Cylinder liner crevice seals and "O" rings are color-coded with two 3/8 inch [9.5250 mm] wide white stripes. Make sure the proper packing rings and crevice seals are installed.

a. Lubricate packing rings with clean lubricating oil; wipe off excess oil.

b. Roll black "O" ring (2), with two white marks, into position in upper groove. Fig. 14-1-16.

c. Install the red silicone "O" ring (1) with two white marks in lower groove.

d. Check for twisted rings in grooves. Using mold mark on rings as guide, straighten as required.

e. Install crevice seal (3) on liner.

4. Lubricate machined portions of block on which packing rings seat with clean lubricating oil.

Caution: Never use white lead for lubricant. White lead will harden and make cleaning difficult at next engine tear-down.

Install Liner In Block

Two men are required for this operation – one to install the assembly and the other to guide connecting rod over crankshaft journal.

1. Lift liner, piston and rod assembly and slide into cylinder liner bore, Fig. 14-1-17. Numbers on connecting rod must be toward outside of engine. Connecting rods and caps are numbered to correspond with their respective cylinders; numbers on rods and caps must be matched. Two rods are assembled on each crank journal.

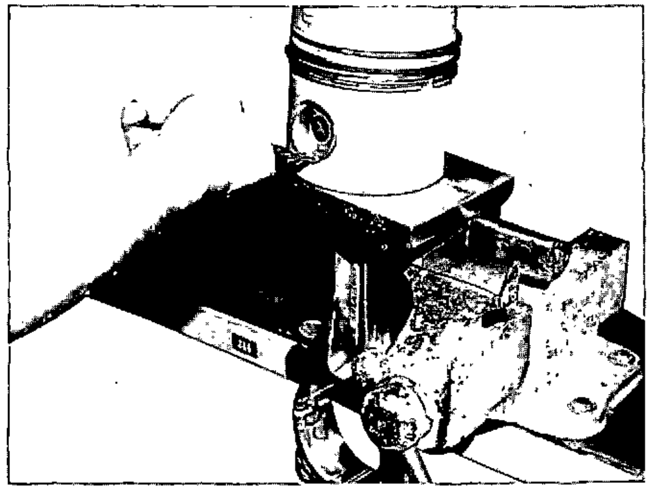


Fig. 14-1-14, V414117. Installing piston pin retainer ring

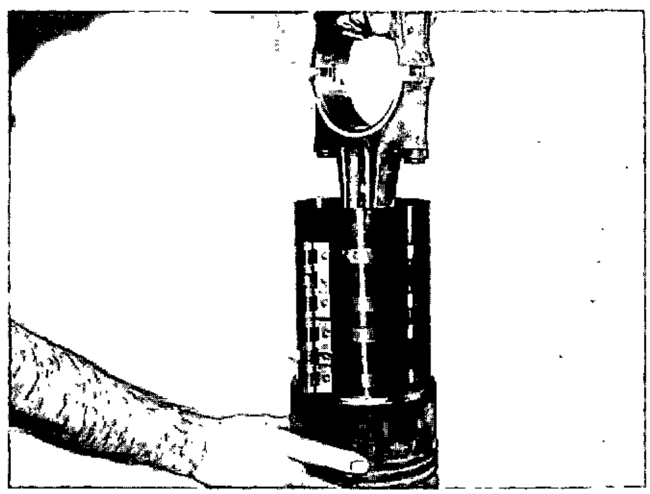


Fig. 14-1-15, V414118. Installing piston in liner

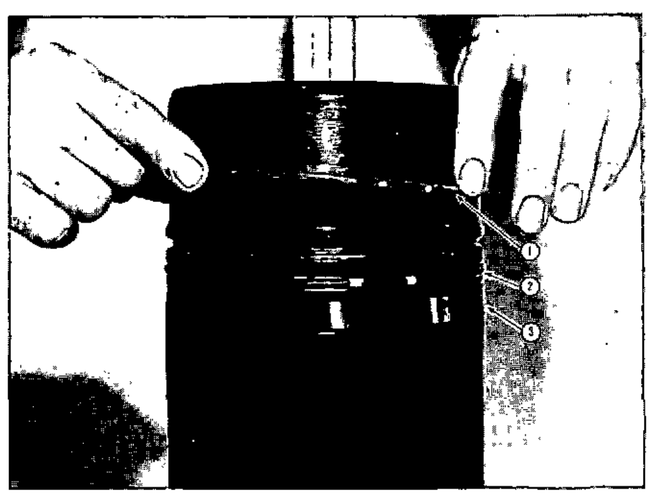


Fig. 14-1-16, V414119. Installing "O" ring on cylinder liner

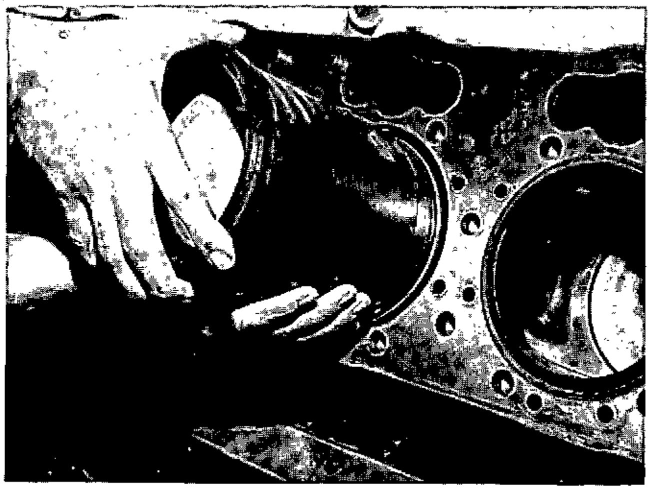


Fig. 14-1-17, V414120. Installing piston and liner assembly in block

2. Lower liners to press-fit shoulder by hand pressure.

Caution: If liner is difficult to push down, the packing rings may be twisted or have slipped. Remove liner to check rings; use extreme care to avoid twist or cut of "O" rings.

3. Drive liners to seat with ST-594 Cylinder Liner Driver; when liner is near seat, tap easily to prevent bouncing off seat as liner is driven in place. Fig. 14-1-18.

4. With piston at lowest possible point, check liner bore for roundness at several points within range of piston travel. Fig. 14-1-19.

a. Check with precision dial bore gauge.

b. Micrometer readings to be taken as near points at C, D, E, F and G along axis A-A and B-B as possible.

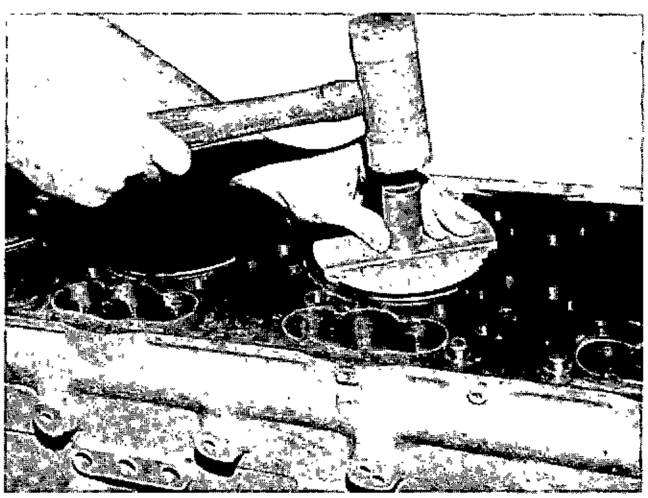


Fig. 14-1-18, V414121. Installing liner with ST-594

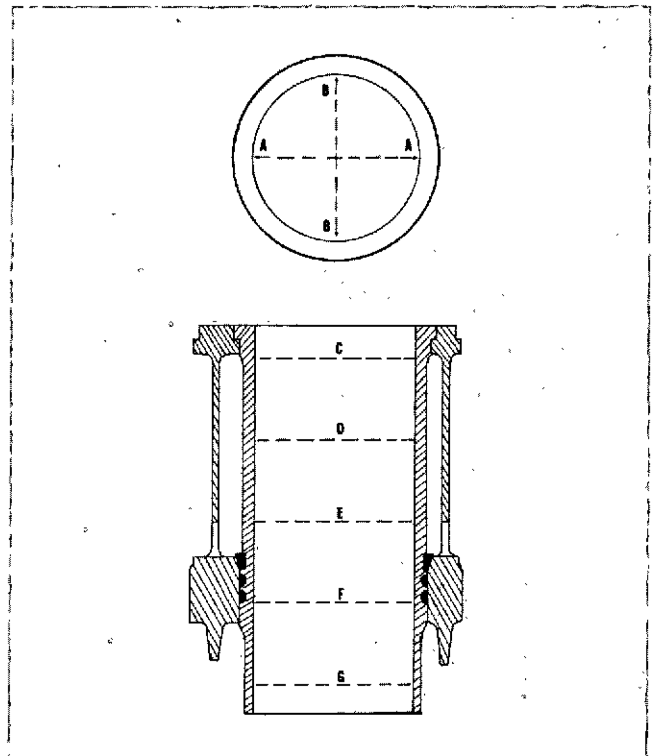


Fig. 14-1-19, V414122. Cylinder liner check points

(1) At point "C," approximately 1 inch [25.4000 mm] below top of liner, it is permissible to have up to 0.003 inch [0.0762 mm] of out-of-round.

(2) At other points, each about 2 inch [50.8000 mm] lower than preceding depth, out-of-round must not exceed 0.002 inch [0.0508 mm].

5. Check liner protrusion at four equidistant points with ST-547 Gauge Block to determine if protrusion is uniform and 0.004 to 0.006 inch [0.1016 to 0.1524 mm] above block. Measure outside of bead, Fig. 14-1-20.

Connecting Rod Bearings And Caps

1. Lubricate crankshaft side of bearing shells with a thin coat of clean engine lubricating oil.

2. Slide upper connecting rod bearing shells into position between the crankshaft journals and rods. Be sure bearing shell locating tang makes firm contact with the recesses in rod.

3. Place lower connecting rod bearing shells in connecting rod caps. The locating tang on shell must index with milled recess in cap. Numbers on rod and cap must match [1 to 1, 2 to 2, etc.) and must be toward outside of their respective banks and must indicate proper position in cylinder block: 1L for left bank, 1R for right bank, etc. Stamp if new rod is

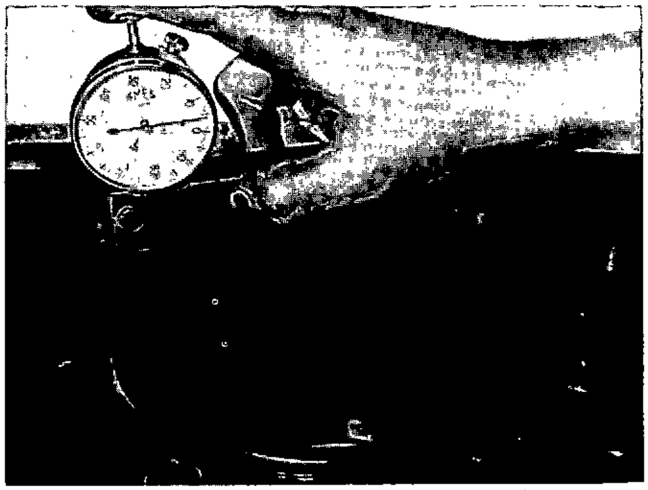


Fig. 14-1-20, V414115. Checking liner protrusion

being used. This provides proper clearance between rod crankpin end chamfer and crankshaft rod journal fillet.

4. Completely lubricate bolt threads and hardened washers with clean SAE 50 lubricating oil.

5. Assemble caps and bearing shells over rod bolts (Fig. 14-1-21) and install washers and nuts.

6. Tighten connecting rod bolt nuts alternately to 70 to 80 ft-lbs [9.6810 to 11.0640 kg m].

7. Tighten the nuts on each connecting rod alternately to 140 to 150 ft-lbs [19.3620 to 20.7450 kg m].

8. Completely loosen both nuts on each connecting rod to relieve all tension.

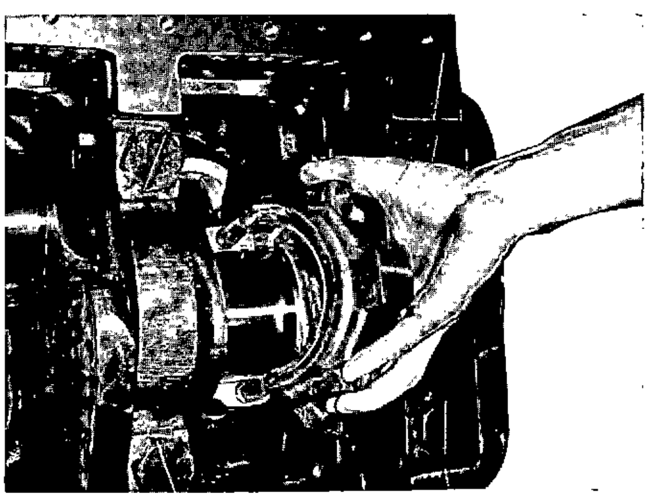


Fig. 14-1-21, V414218. Installing connecting rod bearing and cap

9. Tighten the nuts on each connecting rod alternately to 70 to 80 ft-lbs [9.6810 to 11.0640 kg m].

10. Tighten the nuts on each connecting rod alternately to 140 to 150 ft-lbs [19.3628 to 20.7450 kg m].

11. Check for clearance of 0.006 to 0.013 inch [0.1524 to 0.3302 mm] between rod assemblies located on same journal. Fig. 14-1-22. Rods should move freely sideways with hand pressure. Also check position of rod on piston pin and make sure there is visible clearance between rod and piston boss. This is extremely important to prevent scoring or seizing of piston and liner.

12. Turn crankshaft as each piston and rod assembly is added to gauge additional drag. Increase will be perceptible but must not be excessive for any one rod assembly.

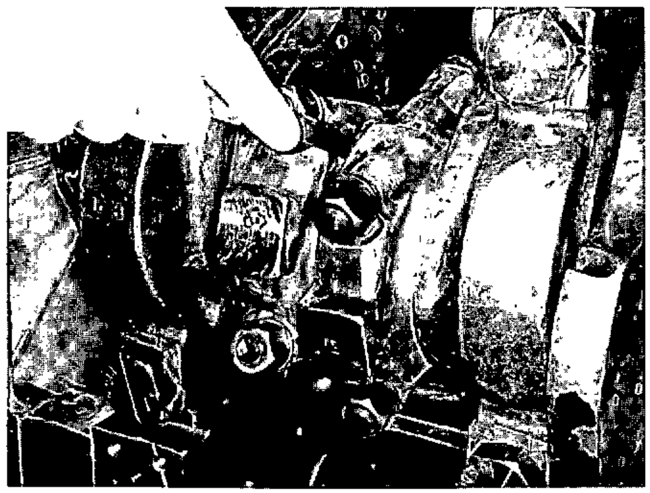


Fig. 14-1-22, V414219. Checking rod side clearance

Installation Of Liners, Pistons And Rods After Serial No. 664253

Cylinder Liners

Caution: Before installing liners, check liner lower skirt end, for nicks or sharp edges protruding into bore that could cause scoring of pistons. Remove nicks or burrs. Also remove all sharp edges or nicks in block lower bore which could distort liner "O" ring sealing.

1. Before installing cylinder liners, check and establish liner protrusion as described previously. If necessary, install shims (Table 1-1-13) around liners to maintain liner protrusion of 0.004 to 0.006 inch [0.1016 to 0.1524 mm].

2. Assemble rubber packing rings and crevice seal on each liner.

Note: Cylinder liner crevice seals and "O" rings are color-coded with two 3/8 inch [9.5250 mm] wide white stripes. Make sure the proper packing rings and crevice seals are installed.

a. Lubricate packing rings with clean lubricating oil; wipe off excess oil.

b. Roll black "O" ring with two white marks, into position in upper groove.

c. Install the red silicone "O" ring with two white marks in lower groove.

d. Check for twisted rings in grooves. Using mold mark on rings as guide, straighten as required.

e. Install crevice seal on liner.

Caution: Never use white lead for lubricant. White lead will harden and make cleaning difficult at next engine tear down.

3. Lubricate machined packing ring bore of block with light coat of clean lubricating oil. Push liner into place by hand carefully to avoid dislodging crevice seal.

4. Drive liner into block counterbore with ST-594 Liner Driver and soft hammer. Tap lightly as liner is seated to prevent "bounce."

5. Install ST-1005 Liner Hold-Down Clamps at four equidistant points; torque capscrews to 50 ft-lbs [6.9150 kg m], check liner to block protrusion with ST-547 Gauge Block to determine if protrusion is uniform. Measure outside bead. Fig. 14-1-12. Remove clamps.

Caution: Do not damage liner bead when using hold-down clamps.

Check Cylinder Liner Bore

1. Check liner bore for roundness at several points within range of piston travel.

a. Check with precision dial bore gauge.

b. Micrometer readings to be taken as near points at C, D, E, F and G along axis A-A and B-B as possible. Fig. 14-1-19.

(1) At point "C," approximately 1 inch [25.4000 mm] below top of liner, it is permissible to have up to 0.003 inch [0.0762 mm] of out-of-round.

(2) At other points, each about 2 inch [50.8000 mm] lower than preceding depth, out-of-round must not exceed 0.002 inch [0.0508 mm].

2. Use clean engine lubricating oil to lubricate liner bores.

Connecting Rods And Pistons

Assemble connecting rods and pistons as previously described.

1. Install piston rings with ST-763 or ST-1146 Ring Expander. This tool is preferred to avoid distortion of piston ring "circle" during installation on piston. Starting on bottom of piston, install oil ring expander and oil ring. MAKE SURE EXPANDER RING ENDS DO NOT OVERLAP. Install intermediate and top compression ring.

2. Remove connecting rod cap and bolts from rod. These parts are not interchangeable.

Note: Before removing rod caps make sure rods and caps are stamped with cylinder number to prevent mixing later.

3. Rotate crankshaft so rod journal for cylinder being worked on is at bottom center position. Using clean cloth, wipe journal clean. Place thin plastic over connecting rod before inserting assembly in cylinder.

4. Use clean engine lubricating oil to lubricate rings and piston. Compress rings with ST-755 Ring Compressor or equivalent.

Note: When using ring compressor, do not force rings to compress. If compressor sticks before rings are compressed, remove compressor and check oil ring expander. Ends of expander could be overlapped. Correct and preceed with installation.

5. With ring compressor in place, insert piston and rod assembly in cylinder. Position numbered side of rod toward outside of block.

Note: Connecting rods crankpin bores are chamfered on one side and square on the other. Position connecting rod so that chamfer of crankpin bore mates with crankshaft fillet.

6. Using clean plastic tipped pushing tool, this tool can be made by making a T handle out of water pipe and welding a nut in opposite end and attaching a plastic hammer head for pushing piston. Push piston and rod assembly through ring compressor until rings seat in liner. Do not force piston into liner. This may require two men, one to push and one to receive the assembly.

Caution: Ring breakage will result from improper use of ring compressor. If band-type compressor is used, make certain inner band does not slip down and bind piston.

7. Grasp connecting rod and pull to rod journal. Remove guards if used. Leave assembly a short distance from actual seating and install rod bolts.

8. Coat rod bearing shell (crankshaft side) with clean engine lubricating oil.

9. Roll rod bearing shell into rod. Shell locking tang must

fit in milled recess. Insure that oil hole in rod and shell are aligned.

10. Coat lower shell (crankshaft side) with clean engine lubricating oil and seat in rod cap with locking tang in place.

11. Install rod cap over bolts so numbered side of cap is matched with numbered side of rod.

12. Completely lubricate bolt threads with clean engine lubricating oil. Completely lubricate hardened washers with clean 140-W oil. Install washers and nuts to bolts.

a. Tighten connecting rod bolt nuts alternately to 140 to 150 ft-lb [19.3620 to 20.7450 kg m] with a torque wrench in 3 equal steps. Fig. 14-1-23.

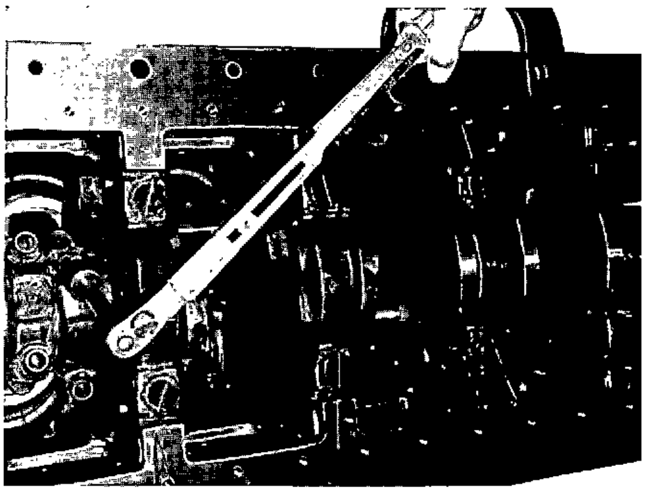


Fig. 14-1-23, V414220. Torquing rod nuts

b. Loosen nuts completely and retighten alternately to 140 to 150 ft-lb [19.3620 to 20.7450 kg m] with a torque wrench in 3 equal steps.

13. Follow Steps 1 through 12 above; install piston and rod assembly opposite the one just installed. Secure rod to same crankshaft journal.

14. Check for clearance of 0.006 to 0.013 inch [0.1524 to 0.3302 mm] between rod assemblies located on same journal. Fig. 14-1-22. Rods should move freely sideways with hand pressure. Also check position of rod on piston pin and make sure there is visible clearance between rod and piston boss. This is extremely important to prevent scoring or seizing of piston and liner.

15. Turn crankshaft as each piston and rod assembly is added to gauge additional drag. Increase will be perceptible but must not be excessive for any one rod assembly.

Lubricating Oil Pump

1. Position lubricating oil pump to block; secure with dowel pins, lockplates and capscrews.

Caution: Make sure lubricating oil pump gear is fully engaged before final tightening of capscrews.

2. Attach a dial indicator to block. Place indicator arm on gear teeth. Fig. 14-1-24.

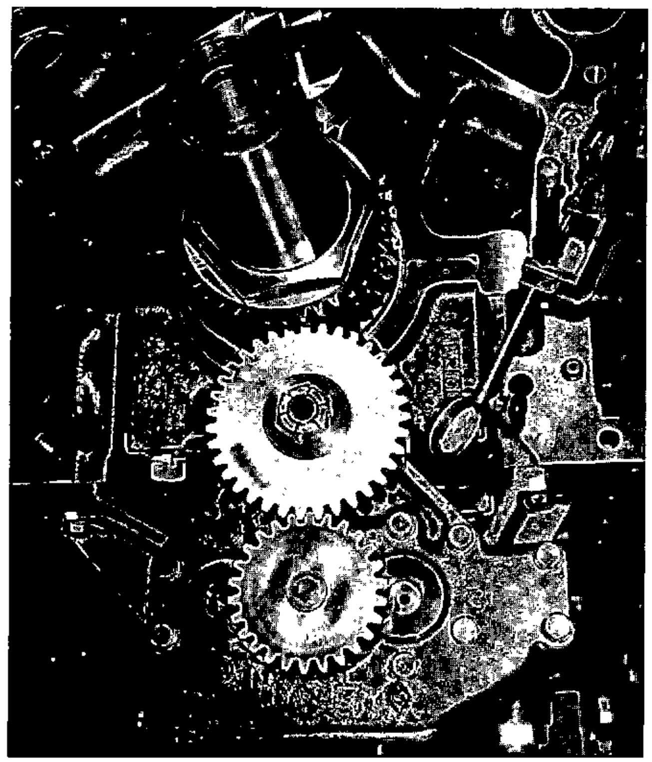


Fig. 14-1-24, V414130. Check lubricating oil pump gear backlash

3. Rotate gear by hand to advance position; "zero" indicator. Back gear to retard position and note reading; permissible backlash is 0.003 to 0.010 inch [0.0762 to 0.2540 mm]. If not within limits, gear train must be replaced.

4. After backlash has been checked, bend lockplates to secure capscrews.

5. Assemble lubricating oil suction and discharge lines, connections and clamp, using new "O" rings and gaskets. Fig. 14-1-25 through 14-1-28.

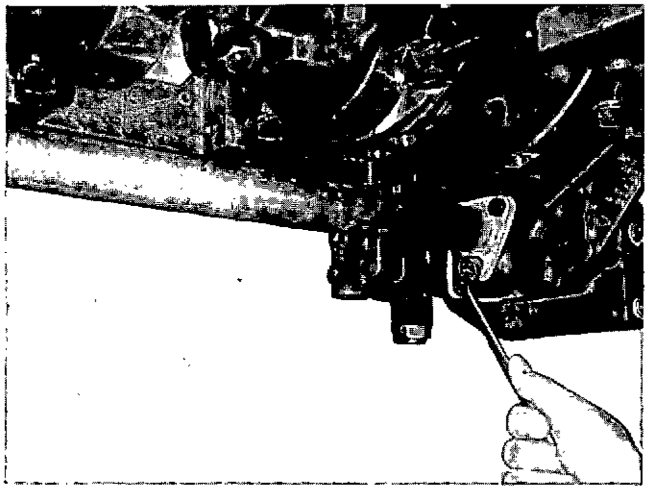


Fig. 14-1-25, V414221. Install suction tube assembly

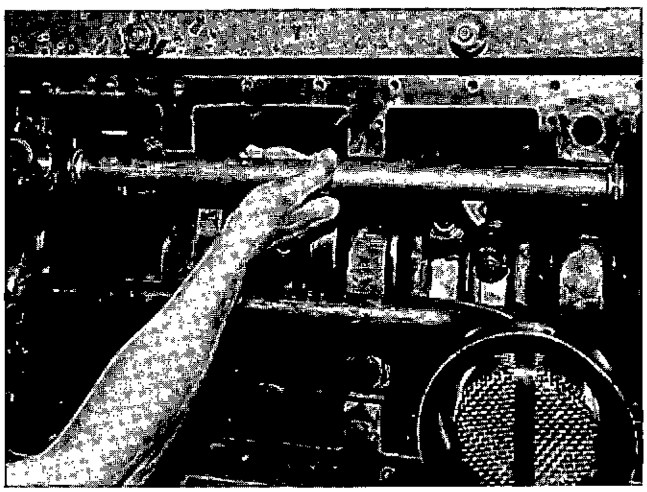


Fig. 14-1-26, V414127. Install outlet line to pump

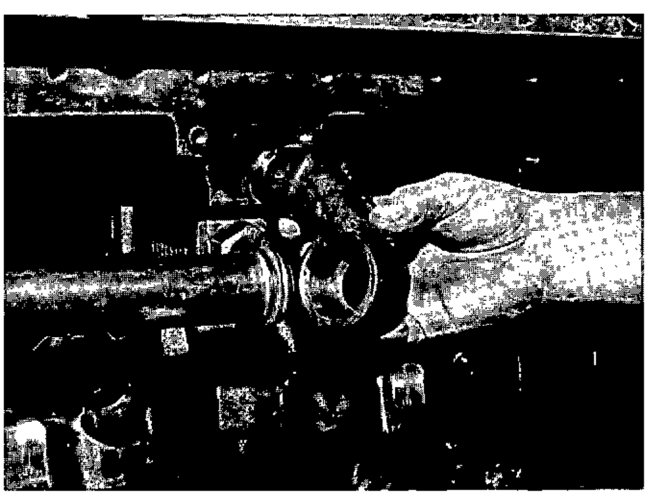


Fig. 14-1-27, V414128. Install outlet to block connection

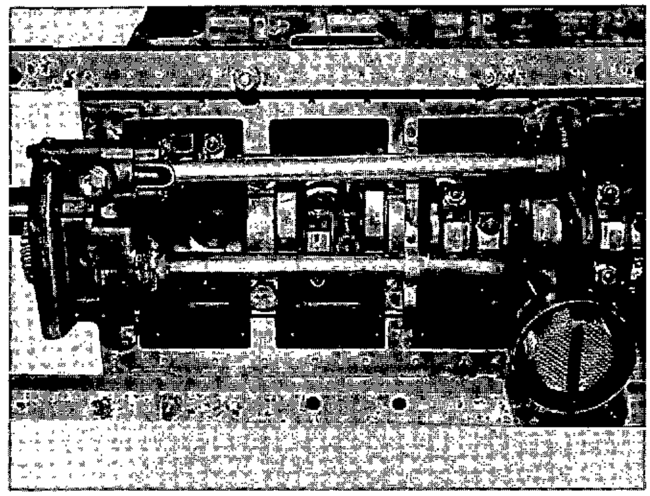


Fig. 14-1-28, V414129. Lubricating oil pump, clamps and connections in position

Gear Case

The procedure for installation of new and used gear cases differs as outlined below.

Install Used Gear Case

1. Install several guide studs in engine block and position gear case gasket over studs.

2. Guide gear case over studs; drive in place over dowels with a soft hammer.

3. Install lockwashers and capscrews and tighten gear case securely in place.

Install New Gear Case

1. Follow Steps 1 and first part of 2 above.

2. Insert an ST-400 Locating Mandrel in each camshaft bore (1, Fig. 14-1-29).

Note: If mandrels are not available, the gear case can be located by installing the camshafts and using an indicator gauge clamped to each camshaft at a low point along cam lobes of No. 1 cylinder. Shift gear case as needed to obtain true concentricity of camshaft bores in block and gear case. This is a long procedure and much time can be saved by using mandrels.

3. Temporarily install and tighten capscrews. Fig. 14-1-30.

4. Assemble all gears in position and check gear lash before doweling gear case. There must be a minimum of 0.003 inch [0.0762 mm] gear lash between each mating pair of gears at all points of rotation.

5. The gear case is now in position to ream and dowel. Standard dowels are 0.500 inch [12.7000 mm]; if necessary, use next oversize.

6. Remove guide studs. Install remaining lockwashers and capscrews and tighten gear case securely in place.

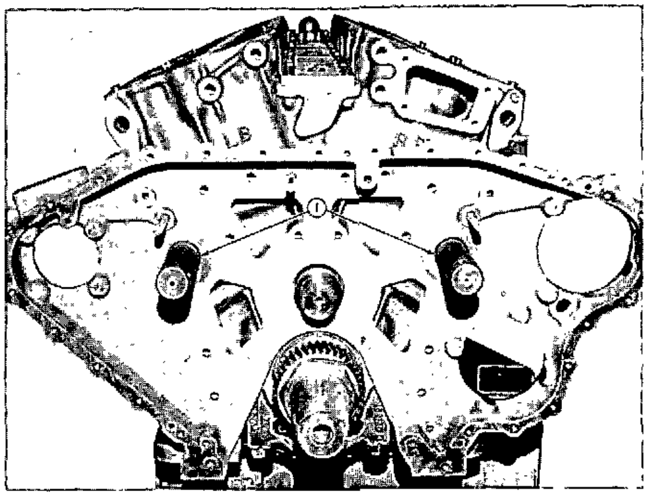


Fig. 14-1-29, V414131. Locating new gear case for doweling

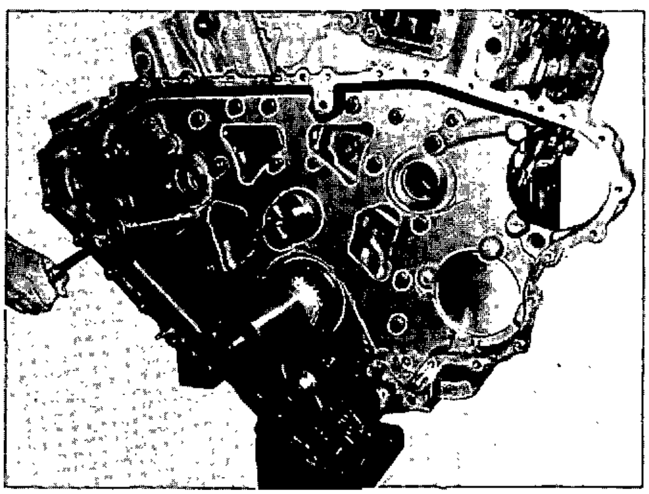


Fig. 14-1-30, V414132. Tighten mounting capscrews temporarily

Idler Gear

1. Install thrust washer on idler shaft with oil grooves facing away from shaft shoulder.

2. Install center idler gear on idler shaft indexing two "O" marks on idler gear astride single "O" mark on crankshaft gear. Fig. 14-1-31.

3. Insert dowel pin in drilled hole in end of idler shaft, if removed.

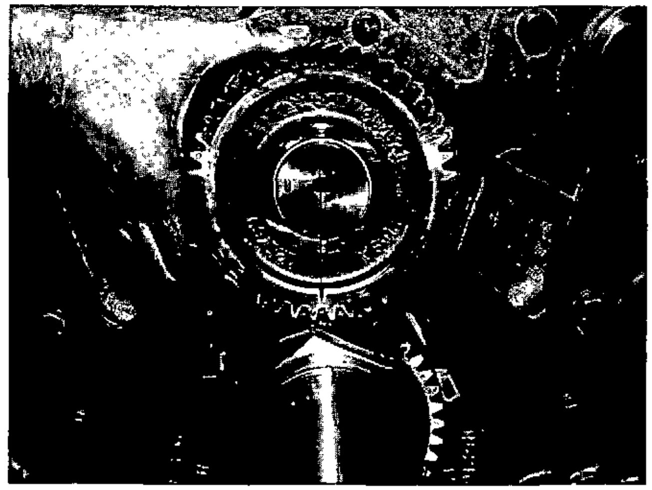


Fig. 14-1-31, V414133. Center idler gear assembly

4. Install outer thrust washer over shaft with oil grooves next to idler gear.

5. Install flatwasher over dowel against end of shaft.

6. Secure assembly to shaft with lockwasher and capscrew.

7. Idler gear end thrust new is from 0.001 to 0.016 inch [0.0254 to 0.4064 mm]; worn limit is 0.020 inch [0.5080 mm]. Check clearance with feeler gauge. Fig. 14-1-32.

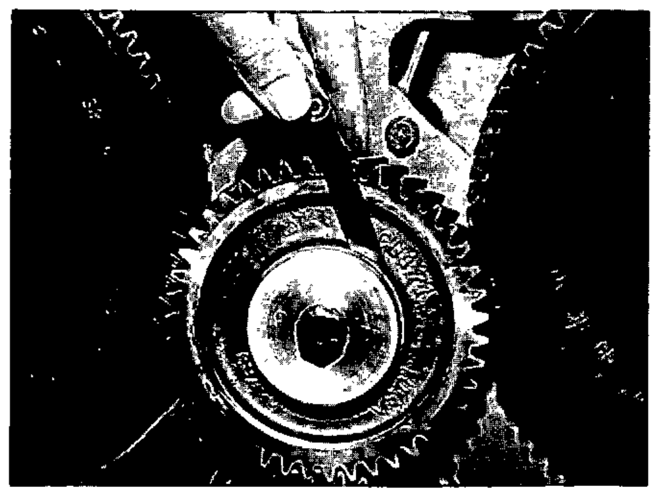


Fig. 14-1-32, V414134. Checking idler gear end thrust

Camshafts

Camshafts have press-on gears. It is not necessary to check engine injection timing unless a camshaft key or gear has been changed or a new camshaft is being used.

Installation of press-on gears is described in Group 1, Unit 110.

Camshaft bushings should have been installed in the block and checked prior to engine assembly as instructed in "Cylinder Block Group 1".

1. Place thrust washer for each camshaft against camshaft front bearing flange with smooth side toward cylinder block.

2. Apply clean engine lubricating oil to camshaft journals and lobes; then carefully rotate camshafts through bores into position. Fig. 14-1-33.

Note: Consult latest parts catalog for camshaft part numbers on right and left banks. Identifying part number is stamped on rear of camshaft.

3. Slide the two camshafts into position with two "O" marks on each camshaft gear aligned with "O" mark on each side of idler gear. Fig. 14-1-34.

4. Attach a dial indicator to gear case. Place indicator arm on camshaft gear teeth. Fig. 14-1-35.

5. Rotate gears by hand to advance position; "zero" indicator. Back gear to retard position and note reading; there must be a minimum of 0.003 inch (0.0762 mm).

Tappets

1. Install tappets in cylinder block bores with larger injector tappets in the center. Fig. 14-1-36. Intake and exhaust valve tappets are the same size.

2. Align tappet slots with holes in side of block.

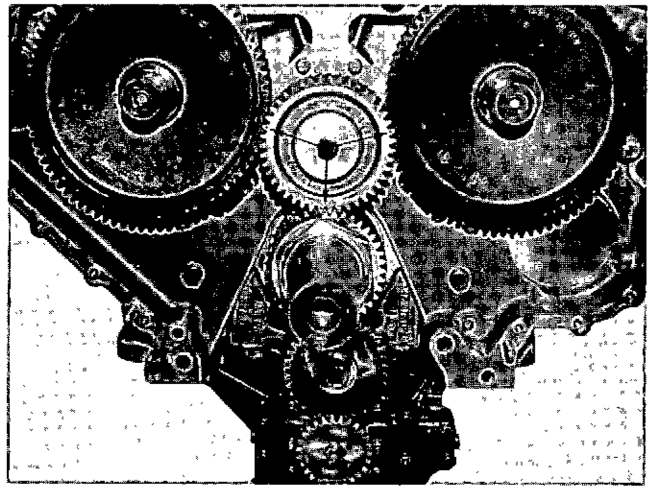


Fig. 14-1-34, V414136. Gear train timing marks

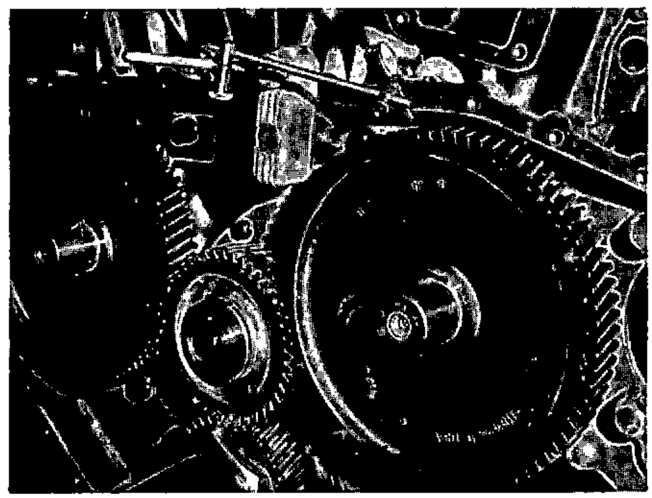


Fig. 14-1-35, V414137. Check camshaft backlash

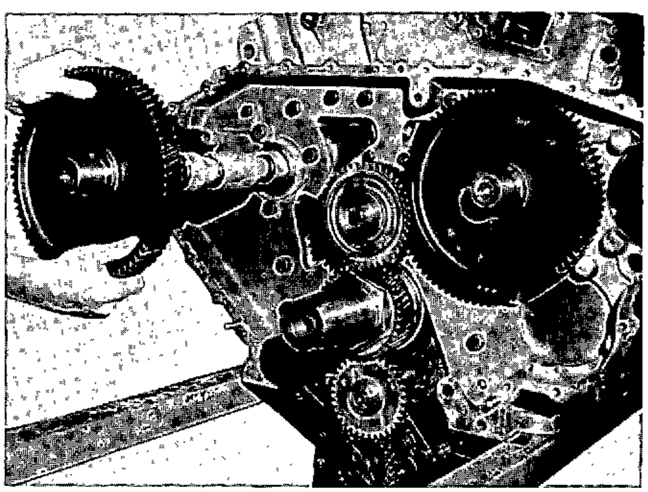


Fig. 14-1-33, V414135. Installing camshaft

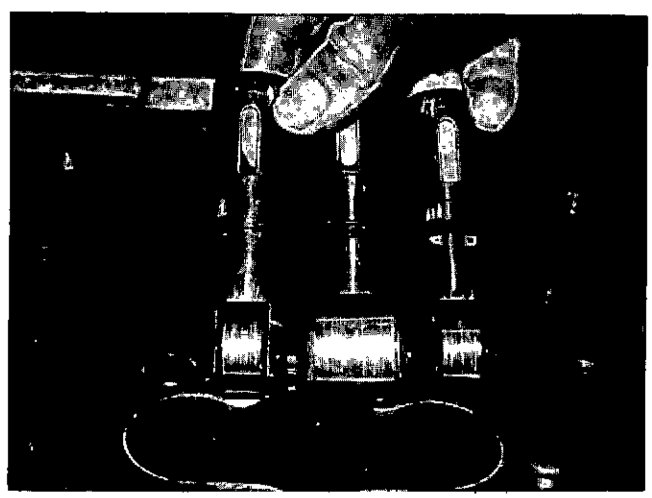


Fig. 14-1-36, V414138. Position tappets

3. Tappets are kept from turning by guide screws with copper washers. Install washers and screws and torque screws to 95 to 115 inch-lb [1.0925 to 1.3225 kg m] Fig. 14-1-37; lockwire each set of three.

Note: The cam lobe and tappet location—counting from the front end—is as follows for each cylinder head:

Right Bank: EFI, EFI, IFE
Left Bank: EFI, IFE, IFE

As abbreviated, "E" = exhaust, "F" = fuel and "I" = intake.

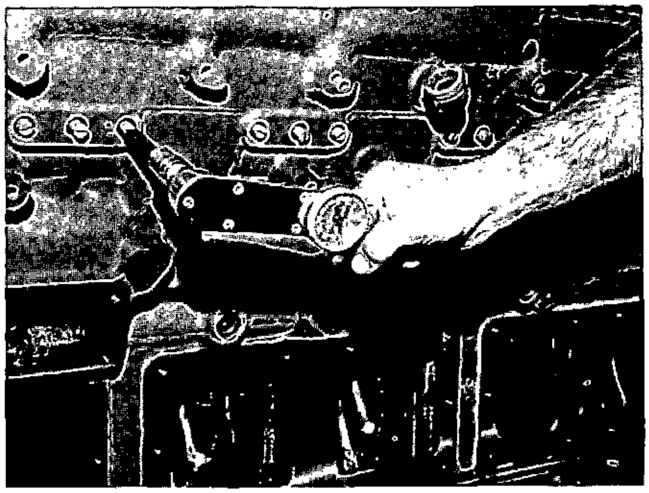


Fig. 14-1-37, V414139. Tighten tappet guide screws

Cylinder Heads

Cylinder heads should have valve guides, oil seals (naturally aspirated only if used), valves and springs assembled in position as described in Group 2 before installing.

1. Make certain breather hole (A, Fig. 14-1-40) in each cylinder head is open.

2. Clean mating surfaces of cylinder block and cylinder heads. Make certain cylinder walls are clean and well lubricated with clean lubricating oil.

3. Install head gasket over dowels so word "top" on gasket is visible. Fig. 14-1-38.

4. Place grommet retainers in water passages in block, small end up. Fig. 14-1-39.

Note: The same grommet retainers and grommets are used in oil passages as in water passages. As an alternate method of assembly, first install grommet retainers in block water and oil holes. Then install gasket making sure grommets are pressed securely into gasket holes. If holes are eroded, install retainers on top of grommets.

