Due to a continuous program of research and development, some procedures, specifications and parts may be altered in a constant effort to update and improve our products.

Periodic revisions may be made to this publication and mailed automatically to dealers. It is recommended that customers contact their dealer for information on the latest revision.

CGES–430–3 DT/DTA–360 DIESEL ENGINES MARCH, 1992

INTERNATIONAL®
DT/DTA–360
DIESEL ENGINE
SERVICE MANUAL
FORM CGES–430–3
March, 1992

Printed in United States of America

SERVICE MANUAL

FORWARD

This manual is part of a series of manuals intended to assist service technicians in maintaining engines, produced by Navistar International Transportation Corp., in accordance with the latest technical advancements.

Due to a commitment of continuous research and development, some procedures, specifications and parts may be altered to improve International® products and introduce technological advances.

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Form No.	Description
CGES–445–*	Diesel Engine Diagnostic Manual
CGED–425–*	DT/DTA–360 Diesel Engine Performance Analysis Guide
CGES–375–*	Robert Bosch PES6MW Fuel Injection Pump
CGES–480–*	Robert Bosch PES6A Fuel Injection Pump
1 171 597 R*	DT/DTA–360 Engine Parts Catalog
1 171 595 R2	DT/DTA–360 Operation and Maintenance Manual (1987–88)
1 171 626 R1	DT/DTA–360 Operation and Maintenance Manual (1989)
1 171 635 R1	DT/DTA–360 Operation and Maintenance Manual (1990)
1 171 641 R1	DT/DTA–360 Operation and Maintenance Manual (1991)

IMPORTANT

THIS ENGINE SERVICE MANUAL APPLIES TO INTERNATIONAL TRUCK APPLICATIONS USING DT–360 AND DTA–360 SERIES DIESEL ENGINES

* — Manual number specified with latest revision will be furnished

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SERVICE DIAGNOSIS

Service diagnosis is a systematic procedure of investigation to be followed in order to locate and correct an engine problem. The engine is first considered as a complete unit in its specific application and then the problem is localized to components or systems; intake, exhaust, cooling, lubrication or injection. Testing procedures will then help analyze the source of the problem.

PREREQUISITES FOR EFFECTIVE DIAGNOSIS:

1. Knowledge of the principles of operation for both the engine and application systems.
2. Knowledge to perform and understand all procedures in the diagnostic and service manuals.
3. Availability of and the ability to use gauges and diagnostic test equipment.
4. Have available the current Guideline Data for the engine application. (Refer to Diagnostic Manual)

Although the cause of an engine failure may be apparent, very often the real cause is not found until a repeat failure occurs. This can be prevented if specific diagnostic action is taken prior to, during and after engine disassembly and during engine reassembly.

It is also very important that specific diagnostic tests follow engine reassembly prior to and after the engine is placed back into service.

Identification of the symptoms which lead to engine failure is the result of proper service diagnosis. Effective service diagnosis requires use of the following references:

1. CGES–445–* Diesel Engine Diagnostic Manual.
2. CGED–425–* DT/DTA–360 Performance Analysis Guide.
3. Component Specifications within this manual.
4. Service Bulletins.

* — Manual number specified with latest revision will be furnished

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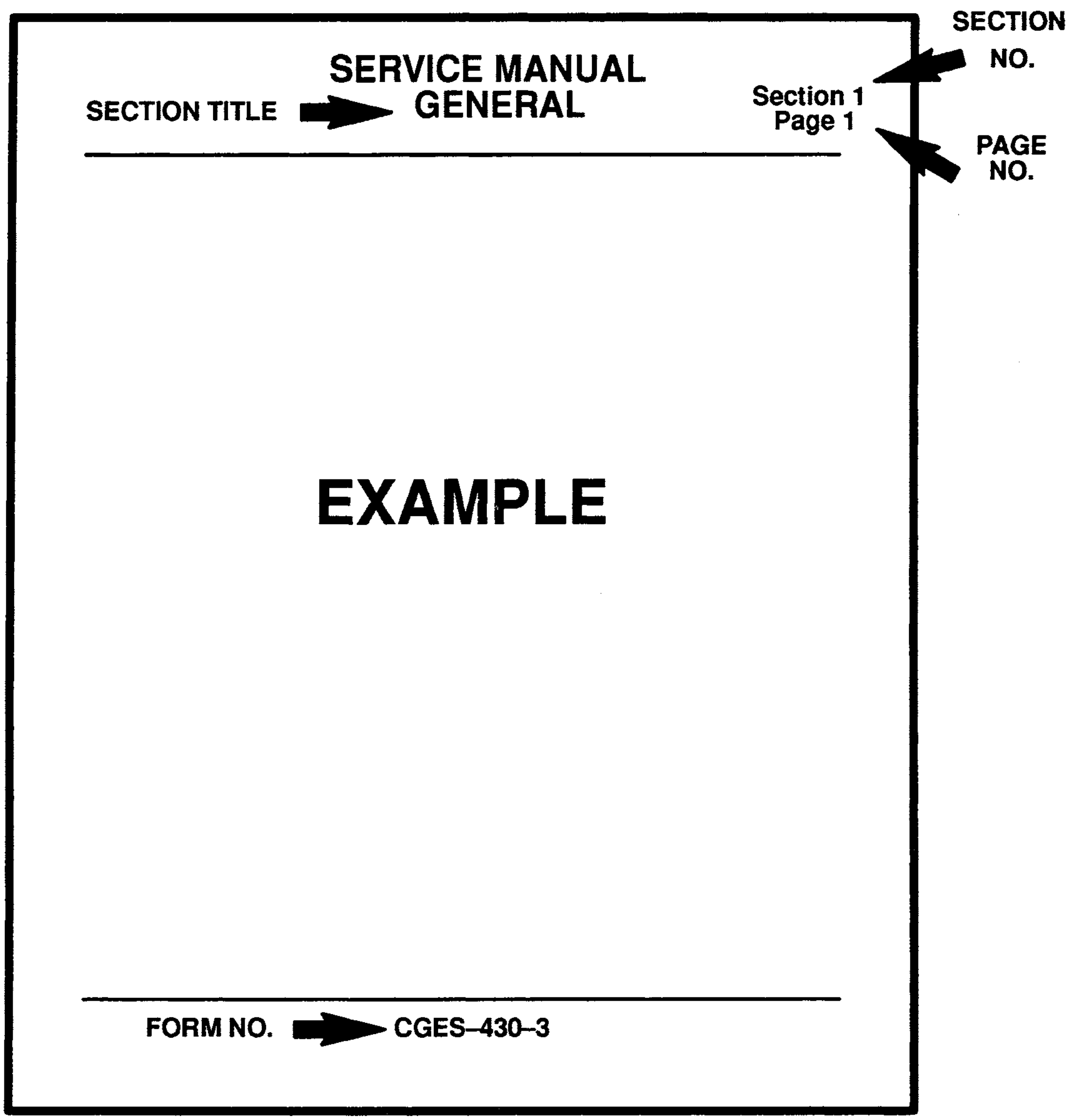
This manual is arranged in sections, with the pages numbered consecutively in each section. Any photos or artist renderings are also numbered consecutively in each section. Included at the top of each page is the Section Title, Section Number and Page Number. The bottom center of each page will show the Manual Form Number (i.e. CGES–430–3).

NOTE: A dash one (–1), two (–2) or three (–3) indicates the number of times the basic manual has been revised.



An index arranged according to sections will be found at the beginning of this manual.

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This manual is divided into three basic parts:

INTRODUCTORY SECTION
COMPONENT SECTIONS
APPENDIX

INTRODUCTORY SECTION

This section addresses the following general subjects which should be read prior to engine repair or overhaul:

Safety Suggestions
Engine Identification
Engine Description
Engine Systems

COMPONENT SECTIONS

These sections address the actual service procedures for each engine component. Each component section is arranged as follows:

Section Index
Exploded View(s)
Specifications
Special Torques
Special Tools
Engine Component Identification (where applicable)
Removal and Reassembly (where applicable)
- — Removal
- — Cleaning
- — Inspection
- — Installation

Reconditioning
- — Disassembly
- — Cleaning
- — Inspection
- — Repair
- — Reassembly

APPENDIX

The appendix is located at the end of the manual and consists of the following:

Component Specifications
General Engine Specifications
Torque Data
Special Service Tool List
English/Metric Conversion Chart

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SERVICE MANUAL
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SECTION 4 — CYLINDER HEAD AND VALVES

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SECTION 6 — CONNECTING RODS, PISTONS, RINGS AND SLEEVES

SECTION 7 — VIBRATION DAMPER, CRANKSHAFT, MAIN BEARINGS, FLYWHEEL & CRANKCASE

SECTION 8 — TIMING GEAR TRAIN AND FRONT COVER

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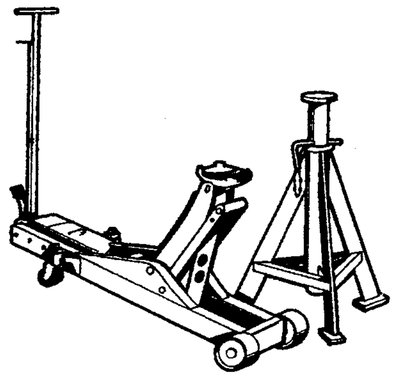
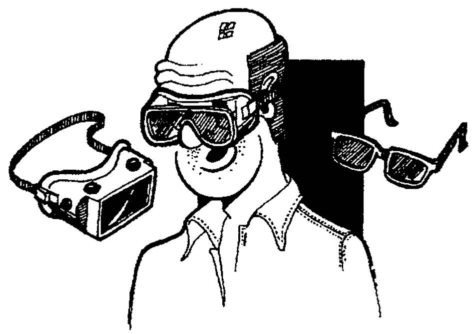


CG-6057

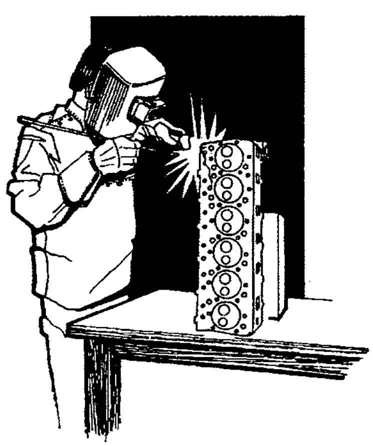
Always use safety stands in conjunction with hydraulic jacks or hoists. Do not rely on jack or hoist alone to carry the load. They can fail.



CG-6058

To prevent injury, always select appropriate type safety glasses for the job.

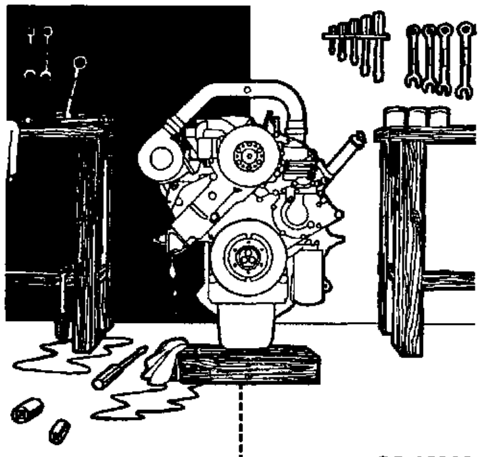
It is especially important to wear safety glasses when using tools such as hammers, chisels, pullers and punches.



CG-6059

When welding or using an acetylene torch, always wear welding goggles and gloves. Insure acetylene and oxygen tanks are separated by a metal shield and are chained to a cart. Do not weld or heat areas near fuel tanks or fuel lines and utilize proper shielding around hydraulic lines.

SAFETY SUGGESTIONS

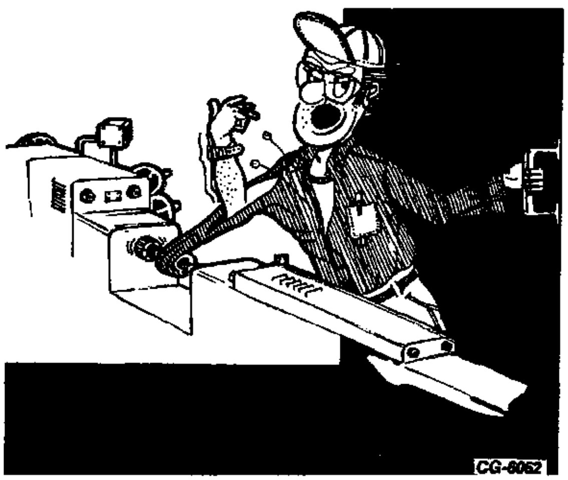


CG-12002

Keep work area organized and clean. Wipe up oil spills of any kind. Keep tools and parts off floor. Eliminate the possibility of a fall which could result in a serious injury.

Be sure to reinstall safety devices, guards or shields after adjusting and/or servicing the machine.

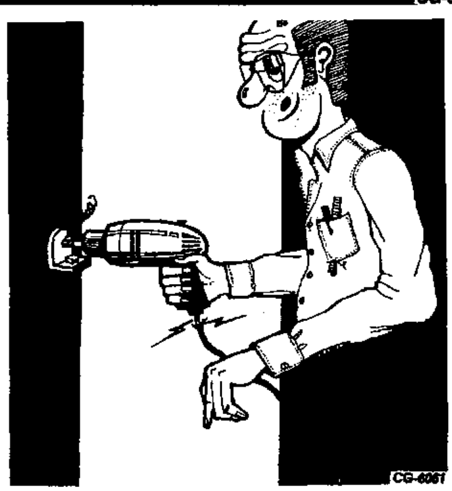
After servicing, be sure all tools, parts, or servicing equipment are removed from the machine.



CG-6062

Be sure to wear safe work clothing. It should be well fitted and in good repair.

Do not wear rings, wrist watches or loose fitting clothing, when working on machinery, they could catch on moving parts causing serious injury. Wear sturdy, rough–soled work shoes. Never adjust and/or service a machine in bare feet, sandals or sneakers.



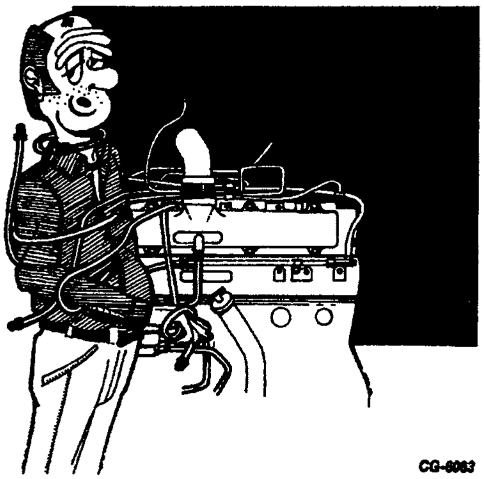
CG-6061

Do not use defective portable power tools. Check for frayed cords prior to using the tool. Be sure all electric tools are grounded. Severe injury can occur if electrical equipment is defective or not used properly.

CG-6980

Be careful when using compressed air. Never apply compressed air to any part of the body or clothing, injury or death can occur.

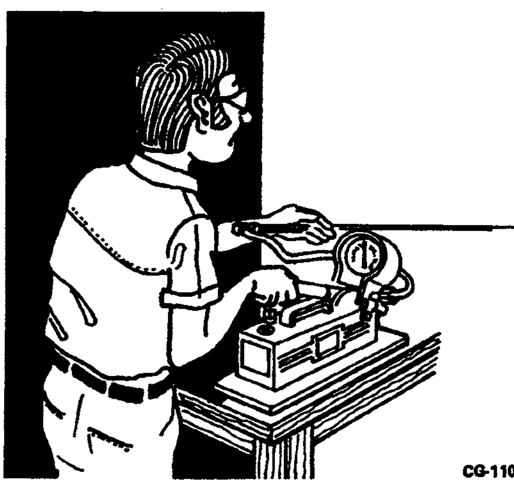
Use approved air blow guns, do not exceed 30 psi, wear safety glasses or goggles and use proper shielding to protect everyone in the work area.



CG-6063

When removing fuel lines remove them as an assembly, not individually.

Avoid getting fuel injection lines mixed up as our friend has.



CG-11040

Be extremely careful when dealing with fluids under pressure.

Fluid under pressure can have enough force to penetrate the skin. These fluids may also infect a minor cut or opening in the skin. If injured by escaping fluid, see a doctor at once. Serious infection or reaction can result if medical treatment is not given immediately.

Never put your hands in front of fluid under pressure.

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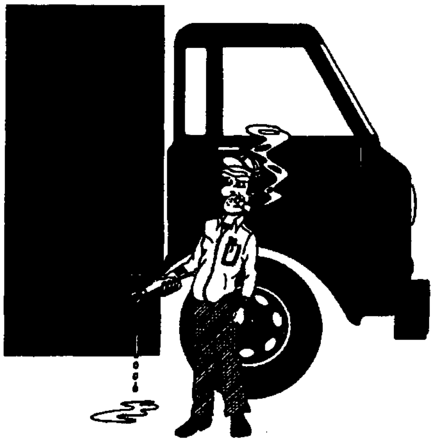
SAFETY SUGGESTIONS

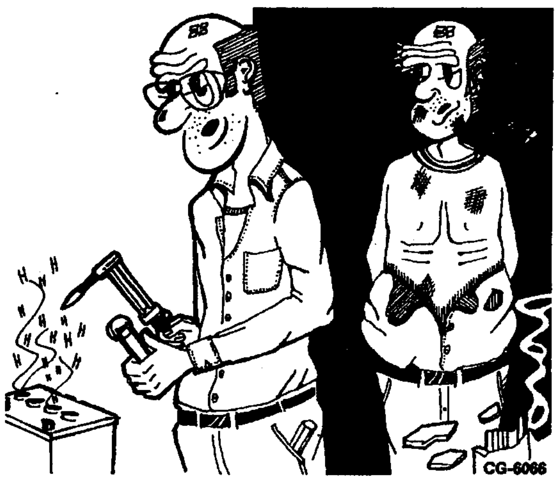


CG-9374

When refueling, keep the hose and nozzle or the funnel and container in contact with the metal of the fuel tank to avoid the possibility of an electric spark igniting the fuel.

Do not over fill the fuel tank — overflow creates a fire hazard.

Do not smoke when refueling and never refuel when the engine is hot or running.

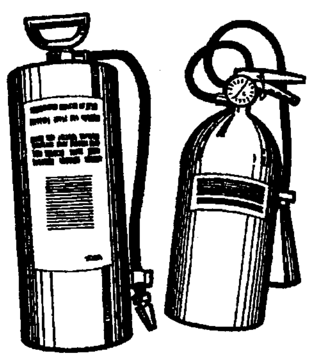


CG-6066

Electrical storage batteries give off highly inflammable hydrogen gas when charging and continue to do so for some time after receiving a steady charge.

Do not under any circumstances allow an electric spark or open flame near the battery or explosion may occur.

Always disconnect a battery cable before working on the electrical system.



CG-6067

Keep a "charged" fire extinguisher within reach whenever you work in an areas where fire may occur.

Also, be sure you have the correct type of extinguisher for the situation:

Type A: Wood, Paper, Textile and Rubbish

Type B: Flammable Liquids

Type C: Electrical Equipment

SERIAL NUMBERS

When in need of parts, always specify the engine model and serial number. The engine serial number is stamped on the crankcase pad located on left side of engine below center of intake manifold (Figure 1.) In some instances, a glue–on label indicating the engine serial number is affixed to the throttle linkage bracket or intake manifold. An engine exhaust emission label is located on the top of the intake manifold (Figure 1). The engine emission label designates the model and shipping date as well as other pertinent information.

Other nameplates, that should be located, are on the turbocharger, fuel injection pump and starter. These nameplates, showing manufacturer and specifications, are important to assist operator or maintenance personnel as to what equipment is on the engine and its operating conditions.

EXPLANATION OF THE 13 DIGIT SERIAL NUMBER

362 T M2 U 30001*

1. First Three Digits————362
   (Engine Family Identification)
2. Fourth Digit (TYPE)————T
   Type Codes used are:
   G–Diesel, Turbocharged & Air Intercooled
   B–Diesel, Turbocharged & Water Intercooled
   D–Diesel, Naturally Aspirated
   T–Diesel, Turbocharged
3. Fifth and Sixth Digits————M2
   (END USE)

   M2–Truck
   A2–Stripped and Service
4. Seventh Digit————U
   Country of Origin–United States
5. Eighth through Thirteenth Digits & Asterisk————30001*
   (Sequence Number)
   NOTE: Asterisk (*) is used to prevent tampering.

   Starting Engine Serial Number Blocks:

ENGINE	SERIAL NO.
DT/DTA–360, 1987 Model Year	30001* – 39374*
DT/DTA–360, 1988 Model Year	39375* – 54458*
DT/DTA–360, 1989 Model Year	54459* – 72705*
DT/DTA–360, 1990 Model Year	72706* – 90975*
DT/DTA–360, 1991 Model Year	90976* –112787

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ENGINE RATING COMPARISON

1987 MODEL YEAR

DT–360———165 HP @ 2700 RPM (Fed.)

DTA–360——180 HP @ 2700 RPM (Fed.)

DTA–360——175 HP @ 2700 RPM (Calif.)

1988/1989 MODEL YEAR

DT–360———170 HP @ 2700 RPM (Fed.)

DTA–360——180 HP @ 2700 RPM (Fed.)

DTA–360——175 HP @ 2700 RPM (Calif.)

1990 MODEL YEAR

DT–360———170 HP @ 2700 RPM (50 States)

DTA–360——185 HP @ 2700 RPM (50 States)

1991 MODEL YEAR

DT–360———170 HP @ 2700 RPM (Fed.)

DT–360———170 HP @ 2700 RPM (Calif.)

DTA–360——185 HP @ 2700 RPM (Fed.)

DTA–360——185 HP @ 2700 RPM (Calif.)

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ENGINE AND ACCESSORY NAMEPLATES — Continued

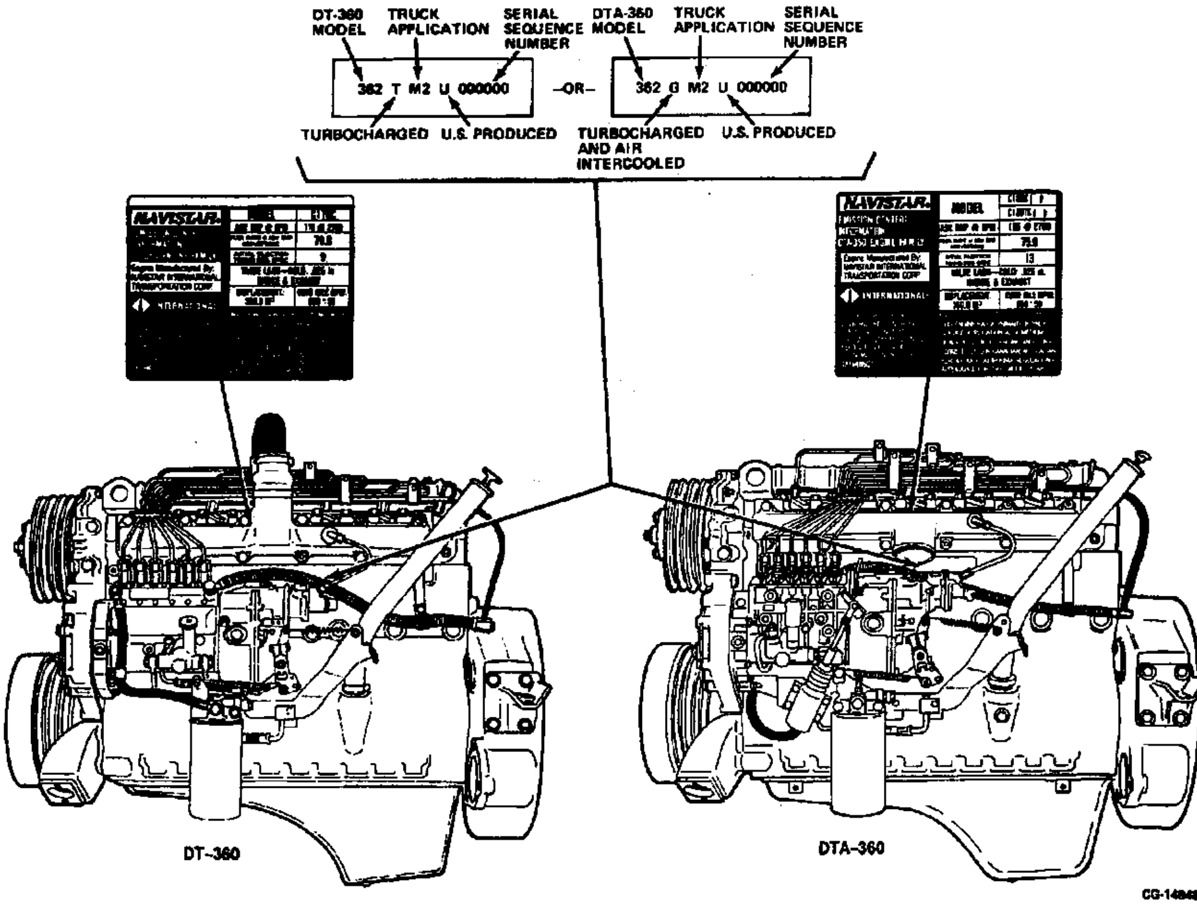

Figure 1. Engine Serial Number Pad and Exhaust Emission Label Identification

INJECTION PUMP IDENTIFICATION

Identification of the injection pump and governor assemblies can be made by referring to the I.D. plates as follows:

INJECTION PUMP HOUSING I.D. PLATE — is located on the left side of the pump housing (Figures 2 & 3). The pump serial number and Robert Bosch part number are found at this location.

GOVERNOR I.D. PLATE — is located on the rear of the governor housing (Figurse 2 & 3). The International Part No. for the complete injection pump and governor assembly, as well as the Robert Bosch governor number, size and rating are found at this location.

NOTE: The fuel injection pumps are calibrated differently for each Model Year DT–360 and DTA–360.

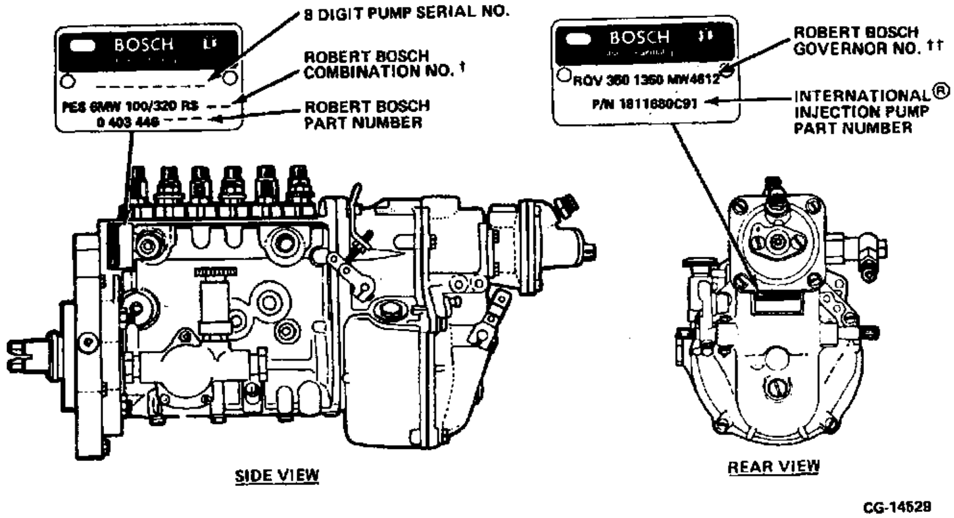

Figure 2. Model MW Fuel Injection Pump and Governor Identification

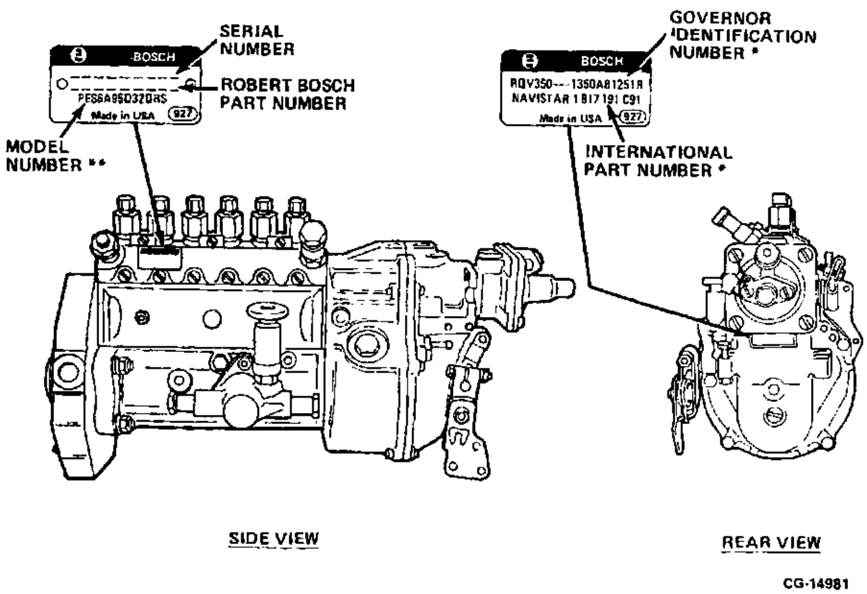

Figure 3. Model PES 6A Fuel Injection Pump and Governor Identification

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TURBOCHARGER IDENTIFICATION

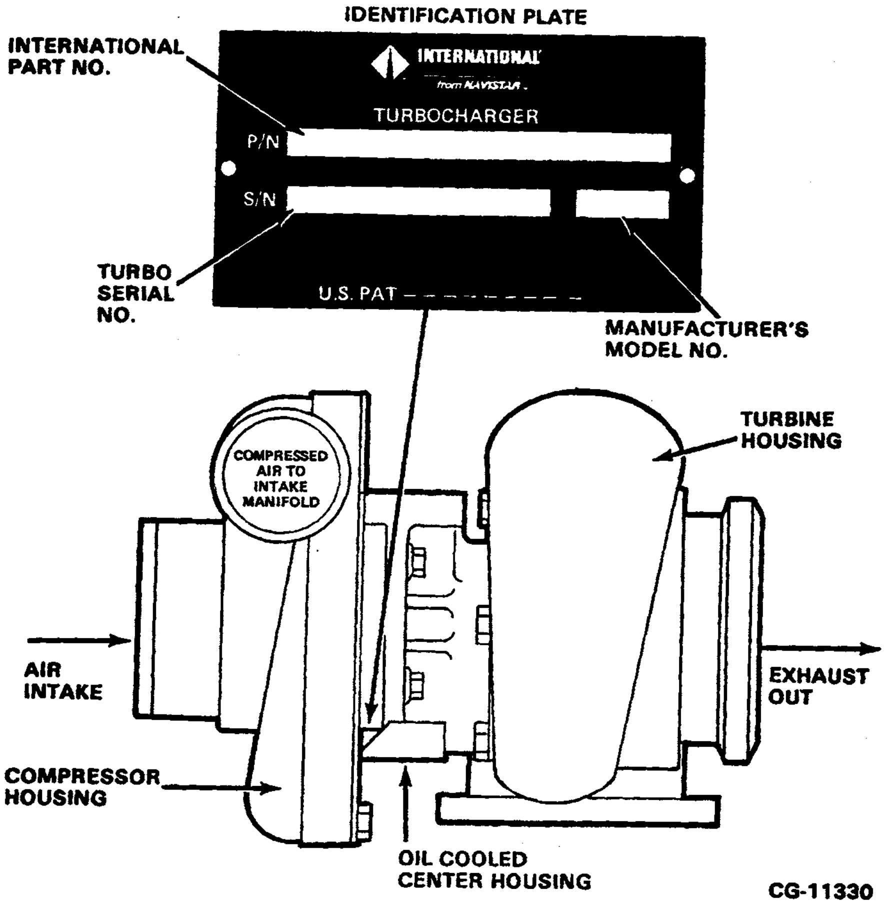

Figure 4. Turbocharger Identification

GENERAL FEATURES

The Models DT/DTA–360 Series engines are in–line six cylinder, 4 cycle, water–cooled overhead valve, direct injection diesel engines, with replaceable valve guides and valve seats for both the intake and exhaust.

Proven premium features have been designed into this series of engines such as externally mounted GEROTOR type lube oil pump and cast–in water and oil passages in the crankcase and front cover. Replaceable wet type cylinder sleeves, one piece cylinder head, cast aluminum alloy pistons, forged connecting rods and a forged steel crankshaft with induction hardened journals and fillets are used. The two high–efficiency spin–on type lube oil filters and one fuel filter are engine mounted. All models of the engine come equipped with an oil cooler. The GEROTOR lube oil pump is mounted on and driven directly by the crankshaft at engine speed. With the exception of the fuel injection pump and turbocharger oil supply, there is no external lube oil piping required.

The crankshaft is supported on seven precision insert bearings and camshaft on four pre–reamed bushings. The rod and main bearing caps are mated parts and are stamped for identification and are not interchangeable. Each engine main bearing web has angled, drilled holes which are fitted with jet tubes that direct lube oil, under pressure, to the underside of each piston.

There are two oil galleries in the crankcase; one handles unfiltered oil from the pump to the cooler and then from the cooler to the filter base. Oil leaving filters enters the second gallery and is distributed to the various points of lubrication throughout the engine. Both galleries are sealed at the rear of the case with plugs. The filtered oil gallery (upper) is also sealed at the front of the case.

CHASSIS MOUNTED CHARGE AIR COOLER OPTION

Engines designated as DTA–360 are equipped with a chassis mounted charge air cooling system. The charge air cooler is chassis mounted in front of or side–by–side of the radiator. Air from the turbocharger is pushed through a network of heat exchanger tubes prior to entering the intake manifold. Outside air flowing over the tubes and fins serves to cool the charge air. The resulting cooler intake air is denser than uncooled air, which results in additional fuel/air mixture entering the cylinders and an increase in output power.

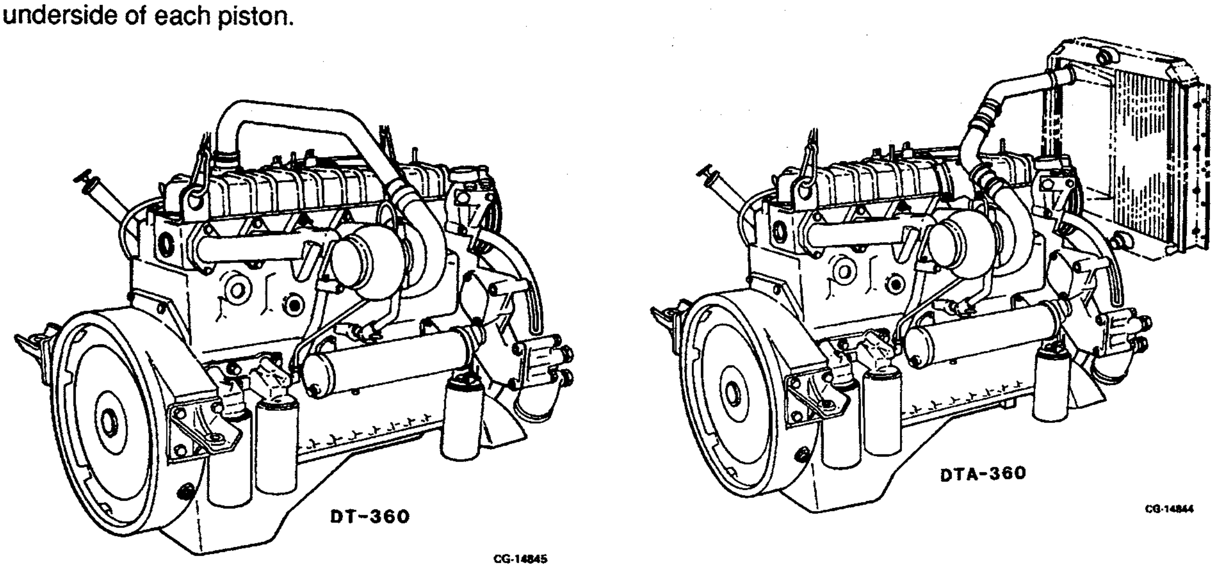

Figure 5. General Features (1991 Model Year Shown)

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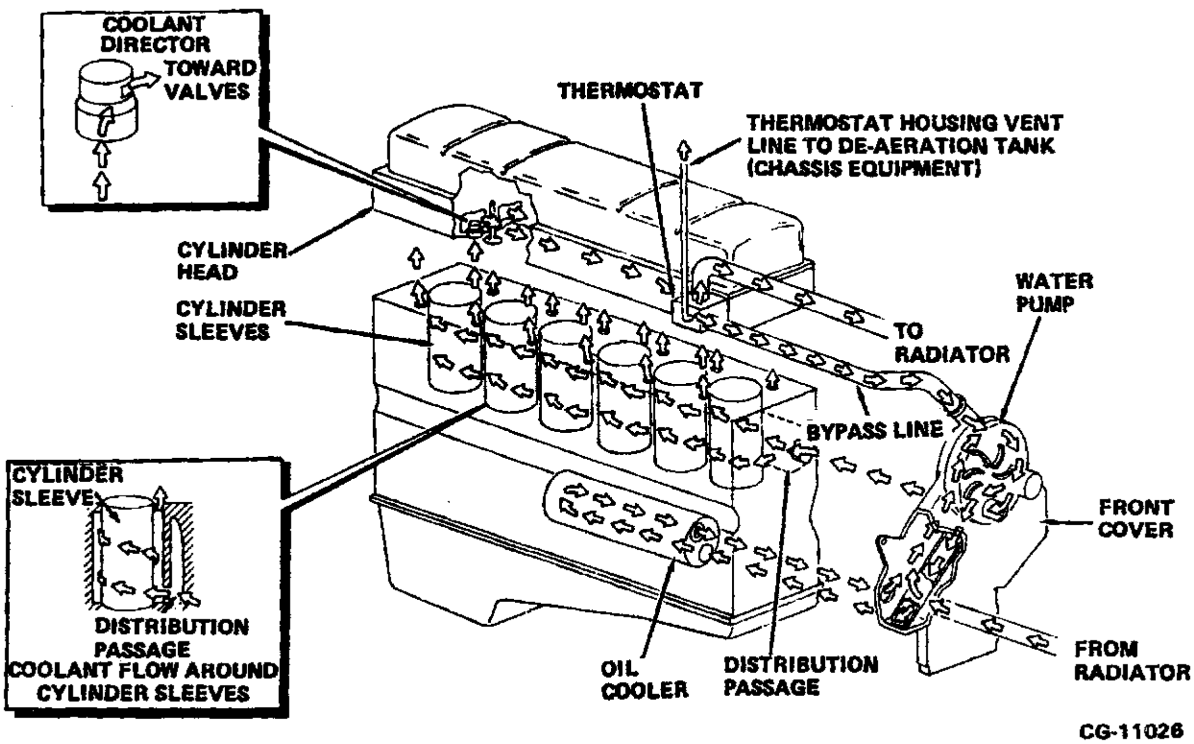

**Figure 6. Engine Cooling System
(DT/DTA–360)**

COOLING SYSTEM

Description

The function of the cooling system is to keep the engine within a designated temperature range. Major components of most cooling systems include a radiator and fan combination with a coolant (water) pump, thermostat, oil cooler and coolant filter. On these engines, the water pump is a belt–driven centrifugal type, which is set into the front cover. This front cover incorporates three separate cored passages. Two passages are used for coolant flow: one to channel coolant to the water pump and the other for coolant from the water pump to the oil cooler. The third passage carries lubricating oil from the oil pump outlet to the crankcase.

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Coolant Flow (See Figure 6)

Coolant flows from the bottom of the radiator to the water pump through the lower radiator hose and a cored passage in the front cover. The coolant is directed to the center of the water pump where the impeller distributes the coolant to the oil cooler and crankcase. The coolant that flows to the oil cooler flows through passages in the cooler and then exits to be re–mixed with incoming coolant from the radiator. This coolant is directed to the center of the water pump.

The crankcase portion of the water pump flow enters the distribution passageway, cast in the crankcase. The passageway directs coolant from front to rear of the crankcase, evenly distributing coolant to the lower sections of the cylinder sleeves. The coolant flow is directed toward each cylinder sleeve on a tangent causing a swirling motion upward towards the cylinder head. This swirling action improves heat dissipation.

Coolant then exits from the crankcase through two cored holes at the top of each cylinder sleeve bore. These holes index with twelve coolant entry holes in the cylinder head that are fitted with brass coolant directors. These coolant directors aim a high pressure stream of coolant around the injection nozzle sleeves and the valve seat areas for efficient cooling.

Coolant flows through the cylinder head to the thermostat. The thermostat housing incorporates two outlets to direct coolant either to the radiator when the engine is at operating temperature, or directly back to the water pump when the engine has not yet reached operating temperature.

THERMOSTAT OPERATION (See Figure 7)

When the engine coolant temperature is below specified thermostat opening temperature, the coolant flows through the bypass hose to the water pump because the radiator outlet port is blocked. As the engine reaches operating temperature, the thermostat opens, directing coolant towards the radiator; this also restricts the by–pass opening.

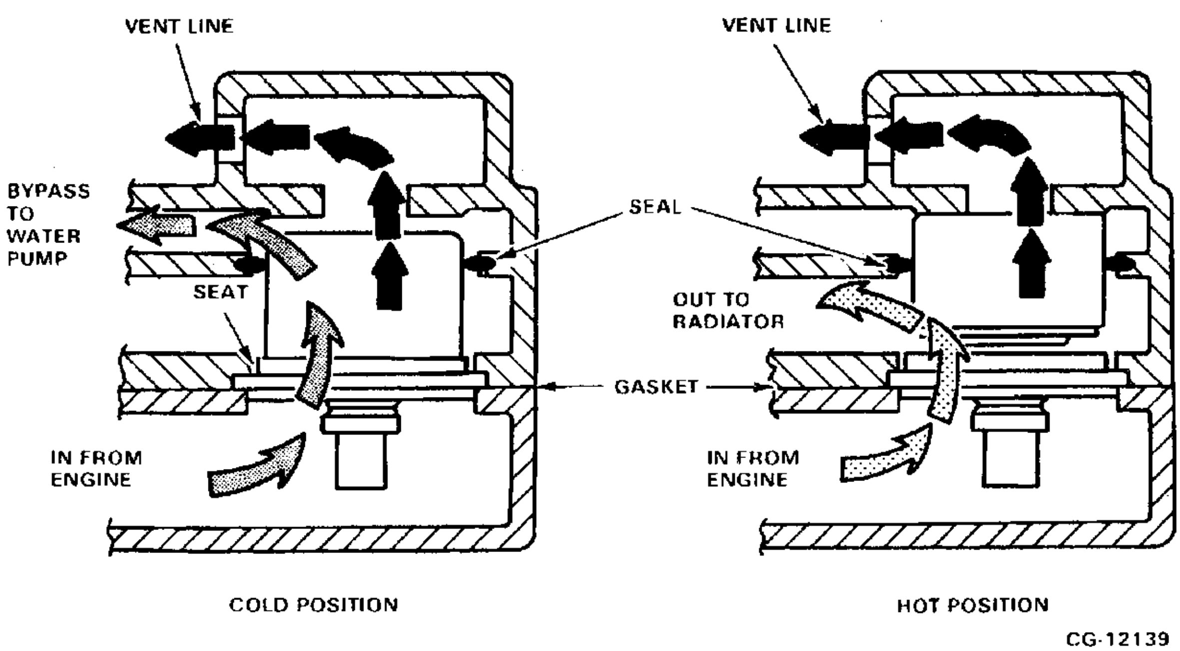

Figure 7. Thermostat Operation

LUBRICATION SYSTEM

Description

The pressurized lubricating oil system is a full–flow filtered and cooled type with bypass valve and pressure regulation. External oil piping is kept to a minimum to avoid oil leakage.

Location

The GEROTOR oil pump is mounted on and driven by the engine crankshaft at the front of the engine, at engine speed. The right side of the engine has the replaceable oil filters, oil cooler, turbocharger oil line, and crankcase breather tube. The left side of the engine has the oil filler, oil level gauge, and oil supply line for the fuel injection pump.

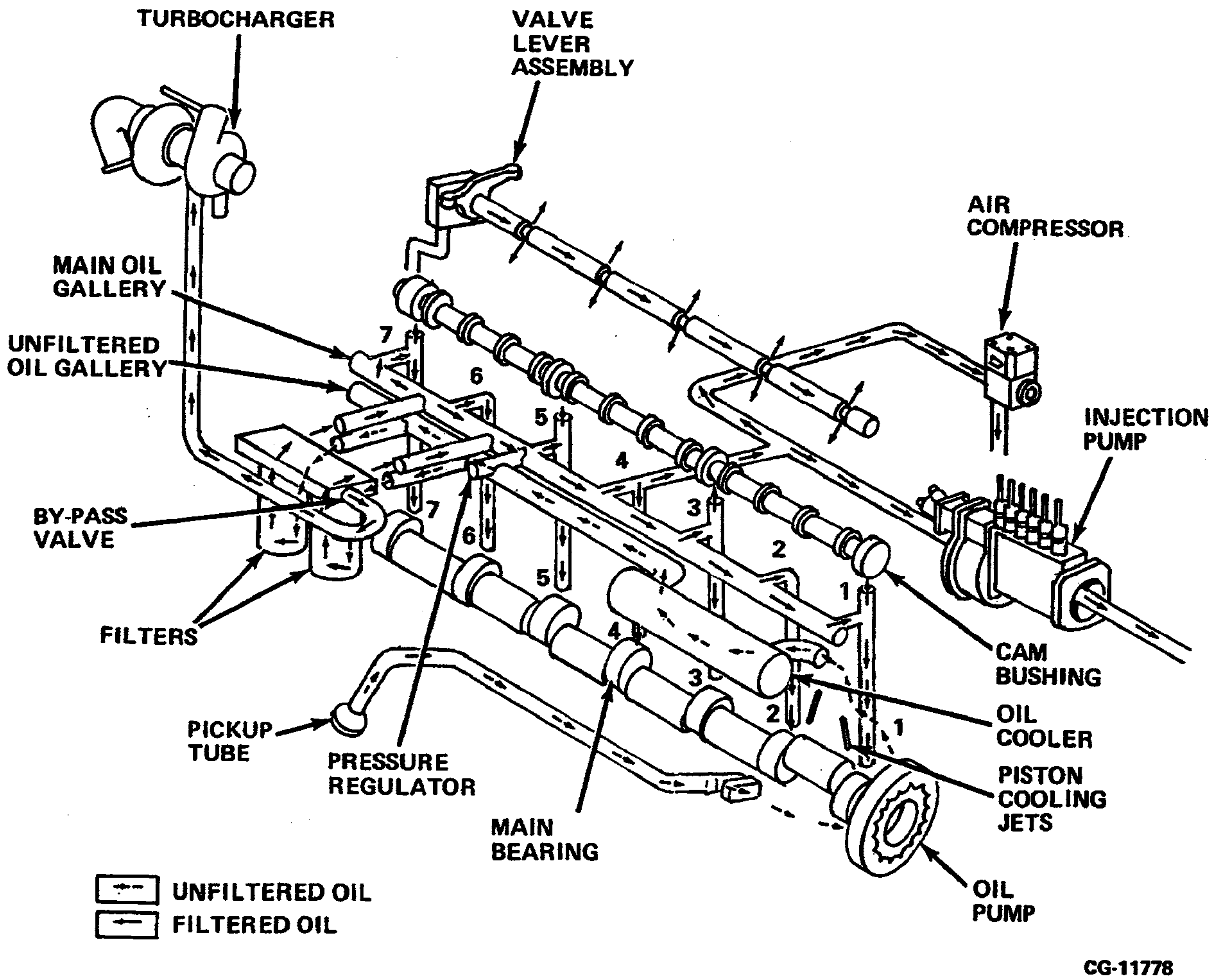

Figure 8. Engine Lubrication System
(DT/DTA–360)

LUBRICATION SYSTEM — Continued

Oil Flow

Oil flows from the oil pan through the strainer and suction tube to the inlet port at the rear of the front cover. Oil leaving the pump is channeled to the crankcase through the cored passage in the front cover.

The crankcase has two main oil galleries, one gallery for unfiltered oil and the other (main gallery) for filtered oil. Oil from the pump enters the unfiltered gallery and is conducted to the externally mounted oil cooler, where it is directed back and forth across the outside of the oil cooler tubes. The oil is cooled by engine coolant flowing through the tubes. After cooling, oil leaving the oil cooler flows back into the unfiltered gallery and past the main regulator valve assembly, which controls oil pressure in the crankcase. Under pressure oil leaves the crankcase to be filtered through the high efficiency oil filters. Oil is filtered and directed into the main oil gallery through passages in the filter header and crankcase for distribution throughout the engine. Oil in the filtered main gallery is channeled through passages in the crankcase to lubricate the seven main bearings and four camshaft bushings. Oil delivered to the main bearings is directed through drilled passages in the crankshaft to connecting rod bearings. Main bearing oil also supplies the piston cooling jets which direct a stream of oil to the underside of pistons for piston cooling and piston pin lubrication. A rear camshaft bushing groove transfers oil through a drilling in the crankcase, around the rear cylinder head bolt to the rear rocker arm bracket. Oil flows through the rocker arm shaft to insure lubrication of all the rocker arms. Drilled passageways with orifice tubes in each rocker arm bracket direct a stream of oil to the push rods, then down the push rods to assist in lubricating the tappets and camshaft.

The turbocharger receives oil through an external tube connected at the oil filter header. The fuel injection pump and air compressor (if equipped) also receive oil through external tubes which are connected at a common fitting on the left side of the crankcase main filtered oil gallery. This fitting is supplied with oil directly from the main gallery. The front gear train is splash lubricated by oil draining from the injection pump and air compressor (if equipped).

Bypass Valve

The bypass valve, located in the oil filter header, monitors lube oil filter restriction. The bypass valve operates at a pressure of 18–20 lbs. and opens when the filter restriction reaches this pressure. The open bypass valve allows the oil to "bypass" the oil filters and circulate unfiltered. Unfiltered oil circulation is better than a drastically reduced lube oil supply caused by high oil filter restriction.

NOTE: Bypassing will only occur due to extended oil change intervals or cold starts.

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LUBRICATION SYSTEM — Continued

Oil Pressure Regulator Valve
(Refer to Figure 9)

The unique design of the lubricating oil pressure regulating valve extends the life of the oil filters because it controls the volume and pressure of the filtered oil supplied to the engine. The volume of oil supplied by the pump is always in excess of what is needed to lubricate the engine. The volume needed to lubricate the engine is directed to the filters and the excess is dumped to the return. When all points of lubrication within the engine are satisfied, restriction to flow causes back pressure to build in the filtered oil gallery and on the face of the valve. As this force moves the valve toward the regulator spring, the port in the unfiltered oil gallery is opened and excess oil is dumped to the return. Due to volume changes caused by changes in engine RPM, the valve will direct more or less oil to the return keeping filtered oil pressure and volume within the specified range. Thus, the only oil filtered is that which is needed to lubricate the engine.

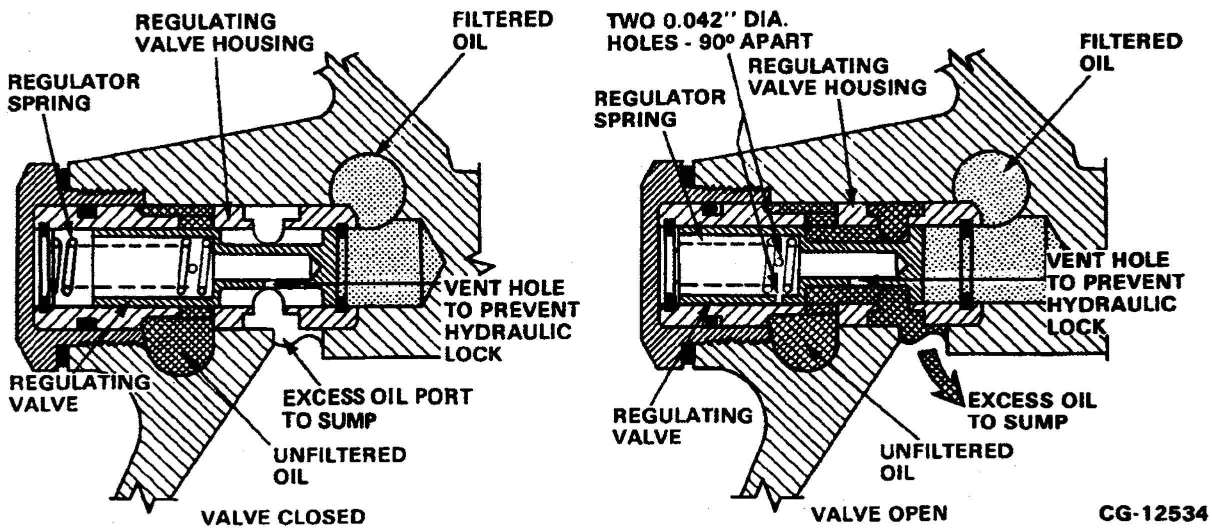

Figure 9. Oil Pressure Regulator Valve Operation

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FUEL SYSTEM

Location

The fuel system consists of a fuel tank, fuel filter, hand primer pump, fuel supply pump, fuel injection pump, fuel injection nozzle assemblies, and all necessary piping. All of these items are located on the left side of engine.

FUEL FLOW (Robert Bosch A–2000 Pump)

As fuel travels through the fuel system, it will be under vacuum (negative pressure), intermediate pressure, high pressure (injection pressure) and low pressure (Figures 10 & 11).

Negative Pressure (Effective with S/N 84779)

The piston type supply pump creates a vacuum at its inlet which draws from the fuel tank, through the fuel supply lines and into the supply pump. Fuel lines and fittings between the supply pump inlet and the fuel tank must be a minimum of three–eighths inches inside diameter. Smaller diameter fuel supply lines or fittings will reduce fuel flow and engine power output.

Negative Pressure (Prior to S/N 84779)

The piston type supply pump creates a vacuum at its inlet which draws from the fuel tank, through the fuel supply lines, through the fuel filter and then into the supply pump. Fuel lines and fittings between the supply pump inlet and the fuel tank must be a minimum of three–eighths inches inside diameter. Smaller diameter fuel supply lines or fittings will reduce fuel flow and engine power output.

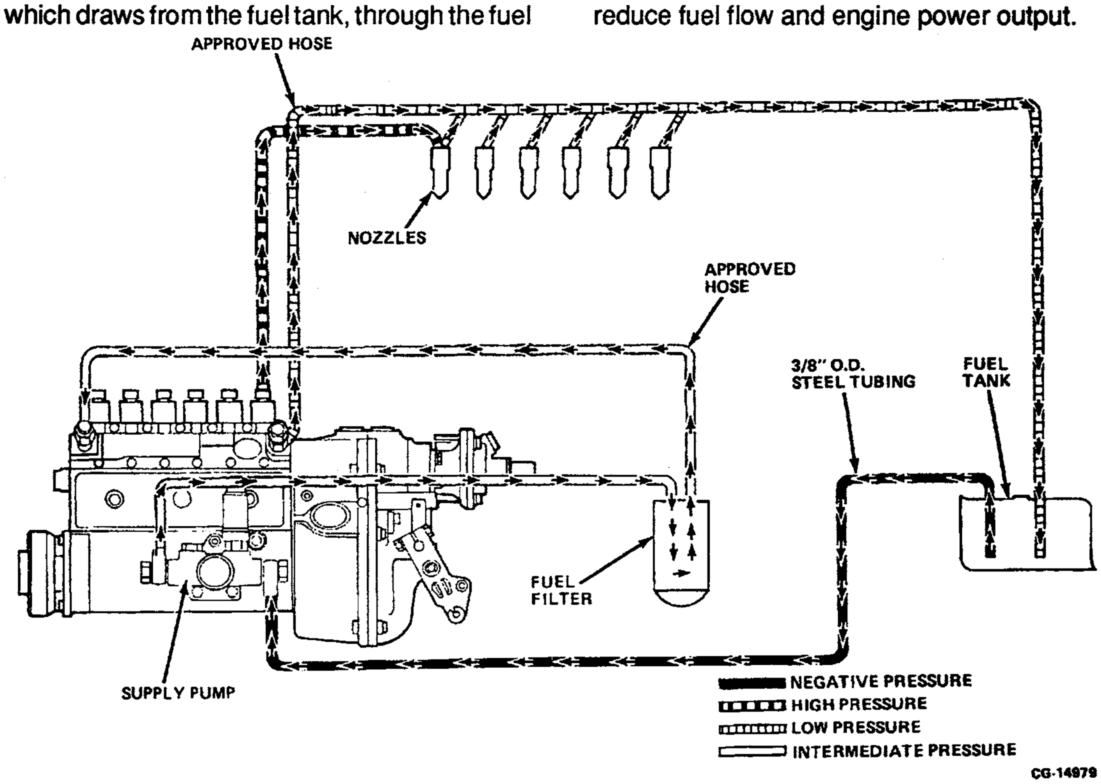

Figure 10. DT/DTA–360 Fuel System Flow (PES 6A) (Effective with S/N 84779)

FUEL SYSTEM — Continued

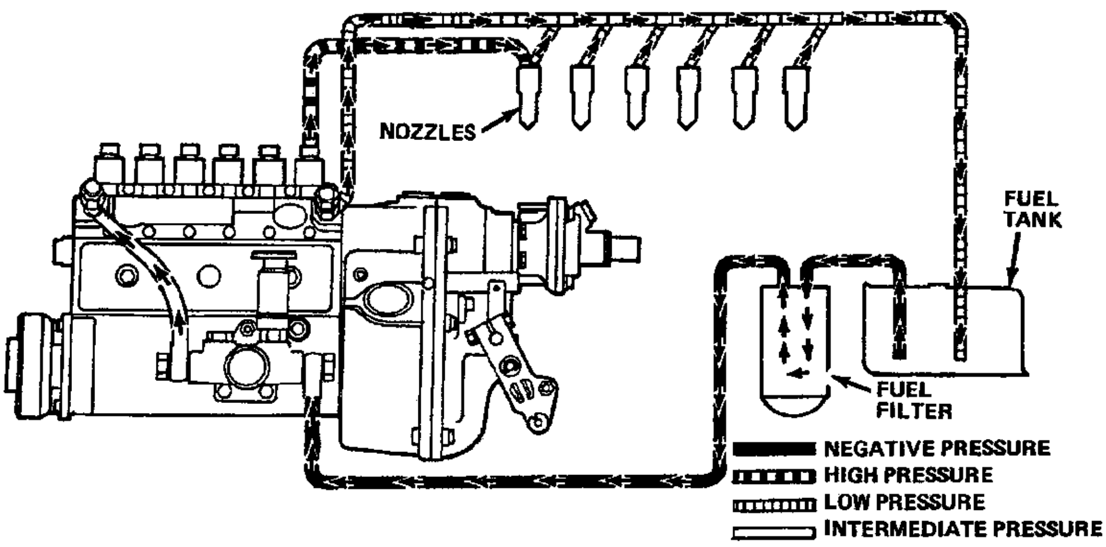

Figure 11. DT/DTA–360 Fuel System Flow (PES 6A) (Prior to S/N 84779)

Intermediate Pressure (Effective with S/N 84779)

The supply pump produces an intermediate pressure, called supply pump pressure, at its outlet and forces fuel into the fuel filter and injection pump housing. Fuel under intermediate pressure surrounds each barrel assembly. Fuel pressure in the housing is controlled by the fuel return check valve and the supply pump piston spring calibration.