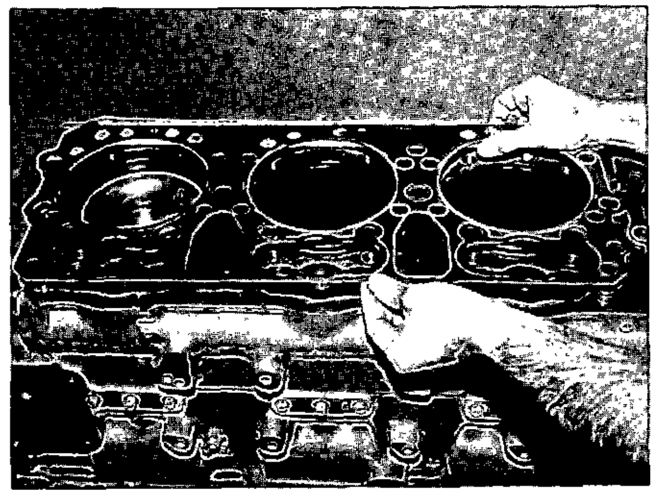


Fig. 14-1-38, V414140. Installing cylinder head gasket

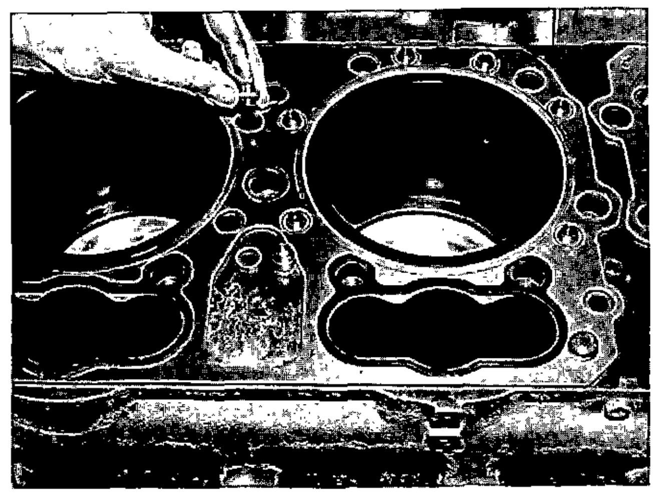


Fig. 14-1-39, V414141. Install head gasket grommets and retainers

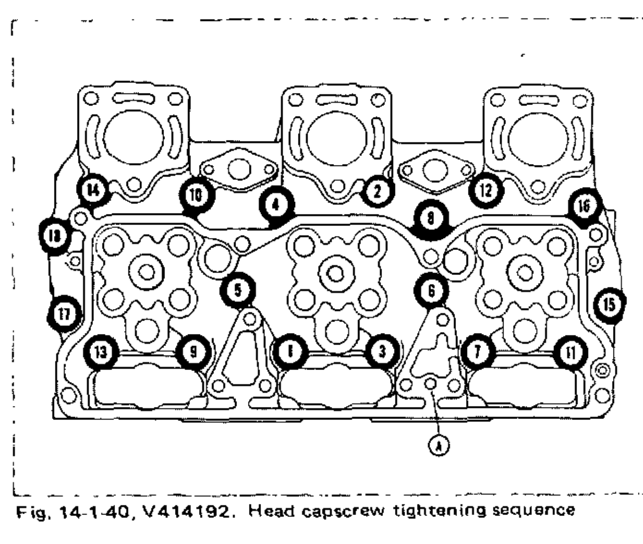


Fig. 14-1-40, V414192. Head capscrew tightening sequence

5. Lubricate capscrews and washers with Shell Rust Preventive–ENSIS-105 or equivalent.

Caution: Dip capscrews and allow to drain; do not allow rust preventive oil to get into engine.

6. Tighten capscrews slightly in sequence shown in Fig. 14-1-40. Continue tightening in sequence in 100 ft-lb [13.8300 kg m] increments with a torque wrench to 315 to 335 ft-lb [43.5645 to 46.3305 kg m]. Fig. 14-1-41.

7. Place a straight edge on top of, and parallel to, the cylinder head exhaust ports to check port flatness across all six ports with feeler gauge. Variance up to 0.016 inch [0.4064 mm] is acceptable.

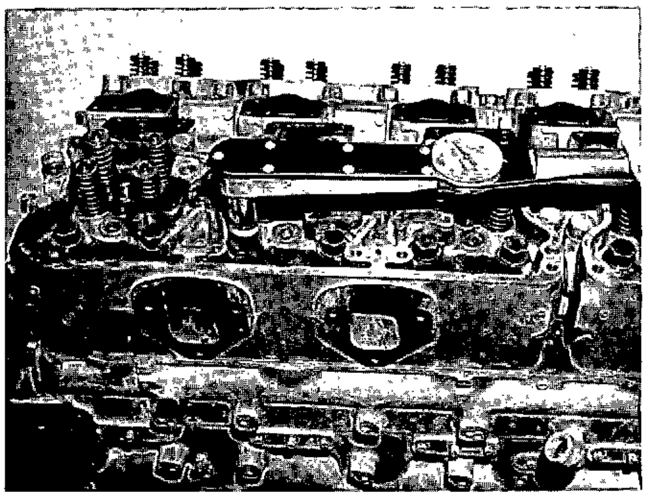


Fig. 14-1-41, V414142. Tightening cylinder head capscrews

Injection Timing

Timing No. 1 cylinder on right bank and on left bank will accomplish complete engine timing. Repeat following steps for each of the two cylinders.

1. Install injector push tubes in their sockets for timing operation.

2. Check No. 1 cylinder on each bank with ST-593 Injector Timing Tool at 19 deg., 12 deg. and 5 deg. Before Top Center firing position.

3. Install timing tool in place of injector with one rod in push tube socket and with other rod resting on piston as shown in Fig. 14-1-42. Follow procedures as shown by diagram, Fig. 14-1-43, and instructions beneath to check injection timing. Numbers on the diagram show check points corresponding to numbered instruction steps.

4. When indicator gauges are set at "O", they must be near fully compressed position. Gauges should have at least 0.250 inch [6.3500 mm] travel range.

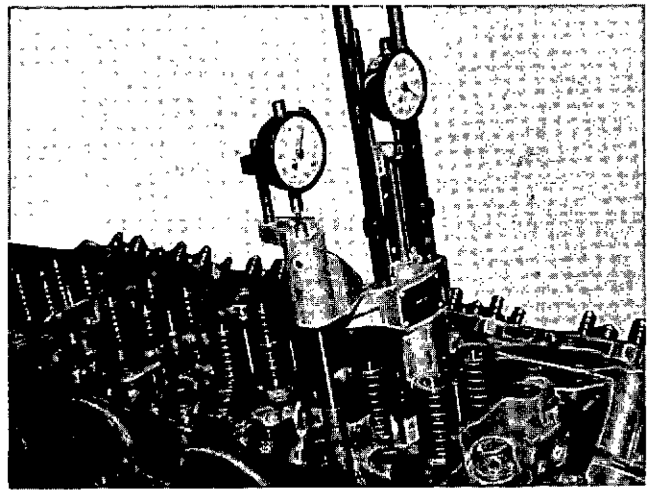


Fig. 14-1-42, V414143. ST-593 Injection Timing Fixture

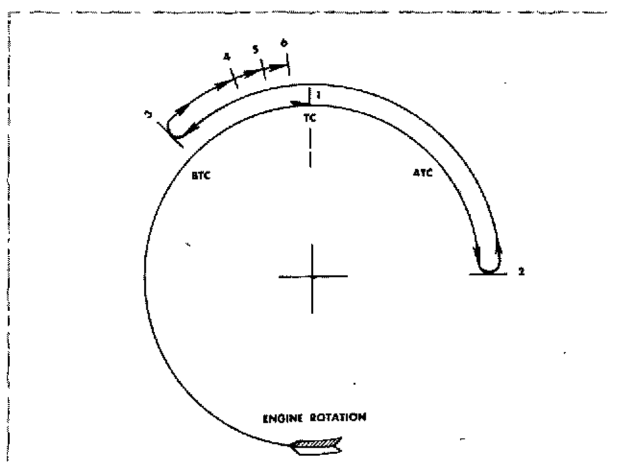


Fig. 14-1-43, V31435. Engine injection timing procedure diagram

5. Engine must be barred accurately to each check point as specified for the gauge above piston.

6. If timing is not within limits, refer to "Cylinder Block Group 1, Unit 110" for instructions for changing key to adjust injection timing.

Note: For each 0.001 inch [0.0254 mm] of key affect, push tube travel will change 0.00012 inch [0.0030 mm].

7. To prevent necessity for removing tappets, remove guide screws and lift tappets with wire hooks so camshafts can be withdrawn.

Injection Timing Procedure (See Fig. 14-1-43)

1. Bar engine in direction of rotation to No. 1 TC (top center) firing position (highest point of piston travel). Set indicator above piston at "O".

2. Advance engine to 90 deg. ATC (after top center). Top of tool rod above piston will be at 90 deg. mark on tool scale. Set indicator above push tube to "O".

3. Bar engine opposite rotation to 45 deg. BTC (before top center). This is to take up gear lash. Top of tool rod will be at 45 deg. mark.

4. Bar engine forward until piston is only 0.2032 inch lower than at top center position which results in a minus reading on indicator (−0.2032 inch). This is 19 deg. BTC. Indicator above push tube should read within fast and slow limits indicated in Table 14-1-3; if reading is outside limits, check camshaft and key combination and change as necessary.

5. Continue to bar engine forward until piston is only 0.0816 inch lower than at top center position. This is 12 deg. BTC; see Table 14-1-3 for push tube indicator reading.

6. Continue to bar engine forward until piston is only 0.0143 inch lower than at top center position. This is 5 deg. BTC; see Table 14-1-3 for push tube indicator reading.

Hand Hole Covers

Assemble hand hole covers to cylinder block in same position as removed. In some cases due to long dipstick or filler tubes it may be more convenient to leave the one hand hole cover off until engine assembly is near completion.

Note: Do not use copper washers with the "Nylock" (nylon insert) self-locking capscrews.

Oil Spray Nozzles

1. On engines equipped with oil-cooled pistons, check nozzle spray holes to make sure they are open.

2. Position "O" ring seal on nozzle; make sure "O" ring is not twisted.

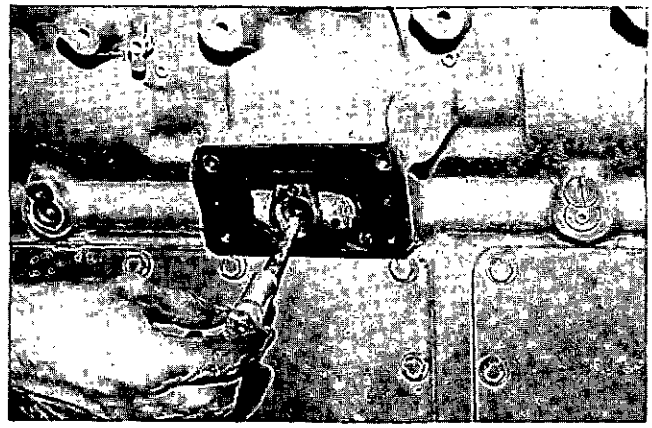


Fig. 14-1-44, V414144. Installing piston cooling nozzles

Table 14-1-3: Injector Timing Specifications

	Crank Angle Degrees	Piston Travel Inches [mm]	Push Tube Travel Inches [mm] Nominal	Fast	Slow
V-1710-500	19 deg. BTC	-0.2032 [-5.1613]	-0.0340 [-0.8636]	-0.0320 [-0.8128]	-0.0360 [-0.9144]
	12 deg. BTC	-0.0816 [-2.0625]	-0.0194 [-0.4928]	-0.0175 [-0.4445]	-0.0213 [-0.5410]
	5 deg. BTC	-0.0143 [-0.3632]	-0.0060 [-0.1524]	-0.0045 [-0.1143]	-0.0075 [-0.1905]
VT-1710-635 VT-1710-700	19 deg. BTC	-0.2032 [-5.1613]	-0.0450 [-1.1430]	-0.0420 [-1.0668]	-0.0470 [-1.1938]
	12 deg. BTC	-0.0816 [-2.0625]	-0.0270 [-0.6858]	-0.0252 [-0.6400]	-0.0292 [-0.7416]
	5 deg. BTC	-0.0143 [-0.3632]	-0.0126 [-0.3200]	-0.0107 [-0.0431]	-0.0145 [-0.3683]
VT-1710-800	19 deg. BTC	-0.2032 [-5.1613]	-0.0525 [-1.3335]	-0.0500 [-1.2700]	-0.0550 [-1.3970]
	12 deg. BTC	-0.0816 [-2.0625]	-0.0343 [-0.8712]	-0.0318 [-0.8077]	-0.0358 [-0.9093]
	5 deg. BTC	-0.0143 [-0.3632]	-0.0192 [-0.4876]	-0.0174 [-0.4419]	-0.0204 [-0.5181]

3. Install nozzles in block and secure each nozzle flange with a flatwasher, lockwasher and capscrews or slotted screw with Nylok insert. Fig. 14-1-44.

4. Torque capscrew to 16 to 21 ft-lb [2.2128 to 2.9043 kg m]. Torque slotted screw with Nylok insert to 5 to 8 ft-lb [0.6915 to 1.1064 kg m].

Note: One nozzle on either side of block is located under a cover plate. Fig. 14-1-44.

Fuel Pump/Accessory Drive

1. Assemble gasket over drive assembly.

2. Bar engine to position No. 1 cylinder at Top Center.

3. Install drive in gear case aligning single "X" on drive gear between double "X" marks on right-bank camshaft gear (1, Fig. 14-1-45). This procedure is necessary to assure proper positioning of external timing marks on water pump drive pulley to show correct injector and valve adjustment position.

4. Secure in place with lockwashers and capscrews. Fig. 14-1-46.

5. Check backlash of gear with dial indicator; backlash new should be 0.003 to 0.010 inch [0.0762 to 0.2540 mm]. Fig. 14-1-47.

6. On occasion it may be necessary to install a drive assembly with gear case cover in place; if so, see Fig. 14-1-48 for timing mark location.

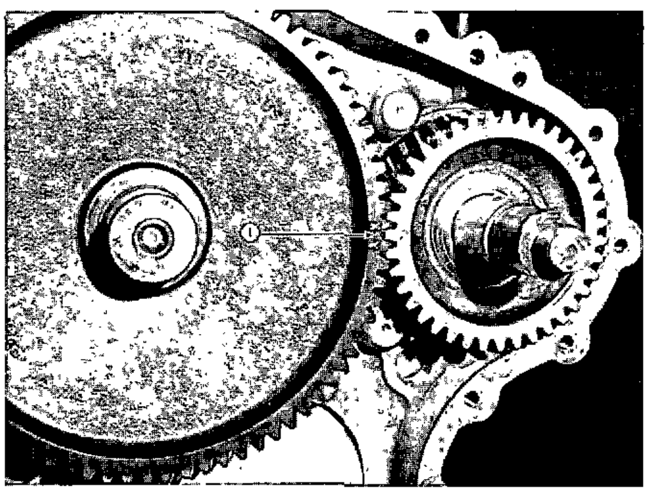


Fig. 14-1-45, V414145. Timing marks alignment

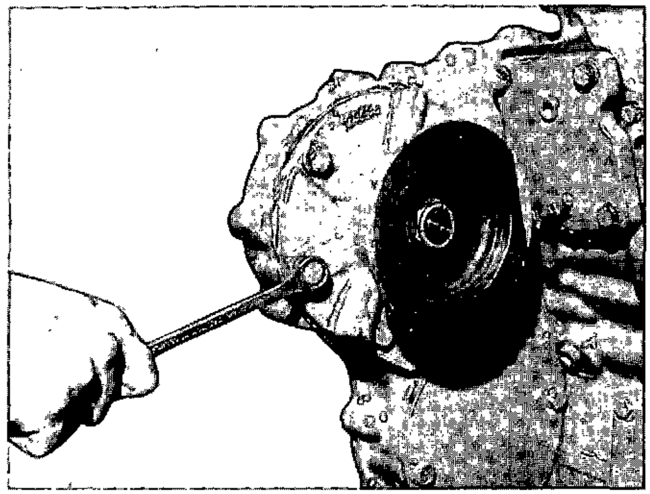


Fig. 14-1-46, V414147. Fuel pump drive mounting

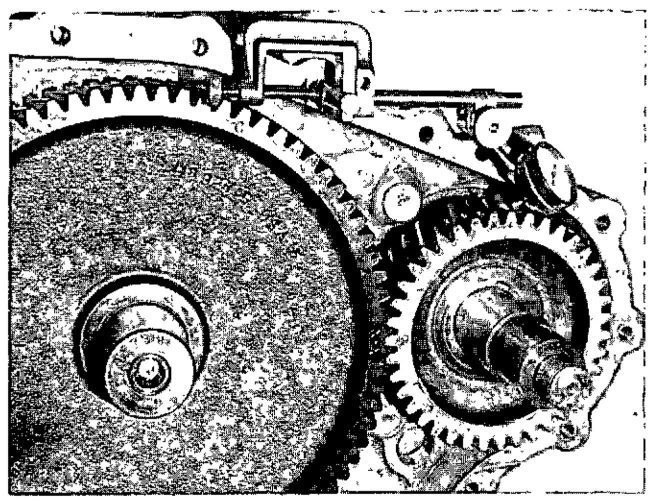


Fig. 14-1-47, V414148. Check drive gear to camshaft gear back lash

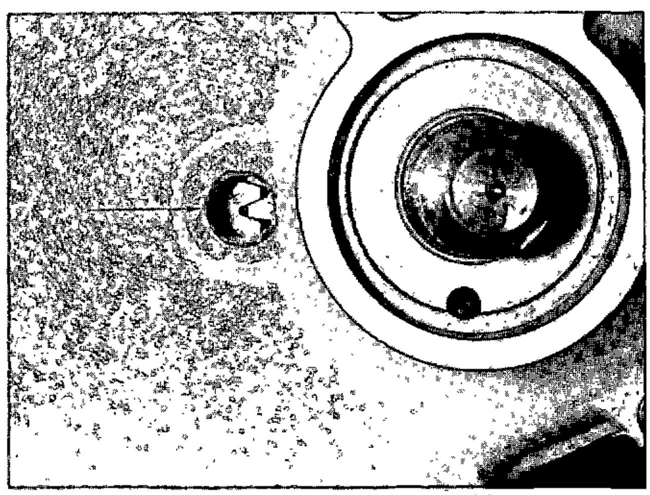


Fig. 14-1-48, V414149. Timing marks location with gear case cover installed

Air Compressor

1. Assemble splined coupling to compressor drive shaft. Fig. 14-1-49.

2. With a new gasket in place, position air compressor coupling to accessory drive shaft; secure compressor to accessory drive housing with lockwashers and capscrews.

3. Connect air and water lines to compressor.

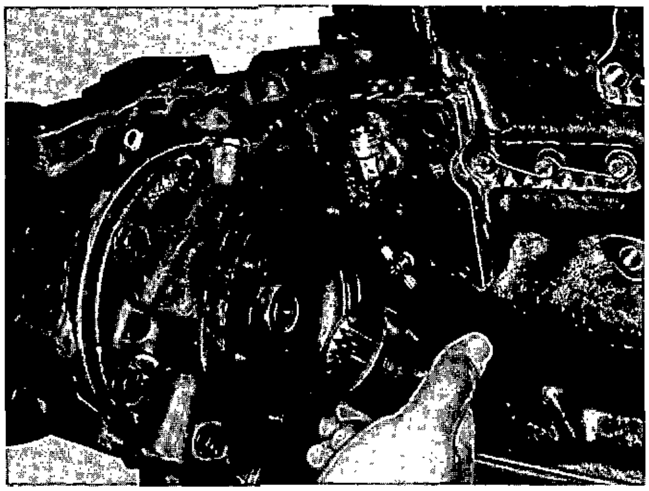


Fig. 14-1-49, V414222. Installing splined coupling

Auxiliary/Generator Drive

Auxiliary drive assemblies differ according to application. On some engines, the unit drives the generator. On other engines, the auxiliary drive may not be used and covers are placed over the auxiliary drive opening.

1. Place new gasket on drive assembly; install assembly in gear case meshing drive gear with left-bank camshaft gear. This gear is not timed.

2. Secure drive with lockwashers and capscrews.

Gear Case Cover

Check Gear Train Timing

1. Before installing gear case cover, check to be sure that all "O's" and "X's" on the gear train are properly indexed. Fig. 14-1-34 and Fig. 14-1-45.

Note: Due to an odd number of teeth in idler gear, timing marks on the gear train will be indexed only once in 86 revolutions.

2. If several engine revolutions were required for injection timing, bar engine in either direction one or two revolutions until teeth marked "OO" on each camshaft gear mesh with unmarked idler gear teeth. The timing mark on camshaft gear will be at top position, and camshaft and fuel pump drive timing marks will be indexed. Next, pull center idler gear and reassemble it with position marked teeth in alignment with timing marks on crankshaft and camshaft gears. Fig. 14-1-34.

Installation, New Gear Case Cover

If a new gear case cover is being installed, it must be doweled to the gear case after it is aligned and the gear case dowel holes are reamed to next oversize.

Note: Check oil hole in generator drive area. Plug hole on units not using generator drive, and be sure it is open when drive units are used.

1. Remove old dowels.

2. Install thrust washers over end of camshaft with oil grooves toward camshaft gear.

3. Screw four guide screws, 3/8–16, 6 inch [152.4000 mm] long into gear case.

4. Coat oil seal lips and O.D. with clean lubricating oil and install in gear case cover.

5. Place gear cover gasket over guide screws and position gear cover over guide screws.

6. Install ST-757 Guide Mandrels through camshaft thrust plate bores and over nose of camshafts. Fig. 14-1-50. The gear case cover may have to be shifted to permit installation of ST-757 Guide Mandrels.

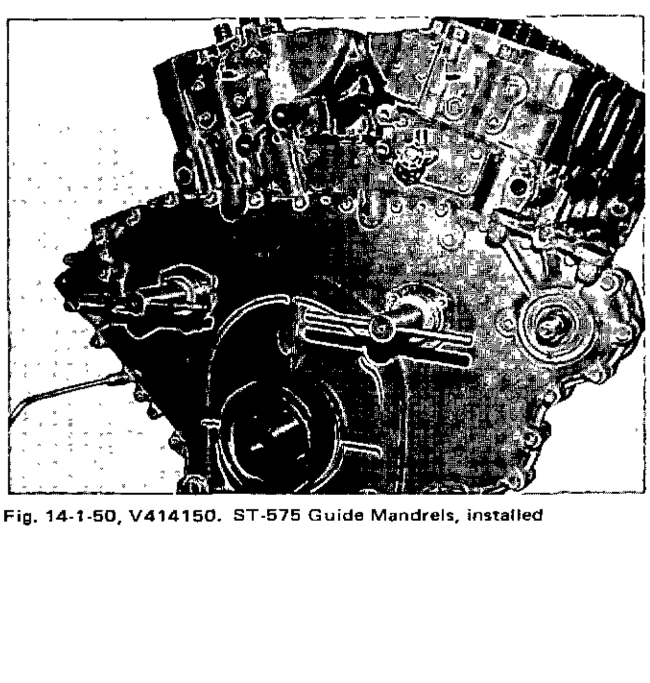


Fig. 14-1-50, V414150. ST-575 Guide Mandrels, installed

7. Secure cover to gear case with lockwashers and capscrews and remove guide screws.

8. Check bottom surface of gear case cover to make certain it is flush with bottom surface of block.

9. Ream dowel holes to next oversize and drive in oversize dowels; remove guide mandrels.

10. Install camshaft thrust plates.

a. Remove "O" ring seal and spacers.

b. Push plate against camshaft so camshaft rests against thrust washer.

c. Measure clearance between thrust plate and gear case cover with feeler gauge. Fig. 14-1-51.

d. Using micrometers, select spacers as necessary to provide 0.010 to 0.015 inch [0.2540 to 0.3810 mm] end clearance.

e. After establishing proper end clearance, install a 1/4 inch pipe plug in end of each camshaft.

f. Install spacers and "O" ring seal; secure thrust plate to gear case cover with lockwashers and capscrews.

11. Install cover plates to gear case cover as necessary; secure with lockwashers and capscrews.

12. If not previously installed, install pipe plug in inspection hole between camshaft thrust plate and fuel pump/compressor drive. Fig. 14-1-48.

13. Install auxiliary drive bearing. Fig. 14-1-52. Use piece of tubing and drive against inner race.

14. Attach bracket to gear case cover, if used.

15. Insert drive pulley key in auxiliary drive shaft and mount pulley with flatwasher and nut, as used. Fig. 14-1-53.

Water Pump Drive Pulley

1. Position slinger over shaft, and through oil seal, seating it against shoulder of shaft.

2. Insert drive key in shaft slot.

3. Install water pump drive pulley and press in position with ST-386. Fig. 14-1-54.

4. Install washer and self-locking nut; torque to 90 to 110 ft-lb [12.4470 to 15.2130 kg m]. Fig. 14-1-55.

Compression Release Shafts and Push Tubes

1. Install longest shaft in right bank.

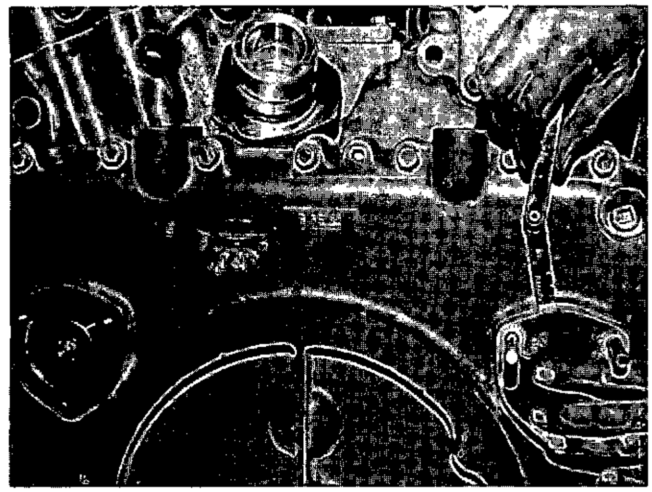


Fig. 14-1-51, V414151. Checking camshaft thrust plate clearance

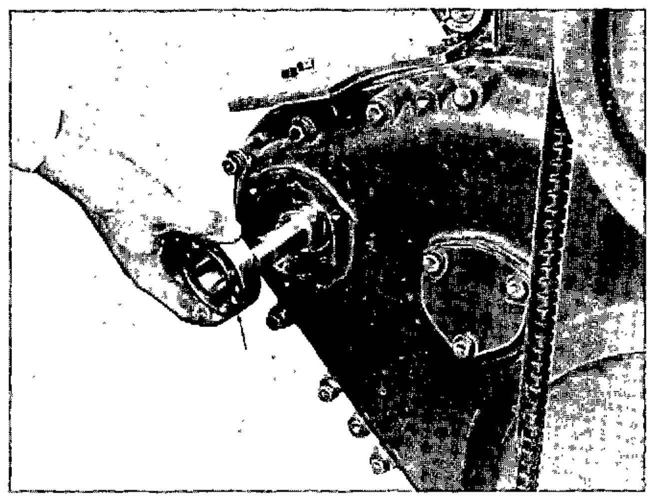


Fig. 14-1-52, V414152. Install auxiliary drive bearing

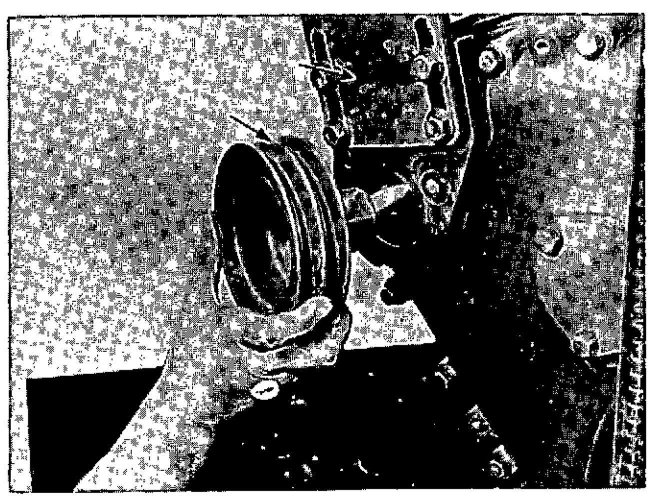


Fig. 14-1-53, V4141b3. Install auxiliary drive pulley

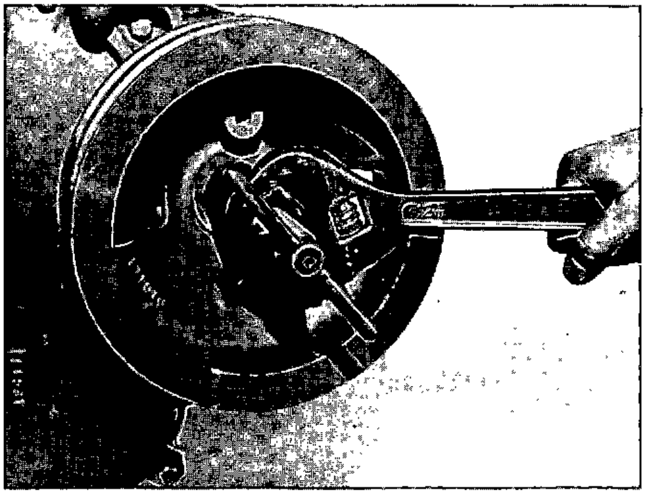


Fig. 14-1-54, V414154. Installing water pump drive pulley

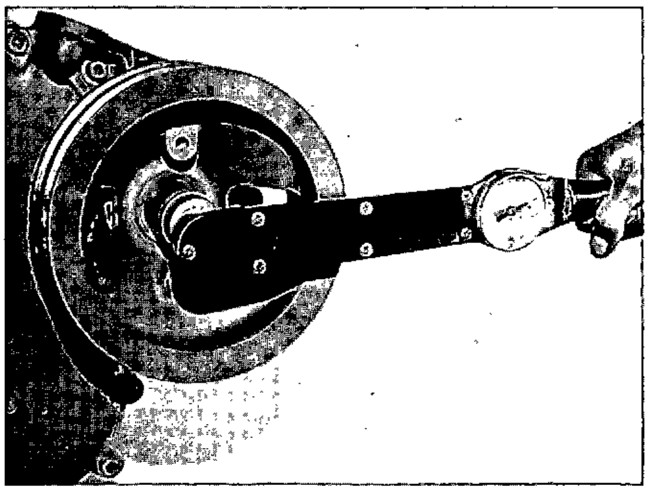


Fig. 14-1-55, V414155. Torquing pulley self locking nut

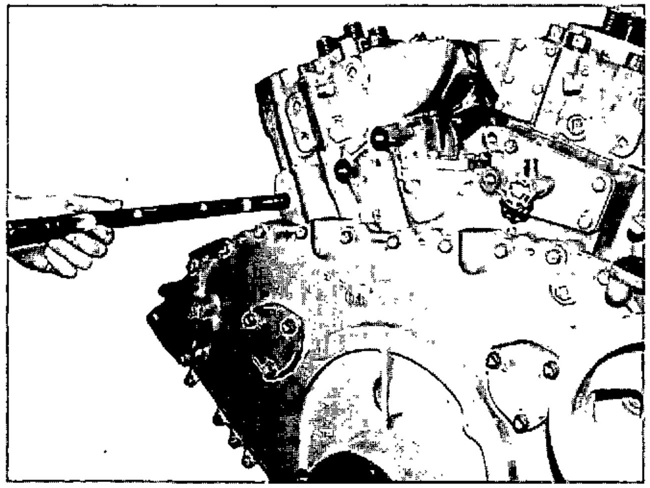


Fig. 14-1-56, V414156. Installing compression release shaft

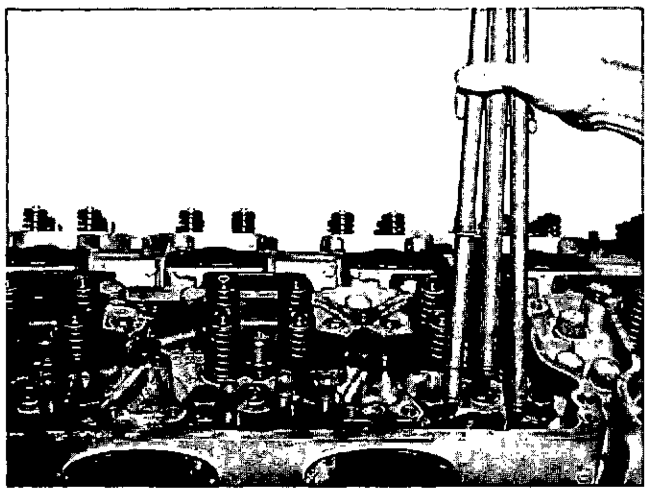


Fig. 14-1-57, V41499. Installing push tubes

2. Position shafts with locking groove to rear of cylinder block. Fig. 14-1-56. Insert shaft and push through block until it protrudes from rear. Install "O" ring seal and push shaft toward front. Install "O" ring over shaft at front of block.

3. Lock shafts in place with copper washers and capscrews.

4. Insert push tubes in their respective tappets, there must be 0.060" [1.5240 mm] clearance between the lever and socket. The largest one in the center is for the injector. Tubes with lift collars are for intake valves. Fig. 14-1-57.

Water Pump

1. Position water pump assembly atop gear case cover and secure in position with lockwashers and capscrews.

2. Position red engine timing "arrow" on water pump outside front capscrew on line parallel to center line of crankshaft.

3. Install drive belts; install front pulley sheave.

Note: Always use new belts in pairs on two-groove pulleys.

4. Adjust belt tension by turning pulley sheaves. Fig. 14-1-58. See "Belt Adjustment" at end of this section.

5. Lock sheaves in place with Nylok capscrews torqued to 17 ft-lb [2.3511 kg m].

Injectors

1. Clean injector sleeve with cloth wrapped around wooden stick.

2. Lubricate the injector body "O" rings with clean engine lubricating oil.

Note: New "O" rings should be seated in groove in injector body.

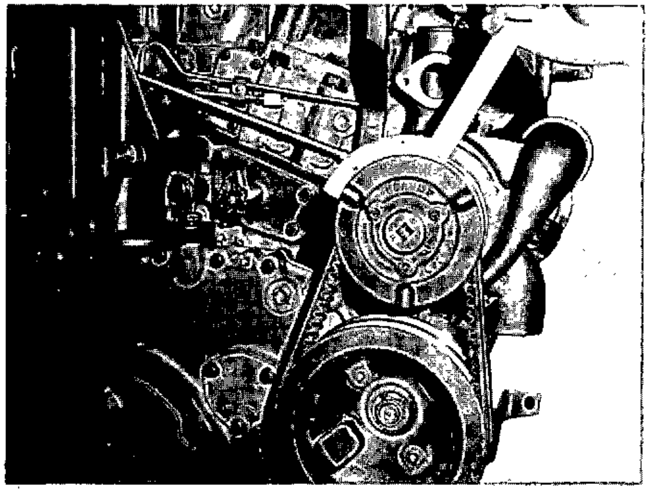


Fig. 14-1-58, V41457. Adjusting belt tension

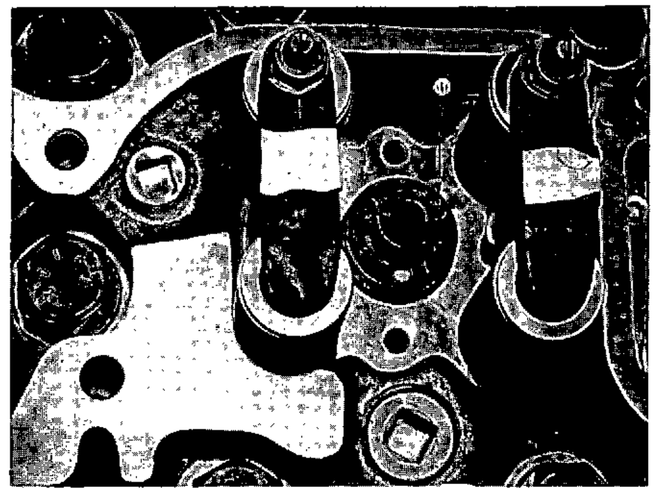


Fig. 14-1-59, V414158. Installing cylindrical injector

3. Start the injector into bore; guide by hand until injector is aligned in bore and not binding in any manner.

Note: Installation—looking at the engine from the side, injectors are to be placed with ball check retainer plug (1, Fig. 14-1-59) at one o'clock. To further clarify the statement of which side, when installing the left bank, stand on that side and when installing the right bank, stand on that side. The ball check retainer plug would always be at one o'clock.

4. Place hammer handle butt on top of injector plunger guide and "seat" injector by giving a quick, hard push on the hammer. A "snap" should be heard and felt as the cup seats in the sleeve.

5. Place hold-down plate over injector body with counterbore up; position half-collet locking clamp in injector body groove. Fig. 14-1-60. Start hold-down capscrews. Do not tighten.

Note: Be sure the two projecting radii do not drop in drilled holes atop injector.

6. Place injector spring on hold-down plate with closed end down.

Caution: Spring must seat on hold-down plate. If spring sits on locking clamp, incorrect injector adjustment will result, causing push tube and camshaft damage.

7. Holding injector spring in position, carefully insert injector plunger. Fig. 14-1-60.

Note: Position plunger in injector bore with class mark on the plunger midway between inlet and drain ports of injector (the inlet port is below the ball retainer plug). This will provide the same operating position in which the injector was calibrated.

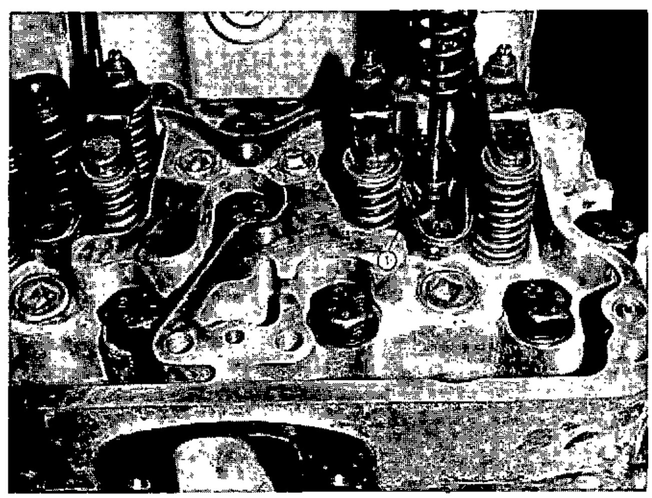


Fig. 14-1-60, V414159. Seating spring around locking clamp

8. Torque procedure for injector hold-down capscrews — make sure injector is positioned correctly in head. Tighten one capscrew until clamp contacts head snugly; then back out one complete turn. Torque hold-down capscrews alternately of the PT (type.D) injectors and all others with Letter A or B stamped after class mark to 11 to 12 ft-lb [1.5213 to 1.6596 kg m] in 4 ft-lb [0.5532 kg m] increments. Fig. 14-1-61.

Water Manifold (with dry exhaust)

1. Install sealing "O" rings to heads.

2. Install front section to manifold, secure with capscrews and lockwashers.

3. With "O" ring in position, lubricate "O" rings on

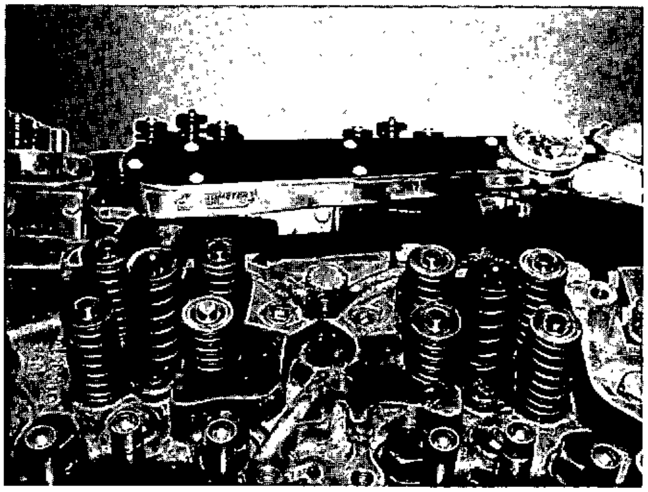


Fig. 14-1-61, V414160. Tighten injector mounting capscrews

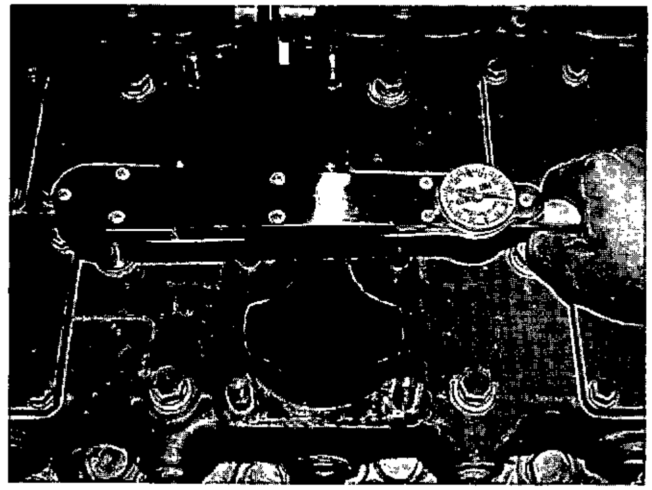


Fig. 14-1-62, V414161. Installing exhaust manifold

connection and slip connection into front section.

4. Install rear section of manifold over other end of connection and to head; secure with capscrews and lockwashers.

5. Repeat steps 1, 2, 3 and 4 on remaining manifold.

6. Install clamps and heat shields to manifold connections; secure with bolts and nuts. Be sure heat shield is in position to protect "O" rings from exhaust manifold temperatures.

Exhaust Manifold (dry type)

1. Place gaskets on head.

2. Install front section of manifold to head; secure with flatwashers, lockwashers and capscrews.

3. Install expander connections to manifold; secure with clamps, bolts and nuts.

4. Install center section of manifold to head and expander connection. Secure to head with flatwasher, lockwashers and capscrews. Secure manifold and expander connection with bolts and nuts.

5. Install expander connection to open end of manifold; secure with clamps, bolts and nuts.

6. Install rear section of manifold to head and expander connection; secure to head with flatwashers, lockwasher and capscrews. Secure manifold and expander connection with clamps, bolts and nuts.

7. Install lifting brackets with spacers in position on center exhaust ports; secure (do not tighten) with capscrews, lockwashers and flatwashers.

8. Torque manifold capscrews 55 to 65 ft-lb [7.6065 to 8.9895 kg m].

9. Torque bolts and nuts securing clamps 15 to 20 ft-lb [2.0745 to 2.3511 kg m].

Exhaust Manifolds and Lifting Eyes (water cooled)

1. If studs were removed they must be installed as follows: eight 6 15/16 inch [171.9375 mm] long for lifting bracket; four 6 3/8 inch [161.9250 mm] long for turbocharger mounting.

2. Assemble new gaskets and exhaust manifolds over studs to cylinder heads.

3. Install two engine lifting eyes on exhaust manifold studs provided; secure with lockwashers and stud nuts.

4. Secure exhaust manifold to heads with lockwashers, stud nuts and capscrews with lockwashers.

5. Start in the center of the manifold and run the mounting capscrews and stud nuts down.

6. Tighten the capscrews and stud nuts alternately 65 to 70 ft-lb [8.9895 to 9.3810 kg m].

7. After engine run-in exhaust manifold studs or capscrews should be retorqued.

Thermostats and Housings

1. Normally, thermostats are mounted at the gear case end of each water-cooled exhaust manifold.

2. Install large half of thermostat housing on the exhaust manifold using a new gasket.

3. Place a new gasket on the remaining half of the thermostat housing and install the thermostat with "V" notch at top to vent as much air as possible.

Note: Failure to do so may result in air lock and incomplete coolant circulation.

4. Install thermostat housing and secure with lockwashers and capscrews. Fig. 14-1-63. Torque to 45 to 55 ft-lb [6.2235 to 7.6065 kg m].

5. When cooling system is filled, make sure drain cock in top of thermostat housing is open to bleed out any air.

Note: Some engine applications have the thermostat mounted in auxiliary oil cooler cover.

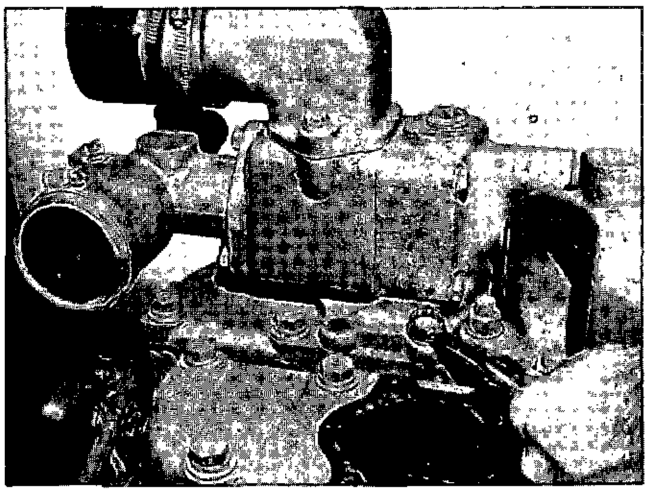


Fig. 14-1-63, V40053. Installing thermostat and housing

Fuel Tubing

1. Install fittings in lower (fuel inlet) drilling at end of each cylinder head. Fig. 14-1-64. Lines illustrated are:

a. Fuel inlet from filter (1).

b. Fuel pump outlet (2).

c. Fuel supply lines (3).

d. Fuel drain lines (6).

e. Fuel return to tank (7).

f. Injector inlet (4) and drain (5) are drilled passages in cylinder head.

2. Install fuel supply crossover between each pair of cylinder heads.

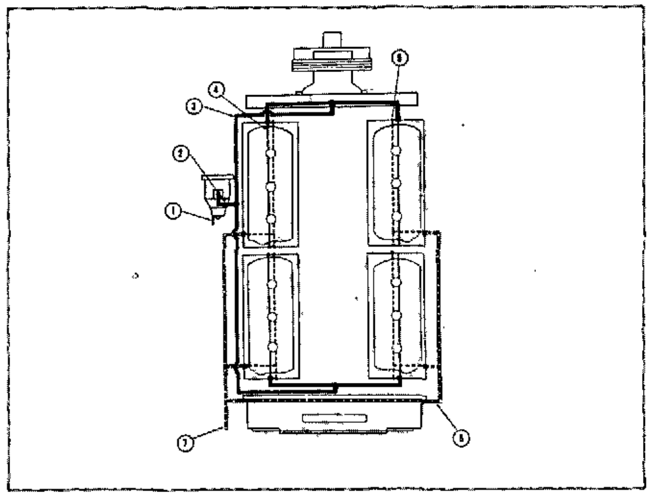


Fig. 14-1-64, V40047, Fuel lines and passages

3. Connect fuel supply tubing to each crossover.

4. Install drain fittings in side of each cylinder head. Fig. 14-1-64.

5. Install drain tubing on fittings on either side of engine; *connect drain tubing with drain crossover.*

Rocker Arm Housing

1. Check breather hole in rocker arm housing. Plug hole with 1/8 inch pipe plug on all turbocharged engines and install ventilator plug on naturally aspirated engines.

2. Check to see that oil restrictor plug in top head surface is flush or below (1, Fig. 14-1-65).

3. Install "O" ring seal (2) around restrictor plug.

4. Position all crossheads over valves so adjusting screw is over valve in exhaust side of cylinder head. Fig. 14-1-66.

5. Hold crosshead so it is seated on valve opposite adjusting screw and straight in guide. Fig. 14-1-66.

6. Adjust screw so it contacts valve stem, advance 20 deg and lock with nut.

Note: On worn crosshead and guide it may be necessary to advance 30 deg to straighten crosshead in guide.

7. Hold adjusting screw in position and tighten nut with torque wrench to 25 to 35 ft-lb [3.4575 to 4.1490 kg m].

8. Using a wire gauge check to make sure there is a minimum of 0.025 inch, [0.6350 mm] clearance between crosshead and valve spring retainer. Fig. 14-1-67.

9. Install rocker arm housing gaskets.

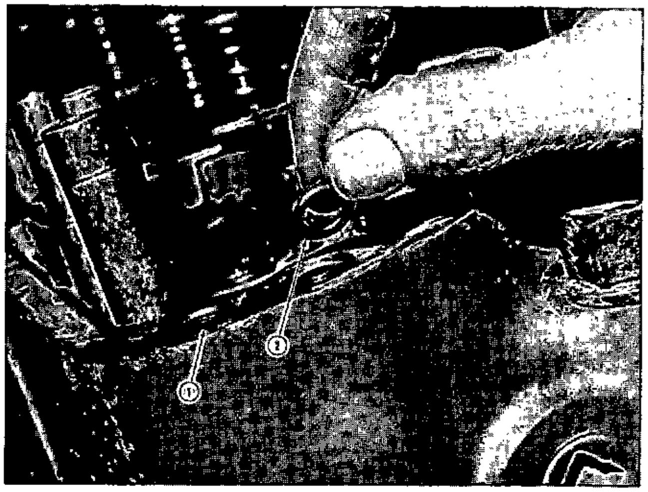


Fig. 14-1-65, V414162. Oil restrictor plug and "O" ring

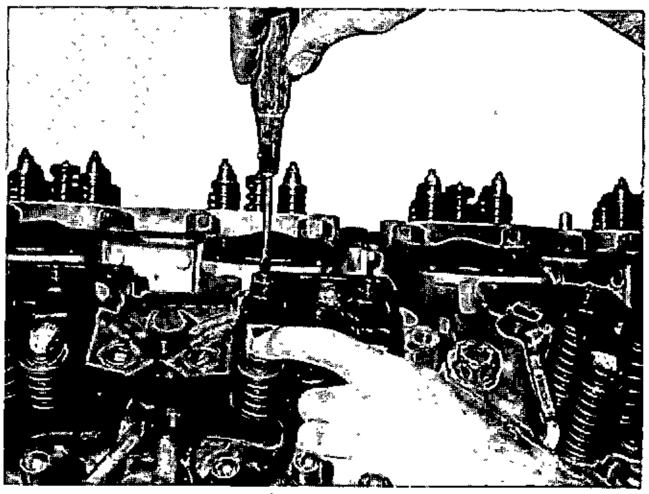


Fig. 14-1-66, V414163. Adjusting valve crosshead screw

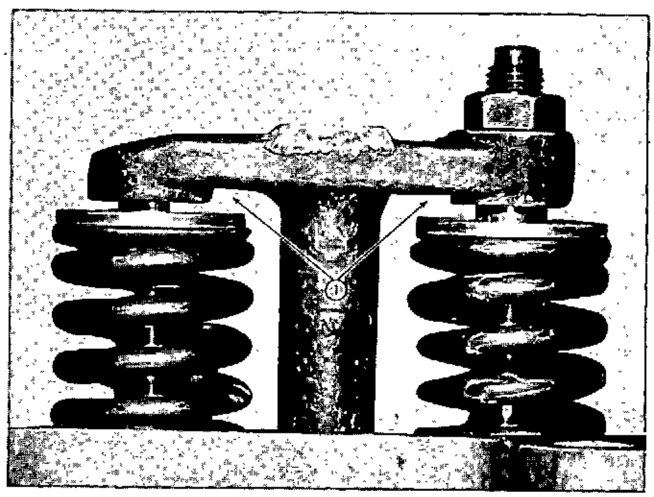


Fig. 14-1-67, V414208. Crosshead to valve spring retainer clearance

10. Carefully lower each rocker arm housing into position.

11. Loosen all rocker lever adjusting screws and place each rocker lever ball end into its correct position in push tube socket.

12. Use a flashlight and check all push tubes in their sockets—at tappet and at rocker lever—to see that they are properly seated.

13. Install capscrews; tighten rocker housing capscrews in sequence shown in Fig. 14-1-68 to 55 to 65 ft-lb [7.6065 to 8.895 kg m] with a torque wrench. Fig. 14-1-69.

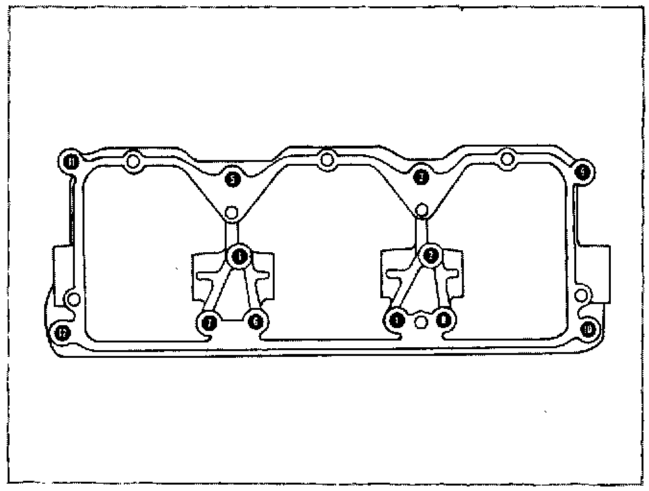


Fig. 14-1-68, V41451. Rocker housing capscrew torquing sequence

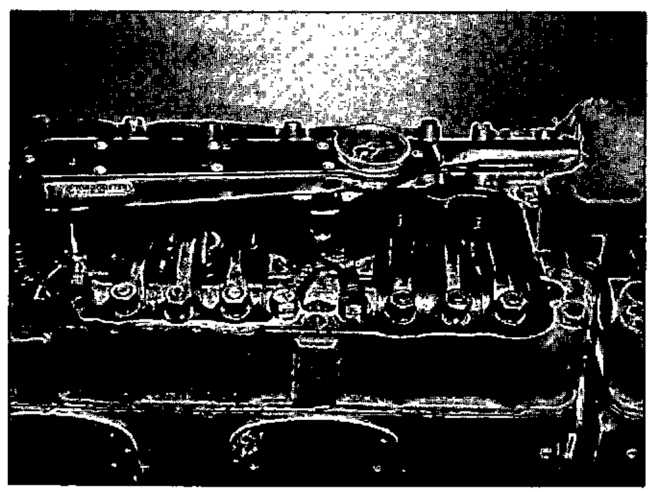


Fig. 14-1-69, V414164. Torquing rocker housing capscrews

Caution: Overtightening may cause cracking of rocker housing.

Fan Bracket

Install fan bracket assembly to protruding bosses on front of cylinder block and gear case; secure with lockwashers and capscrews.

Compression Release Lever

1. Assemble bell crank to fan bracket, if used.

2. Assemble compression release levers loosely to their shafts. Assemble adjustable links to levers and bell crank. With proper thread engagement, both levers and bell crank will be in parallel positions.

3. While holding right lever midway between its stops, turn right-bank compression release lever clockwise with a screwdriver until lifting notch contacts an intake valve push tube collar. Tighten locking screws on right lever. Fig. 14-1-70.

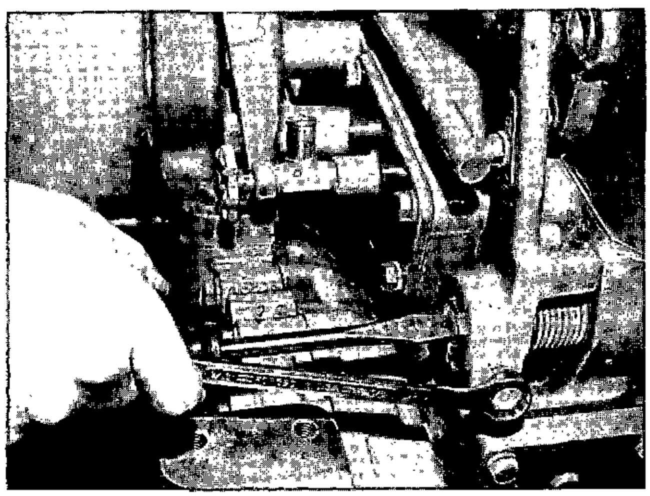


Fig. 14-1-70, V414165. Adjusting compression release lever

4. With right-bank shaft still in contact with a push tube collar, turn left compression release shaft counterclockwise until it contacts a push tube collar. Tighten lockscrew.

Note: When properly adjusted, both compression release shafts will open intake valves at the same time and maximum valve lift will be approximately 1/16 inch [1.5875 mm].

5. Install return spring to right-bank lever and to cylinder head.

Water By-Pass Connections

Install water by-pass connections from thermostat housings to water pump as applicable.

Crankshaft Oil Seal

ST-1164 Sleeve and Seal Driver, Fig. 14-1-71, is used to drive the wear sleeve onto the nose of the V-1710 crankshaft and to drive the seal into the gear cover.

Sleeve Assembly Procedure

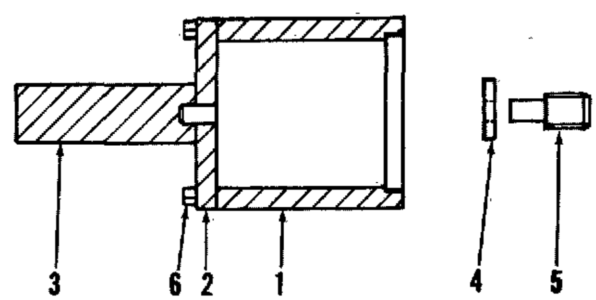
1. Turn the threaded pilot, ST-1164-5, into hole in nose of crankshaft until all threads on pilot are engaged.

2. Place steel sleeve, Part No. 202975, into counterbore in ST-1164 driver with chamfered inside diameter out or toward crankshaft.

3. Place ST-1164 Tool over nose of crankshaft, making sure pilot enters guide hole in handle.

4. Drive sleeve on until driver bottoms against crankshaft.

5. Remove driver.



Part No.	Description	Qty.
ST-1164-1	Driving Ring	1
ST-1164-2	Plate	1
ST-1164-3	Handle	1
ST-1164-4	Spacer	1
ST-1164-5	Pilot	1
ST-1164-6	Socket Head	6

Fig. 14-1-71, V414223. ST-1164 Cross-section and assembly

Seal Assembly Procedure

1. The steel sleeve must always be on the crankshaft before assembling the seal, if seal is to be assembled after gear cover has been mounted.

2. Place ST-1164-4 Spacer over pilot in nose of crankshaft.

3. Lubricate seal and seal lips with clean engine lubricating oil.

4. Place seal over crankshaft nose making sure dust lip is away from engine.

5. Drive seal into gear cover until driver bottoms on spacer.

6. Remove driver, spacer and pilot.

Vibration Damper, Flange and Fan Drive Pulley

Vibration Damper Flange

The vibration damper flange and fan drive pulley are made as a single unit.

Note: Lubricate crankshaft nose in flange area with P-10 lubricant.

1. Install flange unit on crankshaft as far as possible.

2. Secure with washer and Nylok capscrew; torque to 450 to 500 ft. lbs. [62.2350 to 69.1500 kg m]. Fig. 14-1-72.

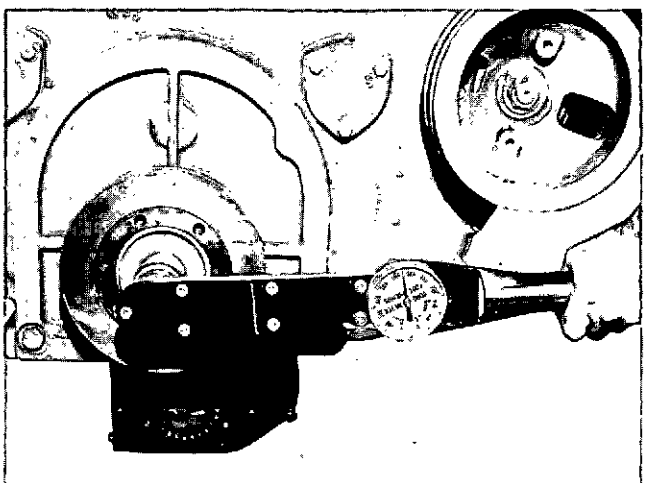


Fig. 14-1-72, V414167. Tighten flange to crankshaft capscrew

Vibration Damper

1. Position spacer (if used) to fan drive pulley, install and tighten capscrews to 60 to 70 ft-lb [8.2980 to 9.6810 kg m]. Fig. 14-1-73.

2. Install vibration damper and fasten securely with capscrews. Fig. 14-1-74. Torque capscrews to 70 to 80 ft-lb [9.6810 to 11.0640 kg m]; Fig. 14-1-75. Lock capscrews in position with lockwire if used.

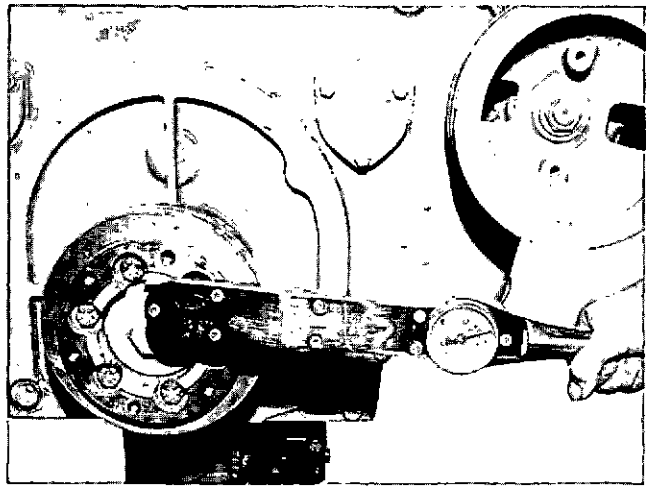


Fig. 14-1-73, V414168. Tighten spacer capscrews

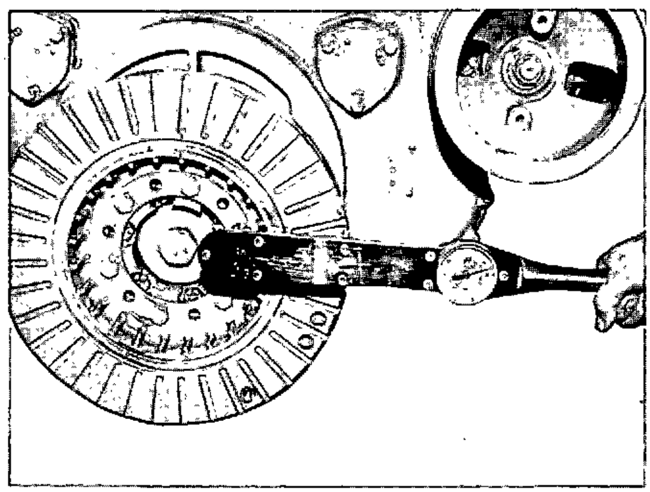


Fig. 14-1-74, V414169. Installing vibration damper

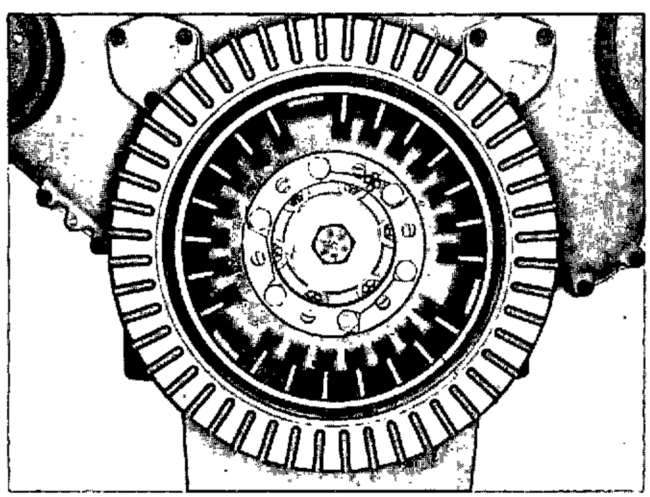


Fig. 14-1-75, V414224. Vibration damper with lockwires installed

3. With a dial gauge mounted to gear case cover and arm resting on the inner machined surface of outer member, check vibration damper eccentricity and wobble at points (1) and (2) as shown in Fig. 14-1-76. Run-out must not exceed values shown in Table 14-1-4.

Note: Crankshaft must be kept to front or rear limit of thrust clearance while wobble is being checked.

Caution: Do not pry against or strike damper.

4. When an accessory drive pulley is mounted in front of vibration damper, pulley must also be checked at points (1) and (2) as shown in Fig. 14-1-76. Readings taken with a dial gauge mounted to gear case cover must not exceed values shown in Table 14-1-4.

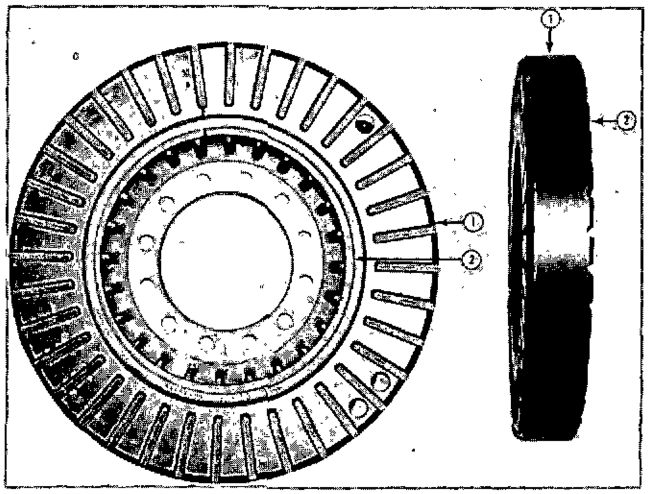


Fig. 14-1-76, V414199. Vibration damper eccentricity and wobble check points

Table 14-1-4: Vibration Damper Data

Serial Suffix	Part No.	Eccentricity Inch [mm]	Wobble Inch [mm]
None, 2	139589	0.030 [0.7620]	0.030 [0.7620]
None, 2	145790	0.030 [0.7620]	0.030 [0.7620]
None, 2	152741	0.030 [0.7620]	0.030 [0.7620]
3	193552	0.030 [0.7620]	0.030 [0.7620]
3	193553	0.030 [0.7620]	0.030 [0.7620]
3	193554	0.030 [0.7620]	0.030 [0.7620]

Note: Number "3" may appear as reference number on nameplate.

Fan Hub and Pulley

1. Assemble fan hub to fan bracket as shown in Fig. 14-1-77.

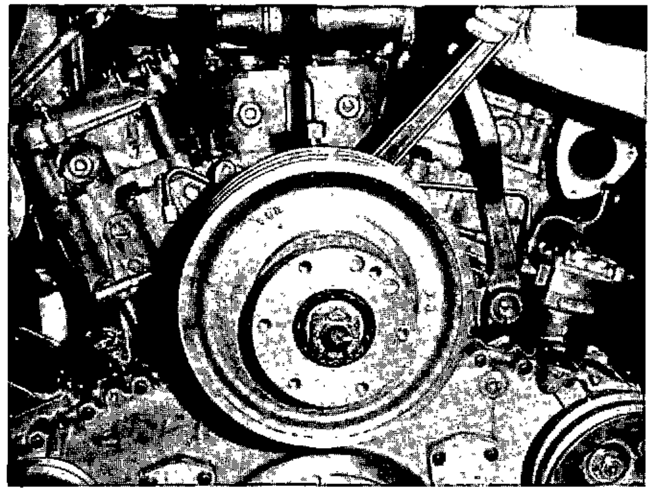


Fig. 14-1-77, V414205. Installing fan hub and pulley

2. Install large spacer and nut on fan hub shaft.

3. Tighten fan hub shaft bracket nut hand tight.

4. Tension fan hub belts correctly as noted at the end of this section.

5. Torque bracket nut to 50 ft-lbs [6.9150 kg m]. Mark corner of the nut and turn one full hex or 60 to 70 deg.

6. Recheck belt tension.

Fan Pilot

A flange on mounting surface of fan pilot fits tightly into bore of fan hub.

1. Check fan hub for lubrication. Bearings should be packed and housing filled 50% to 60% full — but not under pressure — with grease meeting specifications outlined in Group 18.

Caution: Do not leave grease fittings in fan hub or grease will be thrown out during rotation; fill, then install pipe plugs.

2. Secure pilot to fan hub with lockwashers and capscrews.

Intake Manifold

1. Install new gaskets and assemble intake manifold over guide pins to each side of engine; secure with lockwashers and capscrews. Fig. 14-1-78.

2. If end plates have been removed from intake manifolds, install new gaskets and reassemble plates to manifolds.

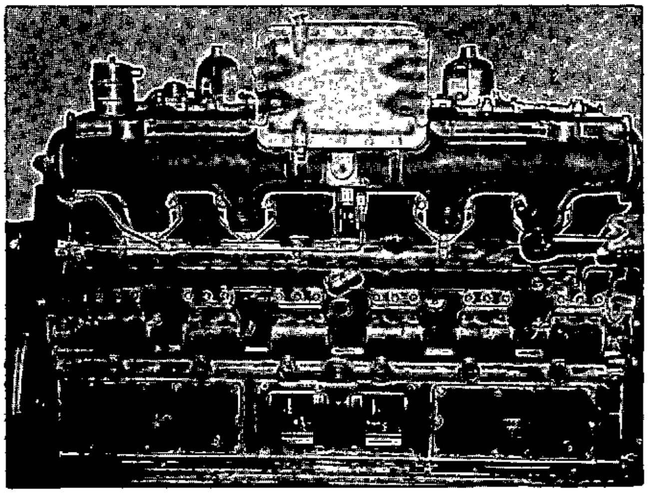


Fig. 14-1-78, V414170. Installing air intake manifold

Note: Many variations of end plates are used; some may be cover plates while others are extended for use as mounting brackets for accessory items. Others mount the intake manifold air balance tube used with turbocharger applications.

Cummins or Bendix-Westinghouse, Coupling Driven

1. Assemble splined coupling to compressor shaft.

2. With a new gasket in place, position coupling over fuel pump/compressor drive shaft; secure compressor to drive housing with lockwashers and capscrews. Fig. 14-1-79.

3. Connect all air and water lines to compressor.

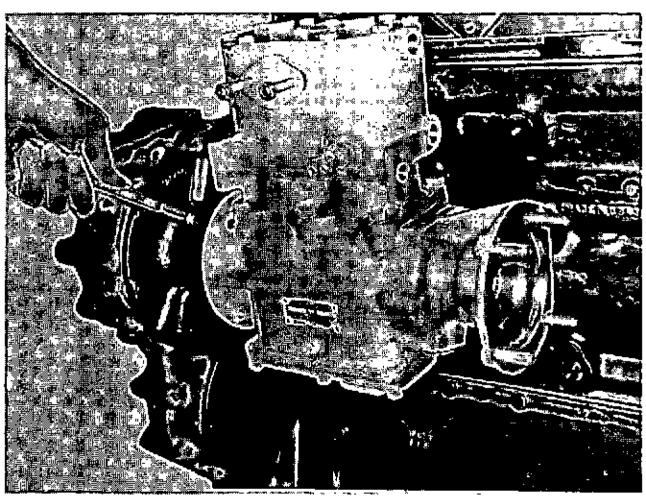


Fig. 14-1-79, V414212. Installing Bendix-Westinghouse compressor

Fuel Pump

1. Install fuel pump to fuel pump drive or air compressor with new gasket and rubber buffer or splined coupling in position. Fig. 14-1-80. Place flatwashers, lockwashers and nuts over studs, or lockwashers and capscrews and tighten.

2. Install line from pump solenoid to fuel supply tubing.

Fuel Filter

1. Position mounting bracket at desired location on block; secure with lockwashers and capscrews. Fig. 14-1-81.

2. Position filter head to mounting bracket; secure with lockwashers and capscrews.

3. Connect fuel outlet hose to fuel pump inlet.

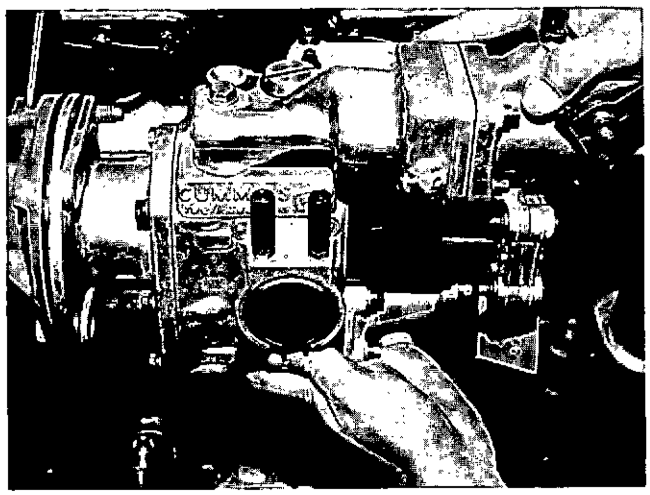


Fig. 14-1-80, V414196. Installing flange mounted fuel pump

Fig. 14-1-81, V40041. Throw-away-type fuel filter

4. Install fuel filter element to fuel filter head.

a. Throw-away-type: Fill new element with clean fuel and install element; tighten by hand until seal touches filter head; tighten an additional 1/2 to 3/4 turn.

b. Replaceable-element type, Fig. 14-1-82. Install a new gasket in filter head and assemble case and element. Tighten center capscrew to 20 to 25 ft-lb [2.7660 to 3.4575 kg m] with torque wrench. Fill filter case with clean fuel to aid in faster pick-up of fuel.

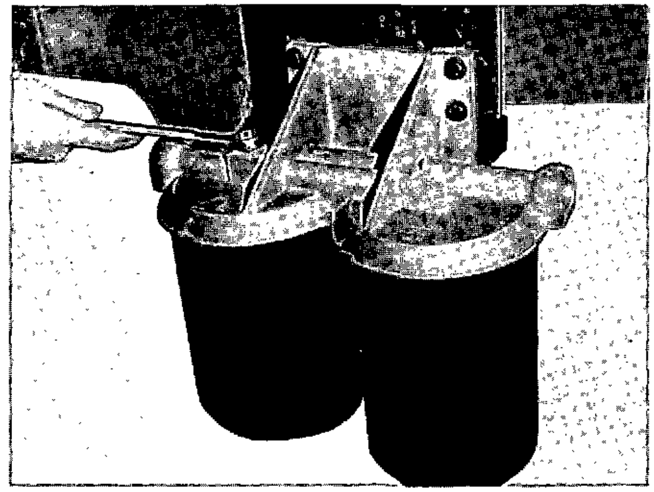


Fig. 14-1-82, V40085. Replaceable-element-type filter

Flywheel Housing

1. Clean mating surfaces of flywheel housing and cylinder block of all dirt and burrs.

2. Install flywheel housing-to-camshaft oil seals to flywheel housing using gasket cement. Fig. 14-1-83.

3. Assemble rubber packing ring to rear cover plate and coat with cup grease, if wet-type clutch is used only. Fig. 14-1-10.

4. Inspect dowels and remove if they show evidence of wear or shearing caused by previous operation.

Note: Where a new flywheel housing is being installed, the old dowels must be removed and housing properly located.

5. Screw two guide screws or studs into cylinder block and slide flywheel housing over them. Snug tighten in place with lockwashers and capscrews.

Fig. 14-1-83, V414171. Install camshaft bore seal to flywheel housing

Indicate Housing Bore

1. Fasten indicator to crankshaft flange as shown in Fig. 14-1-84 and rotate shaft to indicate bore of housing.

2. If total indicator reading exceeds 0.010 inch [0.2540 mm], remove flywheel housing and pull dowels, unless they were previously removed. Loosen capscrews just enough to allow housing to be shifted. Use a soft hammer to shift housing to obtain proper indicator reading. The reading at points A and A1 should agree and readings at points B and B1 should agree. Total runout must not exceed 0.010 inch [0.2540 mm].

3. After these readings are obtained, tighten all capscrews alternately, a little at a time, and recheck.

Caution: Be sure all capscrews are tight. Torque to 159 to 163 ft-lb [21.9897 to 22.5429 kg m].

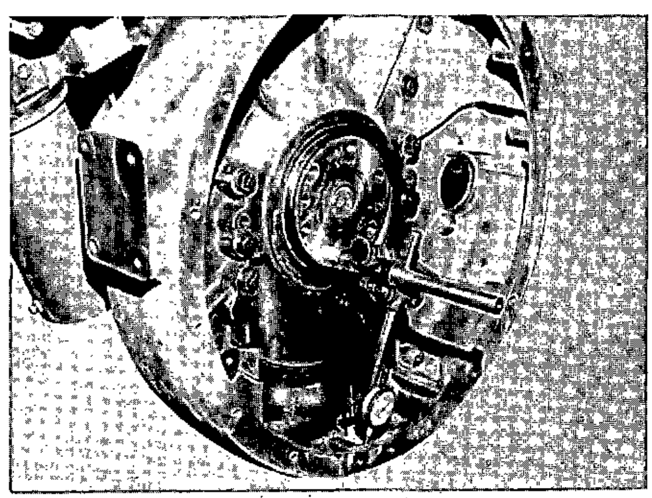


Fig. 14-1-84, V414172. Indicating flywheel housing bore

Indicate Housing Face

1. Shift gauge to indicate housing face. See Fig. 14-1-85. Turn crankshaft to get readings at various points on face of housing. Each time before reading, use a pry bar between a

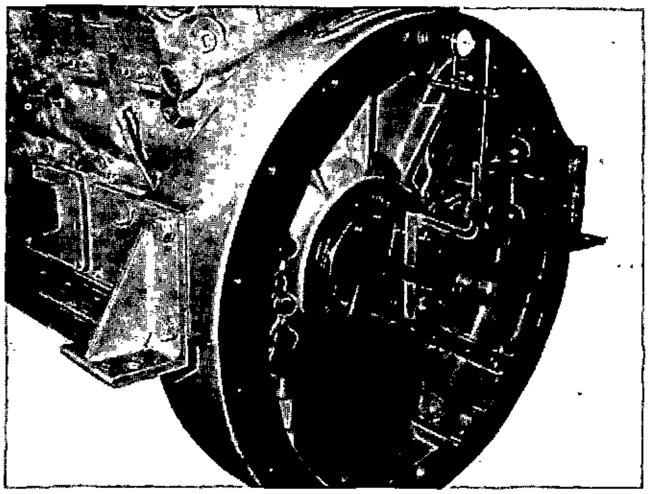


Fig. 14-1-85, V414173. Indicating flywheel housing face

main bearing cap and crankshaft throw to take up crankshaft end clearance in the same direction each time. The readings taken at various points must not vary more than 0.010 inch [0.2540 mm] total indicator readings.

Caution: Do not pry against vibration damper.

2. If dowels were removed, ream dowel holes in housing and block to nearest oversize, and drive in oversize dowels. Use ST-497 Reaming Jig to drill and ream dowel holes. Fig. 14-1-86.

Rear Cover—Piston Ring Seal Type

The silicone seal rear cover was installed previously. The piston ring seal rear cover must be installed before the flywheel but after the flywheel housing.

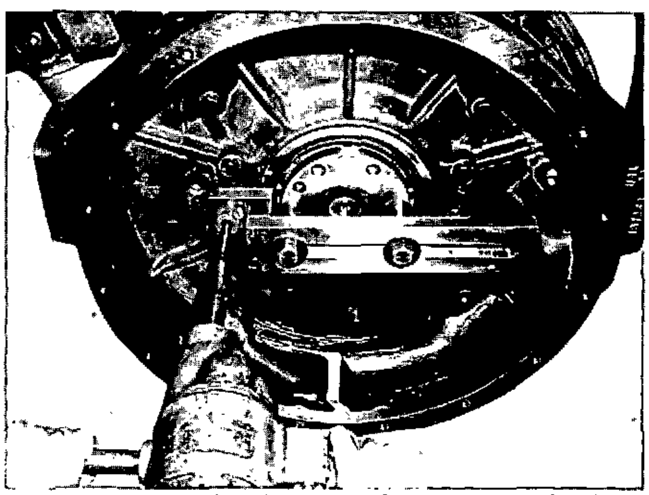


Fig. 14-1-86, V414204. Drill and ream flywheel housing dowel holes

Assembly

The rear seal assembly is a spring-loaded piston ring oil seal using the slinger with four seal rings and two back-up springs.

The sealing ring is marked with yellow dots on one face.

Assemble to slinger as follows:

1. Slide one ring (2, Fig. 14-1-87) into slinger groove so yellow dot on ring is against groove wall.

2. Put on back-up spring (3).

3. Slide second ring into slinger groove so yellow dot on ring is against opposite groove wall (1).

4. Repeat Steps 1, 2 and 3 for second slinger groove.

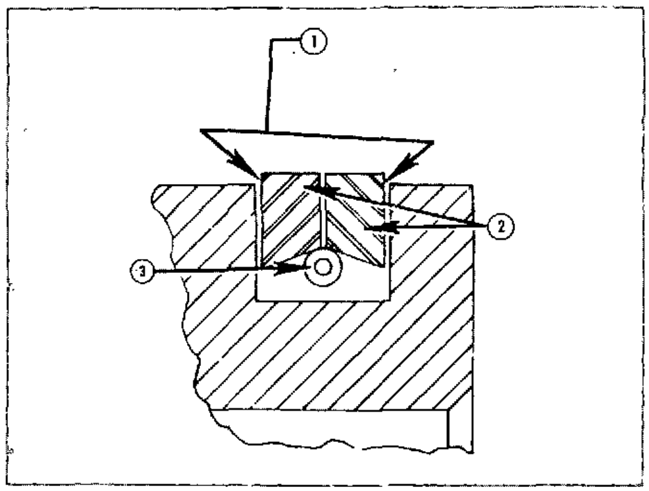


Fig. 14-1-87, V41468. Slinger and ring assembly

Note: When the dual ring and spring assembly is uncompressed, the spring will tend to bulge out. This is normal; do not cut off spring.

The slinger and ring assembly is to be inserted into the housing which was previously mounted on engine and aligned within 0.004 inch [0.1016 mm] total indicator reading. When installing slinger assembly, care must be used to insure that ring splits are correctly staggered and positioned to slide across the three bridges in housing. These bridges span the oil drain slot in housing and provide the only means of sliding compressed rings into their running position. The bridges are located at 12, 4 and 8 o'clock facing the installed housing.

To install slinger assembly in housing, slide slinger over rear crank flange until No. 1 ring (3, Fig. 14-1-88) is at front face of housing. Position No. 1 ring split at 12 o'clock (3),

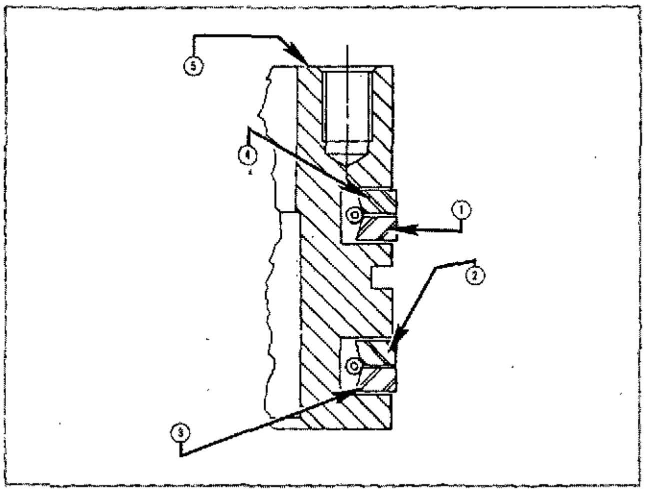


Fig. 14-1-88, V41467. Ring location

compress ring and slide slinger in until No. 1 ring rides in entrance chamfer of the housing. Position No. 2 ring split at 4 o'clock (2), compress ring over back-up spring and slide slinger into housing until No. 3 ring is at front face of housing.

Note: *Do not rotate slinger during installation, since this* may cause ring splits to rotate and drop rings into oil slot in the housing.

Position No. 3 ring split at 12 o'clock (1), compress ring and move slinger in until this ring rides in entrance chamfer of the housing. Position No. 4 ring split at 8 o'clock (4), compress ring over back-up spring and move slinger into housing until capscrew face of slinger is approximately 3/16 inch [4.7625 mm] behind face of crank flange.

Note: Slinger may be rotated at this point to align capscrew holes for flywheel installation.

Caution: When slinger is removed, loosen from flywheel (4, Fig. 14-1-89) and remove flywheel from crankshaft (5). Remove slinger (3) and rear cover (1) from engine and carefully guide rings (2) and slinger from housing. Failure to remove in this manner will result in broken slinger.

Flywheel

1. Thoroughly clean faces of flywheel and crankshaft flange of all dirt and burrs. Inspect dowels. If loose or there are any signs of shearing, remove. If a new flywheel is being installed, remove old dowels, regardless of condition.

2. Screw two manifold studs into crankshaft flange as guides.

3. Put a new gasket in place on flange of crankshaft.

4. Assemble flywheel over studs and dowels to crankshaft

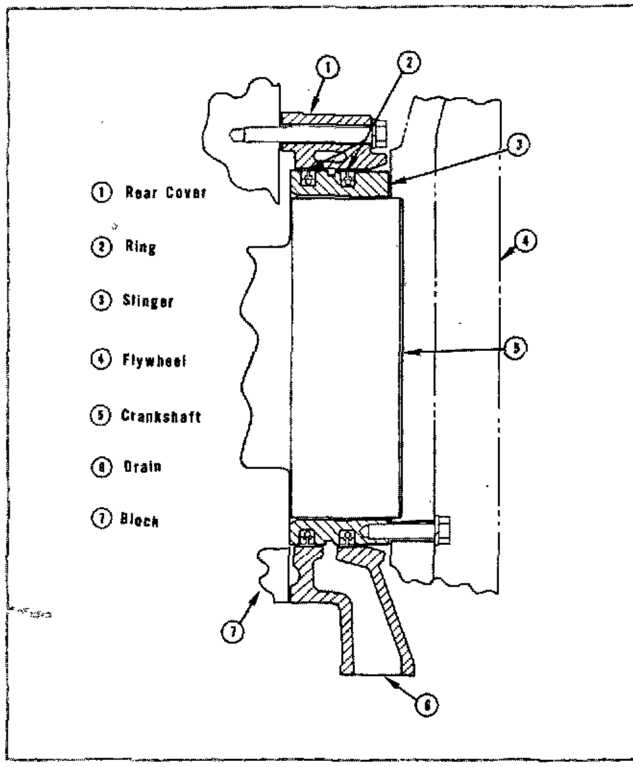


Fig. 14-1-89, V414175. Piston ring type rear cover

flange. If dowels have been removed, drill and ream oversize dowel holes in flywheel and crankshaft; install new dowels.

5. Insert proper capscrews. Tighten them alternately, a little at a time, to pull flywheel up evenly. Continue until all capscrews are tight.

Indicate Flywheel Bore

Attach indicator gauge to side of flywheel housing to indicate bore of flywheel. The total indicator reading must not be greater than 0.005 inch [0.1270 mm]. Fig. 14-1-90 and 14-1-91.

Indicate Flywheel Face

1. Shift gauge to indicate face of flywheel. Fig. 14-1-92. Mark with chalk four spots equidistant on circumference of flywheel.

2. As crankshaft is turned to bring up each of these chalk marks even with indicator, take up crankshaft end clearance in same direction each time. With end clearance taken up, total indicator reading at these four equidistant points must not exceed 0.0005 inch [0.0127 mm] per inch [25.4000 mm] *of diameter of outer 1/3 of clutch face radius. If* runout does exceed limits, remove flywheel and again clean faces of flywheel and crankshaft flange. Reinstall and recheck both bore and face.