Intermediate Pressure (Prior to S/N 84779)

The supply pump produces an intermediate pressure, called supply pump pressure, at its outlet and forces fuel into the injection pump housing. Fuel under intermediate pressure surrounds each barrel assembly. Fuel pressure in the housing is controlled by the fuel return check valve and the supply pump piston spring calibration.

High Pressure

The injection pump meters and delivers fuel at high pressure, up to a peak pressure of 9000 psi before nozzle valve opening, through the injection lines to the nozzle assemblies. This high pressure fuel opens the nozzle valve and fuel flows through the nozzle orifices into the combustion chamber. The amount of fuel delivered is controlled by the injection pump governor. Peak pressures are determined by injection rate and nozzle orifice size.

Low Pressure

A small amount of low pressure fuel returns from the nozzle assemblies and the excess fuel supply check valve to the fuel tank through the leak–off lines. The check valve maintains the fuel injection pump housing pressure.

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FUEL SYSTEM — Continued

Location

The fuel system consists of a fuel tank, fuel filter, hand primer pump, fuel supply pump, fuel injection pump, fuel injection nozzle assemblies, and all necessary piping. All of these items are located on the left side of engine.

FUEL FLOW (Robert Bosch MW Pump)

As fuel travels through the fuel system, it will be under vacuum (negative pressure), intermediate pressure, high pressure (injection pressure) and low pressure (Figure 12).

Negative Pressure

The piston type supply pump creates a vacuum at its inlet which draws from the fuel tank, through the fuel supply lines and into the supply pump. Fuel lines and fittings between the supply pump inlet and the fuel tank must be a minimum of three–eighths inches inside diameter. Smaller diameter fuel supply lines or fittings will reduce fuel flow and engine power output.

Intermediate Pressure

The supply pump produces an intermediate pressure, called supply pump pressure, at its outlet and forces fuel into the fuel filter and injection pump housing. Fuel under intermediate pressure surrounds each barrel assembly. Fuel pressure in the housing is controlled by the fuel return check valve and the supply pump piston spring calibration.

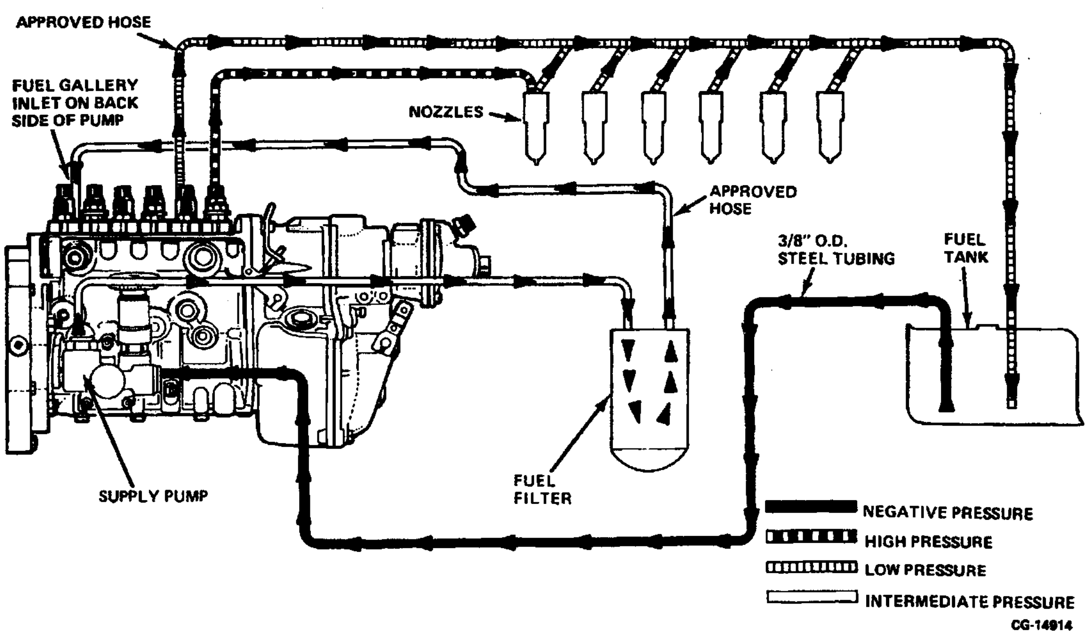

Figure 12. DT/DTA–360 Fuel System Flow (MW)

High Pressure

The injection pump meters and delivers fuel at high pressure, up to a peak pressure of 9000 psi before nozzle valve opening, through the injection lines to the nozzle assemblies. This high pressure fuel opens the nozzle valve and fuel flows through the nozzle orifices into the combustion chamber. The amount of fuel delivered is controlled by the injection pump governor. Peak pressures are determined by injection rate and nozzle orifice size.

Low Pressure

A small amount of low pressure fuel returns from the nozzle assemblies and the excess fuel supply check valve to the fuel tank through the leak–off lines. The check valve maintains the fuel injection pump housing pressure.

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AIR INDUCTION AND EXHAUST SYSTEMS

Description

The intake and exhaust systems consist of those components that flow filtered air to the engine cylinders and exhaust gases to the atmosphere. The intake system includes an air cleaner, air piping, intake manifold and intake valves.

NOTE

DTA engines incorporate a chassis mounted charge air cooler as part of the intake system (See Figure 14).

The exhaust system includes exhaust valves, exhaust manifold, muffler and exhaust piping. The turbocharger compressor side is part of the intake system and the turbine side is part of the exhaust system.

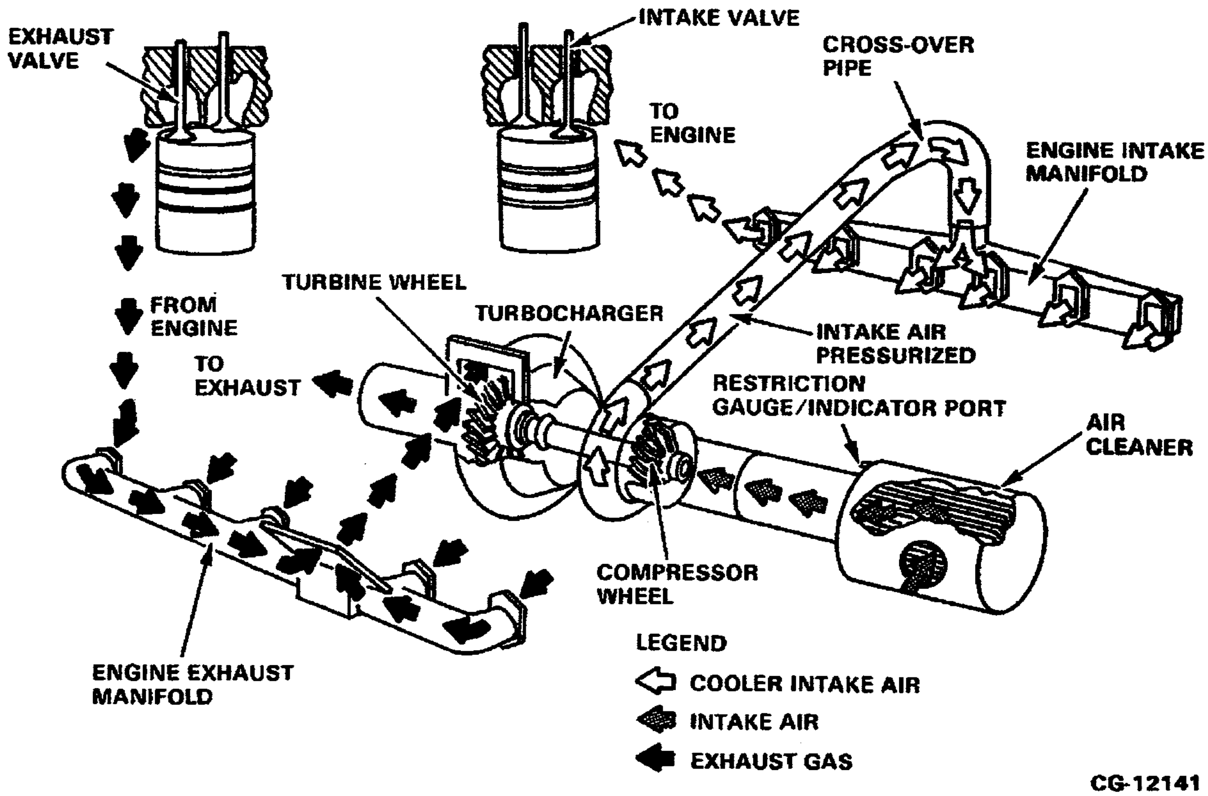

Figure 13. Air Induction and Exhaust Systems
(DT–360 Shown)

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AIR INDUCTION AND EXHAUST SYSTEMS

Air Flow (Refer to Figures 13 & 14)

The intake system consists of an air cleaner, air piping, the compressor side of the turbocharger, intake manifold, and intake valves. During start up, the air is drawn through the air cleaner by the movement of the pistons.

Once the engine is running, the turbocharger pulls air through the air cleaner into the compressor housing. At this point, air is compressed at the turbocharger and is forced into the intake manifold. DTA designated engines have the compressed air cooled by a chassis mounted charge air cooler prior to entering the intake manifold. Air then flows into the combustion chamber where it is mixed with the proper amount of fuel and burned. Exhaust gases leave the cylinders through exhaust ports and the exhaust manifold. From the exhaust manifold, the expansion of exhaust gases on the exhaust turbine drive the turbocharger and are released through the exhaust pipe to the atmosphere.

The turbocharger is used to increase engine power output by increasing air supply to the engine. It is a simply designed oil–cooled exhaust–driven blower that allows filtered air to enter at the center of the compressor housing and is forced under pressure to the combustion chamber. After combustion, hot and expanding exhaust gases move through the turbine housing causing the turbine wheel to spin. The turbine wheel drives the compressor wheel through a common single shaft. The turbocharger responds directly to engine loads. During heavy load, increased flow of exhaust gases turn the turbine wheel faster causing the compressor impeller to turn faster and supply more air (greater boost) to the intake manifold. Conversely, with light engine load, flow of exhaust gases decrease and less air is pumped into the intake manifold.

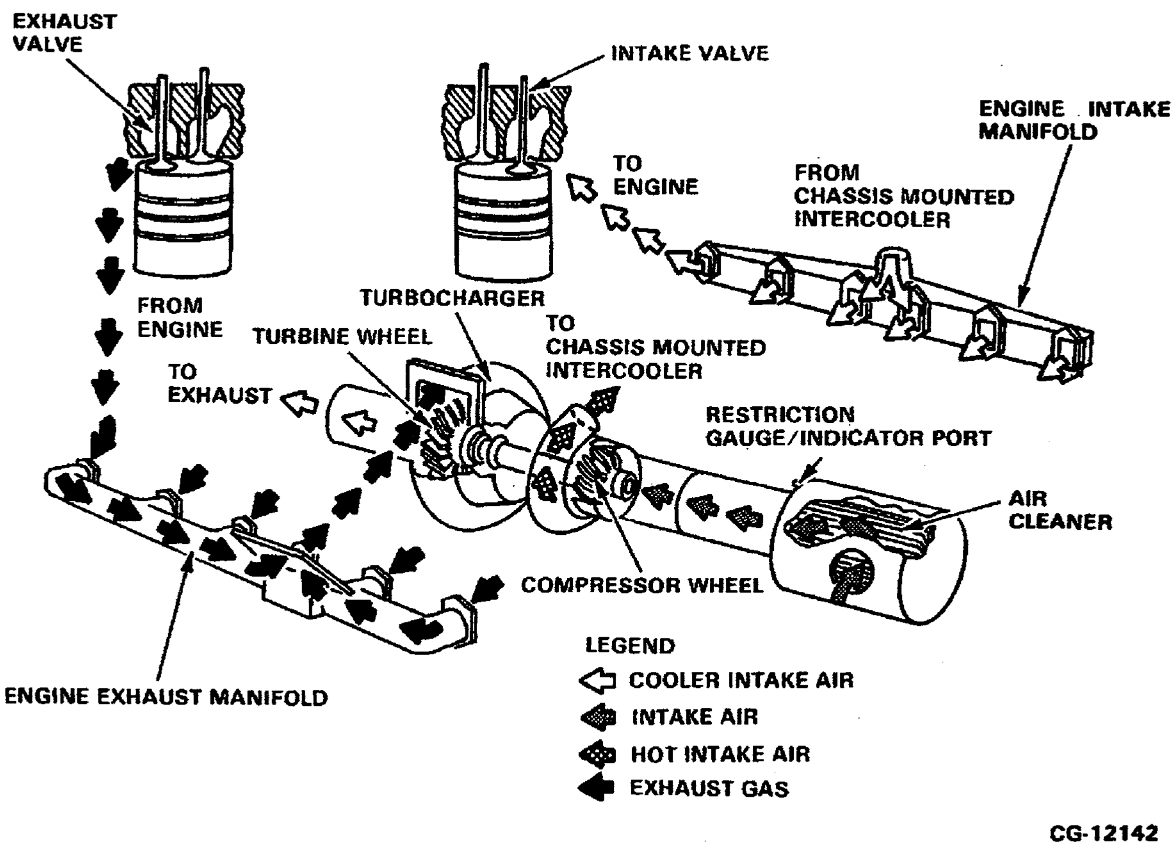

Figure 14. Air Induction and Exhaust Systems
(DTA–360 Shown)

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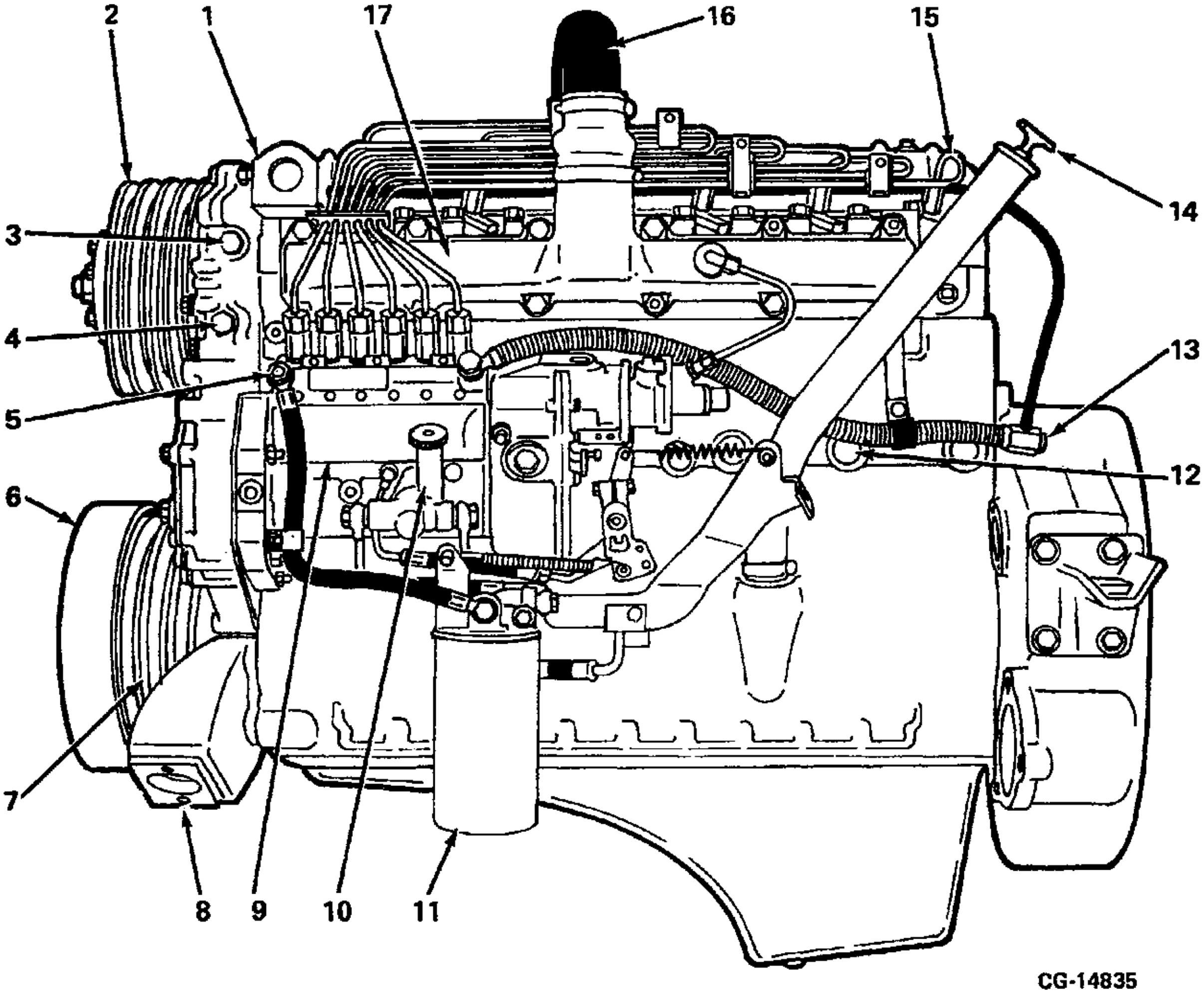

Figure 15. Major Component Location (Left Side)
(DTA–360 Shown w/Intake Manifold Used For Engines Equipped With PTO)

1. Lifting Eye
2. Fan Pulley
3. 1/2–14 NPTF Air Compressor Coolant Return (.188 dia. orificed fitting required)
4. 1/2–14 NPTF Coolant Supply to Air Compressor
5. Fuel Bleed
6. Vibration Damper
7. Crankshaft Pulley
8. Front Engine Mounting Support
9. Fuel Injection Pump (Robert Bosch Model PES6A)
10. Hand Primer Pump
11. Fuel Filter
12. Crankcase Heater – recommended location
13. 1/4–18 NPTF Fuel Return
14. Oil Fill Tube and Oil Level Gauge
15. Nozzle and High Pressure Fuel Lines
16. Turbo Air Inlet Crossover Pipe
17. Intake Manifold

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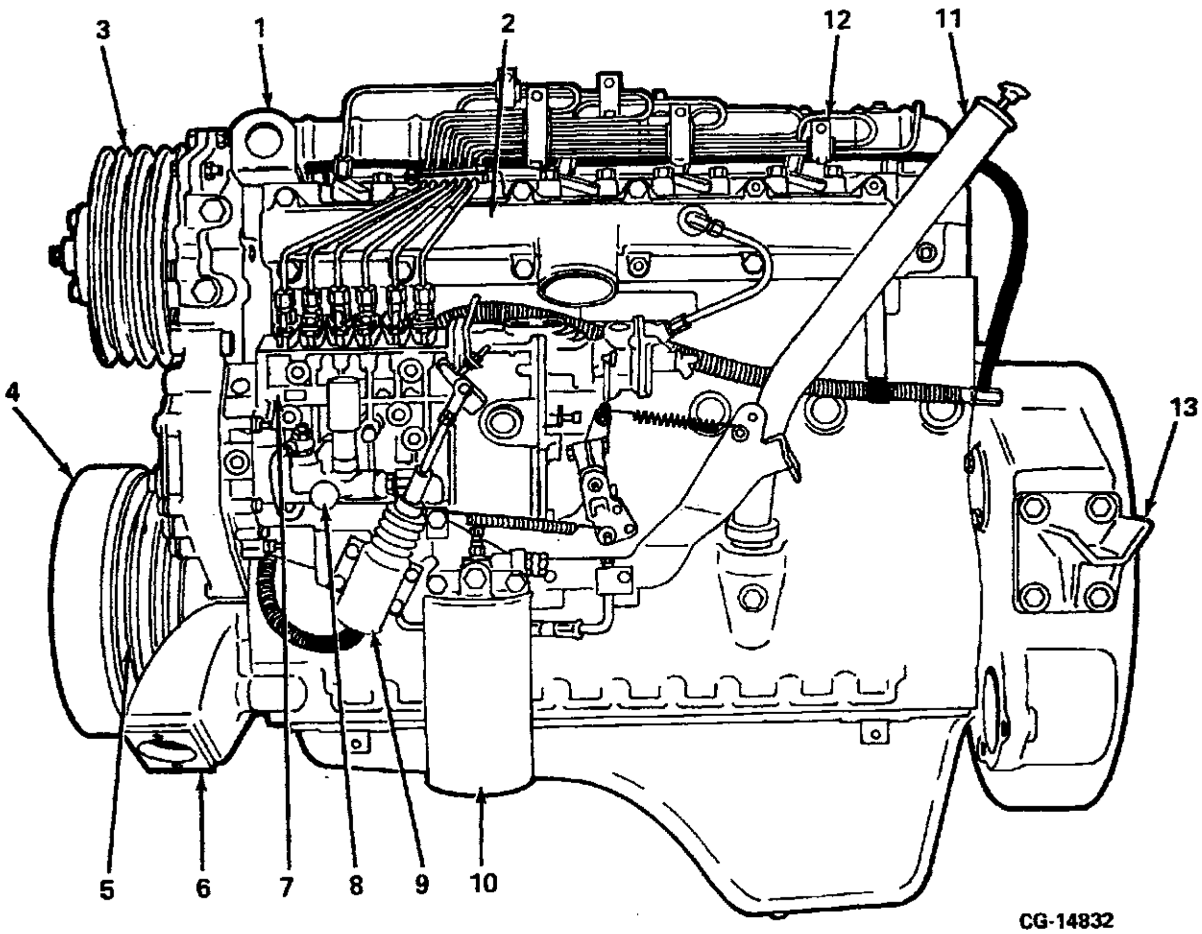

Figure 16. Major Component Location (Left Side)
(DTA–360 Shown w/Intake Manifold For Engines Without PTO)

1. Lifting Eye
2. Intake Manifold
3. Fan Pulley
4. Vibration Damper
5. Crankshaft Pulley
6. Engine Front Mounting Support
7. Fuel Injection Pump (Robert Bosch Model PES6MW)
8. Hand Primer Pump
9. Electric Fuel Shut–Off
10. Fuel Filter
11. Oil Fill Tube and Oil Level Gauge
12. Nozzle and High Pressure Fuel Lines
13. Engine Rear Mounting Bracket

NOTE: DTA–360 Engines with PTO's are equipped with the up mounted intake manifold.

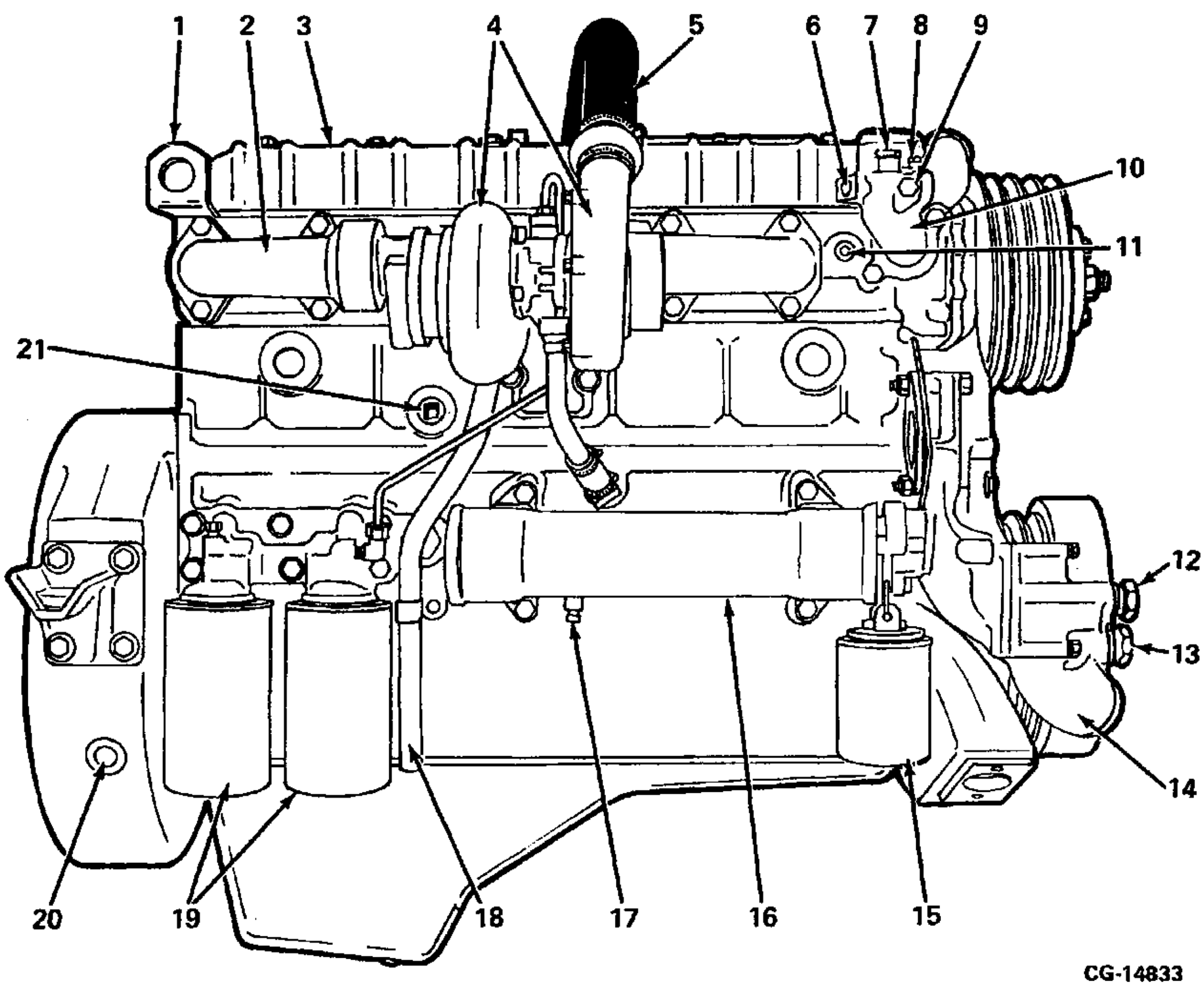

Figure 17. Major Component Location (Right Side)
(DT–360 Shown)

1. Lifting Eye
2. Exhaust Manifold
3. Valve Cover
4. Turbocharger
5. Inlet Crossover Pipe to Intake Manifold
6. 1/2" NPT SHUTTERSTAT Control – recommended location
7. 1/2" NPT Mechanical Temperature Sender – recommended location
8. 1/2" NPT Water Temperature Warning Light – recommended location
9. 1/8" NPT Water Dearation
10. Thermostat Housing
11. 1/2–14 NPTF Water Temperature Gauge Sender – recommended location
12. 3/4–14 NPTF Heater Return
13. 3/4–14 NPTF Fill Line from Deaeration Tank
14. Water Inlet Elbow
15. Coolant Filter
16. Oil Cooler Assembly
17. 1/4–18 NPTF For Bypass Filter Oil Supply and Oil Cooler Drain
18. Crankcase Breather Tube
19. "EXTENDER" Type Oil Filters
20. Tachometer Sender
21. 3/4–14 NPTF For Bypass Filter Oil Return

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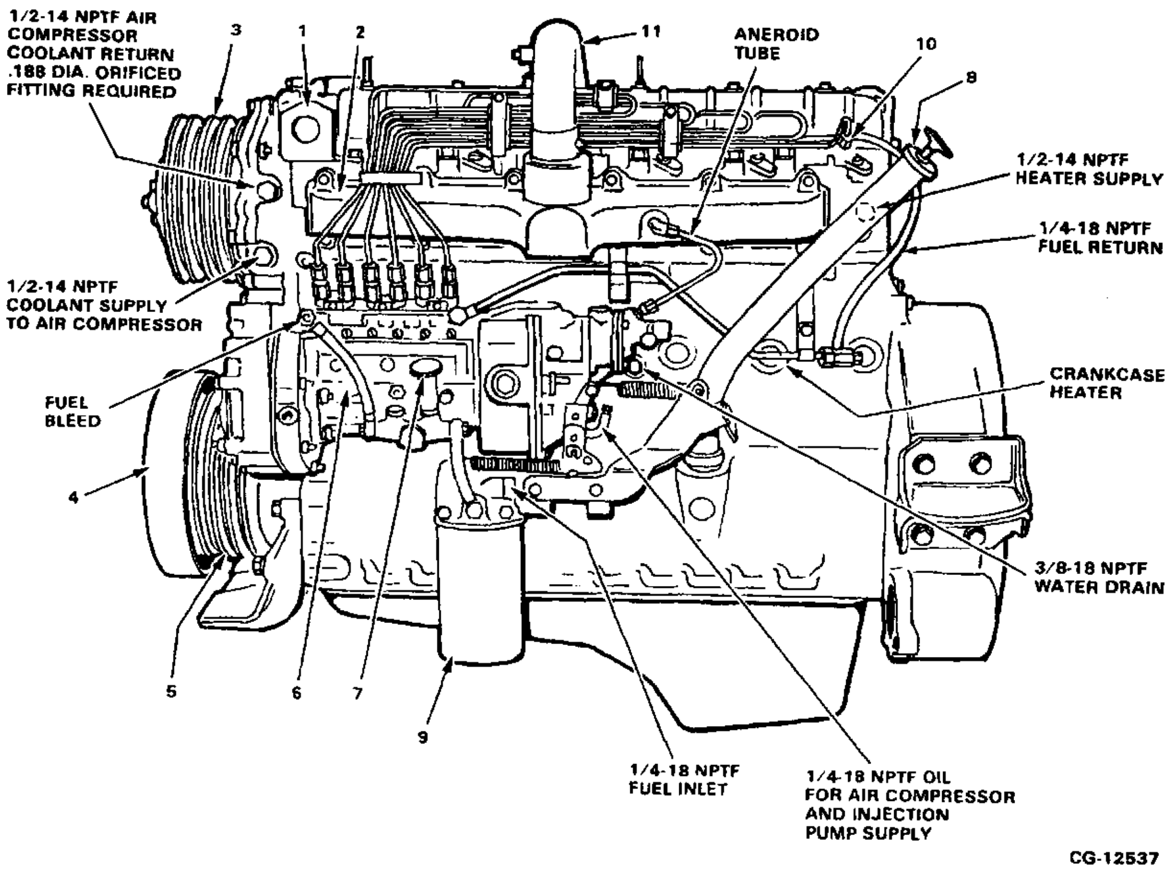

Figure 18. Major Component Location (Left Side)
(DT/DTA–360 with PTO Shown, 1988 Model Year)

1. Lifting Eye
2. Intake Manifold
3. Fan Pulley
4. Vibration Damper
5. Crankshaft Pulley
6. Fuel Injection Pump (Robert Bosch A–2000)
7. Hand Primer Pump
8. Oil Fill Tube and Oil Level Gauge
9. Fuel Filter
10. Nozzle Holder Assembly, High and Low Pressure Fuel Lines
11. Turbo Air Inlet Crossover Pipe

NOTE: DTA–360 engines with PTO's are equipped with the up mounted intake manifold as shown in Figure 14, but without the turbo air inlet crossover pipe.

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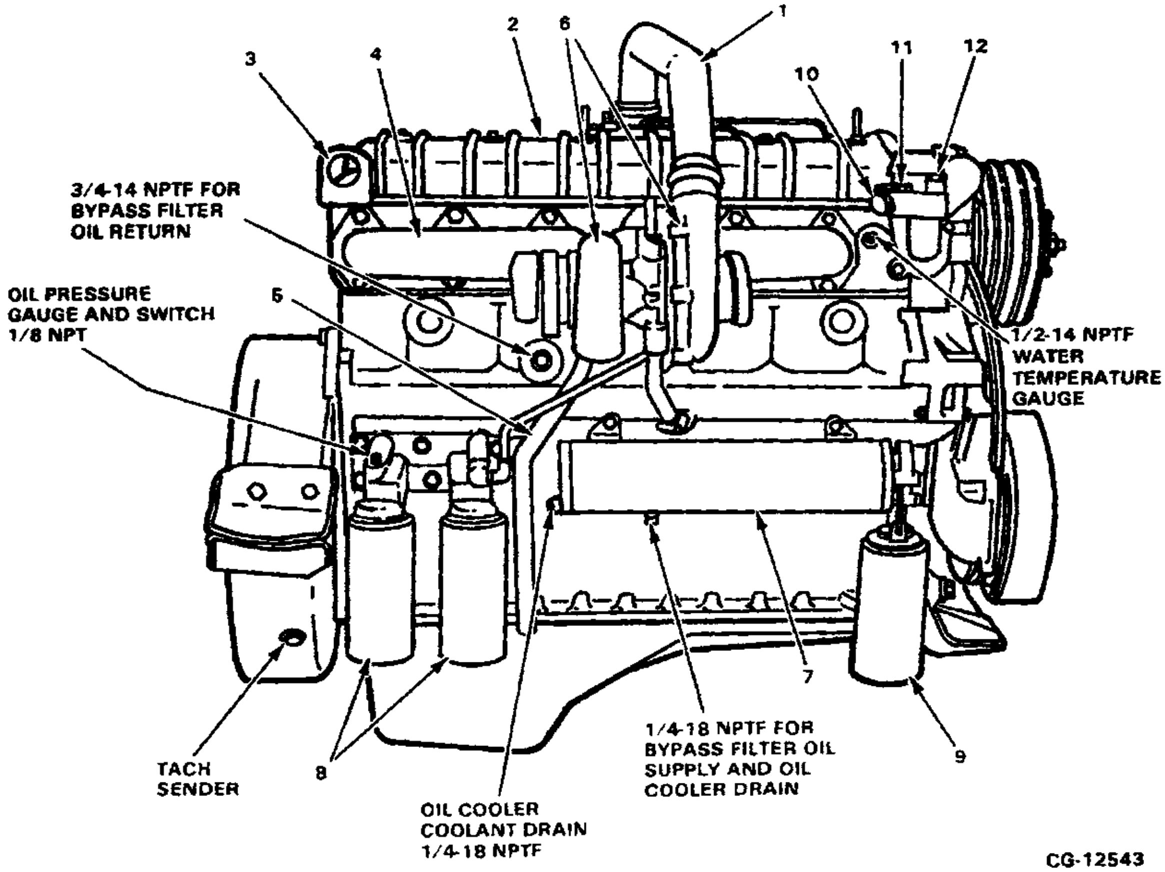

Figure 19. Major Component Location (Left Side)
(DT–360 Shown, 1988 Model Year)

1. Inlet Crossover Pipe to Intake Manifold
2. Valve Cover
3. Lifting Eye
4. Exhaust Manifold
5. Crankcase Breather Tube
6. Turbocharger
7. Oil Cooler Assembly
8. Oil Filters
9. Coolant Filter
10. 1/2" NPT SHUTTERSTAT Control
11. 1/8" NPT Water Deaeration
12. 1/2" NPT Water Temperature Warning Light

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SECTION 1 INDEX

Page

Mounting Engine on Stand 1

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MOUNTING ENGINE ON STAND

1. Remove the items indicated in **Figure 1.1** to allow installation of the engine on the mounting stand.

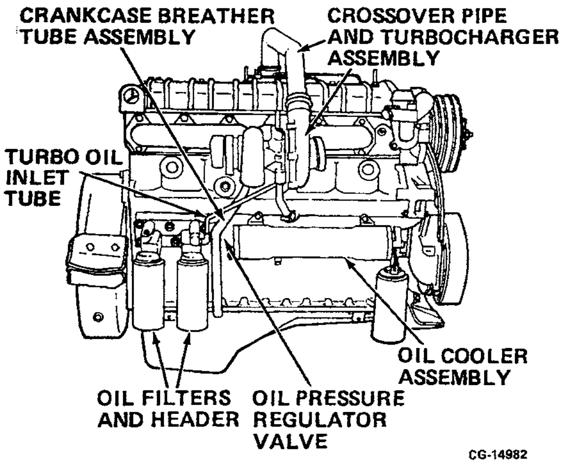

Figure 1.1 Component Removal Prior to Mounting the Engine on the Stand

NOTE: DTA engines require removal of the chassis mounted charge air cooler assembly and the corresponding pipes and engine mounting bracket.

2. Install the recommended adapter plate (ZT–206386) as directed. Refer to the instructions included with the engine stand. See **Figures 1.2 and 1.3.**

IMPORTANT

WHENEVER MOUNTING AN ENGINE TO A REPAIR STAND, REFER TO THE INSTRUCTIONS INCLUDED WITH THE MOUNTING STAND AND ITS CORRESPONDING ADAPTER PLATES FOR SPECIFIC DIRECTIONS ON THEIR SAFE USE. USE ONLY GRADE 8 BOLTS WHEN MOUNTING THE ENGINE TO AN ENGINE STAND.

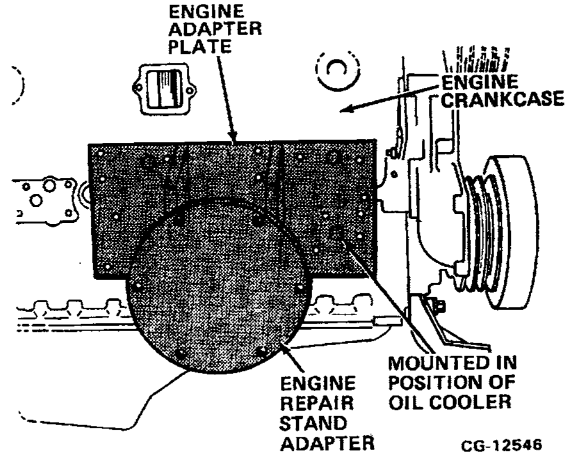

Figure 1.2. Mounting Engine Adapter Plate to Crankcase

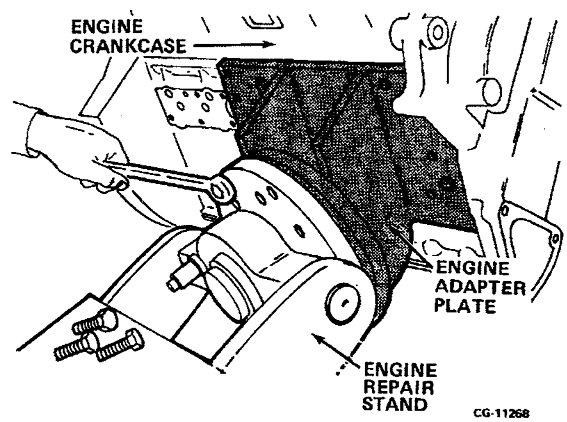

Figure 1.3. Attaching Engine Adapter Plate to Engine Repair Stand

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MOUNTING ENGINE ON STAND – Continued

IMPORTANT

USE A SAFETY CATCH ON THE HOIST HOOK WHEN LIFTING THE ENGINE BY THE LIFTING EYES (SEE FIGURE 1.4). WHEN HOISTING THE ENGINE TO THE STAND, INSERT A SPREADER BAR BETWEEN THE ENDS OF THE LIFTING CHAINS TO PREVENT THE LIFTING EYES FROM TURNING AND DAMAGING THE ROCKER ARM COVER.

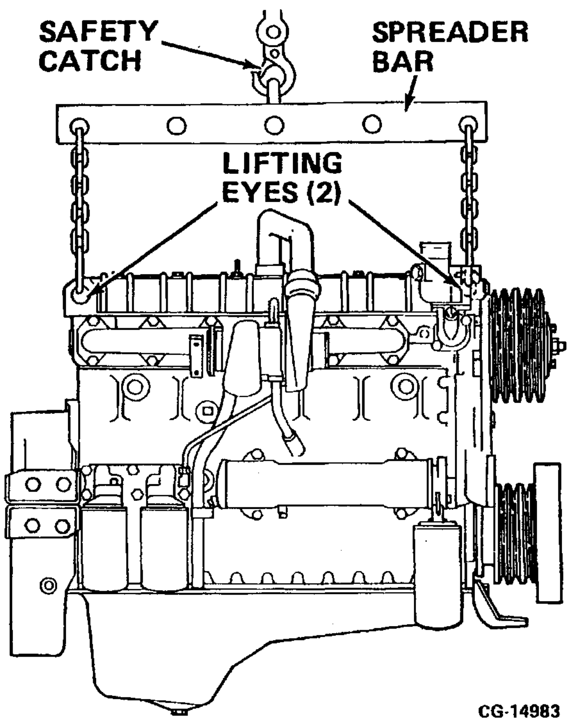

Figure 1.4. Using a Safety Hook and Spreader Bar to Lift Engine

SERVICE MANUAL

TURBOCHARGERS

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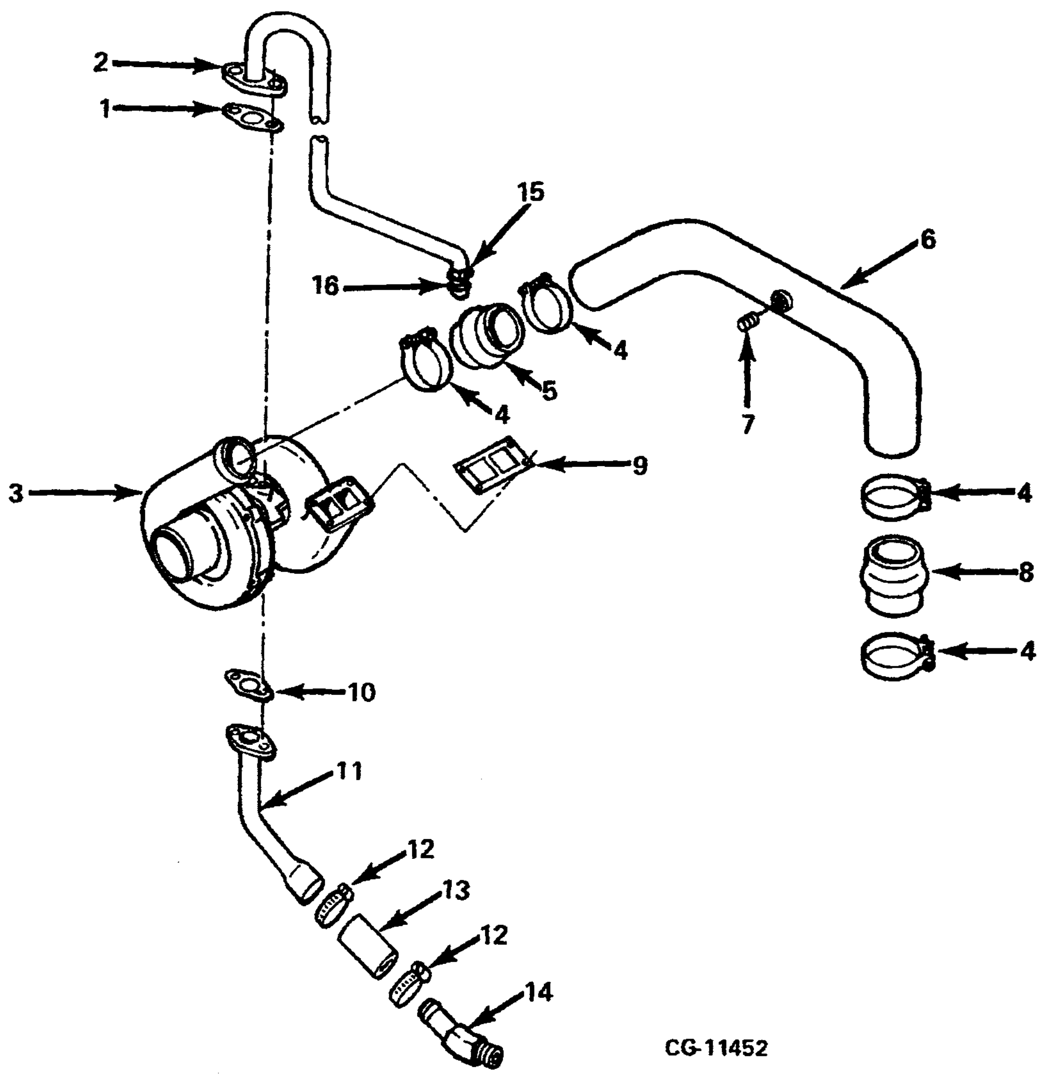

Figure 2.1. Turbocharger Piping
(Typical DT–360 Shown) *

1. Turbocharger Oil Inlet Gasket
2. Oil Inlet Tube Assembly
3. Turbocharger Assembly
4. Air Outlet Clamp
5. Air Outlet Hose
6. Air Outlet Pipe
7. 1/4 NPT Plug
8. Air Outlet Hose
9. Turbo Mounting Gasket
10. Oil Drain Tube Gasket
11. Oil Drain Tube
12. Oil Drain Tube Hose Clamp
13. Oil Drain Tube Hose
14. Oil Drain Tube Elbow
15. Nut, Tube
16. Sealing Gasket, Tube

* Refer to Truck Parts Catalog for DTA–360 Turbo Piping.

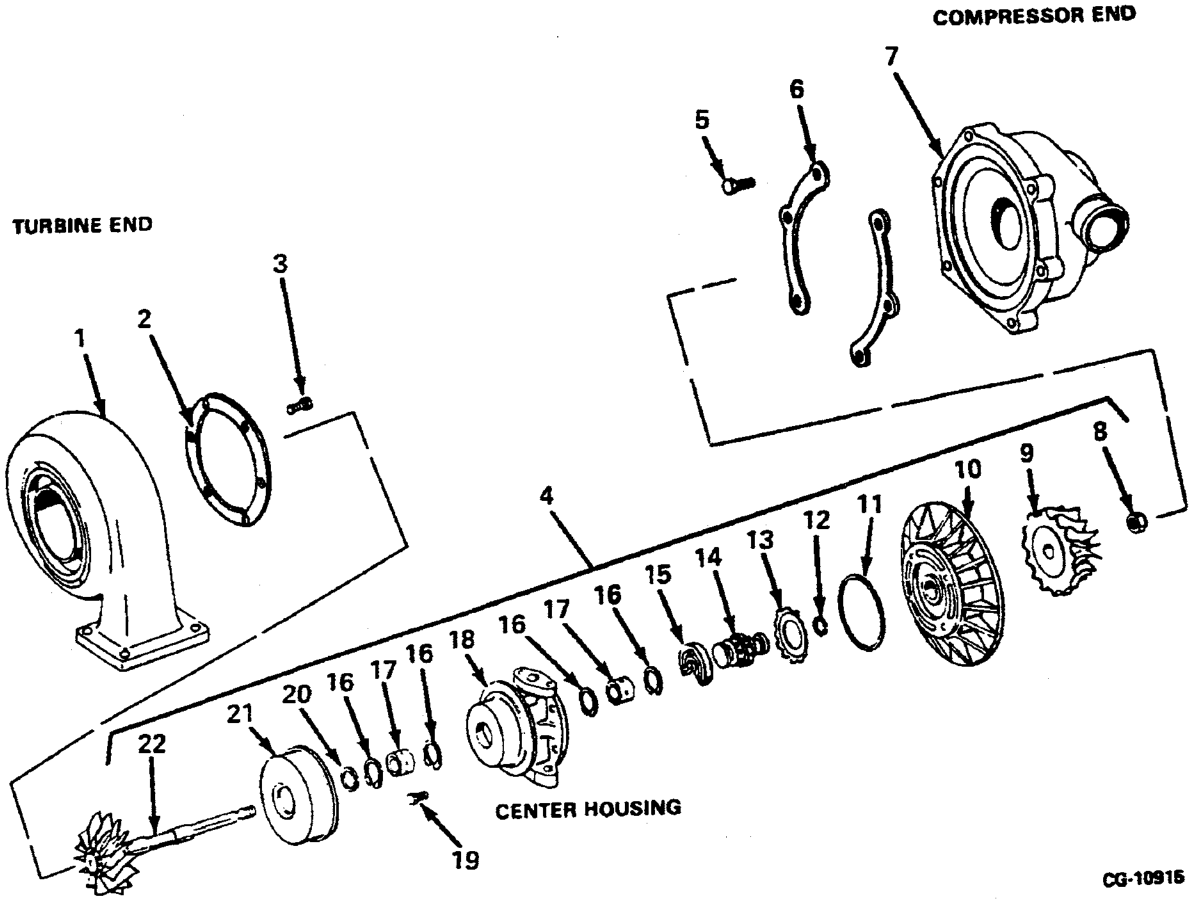

Figure 2.2. Turbocharger Components (T04E)

1. Housing, Turbine
2. Clamp, Housing
3. Screw, Hex Hd Cap
4. Core Assembly
5. Screw, Hex Hd Cap
6. Clamp, Housing
7. Housing, Compressor
8. Nut, Impeller Lock
9. Impeller, Compressor
10. Plate, Back
11. Ring, Plate Seal
12. Ring, Piston Seal
13. Spring, Plate
14. Collar, Thrust
15. Washer, Thrust
16. Ring, Retaining
17. Bearing, Journal
18. Housing, Center
19. Screw, Hex Hd Cap
20. Ring, Piston Seal
21. Shroud, Turbine
22. Turbine Wheel Assembly

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SPECIFICATIONS

MODEL T04E

Turbine Shaft Axial End Play .... 0.001–0.004 in. (0.02–0.10 mm)

Turbine Shaft Radial Shaft Movement (Play) ..... 0.003–0.006 in. (0.08–0.15 mm)

SPECIAL TORQUES

MODEL T04E

Back Plate–to–Center Housing Capscrews .... 117.5 lbf–in. (13.3 Nm)

Impeller Shaft Lock Nut .... 19 lbf–in. (2.15 Nm)
(Tighten finger–tight plus 90°) (Use tee handle wrench only)

Center Housing–to–Turbine Housing Capscrews .... 115 lbf–in. (13 Nm)

Center Housing–to–Compressor Housing Capscrews ...... 150 lbf–in. (16.9 Nm)

Turbocharger Mounting Bolts/Nuts .... 35 lbf–ft. (47 Nm)

Turbocharger Air Hose Clamp .... 45 lbf–in. (5 Nm)

TURBOCHARGER A/R

MODEL	PART NUMBER	A/R
T04E–17	1 810 017 C91	1.00
	1 810 018 C91	1.15
	1 815 607 C91	1.15
	1 817 306 C91	1.15
	1 817 307 C91	1.00
	1 817 529 C91	1.00

REFER TO PARTS CATALOG FOR PART NUMBER AND APPLICATION

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GENERAL OPERATION

The turbocharger is an exhaust–driven centrifugal air compressor. Its purpose is to increase power output by supplying compressed air to the engine. The center housing is oil and air cooled. Engine oil is circulated through the center housing which acts as a heat barrier between the "hot" turbine and the "cold" compressor. Bearings are sleeve–type and are lubricated by engine oil. Oil is pumped directly from the clean–oil side of the engine oil filters, circulated in the center housing of the turbocharger and returned to the engine through an oil drain tube. Ring seals are used at each end of the shaft. High velocity engine exhaust gases drive the turbine shaft assembly to speeds up to 130,000 revolutions per minute. Filtered air entering the compressor side of the turbocharger is compressed and delivered to the engine intake manifold at a pressure higher than the atmosphere. Because more air is delivered to the intake manifold, the result is more power, fuel efficiency and the ability to maintain power at altitude.

COMPONENT IDENTIFICATION

The turbine wheel is located in the turbine housing; the compressor impeller is located at the opposite end on a common shaft that connects the turbine wheel and impeller.

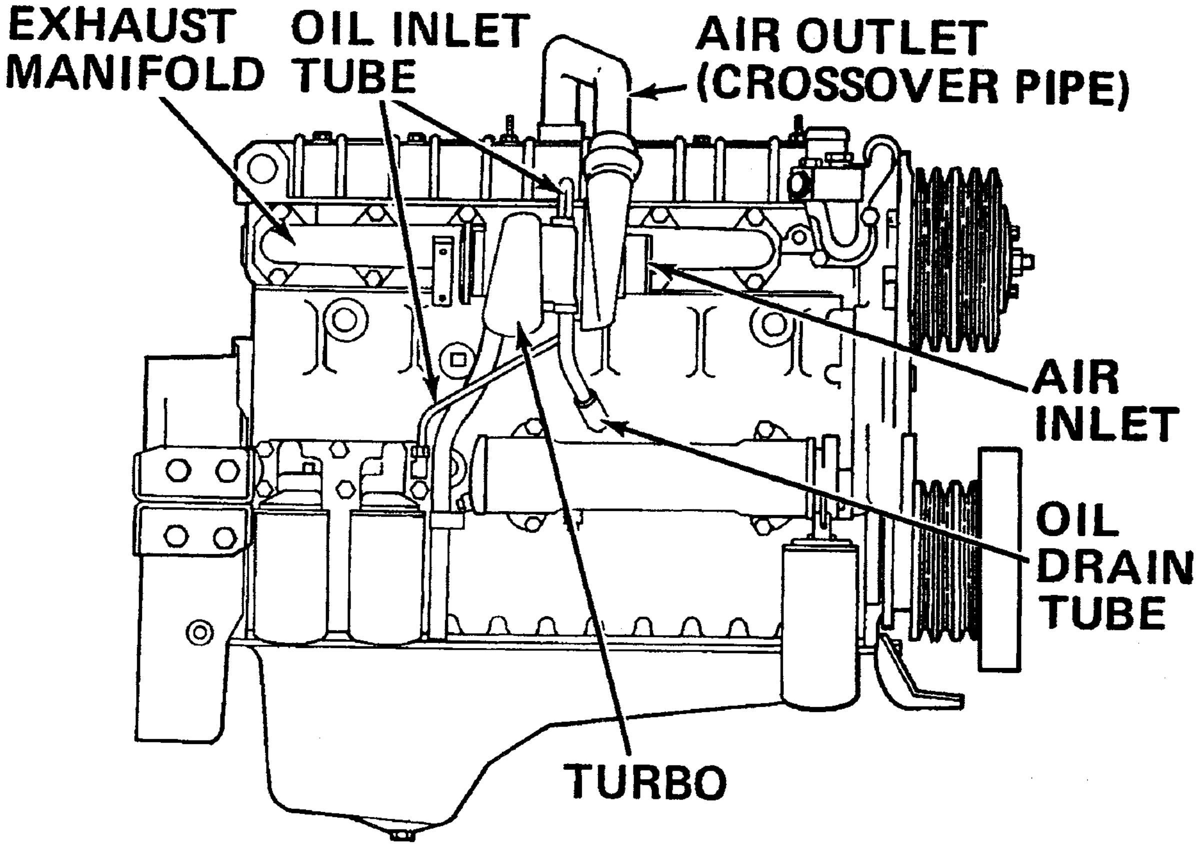

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Figure 2.3. Turbocharger Removal (DT–360 Shown, DTA is Similar)

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REMOVAL AND REASSEMBLY

Removal

1. **DT–360 Only:** Remove the turbocharger to intake manifold crossover pipe (as an assembly) and cap the turbo outlet and manifold inlet. (Refer to **Figure 2.4.**)

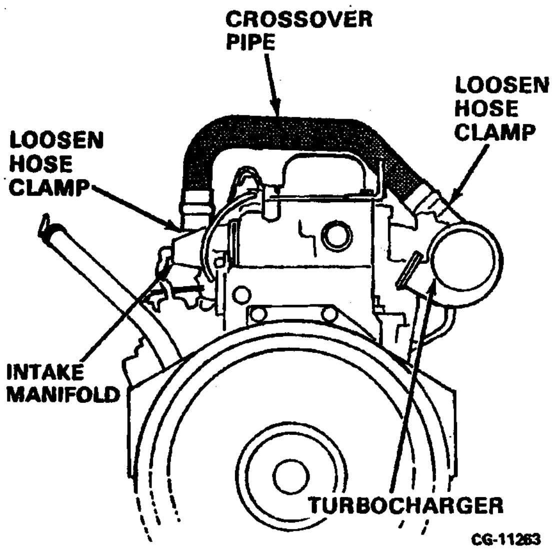

Figure 2.4. Crossover Pipe Removal

2. Disconnect and remove turbo oil inlet tube assembly at filter header. (See **Figures 2.5 and 2.6.**)

   a. Remove tube nut at oil filter header. (See **Figure 2.5.**)

   b. Remove the two capscrews from oil inlet tube flange. (See **Figure 2.6.**)

   c. Remove oil inlet tube flange and discard gasket. (See **Figure 2.6.**)

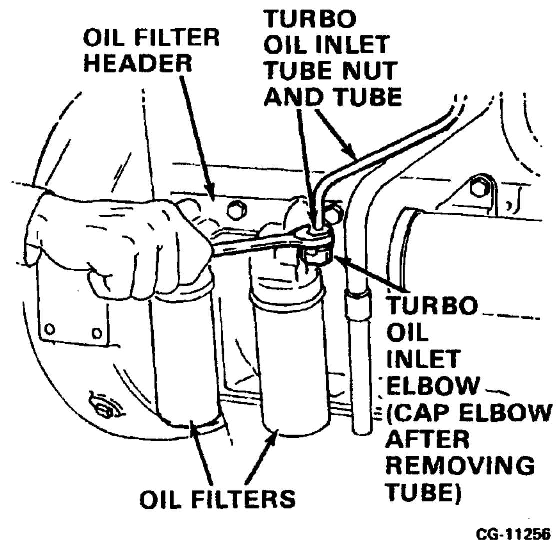

Figure 2.5. Removing Turbocharger Oil Inlet Tube and Sleeve at Oil Inlet Elbow

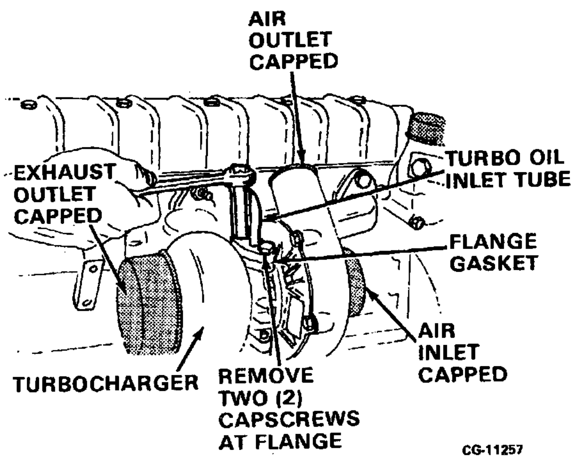

Figure 2.6. Removing Capscrews from Turbocharger Oil Inlet Tube Flange

   d. Remove oil inlet tube assembly and discard the rubber sleeve located at the nut end.

   e. Cap turbo oil inlet tube elbow at oil filter header to prevent debris from entering.

   f. Cap ALL openings as specified in **Figure 2.7.**

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REMOVAL AND REASSEMBLY — Continued

Removal — Continued

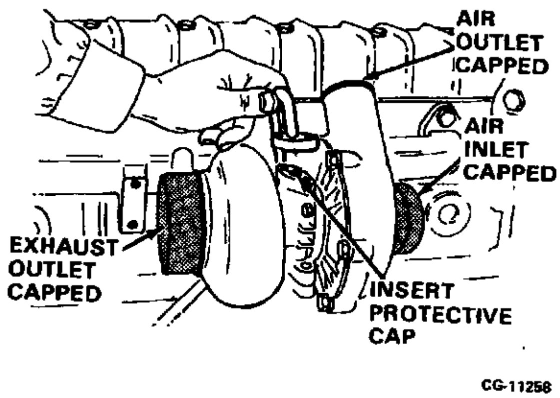

Figure 2.7. Protective Cap Locations

3. Remove the turbo oil drain tube as follows: (Refer to **Figure 2.8.**)

   a. Loosen two worm drive hose clamps on turbocharger oil drain tube. (Clamps secure the drain tube hose to the crankcase inlet.)

   b. Remove two capscrews and hardened washers which secure the oil drain tube to the turbocharger.

   c. Remove the oil drain tube and discard the drain tube flange gasket.

   d. Cap oil drain elbow and oil outlet on turbocharger.

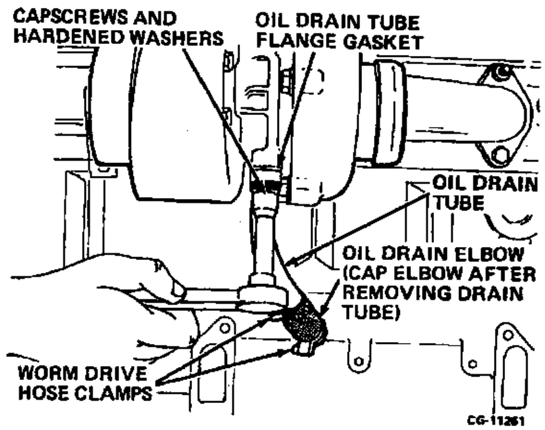

Figure 2.8. Removing Turbocharger Oil Drain Tube

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REMOVAL AND REASSEMBLY — Continued

Removal — Continued

4. Remove turbocharger assembly from exhaust manifold. (See **Figure 2.9.**)
   a. Remove the two turbo mounting bolts with nuts and washers at the lower end of the exhaust manifold flange.

CAUTION !

Support the turbocharger assembly during removal of the mounting hardware to prevent damage.

   b. Remove the two nuts and washers at the exhaust manifold turbo mounting studs. (Do not remove studs from the exhaust manifold flange.)
   c. Remove turbocharger and gasket from engine. Discard gasket.
   d. Assure all turbocharger openings are capped. (See **Figure 2.10.**)

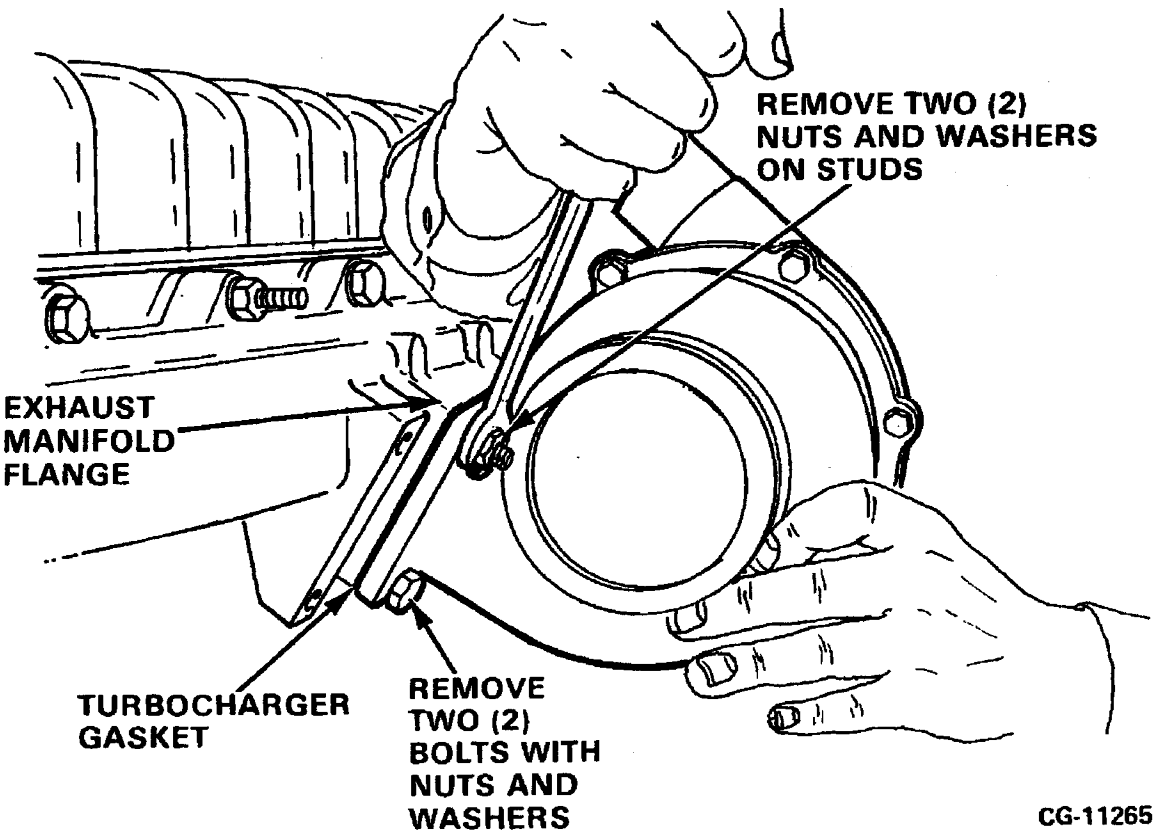

Figure 2.9. Removing Turbocharger Assembly from Exhaust Manifold

REMOVAL AND REASSEMBLY — Continued

Removal — Continued

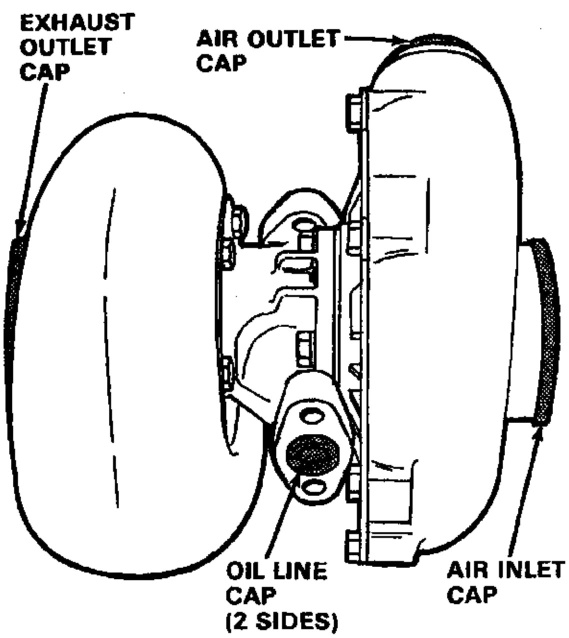

Figure 2.10. Install Protective Caps on Turbocharger when Removed for Service

NOTE: If plastic caps are not available, use duct tape to cover openings.

Cleaning

Related Components

Clean these components as follows:

1. Thoroughly clean the piping connecting the air cleaner to the turbocharger with soap and water. Dry with filtered, compressed air.
2. Remove the vehicle mounted air cleaner and clean inside the air cleaner element housing. (Important to prevent repeat turbocharger or engine failures.)
3. In the event of a turbocharger failure, INSPECT air intake piping for debris and clean as required. Replace the air cleaner element if required.

NOTE: **Use Bendix Metal Cleaner or Gunk Hydroseal to clean components. DO NOT use a caustic solution.**

Turbocharger

1. Clean crossover pipe and connecting hoses with filtered, compressed air.
2. Inspect oil inlet tube and oil drain tube for restrictions. Clean with a suitable (non–caustic) solvent and a nylon brush (see Note). Dry using filtered compressed air.

NOTE: Use Bendix Metal Cleaner or Gunk Hydroseal to clean components. DO NOT use a caustic solution.

Inspection

PRE–DISASSEMBLY INSPECTION

Make the following checks and if the turbocharger meets these requirements, it can be considered satisfactory and reinstalled on the engine. If it does not meet the requirements, it must be replaced or rebuilt. (Refer to "RECONDITIONING".)

CHECK FOR FREE ROTATION

1. Stand the turbocharger on bench with shaft in a horizontal position.
2. Wheels must spin freely when turned by hand.

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REMOVAL AND REASSEMBLY — Continued

Inspection — Continued

CHECK AXIAL END PLAY

1. Clamp turbocharger mounting flange in a vise and position a dial indicator with a magnetic base on the frame of the vise. Place the tip of the indicator on the turbine end of the shaft. (Refer to **Figure 2.11**.)

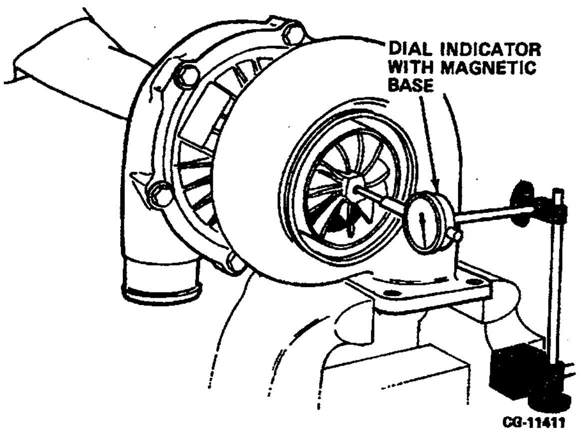

Figure 2.11. Checking Axial End Play

2. Move the shaft back and forth by hand and record the readings.
3. If the reading exceeds the specifications, the turbocharger must be reconditioned.

CHECK RADIAL SHAFT MOVEMENT

1. Remove the protective cover from the oil drain port in the center housing.
2. Install a two–inch contact point extension on the dial indicator and position the indicator as shown in **Figure 2.12.** The indicator contact point must contact the turbine shaft through the oil drain port in the center housing.

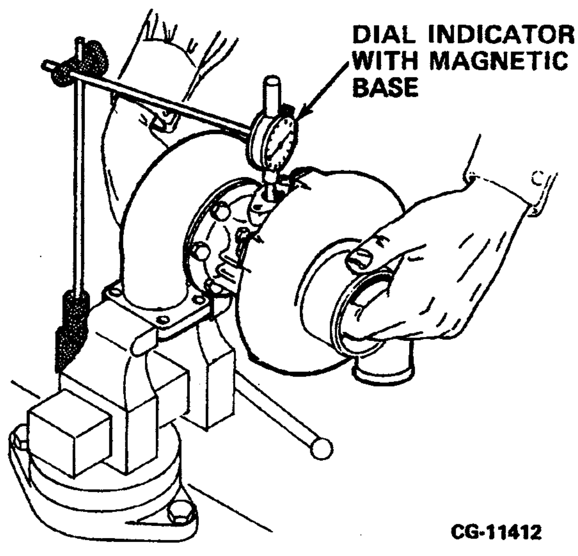

Figure 2.12. Checking Radial Shaft Movement with Housing Installed

3. Check radial shaft movement by lifting the shaft up and then letting it down (**Figure 2.12**).

IMPORTANT

YOU MUST LIFT EVENLY WITH BOTH HANDS TO GET ACCURATE READINGS.

4. If the readings exceed specifications, the turbocharger must be reconditioned.
5. If the radial shaft movement is within specifications, but interference between the compressor housing and compressor wheel is suspected, proceed as follows:
   a. Mark the compressor housing location to the back plate to aid reassembly. Refer to **Figure 2.13.**
   b. Remove the compressor housing mounting bolts and clamps which secure the housing to the back plate.
   c. Visually inspect the housing for any signs of wheel contact. Refer to **Figure 2.14.**

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REMOVAL AND REASSEMBLY — Continued

Inspection — Continued

CHECK RADIAL SHAFT MOVEMENT — Continued

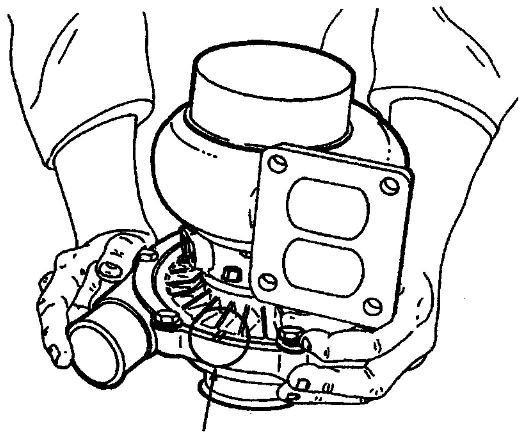

Figure 2.13. Mark Compressor to Back Plate Location

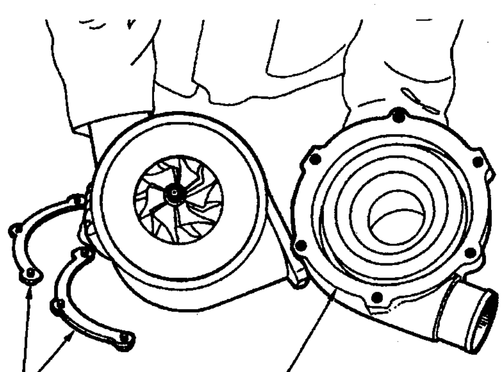

Figure 2.14. Compressor Housing Removal

IMPORTANT

CARE MUST BE TAKEN DURING THE HANDLING OF THE IMPELLER AND TURBINE WHEEL. BE VERY CAREFUL AND AVOID BENDING ANY BLADES. BENT BLADES MUST NEVER BE USED.

6. Install the dial indicator as outlined in Step 2 and recheck the radial shaft movement as outlined in Step 3 (**Figure 2.15**). If the readings exceed specifications, with the housing removed, the compressor wheel is contacting the compressor housing and reconditioning is required.

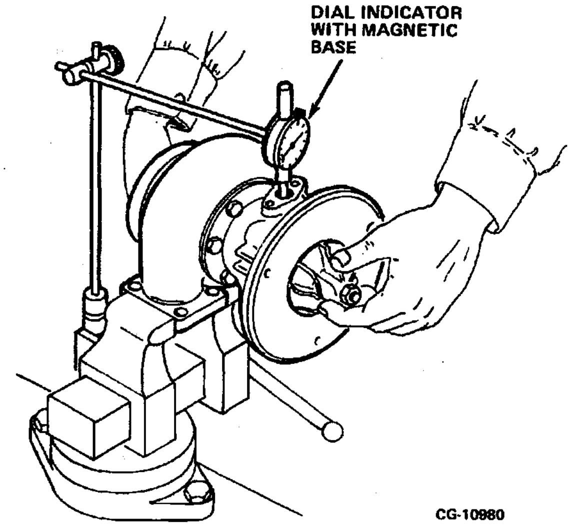

Figure 2.15. Checking Radial Shaft Movement with Compressor Housing Removed

VISUAL INSPECTION

1. Remove the turbine housing as follows:
   a. Mark the turbine housing location to the center housing, to facilitate reassembly. Refer to **Figure 2.16.**
   b. Remove the turbine housing mounting bolts and clamps which secure the turbine and center housings.
   c. Lift the center housing and core assembly from the turbine housing.

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REMOVAL AND REASSEMBLY — Continued

Inspection — Continued

VISUAL INSPECTION — Continued

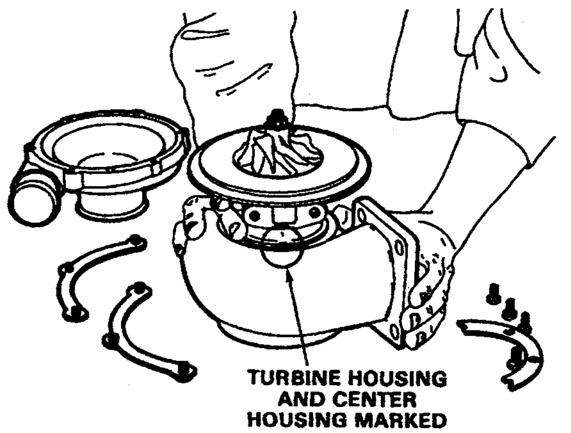

Figure 2.16. Mark Turbine to Center Housing

2. Visually inspect the compressor impeller and turbine wheel for blade erosion, bending, breakage or deposits. Refer to **Figure 2.17.** Replace as required.

NOTE: Compressor impeller and turbine wheel deposits can be caused by:

HIGH AIR INLET RESTRICTION — which allows oil to transfer from the turbocharger center housing, resulting in oil deposits.

ENGINE OPERATION WITH CONTAMINATED ENGINE OIL — which progressively damages the turbocharger, resulting in carbon deposits.

Turbine wheel deposits can be caused by:

EXCESSIVE OIL CONSUMPTION — resulting in turbine wheel carbon deposits.

ENGINE OVERFUELING — can result in excessive operating temperatures which can cause aluminum components to melt. Such deposits may be found on the turbine wheel if such a failure occurs.

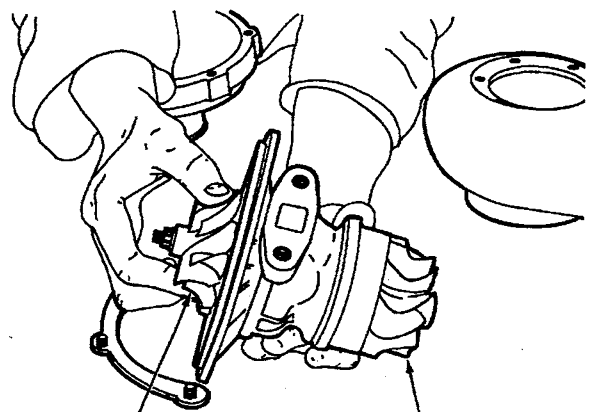

Figure 2.17. Wheel Inspection

3. Visually inspect the turbine and compressor housings for evidence of wheel rubbing. Replace the housing(s) as required.

IMPORTANT

DO NOT ATTEMPT TO STRAIGHTEN BENT WHEEL BLADES.

4. If the turbocharger passes all pre-disassembly inspections, reinstall on engine. (See Installation, this section.) If one or more inspections are out of specification or visually unacceptable, follow the instructions in this section under "**RECONDITIONING**".

INSTALLATION

NOTE: Steps 1 and 2 are required only when reinstalling a turbocharger which passed ALL the pre–disassembly inspections. See "RECONDITIONING" for detailed disassembly and reassembly procedures.

1. Assemble the. turbine housing to the center housing as follows:

IMPORTANT

CARE MUST BE TAKEN DURING THE HANDLING OF THE IMPELLER AND TURBINE WHEEL. BE VERY CAREFUL AND AVOID BENDING ANY BLADES. BENT BLADES MUST NEVER BE USED.

   a. Align the locating marks, refer to **Figure 2.18.**
   b. Install housing clamps and bolts.
   c. Tighten the housing bolts to the specified torque.

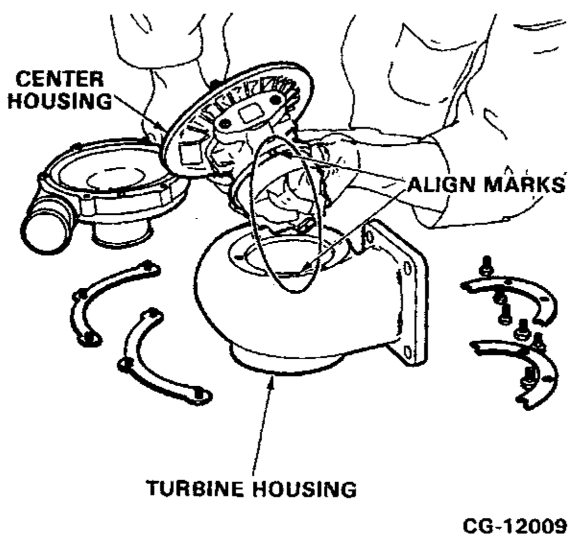

Figure 2.18. Assemble Turbine a Center Housings (Align Marks)

2. Assemble the compressor housing to the center housing back plate as follows:
   a. Align the locating marks, refer to **Figure 2.19.**
   b. Install housing clamps and bolts.
   c. Tighten the housing bolts to the specified torque.

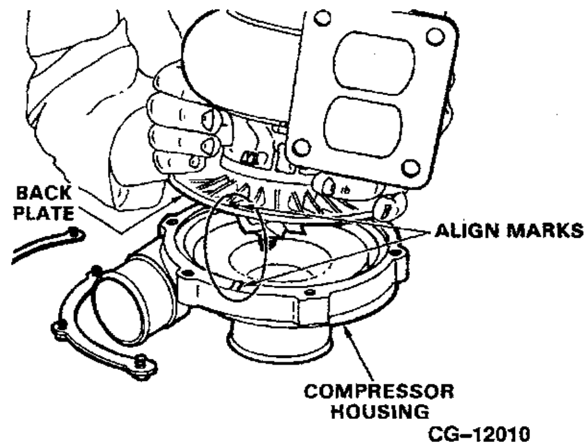

Figure 2.19. Assemble Compressor Housing and Center Housing Back Plate (Align Marks)

3. Install the turbocharger on a clean exhaust manifold flange as follows: (Refer to **Figure 2.20.**)
   a. Install a new gasket on the exhaust manifold flange. (Use grease to keep the gasket in place.)

NOTE: Apply "NEVER SEEZ" compound to the turbocharger mounting hardware. This will aid in future removal.

   b. Install the turbocharger over the two mounting studs and fasten using nuts and washers.
   c. Install the two bolts with nuts and washers at the lower end of the turbo and exhaust manifold flange.
   d. Tighten nuts to specified torque.

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INSTALLATION — Continued

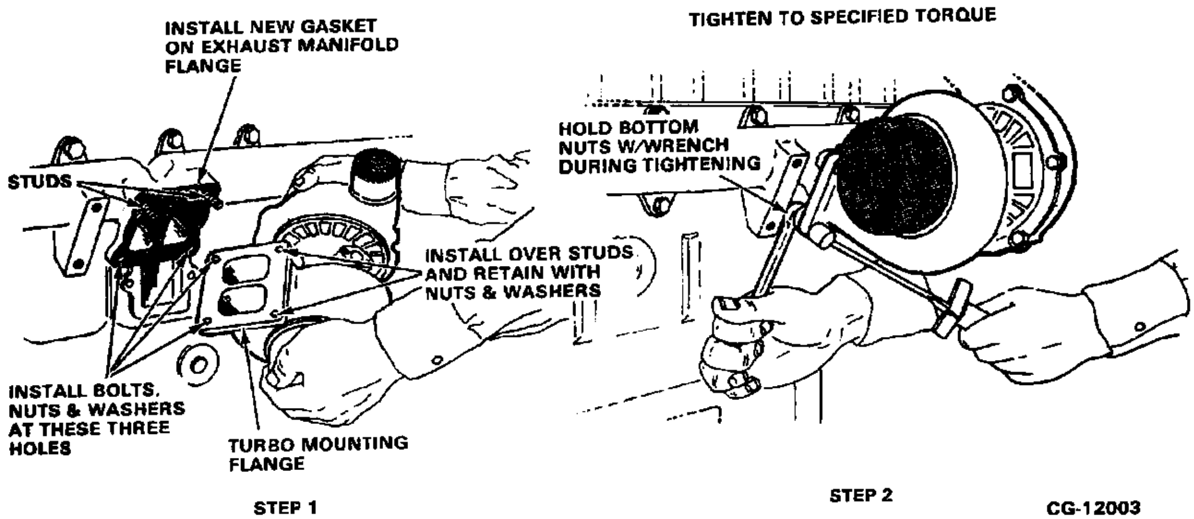

Figure 2.20. Mounting Turbocharger to Engine

NOTE: Prior to installation, inspect the oil drain and oil inlet tubes for debris, kinks or dents which may cause a restriction. Clean or replace, as required.

4. Install the turbo oil drain tube as follows: (Refer to **Figure 2.21**.)

   a. Remove the protective caps from the oil drain port on the turbocharger and from the oil drain elbow at the crankcase.

   b. Insert the oil drain tube hose over the elbow at the crankcase and secure using the worm–drive hose clamps.

   c. Using a new gasket, align the oil drain tube and turbocharger flange and secure with the two mounting bolts.

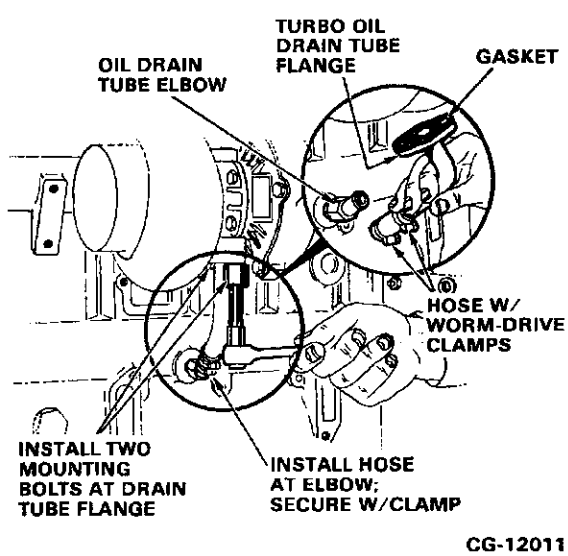

Figure 2.21. Turbocharger Oil Drain Tube Installation

INSTALLATION — Continued

5. Install the turbocharger oil inlet tube as follows: (Refer to **Figure 2.22.**)
   a. Remove the protective caps from the oil inlet port at the turbocharger and the oil inlet elbow at the oil filter header.
   b. Pour four or five ounces of clean engine oil into the oil inlet opening of the turbocharger. This will provide sufficient lubrication for the turbocharger bearings until engine oil pressure is obtained.
   c. Install a new rubber seal ring at the oil inlet tube connector nut.
   d. Position a new gasket on the turbocharger oil inlet flange.
   e. Align the oil inlet tube and fasten the connector nut at the elbow on the oil filter header.
   f. Fasten the oil inlet tube at the turbo oil inlet flange using the two mounting bolts.

DT–360 Only

6. Install the crossover pipe at the turbo air outlet and the intake manifold inlet. Refer to Section 3 for assembly instructions.

DTA–360 Only

6. Install the turbo outlet pipe (to charge air cooler) and engine inlet pipe (to intake manifold). Refer to Section 3 for assembly instructions.
7. Connect the air cleaner housing and piping to the turbocharger.
8. Connect the exhaust piping to the turbocharger exhaust outlet.
9. Run–In Checks:
   a. Start the engine and operate at low RPM for a few minutes before loading engine.
   b. Operate the engine, observing the turbocharger for any of the following:
   1. Unusual noise.
   2. Lubrication leaks.
   3. Insecure fastening to the engine.
   4. Excessive vibration.
   5. Excessive exhaust smoke.
   6. Air leaks in the air cleaner–to–turbocharger or turbocharger–to–intake manifold ducting.

– Investigate and correct any of these conditions immediately to avoid possible turbocharger or engine failure.

– Retighten capscrews, hold–down nuts, air connections to and from the turbocharger after the initial warm–up.

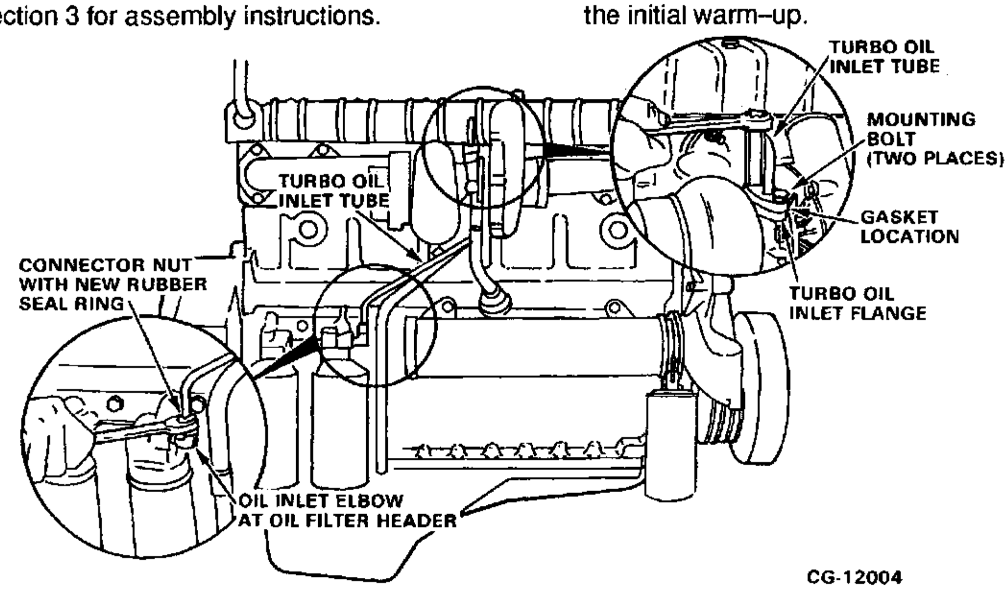

Figure 2.22. Turbocharger Oil Inlet Tube Installation

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INSTALLATION — Continued

RECONDITIONING

DISASSEMBLY

NOTE: Follow the turbocharger reconditioning procedures when the turbo fails one or more pre–disassembly inspections.

1. With the turbocharger removed from the engine as described in this section, cap all openings. Refer to **Figure 2.10**.
2. Wash the exterior of the turbocharger using Bendix Metal Cleaner or Gunk Hydroseal Cleaner.

NOTE: Do NOT use a caustic solution. Certain turbo parts may be damaged by exposure to a caustic cleaner.

3. Place the turbocharger on a clean bench.
4. To make reassembly easier, mark the turbo–charger components as follows: (Refer to **Figure 2.23.**)

   Compressor housing–to–back plate.

   Back plate–to–center housing.

   Center housing–to–turbine housing.

5. Remove the compressor housing capscrews and clamps at the back plate. Carefully lift the turbine and center housing assembly from the compressor housing. Refer to **Figure 2.24.**

IMPORTANT

CARE MUST BE TAKEN DURING THE HANDLING OF THE IMPELLER AND TURBINE WHEEL. BE VERY CAREFUL AND AVOID BENDING ANY BLADES. BENT BLADES MUST NEVER BE USED.

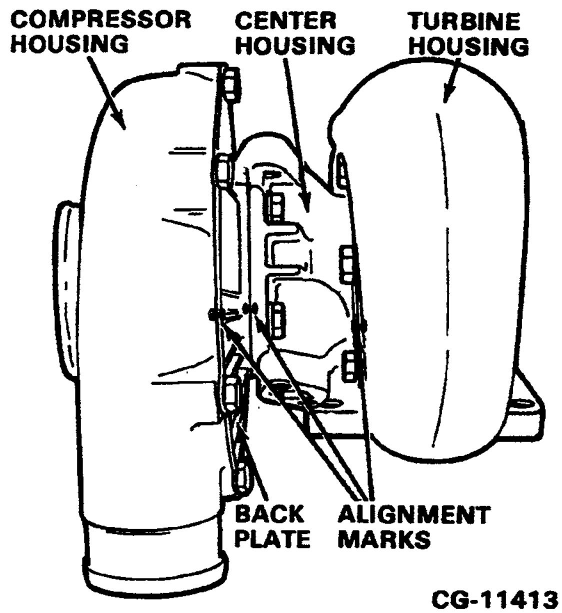

Figure 2.23. Mark Adjacent Components to Facilitate Reassembly

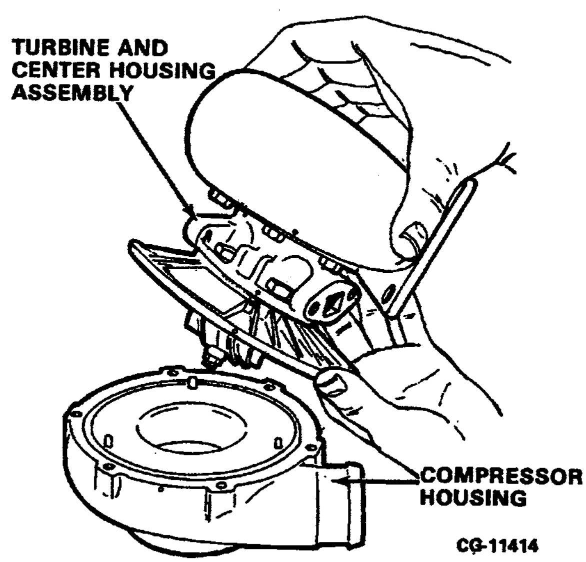

Figure 2.24. Removing Compressor Housing

RECONDITIONING — Continued

DISASSEMBLY — Continued

6. Remove the turbine housing capscrews and clamps which secure the center housing and core assembly to the turbine housing. Carefully lift the center housing and core assembly from the turbine housing. Refer to **Figure 2.25.**

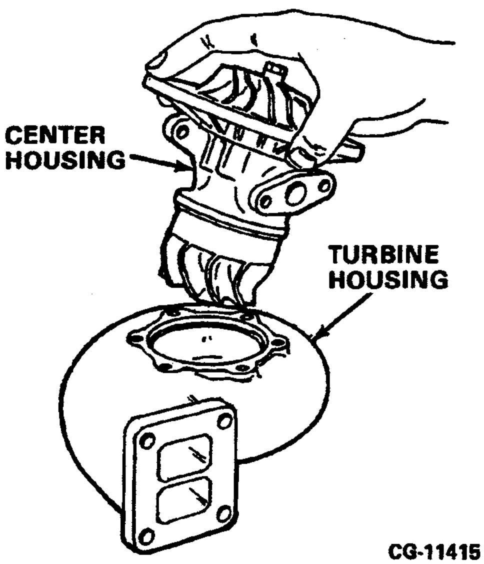

Figure 2.25. Removing Turbine Housing from Center Housing

REPLACEMENT CORE ASSEMBLY

NOTE: When it is not cost–effective to completely disassemble and recondition the turbocharger, a replacement core assembly is available for service. When using this unit, it is only necessary to remove the compressor and turbine housings from the old unit and install them on the new core assembly. BE SURE CORRECT ALIGNMENT IS ACHIEVED SINCE THE CENTER HOUSING ON THE NEW CORE ASSEMBLY WILL NOT HAVE ALIGNMENT MARKS.

IMPORTANT

DO NOT REST CENTER HOUSING ON EITHER COMPRESSOR IMPELLER OR TURBINE WHEEL OR DAMAGE TO WHEEL ASSEMBLY MAY RESULT.

7. Remove the lock nut from the turbine shaft (**Figure 2.26**) as follows:
   a. Construct shaft holding fixture using bar stock and a socket.
   b. Support the center housing and shaft assembly vertically in the holding fixture and vice.
   c. Attach a socket and tee handle wrench to the lock nut. Turn the tee handle wrench to remove the lock nut. Keep wrench straight.
   d. Slide the compressor wheel from the turbine shaft.

NOTE: If carbon build up prevents easy removal, press the shaft from the compressor impeller as explained in step 8.

IMPORTANT

DO NOT APPLY SIDE THRUST WHEN LOOSENING THE LOCK NUT AS IT IS POSSIBLE TO BEND THE SHAFT.

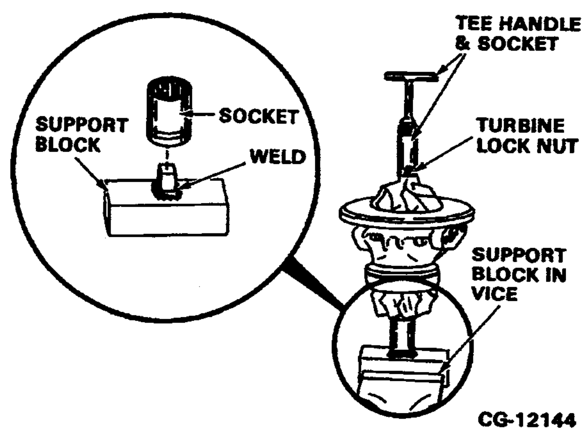

Figure 2.26. Shaft Lock Nut Removal

8. Support the center housing assembly on an arbor press as shown in **Figure 2.27**. Grind a radius on the end of a 1/4 inch bolt to fit the end of the shaft. Press the shaft from the compressor wheel.

RECONDITIONING — Continued

REPLACEMENT CORE ASSEMBLY — Continued

IMPORTANT

HOLD THE TURBINE WHEEL AND SHAFT ASSEMBLY TO PREVENT DAMAGE DUE TO DROPPING.

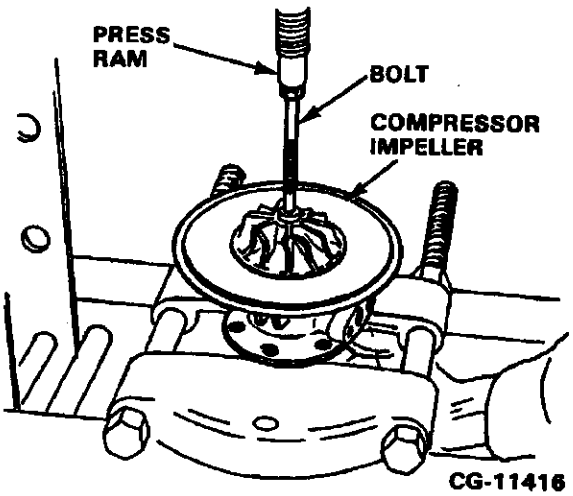

Figure 2.27. Separating Compressor Impeller from Turbine Shaft

9. Place the center housing and back plate on a bench and remove the capscrews and washers which secure the center housing to the back plate. Refer to **Figure 2.28**. Carefully lift the center housing from the back plate.

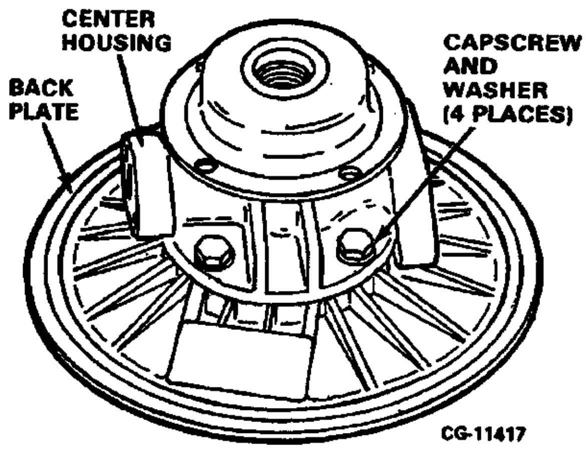

Figure 2.28. Center Housing and Back Plate Disassembly

10. With the back plate removed, the following are easily removed:
    a. Remove the seal ring, thrust collar and thrust washer from the center housing (**Figure 2.29**). The thrust spring located in the back plate is replaceable, but should not be removed unless replacement is necessary.

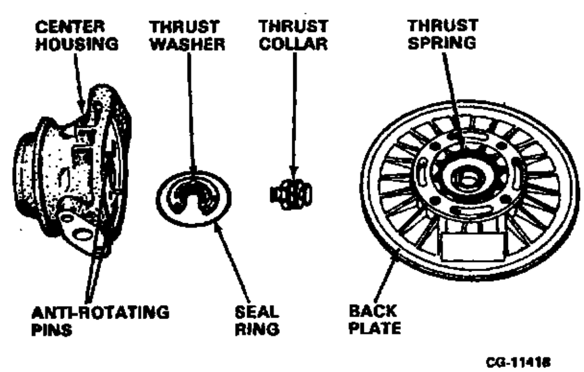

Figure 2.29. Center Housing and Back Plate Components

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RECONDITIONING — Continued

REPLACEMENT CORE ASSEMBLY — Continued

b. Using snap ring tool, remove the outboard bearing retainers and bearings from each side of the center housing. Refer to **Figure 2.30**.

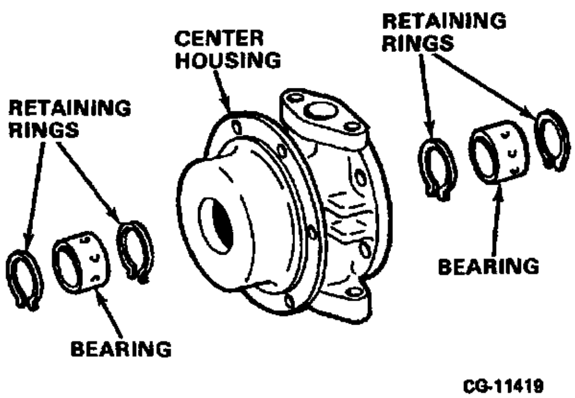

Figure 2.30. Bearing Removal

NOTE: The inboard retainers are subject to distortion during removal. Replace the inboard retainers ONLY if they appear to be damaged or worn.

c. Remove the piston seal ring from the thrust collar using a small screwdriver to carefully pry it free. Refer to **Figure 2.31**.

d. Remove the piston seal ring from the turbine wheel and shaft assembly near the shroud, by carefully prying it free with a small screwdriver.

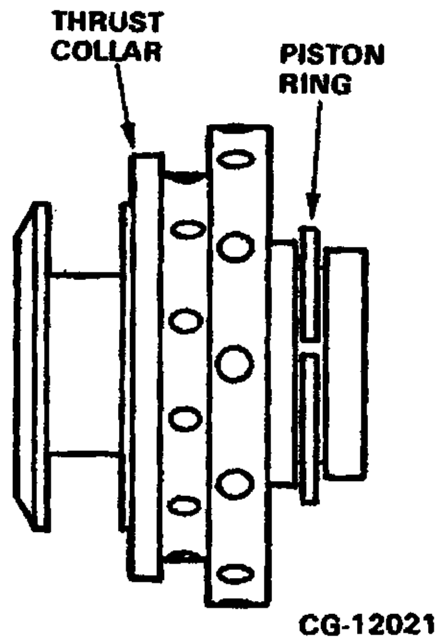

Figure 2.31. Piston Seal Ring Removal

CLEANING AND INSPECTION (After Disassembly)

1. Prior to cleaning, visually inspect ALL the components for signs of rubbing or wear which may not be evident after cleaning.
2. Soak all parts in Bendix Metal Cleaner. DO NOT USE A CAUSTIC SOLUTION OR ALLOW PARTS TO STRIKE ONE ANOTHER TO AVOID DAMAGE.
3. Clean deposits using a soft brush or a plastic scraper.
4. Dry parts using filtered compressed air.

IMPORTANT

DO NOT USE A STEEL BRUSH OR STEEL BLADE SCRAPER TO CLEAN TURBO-CHARGER PARTS.

IMPORTANT

BE SURE ALL BLADES ARE THOROUGHLY CLEANED, AS ANY DEPOSITS LEFT ON THE BLADES WILL AFFECT BALANCE.

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RECONDITIONING — Continued

CLEANING AND INSPECTION
(After Disassembly) — Continued

5. Dry all internal cavities of the center housing using filtered compressed air.
6. Visually inspect both wheels of the rotor assembly for damaged or distorted blades and for possible contact with their respective housings. Check for cracked, bent or broken blades. Replace components if necessary.

IMPORTANT

DO NOT ATTEMPT TO STRAIGHTEN BLADES.

7. Visually inspect the turbine and compressor housings for cracks and/or scoring.
8. Visually inspect the thrust washer and collar for wear or damage and replace as required.
9. Inspect the thrust spring in the back plate for wear or damage. DO NOT remove the thrust spring to inspect it. If damaged, remove and install a new thrust spring.
10. Visually inspect the bearing surfaces for scratches and wear. Replace bearings as necessary.
11. Inspect the turbine wheel shaft for scratches, scoring or pitting. Replace as required.

IMPORTANT

NEVER GRIND OR POLISH THE SHAFT; IT WILL ADVERSELY AFFECT BALANCE.

12. Inspect the piston seal ring groove walls on the shaft for scoring. Replace as required.
13. Inspect for worn or scored surfaces in the center housing bearing bores.
14. Visually inspect the following mating surfaces for nicks or gouges:

Turbine housing–to–center housing.

Center housing–to–back plate.

Back plate–to–compressor housing.

The mating surfaces must be smooth to seal and provide proper clearances for the compressor impeller and turbine wheel. Replace any part which does not meet the inspection criteria.

REASSEMBLY

NOTE: Reference numbers refer to Figure 2.32.

1. If the inboard bearing retaining rings (16) were removed, use a snap ring tool to install new retaining rings into their grooves in the bore of the center housing. Insure the retaining rings are properly seated in the grooves.
2. Lubricate the bearings (17) with clean engine oil and push them into the bores until they seat against the inboard retaining rings (16). Install new outer retaining rings (16) after installing bearings.
3. Carefully install the piston seal ring (20) into the groove on the turbine wheel assembly (22).

NOTE: Install piston seal ring by hand only. Use of tools will cause distortion of the piston ring.

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RECONDITIONING — Continued

REASSEMBLY — Continued

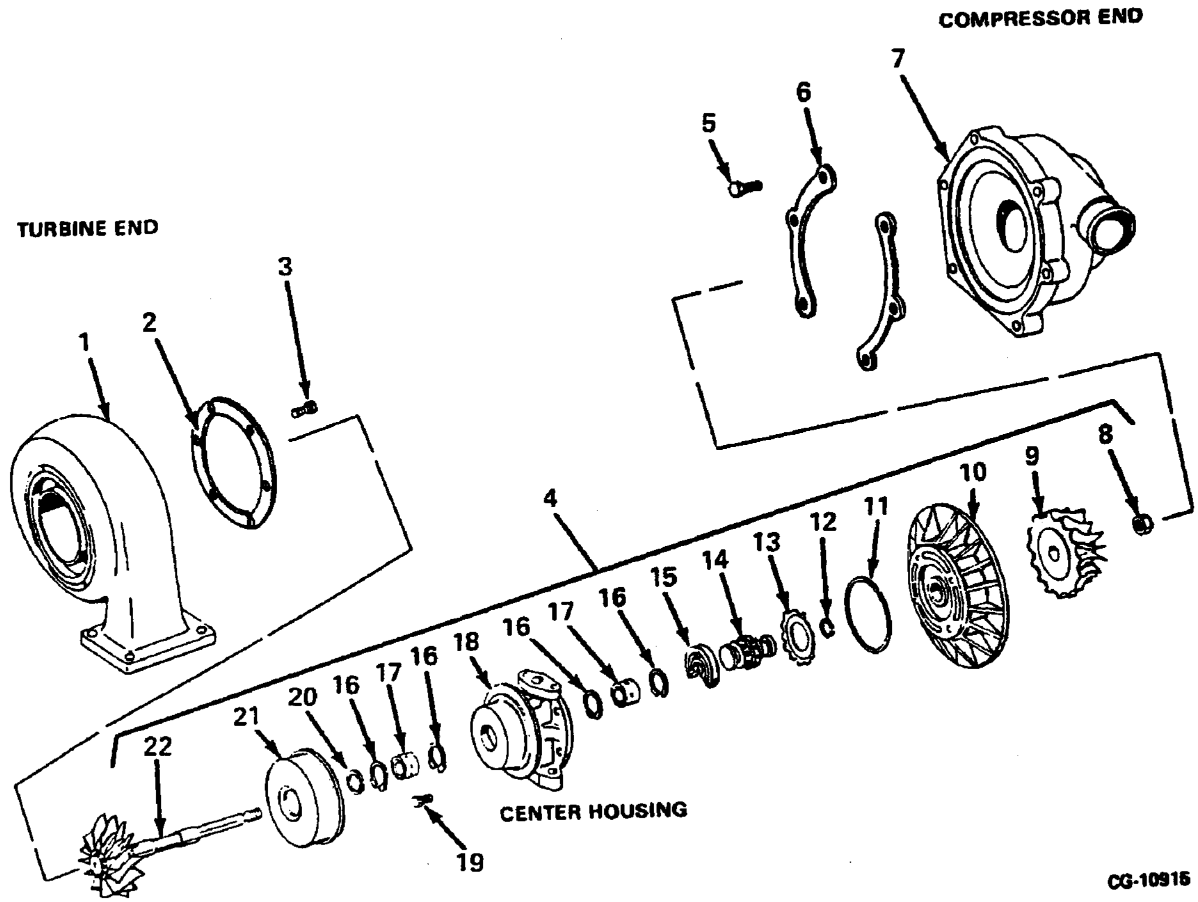

Figure 2.32. Turbocharger Components (T04E)

1. Housing, Turbine
2. Clamp, Housing
3. Screw, Hex Hd Cap
4. Core Assembly
5. Screw, Hex Hd Cap
6. Clamp, Housing
7. Housing, Compressor
8. Nut, Impeller Lock
9. Impeller, Compressor
10. Plate, Back
11. Ring, Plate Seal
12. Ring, Piston Seal
13. Spring, Plate
14. Collar, Thrust
15. Washer, Thrust
16. Ring, Retaining
17. Bearing, Journal
18. Housing, Center
19. Screw, Hex Hd Cap
20. Ring, Piston Seal
21. Shroud, Turbine
22. Turbine Wheel Assembly

RECONDITIONING — Continued

REASSEMBLY — Continued

4. Place the shroud (21) over the turbine end of the center housing. Carefully insert the turbine wheel assembly (22) through the shroud and center housing. The piston seal ring must be positioned with the shroud to align with the center housing bore to prevent piston seal ring damage. Apply a gentle downward pressure to the turbine wheel while rotating the wheel shroud. This will help the piston seal ring seat in its bore.

5. Install a new piston seal ring onto the thrust collar (14). Install the thrust washer onto the collar with the flat surface of the washer next to the large diameter of the collar.

6. Install the thrust collar and washer over the turbine wheel assembly shaft (22); thrust washer first and engage the holes in the washer with the anti–rotating pins (**Figure 2.29**) in the center housing.

7. Install a new seal ring (11) into the groove in the compressor side of the center housing.

8. Insure the thrust spring is correctly seated in the back plate.

9. Align the marks, made prior to disassembly, on the back plate (10) with those on the center housing (18) and carefully install the back plate over the shaft and thrust collar.

NOTE: Be careful not to damage the seal ring when engaging the thrust collar into the bore in the back plate. The back plate is easily installed if the open side of the seal ring is engaged into the back plate bore first.

10. Install the center housing to back plate capscrews (19) and tighten to specified torque. See Specifications.

11. Slip the compressor impeller (9) onto the shaft. Apply a small amount of clean engine oil on the threads and washer face of the lock nut (8). Install the lock nut finger–tight.

12. Carefully place the assembled center housing in a holding fixture (made locally). See **Figure 2.26**. Support the assembly vertically in a vice with the compressor impeller nut in the holding fixture socket.

13. Using a tee handle wrench, with a double universal joint to avoid side (bending) load on the shaft, turn an additional 90*. This will achieve the specified torque.

14. Remove the assembly from the vice and spin the wheel by hand. The wheels must rotate freely; insure the turbine wheel does not rub the shroud (21).

NOTE: Hold a center housing in a vertical position (turbine end up) when performing this check.

15. Align the marks made during disassembly on the center housing with those on the turbine housing. Carefully install the turbine end of the center housing into the turbine housing. Be careful during assembly so blades are not bent.

16. Coat the threads of the capscrews (3) with "NEVER SEEZ" compound. Install the clamps (2), and capscrews (3). Tighten the capscrews to specified torque. See Specifications.

17. Align the marks on the compressor housing with those on the center housing and back plate. Carefully install the compressor housing and secure with capscrews (5) and clamps (6). Be careful during assembly so blades are not bent. Tighten the capscrews to specified torque to secure the housing (see Specifications).

18. Push the shaft as far as possible from the turbine end and check for binding during rotation. Repeat check, pushing from compressor end. The shaft must rotate freely with no interference at either end of the turbocharger.

19. If the turbocharger is not to be installed immediately, lubricate internally and install protective covers on all openings.

20. Refer to "INSTALLATION" in this section for instructions on installing the turbocharger to the engine.

TROUBLESHOOTING

CONDITION	POSSIBLE CAUSE	REMEDY
Shaft and Turbine Wheel		
a. Bearing surfaces scratched or worn.	a. Dirty or insufficient oil. Wheel overspeeding.	a. Replace
b. Discoloration	b. Overheating or insufficient	b. Reuse if slightly discolored and not deeply scratched
c. Worn on one side only.	c. Operating with unbalanced wheel.	c. Replace
d. Cracked, bent or damaged blades.	d. Foreign objects, heat or fatigue	d. Replace
Bearings		
a. Both ID and OD scratched and worn.	a. Dirty or insufficient oil Wheel overspeeding.	a. Replace
b. Seized on shaft or excessive OD wear.	b. Overheating or lubrication	b. Replace
c. Worn on one side only.	c. Operating with unbalanced wheel	c. Replace
Bearing Housing		
a. Bore scratched or worn.	a. Dirty or insufficient oil	a. Replace
b. Carbon deposits.	b. Oil leaking; overfueling.	b. Clean housing. Remove any restriction from air intake system or oil drain.
Compressor End		
a. Dirty	a. Excessive intake restriction or a restricted oil drain line.	a. Check for clogged air cleaner element, collapsed hose or leaks in air inlet pipe. Clean compressor end and oil drain line.
	b. Insufficient air filtration. between the air cleaner	b. Secure the connections and turbocharger.
	c. Long period of operation without cleaning. (Refer to operation and maintenance manual for maintenance schedule.)	c. Disassemble and clean the unit.