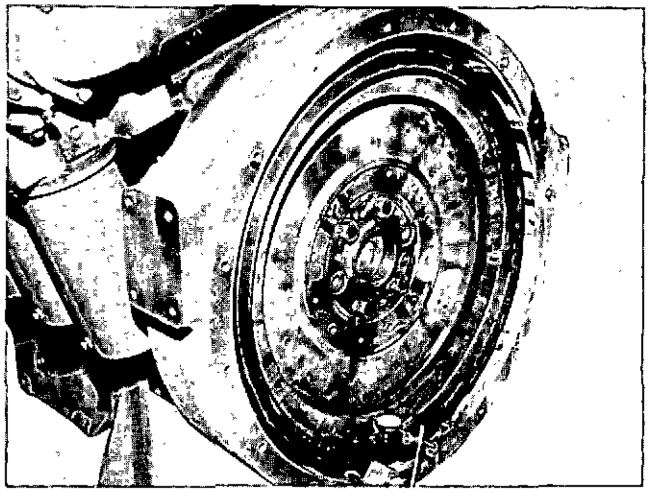


Fig. 14-1-90, V414176. Indicating flywheel bore

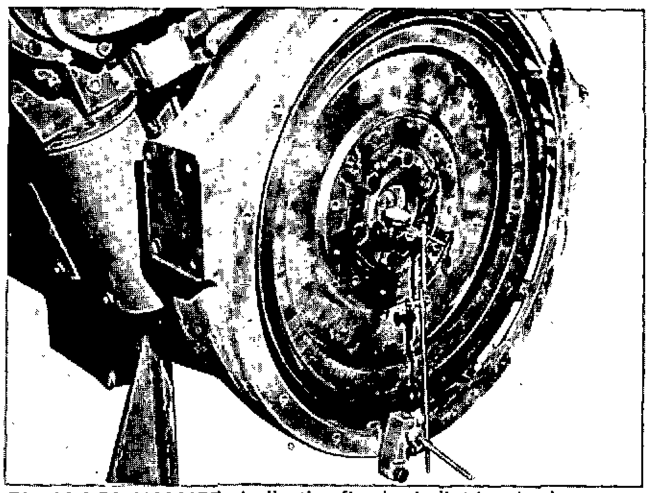


Fig. 14-1-91, V414177. Indicating flywheel pilot bearing bore

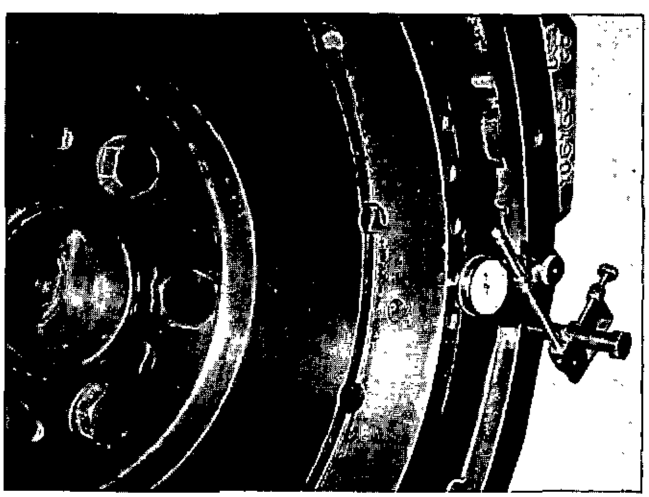


Fig. 14-1-92, V414178. Indicating flywheel face

3. If old dowels have been removed, ream dowel holes in flywheel and flange to nearest oversize and drive in oversize dowels. Use ST-497 Drill and Ream Plate and desired bushing for this purpose. Fig. 14-1-93.

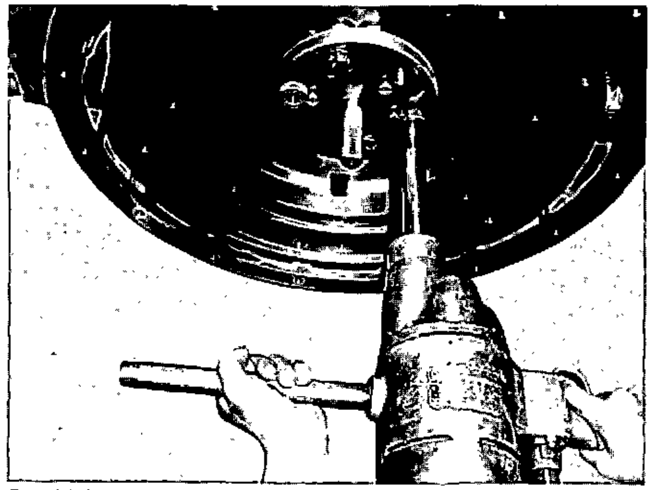


Fig. 14-1-93, V414179. Reaming flywheel and crankshaft dowel holes

Caution: Ream only to within 1/8 inch [3.1750 mm] of going through crankshaft flange to form shoulder preventing dowel from going through and causing damage to rear cover.

4. Tighten capscrews to 280 to 290 ft-lb [38.7240 to 40.1070 kg m]. Fig. 14-1-94.

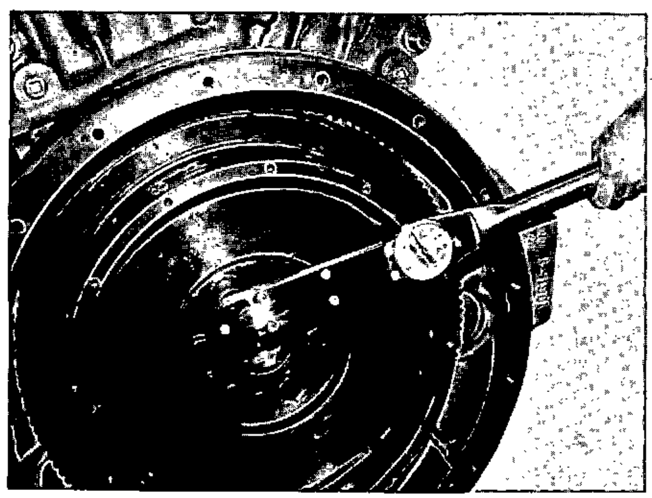


Fig. 14-1-94, V414180. Tighten flywheel capscrews

5. Lock capscrews in pairs with lockwires. Fig. 14-1-95.

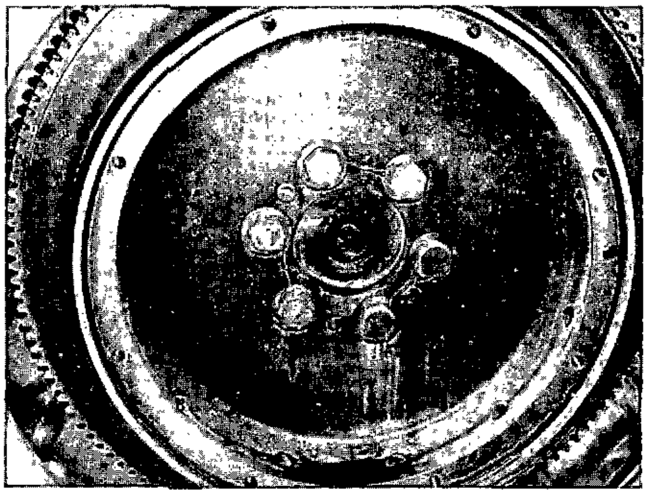


Fig. 14-1-95, V414181. Flywheel capscrews lockwired

Oil Pan

1. Check for proper location of oil gauge hole in relation to *oil gauge tube location if it extends through a baffle plate.*

2. Install rubber packing gasket in groove at rear of pan; use grease to hold in place.

3. Assemble oil pan to block but leave capscrews loose. Fig. 14-1-96.

4. Tighten oil pan capscrews to flywheel and rear cover.

5. Finish tightening remaining pan capscrews. Torque to 30 to 35 ft-lb [4.1490 to 4.8405 kg m].

6. Connect oil drain tube, if used, from rear cover to pan.

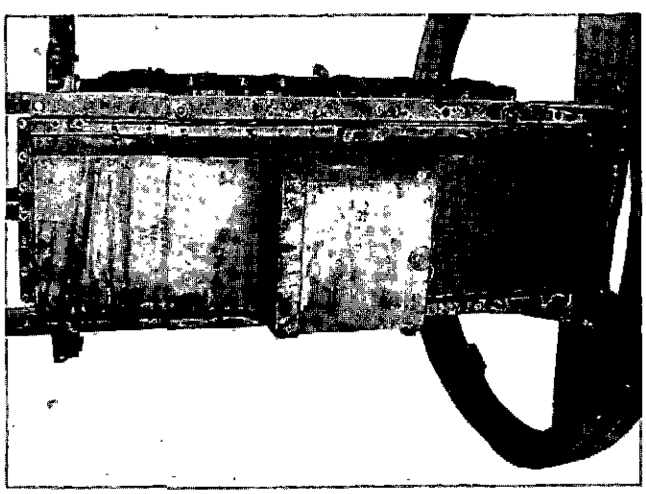


Fig. 14-1-96, V40072. Installing oil pan

Lubricating Oil Cooler and Full-Flow Filter

1. Mount cooler/filter bracket with lockwashers and capscrews. Fig. 14-1-97 and 14-1-98.

2. Mount filter head (to bracket) and oil lines (filter head to engine) with lockwashers, capscrews and "O" rings.

3. Mount oil cooler and secure with lockwashers and capscrews.

4. Mount filter cases with elements to filter head with capscrew at center of each case; replace drain plug in each filter case.

5. Tighten filter center capscrews to 25 to 35 ft-lb [3.4575 to 4.8405 kg m] torque.

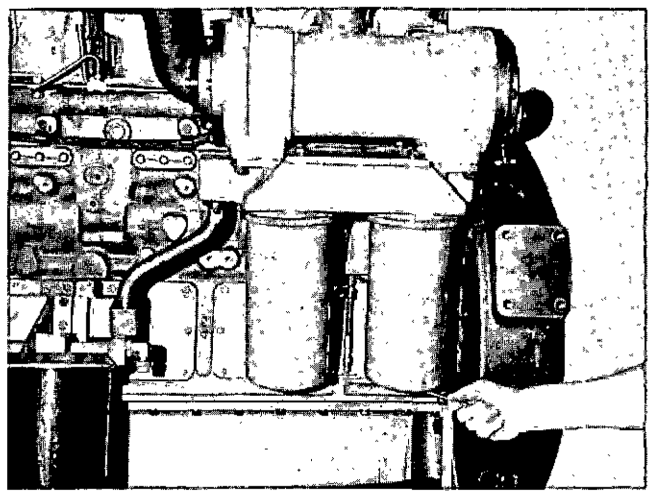


Fig. 14-1-97, V414183. Full-flow filter/cooler for non-piston cooled engines

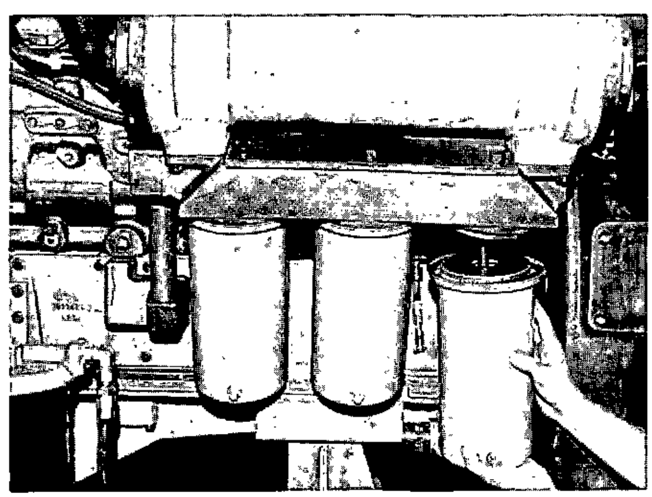


Fig. 14-1-98, V414202. Full-flow filter/cooler for piston cooled engines

Generator

The generator may be mounted at either of two locations depending upon type auxiliary equipment used with the engine—low mounted (generator on hand hole cover), or high mounted (generator on top of gear case).

Low Mount

1. Assemble bracket to generator.

2. Position generator and bracket to front left-bank hand hole cover. Two lugs are provided for this purpose.

3. Loosely assemble the bolts through the generator/alternator lugs, moveable bushing on back lug, and the mounting bracket. A hardened steel washer must be used between the bolt head and bushing. A hardened steel washer and lockwasher is normally used between the nut and bracket.

4. Place belt over generator and drive pulleys.

5. Adjust belt tension and lock the adjustment bar to the generator. Fig. 14-1-99. See "Belt Adjustment" later in this group.

6. Tighten the front generator/alternator lug bolt to standard torque value for size bolt used.

7. Lightly tighten the nut on the rear or bushing bolt. Do not over tighten.

8. Tap bolt head lightly with plastic mallot to slide the bushing up against the mounting bracket. If the bushing is tight in the generator lug, it can usually be moved by again lightly tightening the nut and tapping the bolt. A solid sound will be heard when the bushing reaches the mounting bracket.

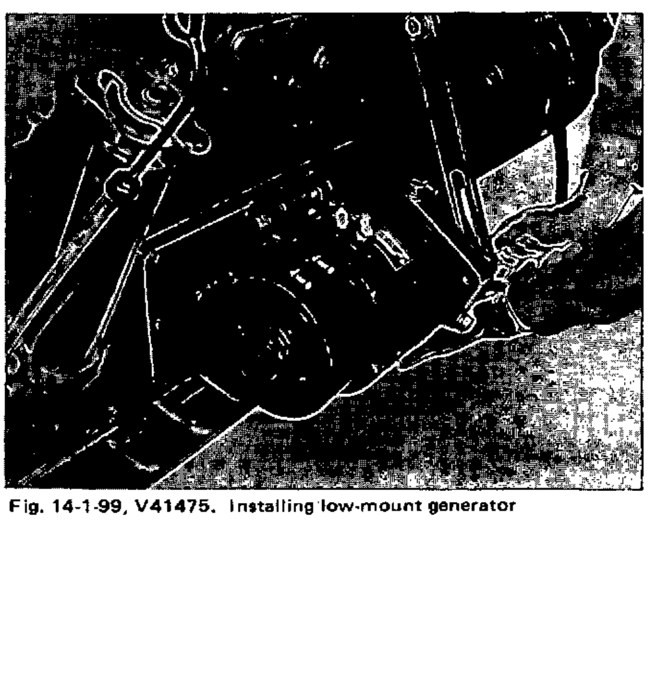


Fig. 14-1-99, V41475. Installing low-mount generator

9. Tighten the rear lug bolt to specified standard bolt torque value.

Note: Standard capscrew torque values are indicated in Group 18.

High Mount

1. Assemble bracket to generator.

2. Mount holding bracket to top of gear case. Fig. 14-1-100 and follow Low Mount assembly procedures.

3. Assemble generator to holding bracket on gear case. Fig. 14-1-100.

4. Place drive belt over generator and drive pulleys.

5. Regulate belt tension by adjustment bar to intake manifold. See "Belt Adjustment" later in this group.

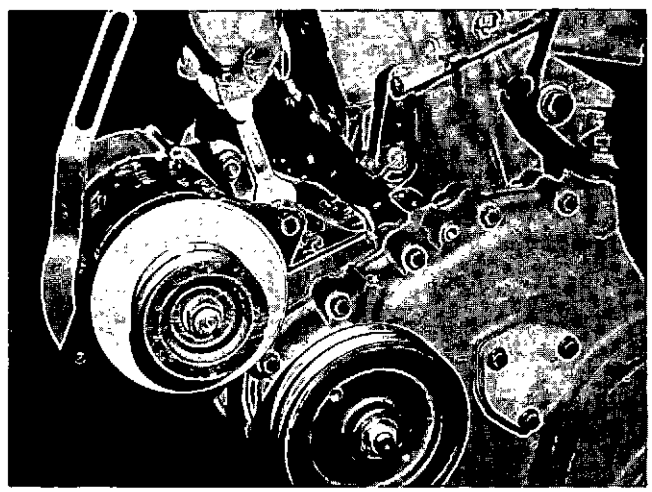


Fig. 14-1-100, V414203. Installing high-mount generator

Cranking Motor

1. If used, assemble spacer to cranking motor.

2. Mount cranking motor to flywheel housing with lockwashers and capscrews.

Engine Water Header Covers

Water header covers are mounted on the cylinder block between engine banks.

1. Use new gaskets and assemble water header covers to block; secure with lockwashers and capscrews.

2. Assemble oil cooler connection with gasket, lockwashers

and capscrews to rear header cover plate. Fig. 14-1-101.

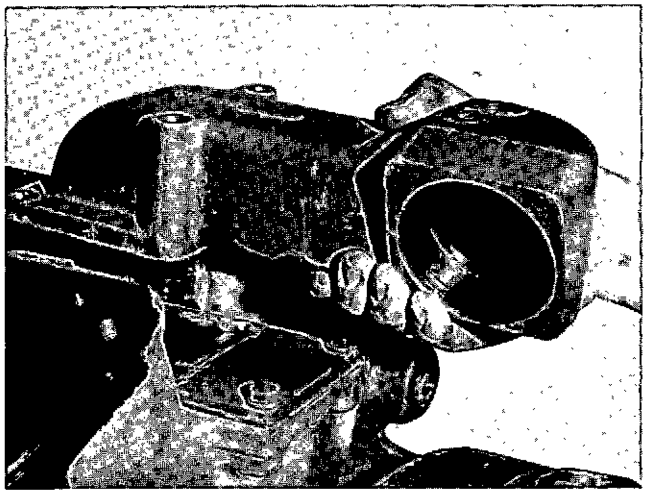


Fig. 14-1-101, V414125. Installing oil cooler water connection

Turbocharger

Turbocharged engines are equipped with dual turbochargers, one for each bank of cylinders. The turbochargers may be either top mounted or rear mounted, depending upon engine application. The following instructions treat installation separately as well as noting variations between right and left-bank mounts.

Note: For information on turbocharger exhaust piping, refer to Group 11.

Coat turbocharger mounting studs with Never-Seez compound or equivalent to aid in prevention of stud seizure.

Top-Mounted Turbocharger

1. Position exhaust riser with new gasket to exhaust manifold secure with stud nuts.

2. Install gasket and lift turbocharger into position against exhaust riser. Secure with bolts and nuts. Fig. 14-1-102.

3. Check position of turbocharger oil drain (large boss). This drain must always be down or within 30 deg. of that position when turbocharger is mounted to engine.

Note: The T-50 turbocharger housing may be rotated to bring oil drain to proper location. Loosen band, rotate; tighten band capscrew to 32 to 36 inch-lb [0.3680 to 0.4140 kg m].

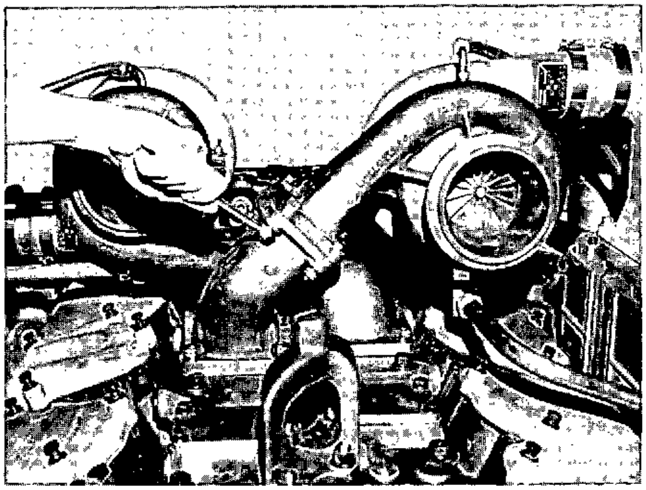


Fig. 14-1-102, V414186. T-50 turbocharger installation

4. Secure turbocharger support bracket between turbocharger casing and rocker housing cover if used.

5. Install oil inlet line from top of turbocharger to turbocharger oil supply.

6. Install oil drain line from large boss at bottom of turbocharger to side of block. Fig. 14-1-103.

7. Install hose from compressor outlet to intake manifold connection.

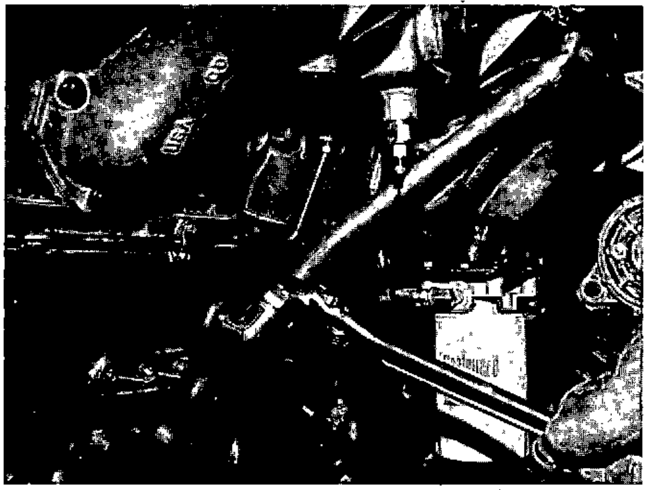


Fig. 14-1-103, V414184. Install turbocharger drain line

Rear-Mounted Turbocharger

1. Same as Step 2, top mounted.

2. Same as Step 3, top mounted.

3. Secure turbocharger support bracket, if used, between turbocharger casing and flywheel housing.

4. Same as Step 5, top mounted.

5. Same as Step 6, top mounted.

6. Same as Step 7, top mounted.

Intake Manifold Balance Tube

1. If not previously installed, position balance tube adapters with new gasket to rear of each intake manifold with lockwashers and capscrews. Do not tighten capscrews.

2. Install new rubber hose and hose clamps on each end of balance tube. Position tube to adapters and slide hose on adapters.

3. Secure assembly capscrews. Tighten hose clamps in desired location.

Oil Cooler Water Connections

1. Position new "O" rings on water inlet and outlet connections.

2. Insert water outlet tube in block connection. Fig. 14-1-104.

3. Slide cooler outlet adapter over tube and "O" ring; position adapter with new gasket to cooler and secure with lockwashers and capscrews.

4. Install water inlet tube between oil cooler and water pump.

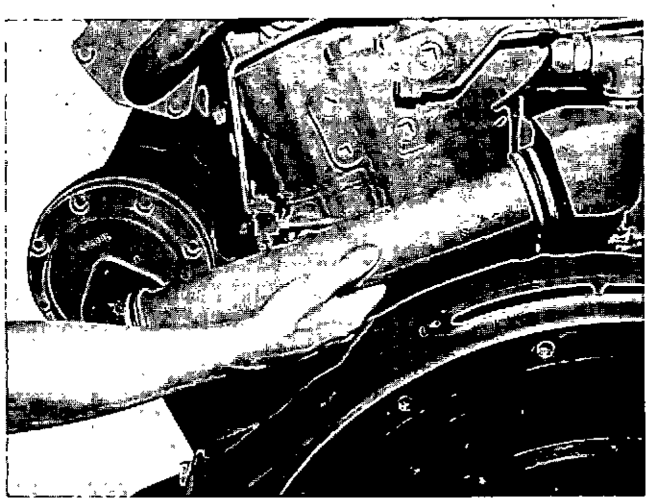


Fig. 14-1-104, V414182. Install water tube from cooler to block connection

Aneroid Control

The fuel pump must be properly calibrated and turbocharger must be operating properly before aneroid control is installed. See "Group 10, Unit 1003".

1. Assemble control and mounting bracket with lockwashers and capscrews. Mount as an assembly as near fuel pump as possible. Fig. 14-1-105.

2. Install fuel pressure line from bottom of fuel pump (outboard fitting) to "IN" connection on aneroid control (1).

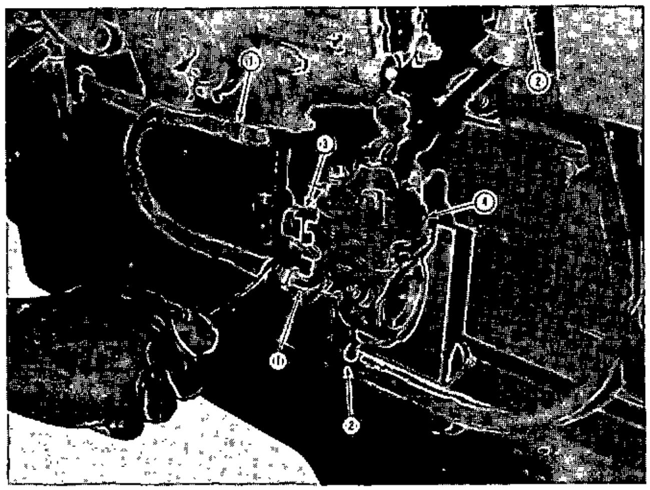


Fig. 14-1-105, V414188. Installing aneroid piping

3. Install return line from "OUT" connection on aneroid control to connection at suction side of gear pump (2).

4. Install line from top of aneroid to air intake manifold.

Note: Use No. 5 flexible hose between aneroid and fuel pump and No. 4 between aneroid (4) and air intake manifold.

5. Make sure filter (3) is in place.

Intercooler (Manifold Mounted)

1. Insert intercooler element in intake manifold (mark "this side down" must be in down position) with new gaskets and secure with lockscrews, lockwashers and locknuts (if used). Refer to Group 8, Unit 809.

2. Position cover with new gasket over element to manifold; secure with flatwashers, lockwashers and capscrews.

3. Position air inlet connections with new gaskets on intake manifold; secure with washers and capscrews.

4. Connect water inlet and return lines between intercooler and termination point. Fig. 14-1-106.

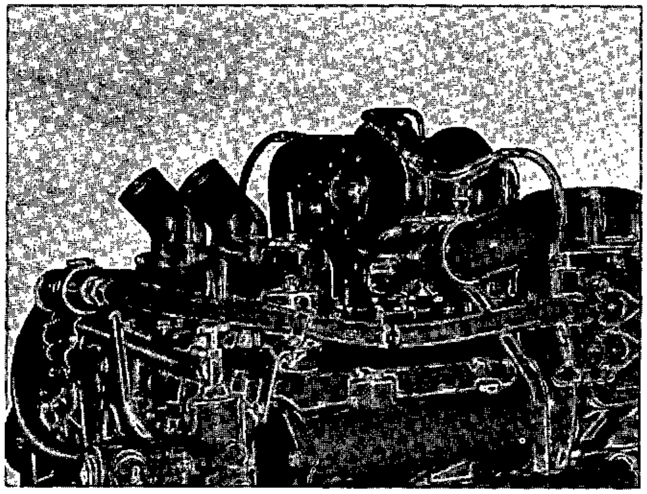


Fig. 14-1-106, V414225. Intercooler connections

Corrosion Resistor

Corrosion resistors with dual elements are standard equipment on V12 engines to provide "automatic" coolant treatment, if filter is properly serviced.

Corrosion resistors mounted to exhaust side of turbocharger should have a heat shield to protect resistor gasket from becoming overheated and turning brittle. The heat shield should be installed with cut-out portion at top to give maximum shielding effect.

1. Select location so resistor will be grounded to engine and inlet line will be less than 18 inch [457.2000 mm] in length.

2. Secure resistor to engine or mounting bracket with capscrews.

3. Attach inlet and outlet lines. Inlet line connects resistor to pressure side of water pump. Outlet line connects to bypass piping to water pump or after thermostat at engine to radiator piping to provide greatest pressure drop through corrosion resistor. Fabricate lines from 5/8 inch heater hose.

Note: Shut-off valves are provided so element may be changed without loss of coolant from engine.

4. Open shut-off valves; when engine is started, check for leaks.

5. After a few minutes when testing engine, check resistor head temperature to see if coolant is circulating. If resistor head is cold, disconnect outlet line to bleed air. Recheck for circulation.

Heat Exchanger

1. Position heat exchanger mounting brackets and braces to engine; secure with lockwashers and capscrews.

2. Position heat exchanger on mounting brackets; secure with lockwashers and capscrews.

3. Attach connection to heat exchanger and lubricating oil cooler.

4. Connect engine coolant connections between heat exchanger and engine coolant pump.

Expansion Tank

1. Position expansion tank mounting brackets to engine; secure with lockwashers and capscrews.

2. Position expansion tank on mounting brackets; secure with lockwashers and capscrews.

3. Connect all water by-pass piping.

4. Place new hose and hose clamps on all water connections and mating parts; secure hose with hose clamps.

Raw Water Pump

1. Position raw water pump on mounting bracket; install mounting lockwashers and capscrews and leave loose.

2. Place drive belt over drive pulley and raw water pump drive pulley.

3. Slide pump outward to obtain desired belt tension; secure pump with lockwashers and capscrews installed in Step 1.

4. Connect raw water inlet and outlet connections between heat exchanger and raw water pump.

Belt Adjustment

Belts

The service life of belts used to drive fans, water pumps and generators/alternators can be greatly extended by properer installation, adjustment and maintenance practices. Neglect or improper procedures often lead to problems of cooling or bearing failures, as well as short belt life. Following are the most important rules to be observed to extend belt life.

Installation

1. Always shorten distance between pulley centers so belt can be installed without force. Never roll or force a belt

over the pulley and never pry it on with a tool such as a screwdriver. Either of these methods will damage belts and cause early failure. Diagonal cuts on a failed belt indicate that the failure was caused by rolling a tight belt over the pulley. Cuts from prying a belt in place may be either diagonal or vertical.

2. Always replace belts in complete sets to prevent early failure and to provide efficient operation belt riding depth should not vary over 1/16 inch [1.587 mm] on matched belt sets.

3. Pulley misalignment must not exceed 1/16 inch [1.587 mm] for each ft. [0.3048 m] of distance between pulley centers.

4. Belts should not bottom on pulley grooves nor should they protrude over 3/32 inch [2.381 mm] above top edge of groove.

5. Do not allow belts to rub any adjacent parts.

Belt Tension

Check the belt tension with applicable Belt Tension Gauge. Fig. 14-1-107. Correct tension is 90 to 110 pounds as indicated on this gauge. If gauge is not available, apply pressure of the index finger at center of the longest span of belt. Deflection should be one thickness per foot of pulley center distance. Fig. 14-1-108. See Table 14-1-5.

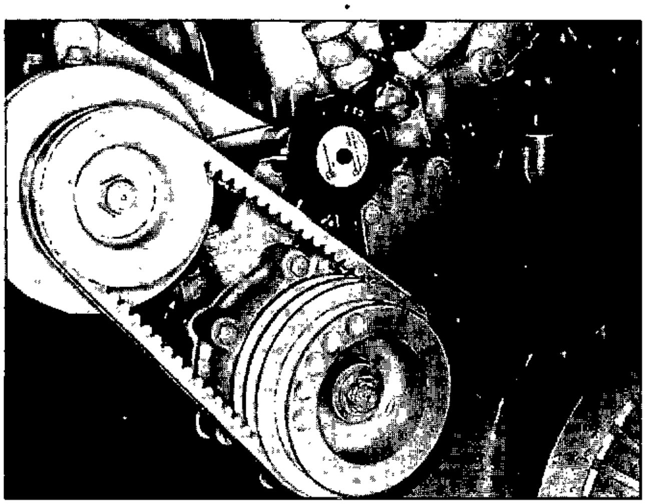


Fig. 14-1-107, V414226. Checking belt tension with ST-1138

Note: Use ST-968 Gauge for belts which are 3/8 to 1/2 inch in width. Use ST-1138 Gauge for belts which are 11/16 to 1 inch in width.

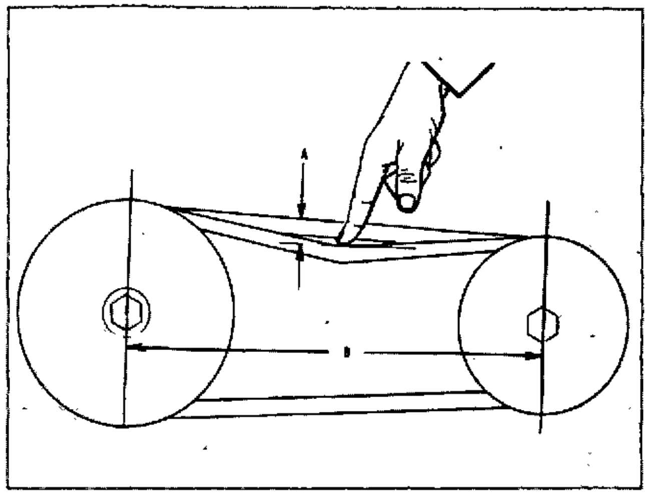


Fig. 14-1-108, N11471. Checking belt tension manually

Table 14-1-5: Belt Tension

Belt Width		Deflection per ft [304.8 mm] of Span	
Inch	[mm]	Inch	[mm]
1/2	[12.7000]	13/32	[10.3187]
11/16	[17.4625]	13/32	[10.3187]
3/4	[19.0500]	7/16	[11.1125]
7/8	[22.2250]	1/2	[12.7000]
1	[25.4000]	9/16	[14.2875]

Belt Adjustment (Split) Pulley

1. Remove the capscrews and lockwashers which secure the sheaves to pulley hub.

Note: Bar engine over to roll belt outward on pulley as pulley sheaves are turned in to obtain desired belt tension.

2. Turn front and rear adjusting sheave while securing hub in stationary position to obtain desired belt tension.

3. Lock sheaves in position with lockwashers and capscrews.

Readjusting New Belts

All new belts will loosen after running for an hour or more and must be readjusted. Readjust as described under "Belt Tension".

Belt Care Or Maintenance

Belts often slip or squeak because of glaze that forms due to dirt or steam cleaning.

Do not tighten belt beyond figures given to eliminate belt squeak. Squeak does not necessarily mean belt slippage. Tightening to excess may damage bearings as well as belts.

Injector And Valve Adjustments

Injector plungers and valves should be adjusted before starting the engine the first time, during engine test, after the first 50 hours service and at every "E" maintenance check (2000 hours) thereafter. See Operation and Maintenance manual.

Timing Marks

Injector plungers and valves are adjusted on engines approximately 90 deg. after top center firing position. The water pump drive pulley is marked to show injector and valve set positions.

Table 14-1-6: Engine Firing Order

Engine Rotation	Cylinder Number and Bank
Right Hand	1L-6R-2L-5R-4L-3R-6L-1R-5L-2R-3L-4R
Left Hand	1L-4R-3L-2R-5L-1R-6L-3R-4L-5R-2L-6R

Valve Crosshead Adjustment

If not adjusted before assembly of rocker lever housings to engine, proceed as follows:

1. Loosen valve crosshead adjusting screw locknut and back off adjusting screw one turn.

2. Use light finger pressure to hold crosshead in contact with valve stem. Turn down crosshead adjusting screw until it touches valve stem. Fig. 14-1-66.

3. For new crossheads and guides, advance crosshead adjusting screw 1/3 of one hex (or 20 deg.) more to straighten stem in its guide and to compensate for slack in threads. On worn crossheads and guides it may be necessary to advance the screw as much as 30 deg. in order to straighten the stem in its guide.

4. Torque locknut to 25 to 30 ft-lb [3.4575 to 4.1490 kg m] with a torque wrench to lock adjusting screw in this position. If ST-669 Tool is used with torque wrench, tighten to 22 to 26 ft-lb [3.0426 to 3.5958 kg m]; this lower torque is necessary due to the longer torque arm formed by ST-669. Adjust both intake and exhaust valve crossheads, Fig. 14-1-109.

5. Check clearance between crosshead and valve spring retainer with a wire gauge; minimum clearance is 0.025 inch [0.6350 mm]. Fig. 14-1-67.

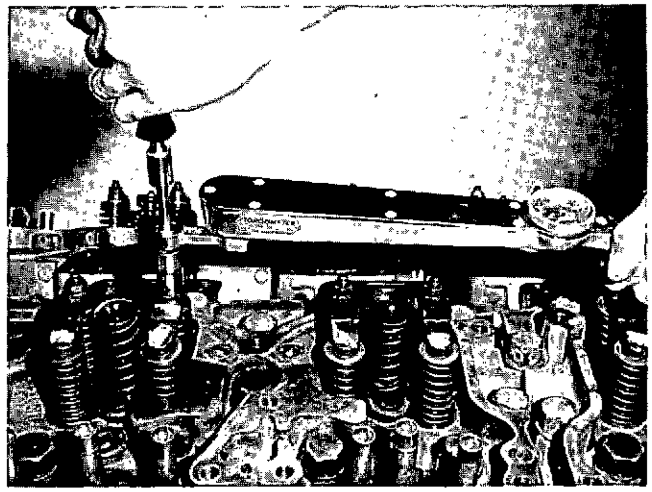


Fig. 14-1-109, V414197. Tightening crosshead locknut with ST-669 and torque wrench

Positions For Injector And Valve Adjustments

1. Pull compression release lever back and block in open position. This lifts all closed intake valves and makes it possible to turn the crankshaft without working against compression.

2. Bar engine in direction of Rotation to No. 1 Top Center firing position for left bank. In this position—after block is removed from compression release lever—both intake and exhaust valves will be closed for No. 1 cylinder, left bank; if not, turn one full turn of crankshaft.

Note: Holes in flywheel and slots in flywheel housing are provided for a cranking bar. As an alternate method, ST-747 Barring Tool can be used on the water pump drive pulley to rotate crankshaft.

3. Continue to rotate crankshaft until "1-6L VS" mark on water pump drive pulley lines up with timing mark on gear case cover or with pointer on water pump capscrew. The engine is now in position to adjust injector plunger and valves for No. 1 left-bank cylinder.

4. Adjust injector plunger and valves of No. 1 cylinder as directed in succeeding paragraphs under "Adjusting Injector Plungers" and "Valve Adjustment."

5. Rotate crankshaft to next "VS" mark corresponding to firing order of engine. For right-hand engines this will be "1-6R VS" and the cylinder ready for adjustment will be No. 6 right bank. Consult firing order for left-hand engines.

6. Continue until all injectors and valves have been correctly adjusted.

Caution: Two complete revolutions of the crankshaft are needed to set all injector plungers and valves. Injector and valves can be adjusted for only one cylinder at any one position.

Adjusting Injector Plungers

Adjust injector plungers and valves in valve-set position for the cylinder being adjusted as detailed in previous paragraphs under "Positions for Injector and Valve Adjustments". Always adjust injector plungers before valves.

1. Check threads of injector adjusting screw and nut to see that they are clean, well oiled and free turning.

2. With engine in valve-set position for injector being adjusted, turn injector adjusting screw until plunger contacts cup and advance an additional 15 deg. to squeeze oil out of cup.

3. Loosen adjusting screw one turn.

4. Use a small, accurately calibrated inch-lb torque wrench to tighten adjusting screw to 50 inch-lb [0.5750 kg m] while engine is cold. Fig. 14-1-110.

Note: If a torque wrench is used, it must have screwdriver adapter and should be in inch-lb divisions. It should have a maximum capacity of no more than 150 inch-lb [1.7250 kg m].

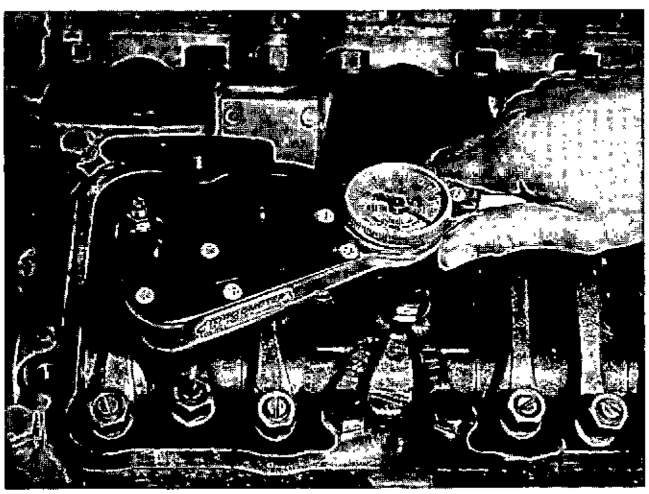


Fig. 14-1-110, V414190. Adjusting injector plunger with torque wrench

Caution: Do not hold injector spring in compressed position during adjustment. Doing so will result in false setting.

5. After making adjustment, tighten locknut to 30 to 40 ft-lb [4.1490 to 5.5320 kg m]. If ST-669 Tool is used, tighten nut to 25 to 35 ft-lb [3.4575 to 4.8405 kg m].

Valve Adjustment

1. The same engine position used in setting the injector is used for setting the intake and exhaust valves. Always make final injector and valve adjustments after the engine is warm.

2. Make sure compression release is in running position before setting intake valves.

3. Loosen valve adjusting locknut and back off adjusting screw.

4. Use a feeler gauge of proper thickness for valve being adjusted. Insert between crosshead and lever and turn adjusting screws down until lever just touches feeler gauge. Fig. 14-1-111.

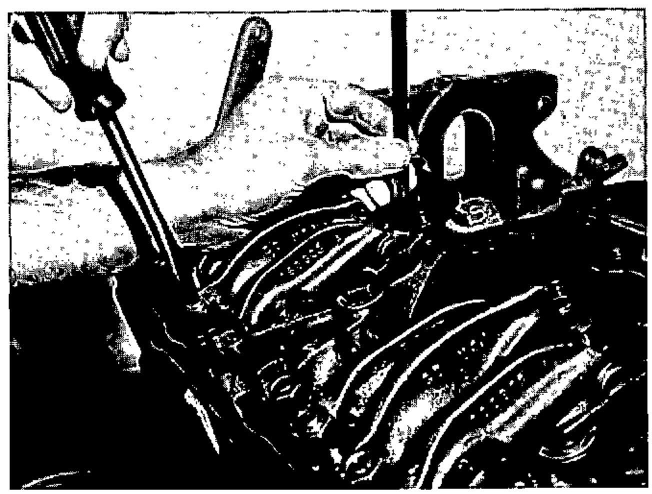


Fig. 14-1-111, V414193. Valve adjustment

5. With engine cold, at 70 deg. F [21.1 deg. C], adjust valves to:

Intake Valves	0.016 in. [0.4064 mm]
Exhaust Valves	0.029 in. [0.7366 mm]

6. Tighten locknuts to 30 to 40 ft-lb [4.1490 to 5.5320 kg m] torque; if ST-669 Tool is used, tighten to 25 to 35 ft-lb [3.4575 to 4.8405 kg m] torque. Fig. 14-1-112.

Rocker Housing Covers

Shellac new gaskets to covers; install covers with flatwashers, lockwashers and capscrews.

The standard location of breathers of V-1710 is as follows:

One breather is to be located in the right-bank front rocker housing cover.

The second breather is to be located in the left-bank rear

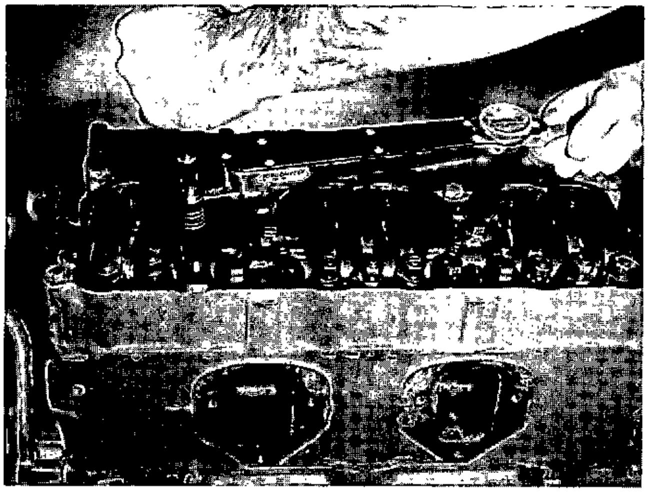


Fig. 14-1-112, V414194. Tighten locknut using ST-669 and torque wrench

rocker housing cover.

By-Pass Filter

If a by-pass filter is used in conjunction with a full-flow filter, install in following manner:

1. Install filter and bracket assembly in desired location.

2. Install supply and drain lines. See Group 7, Unit 703.

3. Connect by-pass filter supply line to tapped hole in flywheel housing end of full-flow filter head. Attach flexible hose from by-pass filter inlet. Fig. 14-1-113.

4. Install a restriction orifice of proper size in by-pass filter to allow minimum oil flow of 3 to 4 U. S. gal [2.4980 to 3.3307 U. K. gal or 11.355 to 15.140 lit] per minute with engine operating at high idle and oil temperature at 175 deg. to 185 deg. F· [79.4 deg. to 85.0 deg. C]. See Group 7, Unit 704.

5. Connect by-pass filter return line to pan.

Scavenger Lubricating Oil Pump (External)

Scavenger lubricating oil pump mounts on fuel pump side of engine on gear case in opening below fuel pump/air compressor and is driven by camshaft gear; pump is internally lubricated, when not pumping oil, by a pressure lubricating oil line attached to oil gallery passages drilled in cylinder block. Fig. 14-1-114.