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TROUBLESHOOTING

CONDITION	POSSIBLE CAUSE	REMEDY
Compressor Wheel		
a. Rubbing on OD of blades.	a. Worn bearing or unbalanced turbine wheel.	a. Replace parts as necessary.
b. Rubbing on cover or back face.	b. Insufficient clearance, cover damaged or thrust washer worn.	b. Improper end play. Replace damaged or worn parts.
c. Inlet leading edge of blades either worn	c. Loose pieces in air intake system.	c. Check air intake system for loose nuts, bolts or other foreign material. Replace wheel assembly.
Shaft Rotation		
a. Wheel drags.	a. Carbon buildup behind turbine wheel or dirt accumulation behind compressor wheel.	a. Disassemble and clean the unit.
	b. Bearing worn excessively or seized to shaft due to dirty oil or low oil pressure	b. Replace bearing and change oil
Shaft End Play		
a. End play exceeds specifications.	a. Thrust bearing or thrust rings worn or distorted.	a. Replace parts as necessary
b. End play less than specifications.	b. Carbon buildup behind turbine wheel or dirt buildup behind compressor wheel	b. Disassemble and clean the unit
Turbine Wheel Radial Movement		
a. Radial movement exceeds specifications	a. Worn bearings or shaft, or bore in bearing housing worn	a. Replace worn parts

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SERVICE MANUAL

MANIFOLDS

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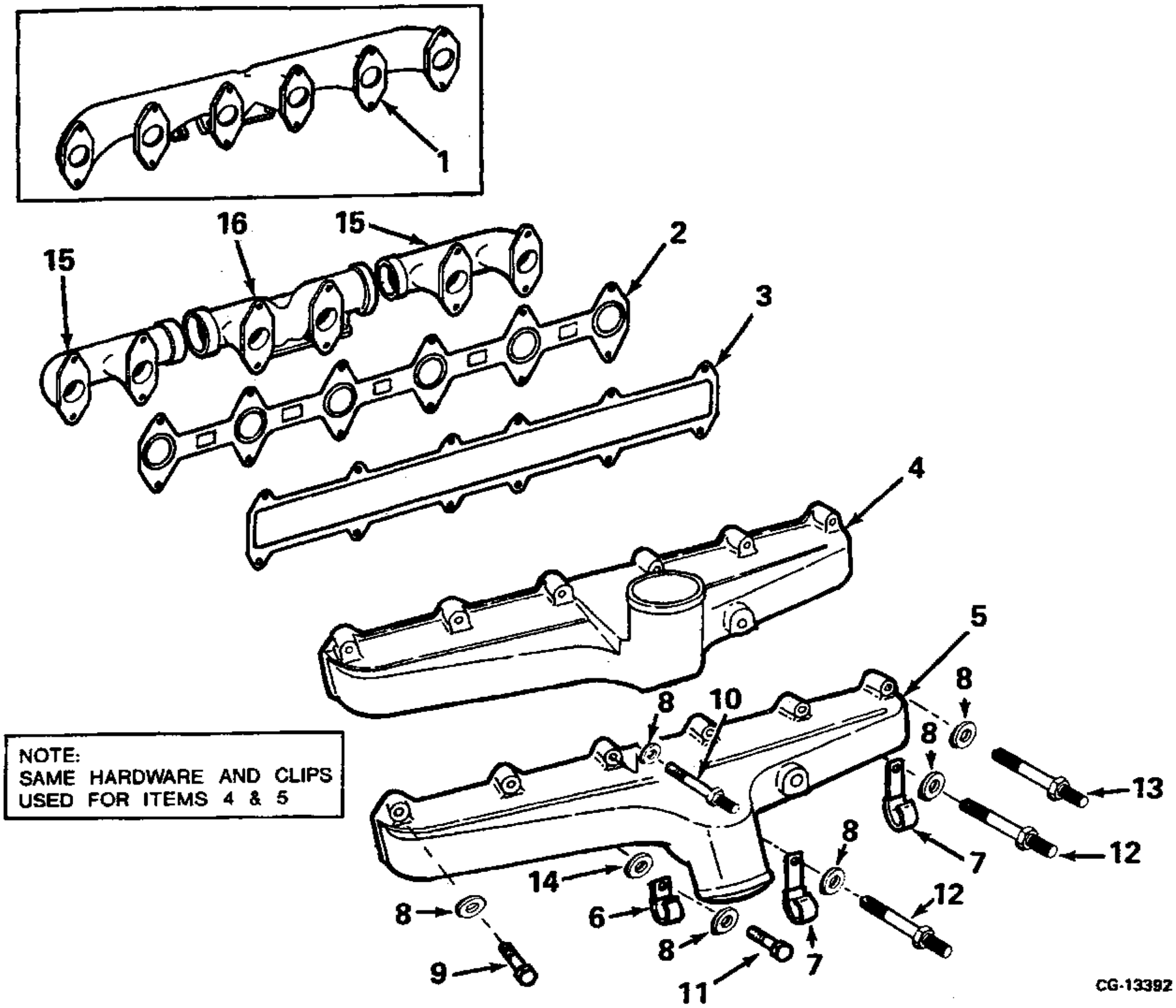

Figure 3.1. Intake and Exhaust Manifold
(Engine Serial Numbers Above 39374)

1. Manifold, Exhaust (one–piece)(Early)
2. Gasket, Exhaust Manifold
3. Gasket, Intake Manifold
4. Manifold, Intake
   (Used When Equipped for PTO)
5. Manifold, Intake
   (Used When Not Equipped w/ PTO)
6. Clamp, for Engine Wiring Harness
7. Clamp
8. Washer, hardened
9. Bolt, prevailing torque
10. Stud Bolt/Bolt, prevailing torque
11. Bolt, prevailing torque
12. Stud Bolt, prevailing torque
13. Stud Bolt/Bolt, prevailing torque
14. Washer, hardened
15. Manifold, Exhaust (front/rear)(Current)
16. Manifold, Center (Current)

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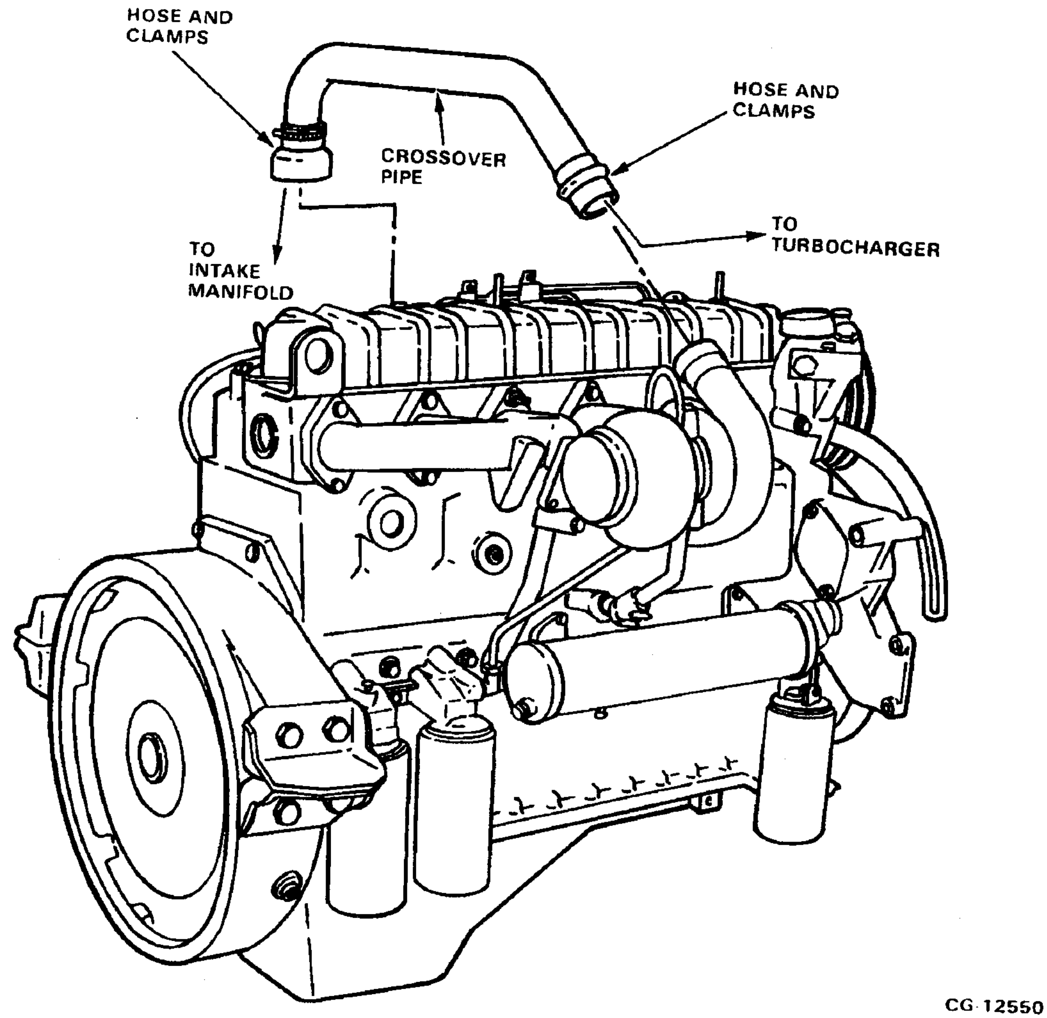

Figure 3.2. Typical DT–360 Air Intake Piping

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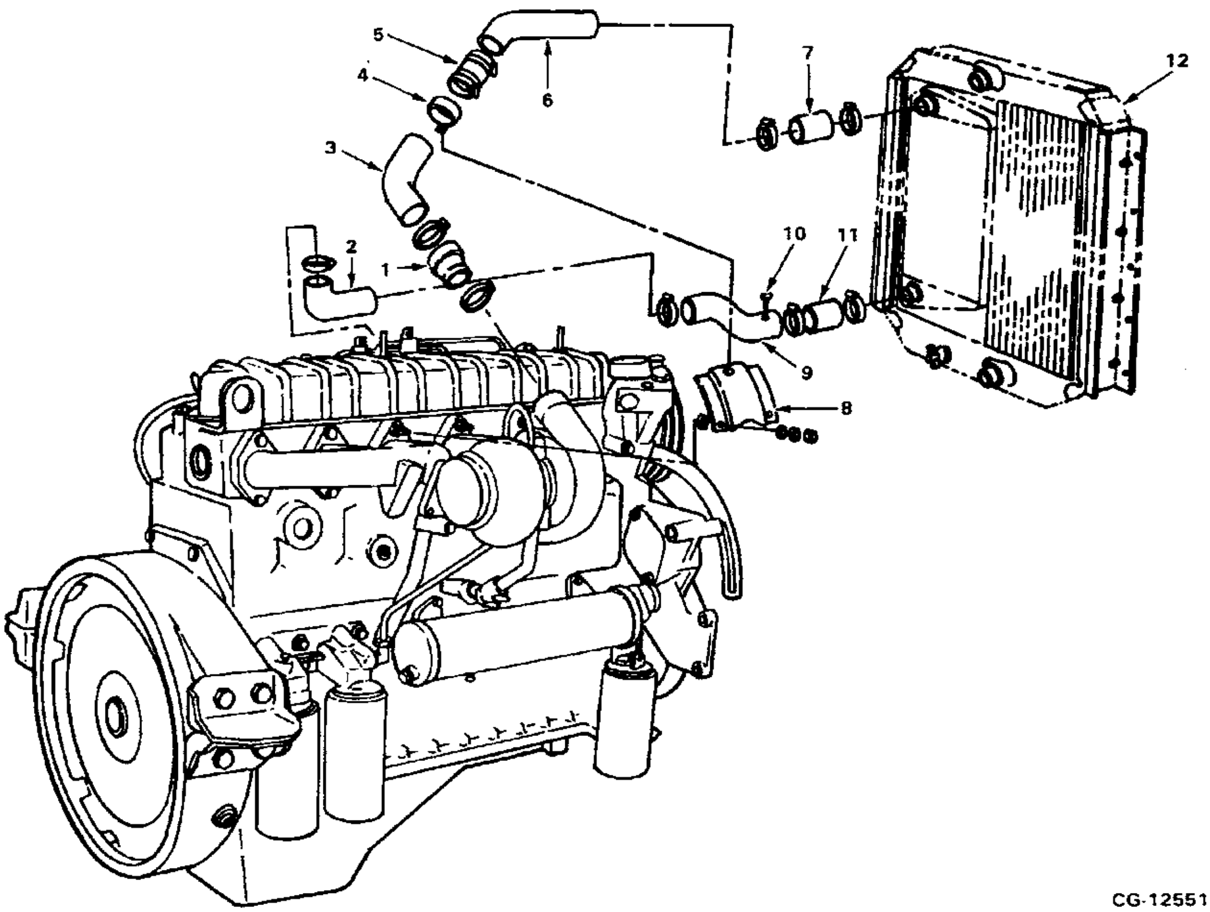

Figure 3.3. Typical Chassis Mounted Charge Air Cooler Assembly

1. Hump Hose w/Clamps
2. 45° Hose Elbow w/Clamps (@ Intake Manifold)
3. Turbo Outlet Pipe
4. Pipe Clamp
5. Hose w/Clamps
6. Air Inlet Pipe (to Charge Air Cooler)
7. Hose w/Clamps
8. Turbo Outlet Pipe Support Bracket
9. Engine Air Inlet Plug
10. 1/4 in. NPT Pipe Plug
11. Hose w/Clamps
12. Side by Side Charge Air Cooler/Radiator

IMPORTANT

THE CHARGE AIR COOLER (12) AND CONNECTING, HARDWARE (1–11) USED ON DTA ENGINES IS CHASSIS MOUNTED. REFER TO THE APPROPRIATE CHASSIS MANUAL AND PARTS CATALOG FOR DETAILED INFORMATION.

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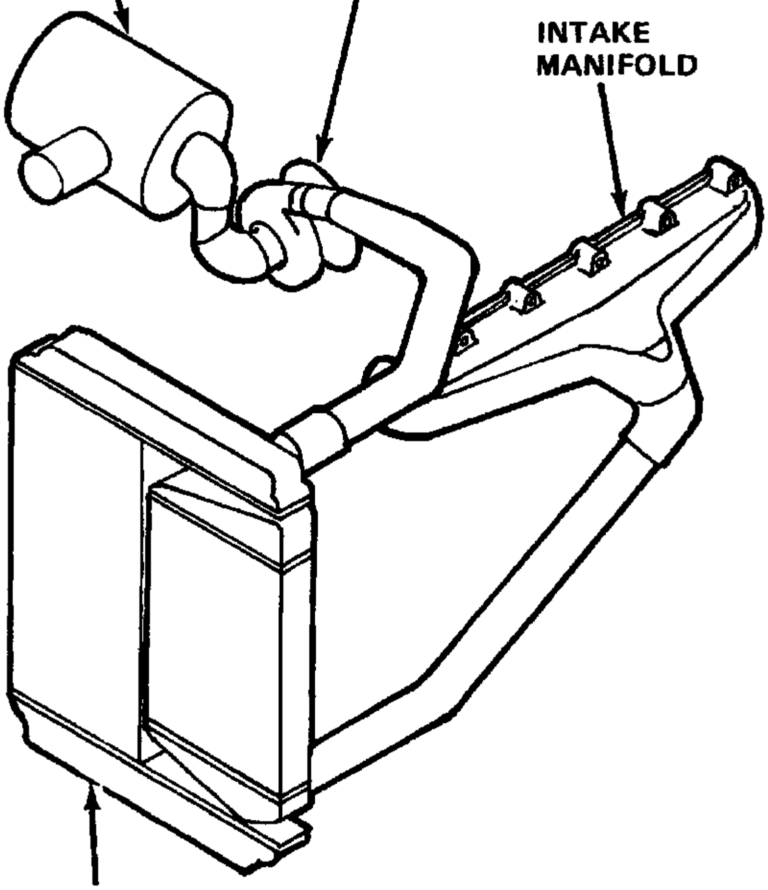

Figure 3.4. Chassis Mounted Intercooler and Piping Installation Schematic (Typical Right side View)

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SPECIFICATIONS

INTAKE MANIFOLD

No Service Specifications Required

EXHAUST MANIFOLD

Max. Allowable Warpage .... 0.010 in. (0.25 mm)
Max. Allowable Removal of Material .... 0.025 in. (0.64 mm)

SPECIAL TORQUES

Intake Manifold Bolts .... 20 lbf–ft. (27 Nm)
(Use prevailing torque [patch type] fasteners)
Exhaust Manifold Bolts .... 60 lbf–ft. (81 Nm)

SPECIAL SERVICE TOOLS

None required for this section

COMPONENT CHANGES

INTAKE MANIFOLD

The intake manifold for the 1988 model year had been enlarged to provide improved air distribution. The large intake manifold is required to meet the 1988 exhaust emission standard. 1988 model year air intake openings for DT and DTA applications are now 3.00 in. diameter. Previously, 1987 models had a 2.25 in. dia. air intake for DT's and 3.25 in. dia. opening for DTA's. Refer to Current Parts Catalog for correct service part numbers.

IMPORTANT

1987 MODEL YEAR ENGINES' AIR INTAKE OPENINGS ALL FACED UP. THE 1988 DTA–360 INTAKE MANIFOLD WAS DESIGNED TO BE INSTALLED WITH THE AIR INTAKE OPENING FACING DOWN (EXCEPT FOR ENGINES EQUIPPED WITH ENGINE DRIVEN POWER TAKE–OFFS (PTO'S). 1988 ENGINES WITH PTO'S USED THE SAME INTAKE MANIFOLD AS DT–360 ENGINES. PIPING AND THE INTERCOOLER ARE SIGNIFICANTLY DIFFERENT FROM 1987 TO 1988. INTAKE MANIFOLDS CANNOT BE INTERCHANGED BETWEEN 1987 AND 1988 MODEL YEAR ENGINES. REFER TO CURRENT PART CATALOG FOR CORRECT SERVICE PART ITEMS.

COMPONENT CHANGES

EXHAUST MANIFOLD

The prior one piece exhaust manifold is replaced by a three piece design effective with engine serial number 079062.

IMPORTANT

The three piece design consists of only two parts; a center assembly and the front and rear exhaust manifold pieces. Removal, cleaning, inspection and installation of the exhaust manifold is not affected by this change. THE NEW "THREE PIECE" AND PRIOR "ONE PIECE" EXHAUST MANIFOLDS ARE INTERCHANGE-ABLE. REFER TO PARTS CATALOG FOR CURRENT PART NUMBERS.

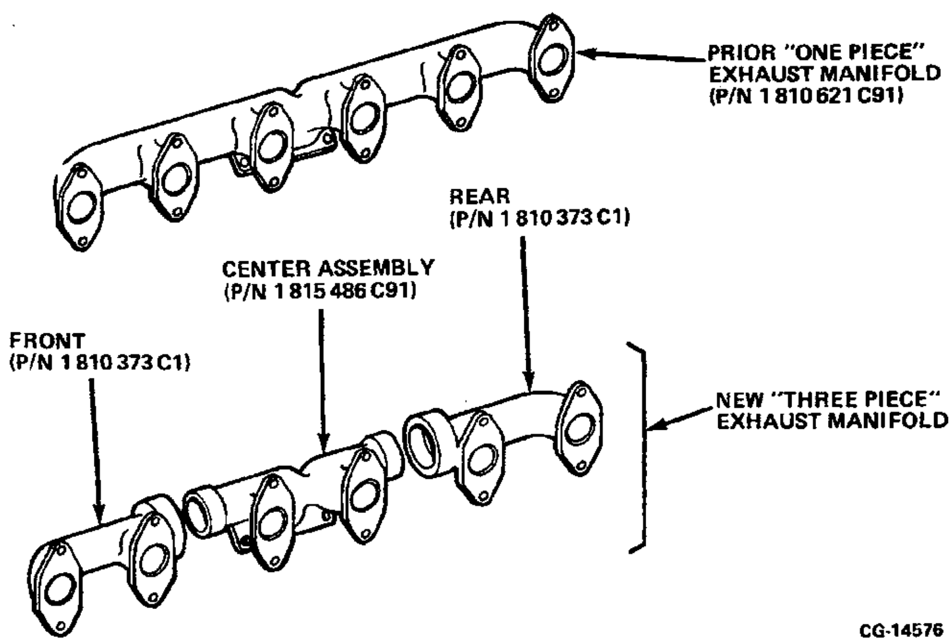

Figure 3.5. Exhaust Manifold Comparison

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EXHAUST MANIFOLD

REMOVAL

Remove the following:

Refer to the appropriate manual section for removal of these components.

Air Crossover Pipe (DT–360 Only)
Turbo Outlet Pipe (DTA–360 Only)
Turbo Outlet Pipe Support (DTA–360 Only)
Turbocharger

ONE–PIECE MANIFOLD REMOVAL (Refer to Figure 3.6)

1. Remove the bolts and stud bolt(s) which secure the exhaust manifold to the cylinder head.
2. Remove the exhaust manifold and metal gasket.

NOTE: Early Model DT–360's used one stud bolt at the #4 cylinder upper exhaust manifold bolt location to support the heater hose bracket brace.

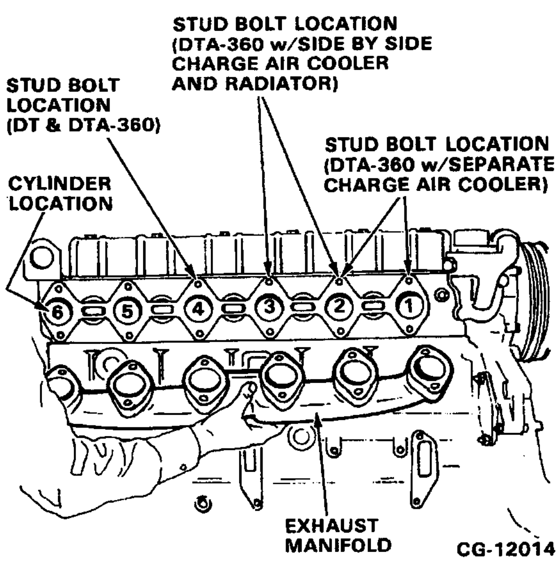

Figure 3.6. Exhaust Manifold Removal (One–Piece Manifold Shown)

THREE–PIECE MANIFOLD REMOVAL (Refer to Figure 3.7)

1. Remove the nine bolts and three stud bolts which secure the exhaust manifold sections to the cylinder head.
2. Remove the exhaust manifold sections and metal gasket.

NOTE: The DTA–360 uses three stud bolts. one–piece manifold use two stud bolts located at the #1 and #2 cylinder upper exhaust manifold bolt locations to hold the support bracket for the turbo air outlet pipe. The other stud bolt is located at the #4 cylinder upper exhaust manifold bolt location to support the heater hose bracket brace. Engines equipped with a three–piece manifold use stud bolts at cylinder's #2, 3 and 4.

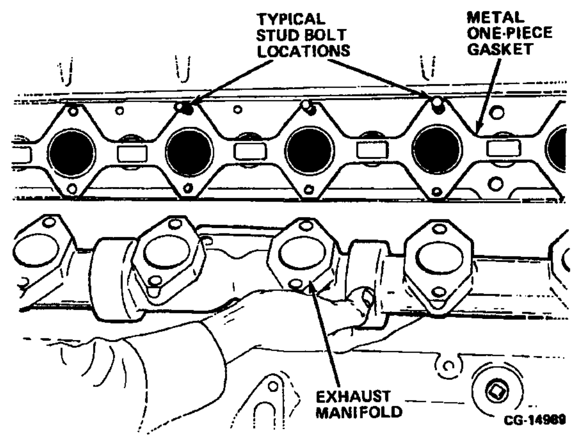

Figure 3.7. Exhaust Manifold Removal (Three–Piece Manifold Shown)

CLEANING

1. The exhaust manifold is cast in one piece and may be cleaned with a suitable non–caustic solvent or steam cleaned.
2. After cleaning, blow dry using filtered, compressed air.

INSPECTION

1. Visually inspect the exhaust manifold for cracks. Replace as required.
2. Inspect for warpage as follows:

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EXHAUST MANIFOLD — Continued

INSPECTION — Continued

METHOD ONE (See **Figure 3.8**)

a. Place a straightedge across the exhaust manifold mounting flanges.

b. Try to pass a .015 in. feeler gauge between the straightedge and the manifold flange.

c. If the feeler gauge will pass under the straightedge, the manifold must be resurfaced.

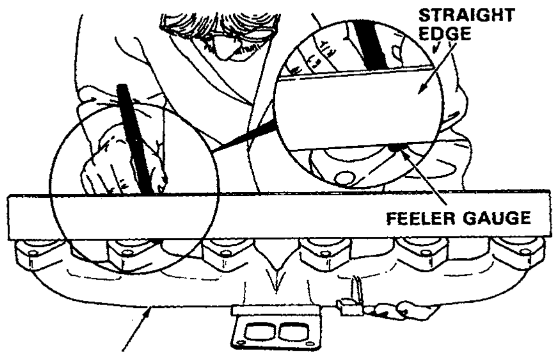

Figure 3.8. Checking for Warpage (With One–piece Manifold Shown) {Method One}

METHOD TWO (See **Figure 3.9**)

a. Bolt the exhaust manifold to the cylinder head WITHOUT THE GASKET. Tighten to specified torque.

b. Using a.015 in. feeler gauge, measure the gap between the bolts at the manifold flange to cylinder head mating surface.

c. If the feeler gauge will pass through, the exhaust manifold requires resurfacing.

IMPORTANT

A MAXIMUM OF .025 INCH MATERIAL CAN BE GROUND OFF TO CORRECT WARPAGE.

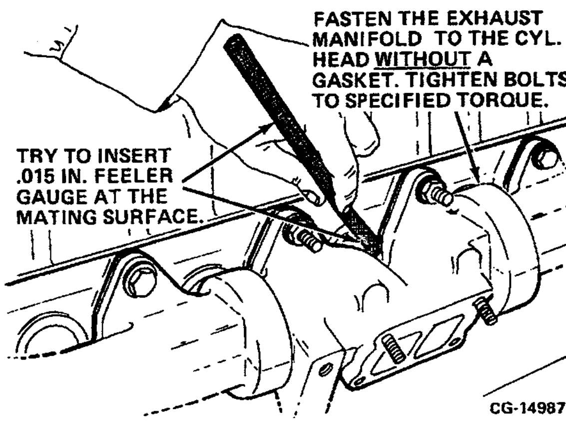

Figure 3.9. Checking for Warpage (With Three–Piece Manifold Shown) {Method Two}

3. If warpage cannot be corrected by grinding, replace the exhaust manifold.

INSTALLATION

1. Install the exhaust manifold using a new gasket as follows:

   a. Apply "ANTI–SEEZ" compound to the bolts and stud bolts.

   b. DT–360: Install the eleven bolts and one stud bolt (at #4 cylinder upper bolt location).

   c. DTA–360 (with separate charge air cooler): Install the nine bolts and three stud bolts (at the #1, 2 and 4 cylinder upper bolt locations).

   d. DTA–360 (with side by side charge air cooler): Install the nine bolts and three stud bolts (at the #2, 3 and 4 cylinder upper bolt locations).

   e. Tighten bolts to the specified torque.

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INTAKE MANIFOLD

REMOVAL

Remove the following:

Refer to the appropriate manual section for removal of these components.

Air Crossover Pipe (DT–360 Only)
Air Inlet Pipe (DTA–360 Only)
High Pressure Fuel Injection Lines

NOTE: LOCATIONS OF STUD BOLTS, CLAMPS AND BOLTS ARE BY APPLICATION AND MODEL YEAR. FOR ACCURATE ASSEMBLY OF MANIFOLD, NOTE LOCATION OF THESE ITEMS PRIOR TO REMOVAL FROM ENGINE.

1. Remove the aneroid tube as follows:
   a. Loosen connecting nuts at the intake manifold and injection pump.
   b. Discard the rubber sealing ring at each end.
   c. Cap the openings at the pump and the intake manifold. Refer to **Figure 3.10.**

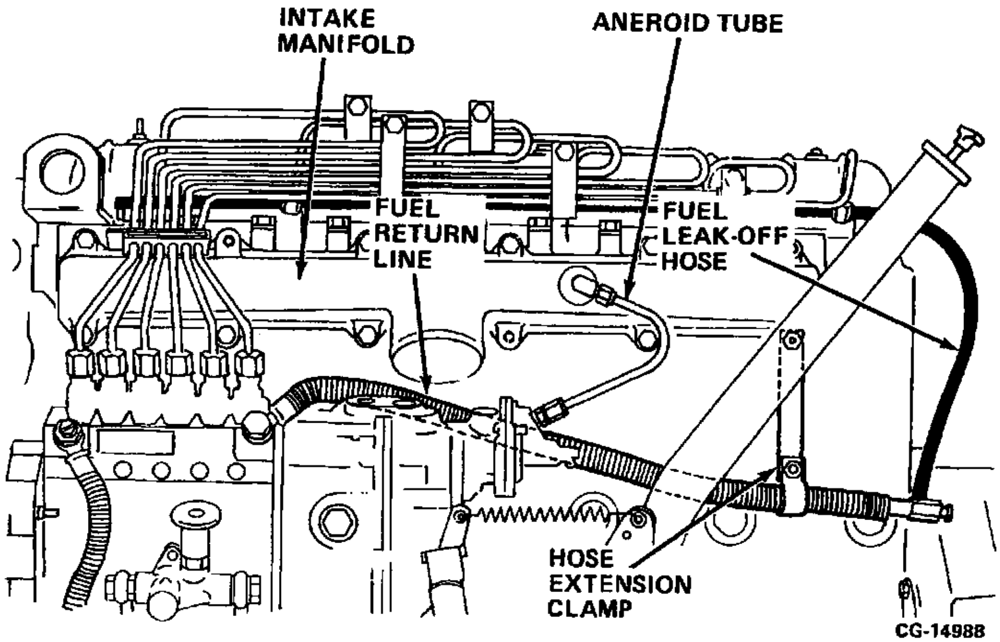

Figure 3.10. Removing Aneroid and Fuel Return Tubes (Typical PESA Pump Application Shown)

2. Remove the fuel return tube assembly as follows:

NOTE: Fuel return tube removal is not required to only remove and replace the intake manifold. However, if complete engine tear down is required, remove the fuel return line as instructed.

   a. Disconnect the fuel leak–off hose at the return tube assembly using pliers to expand the retaining clamp.
   b. Remove the intake manifold bolt (at the #6 cylinder, bottom bolt position).

NOTE: This bolt retains a washer, fuel return tube clamp, wiring harness clamp, washer and a spacer, for 1987 model year engines. Later Model Year engines do not have the spacer.

   c. Remove the intake manifold stud bolt (at the #4 cylinder {if applied}.

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INTAKE MANIFOLD — Continued

REMOVAL — Continued

NOTE: The stud bolt retains a washer, fuel return tube clamp, wiring harness clamp, washer and a spacer. Later model year engines do not use a spacer.

d. Remove the hex head hollow screw and washers from the fuel return tube banjo fitting at the fuel injection pump.

e. Remove the fuel return line as an assembly. Keep the hardware together to facilitate reassembly.

3. Loosen and remove the remaining intake manifold bolts and studs. Refer to **Figure 3.11**.

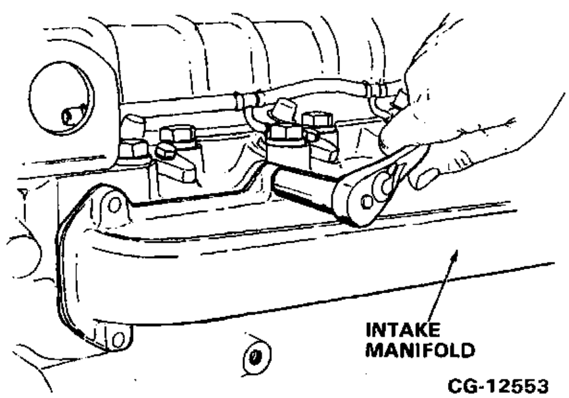

Figure 3.11. Intake Manifold Bolt Removal

4. Remove the manifold and gasket from the cylinder head.
5. Discard the gasket.

CLEANING

1. Clean the aluminum intake manifold thoroughly, using a suitable non–caustic solvent. Remove all gasket material.
2. Dry using filtered, compressed air, prior to inspection.

INSPECTION

1. Visually inspect the intake manifold for cracks.
2. Place the mounting surface of the intake manifold on a smooth flat surface and visually inspect for warpage.
3. Replace the manifold if cracked or warped.

NOTE: The intake manifold is not repairable. DO NOT grind in an attempt to correct warpage.

INSTALLATION

IMPORTANT

DO NOT INTERMIX MODEL YEAR INTAKE MANIFOLDS. IF INSTALLING A NEW INTAKE MANIFOLD, BE SURE YOU SELECT THE CORRECT MANIFOLD FOR THE APPLICATION. REFER TO CURRENT PARTS CATALOG FOR CORRECT SERVICE PART NUMBERS

1987 MODEL YEAR: DT–360 USES A MANIFOLD WITH A2–1/4 IN. DIA. AIR INLET HOLE. THE DTA–360 USES A MANIFOLD WITH A 3–1/4 IN. DIA. AIR INLET HOLE.

1988 MODEL YEAR: THE 1988 MODEL YEAR ENGINES USE AN INTAKE MANIFOLD WITH A 3 IN. AIR INLET HOLE FOR BOTH DT AND DTA APPLICATIONS. PREVIOUSLY, ALL AIR INLET OPENINGS FACED UP; HOWEVER, ONLY DT–360 AND DTA–360 WITH ENGINE DRIVEN PTO's USE THE UP MOUNTED INTAKE MANIFOLD. DTA–360 WITHOUT PTO's USES AN INTAKE MANIFOLD WITH AIR INLET OPENING FACING DOWN. USE THE CAST IN PART NO. TO IDENTIFY THE MANIFOLDS.

1. Using a new gasket, install the intake manifold as follows:

   a. Assure gasket alignment with bolt holes and install "prevailing torque bolts" and washers: Tighten to the specified special torque.

NOTE: LOCATIONS OF STUD BOLTS, CLAMPS AND BOLTS ARE BY APPLICATION AND MODEL YEAR. FOR ACCURATE ASSEMBLY OF MANIFOLD, NOTE LOCATION OF THESE ITEMS PRIOR TO REMOVAL FROM ENGINE.

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INTAKE MANIFOLD — Continued

INSTALLATION – Continued

b. Install the clamps, washers, spacers (if required) and fuel return tube. Tighten the "prevailing torque bolts" and "prevailinf torque" stud bolt to the specified special torque. Refer to **Figures 3.10 and 3.12**.

c. Reconnect the fuel return tube to the pump using the washers and hollow screw at the banjo fitting.

2. Reconnect the fuel leak–off hose to the return tube.
3. Reinstall the aneroid tube using new rubber sealing sleeves.
4. Reinstall the high pressure fuel injection lines, if removed. Refer to the Section 11 for the correct procedure.
5. Reinstall the air crossover pipe (DT–360) or air inlet pipe (DTA–360).

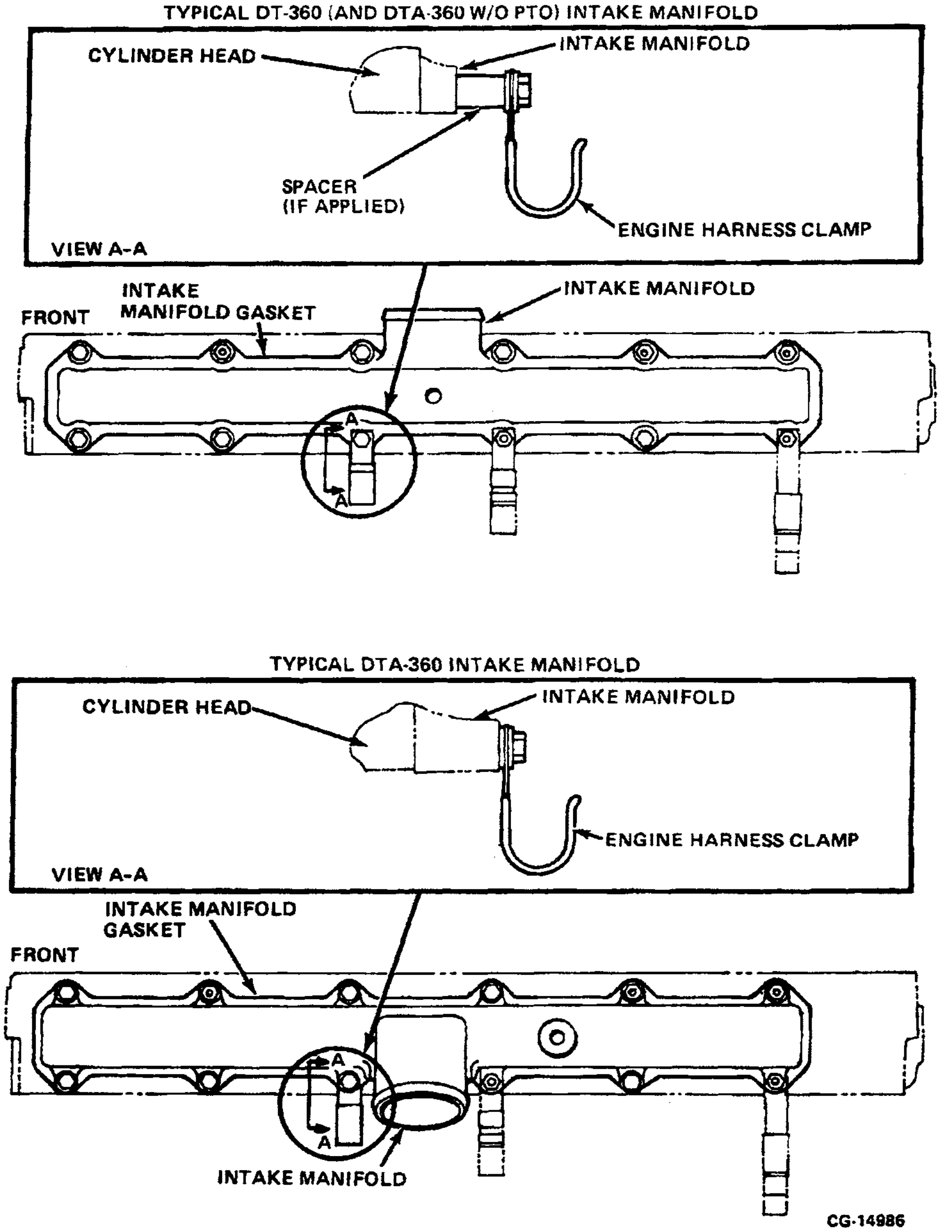

Figure 3.12. Intake Manifold Installation

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SERVICE MANUAL

CYLINDER HEAD AND VALVES

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CYLINDER HEAD INSTALLATION 33

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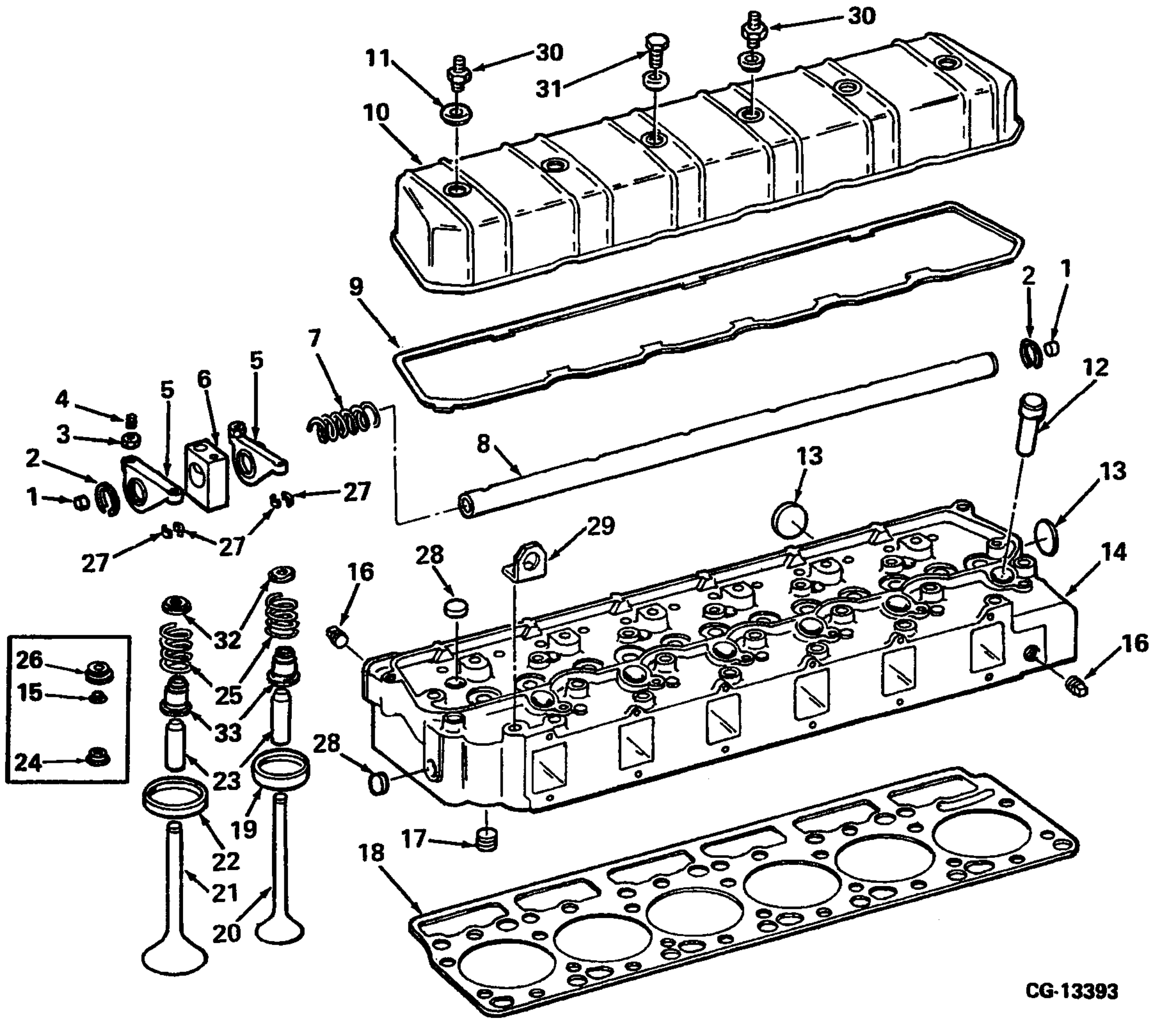

Figure 4.1. Cylinder Head, Valves and Related Parts

1. Cup Plug, Rocker Arm Shaft*
2. Retainer Ring, Rocker Arm Shaft*
3. Lock Nut, Rocker Arm Adjusting*
4. Screw, Rocker Arm Adjusting*
5. Rocker Arm*
6. Bracket, Rocker Arm Shaft*
7. Spring, Rocker Arm Shaft*
8. Shaft, Rocker Arm*
9. Gasket, Valve Cover
10. Cover, Valve
11. Grommet, Valve Cover
12. Sleeve, Nozzle
13. Cup Plug
14. Cylinder Head
15. Oil Shield (S/N 72706 & Below)
16. Pipe Plug
17. Water Director
18. Gasket, Cylinder Head
19. Insert, Exhaust Valve
20. Valve, Exhaust
21. Valve, Intake
22. Insert, Intake Valve
23. Guide, Valve
24. Seat, Valve Spring (S/N 72706 & Below)
25. Spring, Valve
26. Roto Coil w/shieldlp, Valve (S/N 72706 & Below)
27. Lock, Valve Spring
28. Cup Plug
29. Lifting Eye
30. Stud Bolt (1st & 4th Hole)
31. 5/16" NC x 1–1/2" Hex Head Bolt (4 Places)
32. Rotator w/Nylon Bushing, Valve (S/N 72707 & Above)
33. Seal, Valve Stem (S/N 72707& Above)

*These components are addressed in Section 5 and shown here for illustrative purposes only.

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SPECIFICATIONS

EXHAUST VALVES:

Stem Diameter (at Tip End) (Refer to Figure 4.39 for Illustration)	<u>0.3710 in. (9.423 mm)</u> 0.3720 in. (9.449 mm)
Stem to Guide Clearance (Max. Allowable Before Replacement)	
(With Tapered Shaft) (Refer to Fig. 4.39)	0.007 in. (0.18 mm)
(With Straight Shaft)	0.006 in. (0.15 mm)
Face to Stem Run–Out (T.I.R. Max.)	0.0015 in. (0.038 mm)
Valve Face Angle	45°–00' — 45°–15'
Valve Face Margin (Min)	0.045 in. (1.14 mm)
Valve Lash	0.025 in. (0.64 mm)

INTAKE VALVES:

Stem Diameter	<u>0.3718 in. (9.444 mm)</u> 0.3725 in. (9.462 mm)
Stem to Guide Clearance (Max. Allowable Before Replacement)	0.006 in. (0.15 mm)
Face to Stem Run–Out (T.I.R. Max.)	0.0015 in. (0.038 mm)
Valve Face Angle	30°–00' — 30°–15'
Valve Face Margin (Min.)	0.068 in. (1.73 mm)
Valve Lash	0.025 in. (0.64 mm)

CYLINDER HEAD:

Valve Guide Type	Replaceable
Valve Guide Length (Overall) (S/N 072707 & Above)	2.610 in. (66.29 mm)
Valve Guide Length (Overall) (S/N 072706 & Below)	2.750 in. (69.85 mm)
Valve Guide Bore Diameter in Cylinder Head for Valve Guide Insert	<u>0.6252 in. (15.880 mm)</u> 0.6239 in. (15.847 mm)
Valve Guide O.D.	<u>0.6260 in. (15.900 mm)</u> 0.6265 in. (15.913 mm)
Valve Guide I.D. (Reamed After Assembly)	<u>0.3740 in. (9.500 mm)</u> 0.3750 in. (9.525 mm)
Valve Guide Interference Fit Dimension	<u>0.0008 in. (0.020 mm)</u> 0.0026 in. (0.066 mm)
Valve Guide Bore Out–of–Round (Max.)	0.002 in. (0.05 mm)
Valve Guide Bore Taper (Max.)	0.005 in. (0.13 mm)

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SPECIFICATIONS — Continued

CYLINDER HEAD — Continued

Valve Guide Height from Top Deck Cylinder Head Surface (Intake)(S/N 072707 & Above)	1.090 in. (27.69 mm) 1.110 in. (28.19 mm)
Valve Guide Height from Top Deck Cylinder Head Surface (Intake)(S/N 072706 & Below)	0.992 in. (25.20 mm) 1.012 in. (25.70 mm)
Valve Guide Height from Top Deck Cylinder Head Surface (Exh.)(S/N 072707 & Above)	1.090 in. (27.69 mm) 1.110 in. (28.19 mm)
Valve Guide Height from Top Deck Cylinder Head Surface (Exh.)(S/N 072706 & Below)	1.272 in. (32.31 mm) 1.292 in. (32.83 mm)
Valve Seat Insert Angle (Int.)	30°–00' — 30°–15'
Valve Seat Insert Angle (Exh.)	45°–00' — 45°–15'
Valve Seat Width (Int. & Exh.)	0.075 in. (1.91 mm) 0.085 in. (2.26 mm)
Valve Seat Run–Out (T.I.R. Max.)	0.002 in. (0.05 mm)
Valve Seat Insert O.D.	
(Intake)	
0.002" Oversize	1.7805 in. (45.225 mm)
0.015" Oversize	1.7955 in. (45.606 mm)
(Exhaust)	
0.002" Oversize	1.5345 in. (38.976 mm)
0.015" Oversize	1.5495 in. (39.357 mm)
Valve Seat Insert Counterbore Diameter	
Intake (Std. Seat)	1.777 in. (45.14 mm) 1.778 in. (45.16 mm)
Exhaust (Std Seat)	1.532 in. (38.91 mm) 1.533 in. (38.94 mm)
Valve Head Recession Relative to Deck (Head Gasket Surface) (Int. & Exh.)	0.000 in. (0.00 mm) 0.014 in. (0.36 mm)
Gasket Surface Flatness	0.004 in. (0.10 mm) in 6 inches 0.006 in. (0.15 mm) Overall
Deck to Deck Dimension (Head Thickness) (New)	4.198 in. (106.63 mm) 4.202 in. (106.73 mm)
Minimum Deck to Deck Dimension After Rework	4.188 in. (106.38 mm)

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SPECIFICATIONS — Continued

VALVE SPRINGS:

Number of Springs per Valve 1
Intake & Exhaust
Free Length .... 2.340 in. (59.44 mm)
Test Length (Valve Closed) .... 2.007 in. (50.98 mm)
Test Load (Valve Closed) .... 66–70 lbs.
Test Length (Valve Open) .... 1.552 in. (39.42 mm)
Test Load (Valve Open) .... 156–164 lbs.

SPECIAL TORQUES

Cylinder Head Valve Cover Bolt .... 26 lbf–in. (3 Nm)
Cylinder Head Bolts + ... 165 lbf–ft. (225 Nm)
Valve Adjusting Screw Nut .... 20 lbf–ft. (27 Nm)

Tighten cylinder head bolts following the assembly steps listed:

1. Lubricate bolt threads, bolt head seating areas and washers with clean engine oil.

+ Tighten in steps as shown in Figure 4.2.

2. Tighten bolts in three (3) stages:

Stage 1 — Following sequence "A" tighten bolts to 110 lbf–ft. (150 Nm).
Stage 2 — Following sequence "A" tighten bolts to 155 lbf–ft. (210 Nm).
Stage 3 — Following sequence "B" tighten bolts, in row, to 165 lbf–ft. (225 Nm).

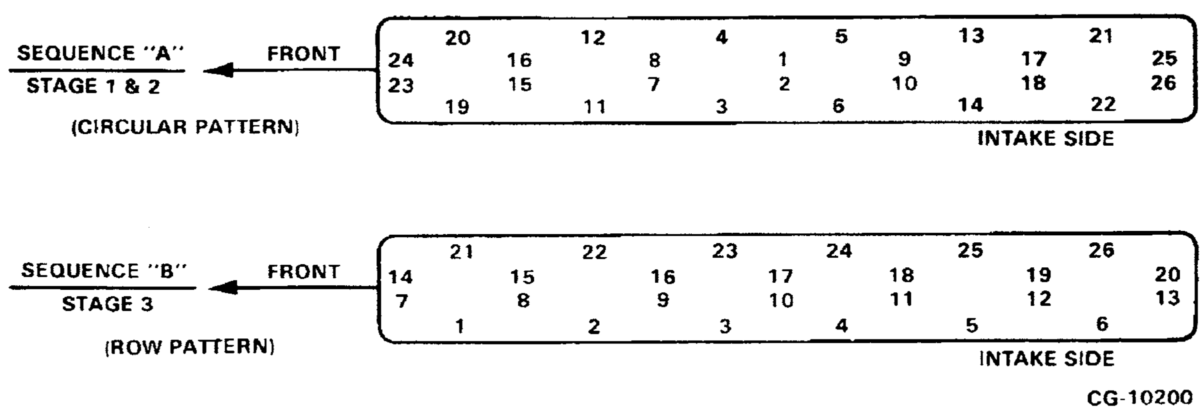

Figure 4.2. Sequence for Tightening Cylinder Head Bolts

SPECIAL SERVICE TOOLS AND MATERIALS

Tool No.	Description
ZTSE–1300	Valve Guide Cleaner
ZTSE–1631A	Eccentric Valve Seat Grinder
ZTSE–1631–46	Valve Seat Grinding Kit
ZTSE–1722	Valve Guide Remover
ZTSE–1846	Valve Spring Compressor
ZTSE–1943	Valve Guide Installer
ZTSE–1951B	Universal Valve Seat Extractor
ZTSE–1951–20	Exhaust Collet
ZTSE–1951–21	Intake Collet
ZTSE–2215A	Valve Guide Reamer (.3740" Dia.)
ZTSE–2241	Valve Spring Tester
ZTSE–2534A	Nozzle Sleeve Installing Tool
ZTSE–2587A	Nozzle Sleeve Puller Adapter
ZTSE–4164	Valve Seat Installer (Intake & Exhaust)
ZTSE–4289A	Cylinder Head Pressure Testing Kit (Incl. ZTSE–4289–3 Plate and ZTSE–4289–1 Hardware Kit

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CYLINDER HEAD REMOVAL

Remove the following:

- Injection lines (high pressure)
- Fuel leak–off lines (low pressure)
- Fuel injection nozzles
- Intake manifold
- Turbocharger
- Exhaust manifold
- Thermostat & housing

Refer to the appropriate manual section for removal procedures.

Head Bolt Torque Verification (Pull–Up–to–the–Mark Method)

1. Remove the valve cover bolts and grommets, then remove the valve cover and gasket. Discard the gasket. (Refer to **Figure 4.3.**)

2. Verify cylinder head bolt torque, before removing the cylinder head, as follows: (Refer to **Figure 4.4**)

   a. Mark the edge of the socket and a point on the cylinder head that is in line with the socket mark.

   b. Using a breaker–bar, loosen the bolt one–eighth of a turn.

   c. Without disturbing the socket location, remove the breaker–bar and install a torque wrench in its place.

   d. Tighten the bolt until the socket mark and the cylinder head marks are aligned.

   e. With marks aligned, record the torque reading.

   f. Repeat this procedure for all cylinder head bolts.

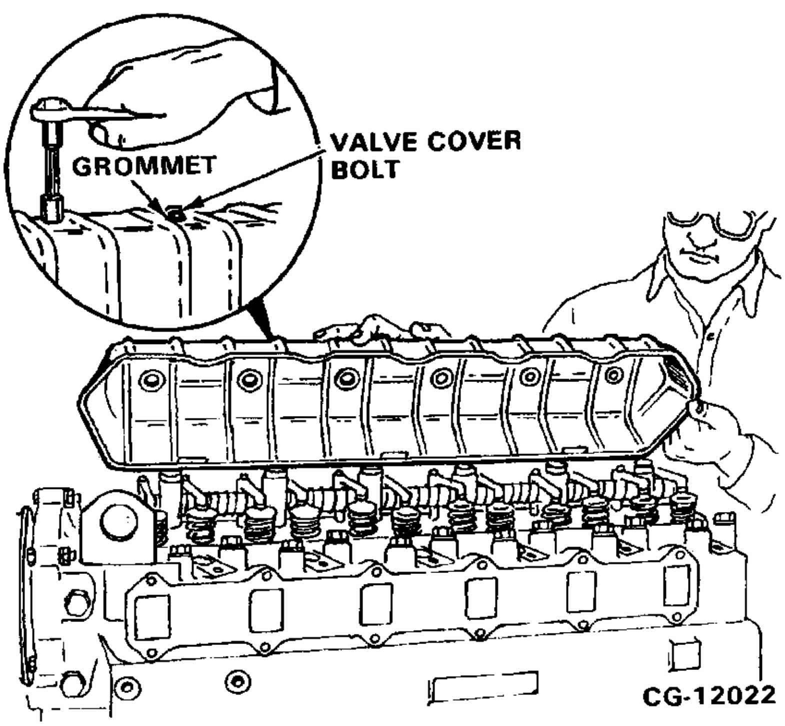

Figure 4.3. Valve Cover Removal

CYLINDER HEAD REMOVAL — Continued

Head Bolt Torque Verification (Pull–Up–to–the–Mark Method) — Continued

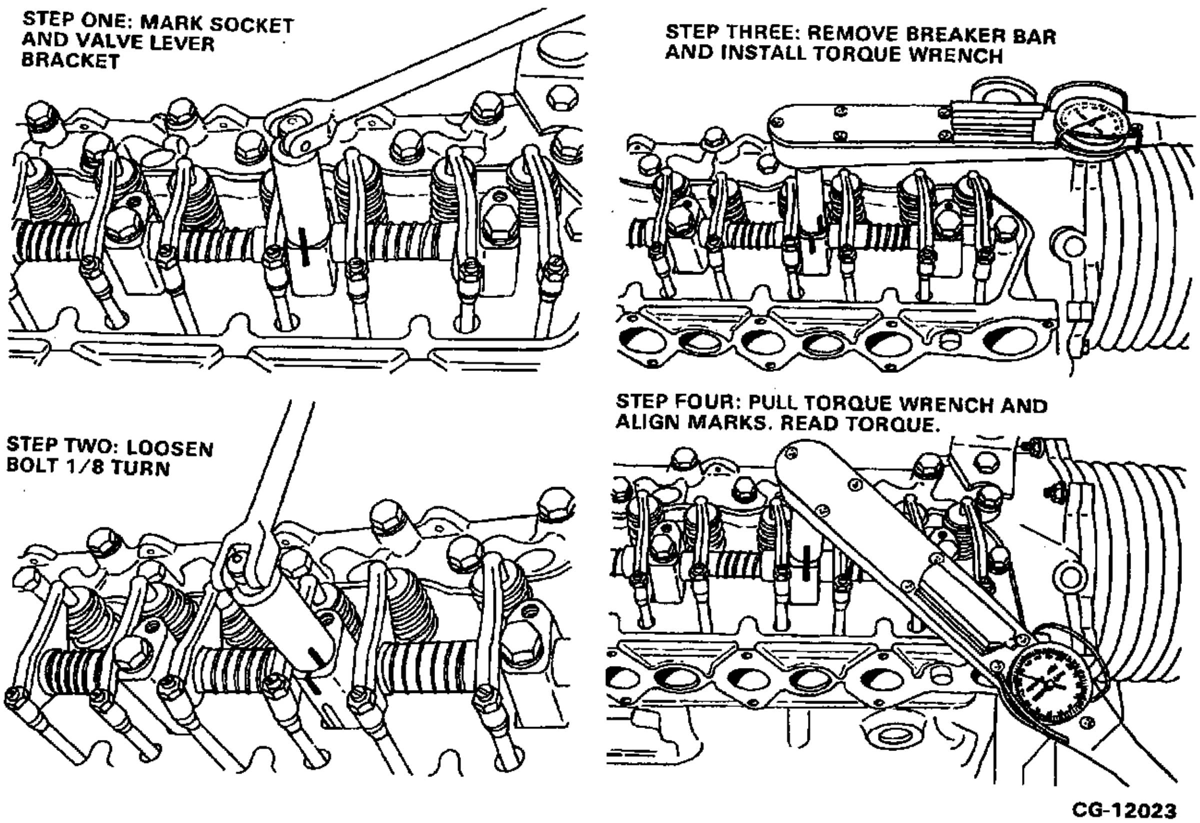

Figure 4.4. Checking Bolt Torque (Using Pull–Up–to–the–Mark Method)

Head Bolt Torque Verification (Pull–Up–to–the–Mark Method) — Continued

3. Loosen the rocker arm adjusting nuts and screws. Then remove the rocker arm bracket bolts (long cylinder head bolts). Remove the rocker arm assembly from the cylinder head. Refer to **Figure 4.5.**

NOTE: Loosening the rocker arm adjusting nuts and screws 1/2 turn will avoid possible valve train damage during installation.

IMPORTANT

THIS STAGE OF DISASSEMBLY PROVIDES AN IDEAL TIME TO MEASURE CAMSHAFT LOBE LIFT. FOLLOW THE INSTRUCTIONS IN SECTION 5, "CAMSHAFT, TAPPETS, PUSH RODS AND ROCKER ARM ASSEMBLY".

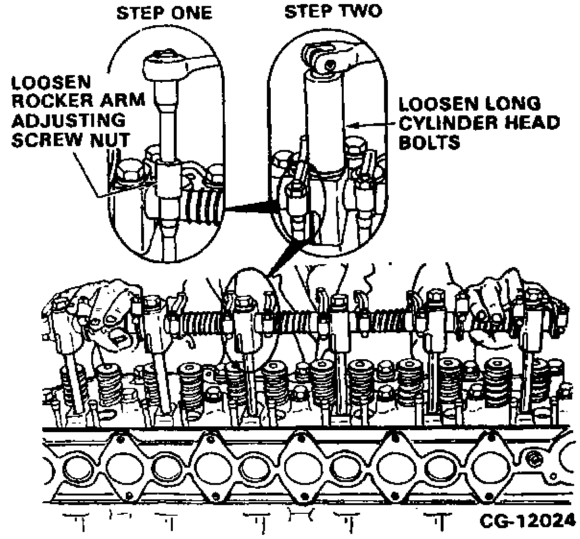

Figure 4.5. Remove Rocker Arm Assembly

CYLINDER HEAD REMOVAL — Continued

Head Bolt Torque Verification (Pull–Up–to–the–Mark Method) — Continued

4. Remove the push rods, after measuring camshaft lobe lift. Refer to **Figure 4.6**.

NOTE: Be sure the push rod is separated from the tappet prior to removal.

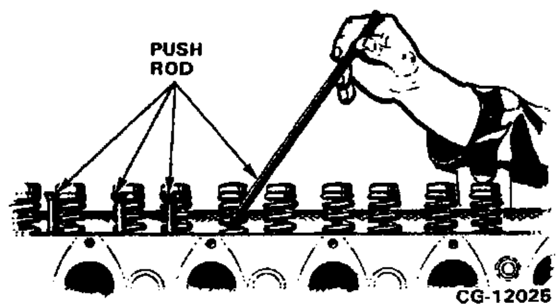

Figure 4.6. Remove the Push Rods

5. Remove the remaining "short" cylinder head bolts. Refer to **Figure 4.7**.

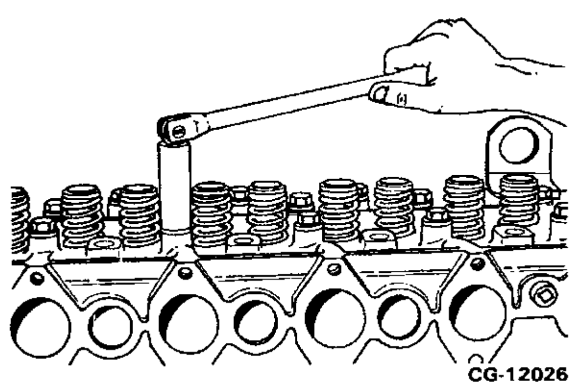

Figure 4.7. Remove "Short" Cylinder Head Bolts

6. Using a small pry bar, carefully pry the head loose from the gasket so the cylinder head will lift off easily. Refer to **Figure 4.8.**

NOTE: Only light force should be required on the pry bar to break the cylinder head loose from the gasket.

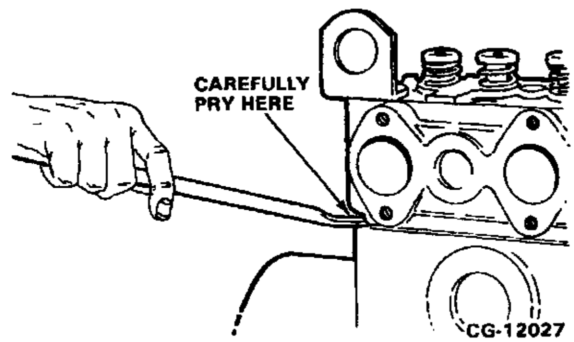

Figure 4.8. Break Cylinder Head Gasket Seal

7. Lift the cylinder head from the crankcase using appropriate lifting equipment. Refer to **Figure 4.9.**

NOTE: Place the cylinder head on wood blocks to protect the valves and bottom deck surface.

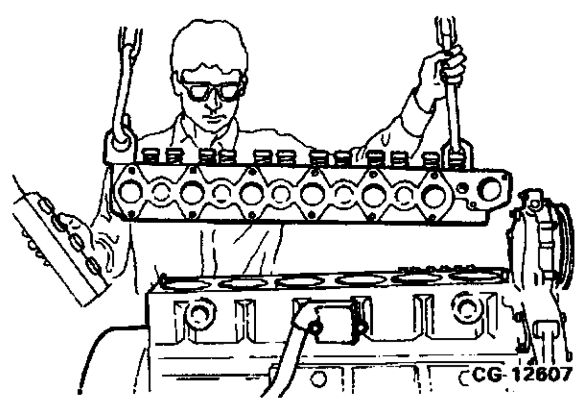

Figure 4.9. Remove Cylinder Head

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CYLINDER HEAD REMOVAL — Continued

Cleaning

1. With the valves installed to protect the seats, remove deposits and gasket material from the gasket surface of the cylinder head using a rotary wire brush or sanding block with mineral spirits. **BE SURE INJECTION NOZZLES ARE REMOVED BEFORE WIRE BRUSHING, TO PREVENT INJECTION NOZZLE DAMAGE.**

2. Clean all bolt holes with a tap. Clear debris from the bolt holes, oil return and water passages, using filtered compressed air.

3. Clean the cylinder head bolt threads with a bristle brush and solvent.

IMPORTANT

DO NOT CLEAN BOLTS WITH A WIRE BRUSH. THE PHOSPHATE COATING ON THE BOLT THREADS CAN BE REMOVED.

4. Wash all bolts and washers with a suitable solvent and dry thoroughly.

NOTE: Dirt in threads or damaged threads may cause binding and result in a false torque reading.

CYLINDER HEAD INSPECTION

NOTE: Cylinder head condition must be evaluated by inspecting for warpage, thickness, cracks or valve leakage.

INSPECT FOR WARPAGE

1. Using a straightedge and feeler gauge, check the cylinder head gasket surface for warpage utilizing the checking pattern shown in **Figure 4.10**. If specifications are NOT met, check head thickness prior to resurfacing. The minimum deck to deck dimension must be maintained after resurfacing.

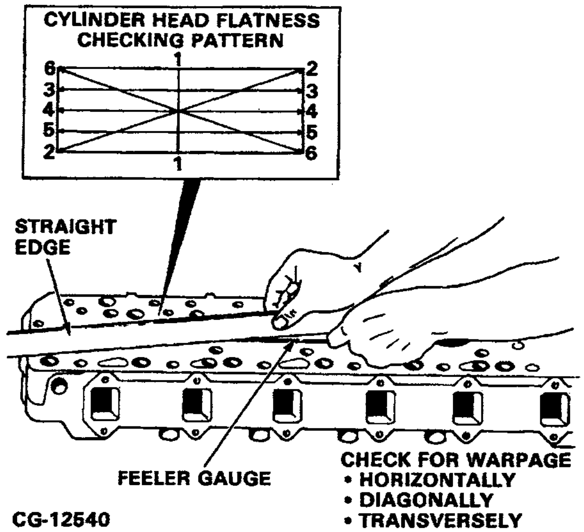

Figure 4.10. Inspect Cylinder Head for Warpage

CHECK THICKNESS

2. Measure cylinder head deck thickness, using a micrometer, at six locations. Refer to **Figure 4.11.** Refer to **"SPECIFICATIONS"**. If the minimum deck to deck dimension cannot be met, replace the cylinder head.

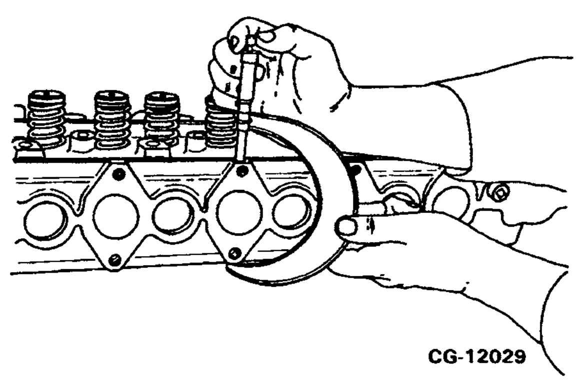

Figure 4.11. Measure Cylinder Head Thickness

INSPECT FOR CRACKS (Using Dye Penetrant Method)

3. Visually inspect for cylinder head cracks using the four step dye penetrant method as follows: (Refer to **Figure 4.12**)

CYLINDER HEAD INSPECTION — Continued

INSPECT FOR CRACKS — Continued

STEP ONE — Spray the cleaner onto the lower deck (gasket surface) of the head and wipe dry.

STEP TWO — Spray on the dye penetrant. Allow the dye to remain on the surface from one to thirty minutes.

STEP THREE — Wipe the dye off the surface.

NOTE: Dye will remain in any cracks during the "wipe off" step.

STEP FOUR — Spray on the developer and let dry for five to fifteen minutes.

NOTE: Cracks will show up as purple lines against the white developer. Refer to Figure 4.13.

The "spot check" dye penetrant system is available from:

MAGNAFLUX CORPORATION
7300 W. Lawrence Ave.
Chicago, IL 60656
Phone: 312-867-8000

IMPORTANT

IF ANY CRACKS ARE PRESENT, REPLACE THE CYLINDER HEAD.

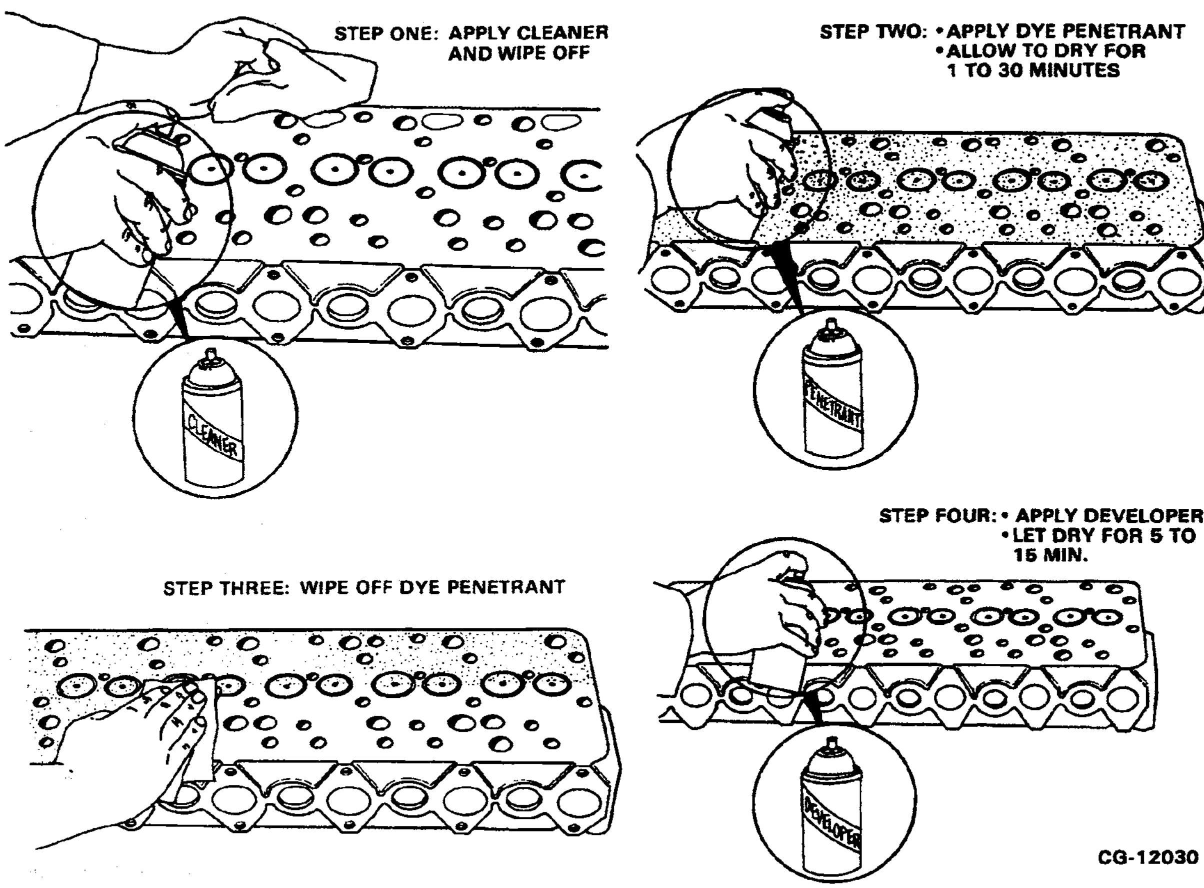

Figure 4.12. Inspect for Cracks Using Dye Penetrant Method

CYLINDER HEAD INSPECTION — Continued

INSPECT FOR CRACKS — Continued

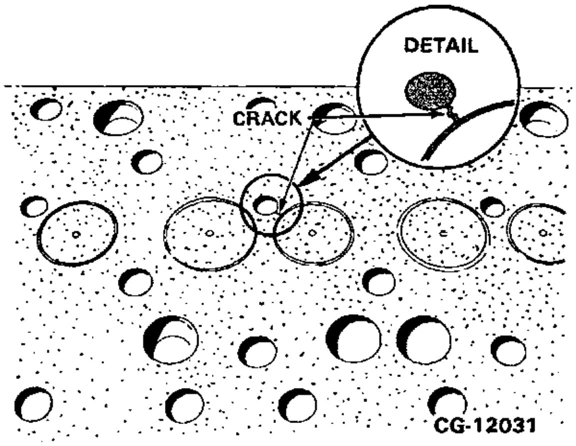

Figure 4.13. Example of Cylinder Head Crack

CHECK FOR VALVE LEAKAGE (Using Mineral Spirits)

4. Visually inspect for valve leakage as follows:

a. Position the cylinder head on wood blocks with the gasket surface facing down.

b. Squirt mineral spirits into the intake and exhaust valve ports as shown in **Figure 4.14.**

c. Wait five minutes. Using an inspection mirror, visually inspect the valve seat area for leakage of the mineral spirits. Refer to **Figure 4.15.** Repeat and check all intake and exhaust valves.

IMPORTANT

THERE SHOULD BE NO LEAKAGE. A VALVE JOB IS NOT REQUIRED, IF THE CYLINDER HEAD PASSES THE MINERAL SPIRITS TEST. IF LEAKAGE IS OBSERVED, THE VALVES REQUIRE RECONDITIONING. REFER TO "CYLINDER HEAD RECONDITIONING" IN THIS SECTION.

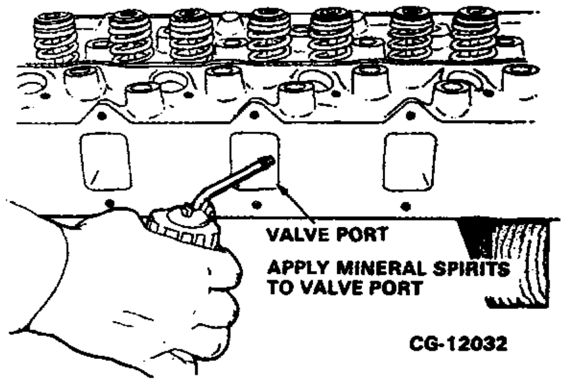

Figure 4.14. Mineral Spirits Test for Valve Leakage

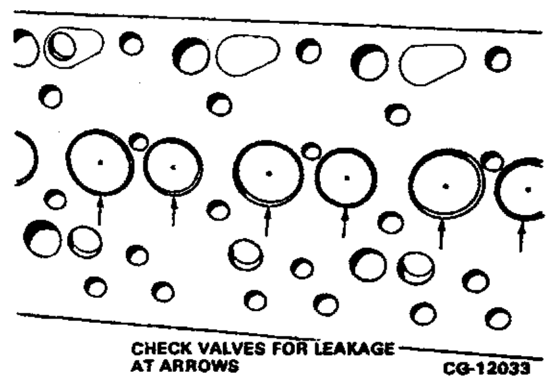

Figure 4.15. Inspect Valves for Leakage

PRESSURE CHECK CYLINDER HEAD

5. Pressure testing the cylinder head will reveal cracks in ports or nozzle sleeve leakage which cannot be observed using dye penetrant. Pressure–test the cylinder head as follows:

a. Reinstall injection nozzles before pressure testing.

NOTE: Nozzle clamping seals the nozzle sleeve at the bottom of the bore in the head. Good nozzle sleeves will be condemned needlessly if nozzles are not installed prior to pressure testing.

CYLINDER HEAD INSPECTION — Continued

PRESSURE CHECK CYLINDER HEAD — Continued

b. Remove the valves, using a valve spring compressor. Refer to "**CYLINDER HEAD RECONDITIONING**", in this section for valve removal instructions.

c. Pressure test the cylinder head using the Cylinder Head Pressure Testing Kit (ZTSE–4289A) Refer to **Figure 4.16**

NOTE: Cylinder Head Pressure Testing Kit ZTSE–4289A includes:

ZTSE–4289–1	**Hardware Kit (Bolts, Nuts and Regulator**
ZTSE–4289–2	**DT–466 Testing Plate**
ZTSE–4289–3	**DT–360 Testing Plate**

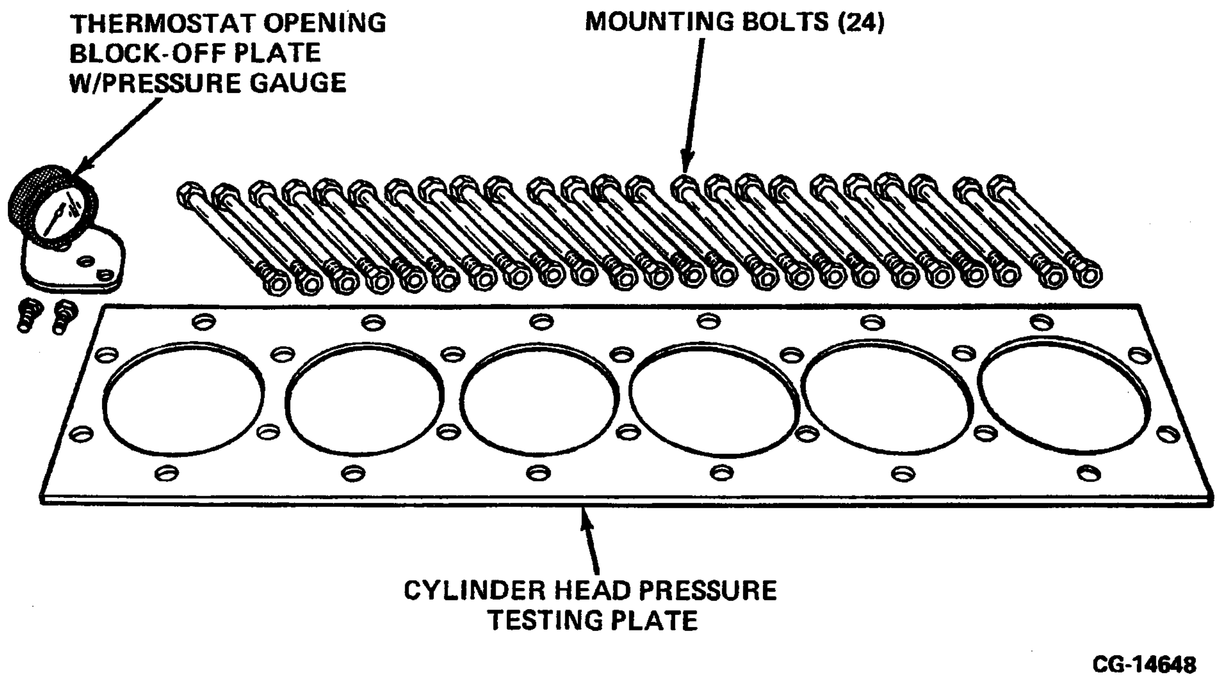

Figure 4.16. Cylinder Head Pressure Testing Kit (ZTSE–4289A)

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CYLINDER HEAD INSPECTION — Continued

PRESSURE CHECK CYLINDER HEAD — Continued

d. Fasten the pressure plate and head gasket to the cylinder head gasket surface using the mounting bolts and nuts supplied with the kit. Refer to **Figure 4.17.**

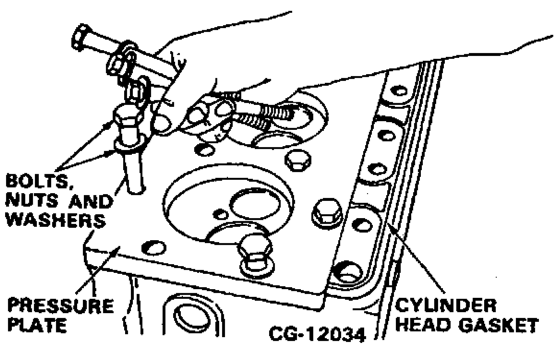

Figure 4.17. Install Bottom Pressure Plate

e. Fasten the block–off plate and thermostat housing gasket to the thermostat opening. Remove the pipe plug next to the thermostat opening. Refer to **Figure 4.18.**

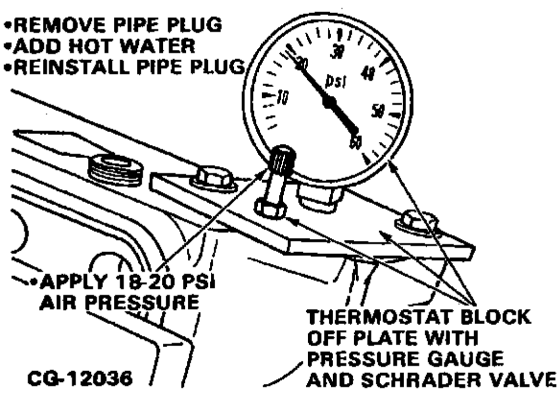

Figure 4.19. Install Thermostat Opening Block–Off Plate

f. Install a hose fitting to the cylinder head at the removed plug. Attach a "HOT" water source to the fitting and fill the cylinder head with water.

g. Apply a regulated air supply of 18–20 psi to the schrader (tire) valve located in the thermostat block–off plate. Refer to **Figure 4.19.**

Visually inspect for leaks at the:

Nozzle sleeves

Ports

Upper deck

Lower deck

NOTE: If leakage is observed at any port of the upper and lower deck, REPLACE THE CYLINDER HEAD. If nozzle sleeve leakage is observed. follow the procedures under "CYLINDER HEAD RECONDITIONING".

NOZZLE SLEEVE REPLACEMENT

IMPORTANT

REPLACE THE NOZZLE SLEEVE ONLY IF LEAKAGE IS PRESENT.

1. Insert the nozzle sleeve puller adapter ZTSE–2587A into the sleeve to be removed. Refer to **Figure 4.20.**

NOTE: This tool grips the nozzle sleeve by threading into it. Start the adapter into the nozzle sleeve by striking it with a hammer. Then screw the nozzle. sleeve puller adapter into the sleeve using a wrench.

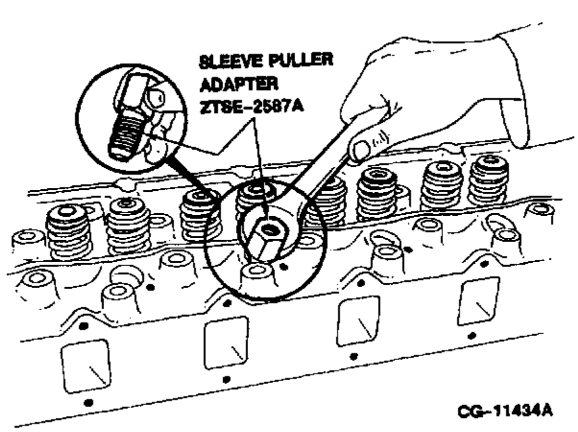

Figure 4.20. Install Nozzle Sleeve Puller Adapter Into Sleeve

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CYLINDER HEAD RECONDITIONING

NOZZLE SLEEVE REPLACEMENT – Continued

2. Connect a slide hammer to the adapter and pull the sleeve from its bore. Refer to **Figure 4.21**.

3. Discard the sleeve.

4. Clean the nozzle bore at the top and bottom using a rotary wire brush. Blow out with filtered compressed air.

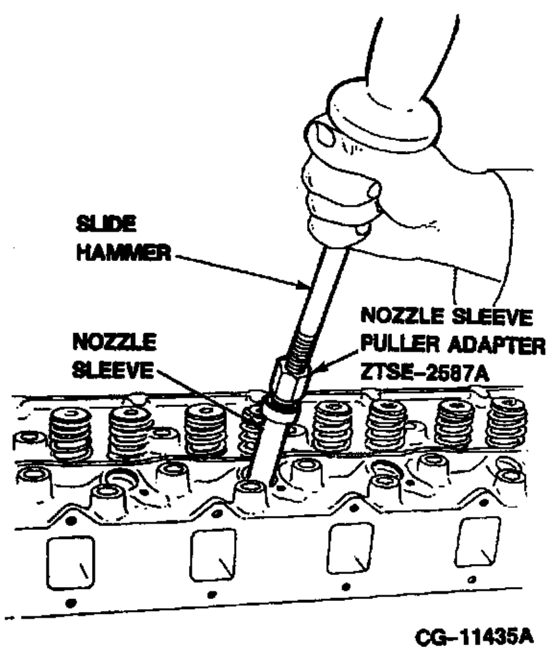

Figure 4.21. Remove Nozzle Sleeve

5. Apply Loctite® 262 or equivalent to the nozzle sleeve contact points. Refer to **Figure 4.22.**

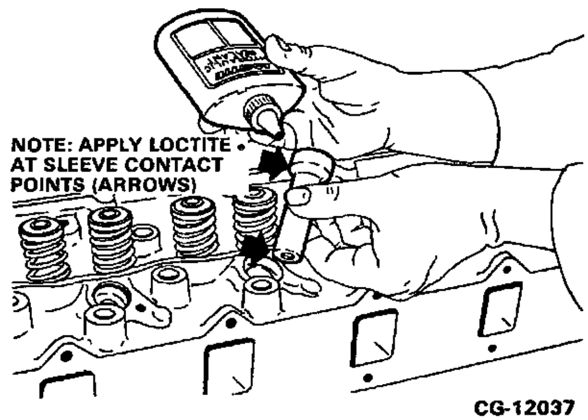

Figure 4.22. Apply Loctite® to Nozzle Sleeve

6. Install the nozzle sleeve using the nozzle sleeve installer ZTSE–2534A. Drive the sleeve until it bottoms in the bore. Refer to **Figure 4.23.**

NOTE: Nozzle sleeve installation can be done without removing the cylinder head. Be sure to drain the coolant before replacing the nozzle sleeves in chassis.

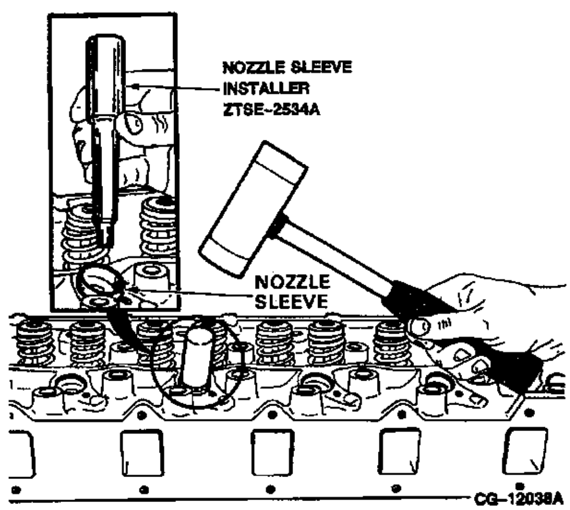

Figure 4.23. Drive Nozzle Sleeve into Bore Using Installer Tool

CYLINDER HEAD RECONDITIONING – Continued

COOLANT DIRECTOR REPLACEMENT

IMPORTANT

REPLACE COOLANT DIRECTORS ONLY IF THEY ARE LOOSE IN THE BORE.

1. Remove loose coolant directors, using a "J" hook seal puller and a slide hammer. Insert the "J" hook under the coolant director opening. Refer to **Figure 4.24.**

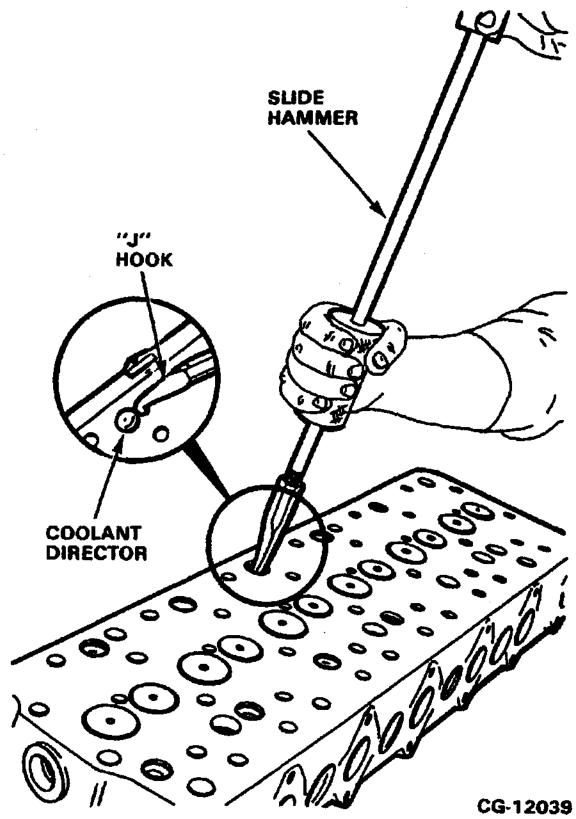

Figure 4.24. Remove Coolant Director

2. Clean the coolant director bore.

3. Prior to driving in coolant directors, they must be aimed. Coolant directors on the intake manifold side must be aimed at the valve bridge area, while those on the exhaust manifold side must be aimed at the exhaust valve. Refer to **Figure 4.25.**

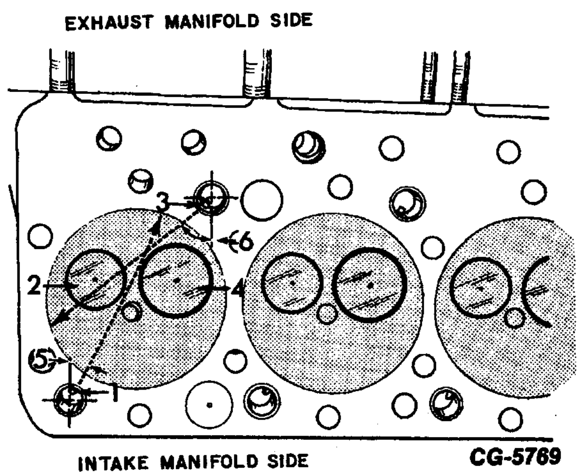

Figure 4.25. Aim Coolant Directors

1. Coolant Director	**2. Exhaust Valve**
3. Coolant Director	**4. Intake Valve**
5. 35° Angle	**6. 45° Angle**

CYLINDER HEAD RECONDITIONING — Continued

COOLANT DIRECTOR REPLACEMENT — Continued

4. After aiming the coolant director, install it using a plastic hammer and block of wood to drive it into the cylinder head. Refer to **Figure 4.26**.

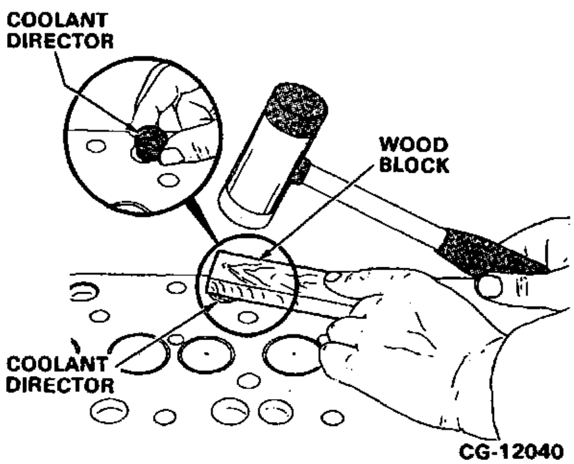

Figure 4.26. Install Coolant Director

5. Recess the coolant directors approximately 0.060 in. by using a socket and plastic hammer. Refer to **Figure 4.27.**

NOTE: The coolant director is recessed to assure that no sharp edges will protrude below the deck area which could damage the head gasket during cylinder head installation.

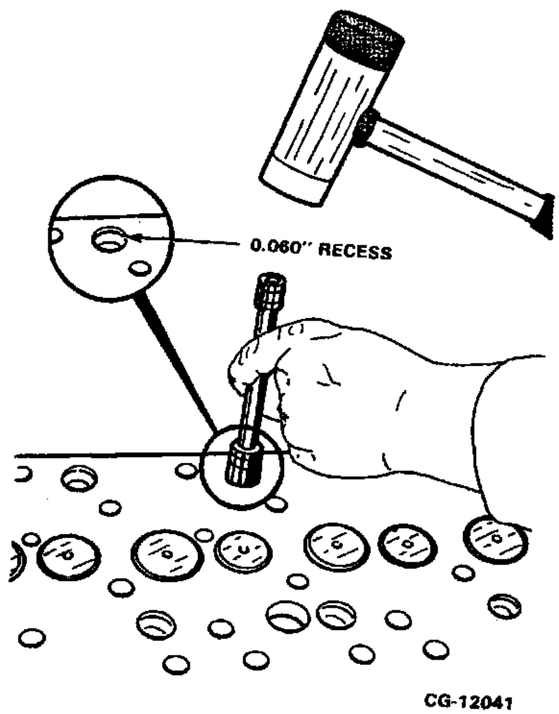

Figure 4.27. Recess Water Director

CYLINDER HEAD RECONDITIONING — Continued

COMPONENT CHANGES

In order to achieve lower emissions levels, the cylinder head has been redesigned to reduce the amount of oil flow at the intake and exhaust valves. This has been accomplished by removing the oil shield/seal from the rotator assembly and the valve spring seat and including a new valve stem seal assembly. The new valve stem seal assembly requires the use of the shorter valve guide.

NOTE: For comparison between complete intake and exhaust valve assemblies used prior to and effective with S/N 072706, refer to Figure 4.28.

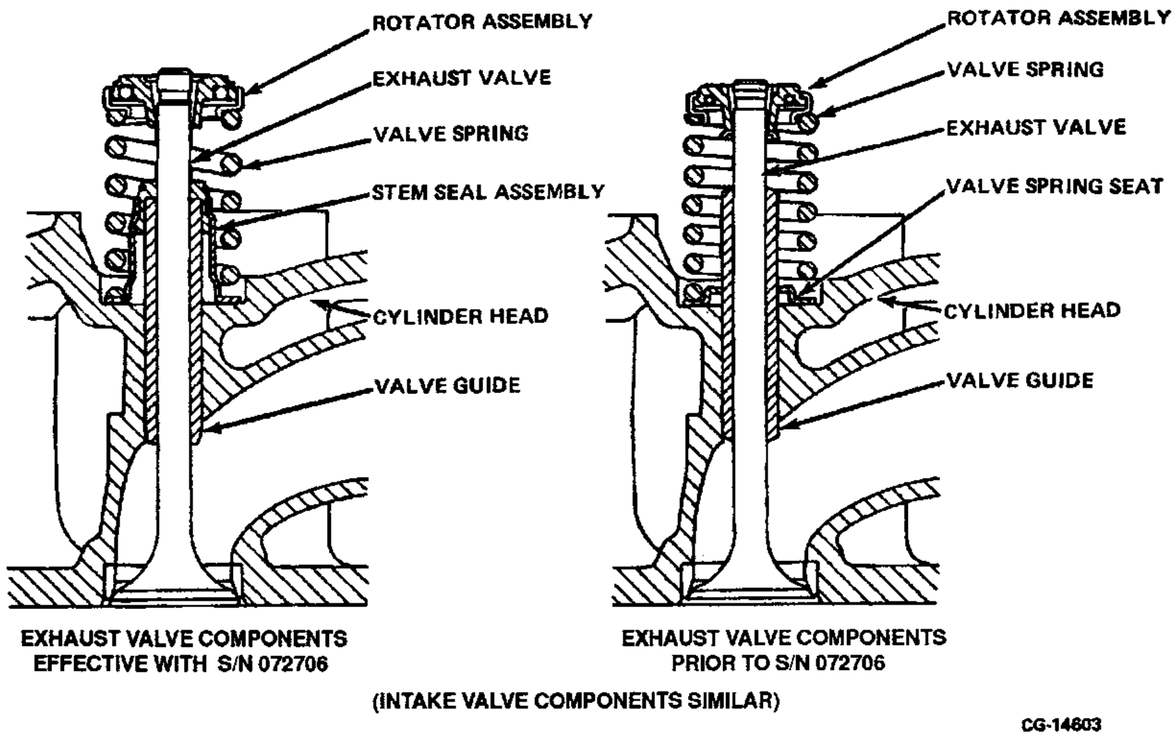

Figure 4.28. Intake & Exhaust Valves Components Comparison

NOTE: The revised (shorter in height) valve rotator assembly can only be used on engines with serial numbers 072706 and up. DO NOT use the early rotator assembly on current engines as damage to the stem seal assembly will occur. Refer to the current Parts Catalog for correct service part numbers.

NOTE: A new valve stem seal assembly (intake & exhaust) is added to engines with serial numbers 072706 and up. The new valve stem seal assembly features an integral stem seal and spring seat. With the introduction of new valve stem seal assembly, the valve spring seat used on earlier model year engines is now only required for service.

IMPORTANT

DO NOT use new shorter valve guides for service on 1987, 1988 or 1989 model year engines (Prior to S/N 072706). Interference and resultant damage to engine will occur. Measure valve guide to verify length.

CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING

REMOVE VALVES

1. Using a valve spring compressor tool, remove the valves as follows:
2. Install the valve spring compressor over the valve to be removed and compress the spring.
3. Remove the valve spring locks (keepers). Refer to **Figure 4.29**.
4. Remove the valve spring compressor tool.

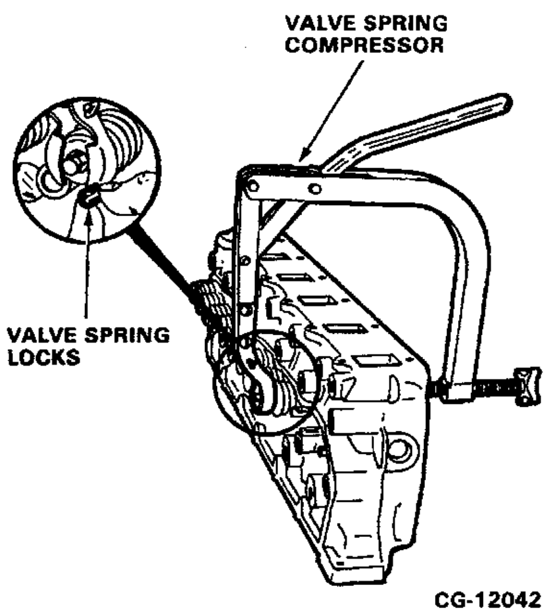

Figure 4.29. Remove Valve Spring Locks

FOR ENGINES BUILT AFTER S/N 072706

5. Remove the valve rotator, valve spring, stem shield assembly and valve as shown in **Figure 4.30**.

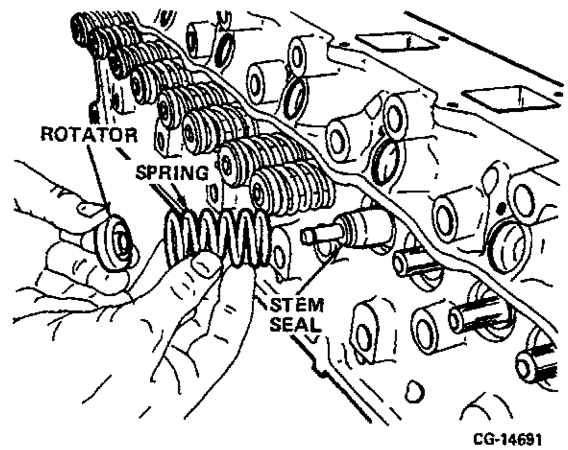

Figure 4.30. Remove Valve Rotator, Spring and Stem Seal Assembly

FOR ENGINES BUILT BEFORE S/N 072707

5. Remove the valve rotator, valve spring and oil shield as shown in **Figure 4.31**.

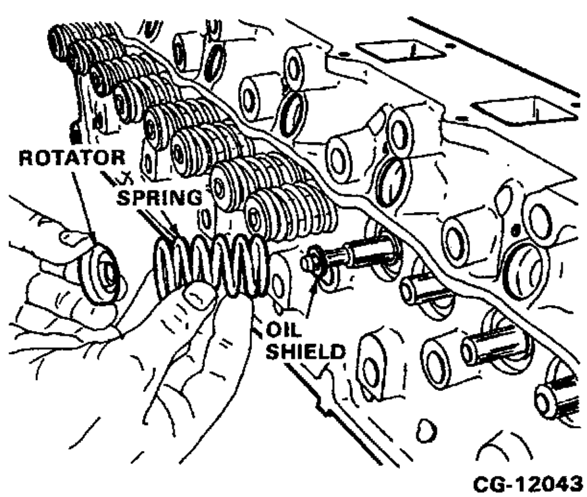

Figure 4.31. Remove Valve Rotator, Spring and Oil Shield (Engine S/N 72706 and Below Shown)

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CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING - Continued

FOR ENGINES BUILT BEFORE S/N 072707 - Continued

6. Remove the valve spring seat off the valve guide, then remove the valve. Refer to **Figure 4.32.**

NOTE: If valve does not slide out easily, inspect the valve stem for burrs. If a burr is present, remove it to prevent valve guide damage. Keep valves in order if they are to be reinstalled into their original positions.

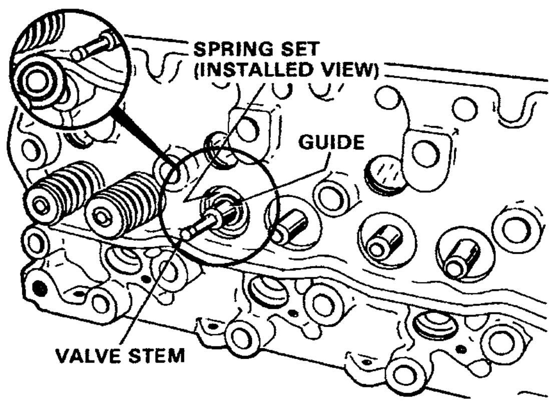

Figure 4.32. Remove the Valve Spring Seat and Valve

CLEAN VALVE GUIDES

1. With valves removed, clean all valve guides using ZTSE–1300 valve guide cleaner, soap and water. Refer to **Figure 4.33.**

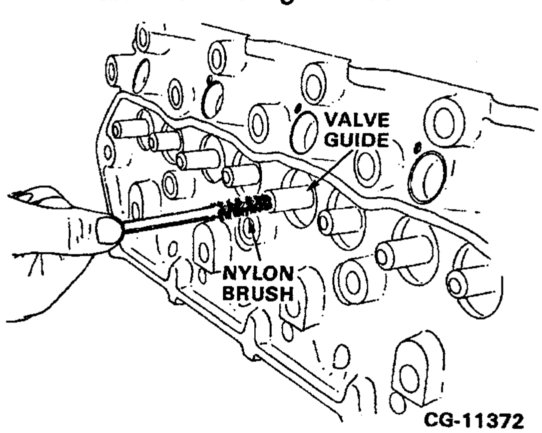

Figure 4.33. Clean Valve Guide Bores

INSPECT VALVE GUIDES

1. Position an inspection light at the bottom of the valve guide bores and visually examine the walls for burning, cracking or loss of spiral grooves. Replace any guides which do not pass the visual inspection.

NOTE: The spiral grooves on the valve guides are for oil retention.

2. Measure each valve guide using a telescoping gauge and outside micrometer as shown in **Figure 4.34.**

IMPORTANT

MEASURE THE VALVE GUIDES WITHIN 1/4 INCH OF EACH END OF THE GUIDE, 90° FROM THE CRANKSHAFT CENTERLINE. RECORD VALVE GUIDE I.D. READINGS SO VALVE–TO–GUIDE RUNNING CLEARANCE MAY BE DETERMINED LATER.

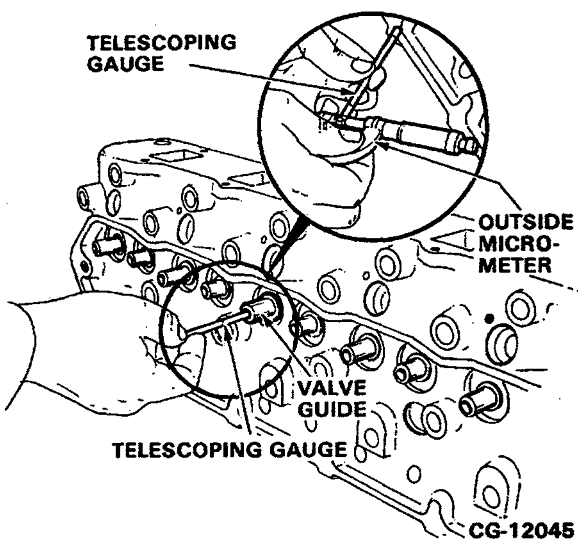

Figure 4.34. Measure Valve Guide I.D.

If valve guide exceeds specifications, replace the guide.

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CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

REPLACE VALVE GUIDES

IMPORTANT

DO NOT USE NEW SHORTER VALVE GUIDE FOR SERVICE ON CYLINDER HEADS PRIOR TO S/N 072706. USING THE SHORTER GUIDE WILL CAUSE INTERFERENCE AND DAMAGE TO THE ENGINE. MEASURE VALVE GUIDE TO VERIFY LENGTH.

1. Remove any valve guides which do not pass the inspection criteria as follows:

   a. Insert the valve guide remover ZTSE–1722 into the guide from the valve port side of the cylinder head.

   b. Drive out the valve guide with a hammer. Refer to **Figure 4.35**.

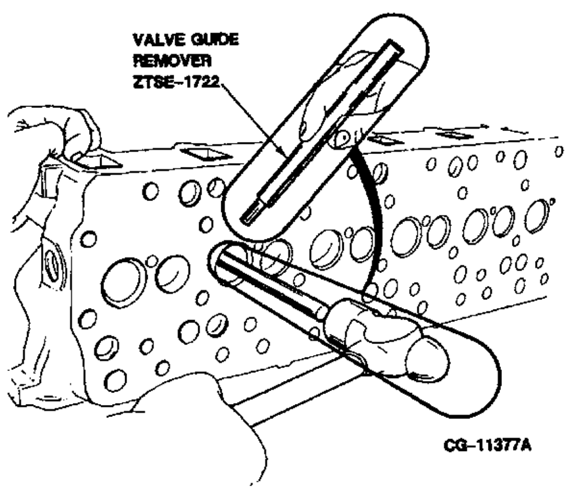

Figure 4.35. Remove Valve Guide

2. Install new valve guide inserts as follows:

   a. Adjust the valve guide installer tool, ZTSE–1943, using a caliper as shown in **Figure 4.36.**

IMPORTANT

FOR ENGINE SERIAL NUMBER 072706 AND BELOW, INTAKE AND EXHAUST VALVE GUIDES ARE INSTALLED AT DIFFERENT HEIGHTS, AS MEASURED FROM THE TOP DECK OF THE CYLINDER HEAD. REFER TO SPECIFICATIONS AND ADJUST THE TOOL TO CORRESPOND TO THE DESIRED VALVE GUIDE HEIGHT.

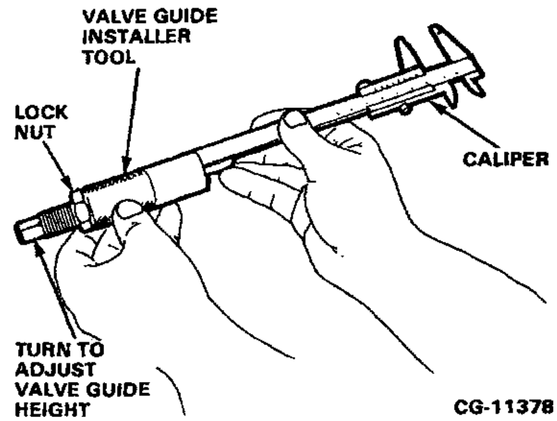

Figure 4.36. Adjust Valve Guide Installer Tool to Specified Height

   b. Lubricate the valve guide insert using clean engine oil and drive into the cylinder head until the installer tool bottoms against the cylinder head. Refer to **Figure 4.37.**

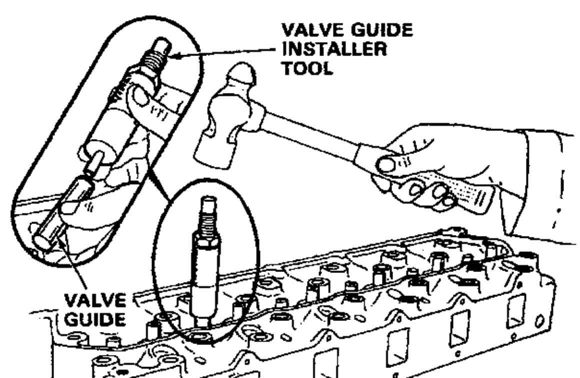

Figure 4.37. Install Valve Guide

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CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

IMPORTANT

INSTALL THE VALVE GUIDE INSERTS WITH THE CHAMFER END UP AND THE INTERNAL SPIRAL THREADED PORTION DOWN. THE CHAMFER EDGE UP ALLOWS EXCESS OIL TO DRAIN AWAY FROM THE STEM WHILE THE INTERNAL THREADS AT THE BOTTOM PROVIDE PROPER OIL RETENTION.

c. Ream the valve guide, after installation, using a 0.3740 in. reamer (ZTSE–2215A). Refer to **Figure 4.38.**

NOTE: Reaming is required to re–size the guide and to remove any peening resulting from the guide installation process.

NOTE: Clean valve guides after reaming, as shown in Figure 4.33.

CLEAN VALVES

1. Remove all carbon from the valve stems and valve heads.

INSPECT VALVES

1. Visually inspect each valve, replacing any that show evidence of burn marks, warpage, scuffing or bending.

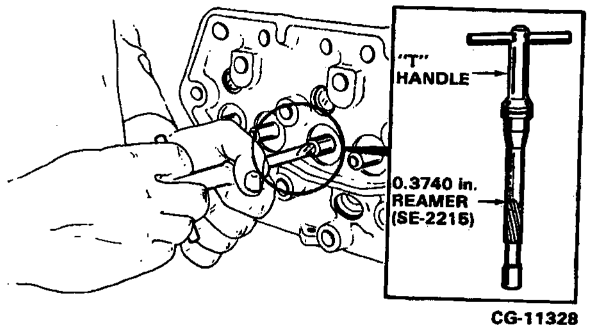

Figure 4.38. Ream Valve Guides

NOTE: The current intake valve and exhaust valves are flash chrome plated in the stem area to improve valve life. The exhaust valve is also tapered inthe stem area.

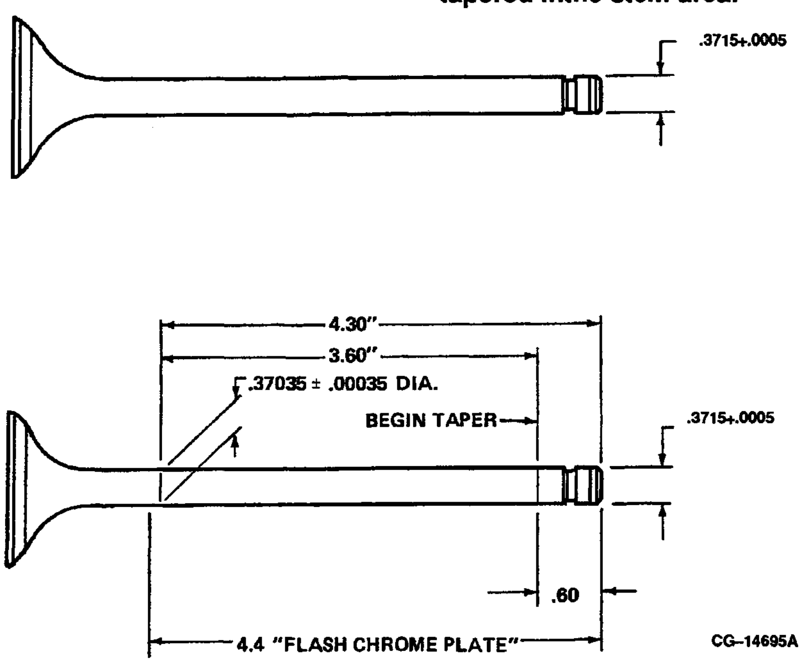

Figure 4.39. Exhaust Valve Comparison

CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

2. Measure each valve stem for wear using a micrometer to measure valve stem diameter. Record the readings.

NOTE: Measure at three locations 90° apart. Refer to the "SPECIFICATIONS" and replace valves which exceed the minimum stem diameter specification.

3. Using the valve stem diameter and valve guide inside diameter measurements, recorded earlier (see Inspect Valve Guides in this section), determine valve stem–to–guide running clearance. Refer to "**SPECIFICATIONS**". Replace the valve or valve guide as required.

REFACE VALVES

NOTE: If valves are in serviceable condition, reface the valve to the specified angle, as required. Refer to Figure 4.40.

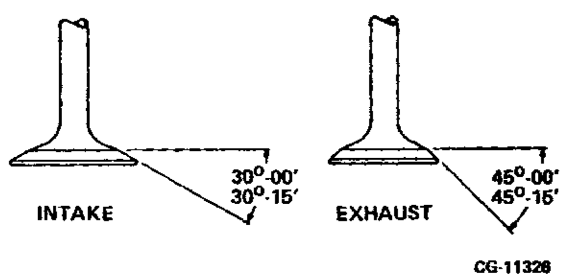

Figure 4.40. Valve Face Angles

1. Reface the valves as follows:

   a. Dress the cutting stone, prior to refacing the valves, using the dressing stud attachment on the grinder.

   b. Install the valve in the grinder and set to the specified angle.

   c. Grind the valve face. Remove only the minimum amount of material necessary to true up the valve face. Refer to **Figure 4.41**.

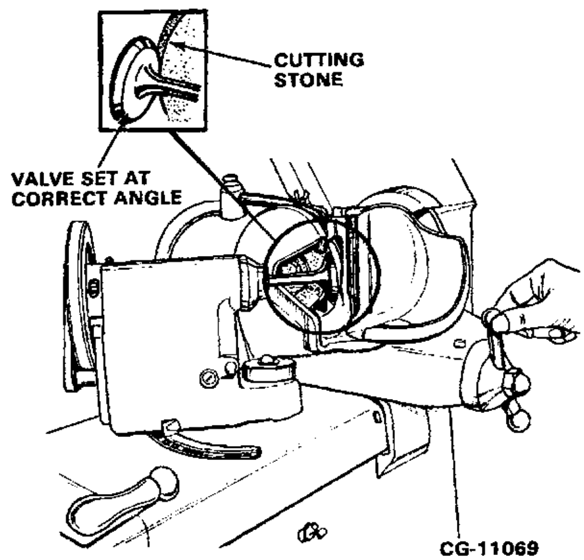

Figure 4.41. Grind Valve Face Angle

2. Measure valve face margin at four locations using a caliper. Refer to **Figure 4.42**.

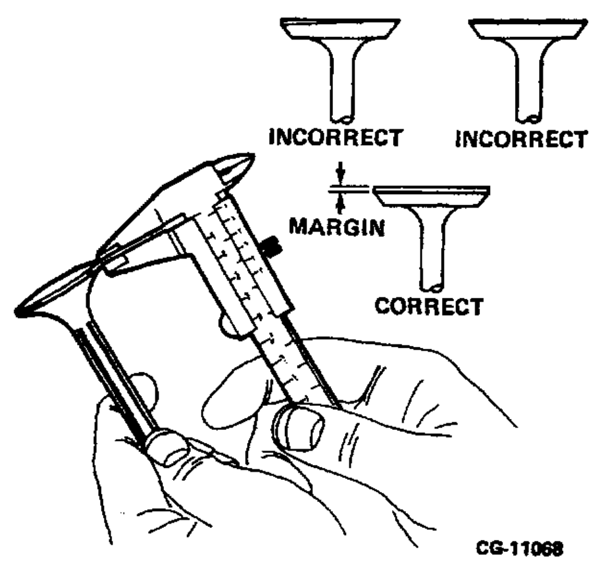

Figure 4.42. Measure Valve Face Margin

CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

NOTE: The minimum valve face margin (see "SPECIFICATIONS") must be maintained across the entire valve face. An insufficient margin will NOT provide proper heat dissipation and lead to valve warpage or breakage. Intake and exhaust valve margins are different. Replace the valve if the margin is less than the specified minimum, after grinding.

3. Reface the valve stem tip as follows:

a. Dress the cutting stone using the dressing stud on the grinder.

IMPORTANT

WHEN RESURFACING THE VALVE STEM TIP, LEAVE SUFFICIENT MATERIAL SO THE ROCKER ARM DOES NOT CONTACT THE VALVE SPRING LOCKS OR ROTATORS, DURING OPERATION.

b. Install the valve in the grinder as shown in **Figure 4.43.**

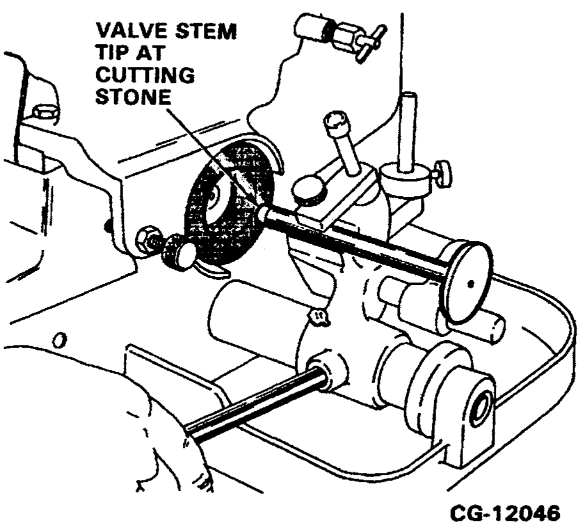

Figure 4.43. Reface Valve Stem Tip

c. Touch the valve stem tip to the cutting stone removing only a minimum of material.

NOTE: Refacing the valve stem tip provides a new wear surface for the rocker arm.