Installation Of Natural Gas Engine Components

Spark Plug Adapter Tube And Spark Plugs

1. Lubricate "O" rings and position red "O" ring in bottom groove and black "O" ring in top groove of each spark plug adapter tube. Insert spark plug adapter tubes in heads and secure with yokes and screws.

2. Check spark plug gap; it should be 0.018 inch [0.4572 mm].

3. Position new gasket on spark plug; insert spark plug in adapter and torque to 28 to 30 ft-lbs [3.8132 to 4.1490 kg m].

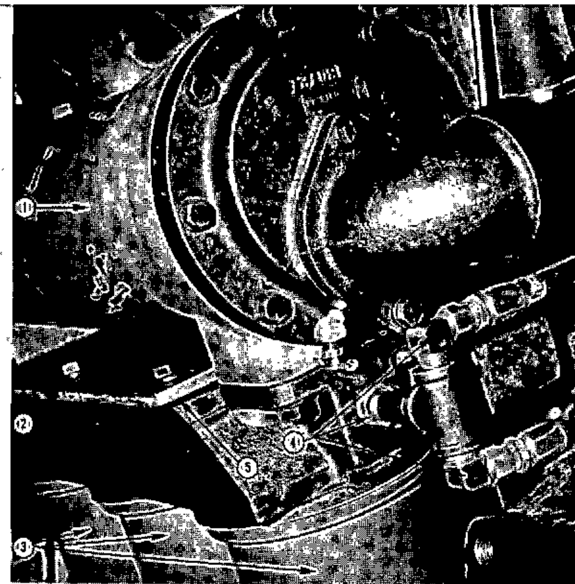


Fig. 14-1-113, V40735. Mounting by-pass filter supply line

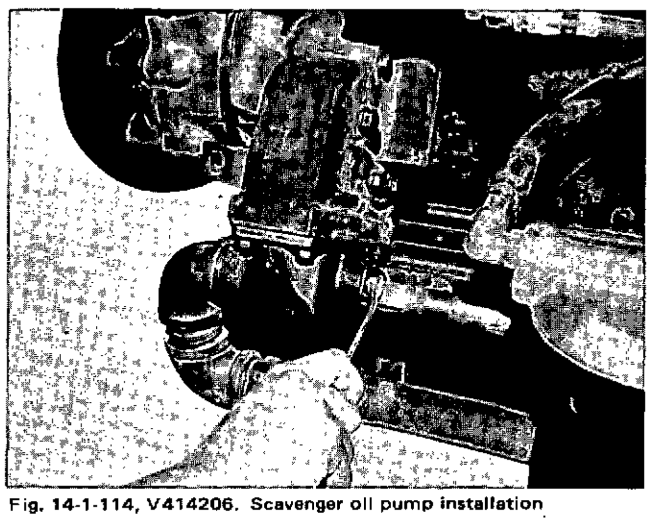


Fig. 14-1-114, V414206. Scavenger oil pump installation

Carburetor And Pressure Reduction Valve

1. Apply sealing compound and install pipe fittings in carburetor and pressure reduction valve; connect carburetor to pressure reduction valve.

Note: Install valve with arrow on bottom of pressure reduction valve pointing toward carburetor gas inlet.

2. Position carburetor with new gasket on intake manifold; secure with washers and capscrews.

3. Secure pressure reduction valve to mounting bracket with clamps.

4. Connect gas supply line to pressure reduction valve.

5. Connect throttle linkage to carburetor.

6. Connect air intake piping to carburetor.

Mag-tronic Ignition System

1. Install ignition transformers in rocker housing covers in each spark plug adapter, secure cover with screws.

2. Rotate "Mag-tronic" drive until red rotor arm is centered in timing window. Fig. 14-1-115.

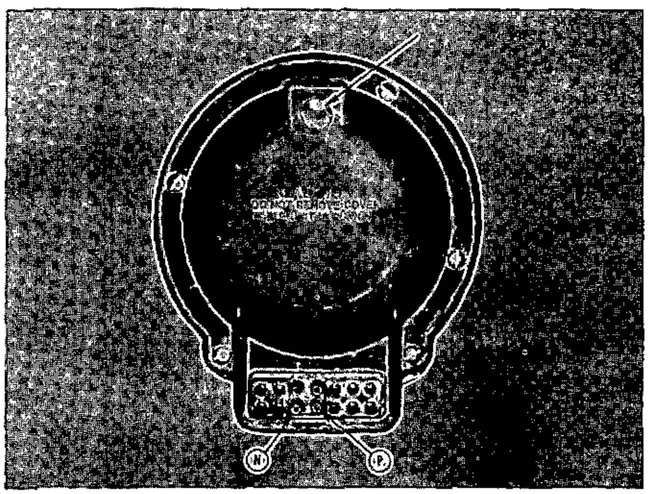


Fig. 14-1-115, NG25. Installing Mag-tronic generator

3. Position No. 1 cylinder on T.D.C. – Compression stroke.

4. Position "Mag-tronic" to drive assembly, engaging drive coupling and secure with capscrews, lockwashers, flatwashers and nuts. (Do not tighten capscrews.)

5. Install ignition wiring harness. Refer to wiring diagram. Fig. 13-5-2.

Hydraulic Governor

1. Position governor assembly with new gasket over studs of governor drive assembly. Take care to align splines of drive in drive coupling while positioning governor on housing.

2. Align scribe marks and install governor speed control lever on speed-adjusting shaft; connect speed-adjusting linkage to governor speed control lever.

3. Align scribe marks and install governor lever on governor terminal shaft; connect linkage from governor terminal to carburetor.

4. Remove tags from electrical wiring; connect wires to their respective terminals of motor-driven head, if used.

Engine Testing—Unit 1402

Engine break-in and testing are accomplished simultaneously. Break-in on a new or rebuilt engine is necessary because it provides an operating period during which moving parts acquire their final finish and mating surfaces reach a full seat. Engine testing helps detect possible assembly errors, need for adjustments as engine "breaks in," and establishes a period for final adjustments for best engine performance.

An engine dynamometer provides the simplest and most accurate tool for testing and break-in. Follow the instructions listed below in sequence for prestarting checks, dynamometer mounting, starting, testing, adjustments and break-in.

Engine Dynamometer

Check dynamometer capacity. Make sure capacity is sufficient to allow testing at 96% to 100% maximum engine horsepower. If capacity is insufficient, testing procedures must be modified to prevent damage to dynamometer.

Installation Of Engine

1. Using proper lifting device, place engine on dynamometer test stand.

2. Position engine on front engine support and preselected risers for rear engine supports; secure engine mounting pads to engine support risers with bolts, lockwashers and nuts. Remove lifting device.

3. Position dynamometer drive shaft flange to engine flywheel. Use proper flywheel adapter flange to match flywheel capscrew holes.

4. Check for proper alignment.

a. If direct of flexible-drive coupled, place a dial gauge holding fixture on face of flywheel housing and dial gauge on adapter flange hub; bar engine to obtain reading. Relocate flange hub on flywheel as needed and retighten capscrews. Flywheel adapter flange must be concentric to flywheel and flywheel housing within 0.005 inch [0.1270 mm] total runout. When using a direct-coupled dynamometer, a reading must be taken from face of flywheel housing to outer edge of dynamometer drive flange. It must not exceed 0.005 inch [0.1270 mm] total runout when barring dynamometer one complete revolution.

b. If universal-drive coupled, flywheel and dynamometer drive flanges must be concentric within 0.005 inch [0.1270 mm] runout, reading to be taken as above. Install engine so centerline of engine crankshaft and centerline of dynamometer drive shaft are, by design, out of plane either horizontally or vertically from 1/4 inch [6.3500 mm] minimum to 1/2 inch [12.7000 mm] maximum. True alignment will cause universal bearing failure. Secure flywheel to drive flange with lockwashers and capscrews.

5. Connect water supply and return hose to the water-cooling arrangement.

6. Attach ST-502 Flow Tank fuel line to engine fuel drain connection.

7. Attach fuel pump return line, if used.

8. Attach fuel supply line to fuel pump suction connection.

9. If engine is turbocharged and equipped with an aneroid control, disconnect fuel pressure and fuel return line from aneroid control. Plug lines to prevent air and dirt from entering fuel system. The aneroid is reconnected just before "power check" is made.

10. Connect electrical wiring to cranking motor if motor is to be used for starting. If another means of starting is to be used, make necessary connections.

11. Connect throttle linkage, all instruments and electrical wiring, which are included on the control panel or the particular dynamometer being used.

12. Connect exhaust piping to engine exhaust system.

13. Connect air intake piping to air intake manifold or air inlet connection. Use a standard air cleaner approved for engine model being tested.

14. Always use full-flow lubricating oil filter to remove dirt or grit.

15. On naturally aspirated engines, remove rocker housing covers and plug vent holes in cylinder heads before making blow-by check. Failure to do so will give false readings.

Caution: After testing, remove pipe plugs from cylinder heads of naturally aspirated engines.

16. Install ST-487 Blow-By Checking Tool (2, Fig. 14-2-1) to each bank crankcase breather opening or special rocker cover (1) with adapter.

17. Tee (3) both ST-487 tools to water manometer (4) and fill manometer with water to "O" mark at middle of scale.

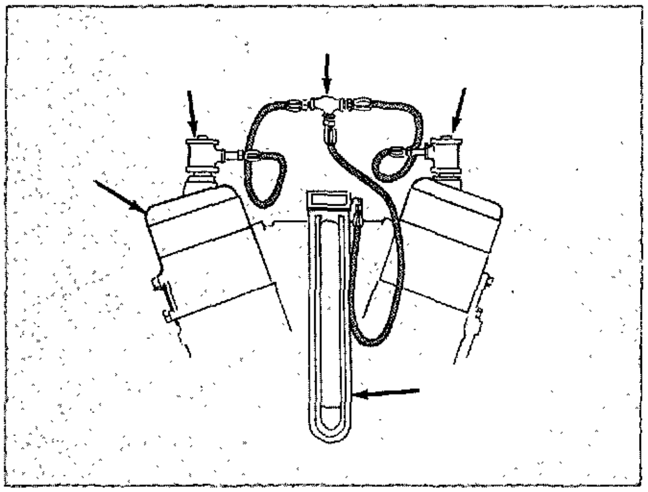


Fig. 14-2-1, V41488. Checking blow-by with ST-487

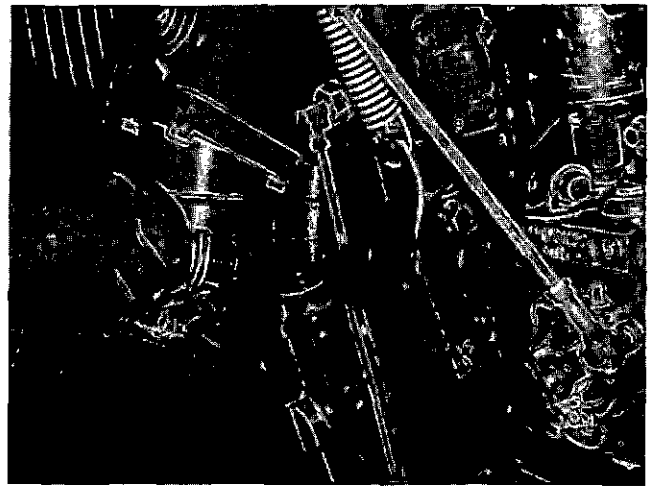


Fig. 14-2-2, V414227. Checking hydraulic governor oil level

18. Close all openings that would allow blow-by pressure to escape. *All connections must be air tight.*

Priming Fuel System

Priming of fuel system is not necessary except as an aid to faster pick-up of fuel, especially where fuel tank is located away from engine.

1. If fuel pump has a return line to fuel tank, a few drops of clean lubricating oil in gear pump will aid in fuel pick-up.

2. If fuel pump return opening, next to tachometer drive, is plugged, remove plug and fill fuel pump housing with clean No. 2 diesel fuel. See Group 18 for fuel specifications.

3. Fill fuel filter with clean No. 2 diesel fuel.

Lubricating Cranking Motor And Generator

1. Use 6 or 8 drops of clean engine lubricating oil to lubricate cranking motor bearings. Avoid excessive oiling which would cause damage to wire insulation.

2. Use 6 or 8 drops of clean engine lubricating oil to lubricate generator bearing. Avoid excessive oiling which would cause damage to wire insulation.

Fill Hydraulic Governor

1. Many engines used in stationary power applications are equipped with hydraulic-governed fuel pumps. This governor uses lubricating oil (of the same weight as used in the engine) as an energy medium.

2. *Oil level in governor sump must be at full mark on* dipstick, or half-way level on inspection glass. Fig. 14-2-2.

Injector And Valve Adjustments

Injector plungers and valves should be adjusted before starting the engine; refer to Group 14-1.

Priming Lubricating System

Note: Remove turbocharger oil inlet line from turbocharger. Fill bearing housing by pouring clean lubricating oil through inlet opening. Fill lubricating oil supply line with clean lubricating oil; reconnect oil supply line to turbocharger lubricating oil inlet fitting.

1. Fill crankcase to "L" (low) mark on bayonet gauge with clean lubricating oil. See Group 18 for lubricating oil specifications.

Note: Some dipsticks have dual markings, with high low level marks: static oil marks on one side, engine running at low idle speed marks on opposite side. Be sure to use proper scale. Fig. 14-2-3.

2. Remove pipe plug from priming point. The priming point is in filter head as indicated in (1, Fig. 14-2-4).

Caution: Priming paper element filter at wrong point will rupture filtering media.

3. Connect a hand or motor-driven priming pump line from source of clean lubricating oil to engine priming point.

4. *Prime until a 30 psi [2.1090 kg/sq cm] minimum* pressure is reached.

5. Pull compression release and crank engine for a minimum of 15 seconds with external oil pressure at a minimum of 15 psi [1.0545 kg/sq cm].

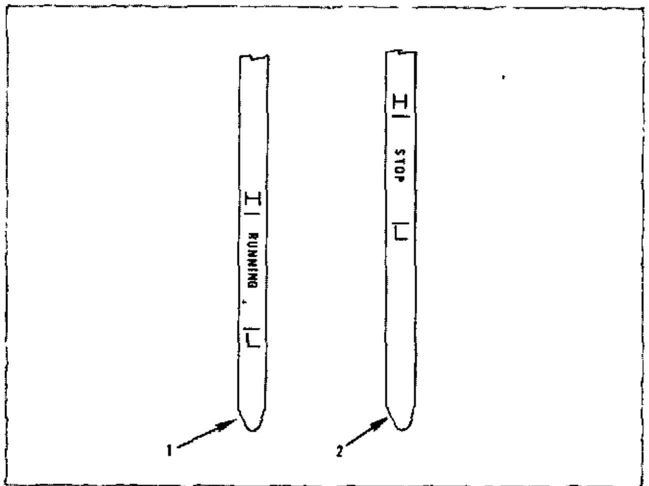


Fig. 14-2-3, V40726. Oil dipstick markings

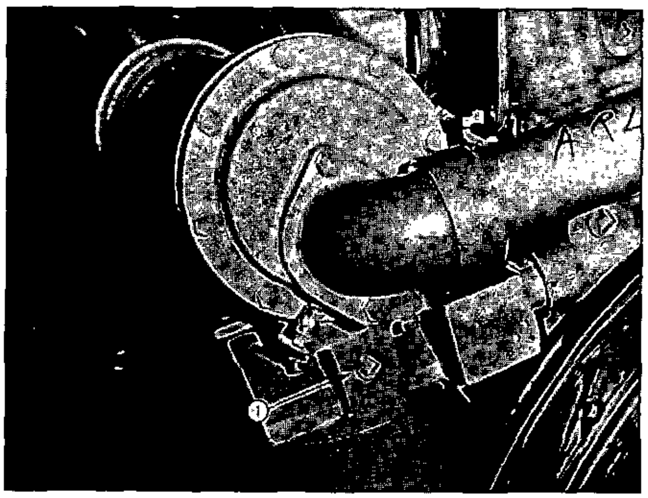


Fig. 14-2-4, V41816. Lubricating system priming point

6. Return compression release to "run" position and allow engine to fire and operate from 5 to 10 seconds; then shut down engine.

7. Remove external oil supply and replace plug.

8. Check oil level on dipstick; bring level to "H" mark.

Caution: After engine has run a few minutes, it will be necessary to add lubricating oil to compensate for that taken by the filter and oil cooler.

9. Check operation on units equipped with air activated prelube device, open the air valve for 10 to 12 seconds to activate the piston in prelube device which will lubricate all moving parts in the engine prior to engaging starter.

Starting Procedure

Normal Without Cold-Starting Aid

1. Set throttle for idle speed.

2. Open manual fuel shut-down valve, if used. Electric fuel shut-down valves operate automatically.

Note: The manual over-ride knob provided on forward end of electric shut-down valve allows valve to be opened in case of electric power failure or if power is not available during testing. To use, open by turning fully clockwise.

3. Pull compression release.

4. Start engine: press starter button (1, Fig. 14-2-5) or turn switch key to "start" position.

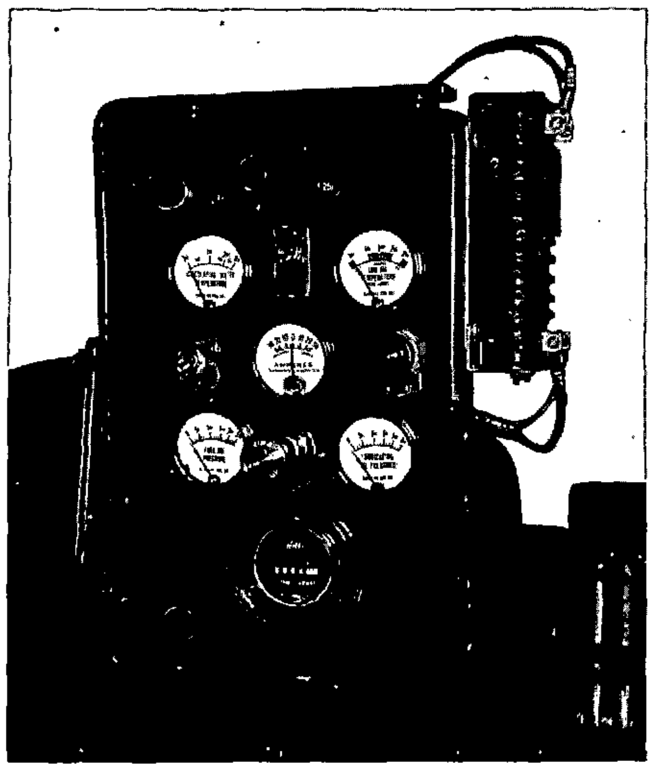


Fig. 14-2-5, V414228. Instrument panel

5. After three or four seconds of cranking, close compression release and continue to crank until engine fires.

Caution: Do not crank engine continuously for more than 30 seconds. If engine does not fire within 30 seconds, wait two to five minutes before repeating to avoid cranking motor damage.

Cold Start With Glow Plug

1. Set throttle in idle position; do not accelerate engine during starting procedure.

2. Turn glow plug toggle switch to "ON" position. (Red indicator light must be on).

3. After red light has been on for 20 seconds, start cranking engine. As soon as engine begins rotating, operate preheater priming pump to maintain 80 to 100 psi [5.6240 to 7.0300 kg/sq cm] fuel pressure. (Use of primer before 20-second interval will wet and cool glow plug and prevent heating).

Note: On engines equipped with an oil pressure switch, the fuel by-pass switch must be in "START" position before use of priming pump.

4. If engine does not start within 20 seconds, stop cranking, wait two to five minutes and repeat cranking operation.

Note: On engines with oil pressure safety switch, hold fuel by-pass switch in "START" position until engine oil pressure reaches 7 to 10 psi [0.4921 to 0.7030 kg/sq cm]; then move to "RUN" position.

5. After engine starts, pump primer slowly to keep engine idling smoothly. In cold weather this may require 5 minutes or longer. Do not accelerate engine.

6. When engine has warmed up so it does not falter between primer strokes, stop pumping. Close and lock primer. Turn off glow plug toggle switch. (Red indicator light will go out).

Failure To Start

1. If engine gives no indication of starting during first three full strokes of preheater pump, check intake manifold for heat. If there is no heat, check electric wiring. If wiring is all right, remove pipe plug from manifold near glow plug and check flame while a helper performs Steps 2, 3 and 4.

2. If no flame is observed, close glow plug manual switch for 15 seconds and observe glow plug through pipe plug hole. Glow plug should be white hot; if not, connect plug to a six or twelve-volt source and check amperage which should be 30 (minimum). If glow plug is all right, check manual switch and resistor; replace if necessary.

Other Cold-Starting Aids

1. Ether-Compound Metering Equipment consists of a metering chamber for ether compound capsules and controls to release the starting compound during cranking.

The starting fluid is released so it enters air intake manifold. To start engine so equipped:

a. Close shut-off cock. If properly installed, the spring will hold it closed.

b. Remove cap and insert capsule of starting fluid.

c. Push cap down sharply to puncture capsule; tighten one-fourth turn.

d. Wait 30 seconds before engaging starter.

e. Engage starter and, while engine is being cranked, open the shut-off valve.

Caution: Do not open valve before cranking engine or all fluid will drain into the intake air before cranking, and there will be one excessively heavy charge instead of the metered amounts which starting requires.

f. After engine has started and all fluid has drained out of chamber, close valve to keep dusty air out of engine.

g. Remove and discard empty capsule; reassemble empty primer.

2. If engine is not equipped with a preheater arrangement or ether-compound metering equipment, the following method can be used to start the engine:

a. Two men will be required for this operation; one cranks the engine while the other applies ether to air intake.

Caution: Never handle ether near an open flame. Never use with preheater or flame thrower equipment. Do not breathe fumes.

b. Use Cummins spray can of starting fluid and apply spray to air intake of air cleaner.

Caution: Use of too much ether causes excessively high pressures and detonation.

c. Ether fumes will be drawn into intake air manifold and engine should start without difficulty.

Engine Checks

1. Open coolant supply valves to heat exchanger or water connection. Introduce water to absorption unit per manufacturer's instructions.

2. Check all tubing, hose, lines, fittings and plugs for leaks. Correct as necessary.

3. For engine run-in, see "Test Procedure".

4. After test, remove plugs from naturally aspirated engine vent holes.

Check Turbocharger Oil Flow

Note: The oil supply should be engine oil which has been filtered by a full-flow engine oil filter.

1. Prelubricate turbocharger by pouring clean lubricating oil through inlet opening. Turn rotating assembly by hand to coat bearings and thrust washer with oil.

2. Install oil inlet line and fill with clean lubricating oil. Use SAE Type 100R5 wire braid hose with minimum inside diameter of 5/16 inch [7.9375 mm] (SAE No. 6) and that will withstand up to 350 deg. F [176.7 deg. C] oil temperature.

3. During initial starting, check for oil pressure at inlet connection to turbocharger (10 psi [0.7030 kg/sq cm] minimum at idle).

4. Disconnect oil drain line to determine if oil is flowing through turbocharger. Reconnect line.

5. Remove air inlet connection from turbocharger and observe rotation of turbocharger rotor. The rotor must be entirely free of any evidence of rubbing or binding.

6. Shut down engine momentarily to determine if rotor coasts freely to a stop.

7. Restart engine and check full speed and load.

8. Recheck all connections and piping for tightness. If no leakage of oil, air or exhaust gas can be noted, the engine is ready for operation.

9. Performance of turbocharger must be observed at reasonable intervals.

Air Compressor Run-In

No special or extended air compressor break-in is required. When a rebuilt air compressor is installed, it is recommended that it be operated for a short period of time (10 to 15 minutes is satisfactory) at various engine speeds against the vehicle tank pressure (if engine is in frame) while the engine is warming up to check for abnormal noises, leaks or signs of faulty operation.

Note: Air compressor should be operated in unloaded condition, when engine is being run in on engine dynamometer. Approximately 90 psi [6.3279 kg/sq cm] or shop air pressure connected to the unloader valve is required to unload compressor.

Determining Brake Horsepower

Evaluation of engine performance during testing is, for the most part based on accurate horsepower readings. Therefore, it is imperative that the following formulas be used with the test procedures. The basic formula to determine brake horsepower is as follows:

$$\text{Brake Horsepower} = \frac{\text{Torque (In Ft-Lb)} \times \text{Engine RPM}}{5252}$$

Most engine dynamometer manufacturers provide a figure known as a "brake constant" with each dynamometer. The constant simplifies the process of compouting brake horsepower since only engine rpm and the scale reading (in pounds) need be found by test mechanic. The formula used with a known constant is:

$$\text{Brake Horsepower} = \frac{\text{LB (on Dyno. Scale)} \times \text{Engine RPM}}{\text{Dynamometer Constant}}$$

Example: Dynamometer in operation has brake constant of 500. Scales show a reading of 50 pounds and tachometer shows engine rpm of 1600.

$$\text{Brake Horsepower} = \frac{50 \times 1600}{500} = 160$$

The above formulas apply to engine dynamometers only. Where chassis dynamometers are used, a factor of approximately 25% must be used to compensate for gear ratio, tire size, etc.

Procedures Of Converting Horsepower

1. All horsepower ratings are given as Sea Level Ratings. To convert sea level ratings to Cummins Horsepower values (See Table 14-2-1) deduct 3% per 1000 ft [304.8 m] above Sea Level and 1% per 10 deg. F above 60 deg. F [5.56 deg. C above 15.6 deg. C].

a. Turbocharged engines develop stated horspower from sea level to altitude given in Table 14-2-2.

b. All engines derated in power only, or in-power and speed combined, need not be converted for any difference between Cummins and Sea Level standards.

2. Data given in Table 14-2-1 is intended as a guide to be used in the conversion of horsepower as expressed in one system to that of another system. Standard test conditions vary from one system to another as noted.

Note: The Din (German) horsepower ratings include fan horsepower, whereas other systems listed do not include horsepower required to drive engine-cooling fan or a battery-charging generator. In general, approximately 10 percent adjustment of horsepower rating will make up the difference. When horsepower required to drive fan and generator is known, exact adjustment in net horsepower may be made.

3. Including differences in altitude and temperature in standard test conditions, the following conversion must also be made in addition to the conversion from the difference in ft-lb/sec., so the total conversion becomes:

Cummins, SAE or British HP = Metric or Din (German) HP x 0.9808.

Table 14-2-1: Test Standards For Conversions

Measurement System	Altitude or Elevation Ft	[m]	Barometric Pressure Inch Hg.	[Mm. Hg.]	Degrees Temperature and Humidity °F	[°C]	Relative Humidity	Ft-Lb/Sec.	[Kg m/Sec.]
Cummins	500	[152.4]	29.38	[746.25]	85°	[29.4°]	30%	550.0	[76.04]
SAE	500	[152.4]	29.38	[746.25]	85°	[29.4°]	50%	550.0	[76.04]
British	500	[152.4]	29.38	[746.25]	85°	[29.4°]	50%	550.0	[76.04]
Din (German)	984	[300.0]	28.88	[733.55]	68°	[20.0°]	60%	542.5	[75.00]
Metric	984	[300.0]	28.88	[733.55]	68°	[20.0°[	60%	542.5	[75.00]
Sea Level	Sea Level	Sea Level	29.92	[759.97]	60°	[15.55°]	Dry Air	*550.0	[*76.04]

*Horsepower for Metric or Din will be 75.00 Kg m/Sec. or 542.5 Ft-Lb/Sec.

Metric or Din (German) HP = Cummins, SAE or British HP x 1.0197.

Note: The above conversion disregards the very slight percentage of difference in relative humidity between Cummins and SAE or British systems.

4. Units of measurement conversions from one system to another:

a. Altitude or Elevation Conversion 100 feet = 30.48 meters.

b. Barometric Pressure Conversion 1 inch Hg. - 25.4 millimeters Hg.

c. Temperature Conversion
Deg. F = 9/5 x Deg. C + 32.
Deg. C = 5/9 x Deg. F −32.

d. Horsepower Conversion
kg m/sec. x 7.233 = ft-lb/sec.
ft-lb/sec. ÷ 0.13825 = kg m/sec.

Test Procedure

Horsepower Ratings

1. *The maximum horsepower ratings at rpm shown in Table* 14-2-2 "Dynamometer Test Chart" are for engines operating at No. 1 curve or intermittent-duty applications at sea level, 60 deg. F [15.6 deg. C] intake air temperature and 29.92 inch [759.97 mm] Hg (Mercury) barometric pressure.

2. Where it is necessary or desirable to derate because of high altitude operation, or for the sake of fuel economy, etc., the derating may be done by reducing maximum governed rpm or maximum fuel rate in the proportion desired.

3. Naturally aspirated engines must be derated 3% for each 1000 ft [304.8 m] altitude above sea level, and 1% for each 10 deg. F [−5.56 deg. C] ambient temperature rise above 60 deg. F [15.6 deg. C].

4. Turbocharged engines do not require fuel derating below maximum altitudes shown in the "Dynamometer Test Chart." Above maximum altitudes, derate at 4% for each 1000 ft [304.8 m] additional altitude and 1% for each 10 deg. F [−5.56 deg. C] air temperature rise above 125 deg. F [51.6 deg. C].

5. New or newly rebuilt engines during dynamometer tests are not required to deliver more than 96% of maximum horsepower at power checks. The additional 4% will be achieved after a few hours of operation.

Break-In Run

Initial Starting

1. Start engine and idle at approximately 800 rpm no load for five to ten minutes.

2. Check oil pressure and water circulation; look for leaks.

At Each Phase

1. Apply dynamometer load to develop horsepower (± 10%)

Table 14-2-2: Dynamometer Test Chart

Model	Max. Rated HP @ RPM Sea Level	Maximum Fuel Rate LB/HR	Rating @ Altitude Maximum	Crankcase Pressure W/ST-487	Phase 1 To Oil Temp. HP @ RPM	Phase 2 30 Min. HP @ RPM
V-1710-460	460 @ 2100	190	Sea Level	5.0	100 @ 1800	200 @ 2100
V-1710-500	500 @ 2100	200	Sea Level	5.0	100 @ 1800	200 @ 2100
VT-1710-635	635 @ 2100	249	11,000	12.0	100 @ 1800	200 @ 2100
VTA-1710-700	700 @ 2100	270	8,500	12.0	100 @ 1800	200 @ 2100
VTA-1710-800	800 @ 2100	300	7,500	12.0	100 @ 1800	200 @ 2100

Model	Phase 3 45 Min. HP @ RPM	Phase 4 30 Min. HP @ RPM	Phase 5 30 Min. HP @ RPM	Phase 6 30 Min. HP @ RPM	Phase 7 30 Min. HP @ RPM	Power Check 30 Min. HP @ RPM
V-1710-460	300 @ 2100	375 @ 2100	415 @ 2100	---	---	442/460 @ 2100
V-1710-500	300 @ 2100	400 @ 2100	450 @ 2100	---	---	460/480 @ 2100
VT-1710-635	300 @ 2100	400 @ 2100	550 @ 2100	---	---	609/635 @ 2100
VTA-1710-700	300 @ 2100	400 @ 2100	550 @ 2100	650 @ 2100	---	672/700 @ 2100
VTA-1710-800	300 @ 2100	400 @ 2100	550 @ 2100	650 @ 2100	700 @ 2100	770/800 @ 2100

Notes:

1. Naturally aspirated engines must be derated 3% for each 1000 ft [304.8000 m] above sea level, and 1% for each 10 deg. F [−5.56 deg. C] ambient temperature rise above 60 deg. F [10 deg. C].

2. Turbocharged engines do not require fuel derating below altitude shown in column entitled "Rating @ Altitude Maximum". Above maximum altitude, derate at each 1000 ft [304.8000 m] additional altitude by 4%. Altitude figures are for T-50 turbochargers on VT-1710-635 and VTA-1710-700 engines. T-18A is used on VTA-1710-800.

3. Crankcase pressure with ST-487 is given in inches of water.

at speed (± 5%) shown in Table 14-2-2 "Dynamometer Chart".

2. Check crankcase pressure (blow-by) with ST-487. Refer to Blow-By Readings. If pressure continues to drop, reduce run-in time by half; otherwise, run engine for time period shown on dynamometer chart.

At Phase 1 Only

1. Run engine until lubricating oil temperature reaches minimum 140 deg. F [60 deg. C], do not exceed 225 deg. F [107 deg. C].

2. Add lubricating oil to bring level up to "H" mark on bayonet gauge.

At Phase 2 Only

1. Reset valves and injectors. See Section 14-1.

2. Set engine idle, governed speed and fuel rate.

At Phase 3

If blow-by rises, reduce load to preceding phase and run for 30 minutes; then return to original phase specifications.

At Phase 4

1. Run at speed and horsepower indicated.

2. Check thoroughly for leaks and tighten all exposed capscrews.

At Phase 5

1. Run at speed and horsepower indicated.

2. Check blow-by; if pressure continues to drop, reduce run-in time by half; otherwise, run engine for time period shown on dynamometer chart.

At Phase 6

1. Run at speed and horsepower indicated.

2. Check blow-by; if pressure continues to drop, reduce run-in time by half; otherwise, run engine for time period shown on dynamometer chart.

At Phase 7

1. Run at speed and horsepower indicated.

2. Check blow-by; if pressure continues to drop, reduce run-in time by half; otherwise, run engine for time period shown on dynamometer chart.

Power Check

1. Run engine at rated speed for 5 minutes. It should develop 96% of rated horsepower at standard fuel rate. Check crankcase pressure (blow-by).

2. If crankcase pressure exceeds value shown, reduce engine speed and load to preceding phase; run engine 30 to 45 minutes.

3. Repeat procedure described above until engine develops 96% rated horsepower at standard fuel rate within permissible crankcase pressure limit.

4. After power check is completed, remove vent plugs in naturally aspirated engine cylinder head (See Group 2) and install ventilator plugs.

5. After power check, connect and adjust aneroid, if used. See Aneroid Control Adjustment.

Checks During Run-In Test

During the period of engine run-in, the following checks should be made frequently:

Lubricating Oil

1. Lubricating oil pressure should remain at or near a constant figure at constant engine speed and load (see Table 14-2-3) after normal operating temperature has been reached. Abnormally high pressures may indicate blocked lubricating oil lines. Abnormally low pressures indicate an insufficient supply of lubricating oil from the pump or increased oil clearances which may be due to bearing failure.

Table 14-2-3: Normal Lubricating Oil Pressure

Idle (525-575 rpm) PSI [kg/sq cm]	Rated Speed (2100 rpm) PSI [kg/sq cm]
15/35 [1.0545/2.4605]	50/90 [3.5150/6.3270]

Note: Individual engines may vary from above pressures.

2. Temperature of lubricating oil should be approximately 225 deg. F [107 deg. C] or less during engine operation. If oil temperature rises sharply above 225 deg. F [107 deg. C], shut down engine and correct as necessary.

3. The new elements in lubricating oil filter will absorb lubricating oil; therefore, engine must be shut down after five or ten minutes of operation and additional lubricating oil added to crankcase to bring oil level to "H" mark on bayonet oil gauge. Check oil level every phase during run-in test.

Engine Coolant

1. After engine is started, add coolant as necessary to completely fill cooling system and replace entrapped air.

2. Coolant should not exceed 200 deg. F [93 deg. C] or drop below 160 deg. F [71 deg. C] during engine operation.

3. Do not turn engine off immediately after a load run. Heat stored in the iron masses will boil coolant in the jackets if air and coolant circulation is immediately stopped while engine is hot. Allow engine to idle for a few minutes before shutting down.

Fuel Pressure

Listed below are three methods of checking fuel manifold pressure. The engine must be at operating temperature and fuel system purged of all air.

1. The preferred method of checking engine manifold pressure is to load engine on an engine or chassis dynamometer as follows.

a. Check governor cut-off:

b. At full throttle increase load until engine is pulled down to rated speed (accurate tachometer must be used). Read fuel manifold pressure. If engine fuel manifold pressure is below minimum or above maximum specifications as listed in Fuel Pump Calibration Manuals 983505 (PT type R) or 983525 (PT type G), make the following adjustments:

To Raise Pressure:

(1) Screw out maximum throttle rear-stop screw and utilize throttle restriction that may be present.

Caution: Do not turn screw out beyond maximum throttle opening point; otherwise dead throttle travel may occur.

(2) Remove throttle shaft and add fuel adjusting shims as required.

Caution: Under no circumstances should engine manifold pressure be set above maximum specifications. Doing so will void engine warranty.

To Decrease Pressure:

(1) Remove throttle shaft and remove shims as required.

(2) It should not be necessary to adjust fuel manifold pressure on a newly calibrated pump more than 5 psi [0.3515 kg/sq cm]. If adjustments greather than these are required, fuel pump test, injector test stand or engine problems may exist.

2. The next best method of checking maximum engine fuel manifold pressure (engine installed in vehicle) is to note maximum pressure while accelerating at full throttle when going up through the transmission ratios. With proper gauge snubbing, this method can be relatively accurate, especially if a heavy load is being pulled and engine acceleration in higher gears is slow.

3. The least preferred method of checking maximum engine fuel manifold pressure is the so-called "snap" pressure check method.

a. The "snap" method is not as reliable as method 1 and 2 because the pressure reading is of very short duration. Gauge inertia, the degree of throttle manipulation, also reduces the reliability of "snap" pressure readings.

b. To take "snap" pressure readings, attach the ST-435 pressure gauge at the shut-down valve in the usual manner. Fig. 14-2-6.

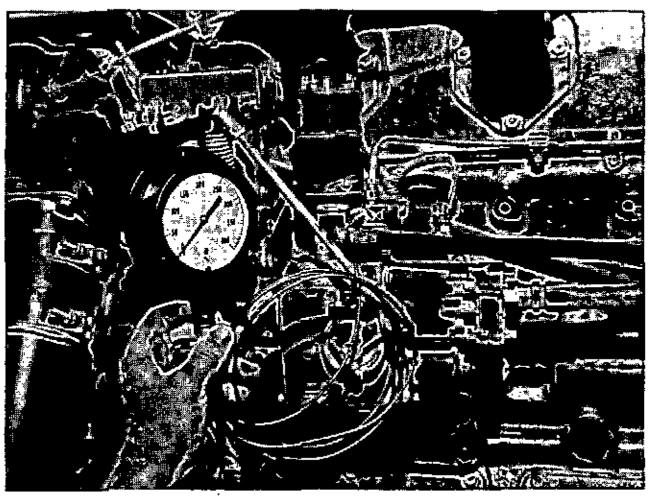


Fig. 14-2-6, F5203. Checking fuel manifold pressure with ST-435

c. Disconnect throttle control linkage at throttle lever. Move lever clockwise against stop.

d. Start engine and run engine speed up to 200 to 300 rpm above idle by opening throttle slightly; then snap throttle to fully open position and permit engine to accelerate to maximum speed while observing pressure gauge. Note momentary maximum pressure. Take this reading several times.

Notes:

(1) Due to its poor reliability and inherent inaccuracy this check should not be used to gauge fuel pump test stand calibration accuracy.

(2) On turbocharged engines having aneroids, it is necessary that fuel routing through the aneroid be blocked or removed when making "snap" pressure checks.

Fuel Lines

Check all fuel lines and fuel connections; see that they are tight and not leaking.

Lubricating Oil Lines

Check all lubricating oil lines and connections; see that lines are not leaking oil.

Overspeed Stop

1. Overspeed stops, when used, are set to trip and shut off fuel supply when engine exceeds maximum rated speed by approximately 15%. Under certain conditions, overspeed stops may permit enough fuel to pass to operate engine at idling speed.

2. After determining and correcting cause of overspeed stop trip, reset in running position.

Engine Fuel Rate

Engine fuel rate (fuel consumption) in lb per hr. is measured by using ST-502 Flow Tank, or a suitable means of weighing the fuel.

1. The fuel rate specified in fuel pump calibration specifications is at full throttle and rated speed. Reference PT Pump Calibration manuals, Bulletin Numbers 983525 (PT type G) or 983505 (PT type R).

2. An engine dynamometer, chassis dynamometer or other controlled means of loading engine must be used. Accurate fuel manifold pressure and speed readings must also be taken.

3. To check engine fuel rate, load engine at full throttle until engine speed is pulled down to, and kept at, rated speed (check governor cut-off speed as described above while loading engine). Note fuel manifold pressure at rated speed. Hold engine speed and load stable at rated speed long enough for flow meter float to stabilize. Take fuel rate reading.

4. If weight scales are used, hold load and fuel manifold pressure stable with full throttle at rated speed. With stop watch or other suitable timer, check number of pounds of

fuel to be used in a five-minute period of time (this can then be multiplied by twelve, giving the lb per hr. fuel rate). Run several checks and average the readings, if they vary several lb. Note full power smoke level for use in analyzing engine performance.

Blow-By Readings

1. Manometer readings must be taken frequently during run-in test so test mechanic will note any blow-by increase at a given speed and load. If there is any indication of blow-by increase, engine speed must be reduced for a few minutes and then brought back to the original setting.

2. During each power check, keep a constant check on the manometer; if pressure rises, more run-in is required. Representative pressure limits for engine running at governed speed and pulling 96 to 100% of rated horsepower are given in Table 14-2-2.

3. If crankcase pressure, or blow-by, is greather than values listed in Table 14-2-2 at end of testing period, engine should be checked as follows.

4. Conditions under which engines exceeding maximum blow-by limits (specified in table) during break-in may be accepted are:

a. Naturally aspirated engines:

Operate 30 minutes extra at 96 to 100% rated load and rpm. If there is no rapid change in excess of 1 inch [25.4000 mm] of water and maximum reading does not exceed 125% of representative pressure, blow-by is acceptable.

b. Turbocharged engines:

Operate 30 minutes extra at 96 to 100% rated load and rpm. If there is no rapid change in excess of 2 inch [50.8000 mm] of water and reading does not exceed 125% of representative pressure, blow-by is acceptable.

Load Applications (Installed Engine)

After run-in procedure described above, it should be explained to the operator that during long hard pulls in excess of ten minutes of continuous operation, it is best to drop to a lower gear to prevent maximum horsepower demand during first 50 hours of operation. This gives new parts a chance to "wear in" without undue stress and strain.

Maintenance Of Dynamometer

Follow manufacturer's maintenance instructions to service dynamometer.

Calibrating Instruments

1. Keep beam or spring scales properly calibrated.

2. Follow manufacturer's recommendation when recalibrating is necessary.

3. If instruments need adjustment, follow manufacturer's instructions.

In-Chassis Run-in

In-chassis repaired engines should receive run-in equivalent to that on an engine dynamometer. Follow procedure given below after an in-chassis repair or rebuild.

1. Start engine. Idle at 800 to 1000 rpm, no-load, for 5 to 10 minutes.

2. Check oil pressure and water circulation. Correct any leaks.

3. Operate at 1/4 to 1/2 throttle for first 5 to 10 hours.

4. Operate at 1/2 to 2/3 throttle for next 50 to 100 hours.

5. Do not operate engine at full load and speed in excess of 5 minutes continuously at any time. After 5 minutes full power run, drop back to 3/4 throttle.

6. During the first 100 hours' service:

a. Do not idle engine for long periods as this will cause cylinder walls to glaze before piston rings seat properly and result in excessive lubricating oil consumption.

b. Watch instruments closely. Decrease engine rpm if oil temperature reaches 250 deg. F [121 deg. C] or if coolant temperature exceeds 190 deg. F [88 deg. C].

c. Operate with a power requirement low enough to allow acceleration to governed speed under any condition.

SG Hydraulic Governor Adjustment

1. Governor to fuel pump linkage must be corrected with both fuel pump throttle and governor terminal shaft in fuel shut-off position. The fuel pump throttle will be all the way down and the terminal shaft on right side of governor will be in extreme clockwise position.

2. Adjust high-limit adjusting screw so it contacts its stop when fuel pump throttle is in full-fuel position.

3. Start engine.

4. Adjust low-limit adjusting screw for correct idling speed of 515 to 525 rpm. With this idling adjustment, some arrangement must be provided for an over-riding shut-down

lever.