4. After resurfacing valves, insert valves in clean valve guide and check valve face contact with valve seat using Prussian Blue™ (or equivalent) as follows:

a. Spread thin film of Prussian Blue™ on valve face. Insert valve into its guide. Refer to **Figure 4.44.**

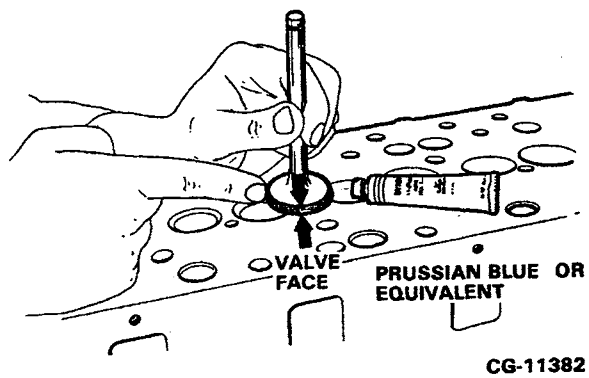

Figure 4.44. Apply Bluing to Valve Face

b. Apply pressure on exact center of valve head while making a quarter–turn in the seat. Refer to **Figure 4.45.**

c. Remove valve, inspect impression made on seat and on valve face.

d. Bluing should appear around entire contact surface of valve face and valve seat to be acceptable. **CHECK SEVERAL TIMES TO PREVENT ERROR**. If acceptable, proceed with valve installation.

CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

IMPORTANT

IF SEATS ARE ACCEPTABLE, INSTALL THE VALVES WITHOUT GRINDING THE SEATS. IF VOIDS APPEAR IN THE BLUING, SEAT GRINDING IS REQUIRED.

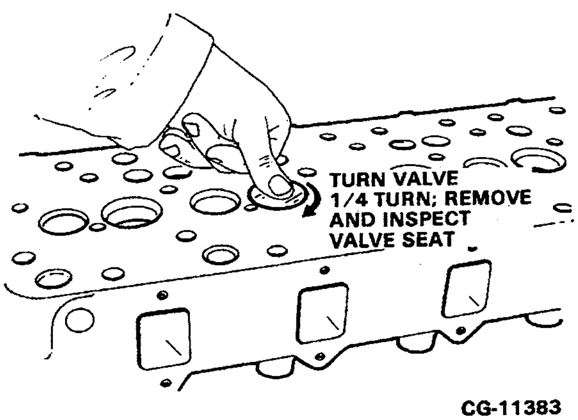

Figure 4.45. Check Valve Seat Contact

VALVE SEAT GRINDING

1. If required, resurface the valve seat as follows: (Refer to **Figure 4.46**)

NOTE: Use Eccentric Valve Seat Grinder ZTSE–1631A and Valve Seat Grinding Kit ZTSE–1631–46.

a. Lightly lubricate and install the correct size pilot into the valve guide.

b. Choose the correct angle grinding stone and dress the stone. Refer to "**SPECIFICATIONS**" for valve seat angles.

c. Install the grinding stone over the pilot.

d. Lower grinder head over pilot shank until wheel barely clears the valve seat. Turn on power. **GENTLY** apply grinding wheel to valve seat with little pressure other than weight of the wheel.

e. Raise wheel frequently to prevent overheating.

f. Grind seat to a smooth even finish.

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CYLINDER HEAD RECONDITIONING — Continued

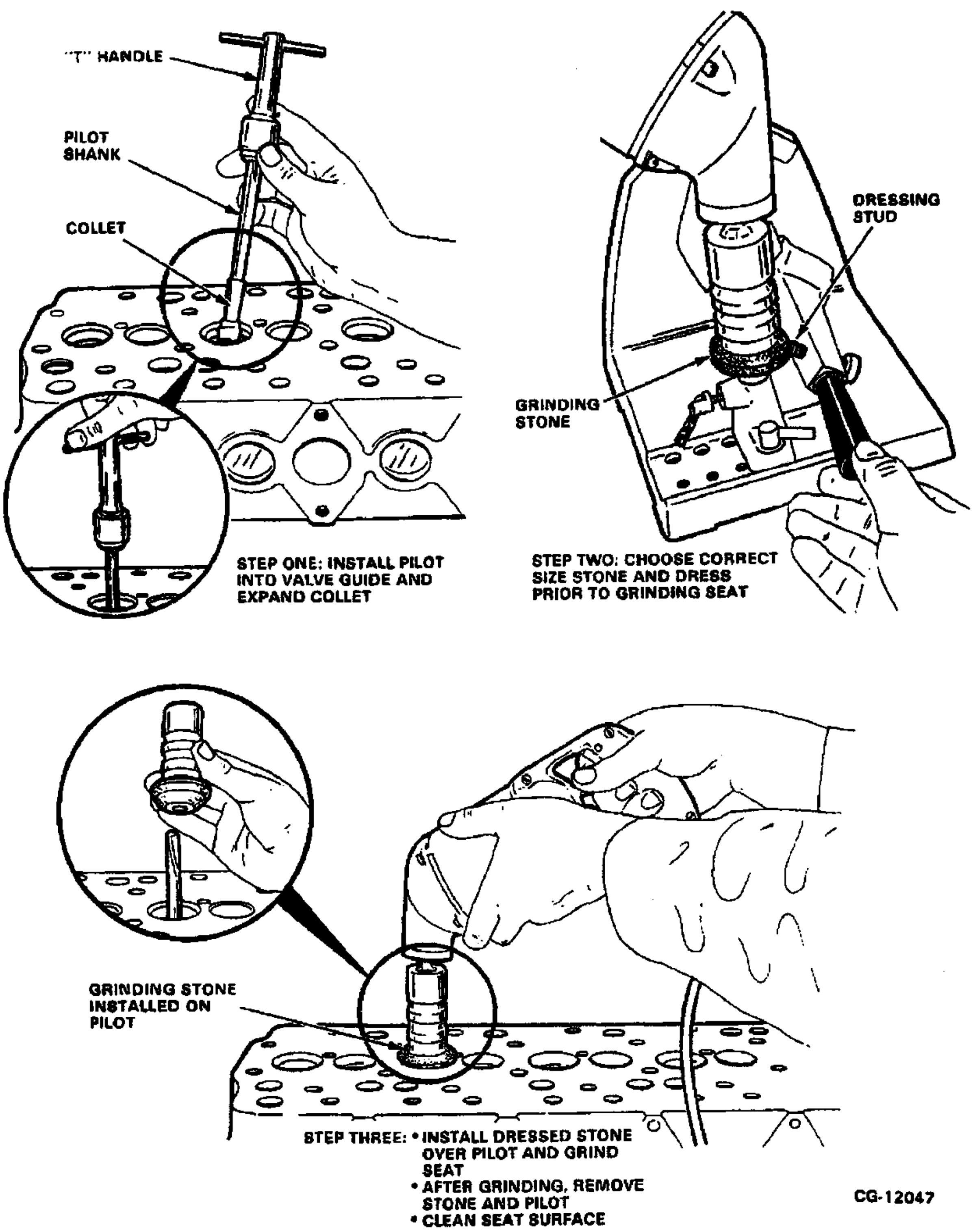

Figure 4.46. Grind Valve Seat

CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

2. After grinding, check valve seat width using a caliper as shown in **Figure 4.47**. Refer to "**SPECIFICATIONS**" for seat width limits. If seat widths are excessive, they may be corrected by grinding with a 15 degree smaller angle stone.

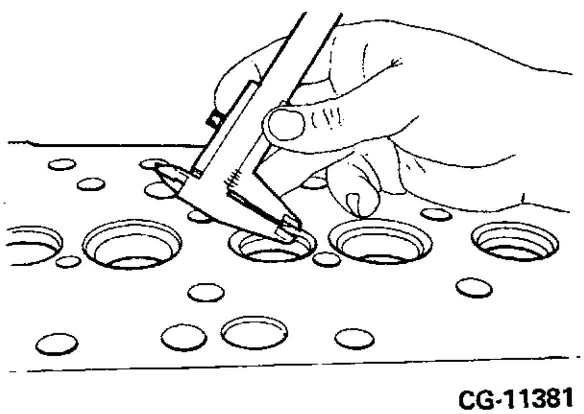

Figure 4.47. Measure Valve Seat Width

3. Check valve recession using a straightedge and feeler gauge or a surface gauge. Refer to **Figures 4.48** and **4.49**. Refer to "**SPECIFICATIONS**" for recession limits. If valve recession is excessive, install a new valve or replace the valve seat. If the valve protrudes above the deck, regrind the valve seat.

IMPORTANT

ALWAYS CLEAN THE VALVE GUIDES AS DESCRIBED IN THIS SECTION, PRIOR TO REINSTALLING THE VALVES.

IMPORTANT

IF A NEW VALVE WILL NOT CORRECT AN EXCESSIVE RECESSION CONDITION, THE VALVE SEAT MUST BE REPLACED AND REGROUND. IF THE VALVE FACE PROTRUDES ABOVE THE DECK, THE VALVE SEAT WILL HAVE TO BE REGROUND DEEPER INTO THE HEAD. AFTER REGRINDING ANY SEAT, RECHECK THE SEAT WIDTH (SEE FIGURE 4.47) AND CONFIRM VALVE SEAT CONTACT USING PRUSSIAN BLUE™. (SEE FIGURES 4.44 AND 4.45.)

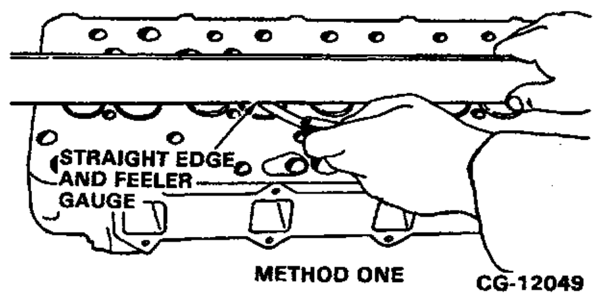

Figure 4.48. Measure Valve Recession — Method One

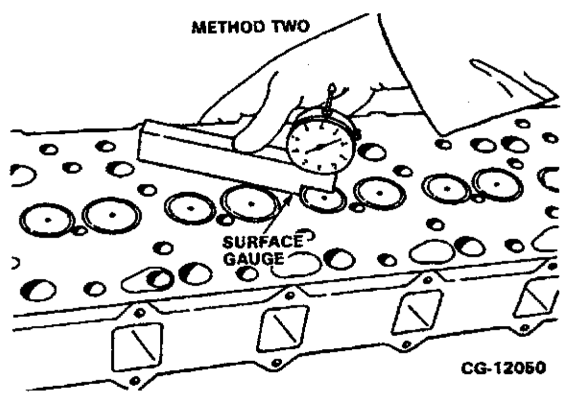

Figure 4.49. Measure Valve Recession — Method Two

CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

4. After grinding the valve seat, check the seat for runout, using an appropriate dial indicator. Valve seat runout should not exceed limits shown in "**SPECIFICATIONS**".

IMPORTANT

IF VALVE SEAT RUNOUT, CONCENTRICITY AND/OR SEAT WIDTH CANNOT BE MAINTAINED, REPLACE AND REGRIND THE VALVE SEATS.

VALVE SEAT REPLACEMENT

1. Use the Universal Valve Seat Extractor (ZTSE–1951B) to remove defective valve seat inserts as follows:

   a. Choose the appropriate size pin collet and position the collet at the valve seat insert.

NOTE: Exhaust Collet is tool number ZTSE–1951–20 and Intake Collet is tool number ZTSE–1951–21.

   b. Expand the pin collet by turning the small nut at the top of the bridge assembly. Refer to **Figure 4.50.**

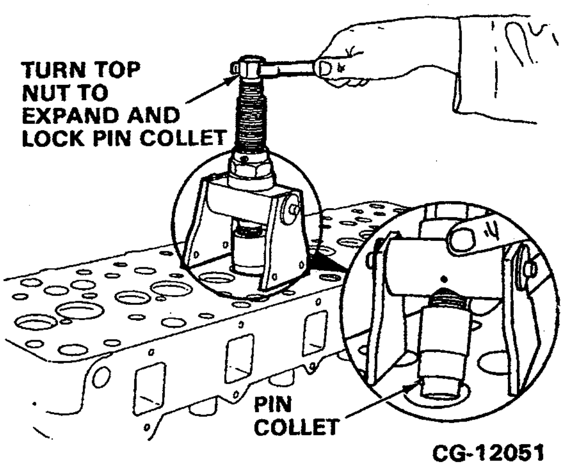

Figure 4.50. Install Universal Valve Seat Extractor

   c. Turn the large nut on the bridge assembly to pull the valve seat insert from the cylinder head. Refer to **Figure 4.51**.

   d. Unlock the pin collet by turning the small nut and discard the valve seat insert.

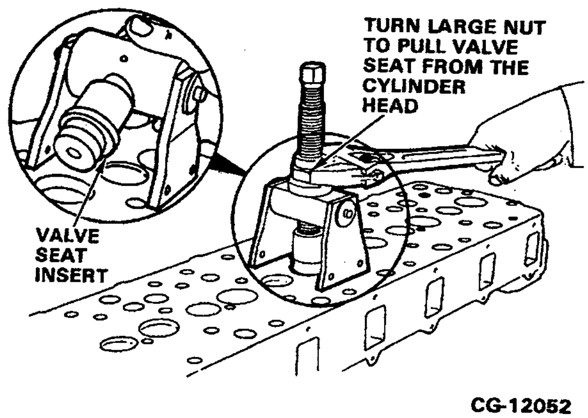

Figure 4.51. Pull Valve Seat Insert from Cylinder Head

2. Select the appropriate size valve seat insert. Refer to "**VALVE SEAT INSERT CHART**".

IMPORTANT

STANDARD SERVICE VALVE SEAT INSERTS ARE 0.002 IN. OVERSIZE. IF THE SEAT IS DAMAGED BEYOND THE STANDARD DIAMETER, IT WILL BE NECESSARY TO MACHINE THE INSERT COUNTERBORE IN THE CYLINDER HEAD FOR AN OVERSIZE SEAT INSERT. STANDARD SIZE INSERTS DO NOT REQUIRE COUNTERBORE ENLARGEMENT.

CYLINDER HEAD RECONDITIONING — Continued

VALVE AND VALVE GUIDE RECONDITIONING — Continued

VALVE SEAT INSERT CHART

OVERSIZE INSERT	DIAMETER OF CYLINDER HEAD COUNTERBORE INTAKE	EXHAUST
.002 IN.* (STANDARD)	1.780–1.781 IN.	1.534–1.535 IN.
.015 IN.	1.792–1.793 IN.	1.547–1.548 IN.

*** STANDARD SIZE SERVICE INSERT DOES NOT REQUIRE INSERT COUNTERBORE ENLARGEMENT BEFORE INSTALLING.**

3. Install the valve seat insert as follows:
   a. Chill the valve seat insert in a freezer for 30 minutes before installing.

NOTE: Chilling the valve seat insert prevents peeling of metal from the cylinder head counterbore during installation.

   b. Align the insert to avoid cocking.
   c. Drive the insert into its counterbore using ZTSE–4164 for the intake and exhaust valve seat inserts. Refer to **Figure 4.52**.
4. Grind the new valve seat(s) to the specified angles and width. Refer to "**VALVE SEAT GRINDING**" in this section.

IMPORTANT

AFTER VALVE SEAT GRINDING, CLEAN THE VALVE GUIDES AS DESCRIBED IN THIS SECTION, PRIOR TO REINSTALLING THE VALVES.

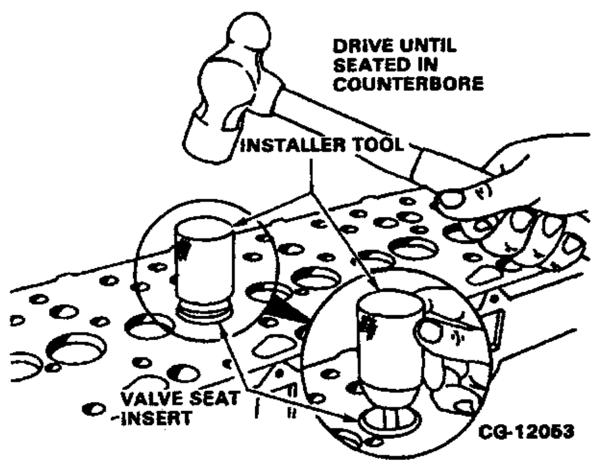

Figure 4.52. Install Valve Seat Insert

CYLINDER HEAD RECONDITIONING — Continued

VALVE SPRINGS

Cleaning

1. Clean all valve springs and seats in a suitable solvent.

Inspection

1. Visually inspect valve springs for rust, pitting and cracks. Look for spring distortion.
2. Spring ends must be flat and square to prevent lateral loads on valve stem. Refer to **Figure 4.53**.

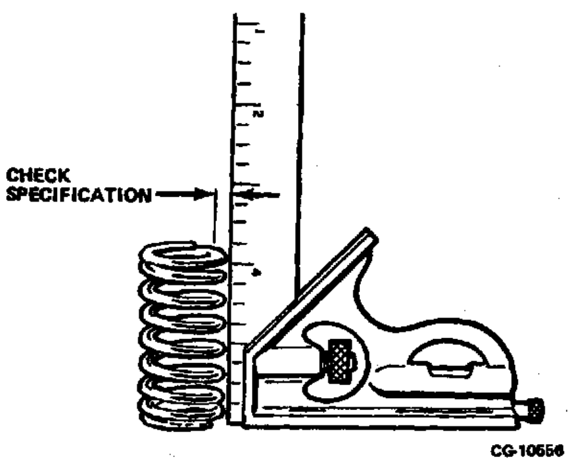

Figure 4.53. Checking Valve Spring Squareness

NOTE: Out of square springs place a side load on the stem causing rapid guide wear.

3. Measure valve spring tension using valve spring tester ZTSE–2241. Refer to **Figure 4.54** and **"SPECIFICATIONS"**.
   a. Measure maximum spring length in use (valve closed).
   b. Measure minimum spring length in use (valve open).

NOTE: Apply the appropriate test load to each spring and determine if test length is achieved.

4. Replace any valve spring which is rusted, pitted, cracked, bent or incapable of meeting tension requirements.

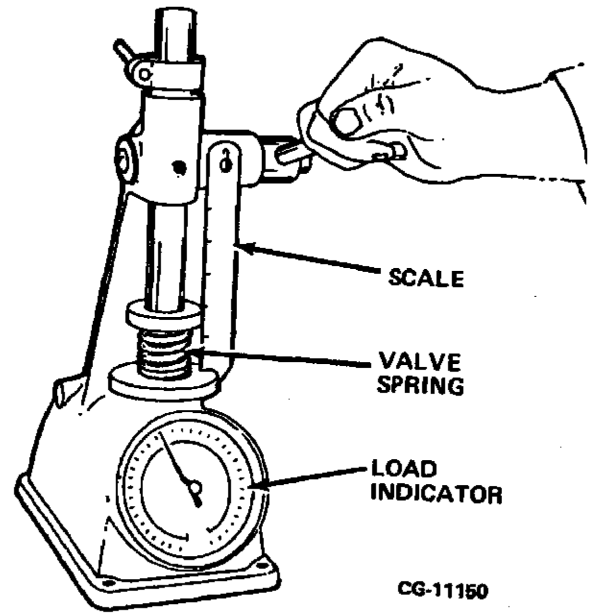

Figure 4.54. Checking Valve Spring Tension Using ZTSE–2241

VALVE ROTATORS

NOTE: A revised (shorter in height) valve rotator assembly is used on engines with S/N 072707 and up. Refer to Parts Catalog for correct service part number.

Cleaning

1. Clean rotators in a clean solvent.

Inspection

1. To properly test the rotator for function, a valve spring load must be applied to the rotator.

NOTE: The rotator must be lubricated with clean engine oil prior to testing

2. Place the valve spring, with the rotator in the spring tester ZTSE–2241. Place a ball bearing between the rotator and ram of the spring tester.

NOTE: The ball bearing must be large enough to prevent the ram from touching any part of the rotator.

3. Paint a reference line on the rotator.

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CYLINDER HEAD RECONDITIONING — Continued

VALVE ROTATORS — Continued

4. Compress the valve spring rapidly and with even pressure and observe the rotator as it turns. (Refer to **Figure 4.55.**)
5. Replace any rotator which does **NOT** turn.

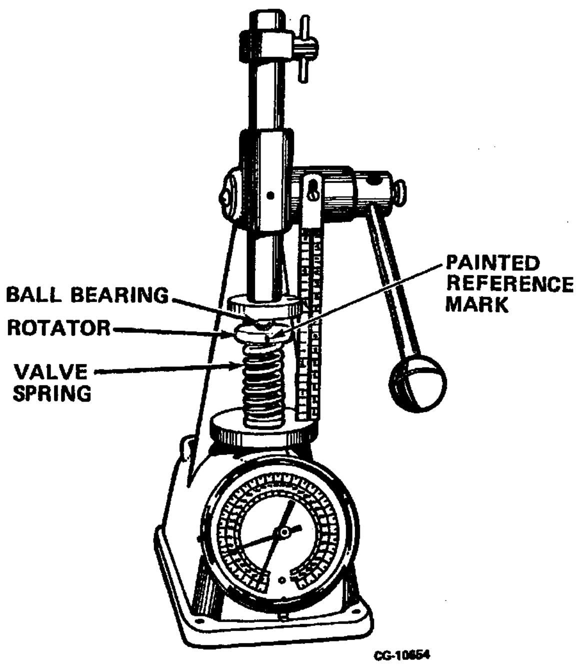

Figure 4.55. Test Valve Rotator

VALVE SPRING LOCKS

Cleaning

1. Clean valve spring locks in a suitable solvent.

Inspection

1. Visually inspect inside and outside of the valve spring locks for wear.
2. Replace any worn spring locks, as required.

CYLINDER HEAD REASSEMBLY

1. Clean valve faces and seats with a suitable cleaning solvent to remove all dirt or foreign material. Blow dry all new and used components using filtered compressed air.
2. Thoroughly clean all valve guides, prior to valve installation, as follows: (Refer to **Figure 4.33)**
   a. Coat a nylon brush with soap and water.

NOTE: Brush must have a slightly larger diameter than the I.D. of the valve guide.

   b. Insert brush into valve guide bore and clean with a turning motion to insure removal of any deposits.
   c. Dry with filtered compressed air.

IMPORTANT

PERFORM VALVE GUIDE BORE CLEANING ON:
1. NEW SERVICE VALVE GUIDES.
2. VALVE GUIDES INSTALLED IN NEW SERVICE CYLINDER HEADS (LESS VALVES).
3. VALVE GUIDES PRESENTLY INSTALLED IN CYLINDER HEAD, WHICH MEET BORE SPECIFICATIONS.

3. Lubricate the valve stem with clean engine oil and insert the valve into the valve guide.
4. Snap the new rotator bushing (If Applied — See Note) into the valve rotator bottom side (rotator cone) as shown in **Figure 4.56.**

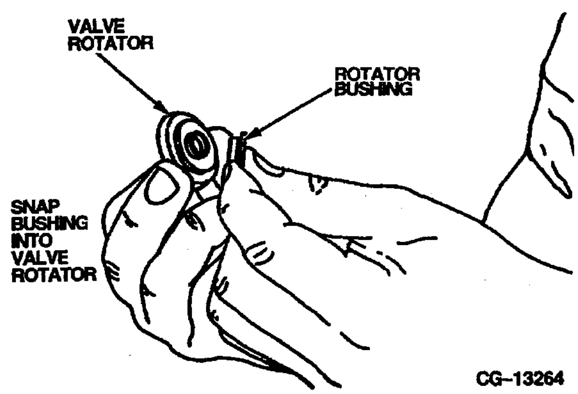

Figure 4.56. Assemble Rotator and Oil Shield

NOTE: Engines built between S/N's 098372 and 100135 were installed without the rotator bushing. The current replacement rotator assembly(with bushing) can be used for service of all rotators after S/N 072706. Refer to Parts Catalog for proper service part number.

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CYLINDER HEAD REASSEMBLY – Continued

IMPORTANT

EACH TIME THE CURRENT (REVISED) VALVE ROTATOR IS REMOVED DURING SERVICE, THE ROTATOR BUSHINGS MUST BE REPLACED WITH NEW BUSHINGS.

FOR ENGINES BUILT AFTER S/N 072706

4. Install the stem seal assembly over the valve and valve guide and against the cylinder head as shown in **Figure 4.57.**

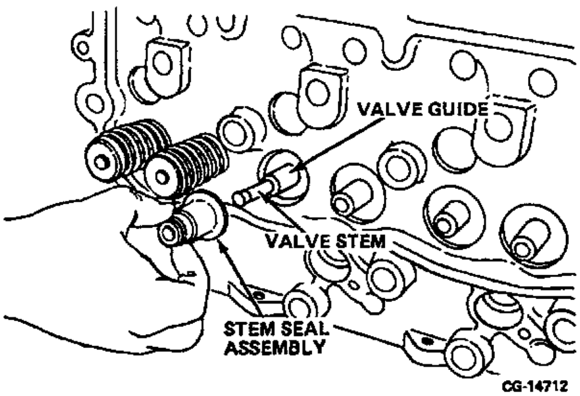

Figure 4.57. Install Stem Seal Assembly

5. Install the valve spring over the stem seal assembly.
6. Install the rotator assembly over the valve spring. Refer to **Figure 4.58.**

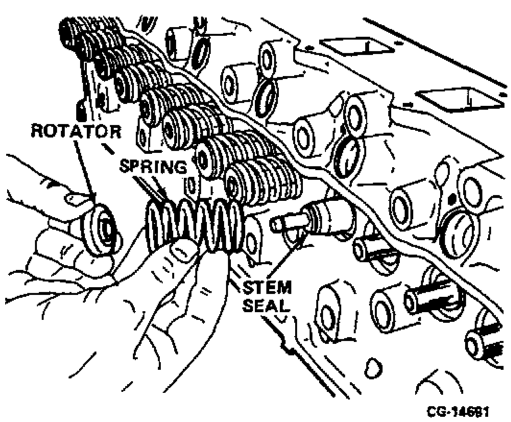

Figure 4.58. Install Valve Spring and Rotator

7. Compress the valve spring and install the spring locks as shown in **Figure 4.59.**

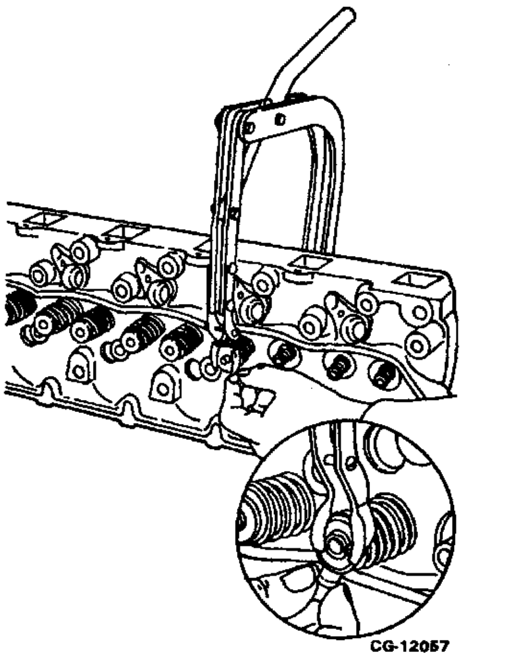

Figure 4.59. Compress Springs and Install Spring Locks

FOR ENGINES BUILT BEFORE S/N 072707

4. Snap the nylon oil shield into the valve rotator as shown in **Figure 4.60.**

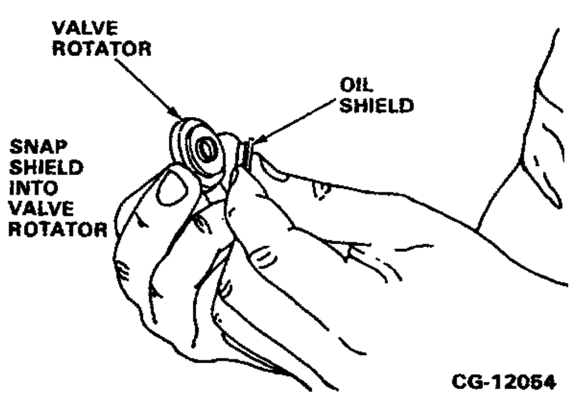

Figure 4.60. Assemble Rotator and Oil Shield (Used Prior to S/N 072707)

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CYLINDER HEAD REASSEMBLY – Continued

FOR ENGINES BUILT BEFORE S/N 072707 – Continued

IMPORTANT

THE SHIELD MUST BE SNAPPED INTO THE ROTATOR (FIGURE 4.60). IF NOT PROPERLY INSTALLED, EXCESSIVE LUBE OIL CONSUMPTION COULD OCCUR.

5. Install the spring seat over the valve stem and guide. Refer to **Figure 4.61**.

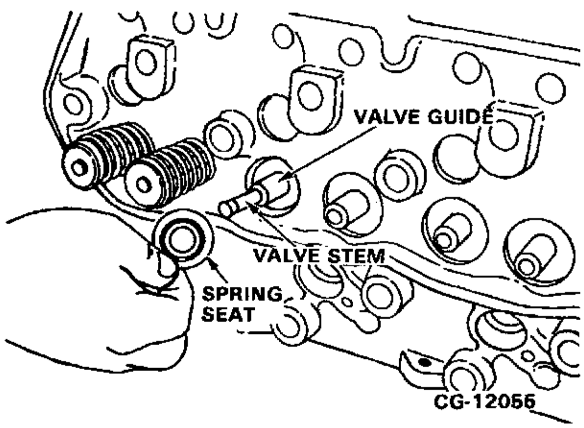

Figure 4.61. Install Spring Seat (Used Prior to S/N 072707)

6. Install the valve spring and rotator with oil shield. Refer to **Figure 4.62**.

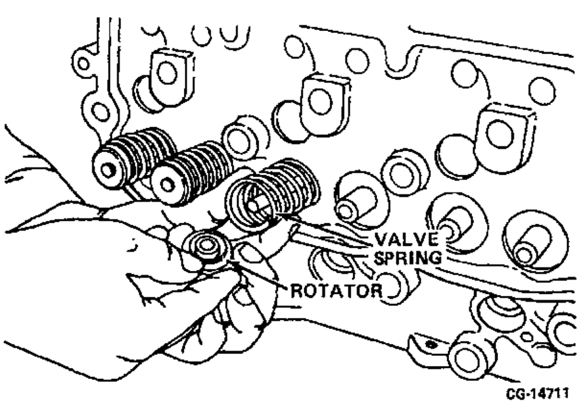

Figure 4.62. Install Valve Spring and Rotator

7. Compress the valve spring and install the spring locks as shown in **Figure 4.63**.

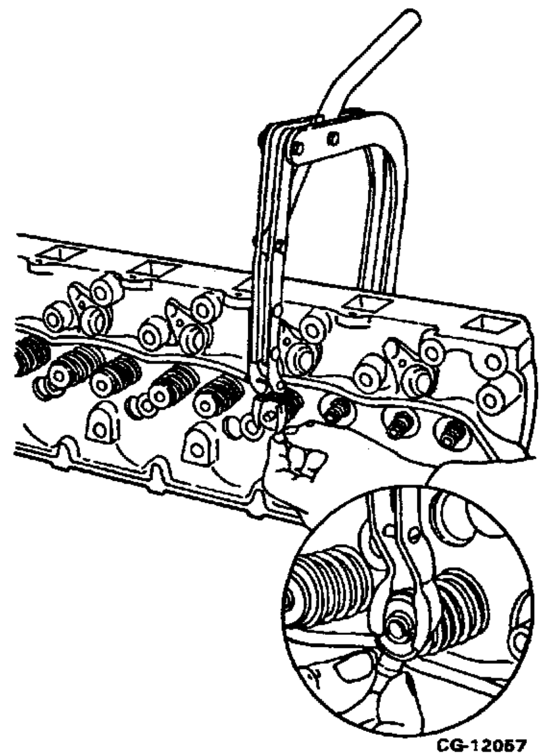

Figure 4.63. Compress Spring and Install Spring Locks

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CYLINDER HEAD INSTALLATION

Install the cylinder head assembly as follows:

1. Clean and dry the cylinder head gasket surfaces.
2. Clean all cylinder head bolt holes using an appropriate tap and blow out bolt holes with filtered compressed air.

IMPORTANT

PRIOR TO CYLINDER HEAD INSTALLATION, CHECK CYLINDER SLEEVE PROTRUSION AS DESCRIBED IN SECTION 7. IF PROTRUSION IS NOT WITHIN SPECIFICATIONS, FOLLOW THE COUNTERBORING PROCEDURE.

3. Install the dowel rings into the crankcase top deck. Refer to **Figure 4.64**.

NOTE: The dowel rings are used to locate the cylinder head gasket.

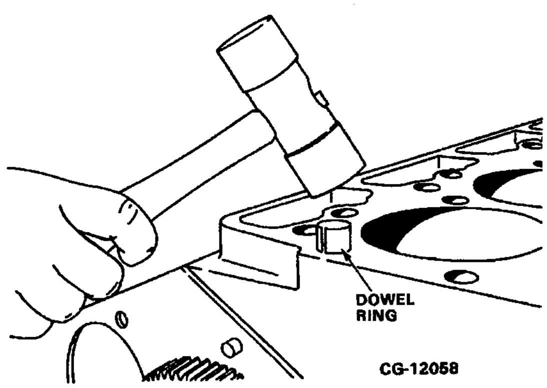

Figure 4.64. Install Dowel Rings in Crankcase

4. Install a new cylinder head gasket over the "locating" dowel rings and gently lower the cylinder head onto the gasket. Refer to **Figure 4.66**.

NOTE: The slotted gasket has been updated to eliminate three holes "A" at the front left corner of the gasket. Refer to Figure 4.65. While the three holes are no longer utilized, the surrounding "PRINTOSEAL" remains to enhance gasket sealing. This current gasket will work for service on all DT/DTA–360 engines.

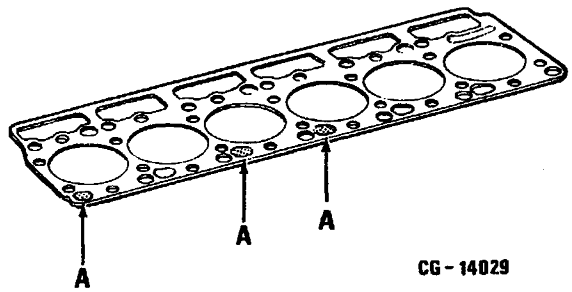

Figure 4.65. Location of Three Holes in Cylinder Head Gasket

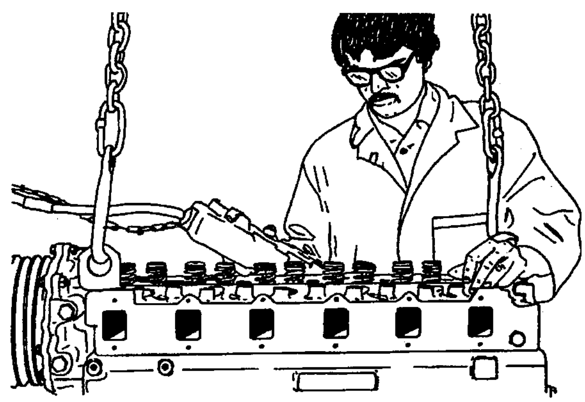

Figure 4.66. Install Cylinder Head onto New Gasket

5. Lubricate the cylinder head bolt threads, washers and under head seating area using clean engine oil. Refer to **Figure 4.67**.

NOTE: Lubricate both long and short bolts.

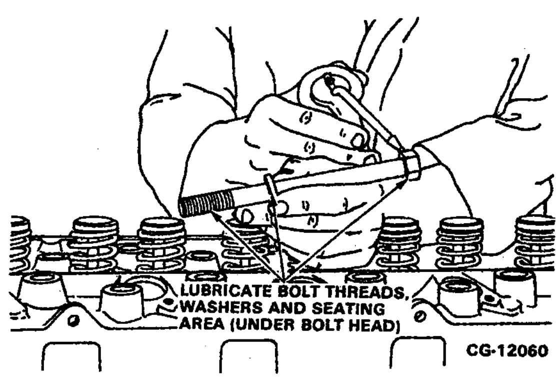

Figure 4.67. Lubricate Cylinder Head Bolts

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CYLINDER HEAD INSTALLATION — Continued

6. Run the short head bolts in finger–tight.
7. Install the push rods with the cup end up as shown in **Figure 4.68**.

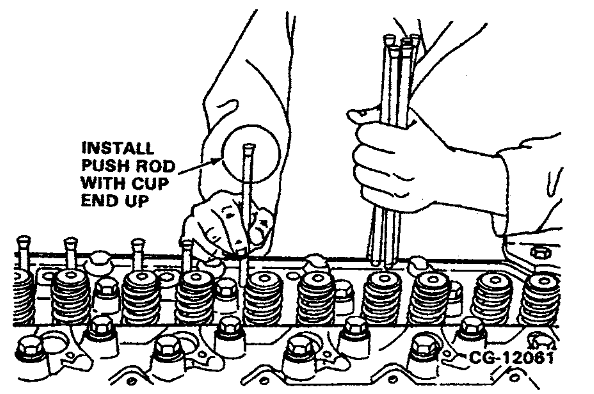

Figure 4.68. Install Push Rods

8. Install the rocker arm assembly onto the cylinder head using the long cylinder head bolts as follows:
   a. Insert the rocker arm and shaft assembly with the long cylinder head bolts into their respective bolt holes. Refer to **Figure 4.69**.

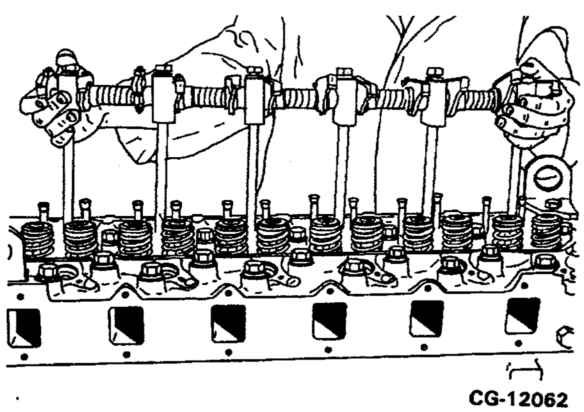

Figure 4.69. Install the Rocker Arm Assembly

   b. Run the long cylinder head bolts in finger–tight (except the two end bolts). Place a 0.005 in. feeler gauge between the outside brackets and the rocker levers to prevent binding. Refer to **Figure 4.70.**

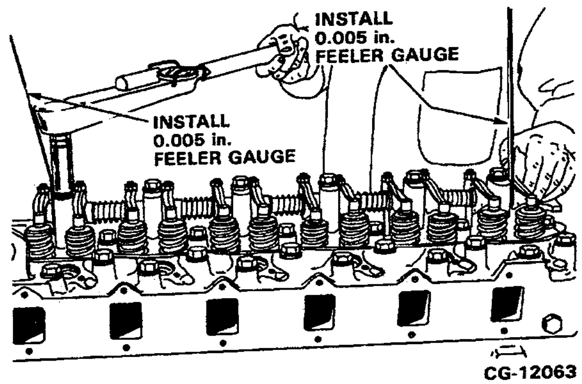

Figure 4.70. Install Feeler Gauges to Prevent Rocker Lever Binding

   c. Tighten the cylinder head bolts in three stages as specified under "**SPECIAL TORQUES**" in this section.

NOTE: Check the two end rocker arms for freedom of movement after tightening the cylinder head bolts.

   d. Remove the two 0.005 in. feeler gauges.

9. Adjust valve lash as follows:

NOTE: All valves are adjusted by rotating the engine only twice.

   a. Rotate the crankshaft until the #1 piston he compression stroke and the timing pointer on the front cover is in line with the TDC mark on the vibration damper.

NOTE: Confirm that the #1 piston is on the compression stroke by turning both push rods by hand to verify that both valves are closed. The valves are closed when the push rods are loose and can be turned easily.

CYLINDER HEAD INSTALLATION — Continued

b. Set valve lash by loosening the lock nut and turning the valve adjustment screw with the appropriate size feeler gauge inserted between the rocker arm and valve stem tip. Tighten the valve adjustment screw until the valve lever can support the feeler gauge. Refer to **Figure 4.71** and "**SPECIFICATIONS**" for valve lash.

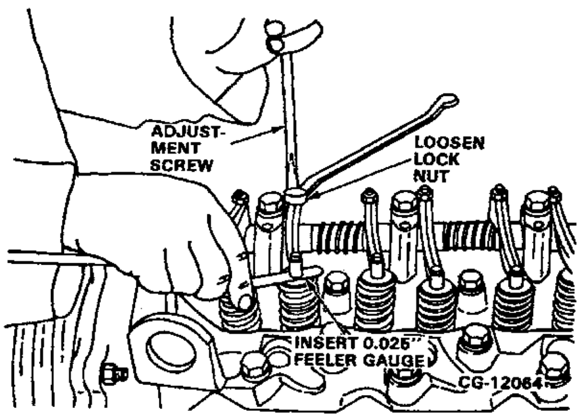

Figure 4.71. Adjust Valve Lash

c. Tighten the lock nut once the valve adjustment is set. Remove the feeler gauge. Refer to **Figure 4.72.**

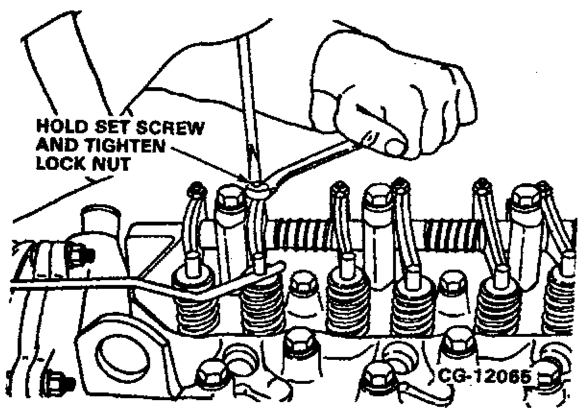

Figure 4.72. Tighten Valve Adjustment Screw Lock Nut

Valve lash adjustment sequence:

Six valves are adjusted when the #1 piston is at TDC (compression) and the remaining six are adjusted when the #6 piston is at TDC (compression). Refer to **Figure 4.73**.

WITH	ADJUST VALVES											
No. 1 Piston at T.D.C. (Compression)	INT 1	EXH 2	INT 3			EXH 6	INT 7			EXH 10		
No. 6 Piston at T.D.C. (Compression)				EXH 4	INT 5			EXH 8	INT 9		INT 11	EXH 12

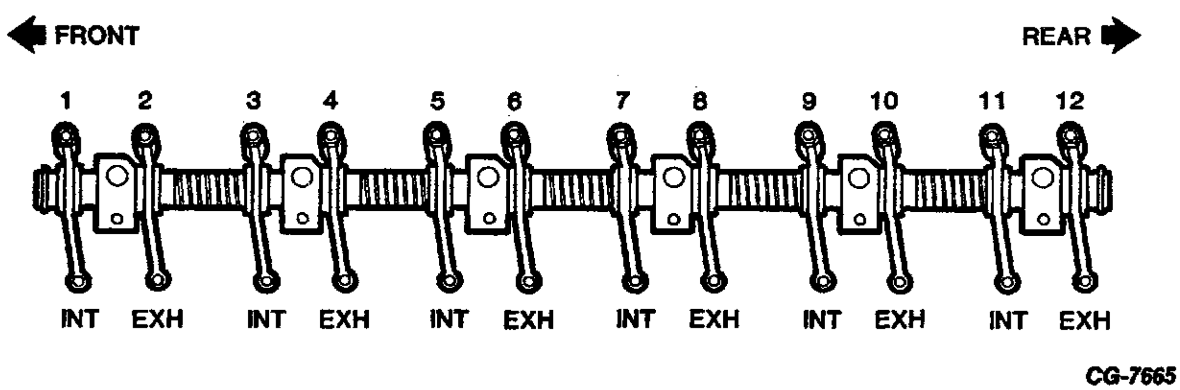

Figure 6.73. Valve Lash Adjustment Sequence

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CYLINDER HEAD INSTALLATION — Continued

10. Install a new gasket onto the valve cover and align the cover and gasket onto the cylinder head. Tighten the valve cover mounting bolts and rubber sealing grommets to the specified torque. See **"SPECIAL TORQUES"**. Refer to **Figure 4.74**.

NOTE: Be sure valve cover gasket is aligned before tightening.

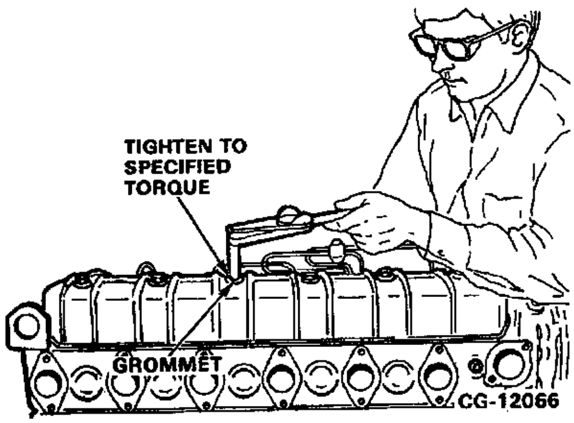

Figure 4.74. Install Valve Cover

11. Reinstall the following: (Refer to appropriate manual section for installation procedures,)
    - — Thermostat & housing
    - — Exhaust manifold
    - — Turbocharger
    - — Intake manifold
    - — Fuel injection nozzles
    - — Fuel leak–off lines (low pressure)
    - — Injection lines (high pressure)

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SERVICE MANUAL

ROCKER ARM ASSEMBLY, CAMSHAFT, TAPPETS & PUSH RODS

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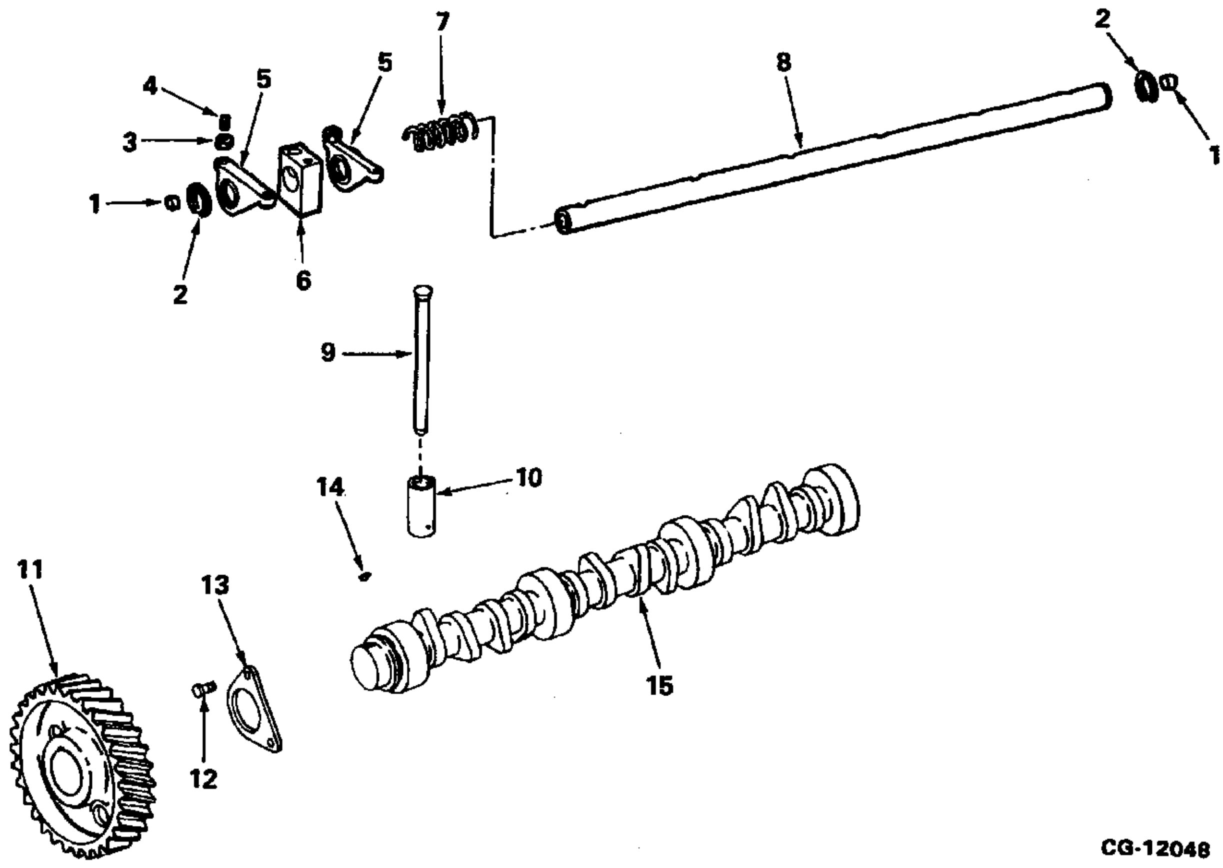

Figure 5.1. Rocker Arm Assembly, Camshaft, Tappets and Push Rods (Exploded View)

1. Cup Plug, Rocker Arm Shaft
2. Retainer Ring, Rocker Arm Shaft
3. Lock Nut, Rocker Arm Adjusting
4. Screw, Rocker Arm Adjusting
5. Rocker Arm (Valve Lever)
6. Bracket, Rocker Arm Shaft
7. Spring, Rocker Arm Shaft
8. Shaft, Rocker Arm
9. Push Rod
10. Tappet
11. Gear, Camshaft
12. Bolt, 5/16–18 x 3/4 Lock
13. Thrust Plate, Camshaft
14. Key, 1/4 x 3/4 Woodruff
15. Camshaft

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SPECIFICATIONS

DIMENSION TITLE	VALUES
CAMSHAFT	
Cam Lobe Lift (Total):	
Intake	0.2705 in. (6.870 mm)
Exhaust	0.2829 in. (7.186 mm)
Maximum Permissible Cam Lobe Wear	0.020 in. (0.51 mm)
	0.002 in. (0.05 mm)
Camshaft Bearing Running Clearance	0.007 in. (0.18 mm)
Maximum Permissible Camshaft Bearing Running Clearance	0.008 in. (0.20 mm)
	2.2845 in. (58.026 mm)
Bushing I.D. (Installed in Crankcase)	2.2880 in. (58.115 mm)
	2.2814 in. (57.948 mm)
Bushing Journal Diameter	2.2825 in. (57.976 mm)
Service Bushings Furnished to Size	Yes
	0.274 in. (6.96 mm)
Thrust Plate Thickness (New)	0.276 in. (7.01 mm)
	0.005 in. (0.13 mm)
End Clearance	0.013 in. (0.33 mm)
ROCKER ARM ASSEMBLY (Valve Lever and Shaft Assembly)	
	0.8491 in. (21.567 mm)
Valve Lever Shaft Diameter	0.8501 in. (21.593 mm)
	0.0019 in. (0.048 mm)
Valve Lever Clearance on Shaft	0.0049 in. (0.124 mm)
	0.852 in. (21.64 mm)
Valve Lever Bushing (I.D.)	0.854 in. (21.69 mm)
Bracket Orifice I.D.	0.042 in. (1.07 mm)
TAPPETS	
	1.1195 in. (28.435 mm)
Diameter	1.1200 in. (28.448 mm)
Length	2.437 in. (61.90 mm)
	0.0025 in. (0.064 mm)
Tappet Clearance in Crankcase	0.0040 in. (0.102 mm)

SPECIFICATIONS —Continued

DIMENSION TITLE	VALUES
PUSH ROD	
Maximum Run–Out (T.I.R.)	0.020 in. (0.51 mm)
ROCKER ARM SHAFT SPRINGS	
Number of Springs	5
Free Length	4.06 in. (103.1 mm)
Test Length	2.07 in. (52.6 mm)
Test Load	71 lbf–ft. (31 Nm)
I.D.	1.02 in. (25.9 mm)

SPECIAL TORQUES

Camshaft Thrust Plate Bolt	20 lbf–ft. (27 Nm)

SPECIAL SERVICE TOOLS

TOOL NO.	DESCRIPTION
ZTSE–2893	Camshaft Bushing Puller & Installer
ZTSE–2241	Spring Tester

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ROCKER ARM ASSEMBLY

REMOVAL

Remove the following:

- Crossover pipe (DT–360 only)
- Valve cover.

Refer to the appropriate manual section for removal procedures.

1. Remove the rocker arm assembly as follows: (Refer to **Figure 5.2**)
   a. Loosen the rocker arm adjusting nuts and screws 1/2 turn.
   b. Loosen the rocker arm bracket bolts (long cylinder head bolts).
   c. Lift the rocker arm assembly from the cylinder head.

NOTE: Loosening the rocker arm adjusting nuts and screws 1/2 turn will avoid possible valve train damage during installation.

IMPORTANT

AT THIS STAGE OF DISASSEMBLY, MEASURE CAMSHAFT LOBE LIFT. REFER TO "CAMSHAFT" IN THIS SECTION FOR THE CAMSHAFT LOBE LIFT MEASUREMENT PROCEDURE.

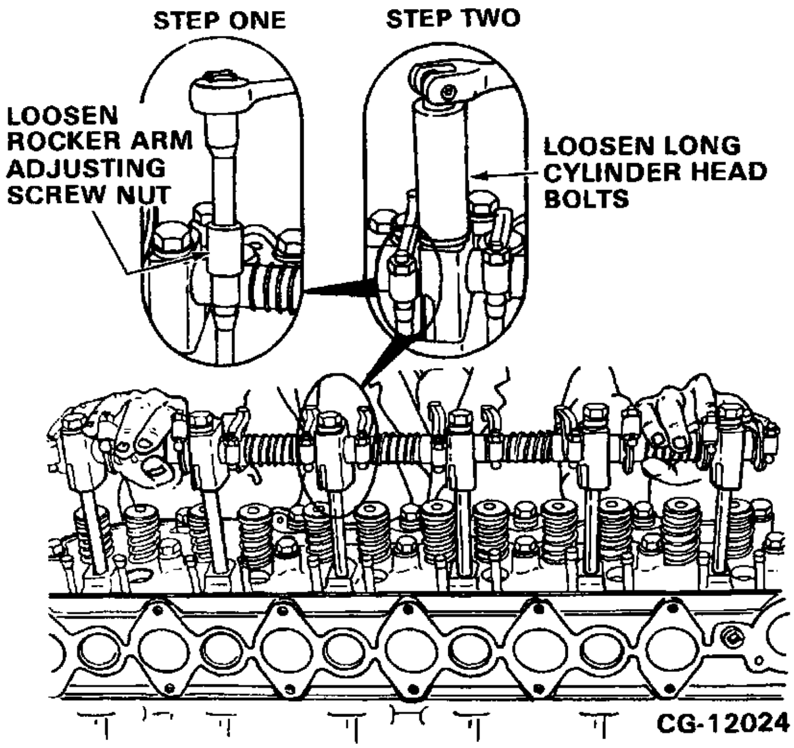

Figure 5.2. Remove Rocker Arm Assembly

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ROCKER ARM ASSEMBLY — Continued

DISASSEMBLY

1. Place the rocker arm assembly on a clean flat surface.

2. Using a snap ring tool, remove the rocker arm retainer ring at the end of the shaft. Refer to **Figure 5.3.**

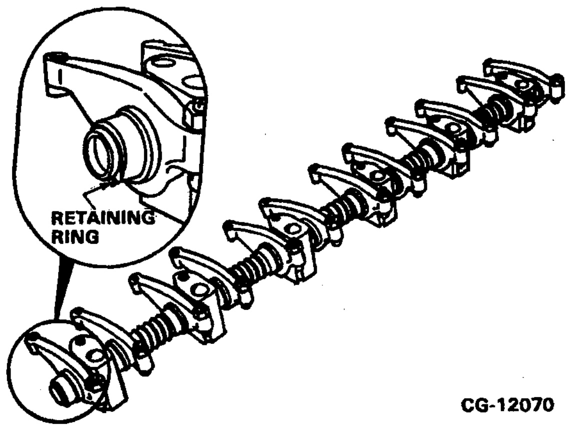

Figure 5.3. Remove Retaining Ring from Shaft

3. Slide the rocker arm components off the shaft as shown in **Figure 5.4.**

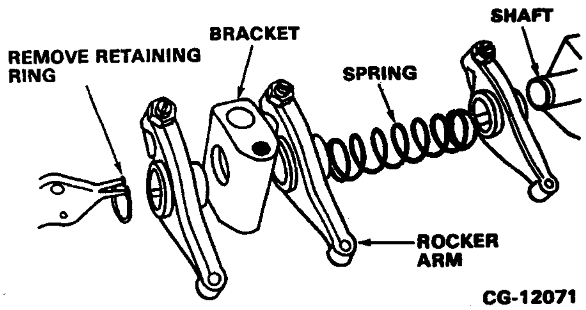

Figure 5.4. Remove Components from Rocker Arm Shaft

CLEANING

1. Immerse all components in a suitable solvent.
2. Remove and dry using filtered compressed air.

INSPECTION

1. Visually inspect the rocker arm shaft and rocker arm bushings for scoring or signs of excessive wear. If visibly damaged, replace the shaft and/or rocker arms, as required.
2. Measure rocker arm shaft spring tension using valve spring tester ZTSE–2241. Refer to "SPECIFICATIONS".
   a. Measure maximum spring length in use (valve closed).
   b. Measure minimum spring length in use (valve open).

NOTE: Apply the appropriate test load to each spring and determine if test length is achieved.

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ROCKER ARM ASSEMBLY — Continued

INSPECTION — Continued

3. Measure rocker arm bushings using a telescoping gauge and outside micrometer as shown in **Figure 5.5.** Measure the bushings at the vertical location and record the readings.

4. Measure the rocker arm shaft with a micrometer. If more than 0.005 in. difference is found between the rocker arm bushing I.D. and the rocker arm shaft O.D., replace the rocker arm and/or shaft; whichever is worn.

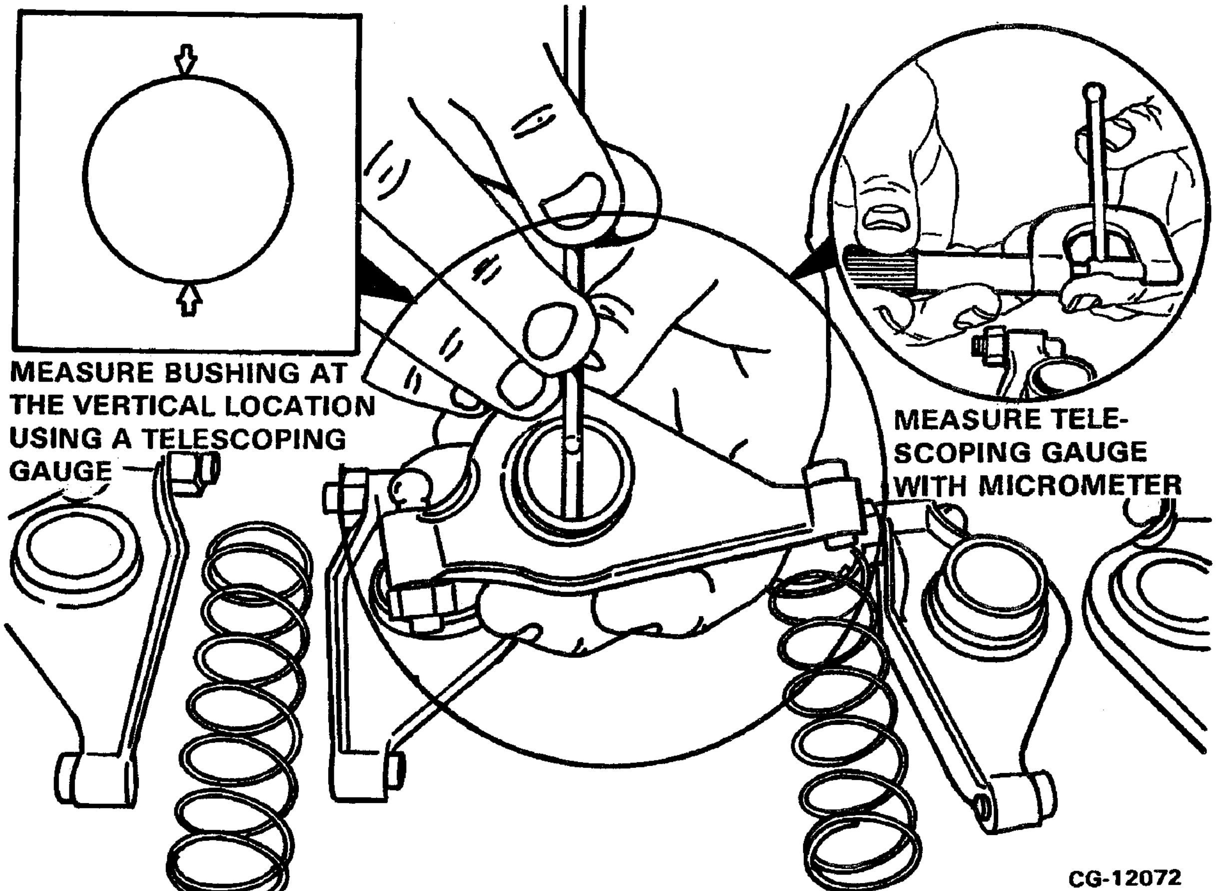

Figure 5.5. Measure Rocker Arm Bushing

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ROCKER ARM ASSEMBLY — Continued

INSPECTION — Continued

5. If the rocker arms are within specifications, they may be reused. Prior to assembly, assure the oil hole in the rocker arms and bushings is open by running a wire through the oil hole. Remove any blockage before reassembly. Refer to **Figure 5.6.**

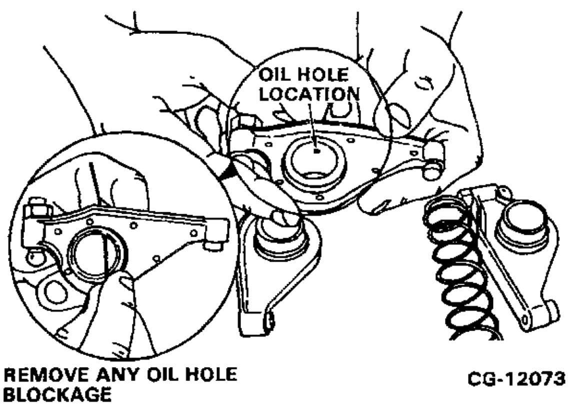

Figure 5.6. Inspect Rocker Arm Oil Hole for Blockage

NOTE: Later production engines have an oil spreader groove on the rocker arm (located opposite the oil holes). Refer to Figure 5.7. Early style rocker arms (without oil spreader groove) and late style rocker arms (with oil spreader groove) may be intermixed on DT/DTA–360 Diesel Engines.

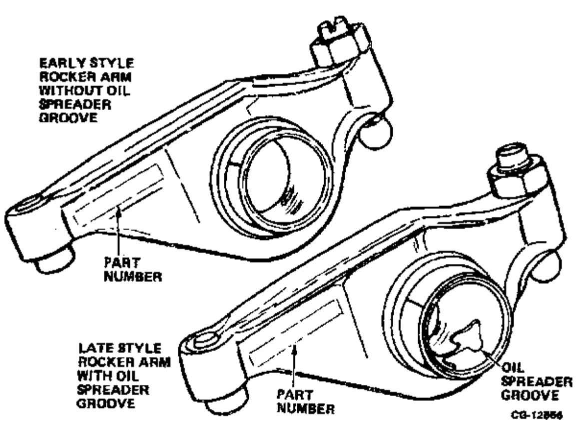

Figure 5.7. Rocker Arm Identification

6. Inspect all rocker arm shaft bracket orifices for blockage. Run a wire through each orifice to assure they are open. Refer to **Figure 5.8.**

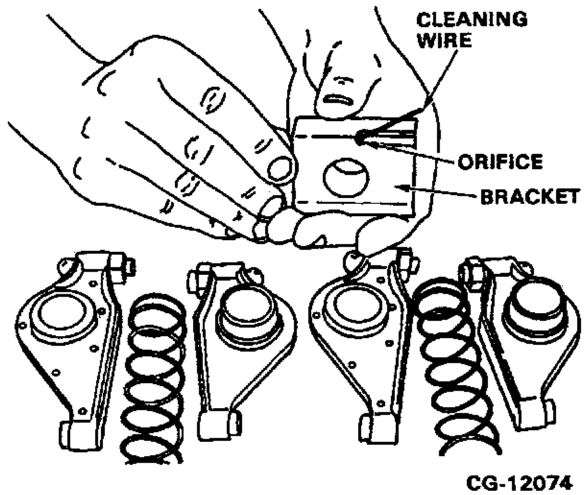

Figure 5.8. Inspect Bracket Orifices for Blockage

REASSEMBLY

1. Lubricate all rocker arm bushings with clean engine oil, install a retaining ring at one end of the shaft and assemble the components with the shaft in the vertical position. Refer to **Figure 5.9.**

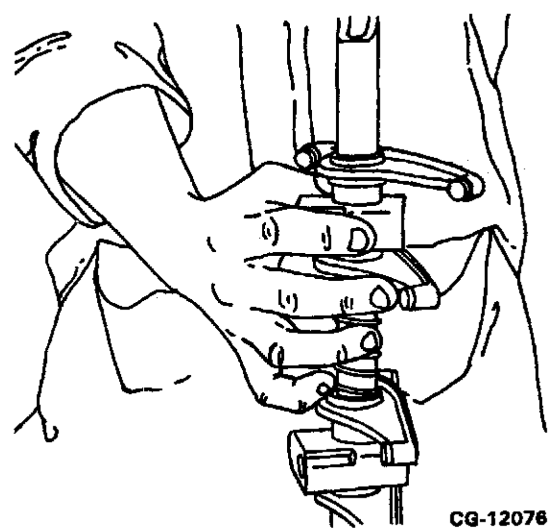

Figure 5.9. Assemble Rocker Arm Components with Shaft in Vertical Position

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ROCKER ARM ASSEMBLY — Continued

REASSEMBLY — Continued

2. Arrange the rocker arm assembly components as shown in **Figure 5.10.**

NOTE: The rocker shaft is marked with the word "TOP" in the center of the shaft. This should face up at all times. The brackets must line up over the shaft bolt grooves. An end view position of the shaft to bracket is shown in Figure 5.11.

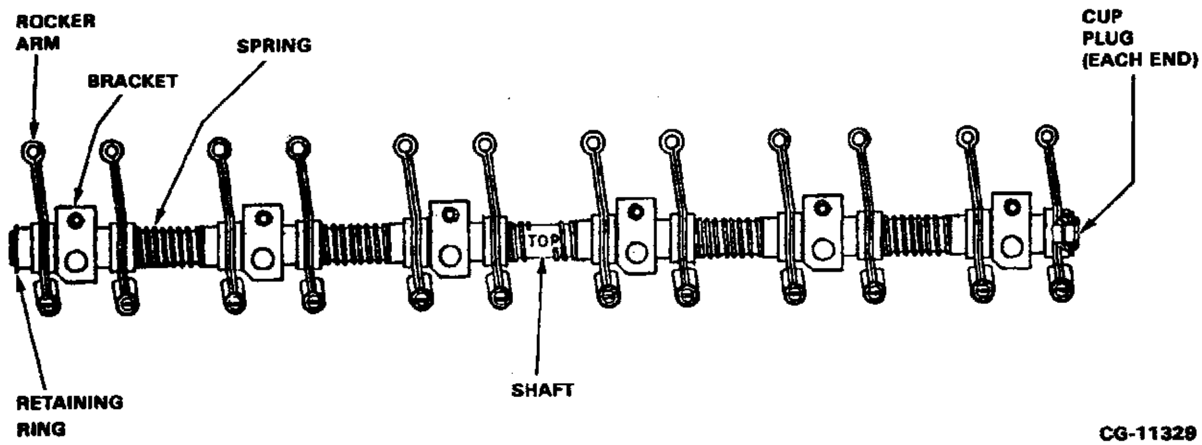

Figure 5.10. Rocker Arm Assembly Component Orientation

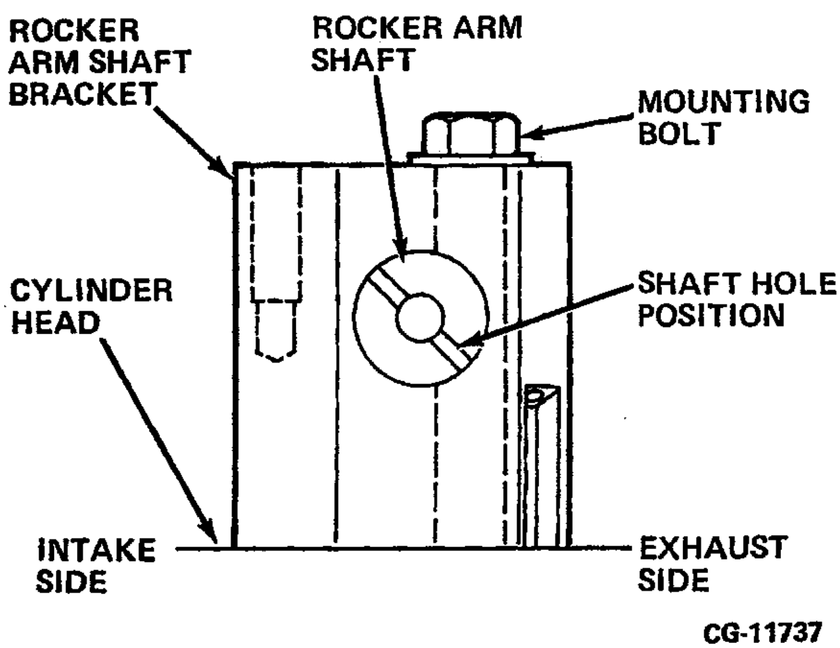

Figure 5.11. Rocker Arm Shaft and Bracket End View

ROCKER ARM ASSEMBLY — Continued

REASSEMBLY — Continued

3. When all components are on the shaft, in the correct order, install the second retaining ring to secure the components. Refer to **Figure 5.12.**

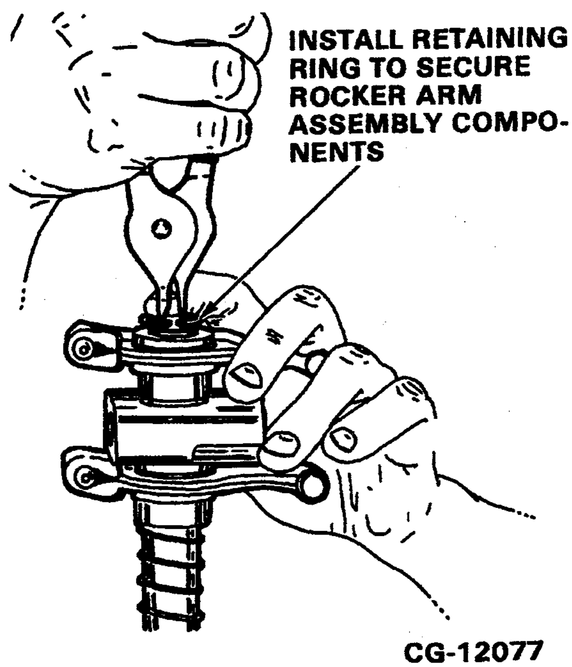

Figure 5.12. Install Retaining Ring

NOTE: Cup plugs (at each end of the shaft) are replaceable. Do not disturb unless damaged or leaking. If replacement is required, pry the damaged plug out and press in a new cup plug. Refer to Figure 5.10.

INSTALLATION

1. Install the rocker arm assembly as outlined in Section 4 "CYLINDER HEAD AND VALVES".
2. Adjust valve lash as outlined in Section 4 "CYLINDER HEAD AND VALVES".
3. Reinstall the valve cover.
4. Reinstall the crossover pipe (DT–360 only).

CAMSHAFT, TAPPETS & PUSH RODS

COMPONENT CHANGES

Effective with Engine S/N 072706 (1990 Model Year) the camshaft assembly has a 4° advance in intake lobe positioning resulting in improved engine cold start and faster warm–up time.

IMPORTANT

DO NOT USE THE 1990 MODEL YEAR CAMSHAFT ASSEMBLY FOR SERVICE ON ENGINE WITH S/N 072706 OR EARLIER.

MEASURE CAMSHAFT LOBE LIFT

IMPORTANT

CAMSHAFT WEAR CAN BE MEASURED WITHOUT COMPLETE ENGINE TEAR DOWN. WITH THE ROCKER ARM ASSEMBLY REMOVED AND THE PUSH RODS IN PLACE, MEASURE CAMSHAFT LOBE LIFT AS FOLLOWS:

1. Mount a magnetic base dial indicator on the cylinder head.
2. Place the dial indicator tip on the top of the push rod and rotate the engine until the push rod is at its lowest point of travel (base circle). Then "zero" the indicator. Refer to **Figure 5.13.**

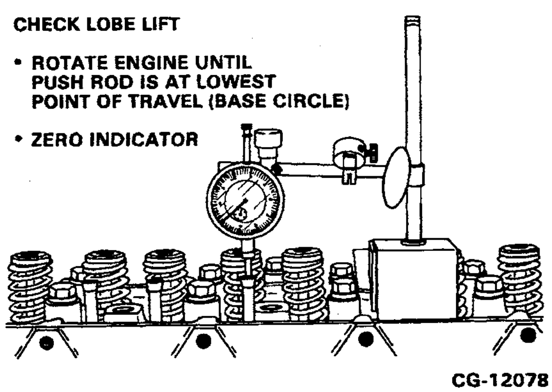

Figure 5.13. Measure Camshaft Lobe Lift — Step One

CAMSHAFT, TAPPETS & PUSH RODS — Continued

MEASURE CAMSHAFT LOBE LIFT — Continued

3. Rotate the engine and bring the push rod to its highest point of travel. Record the indicator reading. Refer to **Figure 5.14.**
4. Repeat this procedure for all lobes.

IMPORTANT

INTAKE AND EXHAUST VALVE LOBE LIFT SPECIFICATIONS ARE DIFFERENT. IF WEAR IS GREATER THAN 0.020 IN. (0.51 MM), REPLACE THE CAMSHAFT.

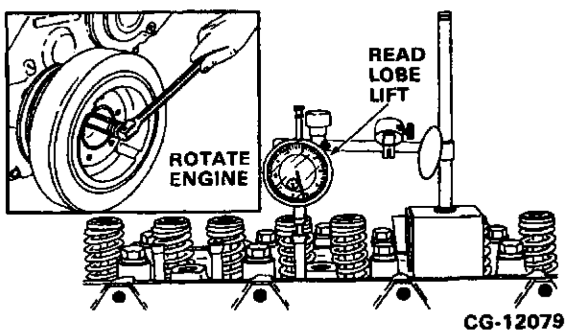

Figure 5. 14. Measure Camshaft Lobe Lift — Step Two

NOTE: If a complete engine overhaul is scheduled, camshaft lobe wear can be determined by measuring the lobes with a micrometer when the camshaft is removed.

REMOVAL

Remove the following:

— Crossover pipe (DT–360 only)
— Fuel injection lines (high pressure)
— Fuel leak–off lines (low pressure)
— Fuel injection nozzles
— Aneroid tube
— Intake manifold
— Turbocharger
— Thermostat housing and thermostat
— Valve cover
— Rocker arm assembly
— Push rods
— Cylinder head
— Injection pump
— Vibration damper and pulley
— Oil pump
— Water pump pulley
— Water pump
— Oil pan and pick–up tube
— Engine front cover

Refer to the appropriate manual section for removal procedures.

1. Remove tappets from their bores.

NOTE: Mark the tappets as to location in the engine block, so they can be returned to their original position.

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CAMSHAFT, TAPPETS & PUSH RODS — Continued

REMOVAL — Continued

2. Prior to camshaft removal, mount a magnetic base dial indicator on the front of the engine and check camshaft gear backlash (**Figure 5.15**).

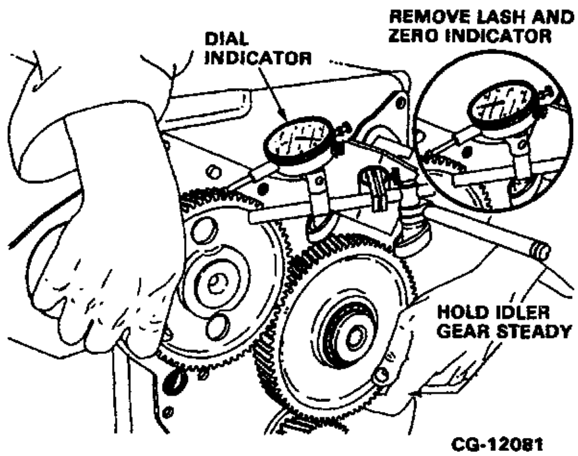

Figure 5.15. Measure Camshaft Gear Backlash

   a. Position the dial indicator tip @ a gear tooth and remove lash.
   b. "Zero" the dial indicator.
   c. Hold the idler gear steady and move the camshaft gear by hand. Read the indicator and record the backlash.

3. Reposition the dial indicator and check camshaft end play (**Figure 5.16**) as follows:
   a. Position the dial indicator tip on the camshaft hub.
   b. Push the camshaft toward the rear of the engine.
   c. "Zero" the dial indicator.
   d. Place a small pry bar between the camshaft gear and the front plate. Push the gear out and read the end play on the dial indicator. Compare the dial indicator reading with the specifications.
   e. Remove the dial indicator.
   f. If end play exceeds specified limits (see **"SPECIFICATIONS"**), replace the camshaft thrust plate.

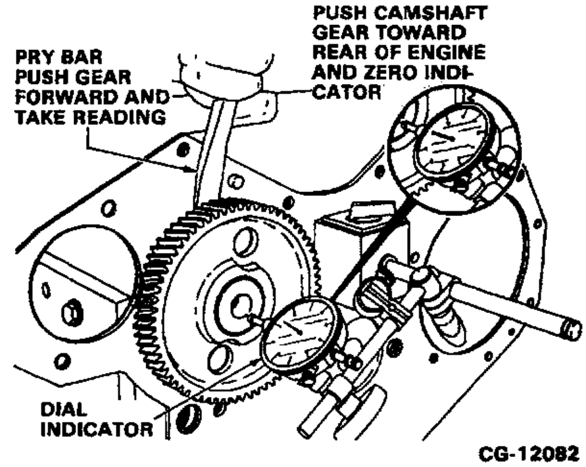

Figure 5.16. Check Camshaft End Play

NOTE: Turn the engine stand so the front of the engine is facing up (engine in vertical position). This position allows for easy removal of the camshaft assembly.

4. Rotate the camshaft gear so the access hole in the gear align with the thrust plate retaining bolts.
5. Remove the two thrust plate bolts an washers. Refer to **Figure 5.17.**

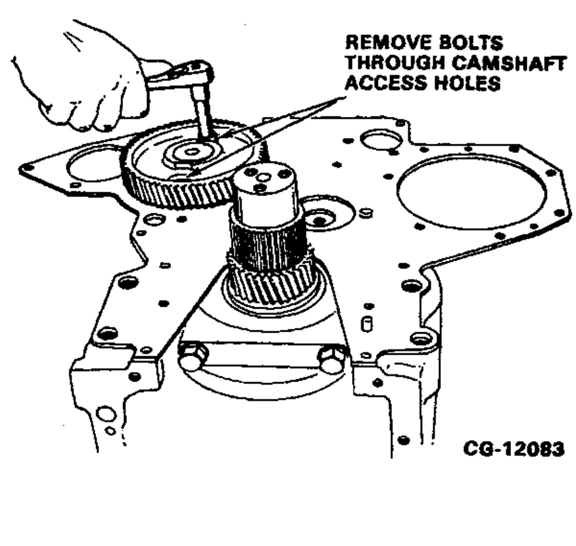

Figure 5.17. Remove Thrust Plate

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CAMSHAFT, TAPPETS & PUSH RODS — Continued

REMOVAL — Continued

6. Remove the camshaft from the crankcase by lifting the assembly straight up. Refer to **Figure 5.18.**

NOTE: This method reduces the risk of damaging the camshaft journals and/or bushings.

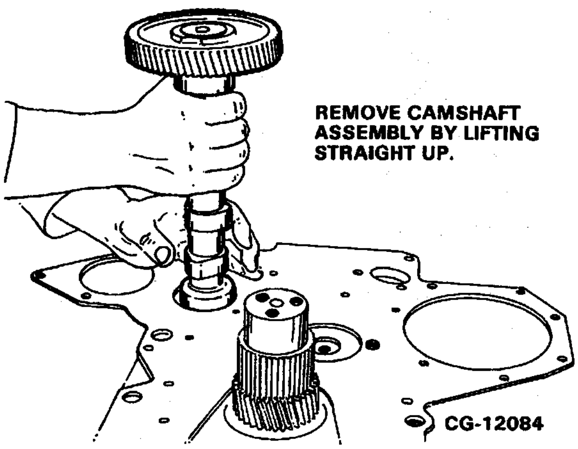

Figure 5.18. Remove Camshaft

CAMSHAFT DISASSEMBLY

NOTE: The camshaft gear is a shrink fit on camshaft and must be pressed off.

1. Using a suitable arbor press, press the camshaft from the gear.
2. With the gear removed, remove the woodruff key and the thrust plate.

CAMSHAFT CLEANING AND INSPECTION

1. Wash the camshaft in a suitable solvent using a soft bristle brush.
2. Visually inspect the camshaft. If any lobes are scuffed, scored or cracked, replace the camshaft.
3. Beyond visual inspection, evaluate camshaft journal and lobe condition using a micrometer as follows:

   a. Check camshaft lobe wear using a micrometer as follows: Refer to **Figure 5.19.**

      1. Measure across (A–C) and across (B–D). Refer to **Figure 5.19.**
      2. Subtract (B–D) from (A–C). This will give cam lobe lift. (See **"SPECIFICATIONS"**.)
      3. Replace camshaft when cam lobe wear exceeds specifications.

   b. Repeat for each cam lobe.

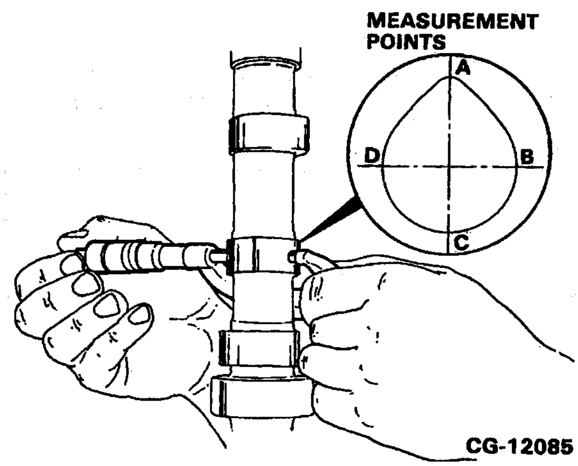

Figure 5.19. Measure Camshaft Lobes

4. Visually inspect the thrust plate for wear, cracks or distortion. Use a micrometer to measure thrust plate thickness (see **"SPECIFICATIONS"**). Replace the thrust plate if worn, damaged or if excessive end play is measured; as previously described.
5. Visually inspect the camshaft gear for worn or damaged teeth or a widened/distorted bore which will prevent a tight fit. Replace the gear if any of these conditions exist.

If camshaft gear backlash exceeds specifications, replace the camshaft gear and/or idler gear, as required.

CAMSHAFT, TAPPETS & PUSH RODS — Continued

CAMSHAFT REASSEMBLY

1. Reassemble the camshaft, thrust plate and camshaft gear as follows:
   a. Support the camshaft in an appropriate arbor press.
   b. Place the thrust plate on the keyway end of the camshaft against the bearing journal.
   c. Insert the woodruff key into the keyway.
   d. Heat the camshaft gear to approximately 400° F (205° C).

NOTE: Use a thermomelt stick, available at any welding supply house, to determine temperature.

   e. Press the gear against the shoulder on the shaft with the timing mark pointed upward as shown in **Figure 5.20.**

CAUTION !

Use protective gloves when installing gear.

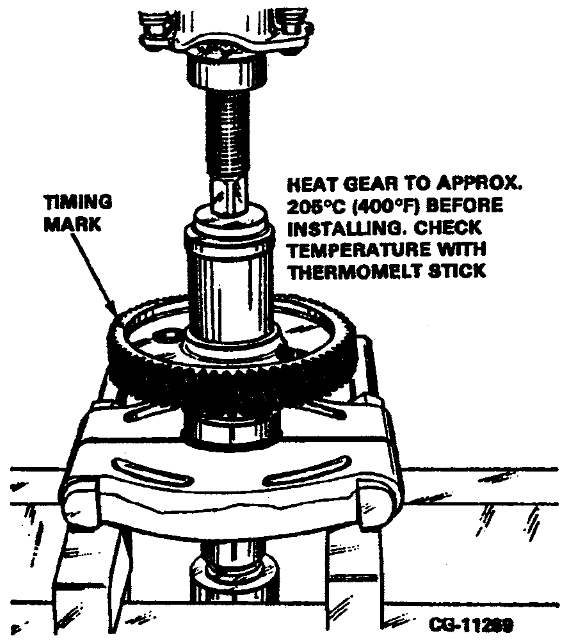

Figure 5.20. Installing Camshaft Drive Gear

CAMSHAFT BUSHING INSPECTION

1. Inspect the four camshaft bushings for wear and proper running clearance as follows:
   a. Measure camshaft bushing journal diameter using a micrometer. Measure at two locations and record the readings.
   b. Using a telescoping gauge and micrometer, measure the camshaft bushing I.D. (with bushing installed in the crankcase). Record the readings.
   c. Subtract the readings obtained in steps a and b, to determine running clearance.
   d. If maximum allowable running clearance is exceeded (see **"SPECIFICATIONS"**), replace the camshaft bushings using the camshaft bushing remover and installer (ZTSE–2893).

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CAMSHAFT, TAPPETS & PUSH RODS — Continued

CAMSHAFT BUSHING REMOVAL

IMPORTANT

WHEN SERVICING THE CAMSHAFT BUSHINGS, THE CRANKSHAFT AND MAIN BEARINGS MUST BE REMOVED FROM THE CRANKCASE TO AVOID DEBRIS CONTAMINATION.

1. Use the camshaft bushing remover and installer (ZTSE–2893) to remove the camshaft bushings.

NOTE: ZTSE–2893 includes:

- **Puller screw**
- **Expanding mandrel**
- **Puller screw extension**
- **Expanding collet**
- **Pulling nut**
- **Back–up nut**
- **Thrust bearing**
- **Extension tube ***

*** Used only during front camshaft bushing removal.**

Refer to **Figure 5.21.**

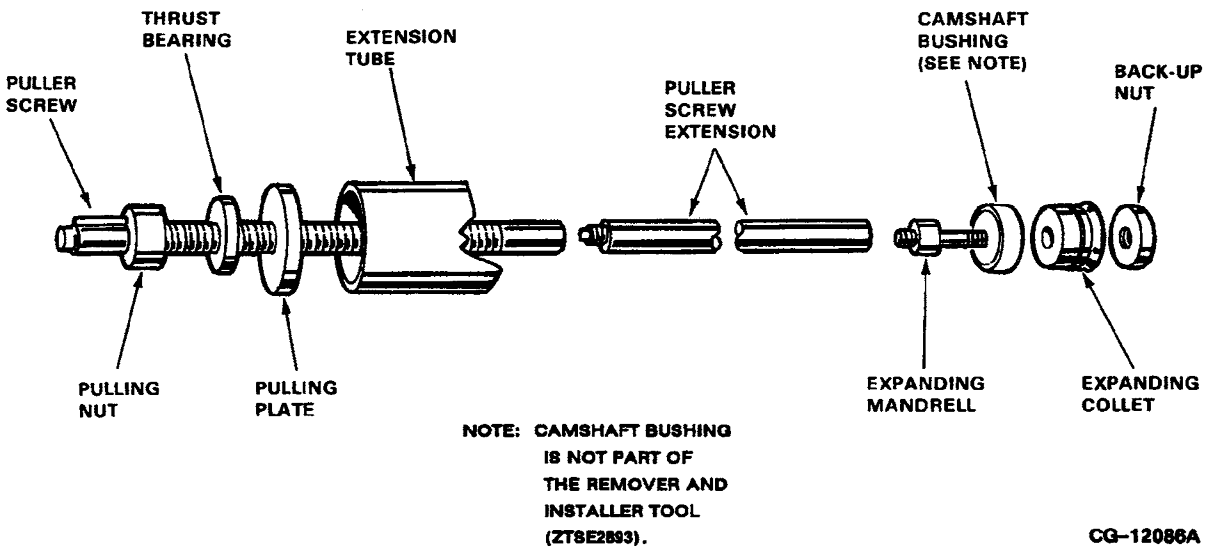

Figure 5.21. Camshaft Bushing Remover and Installer ZTSE–2893

CAMSHAFT, TAPPETS & PUSH RODS — Continued

CAMSHAFT BUSHING REMOVAL — Continued

NOTE: The four camshaft bushings have the same inside diameter, but the outside diameter and widths of each bushing are different, as is the crankcase bore into which each bushing fits. Refer to the chart below.

IMPORTANT

BECAUSE OF THE DIFFERENT SIZE OUTSIDE DIAMETERS OF THE BUSHINGS, THE ORDER OF REMOVAL IS LIMITED AS FOLLOWS: REMOVE THE FRONT AND REAR BUSHINGS FIRST. THEN REMOVE THE TWO INTERMEDIATE BUSHINGS THROUGH THE FRONT OF THE CRANKCASE.

CAMSHAFT BUSHING CHART

BUSHING POSITION	BUSHING O.D.	BUSHING BORE DIA. IN CRANKCASE	BUSHING WIDTH
Front	2.5065 in. 2.5050 in.	2.5020 in. 2.5005 in.	1.00 in.
Intermediate/ Front	2.4865 in. 2.4850 in.	2.4820 in. 2.4805 in.	0.709 in. 0.689 in.
Intermediate/ Rear	2.4665 in. 2.4650 in.	2.4620 in. 2.4605 in.	0.709 in. 0.689 in.
Rear	2.4465 in. 2.4450 in.	2.4420 in. 2.4405 in.	0.740 in. 0.660 in.

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CAMSHAFT, TAPPETS & PUSH RODS — Continued

CAMSHAFT BUSHING REMOVAL — Continued

2. Using the camshaft bushing remover and installer tool (ZTSE–2893), select the proper size expanding collet and back–up nut and assemble onto the expanding mandrel. With the expanding collet collapsed, install the collet assembly into the camshaft bushing to be removed and tighten the back–up nut onto the expanding mandrel until the collet fits the camshaft bushing. Refer to **Figures 5.21 and 5.22.**
3. Assemble the puller screw and extension, if necessary, and install onto the expanding mandrel. Tighten the pulling nut against the thrust bearing and pulling plate to remove the camshaft bushing.

NOTE: Be sure to hold the end of the puller screw with a wrench to prevent it from turning, when tightening the pulling nut.

4. Repeat the procedure for each bushing.

NOTE: To remove the front bushing, install the puller screw from the rear of the crankcase, using the extension tube in front of the pulling plate. All other bushings are removed by going through the front of the crankcase.

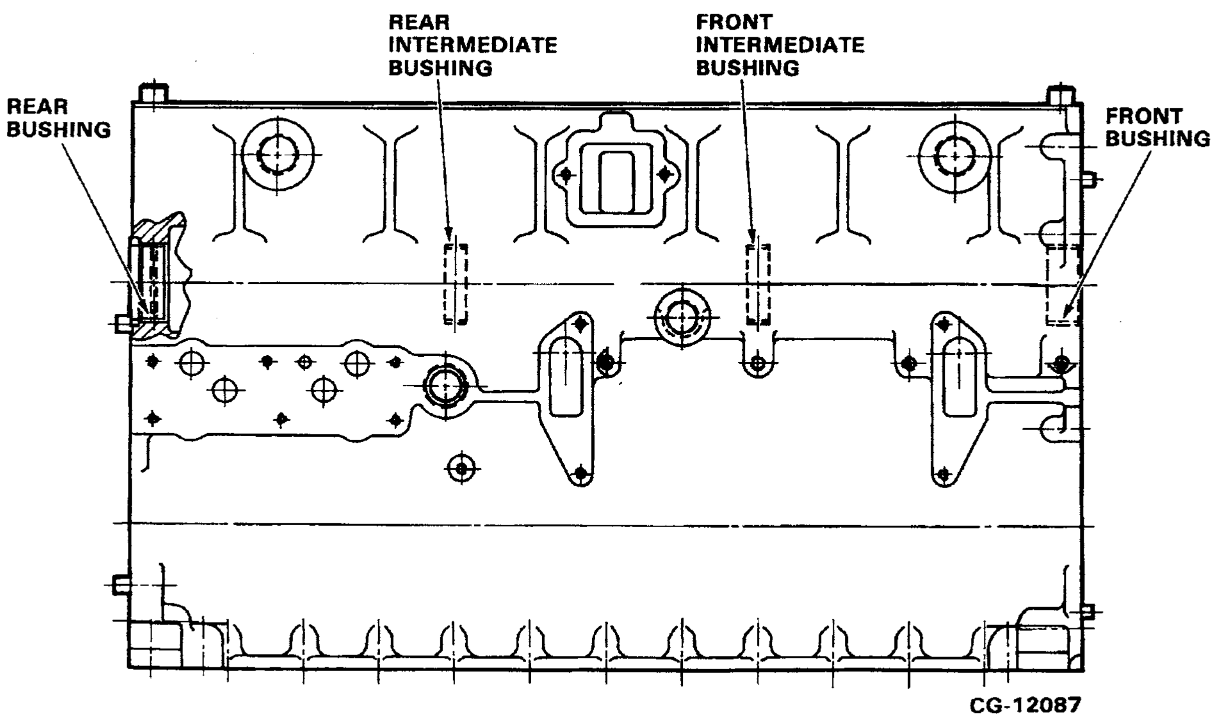

Figure 5.22. Camshaft Bushing Locations in Crankcase

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CAMSHAFT, TAPPETS & PUSH RODS — Continued

CRANKCASE BUSHING BORE INSPECTION

1. Visually inspect each bushing bore in the crankcase for burrs or debris that could damage the new bushings when they are installed.
2. Remove any burrs and clean the bores thoroughly before installing new camshaft bushings.

CAMSHAFT BUSHING INSTALLATION

1. Identify each bushing by its outside diameter. Refer to the "CAMSHAFT BUSHING CHART" which appears earlier in this section.
2. Lubricate the new camshaft bushings as well as the crankcase bushing bores with clean engine oil.
3. Install the new bushing onto the expanding collet and tighten the collet by turning the back–up nut until the bushing is held securely. Refer to **Figure 5.23.**

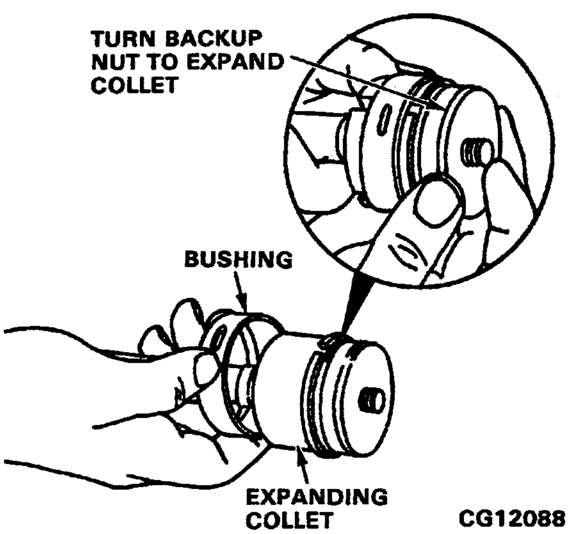

Figure 5.23. Install Bushing on Installer Tool

4. Mark the oil hole location on the back–up nut of the installation tool to aid in the alignment of the bushing and crankcase oil holes. Refer to **Figure 5.24.**

NOTE: This step must be repeated for each bushing installed.

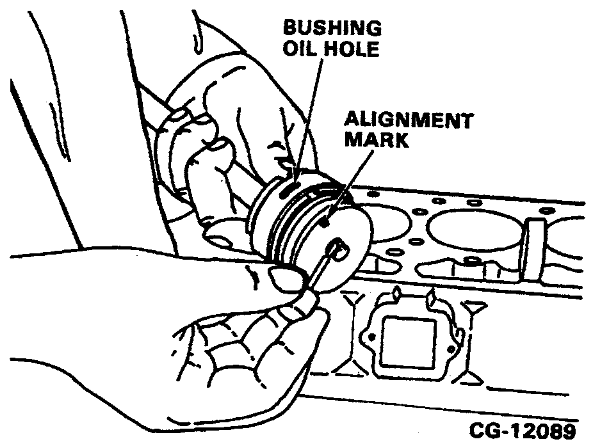

Figure 5.24. Mark Oil Hole Location

IMPORTANT

THE BUSHINGS MUST BE INSTALLED IN THE PROPER ORDER BECAUSE OF THE DIFFERENT OUTSIDE DIAMETERS OF THE BUSHINGS.

5. Install the rear intermediate bushing through the front of the crankcase, then pull it into place at the rear of the crankcase by turning the pulling nut on the puller screw. Refer to **Figure 5.25.** Remove the tool and inspect oil hole alignment.

CAMSHAFT, TAPPETS & PUSH RODS — Continued

CAMSHAFT BUSHING INSTALLATION — Continued

6. Install the front intermediate bushing next. Install through the front of the crankcase and pull into place from the rear. Refer to **Figure 5.25.**
7. Next install the front camshaft bushing by pulling it into place from the rear.
8. The rear camshaft bushing must be pulled into place from the front of the crankcase.

IMPORTANT

ALL BUSHING OIL HOLES MUST BE IN ALIGNMENT WITH THE OIL HOLES IN THE CRANKCASE.

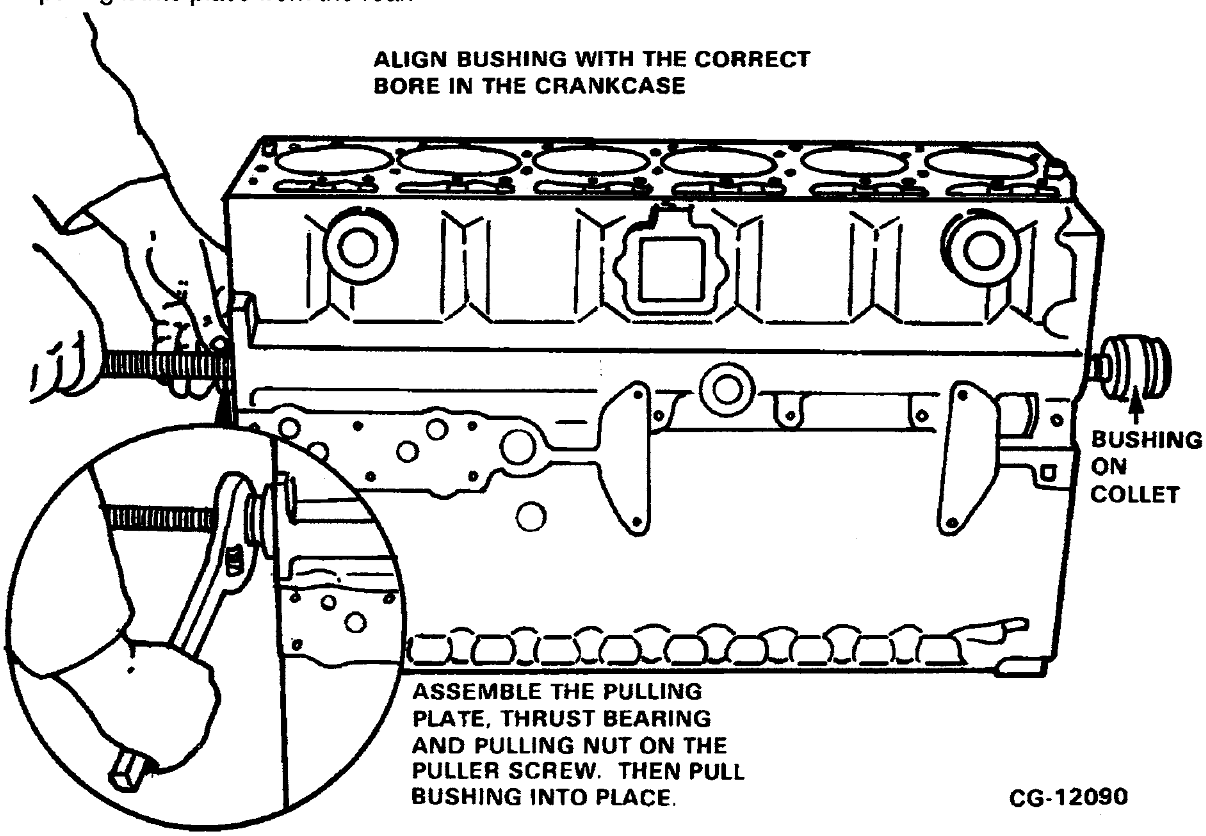

Figure 5.25. Camshaft Bushing Installation

CAMSHAFT, TAPPETS & PUSH RODS — Continued

TAPPET INSPECTION

1. Visually inspect all tappets. Replace any tappet which is scuffed, scored, cracked, pitted or worn.

PUSH ROD CLEANING AND INSPECTION

1. Thoroughly clean each push rod using a suitable solvent and dry using filtered compressed air.
2. Visually inspect each rod for wear at the ends. Replace as required.
3. Check all push rods for straightness by rolling on a flat surface, **Figure 5.26**. Replace any rod which is bent.

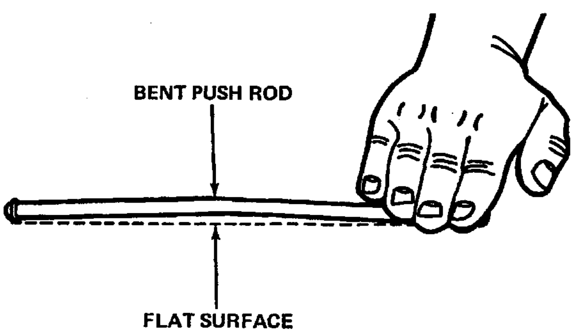

Figure 5.26. Checking Push Rod for Straightness

4. Check push rod run–out. If **"SPECIFI–CATIONS"** are exceeded, replace the rod.

INSTALLATION

CAMSHAFT ASSEMBLY

1. With the engine in the vertical position, lubricate the camshaft and the camshaft bushings using clean engine oil.
2. Gently slide the camshaft assembly into the crankcase. Be careful not to damage the camshaft bushings.
3. Align gear train timing marks. Refer to **Figure 5.27.**

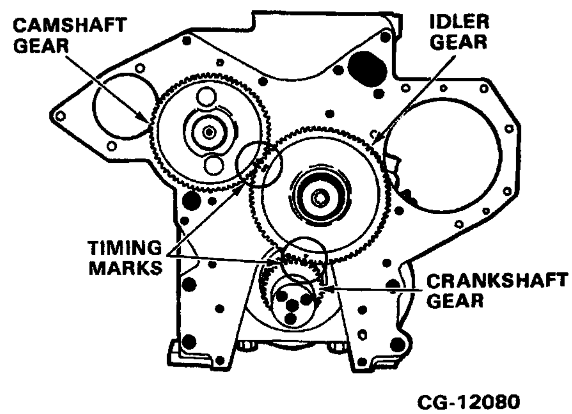

Figure 5.27. Align Gear Train Timing Marks

4. Align the camshaft gear so the bolts can be inserted through the gear access holes into the thrust plate. Tighten each bolt to the specified special torque. Refer to **Figure 5.28.**

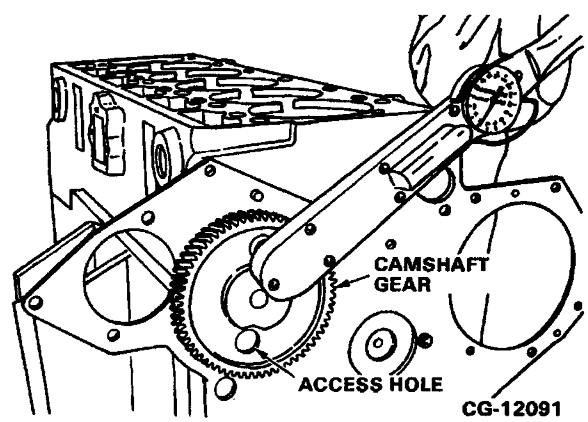

Figure 5.28. Tighten Camshaft Bolts

5. Check camshaft gear backlash and camshaft end play. Refer to **Figures 5.15 and 5.16** for procedure. Specification must be met.

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CAMSHAFT, TAPPETS & PUSH RODS — Continued

INSTALLATION — Continued

TAPPETS

1. Lubricate the tappets with clean engine oil.
2. Install the tappets into their original bores, unless new tappets are used.

PUSH RODS

1. Install push rods with the cup end up. Refer to Section 4.

Reinstall the following:

NOTE: Refer to the appropriate manual section for installation procedures.

- Engine front cover
- Pick–up tube and oil pan
- Water pump
- Water pump pulley
- Oil pump
- Vibration damper and pulley
- Injection pump
- Cylinder head
- Push rods
- Rocker arm assembly
- Valve cover
- Thermostat and housing
- Turbocharger
- Intake manifold
- Aneroid tube
- Fuel injection nozzles
- Fuel leak–off lines
- Fuel injection lines
- Crossover pipe (DT–360 only)

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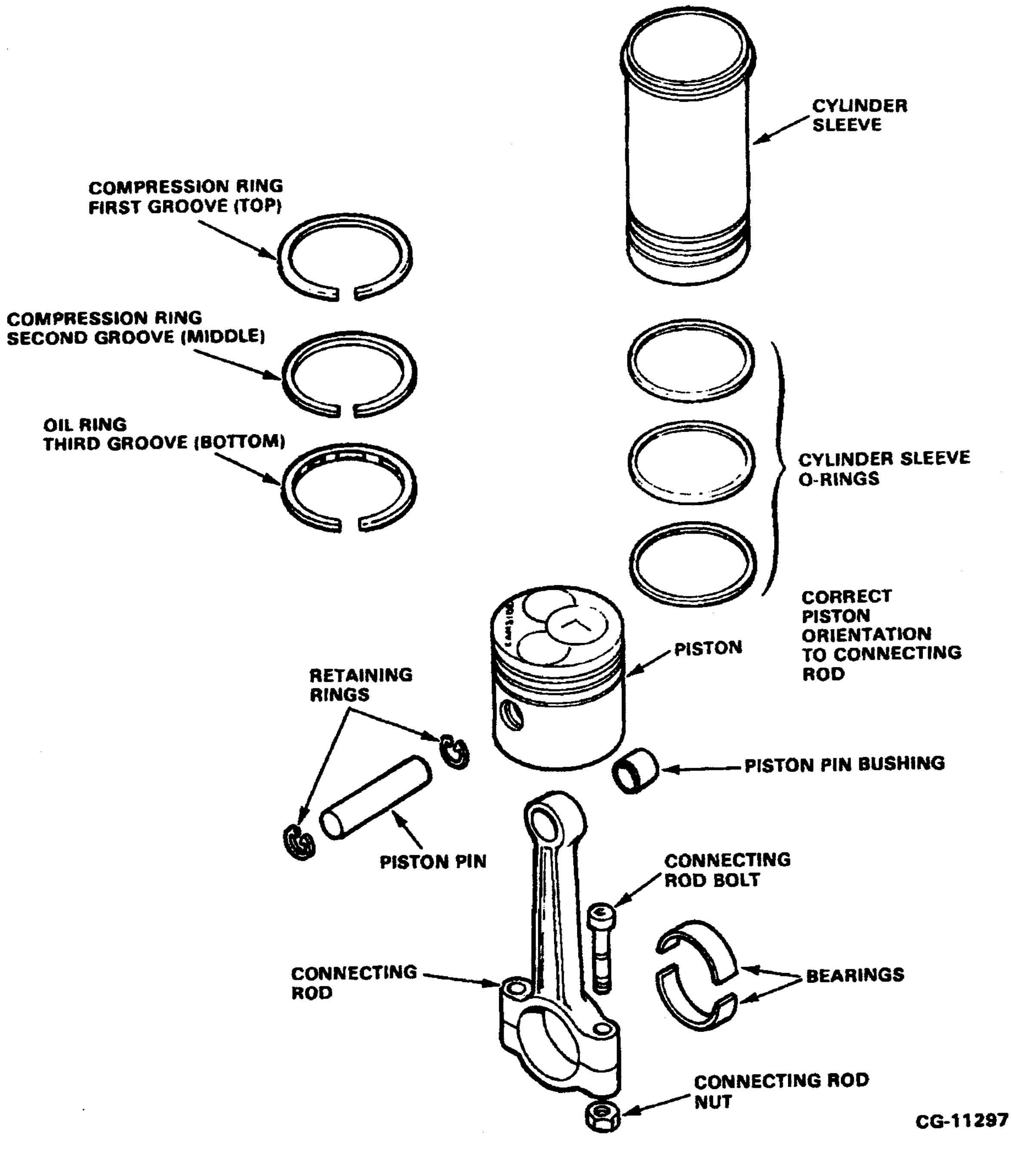

Figure 6.1. Connecting Rods, Pistons, Rings and Sleeves

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SPECIFICATIONS

DIMENSION TITLE	VALUES
CONNECTING RODS:	
Center–to–Center Distance between Connecting Rod Bearing Bore and Piston Pin Bushing Bore	8.419 in. (213.84 mm 8.421 in. (213.89 mm)
Bushing Bore Diameter (Pin End)	1.622 in. (41.198 mm) 1.624 in. (41.249 mm)
Piston Pin Bushing I.D. (Installed)	1.4971 in. (38.026 mm) 1.4975 in. (38.036 mm)
Bearing Bore Diameter (Crankshaft End)	2.6771 in. (67.998 mm) 2.6779 in. (68.018 mm)
Maximum Out–of–Round	0.002 in. (0.05 mm)
Maximum Taper/Inch	0.0005 in. (0.0127 mm)
Connecting Rod Bearing I.D. (Installed)	2.5215 in. (64.045 mm) 2.5233 in. (64.092 mm)
Bearing Running Clearance	0.0018 in. (0.046 mm) 0.0051 in. (0.103 mm)
Maximum Permissible Bearing Running Clearance (Before Reconditioning)	0.007 in. (0.18 mm)
Connecting Rod Slide Clearance on Crankshaft	0.009 in. (0.23 mm) 0.015 in. (0.38 mm)
Maximum Permissible Side Clearance on Crankshaft	0.018 in. (0.46 mm)
Connecting Rod Alignment (Max. Total Difference)	
Twist	0.002"/in. (0.0508 mm/in.)
Bend	0.001"/in. (0.0254 mm/in.)
PISTONS:	
Running Clearance between Piston and Cylinder Sleeve	0.0035 in. (0.089 mm) 0.0065 in. (0.165 mm)
Skirt Diameter (Measured 90° from pin bore and 1.146 in. below bottom ring land)	4.0035 in. (101.689 mm) 4.0045 in. (101.714 mm)
Number of Rings per Piston	3
Piston Ring Groove Widths:	
Top Compression Ring – Measure over 0.1150 in. gauge pins (Full Keystone)	4.0239 in. Upper Limit 3.9933 in. Replacement Limit
Intermediate Compression Ring – Measured over 0.1150 in. gauge pins (Full Keystone)	4.0279 in. Upper Limit 3.9964 in. Replacement Limit

SPECIFICATIONS

DIMENSION TITLE	VALUES
PISTONS — Continued:	
Side Clearance:	
Oil Control Ring	0.0015 in. (0.038 mm) 0.0035 in. (0.089 mm)
PISTON RINGS – COMPRESSION:	
Number of rings per piston	2
Type (face and finish):	
Top Ring (Eff. with S/N 072706)	Full Keystone (barrel face) – Plasma Coated
Top Ring (Prior to S/N 072706)	Full Keystone (barrel face) – Chrome
Intermediate Ring	Full Keystone (tapered face)
Ring Gap with New Sleeve:	
Top Ring	0.015 in. (0.30 mm) 0.033 in. (0.64 mm)
Intermediate Ring	0.060 in. (1.52 mm) 0.078 in. (1.98 mm)
PISTON RINGS – OIL CONTROL:	
Number of Rings Per Piston	1
Type	One Piece Slotted – Chrome
Ring Gap	0.010 in. (0.25 mm) 0.026 in. (0.66 mm)
PISTON PINS:	
Diameter	1.4955 in. (37.986 mm) 1.4957 in. (37.991 mm)
Length	3.287 in. (83.49 mm) 3.297 in. (83.74 mm)
Clearance in Rod	0.0014 in. (0.036 mm) 0.0020 in. (0.051 mm)
Maximum Permissible Clearance in Rod, before replacing	0.003 in. (0.08 mm)
Clearance in Piston (measured in vertical plane)	0.0004 in. (0.010 mm) 0.0008 in. (0.020 mm)
Clearance in Piston (measured in horizontal plane)	0.0010 in. (0.025 mm) 0.0018 in. (0.046 mm)
Maximum Permissible Clearance in Piston, before replacing	0.0025 in. (0.064 mm)

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SPECIFICATIONS

DIMENSION TITLE	VALUES
CYLINDER SLEEVES:	
Inside Diameter (New)	4.0095 in. (101.841 mm) 4.0105 in. (101.870 mm)
Maximum Permissible Diameter Sleeve Wear, at Top of Ring Travel before Replacement (Sleeve Taper)	0.004 in. (0.10 mm)
Counterbore Dimension in Crankcase	0.348 in. (8.84 mm) 0.350 in. (8.89 mm)
Maximum Allowable Variation of Counterbore Depth (Between Four Points)	0.001 in. (0.025 mm)
Maximum Cylinder Sleeve Counterbore Allowable Depth	0.413 in. (10.49 mm)
Flange Thickness	0.352 in. (8.94 mm) 0.353 in. (8.97 mm)
Protrusion above Crankcase	0.002 in. (0.05 mm) 0.005 in. (0.13 mm)

SPECIAL TORQUES

Connecting Rod Nuts .... 85 lbf–ft. (115 Nm)

SPECIAL TOOLS

Tool No.	Description
ZTSE–2536	Universal Wet Sleeve Puller
ZTSE–4220	Piston Ring Expander
ZTSE–3020	Piston Groove Wear Gauge Pins
ZTSE–2515	Surface Gauge
ZTSE–1632	Oil Leak Detector
ZTOEM–6269	Band Type Ring Compressor
– – –	Counterbore Cutter Tool (Includes Driver Unit, Handle, Tool Bits and Adapter Plates)

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COMPONENT IDENTIFICATION

PISTONS:

1987 and 1988 model year engines require different pistons to meet their respective exhaust emission requirements. The pistons are identified by the production part number located on the top of the piston. Refer to **Figure 6.2.** Refer to the current parts catalog for service part numbers.

NOTE: The 1988 model year pistons have a reduced compression height and slightly revised bowel configuration and valve pocket depth. The changes are not visible to the naked eye; however, they are critical to assure compliance with exhaust emission standards and provide expected engine performance.

IMPORTANT

DO NOT INTERMIX 1987 MODEL YEAR PISTONS WITH 1988 MODEL YEAR PISTONS OR VICE VERSA. ENGINE PERFORMANCE AND EXHAUST EMISSIONS WILL BE ADVERSELY EFFECTED.