5. If engine speed varies too much between full-load and no-load conditions, the speed droop should be decreased. If governor "hunts", the speed droop should be increased. To change speed droop:

a. Remove cover from governor.

b. To increase speed droop: Loosen speed droop adjusting screw and move an additional 1/16 inch [1.5875 mm] toward outside of case; tighten screw.

c. To decrease speed droop: Move speed droop adjusting screw toward center of case.

Torque Converter Governor (PTR Fuel Pump)

When a torque converter is used to connect engine with its driven unit, an auxiliary governor may be driven off torque converter output shaft to exercise control over engine governor and limit converter output shaft speed. The engine governor and converter governor must be adjusted to work together.

The PT torque converter governor is fundamentally two mechanical variable-speed governors in series—one driven by engine, the other by converter. See Fig. 14-2-7.

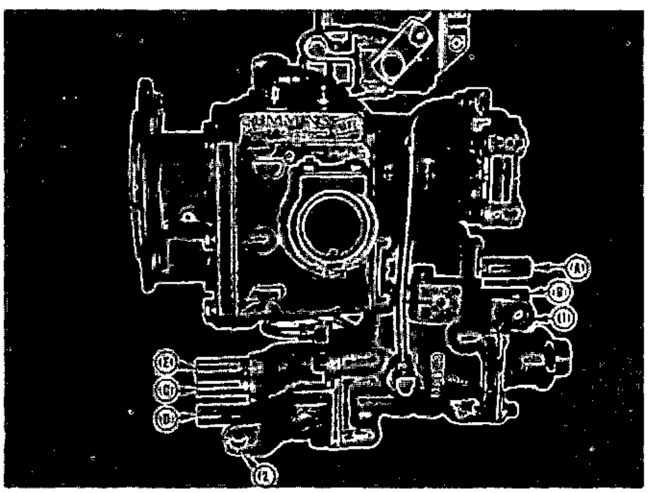


Fig. 14-2-7, F595. PT (type R) fuel pump with torque converter governor

The engine governor gives a variable engine speed and acts as an over-speed and idle-speed governor, while the converter-driven governor is controlling the engine. Each governor has a control lever (1, engine lever and 2, converter lever) and speed-adjusting screws.

The converter-driven governor works on the same principles as the standard engine governor, except it cannot cut off fuel to the idle jet in engine-driven governor insuring that, if the converter tailshaft overspeeds, it will not stop the engine.

Initial Adjustment

1. Disconnect torque converter governor flexible drive cable or declutch converter from engine so engine governor will have complete control of engine. Disconnect drive cable at converter to prevent cable from whipping.

2. Hold converter governor lever in clockwise position and turn in converter governor idle screw "C" Fig. 14-2-7 until spring is compressed. Turn adjusting screw out, then back in slowly to check adjustment.

3. Start engine and rotate engine governor lever in a clockwise direction. Set engine idle speed by adjusting the idle screw "A" to get 515 to 700 rpm.

4. Set approximate engine maximum no-load speed by adjusting maximum-speed screw "B" while holding engine governor lever against stop; turn lever in counterclockwise direction.

5. Stop engine and engage torque converter clutch or connect flexible drive cable to torque converter governor. Make sure engagement is made so torque converter drives the governor. The flexible cable should have 10 inch [254.000 mm] radius bends, or larger, for satisfactory service life.

6. Start engine and bring speed to 1000 rpm with engine governor lever.

7. Advance speed of engine until it reaches rated speed of converter tailshaft.

8. Decrease speed at torque converter governor by adjusting screw "C" out until converter speed can be controlled by converter governor lever; turn lever in a counterclockwise direction.

9. Advance engine governor to maximum speed position.

10. If unit has a single-speed setting:

a. Adjust screw "C" to get rated no-load tailshaft speed of converter.

b. Adjust screw "D" until converter governor lever is locked in place.

11. If unit has a two-speed setting:

a. Adjust screw "C" to get no-load tailshaft speed of converter.

b. Adjust screw "D" until reaching maximum converter speed desired.

Adjustments For Minimum Fuel

1. Operate engine at full speed, no-load, with tailshaft governor in operation.

2. Loosen screw ("C" Fig. 14-2-7) and back out approximately 3/4 inch [19.0500 mm].

3. Move converter governor throttle lever counterclockwise, reducing engine speed to 400 rpm. Hold this position.

4. Loosen screw "E" and turn clockwise approximately 1/16 inch [1.5875 mm], increasing engine speed to 450 rpm.

5. Lock screw "E" in position; readjust screw "C" as described previously.

Stall-Speed Settings

Where a given speed is important with converter output shaft stalled, check as follows:

1. Stall converter and check engine speed.

2. If engine rated speed is excessive, adjust engine governor maximum-speed adjusting screw "B", or if governor adjustment does not affect unit, decrease fuel delivery.

3. If engine speed is low, adjust engine governor maximum-speed adjusting screw "B", or if governor adjustment does not affect unit, the fuel delivery must be increased. Check fuel delivery on a pump test stand.

Changing Speed Droop Of Converter Governor

Due to variety of applications, converter ratios and operator preference for different operating characteristics, converter governor spring furnished in fuel pump may not give desired speed droop. Speed droop is controlled by changing springs. Refer to PT Fuel System Parts Book for up-to-date listing of springs.

Adjustments For Unstable Speeds

1. Start with minimum output shaft speed setting. Loosen pump throttle screws and adjust throttle shaft; turn in counterclockwise direction increasing engine speed 10 to 15 rpm. Continue throttle screw adjustment one-half turn of screws or approximately 10 to 20 rpm more and lock in place.

Note: Make check with a hot engine only.

a. If throttle leakage is too high, engine will tend to overspeed after load is released; engine rpm will stay up.

b. If throttle leakage is too low, engine speed will surge or be unstable at half or no-load.

2. If necessary, readjust converter governor speed-adjusting screws as described in Steps 10 or 11 to get maximum speed from unit.

Aneroid Control Adjustment

The aneroid bellows spring is preset and sealed at Cummins Engine Company, Inc. Only adjustments described in "Group 10, Unit 1003" are to be made on the aneroid. The following adjustment can be made while the engine is on a dynamometer.

Installation—Final Setting

1. Connect line from aneroid to air intake manifold.

2. Remove air filter and fill aneroid with clean lubricating oil. Reinstall air filter.

3. Start engine and check idle speed. In most cases, idle will be low and must be adjusted upward with fuel pump governor idle screw.

4. Check engine rated power and speed. If smoke is not excessive during first 15 seconds of full throttle operation, but becomes excessive thereafter, aneroid is not at fault.

Check fuel system and turbocharger before readjusting aneroid control.

5. If hard starting is encountered, the aneroid pressure valve may be sticking in open position. Replace, if necessary.

Note: The pressure valve sticking in closed position will result in excessive smoke.

6. Accelerate the engine from idle to full throttle and check for excessive smoke. Smoke density should not exceed No. 3 Ringelman during acceleration. Adjust fuel screw as described in "Group 10, Unit 1003".

Natural Gas Engine Adjustments

Mag-tronic Ignition Timing

1. Attach a timing light to No. 1 cylinder ignition transformer. If a low-voltage timing light is not available, it will be necessary to either:

a. Remove the ignition transformer from No. 1 cylinder and attach timing light to the high-tension terminal.

b. If an extra ignition transformer is available, it may be connected in parallel with the No. 1 cylinder ignition transformer to allow use of a high-voltage timing light.

2. Start engine and rotate "Mag-tronic" to obtain correct timing with timing light directed toward timing mark on accessory drive pulley and timing pointer at engines rated speed. Secure "Mag-tronic" in desired position.

Field Adjustment – Carburetors

1. Close main gas supply valve.

2. Set the carburetor power mixture adjustment valve at center between "R" (Rich) and "L" (Lean) marks.

3. Close the idle adjustment; then open two and one-half turns.

4. Remove pipe plug and attach a pressure gauge (water manometer) between the main line passage regulator and the "Thermac" pressure reduction valve. Also remove the pipe plug and attach a pressure gauge (water manometer) on the "Thermac" pressure reduction valve. See Fig. 14-2-8.

5. Remove pipe plug from intake manifold and install a vacuum gauge or mercury manometer.

The intake manifold adjustment on the GV12 engine is a dual operation and requires a power adjustment of each of the two carburetors plus an adjustment of the carburetor butterfly. This butterfly adjustment is made by attaching a "U" tube mercury manometer 15 inches to 0 to 15 inches range to each intake manifold. Rated speed and load must be maintained and the throttle butterfly of one carburetor adjusted open to decrease the vacuum, closed to increase the vacuum to correspond the equal the vacuum of the opposite manifold. The final power adjustment is to be made with equal manifold vacuum and exhaust stack temperature.

6. Open the main line gas supply valve.

7. Adjust line gas pressure to the "Thermac" pressure reduction valve to 10 inches [254.000 mm] of water.

8. Start the engine, using normal starting procedure.

9. Adjust gas pressure to carburetor to 3 inches of water with engine running at 600 to 700 rpm by adjusting "Thermac" pressure reduction valve screw. This adjustment is very important and must be accurately accomplished as

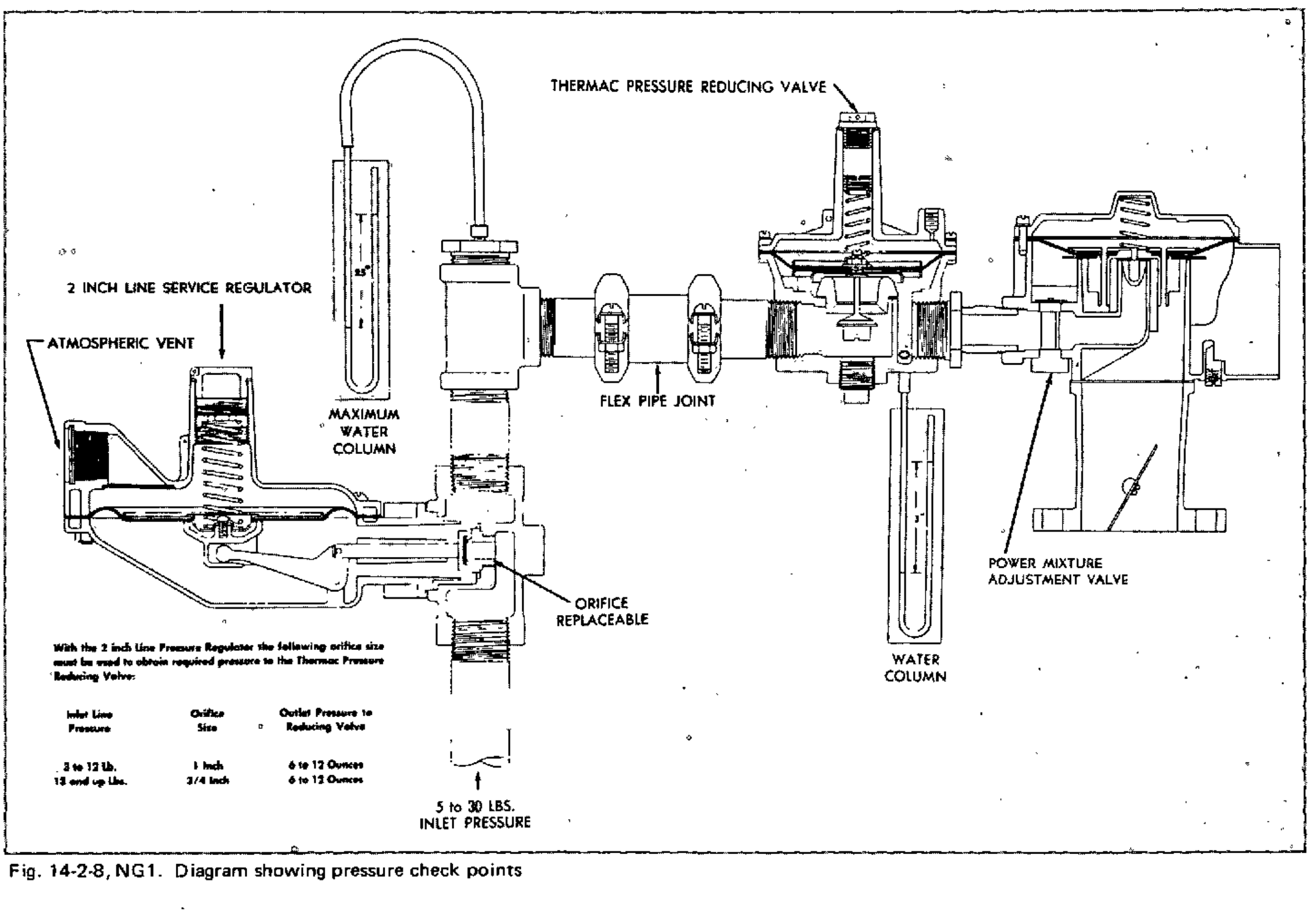


Fig. 14-2-8, NG1. Diagram showing pressure check points the engine fuel economy and power output are directly affected by any variation in inlet gas pressure at the carburetor.

a. Remove cap from "Thermac" pressure reduction valve.

b. Insert screw driver in adjusting screw, and adjust to obtain desired pressure on water manometer; replace cap.

10. After engine coolant attains operating temperature, operate the engine at rated rpm and system load.

a. Check the carburetor inlet gas pressure. This pressure must remain between 2 to 3 inches [50.8000 to 76.2000 mm] of water when the engine rpm and load varies from rated load and speed to no-load at idle. If gas pressure to carburetor falls below 2 inches [50.8000 mm] of water at full load, this may indicate excessive pipe length, flow restriction between the main line pressure regulator and the "Thermac" pressure reduction valve, defective main line pressure regulator or a defective "Thermac" pressure reduction valve. If this condition exists, proceed with the following:

(1) With the engine operating at system load and speed, check the gas pressure to the "Thermac" pressure reduction valve. If this differs considerably from the pressure as set in Step 7, either the main line pressure regulator is faulty or the main line is undersize. Consult the recommendations and instructions of the main line pressure regulator manufacturer.

(2) Check "Thermac" pressure reduction valve for proper operation with the engine shut down and the main gas valve "on." Apply liquid soap solution to atmospheric vent to check for gas leakage through diaphram.

If proper adjustment cannot be obtained, or "Thermac" valve fails to function properly, remove faulty valve and replace.

(3) To compensate for flow restriction and pressure loss, the main line pressure regulator outlet pressure may be raised to 11 inches of water and Steps 8 and 9 repeated. Continue raising the main line pressure regulator outlet pressure in one-inch increments of water until the 2 to 3 inch [50.8000 to 76.2000 mm] "Thermac"-to-carburetor pressure can be maintained at system load and speed.

Caution: The maximum allowable main line pressure outlet pressure setting is 25 inches [635.0000 mm] of water with the engine shut down. If this does not correct the "Thermac"-to-carburetor gas pressure, check the main line pressure regulator for proper operation per the manufacturer's instructions.

b. With engine running at rated rpm and load, move the carburetor power mixture adjustment valve slowly toward the "L" position. Check the intake manifold vacuum reading until highest vacuum is obtained.

12. Shut down engine.

13. Close the main gas supply valve.

14. Remove the two water manometers and the mercury manometer and replace all pipe plugs.

Derating Procedure

To compensate for intake air temperatures above 60 deg. F [15.5 deg. C] and altitude above sea level, the naturally aspirated gas engine must be derated as follows:

1% per each 10 deg. F [5.56 deg. C] above 60 deg. F [15.5 deg. C] plus 3% for each 1000 ft. [304.800 m] altitude above sea level.

Hydraulic Governor Adjustment

Carburetor Throttle Travel

Carburetors on Cummins Gas Engines have a throttle travel of about 65 degrees from idle to full-open position. A correct relationship between governor lever and carburetor throttle travel must be maintained for proper operation.

Governor Shaft And Linkage Adjustment

After installation of governor level and linkage to carburetor throttle, check carburetor throttle for idle position against the throttle stop pin. If the idle throttle plate adjustment screw does not rest against the stop pin, adjust linkage length until screw rests against stop pin.

Manually lift governor lever through carburetor throttle travel range and check for linkage bind. If necessary, adjust linkage length and carburetor throttle lever position to eliminate any binding through the throttle travel range. Tighten linkage and lever assemblies.

Start engine and adjust low-speed stop screw (atop governor head) for desired idling speed, approximately 600 rpm.

With Motorized Head

1. The governor can be fitted with a speed-adjusting motor to enable the switchboard operator to match the frequency of a generator with that of other units or a system before synchronizing, and to change load distribution after synchronizing.

2. The motor used is of the split-field, series-wound, reversible type.

3. A manual speed-adjusting knob with friction clutch assembly is included on units fitted with a speed-adjusting motor.

4. When used on generator set applications, set the

high-speed setting stop screw at approximately 1854 rpm for 60-cycle units and 1545 rpm for 50-cycle units to obtain 3% speed regulation.

5. Adjust the rated speed to 1800 rpm for 60-cycle units and 1500 rpm for 50-cycle units by means of the motor control at full load.

Speed Droop Adustment

1. Remove the top cover from governor to expose speed droop mechanism and adjustments.

2. The speed droop bracket is clamped to terminal lever by the slotted hexagonal head screw. When loosened, it can be moved to the front or rear. Moving bracket to the rear produces more speed droop.

3. This speed droop lever movement thus produces a speed setting which is a function of terminal shaft position. THIS IS SPEED DROOP.

4. Speed droop is increased by moving the bracket to the rear and is reduced to approximately zero when the pivot pin is all the way forward. Since there is no calibration for the droop adjustment, the zero droop position may be precisely set only by trial and error on the engine or by use of a dial indicator on the speed droop lever during manual rotation of the terminal shaft.

5. Speed droop is required when using SG Woodward Governors. It must be set by operation on the engine. The speed droop bracket is adjusted to obtain the desired speed droop between full load and no load.

Surging

PSG-Type Woodward Governor

1. Turn the compensation needle valve counterclockwise until surging occurs and allow 5 to 10 surges to bleed the air from the governor.

2. Turn the compensation needle valve clockwise until surging stops. (The needle valve is near bottom of governor to rear and facing outside.)

Note: Inadequate droop settings can cause surging on both types of governors.

3. If surging continues at no laod, increase the droop setting (move droop bracket to the rear).

SG-Type Woodward Governor

Follow Step 3 under PSG Type.

Paint Engine

1. Prior to painting, accumulated dust, oil splash and heavy rust may be removed by air blowing, hand wiping with paint thinner, wire brushing or other means to insure a good, clean surface for maximum paint adherence. Dry thoroughly with compressed air.

2. Cover all exhaust and intake manifold openings, starter mounting holes, vents on generator, starter, vacuum pump, pulley grooves and instrument faces.

3. Cover or remove belts.

4. Cover firing order, engine serial number, turbocharger warning and other data plates on engine.

5. Cover exposed threads, wire terminals and hose fittings. Pipe openings, fuel pump drain, fuel manifold drain and oil cooler water connection openings must be capped.

6. Cover clutch contact surface on flywheel with anti-rust compound, if engine is not going into immediate service.

7. Spray outside surfaces of castings and corrodible parts with a primer coat of yellow lacquer to serve as a base for the second coat of engine enamel.

8. Spray complete engine with engine enamel.

Engine Storage—Unit 1403

On any engine not in service, whether installed in equipment or waiting to be installed, the unpainted machined surfaces are subject to rust and corrosion. Often an engine is not prepared for storage with rust-proofing measures taken, because it is not thought that the engine will be out of service for a long period. However, any engine temporarily stored, whether one taken out of service, or a new engine not yet placed in service, is subject to rust damage.

The rate of corrosion varies with climatic conditions. An engine stored in a climate with a high amount of moisture in the air will corrode more rapidly than an engine stored in a dry climate. Variance in climatic conditions makes it impossible to state the length of time an engine can be stored without rust and corrosion damage.

Temporary Storage

If an engine remains out of service for three or four weeks (maximum six months) and its use is not immediately forthcoming, special precautions should be taken to prevent rust. Only the operations listed below are required to minimize or prevent damage resulting from lack of attention to temporarily stored engines.

1. Using diesel fuel, the engine must be started and the speed gradually increased to 1,200 rpm or a fast idle, with no load, and operated until the engine is thoroughly warm.

2. Disconnect both fuel lines at fuel supply tank, the line to engine fuel filter and the injector drain line. Fill two portable containers, one with regular diesel fuel and a second with preservative oil U.S. Military Specification MIL-L-644 Type P-9. Preservative oil to this specification is Daubert Chemical Do., Nox-Rust No. 518 or equivalent. Daubert Chemical address is 2000 Spring Road. Oakville, Illinois.

3. Start the engine with the fuel line to the filter and engine pulling fuel from the can with regular fuel. The injector drain line can flow into the container with regular fuel. After engine is started and running smoothly at idle, switch the fuel line to the container with the preservative oil. Operate five to ten minutes on the preservative oil. Stop the engine and reconnect the fuel lines to the supply tank.

4. The oil sump, fuel filters and fuel tank, if so equipped, must be drained and drain plugs reinstalled. New oil may be added or sump may remain empty until engine is ready for use.

5. Remove engine air line from air cleaner to intake manifolds.

6. Turn fuel pump manual shut-off valve to "off" so engine will not start. With hand or power sprayer, spray SAE 10 lubricating oil into intake manifold and air compressor while cranking engine slowly using intermittent turning of switch key.

7. Cover all intake manifold openings with tape to prevent entrance of dirt and moisture.

8. Cover all engine openings, including coolant inlets, cylinder block, oil breather and crankcase.

9. Drain coolant from cooling system unless it is permanent type antifreeze with rust inhibitor added.

10. Store engine in a place protected from weather where air is dry and temperature uniform.

11. Bar engine crankshaft two or three revolutions each three to four weeks.

Permanent Storage

1. When an engine is to be stored for a long time (six months or more), the lubricating system, cooling system, fuel system, crankcase and external parts must be protected against rust and corrosion.

2. Using diesel fuel, the engine should be started and the speed gradually increased to 1200 rpm or a fast idle, with no load, and operated until the engine is thoroughly warm. Stop engine and drain old oil.

3. Fill crankcase to full mark on bayonet gauge or dipstick with preservative oil, U. S. Military Specification MIL-L-21260, type P-10, Grade 2 SAE 30. This specification may be obtained as Shell-Brand Code 66202, Texaco Preservative Oil 30 or equivalent.

4. Disconnect both fuel lines at fuel supply tank, the line to engine fuel filter and the injector drain line. Fill two portable containers, one with regular diesel fuel and a second with preservative oil U.S. Military Specification MIL-L-644 Type P-9. Preservative oil to this specification is Daubert Chemical Co., Nox-Rust No. 518 or equivalent. Daubert Chemical address is 2000 Spring Road, Oakville, Illinois.

5. Start the engine with the fuel line to the filter and engine pulling fuel from the can with regular fuel. The injector drain line can flow into the container with regular fuel. After engine is started and running smoothly at idle, switch the fuel line to the container with the preservative oil. Operate five to ten minutes on the preservative oil. Stop the

engine and reconnect the fuel lines to the supply-tank.

6. The fuel tank, if so equipped, must be drained and drain plug reinstalled. Cover filler vent with tape.

7. Drain all oil sumps of pumps and compressors, coolers, filters, and crankcase. Replace all plugs after draining.

8. Remove intake and exhaust manifolds.

9. Spray all intake and exhaust ports, including air compressor intake port, with preservative oil.

10. Replace intake and exhaust manifolds.

11. Inspect coolant in cooling system. If coolant is contaminated, drain and flush, fill with rust preventive compound. Drain while hot and replace plug. Use a water soluble oil with anti-rust inhibitors obtainable from your oil company. Soluble oil requires thorough flushing of cooling system before placing in service.

12. If air starter is used, remove exhaust plate from top of starting motor and spray with preservative oil. Replace exhaust plate.

13. Loosen V-belt tension.

14. Brush or spray a film of rust preventive compound on all exposed, unpainted surfaces of engine. Use a rust preventive conforming to Type P-2, grade 1 or 2, as described in U. S. Military Specification MIL-C-16173C. C-16173-C specifications can be Daubert Chemical Co., Nox-Rust 207, E. F. Houghton Co., Cosmoline 1046, Pennsylvania Refining Co. Petrotect 3 or equivalent.

15. Remove cylinder head covers and spray preservative oil over rocker levers, valve stems, springs, guides, crossheads and push tubes. Replace Cover.

16. Cover all engine openings, including manifold exhaust and intake ports, coolant inlets to cylinder head and block, oil breather and crankcase, with heavy paper and tape.

17. Tag engine to indicate that it has been treated with preservatives and should not be barred over until ready to run due to possible reduction of the protective film. Tag should show coolant has been removed. The tag should show date of treatment and indicate that engine is not ready to run without prior removal of film.

18. Store engine in a place protected from weather and where air is dry and temperature uniform, if possible.

Note: Engines in storage more than 24 months should, if practical, be thoroughly flushed out with a suitable solvent or light, hot oil and then be reprocessed with rust preventive materials. Periodically inspect engines for rust or corrosion. Take corrective action if necessary.

19. Although the preservative materials may be added to and used for the same purpose repeatedly, they must be kept clean. When repeatedly used, the accumulated deposits should be removed after being allowed to settle.

Preparing A Stored Engine For Service

When an engine is removed from storage and put into service, the operations listed below should be performed. Inspections will be limited to operations indicated for applicable length of storage time.

Clean Engine

1. Clean off all accummulated dirt from exterior of engine.

2. Remove all paper covers, tape and wrappings.

3. Use suitable solvent, cleaner or degreaser to remove rust preventive compound from unpainted surfaces of the engine.

4. Refill crankcase with clean lubricating oil.

5. Flush cooling system.

Inspection

1. When an engine has been stored for six months or less, it is necessary to make only a routine initial inspection. This inspection includes adjustment of injectors, valves and belts, and checking head capscrews, oil filter and connections, air filter, screens and traps.

2. When an engine has been stored for a period of six months or more, the following inspection procedure should be followed:

a. Flush entire fuel system with clean fuel oil until all preservative oil is removed.

b. Remove plug from oil header and force hot, light mineral oil through the oil passages to flush away all preservative oil and gummed oil that may have accumulated. Bar engine over three or four times during flushing operation.

c. Remove all screens and check to make sure they are clean before engine is started.

Precautions

1. When the combustion chambers are treated, remember that total volume of combustion space is small and any excessive preservative oil may cause hydraulic lock, seriously damaging engine if it is started before all the oil is removed.

2. When recommissioning a stored engine, care should be taken to see that any foreign matter which may collect on screens and strainers during initial operation is removed before considering the engine properly prepared for future service.

3. Pressurize the lubricating system including the turbocharger or supercharger prior to starting the engine.

Caution: Always consult the nearest Cummins Distributor or Manufacturer of the preservative oil or compound for the proper grade and kind of oil for preservation of the engine if there is a question regarding the correct oil.

Starting The Engine

After inspecting engine and parts, make sure all preservative oil and gummed oil has been flushed away. Start engine as described in Section II of Operation and Maintenance Manuals.

Instruments and Controls

The instruments show at all times how to get the most satisfactory service from an engine. Safety controls are used on Cummins Engines to shut down the engine because of high coolant temperature, low or loss of lubricating oil pressure and engine speeds above rated rpm.

Engine Safety Controls—Unit 1501

Sentinel Safety Control System

The Sentinel Safety Control System is a complete mechanical system which uses engine lubricating oil pressure as a control medium.

The basic component of the Sentinel System is the Oil Sentinel which contains a flow passage for engine fuel supply and a cavity for high-pressure lubricating oil. A spring-loaded balanced piston within the housing allows fuel to flow unrestricted when there is sufficient lubricating oil pressure. When lubricating oil pressure falls below a preset point, fuel supply is restricted or shut off completely, thus reducing power output or shutting the engine off. A cam arrangement is included to permit a small amount of fuel to by-pass for starting. This override is automatically reset when sufficient lubricating oil pressure is produced. Lubricating oil pressure setting is 10 psi [0.7030 kg/sq cm], but when Oil Sentinel is installed in high-pressure fuel line, the setting increases as pressure increases on fuel system side of the piston. Approximate oil pressure setting with various fuel pressures is shown in Table 15-1-1, with safety control mounted in high-pressure fuel line.

Temperature sensing units in this system are dump valves which open when temperature of coolant or oil exceeds specified setting. Oil pressure is reduced and the Oil Sentinel is actuated. Oil released from Heat Sentinel is returned to oil pan. The following Heat Sentinel settings are used and identified by color indicator on end of unit cap:

1. Coolant temperature — 200 deg. F setting (blue cap).

2. Coolant temperature — 190 deg. F (green cap) (for applications above 5000 ft. altitude).

3. Oil temperature — 255 deg. F (red cap).

Installation

When installing Sentinel System, the manufacturer recommends that reasonable care be taken not to restrict flow between Oil Sentinel and Heat Sentinel(s). This allows oil to flow freely if Heat Sentinel actuates, thus dropping oil pressure in the Oil Sentinel sufficiently to shut off fuel supply. To prevent restriction in this line no more than two 90 deg. fittings should be used in each Heat Sentinal dump circuit, including angle fittings or tee's at Oil Sentinel outlet; the hose sizes specified as follows must be used:

1. Oil Sentinel. Oil inlet from pressure gallery of engine uses 1/8 inch I.D. flexible line.

2. Oil Sentinel Outlet to Oil Inlet of Heat Sentinel uses 5/16 inch I.D. flexible line.

3. Fuel inlet and outlet line of Oil Sentinel uses 3/8 inch I.D. tubing.

4. Heat Sentinel Oil inlet and outlet uses 5/16 inch I.D. flexible lines. Outlet connectors to non-pressure opening in block or oil pan.

Mounting bracket for Oil Sentinel has been designed to attach to fuel pump mounting flange. Metal fuel lines (3/8 inch NPT fittings and related size lines) are used between fuel pump and Oil Sentinel and to the fuel manifold.

The Oil Sentinel may be remotely mounted if desired and plumbed to the fuel line between the fuel tank and fuel pump. This low-pressure installation eliminates advantage of an increasing oil pressure setting with increased fuel pressure during engine operation.

When measuring coolant temperatures, install the Heat Sentinel in a water outlet manifold or thermostat housing. When measuring oil sump temperature, install the Heat Sentinel in oil pan with a 1/2 inch NPT tapped hole below the low oil level and install drain line in a convenient opening in pan.

The following table indicates the approximate oil pressure required to maintain unrestricted engine operation with corresponding fuel system pressures. Pressure balance between oil system and fuel system determines when fuel flow becomes restricted and shuts down the engine.

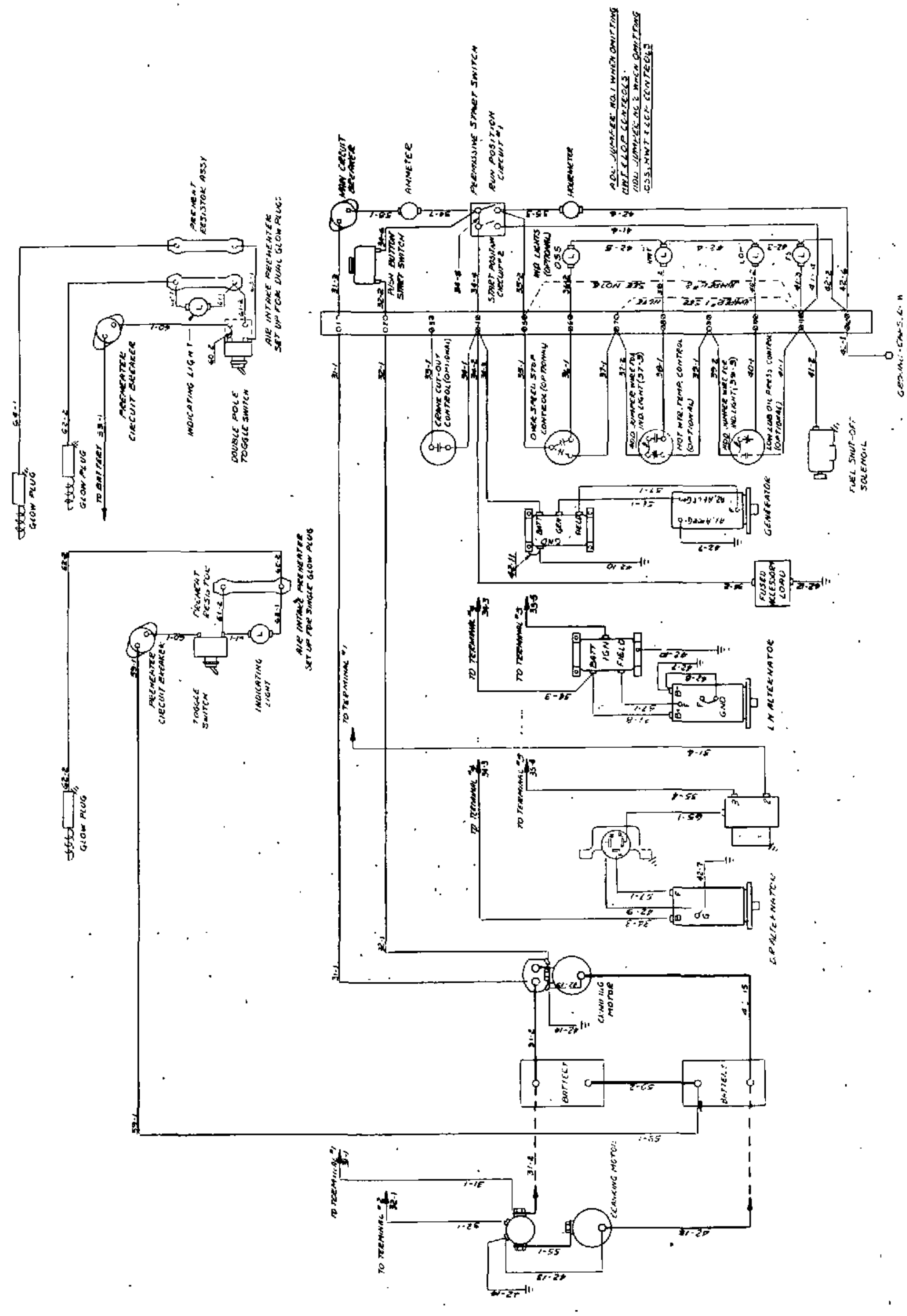


Fig. 15-1-1, V11306. Wiring diagram

Table 15-1-1: Oil Pressure vs. Fuel Pressure Settings

Oil Pressure	Fuel Pressure
10	0
14	25
18	50
22	75
26	100
30	125
34	150
38	175
42	200
46	225
50	250
54	275
58	300

Refer to Sentinel Maintenance Manual for trouble shooting and rebuild procedure.

Nason Safety Control

The Nason Safety Control System provides protection from low lubricating oil pressure and excessive high coolant temperature of preset valves. When either is exceeded, the controls disrupt the electrical circuit to the fuel solenoid shut-down valve and shuts down the engine. The oil pressure safety control is mounted with a short pipe nipple in a main oil gallery.

The temperature safety control mounts directly in the thermostat housing or water manifold as required. This safety control system necessitates use of a progressive toggle switch as a permissive starting switch and a push button type cranking motor switch. When using the Nason Safety Control System, omit the cranking motor switch relay normally used with positive engagement starters; see wiring diagram Fig. 15-1-1.

Speed Switch

Speed switches are used on these engines as an overspeed stop to flash the generator field and to de-energize the automatic start stop panel or to break the cranking circuit. These units operate at 1800 or 2100 rpm.

Removal

1. Disconnect and tag all electrical wiring from terminals of speed switch.

2. Unscrew speed switch from tachometer drive adapter on fuel pump; lift off switch.

Installation

1. Position speed switch over tachometer drive inserting mating drive couplings; screw switch on adapter.

2. Remove tags from electrical wiring and connect to corresponding terminals.

Cleaning And Lubrication

Clean weight assembly every 2500 hours or once a year as follows:

1. Before disassembly mark cap (A, Fig. 15-1-2) position on body (F) with scribe to insure correct reassembly.

2. Break lockwire and remove guide screws (C) securing cap to body; lift off cap.

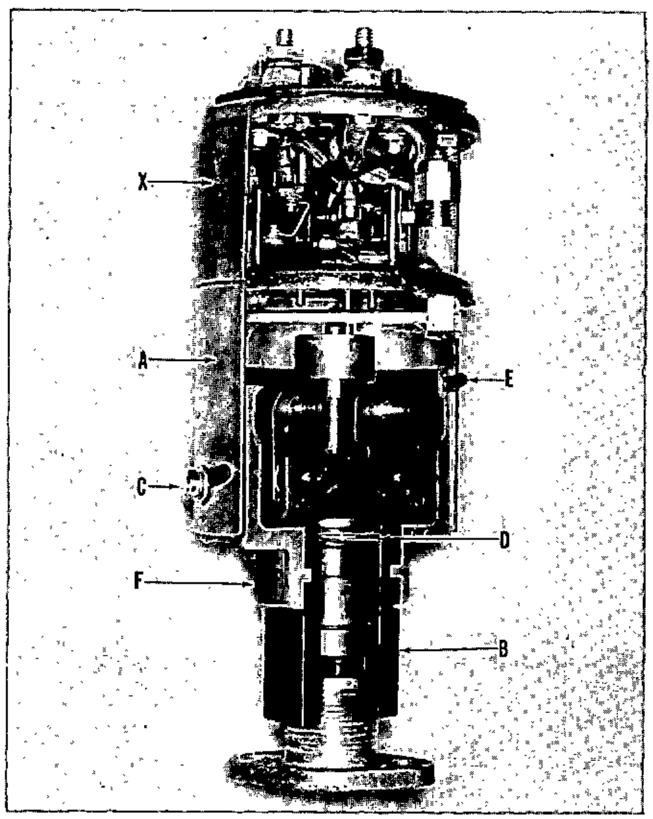


Fig. 15-1-2, CGS72. Synchro-Start switch — Cutaway

3. Remove body from drive.

4. Wash weight assembly in diesel fuel and dry thoroughly. Do not lubricate weight assembly.

5. Install body (F) on drive.

6. Position cap (A) on body (F) and align scribe marks.

7. Secure cap to body with guide screws (C); install lockwire.

Clean and repack grease reservoir every 5000 hours or 2 years.

1. Before any disassembly, mark the relative location of the governor cap (A) and body (F), so they are reassembled in same position.

2. Remove the adjusting guide screws (C).

3. Remove the governor cap (A) from the body (F).

4. Remove assembly retaining ring (D) using a Waldes Tru-arc Pliers No. 1 or No. 21.

5. Remove the weight and shaft assembly.

6. Clean the bearings and shaft. Repack the space between the bearings to approximately 3/4 full of grease such as Texaco "Unitemp," Standard Oil Beacon 235 or equivalent.

7. Assemble governor and shaft assembly after checking the parts. Replace any parts worn or damaged. Lock the assembly in place with the retainer ring (D).

8. Clean the (O) ring (E) and apply a small amount of oil or grease to facilitate assembly of the governor cap (A).

9. Remove flathead screws securing switch assembly and dust cap (X) to cap (A); lift up dust cap and blow dust from switches and dust cap.

10. Position dust cap (X) on cap (A) and secure with flathead screws.

11. Operate the unit to double check the tripping speed or speeds if a multiple element switch is used.

Testing And Adjustment

The testing and adjusting procedure can best be accomplished if the switch is mounted atop a fuel pump to the tachometer drive shaft, installed on a fuel pump test stand.

Single Switch

Test

1. Connect ohmmeter leads to terminals C and NO. Ref. Fig. 15-1-3.

2. Advance test stand rpm and observe ohmmeter. Ohmmeter should indicate switch closes its contacts at 200 ± 40 rpm above rated speed.

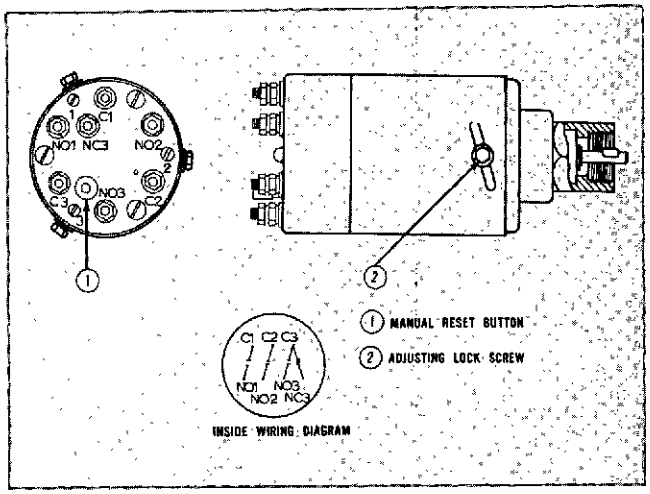


Fig. 15-1-3, CGS26. Single engine control speed switch

3. Decrease test stand rpm and observe ohmmeter. Ohmmeter should indicate switch opens its contacts 100 rpm below rated speed.

4. Should switch not open or close at above rpm, adjust as follows.

Adjustment

1. Remove lockwire from metal screws in diagonal slots securing outer case to inner case.

2. Loosen screws and rotate outer case counterclockwise to increase, or clockwise to decrease, switch actuating or closing rpm.

3. Connect ohmmeter leads to terminals C and NO to indicate switch action and turn switch outer case counterclockwise to set switch action above desired rpm.

4. Advance fuel pump test stand to 200 ± 40 rpm above rated speed. Slowly turn outer case clockwise while observing ohmmeter until switch is actuated, closing its contacts.

5. Decrease test stand rpm and observe ohmmeter. Switch should open 100 rpm below rated speed.

6. Recheck switch closure at 200 ± 40 rpm above rated speed and opening 100 rpm below rated speed.

7. After Step 6 has been obtained, tighten metal screws and insert lockwire. Should either Steps 4 or 5 not be obtained, switch is defective and must be replaced.

Double Switch

Test

1. Switch 1. Ref. Fig. 15-1-4.

a. Connect ohmmeter leads to terminals C1 and NO1.

b. Advance test stand rpm and observe ohmmeter. Ohmmeter should indicate switch closes contacts at 1450 ± 40 rpm.

c. Decrease test stand rpm and observe ohmmeter. Ohmmeter should indicate switch opens contacts above 1200 rpm.

2. Switch 2. Ref. Fig. 15-1-4

a. Connect ohmmeter leads to terminals C2 and NC2.

b. Advance fuel pump test stand rpm and observe ohmmeter. Ohmmeter should indicate switch opens its contacts at 2070 ± 40 rpm.

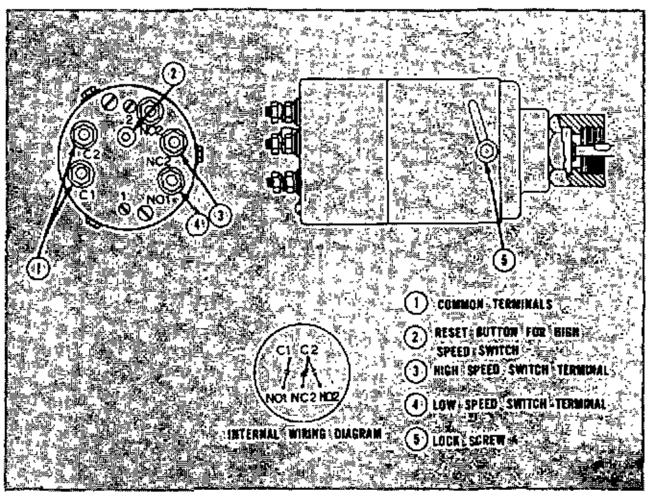


Fig. 15-1-4, CGS27. Double engine speed switch

c. Switch 2 only must be manually reset (closed) by pressing reset button in center of switch when pump speed is below 1700 rpm.

3. Should either switch not open or close at specified rpm, adjust switch as follows:

Adjustment

1. Switch 1.

a. Remove slotted screw marked No. 1; insert an Allen wrench through opening into speed adjusting screw. Turn speed adjusting screw clockwise to increase, or counterclockwise to decrease, switch actuating rpm.

b. Connect ohmmeter leads to terminals C1 and NO1; turn speed adjusting screw clockwise to set switch action above 1500 rpm.

c. Advance fuel pump test stand to 1450 ± 40 rpm. Slowly turn speed adjusting screw counterclockwise, while observing ohmmeter, until switch is actuated, closing its contacts.

d. Decrease test stand rpm and observe ohmmeter. Switch should open above 1200 rpm.

e. Recheck switch closure at 1450 ± 40 rpm and opening above 1200 rpm.

f. After Step "e" has been obtained, remove Allen wrench and install slotted screw. Should either Step "c" or "d" not be obtained, switch is defective and must be replaced.

2. Switch 2.

a. Remove slotted screw marked No. 2; insert an Allen wrench through opening into speed adjusting screw. Turn adjusting screw clockwise to increase, or counterclockwise to decrease, switch actuating rpm.

b. Connect ohmmeter leads to terminals C2 and NC2; turn speed adjusting screw clockwise to set switch action above desired rpm.

c. Advance fuel pump test stand to 2070 ± 40 rpm. Slowly turn speed adjusting screw counterclockwise while observing ohmmeter, until switch is actuated, opening its contacts.

d. Slow down test stand rpm; push down on re-set button, advance test stand rpm and check ohmmeter for switch opening at specified rpm (2070 ± 40).

e. After Steps "c" and "d" have been obtained, remove Allen wrench and install slotted screw. Should either Step "c" or "d" not be obtained, switch is defective and must be replaced.

Triple Switch

Test

1. Switch 1. Ref. Fig. 15-1-5.

a. Connect ohmmeter leads to terminals C1 and NO1.

b. Advance fuel pump test stand rpm and observe ohmmeter. Ohmmeter should indicate switch closes its contacts at 575 ± 20 rpm.

c. Check to be sure switch contacts open when fuel pump speed is slowly decreased to 0.

2. Switch 2. Ref. Fig. 15-1-5.

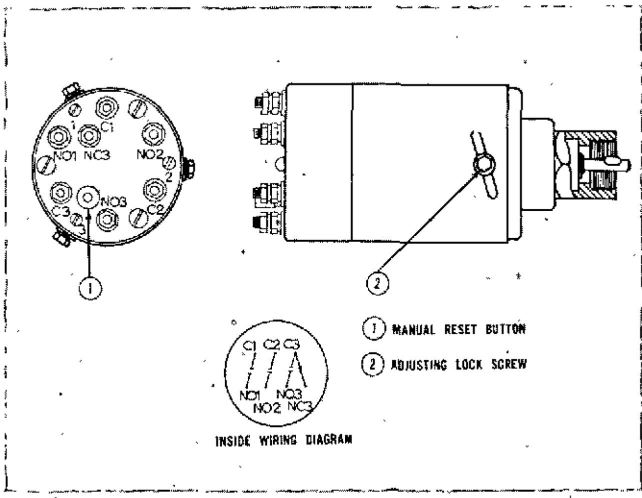


Fig. 15-1-5, CGS28. Triple engine speed switch

a. Connect ohmmeter leads to terminals C2 and NO2.

b. Follow Steps "b" and "c" of Switch 1 under test of Double Switch.

3. Switch 3. Ref. Fig. 15-1-5.

a. Connect ohmmeter leads to terminals C3 and NC3.

b. Follow Step "b" of Switch 2 under test of Double Switch.

c. Should any switch not open or close at specified rpm, adjust switch as follows:

Adjustment

1. Switch 1.

a. Remove slotted screw marked No. 1; insert an Allen wrench through opening into speed adjusting screw. Turn adjusting screw clockwise to increase, or counterclockwise to decrease, switch actuating rpm.

b. Connect ohmmeter leads to terminals C1 and NO1 to indicate switch action. Turn speed adjusting screw clockwise to set switch action above 650 rpm.

c. Advance fuel pump test stand to 575 $\pm$ 20 prm. Slowly turn speed adjusting screw counterclockwise while observing ohmmeter, until switch is actuated, closing its contacts.

d. Shut down test stand; then advance test stand rpm and observe ohmmeter. When switch is actuated, check rpm (575 $\pm$ 20).

e. Check to be sure switch contacts open when fuel pump speed is slowly decreased to 0.

f. After Steps "c" and "d" have been obtained, remove Allen wrench and install slotted screw. Should Steps "c" or "d" not be obtained, switch is defective and must be replaced.

2. Switch 2.

a. Connect ohmmeter leads to terminals C2 and NO2.

b. Follow procedure of adjustment for switch No. 1 under Double Switch.

3. Switch 3.

a. Connect ohmmeter leads to terminals C3 and NC3.

b. Follow procedure of adjustment for switch No. 2 under Double Switch.

Repair

Return defective switch to Manufacturer, Synchro-Start Products, Inc., Skokie, Ill. 60076, for repair as required.

Oil Pressure Sensing Device

The device senses when the oil pressure has gone below a safe level for a certain R.P.M. and sends a signal due to sudden drop in pressure of 12 P.S.I. and below. This safety limit increases with an increase in engine speed.

Note: This device is rated from 1200-3500 R.P.M., and can be adjusted by the adjusting screw to change the range of operation and the safety level as desired.

In order for this device to function, it must be driven at engine speed and must be supplied with oil pressure from the engine.

The accessory adapter assembly is installed in the lower right bank side of the gear case housing. This is directly below the fuel pump drive or air compressor. The accessory adapter assembly is driven by the engine gear train. Fig. 15-1-6.

Lubricating oil is supplied for the accessory adapter assembly from the block and is piped as follows:

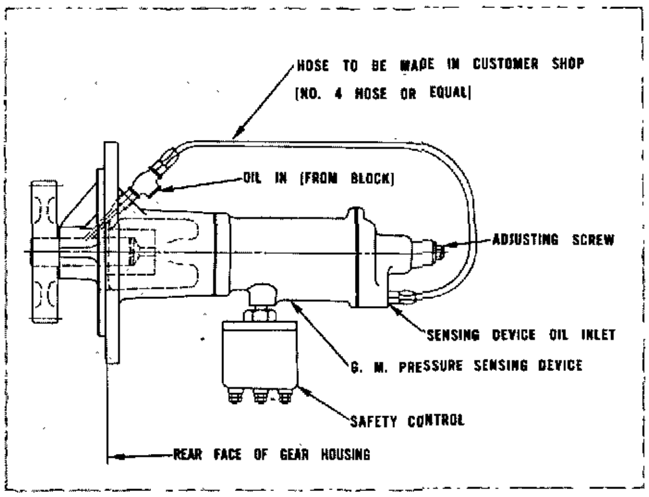


Fig. 15-1-6, V40180. Installation of Pressure Sensing Device

1. Install 1/8 inch Nipple into adapter.

2. Install 1/8 inch Tee onto Nipple.

3. One end of this tee is connected with a No. 4 hose to the oil rifle in the cylinder block. The other opening is plugged with a 1/8 inch Pipe Plug; the pipe plug is to be removed to install a No. 4 hose to the Pressure Sensing Device (supplied by customer).

Engine Adaptations

The engine adaptations group consists of the flywheel, flywheel housing and recommendations for installation of engines and units connected to engines, such as clutches, generators, etc.

Flywheel and Housing–Unit 1601

1. Cummins diesel engines are used in a wide variety of applications. Literally hundreds of flywheel housings and flywheels are provided for adaptation. Special distributor manuals are provided by Cummins Sales Engineering Department to help select the right parts for the application. In case of doubt concerning any application, consult the Cummins Sales Engineering Department.

2. In selecting flywheels, check carefully for safe-speed rating. If there is any doubt, consult Cummins Sales Engineering Department. Flywheels must not be applied over their rated safe speed.

3. No attempt should be made to remachine flywheels in a shop that is not equipped to maintain factory standards both as to dimensions and static balance. The static balance tolerance of flywheels is 2 inch-oz. [144.0160 g cm] maximum.

4. Consult Cummins Sales Engineering Department for specific adapters and clearances when using a flywheel "Belt-Driven" power take-off.

5. One of the most important factors of good service from the engine and drive units is proper flywheel and housing alignment. Consult Group 14 for alignment procedures to be followed during engine assembly.

Replacement Of Flywheel Ring Gears

Inspection And Removal

1. Inspect ring gear for broken or cracked teeth.

2. If replacement is necessary, drive gear from flywheel with blunt chisel.

Replacement

1. If an oven with a heat control is not available, heat gear with a heating torch – not a cutting torch – from inside diameter so heat travels outward to teeth.

2. Use a Templistick crayon or equivalent to determine amount of heat applied.

a. Stroke gear with 600 deg. F [315.6 deg. C] crayon several times while applying heat.

b. The crayon will leave a chalk mark until temperature reaches 600 deg. F [315.6 deg. C]. At 600 deg. F [315.6 deg. C], the crayon will leave a liquid smear.

Caution: Overheating to temperatures above 660 deg. F [348.9 deg. C] will soften gear

3. Place ring gear on flywheel and quickly drive onto flywheel until gear is firmly seated.

Flywheel Drives—Unit 1602

Power-transmitting equipment such as mechanical transmissions, torque converters, clutches, rear axles and drive lines should be selected and installed in accordance with the component manufacturer's recommendation for compatibility with the output of engine and nature of work to be performed. Engine performance should be considered in component selection along with certain limitations on component installation.

Clutches

To limit end thrust on crankshaft, the spring load during disengagement of an automotive spring-loaded type clutch should not exceed 1950 lb. [884.50 kg] load.

Loads given are not to be considered as permissible for continuous operation, but only as maximum values for clutch disengagement. Continuous loading will be evaluated on an individual basis and must be referred to Cummins Engine Company, Inc. for approval.

Mechanical Transmissions

A mechanical transmission for mobile equipment should have a sufficient number of gears which are spaced to enable the vehicle to start under load and accelerate smoothly through the gears to maximum speed. Common practice is to space shift points so that all shifts may be completed without reducing engine speed below engine peak torque speed. If a shift occurs at a low engine rotative speed, sufficient power may not be available at a given vehicle speed and load to permit the vehicle to accelerate. If lower gear ranges where gradeability is normally well above maximum grades to be encountered or on lightly loaded applications such as buses or pickup and delivery units, a shift below peak torque speed may be satisfactory.

Torque Converters

Standard practice in matching an engine-torque converter package to an application is to keep the efficiency of the converter at 70% or greater in the operating range. Sustained operation below this point will result in excessive horsepower loss and fuel consumption due to inefficient operation, plus the addition of a greater heat load from the torque converter. This may result in overheated converters or an inability of the cooling system to handle the higher heat load.

1. The minimum stall speed on naturally aspirated engines is not critical; however, the minimum stall speed of turbocharged engines is critical for acceleration to full turbocharged power. For maximum output, engine stall speed for all engine types should be as high as possible while still maintaining a reasonable output speed range before reaching governed speed.

2. When used in excavator service, turbocharged engines should be rated no higher than 125% of naturally aspirated power to assure proper acceleration characteristics.

3. The torque converter normally constitutes an added heat load which must be provided for in the design of the cooling system. For application limits see Table 16-2-1.

Auxiliary Power Take-Off Drives

In applying a power take-off drive directly from flywheel, consideration should be given to resultant torsional vibration in engine crankshaft to insure satisfactory life of engine gear train. If PTO and engine package is torsionally compatible and physically strong enough to transmit required power, then, in general, the complete power train is acceptable in this respect.

Table 16-2-1: Converter Application Limits for Unknown Environmental Conditions — Turbocharged Engines

Standard Engine Rating				Excavator Operation		
Model	HP	RPM	Minimum Stall Speed*	Maximum HP*	Minimum Stall Speed*	Minimum Tailshift Gov. RPM*
VT-1710-700	700	2100	1600	575	1430	1050

*Assume 3000 ft [914.403 m] altitude and 90°F [32.2°C]

1. The equipment manufacturer should check with Cummins to determine whether the specific drive is compatible with engine involved.

2. For any drive arrangement that is unconventional or not proven with respect to speed of driven accessory, polar moment of inertia of driven accessory and stiffness of drive between PTO and accessory must be referred to Cummins Engine Company, Inc.

Front Power Drives

Accessory Drives

Front power drives are available for the V-1710 Series.

Before any such drives are added to engine, details of driven components and proposed drivelines should be submitted to Cummins Engine Company, Inc., for review and approval.

To aid in the initial planning of accessory or auxiliary drives, the following basic factors should be considered.

Pulley And Belt Drives

1. This type of drive can usually be added to engine provided that the torque and bending moment applied to engine drive shaft by belts is maintained within satisfactory limits. These limits vary for various series of engines as well as being dependent, in some cases, upon direction of loading. Consequently, each specific addition of such drives must be reviewed on an individual basis.

2. The most efficient use of pulley drives is derived by locating components so bending moment caused by belt loads will tend to cancel each other, keeping resultant moment on the shaft at a minimum. Consideration must also be given to engine and accessory mounts to eliminate relative movement between engine drive pulley and accessory driven pulley due to engine roll or frame flexing which could result in extreme changes in tension of drive belts with a resultant increase in bending moment of shaft.

It will be possible in most applications to drive accessories in addition to those normally required (which include fan, water pump, air compressor, fuel pump and generator).

Drive Shaft Or Direct Drive Types

The addition of any couplings or shafts to the engine driving components should not be made without the review and approval of Cummins Engine Company, Inc.

Drives Using Soft Couplings

The soft-type coupling, incorporating fabrics or rubber members, may generally be used without any major problems.

The coupling must have a torsional stiffness value that will allow no torsional problems to be introduced between engine and driven component. Since this depends upon torsional or cyclic porperties of the individual engine and the mass of the driven components, each application must be evaluated individually.

When using soft couplings without splines, proper care must be taken that axial deflection of the coupling due to installation tolerances or frame deflections does not create excessive thrust loads on engine shaft.

U-Joint Couplings And Shafts

The components are generally satisfactory for driving accessories having such relatively small rotating masses that no torsional problems are encountered in either the engine or the driving shaft. In cases where accessories are being driven that have high-inertia rotating masses, it will usually require a torsionally flexible coupling properly matched to engine and driven accessory characteristics.

Drives incorporating U-joints should also allow for axial variations due to deflections and installation tolerances without transmitting thrust loads to the engine.

Direct Drives

Accessory or auxiliary components may be directly driven from engine power take-off points through the use of splines, couplings and clutches. Examples of such drives are adaptations of hydraulic pumps to engine accessory drives and clutches, or power take-off units to crank pulleys or flanges as used on many marine and industrial applications.

Due to variations in characteristics of various types of drives and engines involved, there are no established standards to be followed and each drive must be evaluated individually.

Mountings—Unit 1603

The mounting of an engine must not only provide adequate support for engine in desired location, but should do so in a manner that the engine is not subjected to excessive stress imposed by power take-offs, shock loads or deflection of supporting members.

Bending Moment Restrictions

In the design of an engine mounting arrangement or power-transmitting drive, care must be taken to ensure that the bending moment imposed on engine is not excessive. A zero bending moment at point flywheel housing mounts to engine is preferred for all engine installations. This is with the unit operational, i.e., all components installed and fluids included.

Where it is impossible to locate engine mounts to achieve a zero bending moment, the allowable bending moment is limited to 1000 ft-lb [138.3000 kg m].

1. In an automotive installation, bending moment is based on static load of engine installed with all components and accessories and complete with water, oil, etc.

2. For industrial installation, bending moment must not only include static loading, as for an automotive application, but must also include any dynamic loading imposed by driven component such as a side pull through a chain drive.

The engine weight and center of gravity will vary depending upon optional components and mounting of accessories.

Flexible Vehicle Mounting

It is preferred that a flexible mounting arrangement be used in all vehicle installations to allow for relative movement between chassis and engine. In this way no undue stress will be imposed upon engine due to frame deflection, and engine vibrations will be isolated from chassis to prevent chassis or cab fatigue and provide for operator comfort.

In order to protect engine from excessive stress during frame deflection or movement, a three-point mounting is recommended. With this method of suspension, engine is supported at a single point (either a single mount or a set of mounts inclined at such an angle that the engine will roll around a single point) in front and two points in rear, one on each side of engine in flywheel housing-transmission area.

A four-point mounting system (two mounts each at front and rear) has been used on certain applications requiring either special engine configurations or other unusual application considerations. This type of mounting is not normally recommended due to danger of imposing excessive stress on engine components because of frame movement of deflection.

Front Mounting

The provisions for supporting engine in front may be in the form of a trunnion, a horizontal pad, or a set of inclined mounting pads. Each of these mounting methods will allow engine to rotate sufficiently with respect to frame rails to eliminate high stress in engine during frame flexure. Flexible mounts are required when horizontal pad or set of inclined mounting pads are used to provide required flexibility. If flexible mounts are used for rear mounts, and a trunnion is used for front mount, flexibility must be provided in front mounting arrangement to prevent trunnion failure when shock loading deflects rear mounts.

Inclined pads are used on certain installations to obtain a greater degree of isolation. The physical properties of flexible mounts are quite critical in regard to shear-to-compression ratio in this type of mounting to all engine-transmission package to rotate around its normal (neutral) roll axis. When such a system is used, it is suggested that the manufacturer of the mounts be consulted for specific recommendations. When designing such a system, it is important that the front cross-member be of sufficient strength and rigidity that relative movement of frame rails will not break or bind mounting brackets or engine components.

Rear Mounting

The rear mounts must not only adequately support engine and transmission under conditions of shock loading, but must also restrain engine in a fore and aft direction due to forces imposed by clutch disengagement and sudden deceleration in either forward or reverse gears. It is recommended that the rear mounts be located as close to engine flywheel housing as possible to minimize stress in housing due to fore and aft shock loads.

1. It is important on vehicular installations that an adequate number of frame cross-members, which are properly located and structurally sound, be used to prevent frame deflection in engine area. Particular emphasis should be placed on cross-member at rear of engine since an inadequate design will permit bowing of flexure of frame in this area and engine flywheel housing breakage may occur.

2. A saddle bracket which mounts to both the flywheel housing and the transmission allows the rear mounts to be located at proper location to achieve a minimum bending moment while minimizing shear of flywheel housing capscrews, which would be highly stressed if mounts were to be overhung. This arrangement has advantages of providing extreme flexibility in location of rear mounts, provides great structural strength and reduces relative motion between engine and transmission.

Transmission tail supports are used by many manufacturers to control bending moment. In these cases, tail support is designed to support a portion of engine-transmission package weight in order to obtain a mounting system within allowable bending moment limitations. Care must be exercised in design to preclude restricting roll of engine allowed by rear mountings, or stresses will be imposed, possibly causing breakage of flywheel housing, transmission or tail support.

A properly designed and installed tail support will provide acceptable control of bending moment. However, its strength must be adequate to provide for shock loads, and its design must be compatible with production tolerances in location of front and rear mountings and spring or rubber mount deflection rates. It is desirable for design to be capable of being adjusted at assembly to provide for manufacturing and installation variations in cross-members, mounting brackets and mounts. An excellent method of accomplishing the above design objectives is through the use of a coil spring or leaf spring having a relatively low spring rate in proportion to that of engine mounts. With this type of design, a greater manufacturing tolerance in vertical plane can usually be tolerated while still adhering to the bending moment limitations, since a comparatively large movement of tail support can be tolerated without appreciably changing either the load on tail support or the bending moment.

Design Considerations

1. Many flexible mounting arrangements have been designed and successfully used. Commercially available mounts can normally be used to obtain desirable isolation and flexibility. When exceptional isolation is required, it is advisable to contact a mounting specialist who can design special components for the particular engine-transmission package and consequently obtain desired isolation with adequate support.

2. Although flexible mounts vary considerably in their properties, as a general guide, most will approximate a 1/16 to 1/8 inch [1.5875 to 3.1750 mm] deflection when installed. Proper flexibility from rebound forces can be accomplished by the use of a two-part mount (upper and lower) or by a single mount designed to spread out upon installation and form the rebound portion of the mount.

3. It is desirable to design the mounts so compressibility is limited to a predetermined value to assure designed isolation and flexibility. Many mounts incorporate a center bonded metal insert to limit installation compressibility while a spacer of the proper length may be used on mounts without inserts.

Engine Connections

When a flexible engine mounting system is incorporated, provision must be made in all affected areas to prevent interference or fatigue failure due to engine movement. It will be necessary to incorporate flexible sections in all connections to the engine such as exhaust piping, air intake piping, air compressor lines, water lines, etc. In addition, sheet metal and frame clearance must be sufficient to allow for both relative movement and manufacturing tolerances. Throttle and clutch linkage, fan-shroud clearance and routing of all tubes, hose, wires and cables must be carefully designed.

Vehicle Mounting (Rigid)

In certain heavy equipment where the unit is so constructed that frame deflection is negligible and transmittal of engine vibrations to the unit may be tolerated, a solid type of mounting using a trunnion mount at front has been used. For these installations, it is advisable to use a hard rubber fabric or composition material between engine mounts and chassis to prevent squeaks, help absorb shock loading, compensate for slight misalignment errors in manufacturing or assembly, and to accommodate minor frame deflection.

Industrial Mounting

Stationary power units are usually mounted directly to base rails, a sub-base, a steel deck or other firm foundation. For these installations, pedestal-type front and rear supports with "feet" are utilized to properly secure engine to base rails, sub-base or deck.

1. A sub-base is normally used if engine will be moved occasionally or if a suitable foundation is not available. Base rails are adequate when a suitable foundation is to be used. On units of this type, a chain or belt drive is frequently used to transmit power from engine power take-off package to driven machinery. In these or similar cases where side pull exists, an additional support at output shaft is required since chain pull will normally be sufficient to overstress flywheel housing.

2. A properly designed foundation is required for permanent stationary installations to support weight of engine package, maintain proper alignment between engine and driven equipment and absorb vibration produced by rotating or reciprocating masses.

a. When selection of engine has been made, Cummins Engine Company, Inc. will, on request, provide foundation and engine dimensional drawings giving position of anchor bolts, location of attachments and over-all dimensions.

b. The bearing strength of soil at proposed site must be determined before design of foundation can be made. The soil must adequately support weight of both the engine package and the foundation itself.

It is best if base of foundation rests upon undisturbed soil. If pilings are required, it is recommended that an experienced contractor be obtained. If soil is extremely soft or will readily transmit vibrations, it is recommended that a complete soil analysis be made.

When the foundation rests on rock, foundation is greatly simplified and the yardage of concrete can usually be reduced below normal recommendation.

c. When conditions require that the vibrations caused by engine operation be reduced or noise produced by these vibrations be minimized, the most common methods of control are to isolate engine foundation block from subsoil, or mount engine on vibration-isolating mountings.

When an engine is enclosed within a building, some degree of vibration isolation should be incorporated in the foundation design. The foundation should be separated from floor slab and subsoil so vibrations will not be transmitted to structure. If floor slab has sufficient strength to support weight of engine and a separate foundation is not used, a satisfactory mounting can be accomplished by use of vibration isolators between slab and engine. To limit vibration effects to an absolute minimum, engine should be isolated from foundation by flexible mounts and foundation isolated from floor.

d. Water-resistant, processed natural cork has been found to be one of the most effective organic materials for isolating the foundation from the subsoil. It has sufficient structural strength to withstand combined weight of foundation and engine. By lining foundation pit with cork plates before pouring concrete block, it is usually possible to reduce engine's transmitted vibration to a satisfactory degree.

Another method for isolating a foundation is to use 8 to 10 inch [203.2000 to 254.0000 mm] of wet gravel or sand as a bed in the foundation pit. Tests have shown sand and gravel are capable of reducing amount of engine vibration transmitted by as much as one-third to one-half. The isolating value of gravel is somewhat greater than that of sand and does not vary appreciably with its depth. To minimize settlement of concrete foundation, gravel or sand used in the foundation pit should be thoroughly tamped before pouring concrete block.

To isolate foundation block from floor slab, expansion joints should be incorporated between slab and foundation.

e. When engine foundation is not isolated as described above or by similar means, vibration can be reduced effectively by inserting isolators between engine foundation and engine supports. While the design varies among manufacturers, installation is the same. The proper isolators are bolted between engine and foundation or floor slab.

Several types of vibration isolators are available. Some are made of rubber (or silicones), some of springs, while others are a combination of the two. These isolators not only damp out destructive vibrations, but also reduce the vibration noise level. The weight and speed of the engine, number of cylinders, type of driven machinery and the use of engine balancers all affect the type and stiffness of the vibration isolators to be selected.

Because some vibratory motion is inevitable when using soft mountings, all connections to the engine should be made with components capable of flexing, such as flexible pipe for exhaust, hose for fuel, lube and starting air and flexible conduit for electrical items.

Marine Gears—Unit 1605

The most important precaution to insure satisfactory operation of a marine reverse gear or power generator is to make sure that the closest possible alignment is provided between engine crankshaft and marine gear or power generator.

Marine Gears

Alignment With Crankshaft

Improper alignment will result in undue wear because of excessive stress on parts in both the clutch and the reverse gear mechanism.

1. Check the flywheel housing and see that it is the one specified for use with marine gear.

2. Make sure that flywheel housing and flywheel are assembled as directed in Group 14.

Assembly To Engine

The marine gear and clutch assembly are assembled to engine as one unit.

1. Remove small cover plate atop clutch housing.

2. Install two studs in flywheel housing to act as guides during installation of marine gear.

3. Assemble marine gear to engine. Install bolts and secure loosely.

Caution: Gear clutch plate must pilot in flywheel housing before bolts are tightened.

4. Tighten bolts alternately until secure.

5. For additional details refer to the maintenance manual pertinent to gear being used and follow manufacturer's recommendations.

Assembly To Boat

1. Whenever possible, it is recommended that the new marine gear be assembled to engine before it is installed in boat.

2. After entire assembly has been set on its foundation, it must be properly aligned with propeller shaft. Make this alignment without pulling support brackets on marine gear out of position. It is recommended that clearance for shimming be provided at this point. Recheck alignment after engine foundation bolts have been tightened and then carefully shim up under marine gear support bracket.

3. Experience has shown that hulls often change shape after boat is launched; recheck and correct alignment, if necessary, with boat in water. This can be accomplished by removing the bolts in propeller shaft coupling and checking spacing of the two flanges on the circumference. For satisfactory alignment, variation should not exceed 0.004 inch [0.1016 mm]. Fig. 16-5-1.

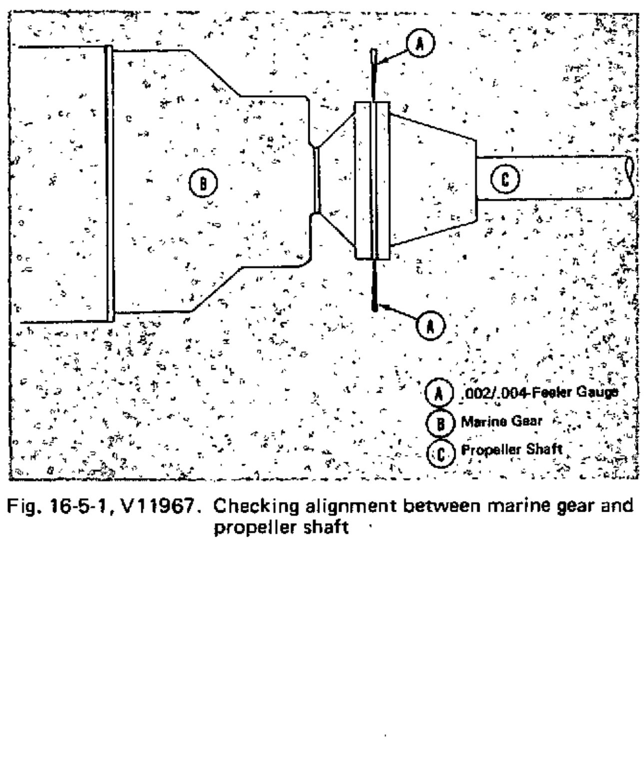


Fig. 16-5-1, V11967. Checking alignment between marine gear and propeller shaft

Specifications And Wear Limits

Worn limit as stated in this manual indicates that the part may be reused if it is at worn limit. Discard only if it exceeds worn limit. Of course, reuse of any part is partially the responsibility of the person making inspection, as it could well be damaged in an area not listed as a worn limit, thus making it unfit for further use.

Limits are given in U.S. and Metric measurements. All Metric units are enclosed in brackets [ ].

Unit No.	Part or Location	New Minimum		New Maximum		Worn Limit	
101	**Cylinder Block**						
	Installed Camshaft						
	Bushing Inside Diameter	2.1245	[53.9623]	2.1283	[54.0588]	2.1295	[54.0893]
	Camshaft Bushing Bore						
	In Block	2.2535	[57.2389]	2.2545	[57.2643]	2.2555	[57.2897]
	Cylinder Liner Counterbore						
	Inside Diameter	6.5615	[166.6621]	6.5635	[166.7129]		
	Depth	0.3500	[8.8900]	0.3510	[8.9154]	0.4110	[10.4394]
	Cylinder Liner Protrusion	0.004	[0.1016]	0.006	[0.1524]		
	Liner-to-Block Clearance	Liner May Contact Block if it Doesn't Force Liner Out of Round					
	Lower Bore (Diametrical)	0.002	[0.0508]	0.006	[0.1524]		
	Cylinder Block Lower Liner						
	Bore	6.1240	[155.5496]	6.1260	[155.6004]		
	Main Bearing Bore	6.095	[154.8130]	6.0960	[153.8384]	6.0965	[154.8511]
	Tappet Bore In Block						
	Injector	1.6245	[41.2623]	1.6255	[41.2877]	1.620	[41.3258]
	Valve	1.1870	[30.1498]	1.1880	[30.1752	1.1895	[30.2133]
	Idler Gear Shaft	1.9975	[50.7365]	1.9980	[50.7492]	1.9970	[50.7238]
	Cylinder Block Height						
	From Main Bore Centerline	19.0040	[482.7016]	19.0060	[482.7524]	18.994	[482.4476]
	From Top of Alignment Bore	15.9565	[405.2697]	15.9580	[405.3332]	15.9457	[405.0207]
	Cylinder Liner Counterbore						
	Shims Pt. No. 143938	0.0063	[0.1600]	0.0077	[0.1955]		
	Pt. No. 143939	0.0072	[0.1828]	0.0088	[0.2235]		
	Pt. No. 143946	0.0081	[0.2057]	0.0099	[0.2514]		
	Pt. No. 143947	0.0018	[0.4572]	0.022	[0.5588]		
	Pt. No. 143948	0.028	[1.4224]	0.034	[0.8636]		
	Pt. No. 143949	0.056	[0.7112]	0.068	[1.7272]		
	Main Bearing Cap Interference						
	Fit In Block	0.002	[0.0508]	0.004	[0.1016]		
	Main Bearing Capscrew						
	Tightening	ft-lb	[kg m]	ft-lb	[kg m]		
	1. Tighten to	200	[27.6600]	210	[29.0430]		
	2. Advance to	410	[56.7030]	420	[58.0860].		
	3. Loosen	All					
	4. Tighten to	120	[16.5960]	125	[17.2875]		
	5. Advance	60 deg.					
	Main Bearing Side Capscrew						
	All Right Side	70	[12.6810]	75	[13.3725]		
	All Left Side	70	[12.6810]	75	[13.3725]		
	All Right Side	135	[18.6705]	145	[20.0535]		
	All Left Side	135	[18.6705	145	[20.0535]		
102	**Cylinder Liner**						
	Liner Inside Diameter	5.4995	[139.6873]	5.5010	[139.7254]	5.5050	[139.8270]
	Liner Protrusion	0.004	[0.1016]	0.006	[0.1524]		

Unit No.	Part or Location		New Minimum		New Maximum		Worn Limit	
103	**Idler Gear**							
	Bushing Inside Diameter		2.0000	[50.8000]	2.0010	[50.8254]	2.0020	[50.8508]
	Idler Gear Hub		1.9975	[50.7365]	1.9980	[50.7492]	1.9965	[50.7111]
	Thrust Washer 9235-1		0.093	[2.3622]	0.098	[2.4892]	0.090	[2.2860]
104	**Crankshaft**							
	Main Bearing Journal		5.7485	[146.0110]	5.7500	[146.5000]	5.7465	[145.9611]
	Connecting Rod Journal		*3.7485*	*[95.2119]*	*3.7500*	*[95.2500]*	*3.747*	*[95.1738]*
	End Clearande - Installed		0.006	[0.1524]	0.013	[0.3302]	0.0260	[0.6604]
105	**Bearings**							
	Standard (Thickness)							
	Main		0.1705	[4.3307]	0.1712	[4.3561]	0.1692	[4.2976]
	Connecting Rod		0.1245	[3.1623]	0.1250	[3.1750]	0.1232	[3.1292]
	Journal Oil Clearance							
	Main		*0.0026*	*[0.0660]*	*0.0060*	*[0.1524]*	*0.0100*	*[0.2540]*
	Connecting Rod		0.0018	[0.0457]	0.0053	[0.1346]	0.0085	[0.2159]
	Crankshaft Thrust Ring (Thickness)							
	180280		0.307	[7.7978]	0.317	[8.0518]		
	180281		0.317	[8.0518]	0.327	[8.3058]		
	180282		0.327	[8.3058]	0.337	[8.5598]		
	Crankshaft End Clearance		0.006	[0.1524]	0.013	[0.3302]		
106	**Vibration Dampers**							
	Misalignment of Index Mark				1/16	[1.5875]	1/16	[1.5875]
	Wobble				0.030	[0.7620]	0.030	[0.7620]
	Eccentricity				0.030	[0.7620]	0.030	[0.7620]
108	**Connecting Rods**							
	Nut Tightening		ft-lb	[kg m]	ft-lb	[kg m]		
	1. Tighten to		70	[9.6810]	80	[11.0640]		
	2. Advance to		140	[19.3620]	150	[20.7450]		
	3. Loosen		All Completely					
	4. Tighten to		70	[9.6810]	80	[11.0640]		
	5. Advance to		140	[19.3620]	150	[20.7450]		
	Crankpin Bore		4.0018	[101.6457]	4.0028	[101.6711]		
	Out-of-Round				0.001	[0.0254]		
	Bolt Pilot		0.6245	[15.8623]	0.625	[15.8750]	0.6242	[15.8546]
	Bolt Minimum O.D.		0.5410	[13.7414]	0.5450	[13.8430]	0.5400	[13.7160]
	Rod Bolt Hole I.D.		0.6243	[15.8572]	0.6248	[15.8669]	0.6249	[15.8724]
	Piston Pin Bushing		2.0010	[50.8254]	2.0015	[50.8381]	2.0025	[50.8635]
	Twist - No Bushing				0.020	[0.5080]		
	Twist - With Bushing				0.010	[0.2540]		
	Length		11.998	[304.7492]	12.00	[304.8000]		
	Bores Misalignment							
	Without Bushing				0.008	[0.2032]		
	With Bushing				0.004	[0.1016]		
109	**Piston and Piston Rings**							
	Piston Ring Gap	Pt. No. 147670	0.017	[0.4318]	0.027	[0.6858]		
	(New Liner)	Pt. No. 132880	0.013	[0.3302]	0.023	[0.5842]		
		Pt. No. 194610	0.010	[0.2540]	0.020	[0.5080]		
	Skirt Diameter (Std. 70 deg. F. [21.1 deg. C])							
	175760, 195250, 199619		5.4870	[139.3698]	5.4880	[139.3952]	5.4830	[139.2682]
	Piston Pin Bore		1.9985	[50.7619]	1.9989	[50.7720]	2.000	[50.8000]
	Piston Pin Diameter		1.9988	[50.7695]	1.9990	[50.7746]	1.9978	[50.7441]

Unit No.	Part or Location	New Minimum		New Maximum		Worn Limit	
110	**Camshaft**						
	Journal Diameter	2.122	[53.8998]	2.123	[53.9242]	2.120	[53.8480]
	Lobe Lift						
	Valve			0.2835	[7.2009]		
	Injector			0.1170	[2.9718]		
111	**Gear Cover**						
	Fuel Pump Drive Bushing						
	132770 (Std.)	1.565	[39.7510]	1.569	[39.8526]	1.5705	[39.8907]
	132771 (0.010)	1.555	[39.4970]	1.559	[39.5986]	1.5605	[39.6367]
	132772 (0.020)	1.545	[39.2430]	1.549	[39.3446]	1.5505	[39.3827]
	Generator Drive Bushing						
	116391 (Std.)	1.316	[33.4264]	1.319	[33.5026]	1.3205	[33.5407]
	Camshaft Support	1.751	[44.4754]	1.754	[44.5516]	1.757	[44.6278]
112	**Rear Cover**						
	Piston Ring Type	8.500	[215.9000]	8.502	[215.9508]	8.504	[216.0016]
201	**Cylinder Head**						
	Head Height	5.490	[139.4460]	5.510	[139.9540]	5.460	[138.6840]
202	**Injector Sleeve**						
	Top Inside Diameter	1.145	[29.0830]	1.155	[29.3370]		
	Injector Cup Protrusion	0.040	[1.0160]	0.055	[1.3970]	0.065	[1.6510]
203	**Valve Seats and Inserts**						
	Run Out			0.002	[0.0508]		
	Sizes Available	Refer to Table 2-3-1, Page 2-3-2.					
204	**Valve Crossheads**						
	Inside Diameter	0.434	[11.0236]	0.436	[11.0744]	0.440	[11.1760]
	Guide Outside Diameter	0.4330	[10.9982]	0.4335	[11.0109]	0.4320	[10.9728]
	Guide Assembled Height	1.860	[47.2440]	1.880	[47.7520]		
205	**Valves, Guides and Springs**						
	Valve Stem Outside Diameter	0.450	[11.4300]	0.451	[11.4554]	0.4490	[11.4046]
	Valve Guide Inside Diameter	0.4525	[11.4935]	0.4532	[11.5112]	0.4545	[11.5443]
	Valve Guide Protrusion	1.065	[27.0510]	1.075	[27.3050]		
	Valve Spring Data	Refer to Table 2-5-2, Page 2-5-4.					
301	**Rocker Levers**						
	Bushing Inside Diameter	1.1245	[28.5623]	1.1275	[28.6385]	1.1285	[28.6639]
	Shaft Outside Diameter	1.1230	[28.5242]	1.1240	[28.5496]	1.1220	[28.4988]
302	**Push Tubes**						
	Valve (Ball End Radius)	0.623	[15.8242]	0.625	[15.8750]		
	Socket (Spherical I.D.)	0.5050	[12.8270]	0.5200	[13.2080]		
	Injector (Ball End Radius)	0.623	[15.8242]	0.625	[15.8750]		
	Socket (Spherical I.D.)	0.5050	[12.8270]	0.5200	[13.2080]		

Unit No.	Part or Location	New Minimum		New Maximum		Worn Limit	
401	**Tappets**						
	Injector						
	Body Inside Diameter	0.998	[25.3492]	1.007	[25.5778]		
	Body Outside Diameter	1.6225	[41.2115]	1.6235	[41.2369]	1.6215	[41.1861]
	Roller Outside Diameter	1.1980	[30.4292]	1.2000	[30.4800]	1.1960	[30.3784]
	Roller Inside Diameter	*0.6280*	*[15.9512]*	*0.6290*	*[15.9766]*	*0.6300*	*[16.0020]*
	Roller Pin Outside Diameter	0.6243	[15.8572]	0.6247	[15.8673]	0.6233	[15.8318]
	Roller Side Clearance	0.0080	[0.2032]	0.0200	[0.5080]	0.0250	[0.6350]
	Roller Concentricity			0.0010	[0.0254]		
	Roller Squareness			0.0040	[0.1016]		
	Valve						
	Body Inside Diameter	0.968	[24.5872]	0.978	[24.8412]		
	Body Outside Diameter	1.1850	[30.0990]	1.1860	[30.1244]	1.1840	[30.0763]
	Roller Outside Diameter	1.0610	[26.9494]	1.0630	[27.0002]	1.0590	[26.8986]
	Roller Inside Diameter	0.5030	[12.7762]	0.5040	[12.8016]	0.5050	[12.8270]
	Roller Pin Outside Diameter	0.4995	[12.6873]	0.5000	[12.7000]	0.4985	[12.6619]
	Roller Side Clearance	0.0080	[0.2032]	0.0220	[0.5588]	0.0270	[0.6858]
	Roller Concentricity			0.0220	[0.0508]		
	Roller Squareness			0.0040	[0.1016]		
701	**Lubricating Oil Pan**						
	Capacities and Angularity	Refer to Table 7-1-1, Page 7-1-2.					
	Drain Plug Torque — Cast Iron	60 ft-lb [8.2980 kg m]			70 ft-lb [9.6810 kg m]		
	Aluminum	Refer to Table 7-1-2, Page 7-1-2.					
702	**Lubricating Oil Lines**						
	Hose Bends	Refer to Table 7-2-2, Page 7-2-2.					
	Hose Size	Refer to Table 7-2-1, Page 7-2-1.					
706	**Lubricating Oil Pump**	Refer to Table 7-6-1, Page 7-6-2					
	Scavenger Pump	Refer to Page 7-6-3.					
801	**Water Pump**						
	Impeller to Shaft Press Fit	0.0015	[0.0381]				
	Impeller to Body	0.020	[0.5080]	0.031	[0.7874]		
	Impeller to Cover	0.020	[0.5080]	0.040	[1.0160]		
802	**Fan Hub**						
	End Clearance	0.001	[0.0254]	0.007	[0.1778]		
803	**Thermostats**						
	Operating Range						
	Low	160 deg. F	[71.1 deg. C]	175 deg. F	[79.4 deg. C]		
	Medium	175 deg. F	[79.4 deg. C]	185 deg. F	[85.0 deg. C]		
	High	180 deg. F	[82.2 deg. C]	195 deg. F	[90.6 deg. C]		
808	**Thermal Controls**						
	Settings With Thermostat	Refer to Table 8-8-1, Page 8-8-1.					
901	**Drive Units**						
	Fuel Pump, Compressor Bushings	1.316	[33.4264]	1.319	[33.5026]	1.3205	[33.5407]
	Generator Bushing	1.316	[33.4264]	1.319	[33.5026]	1.3205	[33.5407]

Unit No.	Part or Location	New Minimum		New Maximum		Worn Limit	
1001	**Air Cleaners**						
	Restriction Water (Inch/Water)						
	Oil Bath			15	[381.000]		
	Dry-Type – Normal Duty			10	[254.000]	25	[635.000]
	Dry-Type – Medium Duty			12	[304.800]	25	[635.000]
	Dry-Type – Heavy Duty			15	[381.000]	25	[635.000]
1003	**Aneroid Control**						
	Intake Manifold Pressure	Refer to Table 10-3-1, Page 10-3-2.					
	Settings	Refer to Table 10-3-2, Page 10-3-3.					
1005	**Turbocharger**						
	T-50	See Bulletin 983615.					
	VT-50	See Bulletin 983681.					
	T-18A	See Bulletin 983678.					
1102	**Mufflers and Piping**						
	Exhaust Back Pressure (Inch/Hg.)						
	Naturally Aspirated			1.5	[38.1000]		
	Turbocharged			2.0	[50.8000]		
1201	**Air Compressor**	See Bulletin 983542.					
1301	**Cranking Motors**						
	Cable Size	Refer to Table 13-1-1, Page 13-1-3.					
	Battery Capacity	Refer to Table 13-1-2, Page 13-1-8.					
1401	**Engine Assembly**						
	Crankshaft End Clearance	0.006	[0.1524]	0.013	[0.3302]		
	Cylinder Liner Protrusion	0.004	[0.1016]	0.006	[0.1524]		
	Con. Rod Side Clearance	0.006	[0.1524]	0.013	[0.3302]		
	Gear Backlash	0.008	[0.2032]	0.016	[0.4064]		
	Lubricating Oil Pump	0.003	[0.0762]	0.010	[0.2540]		
	Camshaft	0.003	[0.0762]				
	Fuel Pump Drive Unit	0.003	[0.0762]	0.010	[0.2540]		
	Camshaft End Play	0.010	[0.2540]	0.015	[0.3810]		
	Injection Timing	Refer to Page 14-1-16.					
	Rear Cover Alignment	Refer to Page 14-1-4.					
	Flywheel Alignment	Refer to Page 14-1-32.					
	Flywheel Housing Alignment	Refer to Page 14-1-30.					
	Injector/Valve Adjustment	Refer to Page 14-1-41.					
	Engine Firing Order	Refer to Page 14-1-40.					
	Belt Tension	Refer to Page 14-1-39.					
	Torque Specifications						
	Cylinder Block Plugs	Refer to Page 1-1-1.					
	Crankshaft Plugs	Refer to Page 1-4-2.					
	Main Bearing Capscrews	Refer to Page 14-1-3, 18-1-1.					
	Connecting Rod Nuts	Refer to Page 14-1-9.					
	Cylinder Head Plugs	Refer to Page 2-6-2.					
	Rear Cover Capscrews	Refer to Page 14-1-4.					
	Tappet Guide Screws	Refer to Page 14-1-14.					
	Cylinder Head Capscrew	Refer to Page 14-1-16.					
	Injector Hold Down Capscrews	Refer to Page 14-1-22.					
	Damper Capscrews	Refer to Page 14-1-27.					
	Damper Flange Capscrew	Refer to Page 14-1-27.					
	Flywheel Housing Capscrews	Refer to Page 14-1-30.					
	Flywheel Capscrews	Refer to Page 14-1-33.					

Unit No.	Part or Location	New Minimum		New Maximum		Worn Limit
	Exhaust Manifold	Refer to Page 14-1-23.				
	Fan Hub Nut	Refer to Page 14-1-28.				
	Rocker Arm Housing Capscrews	Refer to Page 14-1-25.				
	Oil Spray Nozzles	Refer to Page 14-1-18.				
	Water Pump Drive Pulley Nut	Refer to Page 14-1-20.				
	Water Pump Pulley Sheaves	Refer to Page 14-1-21.				
	Fuel Filter Capscrew	Refer to Page 14-1-30.				
	Lubricating Oil Filter Capscrew	Refer to Page 14-1-34.				
1402	**Engine Testing**					
	Oil Pressure Idle P.S.I. [kg/sq cm]	15	[1.0545]	35	[2.4605]	
	Rated Speed P.S.I. [kg/sq cm]	50	[3.5150]	90	[6.3270]	
	Valve Setting	Refer to Page 14-1-41.				
	Injector Adjustment	Refer to Page 14-1-40.				
	Blow-By — Inch/Water	Refer to Page 14-2-10.				
	Horsepower @ 2100 rpm					
	V-1710-500			500		
	VT-1710-635			635		
	VTA-1710-700			700		
	VTA-1710-800			800		
	Engine Fuel Rate	Refer to Page 14-2-9.				

Lubricating Oil Specifications

Lubricating oil is used in Cummins engines to lubricate moving parts, provide internal cooling and keep the engine clean by suspending contaminants until removed by the oil filters. Lubricating oil also acts as a combustion seal and protects internal parts from rust and corrosion.

The use of a quality lubricating oil, combined with appropriate lubricating oil drain and filter change intervals, is an important factor in extending engine life. Cummins Engine Company, Inc. does not recommend any specific brand of lubricating oil. The responsibility for meeting the specifications, quality and performance of lubricating oils must necessarily rest with the oil supplier.

Oil Performance Specifications

The majority of lubricating oils marketed in North America (and many oils marketed world-wide) are designed to meet oil performance specifications which have been established by the U.S. Department of Defense and the Automobile Manufacturers Association. A booklet entitled "Lubricating Oils For Industrial Engines" listing commercially available brand name lubricants in accordance with their ability to meet these performance specifications is available at a price of $1.25 from Engine Manufacturing Association, 333 North Michigan Avenue, Chicago, Illinois 60601.

Following are brief descriptions of the specifications most commonly used for commercial lubricating oils.

Mil-L-2104B (Commonly called Mil B) The current U.S. Military specification for lubricating oils for heavy duty gasoline and diesel service. Lubricating oils meeting this specification are designed to protect the engine from sludge deposits and rusting (aggravated by stand-by operation) and to provide protection from high temperature operation, ring sticking and piston deposits.

Mil-L-45199B (Commonly called Series 3) Current U.S. Military specification for severe duty lubricating oils to be used in highly rated diesel engines operating with high loads. Lubricating oils which meet this specification have a high detergent content and will provide added protection against piston deposits and ring sticking during high temperature operation.

MS This specification was established by the Automobile Manufacturers Association. It requires a sequence of five tests for approval. The primary advantage of lubricating oils in this category is low temperature operation protection against sludge, rust, combustion chamber deposits and bearing corrosion. The test procedure for this specification is published by the American Society for Testing and Materials as STP-315.

Table 18-1-1: Minimum Cummins Oil Recommendations

Light Service (Stand-by Duty) Diesel Models	Continuous Duty Naturally Aspirated Diesel Models	Continuous Duty Turbocharged Diesel Models	All Natural Gas Models All Service
MIL-L-2104B/MS [2] 1.85% Maximum Sulfated Ash Content [3]	MIL-L-2104B [1] 1.85% Maximum Sulfated Ash Content [3]	MIL-L-2104B/MIL-L-45199B [2] 1.85% Maximum Sulfated Ash Content [3]	MIL-L-2104B .03 to 85% Sulfated Ash Content [4]

[1] Mil-L-2104B/Mil-L-45199B quality oils as used in turbocharged engines are satisfactory for use in naturally aspirated engines.

[2] Mil-L-2104B/MS and Mil-L-2104B/Mil-L-45199B indicate that the oil must be blended to the quality level required by both specifications. The range of oil quality permitted by the Mil-L-2104B specification is so broad that some oils that meet the specification will not provide adequate protection (varnish and ring sticking) for engines operated at consistantly high temperatures. Therefore, we recommend that oils for certain applications also meet the Mil-L-45199B requirements. An example is the Oil Recommendations for turbocharged engines.

[3] A sulfated ash limit has been placed on all lubricating oils for Cummins engines because past experience has shown that high ash oils may produce harmful deposits on valves that can progress to guttering and valve burning.

[4] Completely ashless oils or high ash content oils, are not recommended for use in gas engines, instead a range of ash content is specified.

Break-In Oils

Special "Break-in" lubricating oils are not recommended for new or rebuilt Cummins Engines. Use the same lubricating oil as will be used for the normal engine operation.

Viscosity Recommendations

Table 18-1-2: Operating Temperatures Vs Viscosity

Ambient Temperatures	Viscosity
−10 deg. F. [−23 deg. C] and below	See Table 3.
−10 to 30 deg. F. [−23 to −1 deg. C]	10W
20 to 60 deg. F. [−7 to 16 deg. C]	20 - 20W
40 deg. F. [4 deg. C] and above	30

1. Multigraded lubricating oils can be used in applications with wide variations in ambient temperatures if they meet the appropriate performance specifications and ash content limit shown in Table 1. Multigraged oils are generally produced by adding viscosity index improver additives to a low viscosity base stock to retard thinning effects at operating temperatures. Poor quality multigraded oils use a viscosity index improver additive which has a tendency to lose its effectiveness after a short period of use in a high speed engine. These oils should be avoided.

2. Oils which meet the low temperature SAE viscosity standard (0 deg. F [−18 deg. C]) carry a suffix "W." Oils that meet the high temperature viscosity SAE standard (210 deg. F [99 deg. C]) as well as the low temperature carry both viscosity ratings – example 20-20W.

Arctic Operations

For operation in areas where the ambient temperature is consistently below −10 deg. F [−23 deg. C] and there is no provision for keeping engines warm during shutdowns, the lubricating oil should meet the requirements in Table 3.

Due to the extreme operating conditions, oil change intervals should be carefully evaluated paying particular attention to viscosity changes and total base number decrease. Oil designed to meet Mil-L-10295A, which is now void, and SAE 5W, oils should not be used.

Additives

In order to meet the performance specifications, manufacturers find it necessary to supplement the base oil with certain additives. The additives placed in the oil by the manufacturer are tested for their compatibility with each other. Use of additives other than those originally in the lubricating oil is not recommended. Supplemental additives could affect the viscosity level or displace one or a portion of the original additives.

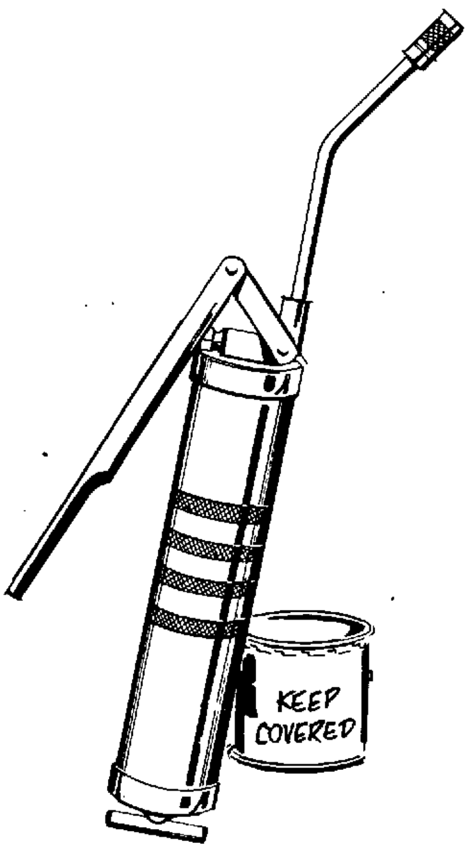
The following paragraphs describe the more common types of additives used by manufacturers in formulating their oils.

Anti-foam – To control foaming and prevent air bubbles from entering the lubricating oil pump.
Anti-scuff/Anti-wear Agent – Provides chemical polishing or coating to reduce wear between highly loaded metal surfaces.
Corrosion Inhibitors – To prevent acids from attacking metal surfaces in the engine.
Detergents/Dispersants – To keep insoluble contaminants in suspension until filtered from the lubricating oil or drained. Maintain engine cleanliness.
Extreme Pressure Additives – To prevent seizure or scuffing of rubbing surfaces.
Oxidation Inhibitor – To maintain the chemical stability of the lubricating oil.
Pour Point Depressant – To modify the oil so it will continue to flow at a lower temperature.
Rust Inhibitor – To prevent rusting of the engine parts during shut-down periods.
Viscosity Index Improvers – To reduce the effect of temperature on the viscosity of the lubricating oil.

Table 18-1-3: Arctic Oil Recommendations

Parameter (Test Method)	Specifications
Performance Quality Level	MIL-L-2104B/MS or MIL-L-2104B/MIL-L-45199B
SAE Viscosity Grade	10W-20, 10W-30, 10W-40
Viscosity @ −30 deg. F (ASTM D-445)	10,000 Centistokes Maximum
Pour Point (ASTM D-97)	At least 10 deg. F [6 deg. C] below lowest expected ambient temperature
Ash, sulfated (ASTM D-874)	1.85 wt. % Maximum

Grease Specifications



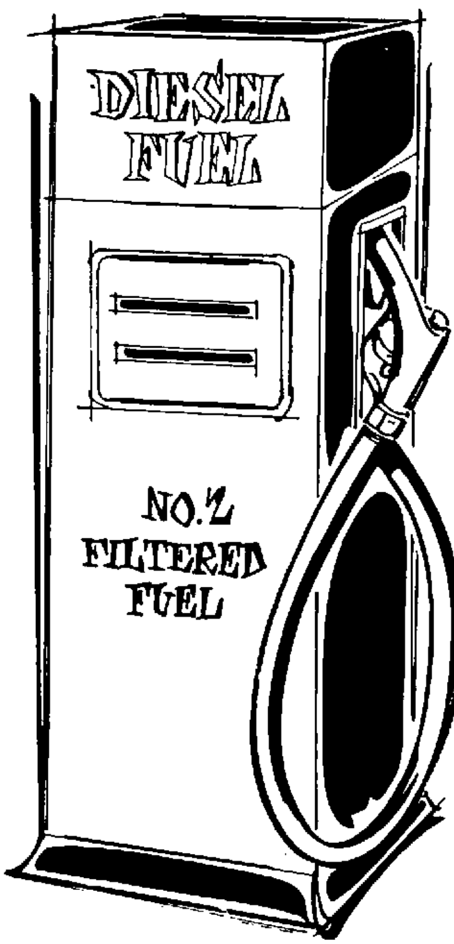
Cummins Engine Company, Inc., recommends use of grease meeting the specifications of MIL-G-3545, excluding those of sodium or soda soap thickeners. Contact your lubricant supplier for grease meeting these specifications.

Test	Test Procedure	
High-Temperature Performance		
Dropping point, deg. F.	ASTM D 2265	350 min.
Bearing life, hours at 300 deg. F. 10,000 rpm	*FTM 331	600 min.
Low-Temperature Properties		
Torque, GCM	ASTM D 1478	
Start at 0 deg. F.		15,000 max.
Run at 0 deg. F.		5,000 max.
Rust Protection and Water Resistance		
Rust test	ASTM D 1743	Pass
Water resistance, %	ASTM D 1264	20 max.
Stability		
Oil separation, %		
30 Hours @ 212 deg. F.	*FTM 321	5 max.
Penetration		
Worked	ASTM D 217	250-300
Bomb Test, PSI Drop	ASTM D 942	
100 Hours		10 max.
500 Hours		25 max.
Copper, Corrosion	*FTM 5309	Pass
Dirt Count, Particles/cc	*FTM 3005	
25 Micron +		5,000 max.
75 Micron +		1,000 max.
125 Micron +		None
Rubber Swell	*FTM 3603	10 max.

* Federal Test Method Standard No. 791a.

Caution: Do not mix grades or brands of grease as damage to bearings may result. Excessive lubrication is as harmful as inadequate lubrication. After lubricating fan hub, replace both pipe plugs. Use of fittings will allow grease to be thrown out, due to rotative speed.

Fuel Oil Specifications



Cummins Diesel Engines have been developed to take advantage of the high energy content and generally lower cost of No. 2 Diesel Fuels. Experience has shown that a Cummins Diesel Engine will also operate satisfactorily on No. 1 fuels or other fuels within the following specifications.

Recommended Fuel Oil Properties:

Viscosity (ASTM D-445)	Centistokes 1.4 to 5.8 @ 100 deg. F. (30 to 45 SUS)
Cetane Number (ASTM D-613)	40 minimum except in cold weather or in service with prolonged idle, a higher cetane number is desirable.
Sulfur Content (ASTM D-129 or 1552)	Not to exceed 1% by weight.
Water and Sediment (ASTM D-1796)	Not to exceed 0.1% by weight.
Carbon Residue (Ransbottom ASTM D-524 or D-189)	Not to exceed 0.25% by weight on 10% residue.
Flash Point (ASTM D-93)	At least 125 deg. for legal temperature if higher than 125 deg. F.
Gravity (ASTM D-287)	30 to 42 deg. A.P.I. at 60 deg. F. (0.815 to 0.875 sp. gr.)
Pour Point (ASTM D-97)	Below lowest temperature expected.
Active Sulfur-Copper Strip Corrosion (ASTM D-130)	Not to exceed No. 2 rating after 3 hours at 122 deg. F.
Ash (ASTM D-482)	Not to exceed 0.02% by weight.
Distillation (ASTM D-86)	The distillation curve should be smooth and continuous. At least 90% of the fuel should evaporate at less than 675 deg. F. All of the fuel should evaporate at less than 725 deg. F.

Coolant Specifications

Water should be clean and free of any corrosive chemicals such as chlorides, sulphates and acids. It should be kept slightly alkaline with pH value in range of 8.3 to 9.5. Any water which is suitable for drinking can be treated as described in the following paragraphs for use in an engine.

Install and/or maintain the Cummins Corrosion Resistor on the engine. The resistor by-passes a small amount of coolant from the system via a filtering and treating element which must be replaced periodically. In addition, a sacrificial metal plate arrests pitting of metals in the system by electro-chemical action. The resistor is available from any Cummins Distributor or Dealer.

The V-1710 Engine must have chromate protection at all times. Use only the standard chromate element with clear water or compatible antifreezes.

Caution: Do not use the "PAF" or Borate element in V-1710 Engine.

In Summer (No Antifreeze)

1. Use the corrosion resistor with chromate element(s). Part No. 132732.

2. Replace corrosion resistor element(s) as recommended in Operation and Maintenance Manual.

In Winter (Using Anti-freeze)

1. Select an antifreeze known to be satisfactory for use with the chromate element of the corrosion resistor and continue to use the 132732 resistor element or;

2. If you are not sure the antifreeze is compatible with the chromate resistor element 132732:

a. Use only antifreeze, with compounded inhibitors, in proper percentage and follow antifreeze supplier's recommendation to prevent corrosion.

b. Check corrosion control by draining a sample of coolant from the system as described under "Check Engine Coolant."

c. If there has been a loss of corrosion control, change antifreeze.

Caution: Never use soluble oil in the cooling system when a Corrosion Resistor is being used.

Make-Up Coolant Specifications

Where possible, it is recommended that a supply of make-up coolant be prepared to the following specifications, using soft water where possible and a compatible antifreeze. Chromate treatment of coolant assures constant level of concentration when coolant is added and requires no change in schedule of element replacement.

Chromate Concentration — NA_2CRO_4 — 3500 PPM

pH Value — 8 to 9.5

Alkalinity — 1500 PPM $CaCO_3$
(Methyl Orange Indicator)

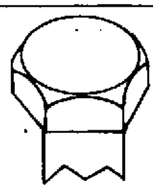
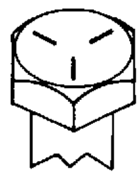
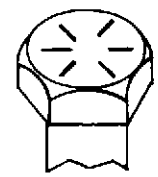
Pre-charge chromates are available as Formula 2389, from Bird-Archer Co., 4337 North American St., Philadelphia, Pennsylvania.

Dearborn Compound 530 from, Dearborn Chemical Co., 14230 Ridge Road, Plymouth, Michigan.

Nalco 38 from, National Aluminate Corp., 6216 West 66th. Place, Chicago, Illinois.

Note: Corrosion resistor element must continue to be used with pre-treated water.

Standard Capscrew Markings And Torque Specifications

Usage	Much Used	Much Used	Used at Times	Used at Times
Capscrew Diameter and Minimum Tensile Strength psi [kg/sq cm]	To 1/2 – 69,000 [4850.7000] To 3/4 – 64,000 [4499.2000] To 1 – 55,000 [3866.5000]	To 3/4 – 120,000 [8436.0000] To 1 – 115,000 [8084.5000]	To 5/8 – 140,000 [9842.0000] To 3/4 – 133,000 [9349.9000]	150,000 [10545.0000]
Quality of Material	Indeterminate	Minimum Commercial	Medium Commercial	Best Commercial
SAE Grade Number	1 or 2	5	6 or 7	8
Capscrew Head Markings Manufacturer's marks may vary. These are all SAE Grade 5 (3-line) 			 6  7	

Capscrew Body Size (Inches) – (Thread)	Torque Ft-Lb [kg m]	Torque Ft-Lb [kg m]	Torque Ft-Lb [kg m]	Torque Ft-Lb [kg m]
1/4 – 20	5 [0.6915]	8 [1.1064]	10 [1.3830]	12 [1.6596]
– 28	6 [0.8298]	10 [1.3830]		14 [1.9362]
5/16 – 18	11 [1.5213]	17 [2.3511]	19 [2.6277]	24 [3.3192]
– 24	13 [1.7979]	19 [2.6277]		27 [3.7341]
3/8 – 16	18 [2.4894]	31 [4.2873]	34 [4.7022]	44 [6.0852]
– 24	20 [2.7660]	35 [4.8405]		49 [6.7767]
7/16 – 14	28 [3.8132]	49 [6.7767]	55 [7.6065]	70 [9.6810]
– 20	30 [4.1490]	55 [7.6065]		78 [10.7874]
1/2 – 13	39 [5.3937]	75 [10.3725]	85 [11.7555]	105 [14.5215]
– 20	41 [5.6703]	85 [11.7555]		120 [16.5960]
9/16 – 12	51 [7.0533]	110 [15.2130]	120 [16.5960]	155 [21.4365]
– 18	55 [7.6065]	120 [16.5960]		170 [23.5110]
5/8 – 11	83 [11.4789]	150 [20.7450]	167 [23.0961]	210 [29.0430]
– 18	95 [13.1385]	170 [23.5110]		240 [33.1920]
3/4 – 10	105 [14.5215]	270 [37.3410]	280 [38.7240]	375 [51.8625]
– 16	115 [15.9045]	295 [40.7985]		420 [58.0860]
7/8 – 9	160 [22.1280]	395 [54.6285]	440 [60.8520]	605 [83.6715]
– 14	175 [24.2025]	435 [60.1605]		675 [93.3525]
1 – 8	235 [32.5005]	590 [81.5970]	660 [91.2780]	910 [125.8530]
– 14	250 [34.5750]	660 [91.2780]		990 [136.9170]

Notes:

1. Always use the torque values listed above when specific torque values are not abailable.
2. Do not use above values in place of those specified in other sections of this manual; special attention should be observed when using SAE Grade 6, 7 and 8 capscrews.
3. The above is based on use of clean, dry threads.
4. Reduce torque by 10% when engine oil is used as a lubricant.
5. Reduce torque by 20% if new plated capscrews are used.
6. Capscrews threaded into aluminum may require reductions in torque of 30% or more, unless steel inserts are used.

Vehicle Braking

This section is devoted to auxiliary braking systems that may be used on Cummins Engines.

Retarders-Unit 2002

To prevent overspeeding due to excessive grades and loads. additional auxiliary brakes should be used to assist vehicle brakes in retarding the vehicular motion.

Hydraulic Retarders

The heat generated by retarder and absorbed by heat exchanger may exceed cooling capacity of engine cooling system. That is, the heat rejected during braking may be greater than the heat rejected during full power operation. The cooling system should be designed around the higher heat input. Safety warning devices are required to prevent damage through overheating.

An automatic high water temperature warning light or buzzer should be provided in all retarder installations to warn the operator of excessive water temperatures and allow him to reduce retarding action so that boiling of coolant will not occur. The retarder manufacturer may also insist on a high oil temperature warning device to protect retarder in the event both warning devices are required.

Hydrotarders

As with hydraulic (oil) retarder, heat generated by a hydrotarder (water) may also exceed maximum heat load of the engine, and this should be provided for in the design of the cooling system.

The water storage tank should have a minimum capacity of 1 gal. [3.785 lit] for each three horsepower of absorption.

It is advisable to install a water temperature gauge on outlet of hydrotarter as well as an automatic warning device on engine water outlet.

Main Power Generator Group

Correct installation of generator set is a prerequisite for long life and satisfactory operation.

Power Generators—Unit 2101 and Unit 2102

To insure satisfactory operation of a power generator, make sure that the closest possible alignment is provided between engine crankshaft and power generator.

1. Using a suitable lifting device, position generator assembly to engine.

2. Secure generator frame snugly to engine flywheel housing with lockwashers and capscrews.

Caution: Do not force alignment of units. Shift generator from side to side and raise or lower with lifting device as necessary.

Note: On V-1710 Generator Sets it may be necessary to use shims under mounting pads of either generator or engine to obtain proper alignment.

3. Position drive disc to flywheel and secure with lockwashers and capscrews.

4. Remove lifting device from generator lifting eyes.

5. Place brushes on slip rings of static excited units and install vent screen.

6. Position control panel on generator, if so located, and secure with mounting hardware.

7. Remove tags and connect all electrical leads to proper terminals of control panel and terminal board. Refer to pertinent wiring diagrams for wiring connections.

Note: Crankshaft end clearance must be maintained after assembly of generator to engine.

For detailed information of generator set, refer to Bulletin 983600 for Static Excited Generator Set or Bulletin 983679 for Brushless Generator Set.

Index

Auxiliary/Generator Drive

Assembly . . . 9-2-1
Cleaning and Inspection . . . 9-2-1
Disassembly . . . 9-2-1
Installation . . . 14-1-19
Removal . . . 0-10

Accessory Drive

Installation . . . 14-1-18
Removal . . . 0-10

Adjust Injectors and Valves . . . 14-1-40

Air Cleaner (Cartridge Type)

Assembly . . . 10-1-4
Cleaning and Inspection . . . 10-1-4
Disassembly . . . 10-1-3
Removal . . . 0-6

Air Cleaner (Composite and Cyclonic Types)

Assembly . . . 10-1-3
Cleaning . . . 10-1-2
Disassembly . . . 10-1-2
Inspection . . . 10-1-3

Air Cleaner (Dry Type)

Assembly . . . 10-1-2
Cleaning and Inspection . . . 10-1-2
Disassembly . . . 10-1-2

Air Cleaner (Oil Bath)

Assembly . . . 10-1-2
Cleaning and Inspection . . . 10-1-1
Disassembly . . . 10-1-1

Air Cleaner Operating Restrictions . . . 10-1-5

Air Cleaner Piping . . . 10-1-6

Air Cleaner Restriction Indicator . . . 10-1-4

Air Compressor . . . 12-1-1

Installation . . . 14-1-29
Removal . . . 0-9

Air Cranking Motor . . . 12-1-1

Aneriod Control

Adjustment . . . 10-3-1, 14-2-12
Fuel Flow . . . 10-3-1
Installation . . . 14-1-37
Removal . . . 0-9
Repair . . . 10-3-4
Settings . . . 10-3-2

Balance Tubes

Installation . . . 14-1-37
Removal . . . 0-6

Ball Bearings . . . 9-1-1

Bearing Shell Inspection . . . 1-5-1

Belts

Adjustment . . . 14-1-39
Care . . . 14-1-39
Installation . . . 14-1-38
Maintenance . . . 14-1-39

Camshafts

Assembly . . . 1-10-2
Cleaning and Inspection . . . 1-10-1
End Play . . . 14-1-13
Installation . . . 14-1-13
Removal . . . 0-14

Camshaft Gears

Installation . . . 1-10-2
Removal . . . 1-10-2

Carburetor and Pressure Reduction Valve

Adjustment . . . 14-2-13
Installation . . . 14-1-43
Removal . . . 0-18

Index

Checks During Run-In 14-2-4, 14-2-8

Check Engine Coolant 8-4-1

Cold-Starting Aids

Ether 10-2-2
Preheater 10-2-1

Compression Release

Installation 14-1-20, 14-1-26
Removal 0-13

Connecting Rod

Assembly 14-1-6
Inspection 1-8-1
Installation 14-1-8
Removal 0-16
Repair 1-8-3

Coolant Specifications 18-1-11

Corrosion Resistor

Assembly 8-4-1
Disassembly 8-4-1
Inspection and Repair 8-4-1
Installation 14-1-38
Removal 0-4

Crankcase Breather

Assembly 3-3-1
Cleaning and Inspection 3-3-1
Disassembly 3-3-1
Installation 14-1-41

Crankcase Breather Tube 0-12

Crankcase Pressure (Blow-By) 14-2-10

Cranking Motor (Air)

Installation 14-1-35
Removal 0-2

Cranking Motor (Electric)

Installation 14-1-35
Removal 0-2

Crankshaft

Assembly 1-4-6
Cleaning and Inspection 1-4-1
Disassembly 1-4-1
End Clearance 14-1-3
Installation 14-1-1
Removal 0-17
Repair 1-4-4

Cylinder Block

Assembly 14-1-1
Cleaning 1-1-1
Inspection 1-1-2
Repair 1-1-7

Cylinder Head

Assembly and Testing 2-6-1
Disassembly 2-1-1
Inspection and Cleaning 2-1-1
Installation 14-1-15
Removal 0-12, 0-13
Repair 2-1-5
Tightening 14-1-16

Cylinder Head Fuse Plug 2-1-3

Cylinder Liners

Cleaning and Inspection 1-2-1
Grinding 1-2-1
Honing 1-2-2
Installation 14-1-5, 14-1-7, 14-1-9
Removal 0-16

Drain Water and Oil 0-1

Drive (Fuel Pump/Compressor)

Assembly 9-1-3
Disassembly 9-1-2
Inspection 9-1-3

Index

Drive (Fuel Pump/Hydraulic Governor)

Assembly 9-1-4
Cleaning and Inspection 9-1-3
Disassembly 9-1-3

Drive Pulley Inspection and Repair 9-1-2

Electric Connections

Installation 14-2-1
Removal 0-1
Specifications 13-1-3

Electrical System

Batteries 13-1-7
Cranking Motor Drives 13-1-5
General 13-1-1
Wire Size 13-1-8

Engine Adaptations 16-1-1

Engine Break-In 14-2-6

Engine Coolant

Adjust 8-4-2
Chromate Test 8-4-2
pH Test 8-4-2

Engine Dynamometer

Horsepower 14-2-5
Installation 14-2-1
Maintenance 14-2-10
Power Check 14-2-8
Test Procedures 14-2-6

Engine Mountings 16-3-1

Engine Oil Flow 7-0-1

Engine Serial Number 0-1

Engine Storage

Permanent 14-3-1
Preparation 14-3-2
Temporary 14-3-1

Engine Safety Controls 15-1-1

Engine Timing 14-1-16

Expansion Tank

Installation 14-1-38
Removal 0-4

Exhaust Manifolds

Cleaning and Inspection 11-1-1
Installation 14-1-23
Removal 0-8

Exhaust System

Aspirators 11-3-1
Muffler 11-2-2
Piping 11-2-1
Pyrometers 11-3-1
Radiation 11-2-3
Restriction 11-2-1

Fan, Fan Hub and Mounting Bracket

Installation 14-1-26, 14-1-28
Removal 0-3, 0-10

Fan Hubs (With Adjusting Screw)

Assembly 8-2-1
Disassembly 8-2-1
Inspection 8-2-1

Flywheel

Installation 14-1-32
Removal 0-13
Repair 16-1-1

Index

Flywheel Drives 16-2-1

Flywheel Housing

Installation 14-1-30
Removal 0-14

Foreword 2

Fuel Filter

Installation 14-1-29
Removal 0-3, 0-4

Fuel Inlet and Drain Connections

Installation 14-1-24
Removal 0-5

Fuel Oil Specifications 18-1-10

Fuel Pump

Installation 14-1-29
Removal 0-9

Fuel Systems

Fuel Pump 5-0-1
Natural Gas 5-0-1

Gear Backlash 14-1-13, 14-1-18

Gear Cover

Assembly 1-11-1
Inspection 1-11-1
Installation 14-1-19
Removal 0-11
Repair 1-11-1

Gear Case

Installation 14-1-12
Removal 0-17

Generator/Alternator

Cleaning and Inspection 13-2-1
Controls 13-2-3
Installation 14-1-35
Removal 0-3
Test, Repair and Adjustment 13-2-5

Glass Bead Cleaning 0-17

Grease Specifications 18-1-9

Hand Hole Covers

Installation 14-1-17
Removal 0-14

Heat Exchanger

Assembly and Testing 8-5-1
Cleaning 8-5-1
Disassembly 8-5-1
Inspection and Repair 8-5-1
Installation 14-1-38
Removal 0-5

Hydraulic Governor

Adjustment 14-2-14
Fill 14-2-2
Installation 14-1-43
Removal 0-18

Idler Gear

Cleaning and Inspection 1-3-1
Installation 14-1-13
Removal 0-14
Repair 1-3-1

Injection Timing 14-1-16

Injector Adjustment 14-1-40

Injectors

Installation 14-1-21
Removal 0-12
Repair 6-0-1

Index

Injector Sleeves

Inspection . . . 2-1-4
Installation . . . 2-2-2
Removal . . . 2-2-1
Repair . . . 2-2-1

Intake Manifold

Installation . . . 14-1-28
Removal . . . 0-7

Intercooler

Assembly . . . 8-9-1
Cleaning and Inspection . . . 8-9-1
Disassembly . . . 8-9-1
Installation . . . 14-1-37
Removal . . . 0-7
Repair . . . 8-9-1

Introduction . . . 7

Load Application . . . 14-2-10

Lubricating Oil Control Valve . . . 1-1-23

Lubricating Oil Cooler

Assembly . . . 7-5-2
Cleaning and Inspection . . . 7-5-1
Disassembly . . . 7-5-1
Installation . . . 14-1-34
Removal . . . 0-5
Repair . . . 7-5-1

Lubricating Oil Cooler (Auxiliary)
Assembly and Testing . . . 7-5-2
Cleaning . . . 7-5-2
Disassembly . . . 7-5-2
Inspection and Repair . . . 7-5-2

Lubricating Oil Dipstick . . . 7-3-1

Lubricating Oil Filter (By-Pass Type)

Assembly . . . 7-4-2
Cleaning and Inspection . . . 7-4-2
Disassembly . . . 7-4-2
Flow Characteristics and Specifications . . . 7-4-2
Hose Size . . . 7-4-2
Installation . . . 14-1-42

Lubricating Oil Filter (Full-Flow Paper Element Type)

Assembly . . . 7-4-1
Cleaning and Inspection . . . 7-4-1
Disassembly . . . 7-4-1
Installation . . . 14-1-34
Removal . . . 0-5

Lubricating Oil Filter Head

Installation . . . 14-1-34
Removal . . . 0-5

Lubricating Oil Lines

Cleaning . . . 7-2-1
Fittings . . . 7-2-2
Inspection . . . 7-2-1
Repair . . . 7-2-1
Specifications . . . 7-2-1

Lubricating Oil Pressure Regulator

Assembly . . . 7-6-1
Disassembly . . . 7-6-1

Lubricating Oil Pump (Scavenger)

Assembly . . . 7-6-3
Cleaning and Inspection . . . 7-6-3
Disassembly . . . 7-6-3
Installation . . . 14-1-42
Repair . . . 7-6-3

Lubricating Oil Pump

Assembly . . . 7-6-1
Cleaning and Inspection . . . 7-6-1
Disassembly . . . 7-6-1
Installation . . . 14-1-11
Removal . . . 0-15

Lubricating Oil Specifications . . . 18-1-7

Index

Mag-tronic Ignition

Adjustment 14-2-12
Installation 14-1-43
Removal 0-18

Main Bearing Caps

Installation 14-1-3
Removal 0-16
Tightening 14-1-3

Marine Gears 16-5-1

Mechanical Controls; Water, Air and Fuel Connections

Installation 14-2-1
Removal 0-2

Mount Engine to Stand 0-3

Oil Gauge Dipstick 7-3-1

Oil Pan

Assembly 7-1-2
Cleaning and Inspection 7-1-1
Disassembly 7-1-1
Installation 14-1-34
Removal 0-15
Repair 7-1-1
Specifications 7-1-1

Oil Seals

General 9-1-1
Installation 14-1-26

Oil Spray Nozzles

Installation 14-1-17
Removal 0-12

Operating Temperature 8-7-1

Paint Engine 14-2-15

Pistons

Assembly 1-9-2, 14-1-6
Cleaning and Inspection 1-9-1
Installation 14-1-7
Removal 0-16

Pistons and Connecting Rods

Installation 14-1-5
Removal 0-15

Piston Rings

Installation 14-1-10
Removal 1-9-1

Power Check 14-2-8

Power Generators 21-1-1

Prime Fuel System 14-2-2

Prime Lubricating System 14-2-2

Push Tubes

Inspection 3-2-1
Installation 14-1-20
Removal 0-12

Radiator

Caps 8-7-1
Disassembly 8-7-1
Hose 8-7-1
Inspection and Rebuilding 8-7-1
Operating Temperature 8-7-1

Rear Cover and Seal

Installation 14-1-4, 14-1-31
Removal 0-15
Repair 1-12-1

Rocker Lever Assembly

Assembly 3-1-3

Index

Rocker Lever Assembly (Cont'd.)

Cleaning and Inspection 3-1-1, 3-1-3
Disassembly 3-1-1
Installation 14-1-24
Removal 0-12

Rocker Housing Cover

Assembly 3-4-1
Cleaning, Inspection and Repair 3-4-1
Disassembly 3-4-1
Installation 14-1-41
Removal 0-12

Sea or Raw Water Pump

Assembly 8-6-1
Disassembly 8-6-1
Inspection 8-6-1
Installation 14-1-38
Removal 0-6

Spark Plugs

Installation 14-1-42
Removal 0-18

Spark Plug Adapters

Removal, Cleaning and Installation 2-2-3

Specifications and Wear Limits 18-1-1

Starting Procedure 14-2-3

Steam Clean Engine 0-3

Steam Cleaning 0-17

Tappets and Guides

Assembly 4-2-1
Disassembly 4-2-1
Inspection 4-2-1, 4-2-2
Installation 14-1-14
Removal 0-13
Torque 4-2-3

Thermal Control 8-8-1

Thermostat Housing and Water By-Pass Connection

Assembly 8-3-1
Cleaning and Inspection 8-3-1
Disassembly 8-3-1
Installation 14-1-23
Removal 0-7

Timing Marks 14-1-16

Timing the Engine 14-1-16

Torque Converter Cooler

General 16-2-1
Removal 0-6

Torque Converter Governor Adjustment 14-2-11

Torque Specifications 18-1-12

Turbocharger

General 10-5-1
Installation 14-1-36
Removal 0-6

Vacuum Pump 12-1-1

Valve Guide Seals 2-5-4

Valves

Grinding 2-5-1
Inspection 2-5-1
Installation 2-6-1
Removal 2-1-1

Valve Adjustment 14-1-40

Valve Crossheads

Adjustment 14-1-40

Index

Inspection 2-4-1
Installation 14-1-24
Removal 0-12

Valve Crosshead Guides

Inspection 2-1-3
Removal 2-4-1
Replace 2-4-1

Valve Guides

Inspection 2-5-2
Installation 2-5-2
Removal 2-5-2

Valve Seat Inserts

Grinding 2-3-1
Inspection 2-1-4
Removal 2-3-1
Replace 2-3-1

Valve Springs

Inspection 2-5-3
Installation 2-6-1
Removal 2-1-1
Testing 2-5-3

Vehicle Braking

Hydraulic Retarders 20-2-1
Hydrotarders 20-2-1

Vent Holes 2-6-2

Vibration Damper and Hub

Installation 14-1-27
Inspection and Repair 1-6-1
Removal 0-10

Water Header Plates

Installation 14-1-35
Removal 0-13

Water Manifold

Installation 14-1-22
Removal 0-8

Water Pump

Assembly 8-1-2
Cleaning 8-1-1
Disassembly 8-1-1
Drive Pulley 14-1-20
Inspection 8-1-2
Installation 14-1-21
Removal 0-7
Replacing Metallic Seal 8-1-2

Index of Tables

Table No.		Page No.
1	Engine Models (Naturally Aspirated)	5
2	Engine Models (Turbocharged)	6
1-1-1	Cylinder Block Pipe Plug Torque	1-1-1
1-1-2	Camshaft Bushing Inside Diameter	1-1-3
1-1-3	Block Camshaft Bushing Bore	1-1-3
1-1-4	Cylinder Liner Counterbore Diameter	1-1-3
1-1-5	Cylinder Liner Counterbore Depth	1-1-3
1-1-6	Liner-To-Block Clearance — Lower Bore	1-1-5
1-1-7	Lower Liner Bore Inside Diameter	1-1-5
1-1-8	Main Bearing Bore	1-1-6
1-1-9	Tappet Bore Size	1-1-7
1-1-10	Main Bearing Capscrew Tightening	1-1-12
1-1-11	Cylinder Block Height From Main Bearing Centerline	1-1-13
1-1-12	Cylinder Block Height From Alignment Bar	1-1-13
1-1-13	Cylinder Liner Counterbore Shims	1-1-17
1-2-1	Standard Cylinder Liner Inside Diameter	1-2-1
1-4-1	Crankshaft Dimensions	1-4-3
1-4-2	Magna-Flux Magnetization	1-4-3
1-5-1	Bearing Shell Thickness	1-5-1
1-5-2	Journal Clearnace	1-5-1
1-5-3	Crankshaft Thrust Rings	1-5-1
1-6-1	Damper Eccentricity and Wobble Limits	1-6-1
1-8-1	Template Tightening Connecting Rod Nuts	1-8-1
1-8-2	Connecting Rod Dimensions	1-8-1
1-9-1	Piston Ring Gap — New Or Reconditioned Liner	1-9-1
1-9-2	Standard Piston Skirt Diameter	1-9-2
1-9-3	Piston Pin Bore	1-9-2
1-9-4	Piston Pin Diameter	1-9-2
1-10-1	Camshaft Journal Diameter	1-10-1
1-10-2	Camshaft Keys	1-10-2
1-10-3	Camshaft Lobe Lift Measurements	1-10-3
1-11-1	Accessory Drive Bushing I.D.	1-11-1
2-1-1	Crosshead Guide Dimensions	2-1-3
2-1-2	Head Height	2-1-6
2-2-1	Injector Sleeve Replacement Specifications	2-2-2
2-2-2	ST-884 Grinding Specifications	2-2-3
2-3-1	Valve Seat Insert Specifications	2-3-2
2-4-1	Crosshead Stem Inside Diameter	2-4-2
2-5-1	Valve Guide Inside Diameter	2-5-2
2-5-2	Valve Spring Data	2-5-4
2-6-1	Cylinder Head Pipe Plug Torque	2-6-2
3-1-1	Rocker Lever Bushing Inside Diameter	3-1-2
3-1-2	Rocker Lever Shaft Outside Diameter	3-1-2
4-2-1	Tappet Specifications	4-2-2
4-2-2	Tappet I.D. and Sleeve Torque	4-2-4
7-1-1	Oil Pan Capacity And Angularity	7-1-2
7-1-2	Aluminum Oil Pan Plug Torques	7-1-2
7-2-1	Hose Size	7-2-1
7-2-2	Hose Bends	7-2-2
7-3-1	Blank (Unmarked) Dipstick Length	7-3-1
7-6-1	V-1710 Lubricating Oil Pump Dimensions	7-6-2
8-7-1	Radiator Caps	8-7-1
8-8-1	Thermal Control Temperatures	8-8-1
10-1-1	Total Intake Restriction Limits	10-1-5
10-2-1	Approved Cold-Starting Aids	10-2-2
10-3-1	Intake Manifold Pressure	10-3-2
10-3-2	Aneroid Control Settings	10-3-3
11-2-1	Exhaust Pipe Size	11-2-2
13-1-1	Cable Sizes — Total Length Allowable In Cranking Motor Circuit	13-1-3
13-1-2	Minimum Battery Capacity in Ampere Hours	13-1-8
13-1-3	Ampere Hour Capacity Ratings Of Battery Systems	13-1-8
14-1-1	Main Bearing Capscrew Tightening	14-1-3
14-1-2	Liner Counterbore	14-1-5
14-1-3	Injector Timing Specifications	14-1-17
14-1-4	Vibration Damper Data	14-1-28
14-1-5	Belt Tension	14-1-39

Table No.		Page No.
14-1-6	Engine Firing Order	14-1-40
14-2-1	Test Standards For Conversions	14-2-6
14-2-2	Dynamometer Test Chart	14-2-7
14-2-3	Normal Lubricating Oil Pressure	14-2-8
15-1-1	Oil Pressure vs. Fuel Pressure Settings	15-1-1
16-2-1	Converter Application Limits For Unknown Environmental Conditions – Turbocharged Engines	16-2-1
18-1-1	Minimum Cummins Oil Recommendations	18-1-7
18-1-2	Operating Temperatures Vs Viscosity	18-1-8
18-1-3	Arctic Oil Recommendations	18-1-8

Cummins Engine Company, Inc.
Columbus, Indiana, U.S.A. 47201

Cummins Engine Company, Ltd.
Coombe House, St. George's Square
New Malden, England
Cable: INTCUMLON MALDEN

Overseas Factories:

Cummins Engine Company, Ltd.
Shotts, Lanarkshire, Scotland
Cable: CUMSCOT SHOTTS

Cummins Engine Company, Ltd.
Yarm Road, Darlington,
County Durham, England
Cable: CUMDAR DARLINGTON

Cummins Diesel Australia
Ringwood, Victoria
Cable: CUMAUS

Bulletin No. 983694-OE 5-70 Printed in U.S.A.