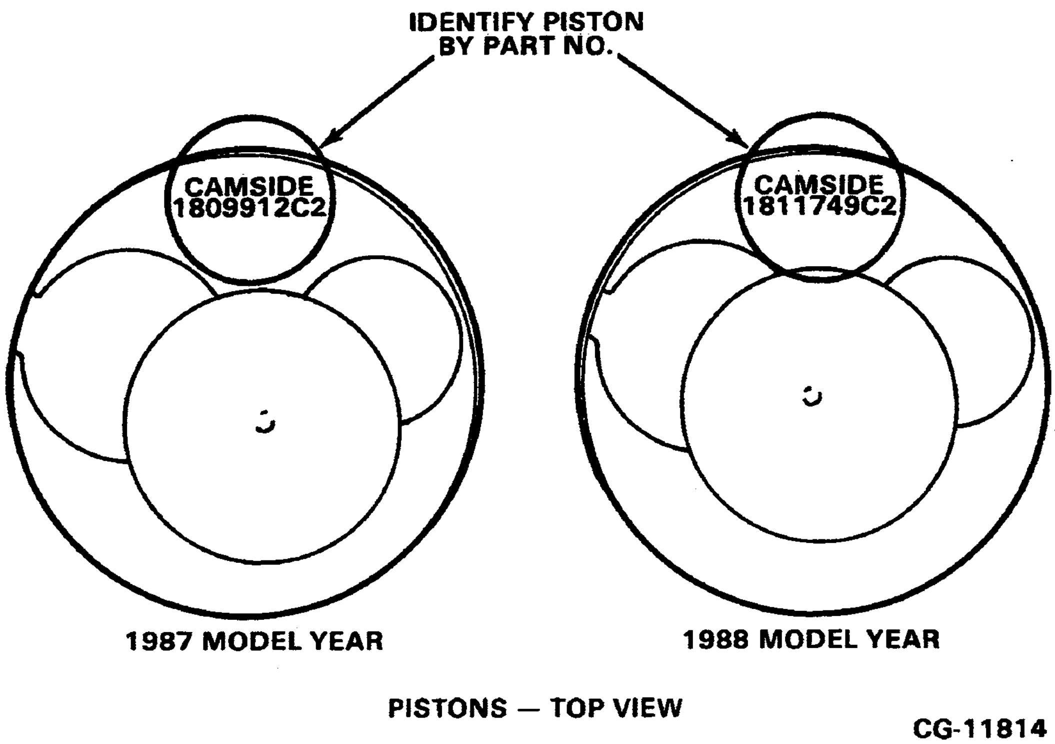


Figure 6.2. Piston Identification

COMPONENT IDENTIFICATION

PISTONS:

Effective with S/N 072706 (1990 model year) pistons have an increased depth and volume in the combustion bowl area. This increase in volume area, decreases the compression ratio to 16.25:1. The correct piston can be identified by the production part number located on top of the piston. Refer to **Figure 6.3.** Refer to the current parts catalog for service part numbers.

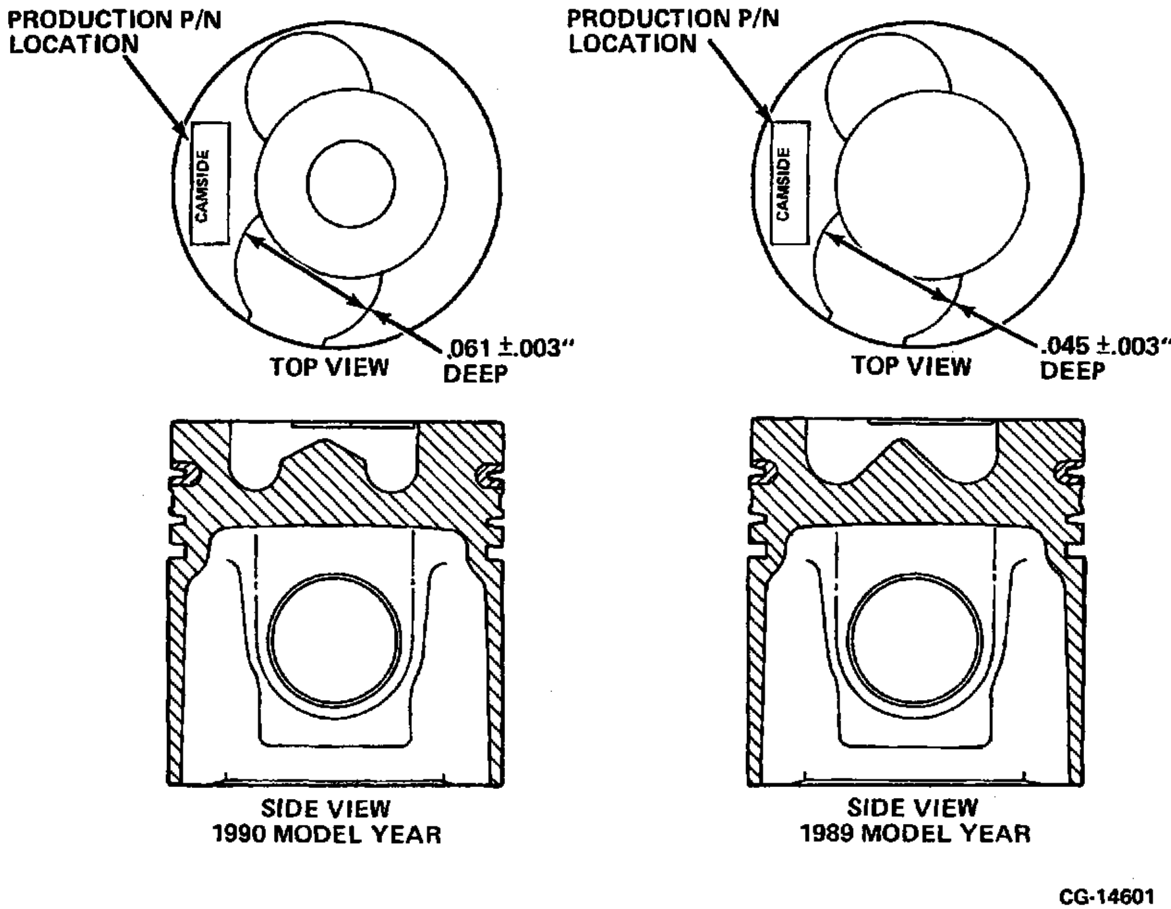


Figure 6.3. 1989 vs. 1990 Model Year Piston Comparison

COMPONENT IDENTIFICATION

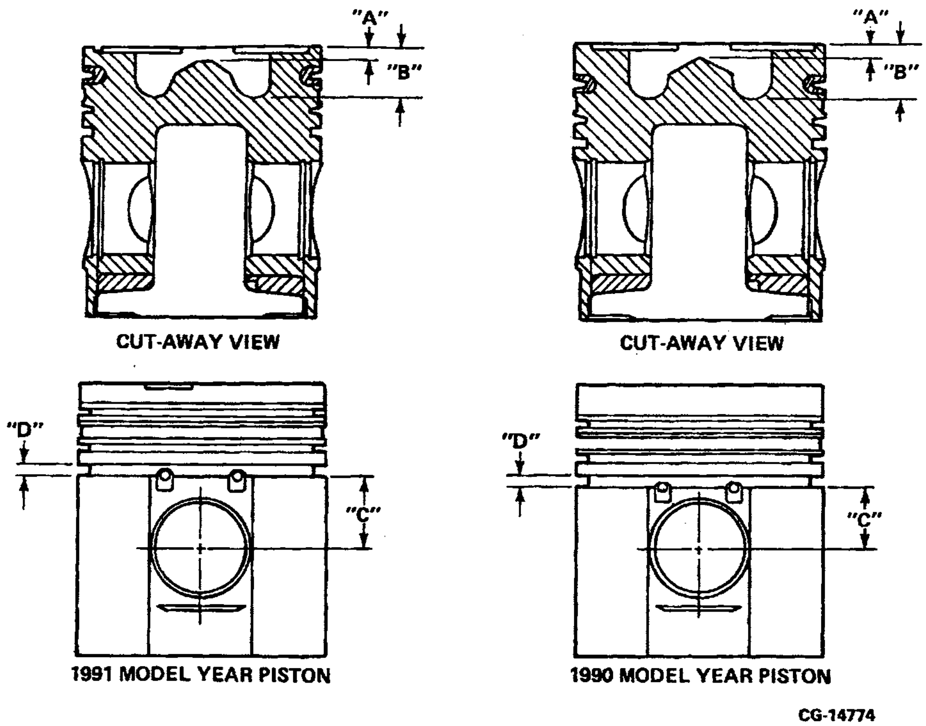
PISTONS:

Effective with S/N 090976 (1991 model year) pistons have the following design changes: Refer to **Figure 6.3.A.**

1. Piston bowl geometry ("A") is increased and ("B") decreased to increase the compression ratio to 17.5:1.
2. Raised groove position ("C") to reduce dead volume.
3. Oil control ring groove ("D") is increased in width to accomodate new wider designed oil control ring.

IMPORTANT

1990 AND 1991 MODEL YEAR PISTONS OR PISTON RINGS ARE _NOT_ INTERCHANGEABLE AND ARE _NOT_ TO BE SUBSTITUTED FOR EACH OTHER IN SERVICE. REFER TO CURRENT PARTS CATALOG FOR SERVICE PART NUMBERS.



MODEL YEAR	DIMENSIONAL CHANGES "A"	"B"	"C"	"D"
1990	.198± .002	.860± .002	.989	.1570± .0005
1991	.200± .002	.808± .002	1.175	.1585± .0005

Figure 6.3.A. 1990 vs. 1991 Model Year Piston Comparison

CONNECTING RODS, PISTONS, RINGS AND SLEEVES

Removal

Remove the following:

- Crossover pipe (DT–360 only)
- Fuel injection lines (high pressure)
- Fuel leak–off lines (low pressure)
- Fuel injection nozzles
- Aneroid tube
- Valve cover
- Thermostat housing to water pump hose
- Turbocharger oil inlet and oil drain tubes
- Rocker arm assembly
- Cylinder head assembly (with intake manifold, exhaust manifold, thermostat housing and turbocharger attached)
- Vibration damper and pulley
- Oil pan
- Oil pickup tube

Refer to the appropriate manual section for detailed removal procedures.

PISTON & ROD ASSEMBLY REMOVAL

1. Using a razor knife, scrape the carbon ridge from the top of the cylinder sleeve. Refer to **Figure 6.4.**

IMPORTANT

THE CARBON RIDGE MUST BE REMOVED BEFORE REMOVING THE PISTON AND ROD ASSEMBLY. THIS REDUCES THE CHANCE OF PISTON RING LAND DAMAGE DURING REMOVAL.

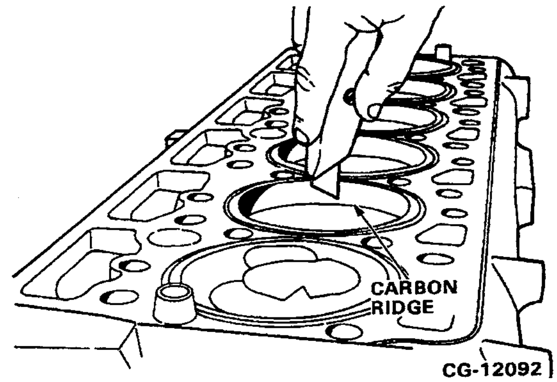


Figure 6.4. Remove the Carbon Ridge from the Top of Each Cylinder Sleeve

2. Verify connecting rod bolt torque on all connecting rods as follows: (Refer to **Figure 6.5**)

<u>PULL–UP–TO–THE–MARK METHOD</u>

a. Place a socket over the connecting rod nut then mark the socket and a point on the connecting rod nut that is in line with the socket mark.

b. Using a breaker–bar, loosen the bolt one–eighth of a turn.

c. Without disturbing the socket location, remove the breaker–bar and install a torque wrench in its place.

d. Turn the nut until the socket mark and the connecting rod mark is aligned.

e. With marks aligned, record the torque reading.

f. Repeat this procedure for all connecting rod nuts.

NOTE: If the torque reading varies by more than 10 lbf–ft. from the specified torque, a <u>CLOSE</u> inspection of the connecting rod cap and bolts are required.

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Removal — Continued

PISTON & ROD ASSEMBLY REMOVAL — Continued

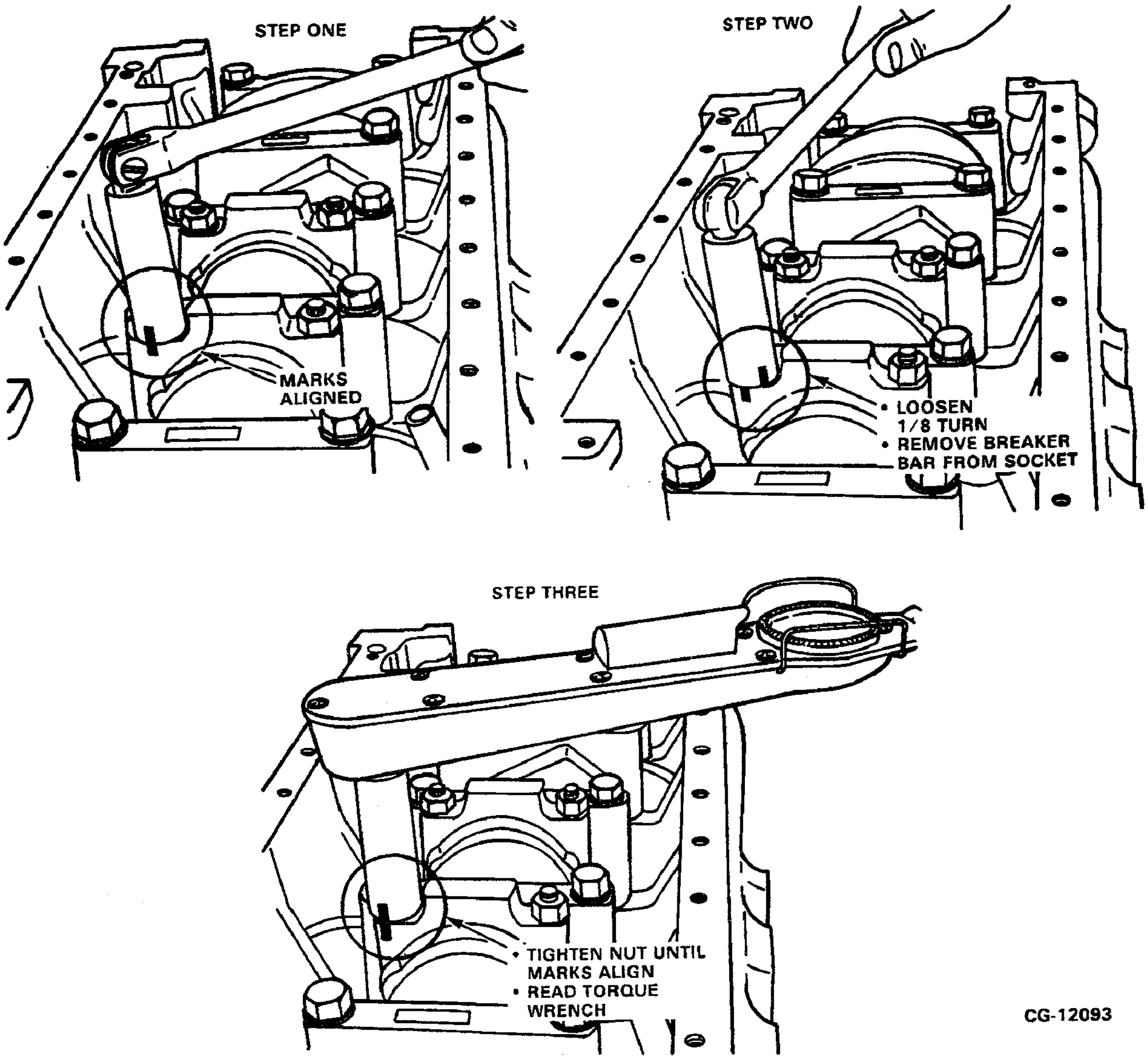


Figure 6.5. Check Bolt Torque (Using Pull–Up–to–the–Mark Method)

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Removal — Continued

PISTON & ROD ASSEMBLY REMOVAL — Continued

3. Loosen the connecting rod nuts using a socket and breaker–bar, **Figure 6.6.**

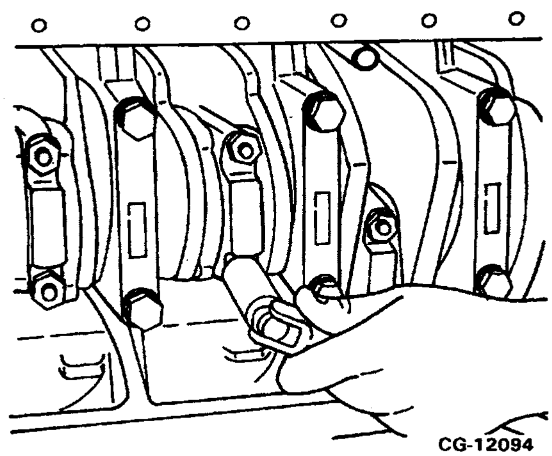


Figure 6.6. Loosen Connecting Rod Nuts

4. Remove the nuts, by hand. Refer to **Figure 6.7**.

NOTE: The nuts should turn off the connecting rod bolt freely. If binding exists, check thread condition carefully.

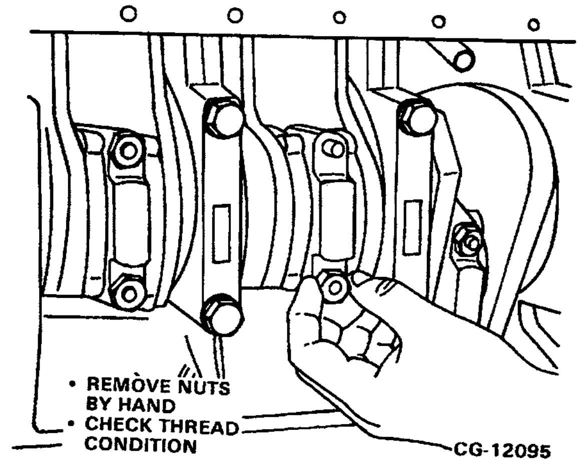


Figure 6.7. Remove Nuts by Hand

5. Remove the connecting rod cap and bearing insert. Refer to **Figure 6.8**.

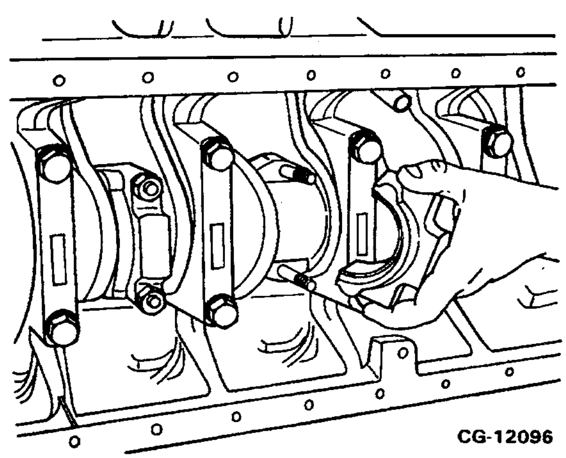


Figure 6.8. Remove the Connecting Rod Cap and Bearing Insert

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Removal — Continued

PISTON & ROD ASSEMBLY REMOVAL — Continued

6. Remove the upper connecting rod bearing insert by carefully inserting a small screwdriver at the edge of the bearing insert (between the connecting rod and the crankshaft journal) to release the tang. Refer to **Figure 6.9.**

IMPORTANT

BE CAREFUL NOT TO SCRATCH THE CRANKSHAFT JOURNAL.

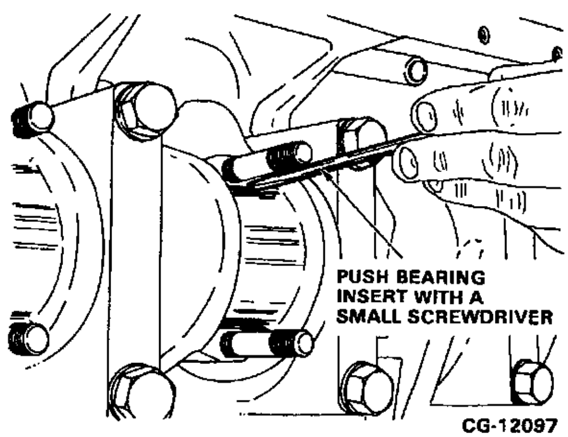


Figure 6.9. Release Bearing Insert Tang

7. Push the connecting rod up slightly to release pressure on the bearing insert. Slide the insert around the crankshaft journal and remove. Refer to **Figure 6.10.**

NOTE: With the connecting rod bearings removed, tape the halves together to form a circle. Mark the tape to indicate the cylinder location. This will aid during bearing inspection.

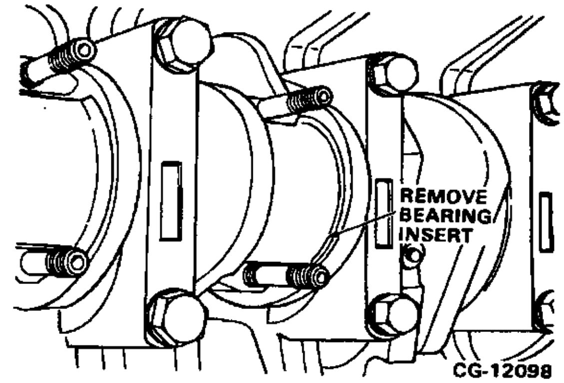


Figure 6.10. Remove Bearing Insert

8. Remove the piston and connecting rod assemblies as follows:
   a. Insert pieces of rubber hose over the rod bolt threads to protect the crankshaft journal from damage.
   b. Push the piston and rod assembly from the cylinder bore using a wood or plastic handle. Once the piston rings are free of the cylinder bore, the assembly can be removed from the top of the crankcase. Refer to **Figure 6.11.**
   c. Identify the connecting rod and piston assemblies upon removal so they can be reinstalled in their respective cylinder bores.

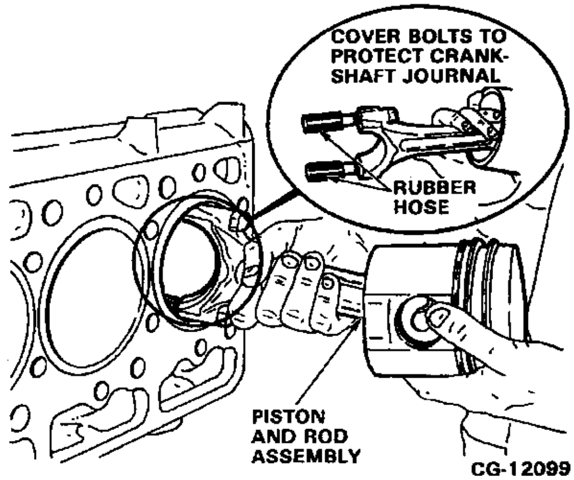


Figure 6.11. Remove Piston and Connecting Rod Assembly

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Removal — Continued

CYLINDER SLEEVE REMOVAL

1. Use the universal wet sleeve puller ZTSE–2536 to remove the cylinder sleeves as follows: (Refer to **Figure 6.12**)

IMPORTANT

PRIOR TO INSTALLING THE PULLER, BAR THE ENGINE OVER SO THE CRANKSHAFT JOURNAL IS LOCATED AT THE BOTTOM (LOW POINT) OF ITS TRAVEL. THIS PREVENTS POSSIBLE DAMAGE TO THE JOURNAL BY THE PULLER LIFTING JAWS DURING PULLER INSTALLATION.

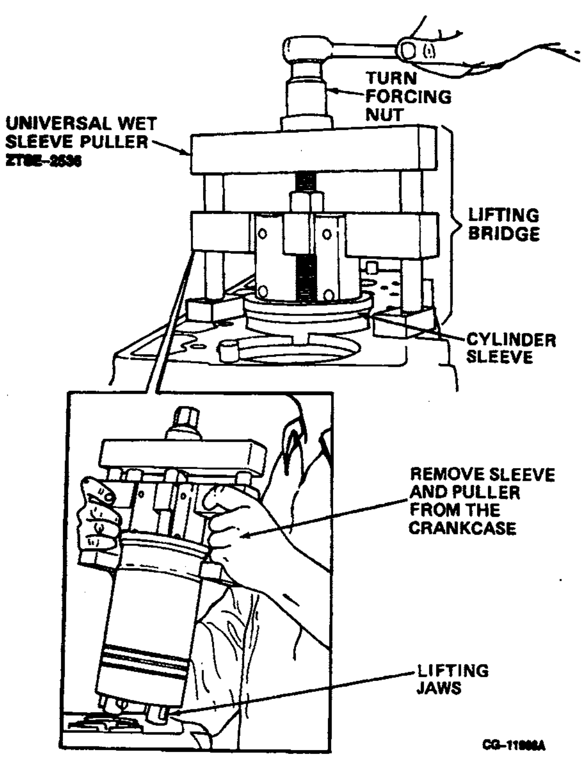


Figure 6.12. Remove Cylinder Sleeve

a. Position the puller in the sleeve and spread the lifting jaws so the tangs grip the bottom of the sleeve.

b. With the lifting bridge firmly on the crankcase top deck, turn the forcing nut to break the cylinder sleeve loose from the crankcase.

c. Lift the sleeve and puller from the crankcase.

d. Remove sleeve from puller and mark the sleeve with its cylinder bore number for purposes of inspection and reassembly.

Disassembly

CONNECTING ROD, PISTON & RING DISASSEMBLY:

1. Using pliers, remove the two piston retaining rings. Refer to **Figure 6.13.**

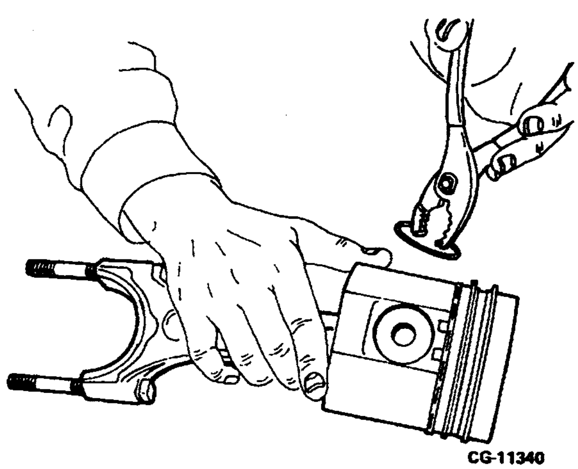


Figure 6.13. Remove Piston Pin Retaining Rings

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Disassembly — Continued

CONNECTING ROD, PISTON & RING DISASSEMBLY — Continued

2. Remove the piston pin from its bore, by hand. Refer to **Figure 6.14**. Then separate the connecting rod from the piston.

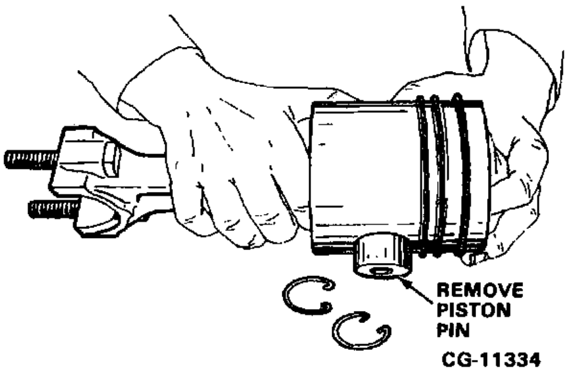


Figure 6.14. Remove Piston Pin

3. Use a piston ring expander tool (ZTSE–4220) to remove the piston rings. Remove the top ring first, then the second ring and the oil control ring. Refer to **Figure 6.15.**
4. Tag or mark the components with the cylinder number from which they were removed, so they may be reinstalled in their respective cylinders once inspected.

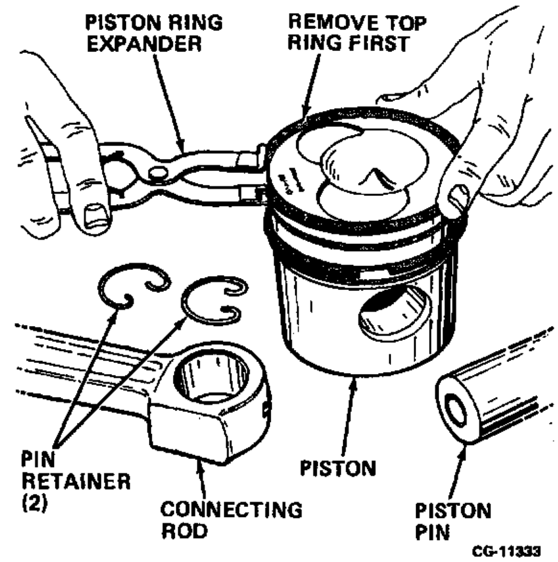


Figure 6.15. Remove Piston Rings

CYLINDER SLEEVE DISASSEMBLY:

1. Use a pic to remove the three O–rings at the lower counterbore area of each cylinder sleeve.
2. Discard the O–rings.

Cleaning

CONNECTING ROD, PISTON & RINGS

1. Clean the aluminum pistons using a soap and water solution; soak, then clean, using a non–metallic brush.

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Cleaning — Continued

CONNECTING ROD, PISTON & RINGS — Continued

NOTE: Never use a caustic solution or a wire brush for cleaning the aluminum pistons.

2. All piston ring grooves must be cleaned thoroughly.

3. The following disassembled components may be cleaned using a suitable solvent:

   - Piston rings
   - Piston pins
   - Piston pin retainers
   - Connecting rods
   - Connecting rod caps
   - Connecting rod bolts and nuts

4. Clean the oil hole at the top of the rod. Make sure it is not blocked.

CYLINDER SLEEVES

1. Soak the cylinder sleeves in a soap and water solution and clean thoroughly using a non-metallic brush.

2. Dry with filtered compressed air.

Inspection

PISTONS

1. Visually inspect the pistons for scuffed or scored skirts and cracked or worn lands. Replace the pistons as required.

2. Check top and intermediate compression ring groove widths for wear as follows:

IMPORTANT

DT/DTA–360 DIESEL ENGINES USE FULL KEYSTONE COMPRESSION RINGS AND A RECTANGULAR OIL CONTROL RING. THE PISTON RING GROOVE CONFIGURATION CORRESPONDS TO THE SHAPE OF THE PISTON RING (FIGURE 6.16). THE KEYSTONE COMPRESSION RING GROOVES ARE MEASURED OVER GAUGE PINS TO DETERMINE WEAR WHILE THE RECTANGULAR OIL CONTROL RING GROOVE DOES NOT USE GAUGE PINS, BUT SIDE CLEARANCE TO DETERMINE PISTON RING GROOVE WEAR.

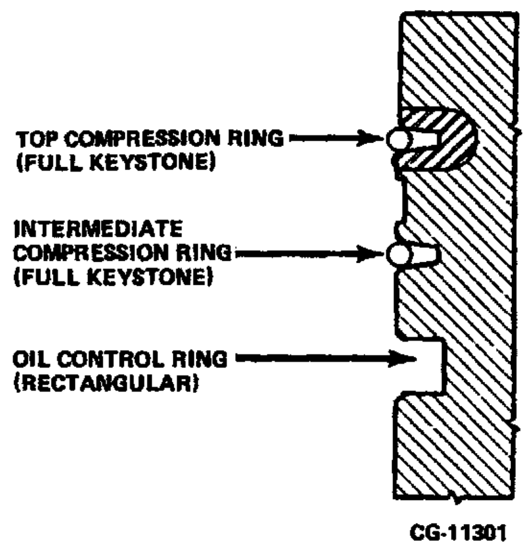


Figure 6.16. Piston Ring Groove Configuration

a. Install the 0.1150 in. gauge pins from the piston groove wear gauge pin set (Tool No. ZTSE–3020), into the groove to be measured. Refer to **Figure 6.17.**

IMPORTANT

GAUGE PINS MUST BE PARALLEL.

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

PISTONS — Continued

b. Measure the piston diameter over gauge pins using an outside micrometer, **Figure 6.17.**

c. If the measurement over the gauge pins is NOT within specifications, excessive piston groove wear exists and the piston must be replaced with new. Refer to "SPECIFICATIONS".

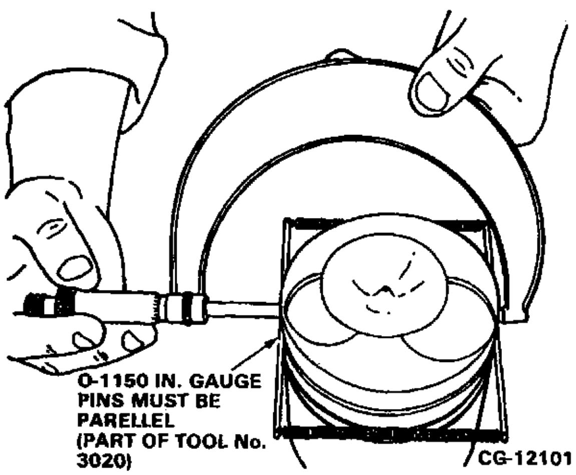


Figure 6.17. Measure Compression Ring Groove Wear

3. Check the rectangular oil control ring for side clearance as follows:

a. Using a new ring, place the outer edge of the ring in the oil control ring groove.

b. Roll the ring, in its respective groove, entirely around the piston. Make sure the ring is "free" in the groove.

c. With a feeler gauge check the side clearance of each oil control ring in its respective groove, **Figure 6.18.**

d. Excessive side clearance indicates ring groove wear and requires piston replacement.

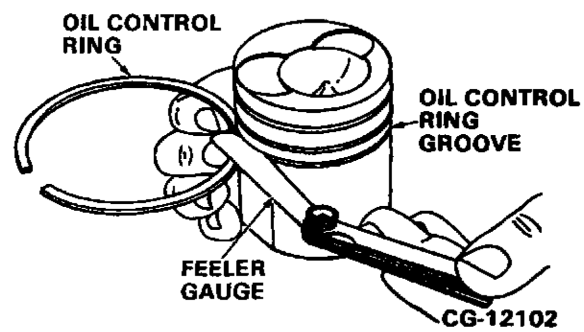


Figure 6.18. Check Oil Control Ring Groove Side Clearance

4. Check piston to cylinder sleeve running clearance, as follows:

a. Measure and record the piston skirt diameter. With the piston at room temperature, place an outside micrometer 1.146 in. below the bottom land of the oil control ring, 90 degrees from the pin bore. Refer to **Figure 6.19.**

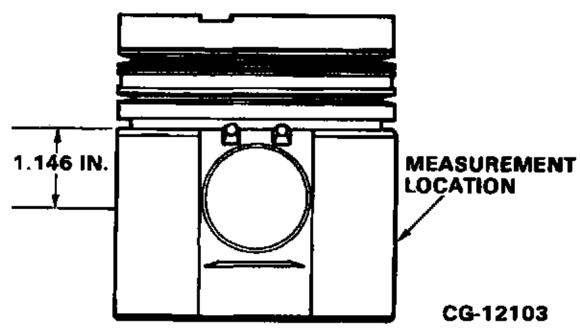


Figure 6.19. Measure Piston Skirt Diameter

b. Measure cylinder sleeve inside diameter, refer to "CYLINDER SLEEVE INSPECTION" later in this section for the procedure. Record the reading.

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CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

PISTONS — Continued

c. Subtract the piston skirt diameter from the cylinder sleeve I.D. The resulting dimension is the piston to cylinder sleeve running clearance.

d. If running clearance is NOT within **"SPECIFICATIONS"**, replace the piston.

PISTON RINGS

NOTE: Faulty rings cannot always be detected by visual inspection. Therefore, whenever a piston is removed from a cylinder, it is recommended that the piston rings & replaced.

1. Visually inspect NEW rings for cleanliness.

NOTE: Effective with S/N 072706 all DT/DTA-360 engines are equipped with a plasma-coated top compression ring. Individual compression rings are not serviced separately and can only be obtained by ordering the appropriate service package from the current parts catalog. Refer to Figure 6.20. for identification of ring.

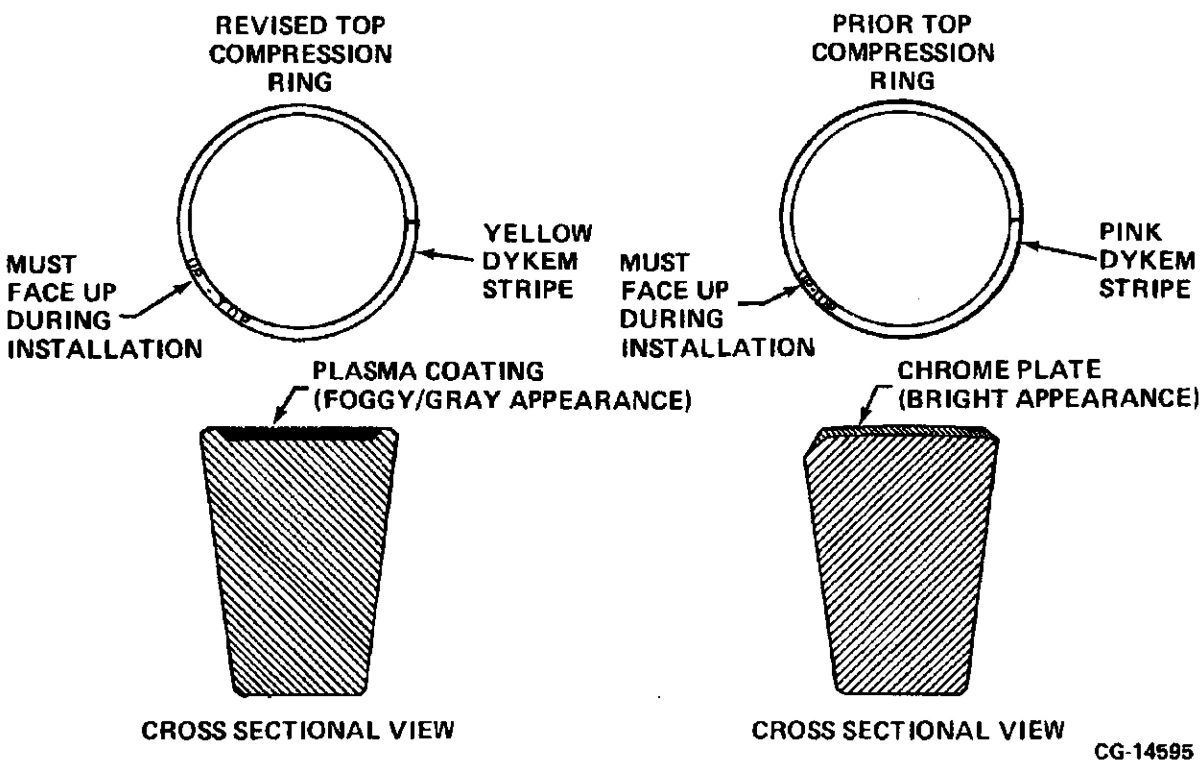

Figure 6.20. Top Compression Ring Identification

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

PISTON RINGS — Continued

2. Prior to installing the rings on the piston, check each ring for proper gap as follows:

   a. Push the ring down into the cylinder bore making sure the ring is square with the cylinder wall.

   b. Measure the gap between the ends of each ring with a feeler gauge as shown in **Figure 6.21.** Refer to **"SPECIFICATIONS"** for ring gap. Discard any ring which does not meet the specifications.

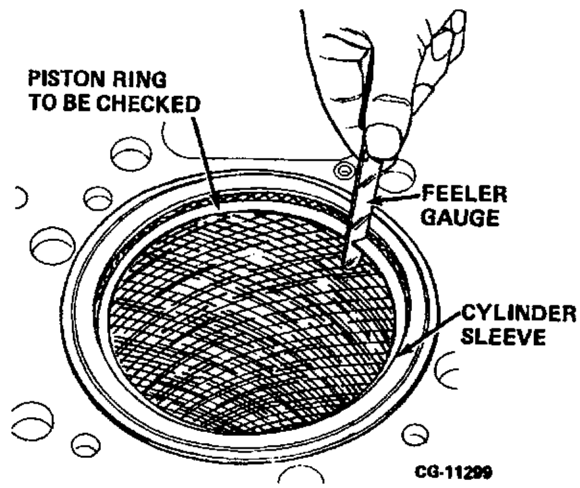

Figure 6.21. Check Piston Ring Gap

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

CONNECTING RODS

1. Visually inspect the connecting rod bolts and nuts for nicks or damage.

IMPORTANT

WHEN LUBRICATED WITH CLEAN ENGINE OIL, THE NUTS MUST SCREW ONTO THE BOLTS BY HAND. IF RESISTANCE IS MET, REPLACE THE BOLTS AND NUTS WITH NEW.

2. Visually inspect the rod and cap mating surfaces for fretting. Replace as required.
3. Inspect the connecting rod piston pin bushing for wear as follows:
   a. Using a telescoping gauge and an outside micrometer, measure the pin bore at two locations and record the readings. Refer to **Figure 6.22.**
   b. Refer to **"SPECIFICATIONS"**. If the piston pin bushing I.D. exceeds the minimum specification, it is worn and must be replaced.

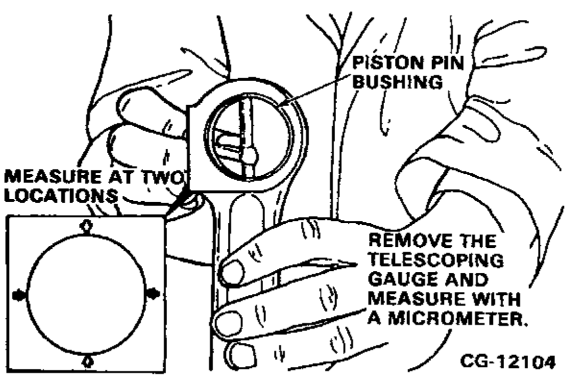

Figure 6.22. Check Piston Pin Rushing I.D.

4. Remove any worn bushing using a press and a driver.
5. Clean the connecting rod piston pin bushing bore thoroughly and visually inspect for defects. Using a telescoping gauge and a micrometer, measure the connecting rod piston pin bushing bore diameter at two locations. Refer to **Figure 6.23.** If out of **"SPECIFICATIONS"**, replace the connecting rod.

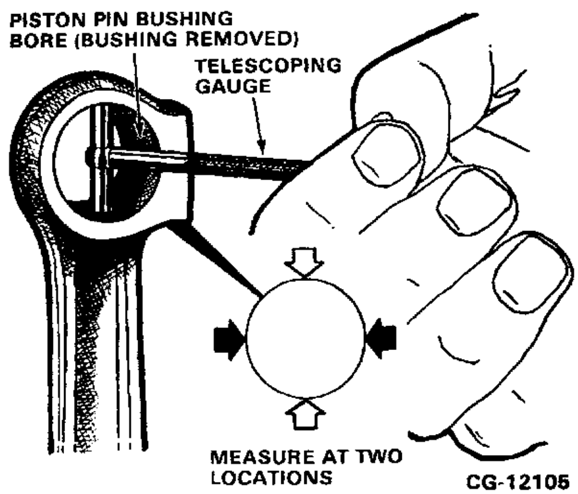

Figure 6.23. Check Connecting Rod Piston Pin Bushing Bore Diameter

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

CONNECTING RODS — Continued

6. Check the connecting rod bearing bore for "out–of–round" as follows:
   a. Lubricate connecting rod bolts and nuts with clean engine oil and assemble the cap to the rod without the bearing insert. Tighten the nuts to the specified torque.
   b. Use an inside micrometer or a dial bore gauge and measure the connecting rod in three locations as shown in **Figure 6.24.**
   c. If the difference between point "B" and the average of points "A" and "C" ([A + C] / 2), exceeds 0.002 in., the rod must be replaced.

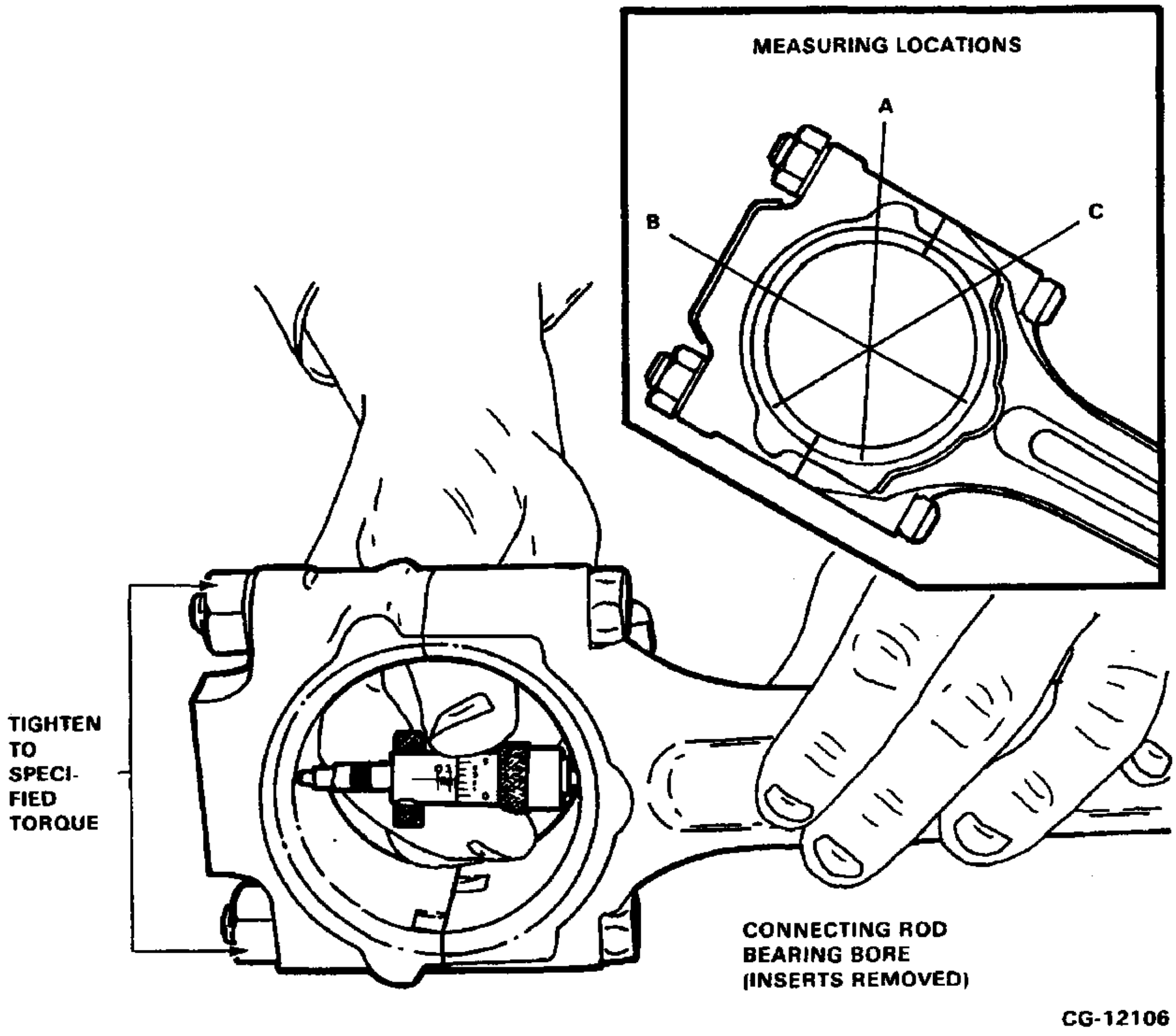

Figure 6.24. Check Bearing Bore Roundness

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

CONNECTING RODS — Continued

7. Measure the connecting rod bearing bore taper (**Figure 6.25**), by measuring the bore I.D. on each side of the bearing bore. Record the readings. The difference between the two readings is the bore taper. (See "**SPECIFICATIONS**".) Replace rod as required.

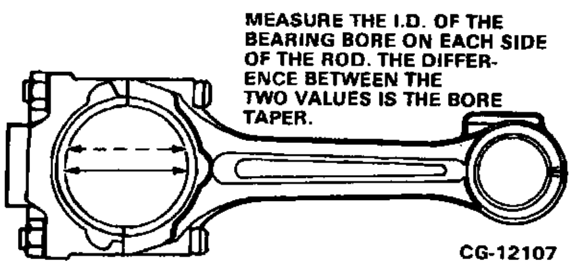

Figure 6.25. Measure Bearing Bore Taper

8. With the connecting rod cap removed, visually inspect the surface finish of the connecting rod bearing bore. The bore must be smooth and free of scoring, nicks or burrs. Replace as required.
9. CONNECTING ROD BEND AND TWIST: Often engine component wear patterns can be identified and used to diagnose a problem. Some common examples of connecting rod wear patterns include:
   a. A shiny surface on edge of piston pin bushing usually indicates that a connecting rod is bent or piston pin hole is not in proper relation to piston skirt and ring grooves.
   b. Abnormal connecting rod bearing wear can be caused by either a bent connecting rod or a tapered connecting rod bore.
   c. Twisted connecting rods will not create an easily identifiable wear pattern, but badly twisted rods will disturb action of entire piston, rings, and connecting rod assembly and may be the cause of excessive oil consumption.

If any of these conditions exist, check the connecting rods for bends or twists using a suitable alignment fixture. Follow the instructions of the fixture manufacturer. If bend or twist exceeds "**SPECIFICATIONS**", replace the rod.

IMPORTANT

IF THE CONNECTING RODS DO NOT MEET THE REQUIREMENTS SET FORTH IN PARAGRAPHS 1–9 "CONNECTING ROD INSPECTION", REPLACE THE ENTIRE CONNECTING ROD ASSEMBLY.

PISTON PINS

1. Visually inspect the piston pins for corrosion or etching. Replace as required.
2. Use a micrometer to measure the piston pin O.D. at two locations. Record the readings. Refer to **Figure 6.26.** If the pin wear exceeds "**SPECIFICATIONS**", replace the pin.

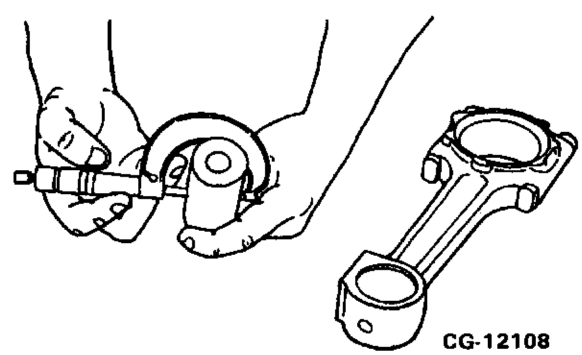

Figure 6.26. Measure Piston Pin O.D. to Check for Wear

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

PISTON PINS — Continued

3. Check piston pin clearance in rod as follows:
   a. Subtract the piston pin O.D. from the piston pin bushing I.D. measurement. Refer to **Figure 6.22.**
   b. If clearance exceeds the **"SPECIFICATIONS"**, replace the bushing.

CYLINDER SLEEVES

1. Visually inspect the inside surface of the sleeve for scuffing or scoring. Replace the sleeve (and piston) as required. Examine the outer surface of the sleeve for cavitation erosion, replace as required.
2. Check cylinder sleeves for wear (taper) using any one of the three methods described.

METHOD ONE

"TELESCOPING GAUGE METHOD" (Refer to **Figures 6.27 and 6.28**). Using a telescoping gauge and an outside micrometer:

a. Measure the sleeve I.D. at the top of piston ring travel (just below the carbon ridge area) and record the reading.

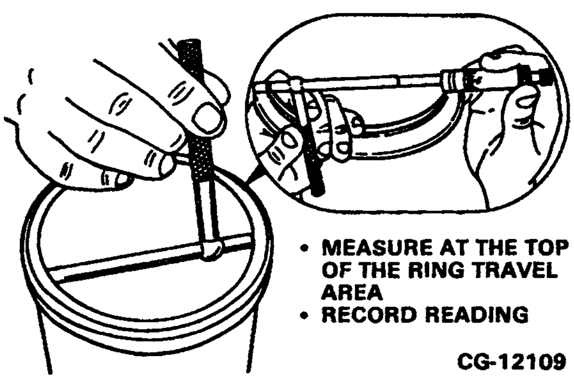

Figure 6.27. Check Cylinder Sleeve I.D. @ Top of Ring Travel

b. Measure the sleeve I.D. below the ring travel area and record the reading.

c. The difference between the two readings is the cylinder sleeve taper. If specifications are exceeded, replace the sleeve.

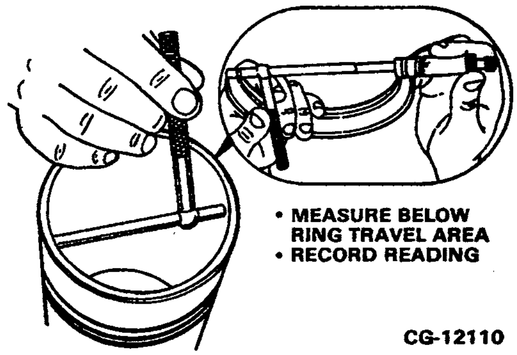

Figure 6.28. Check Cylinder Sleeve I.D. @ Below Ring Travel

METHOD TWO

"DIAL BORE GAUGE METHOD" (**Refer to Figures 6.29 and 6.30**).

Using a dial bore gauge:

a. Measure at the top of the piston ring travel (just below the carbon ridge area) and record the reading.

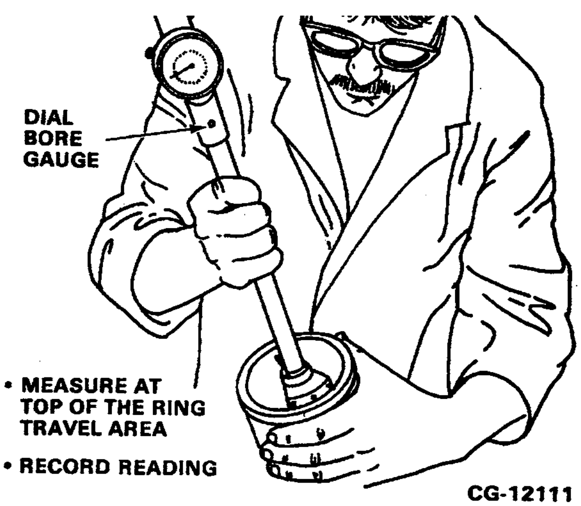

Figure 6.29. Check Cylinder Sleeve I.D. @ Top of Ring Travel

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Inspection — Continued

CYLINDER SLEEVES — Continued

b. Measure below the ring travel area and record the reading.

c. The difference between the two readings is the cylinder sleeve taper. If specifications are exceeded, replace the sleeve.

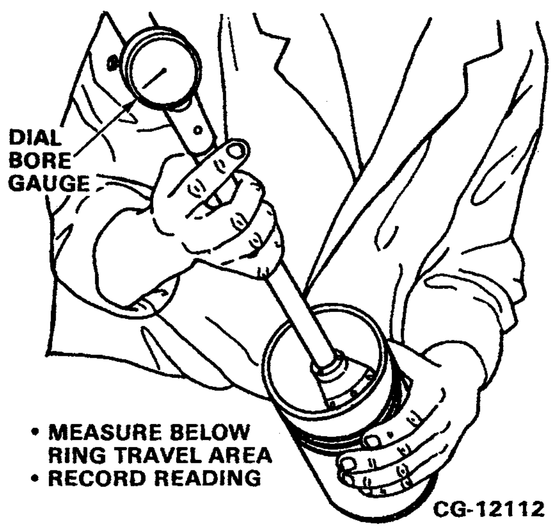

Figure 6.30. Check Cylinder Sleeve I.D. Below Ring Travel Area

METHOD THREE

"FEELER GAUGE METHOD" (Refer to **Figures 6.31 and 6.32**).

a. Install a top compression ring squarely at the top of ring travel and measure the ring end gap with a feeler gauge. Record the reading.

b. Install the same piston ring below the ring travel area and measure the ring end gap. Record the readings.

c. Every 0.003 in. increase in ring gap equals a 0.001 in. increase in bore size.

d. If the sleeve is worn beyond specifications, replace the sleeve.

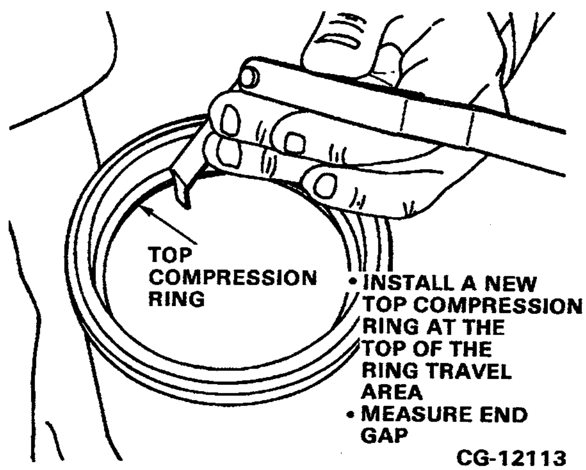

Figure 6.31. Check Ring End Gap at Top of Ring Travel

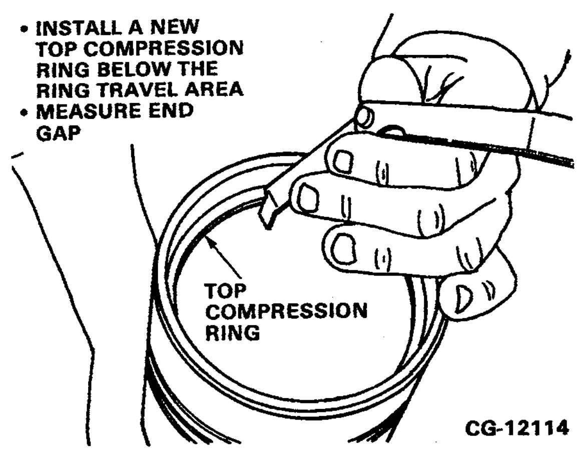

Figure 6.32. Check Ring End Gap Below Ring Travel Area Reconditioning

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning

CONNECTING RODS

1. If required, install a new connecting rod piston pin bushing using a press and a driver.

IMPORTANT

LUBRICATE THE BUSHING BORE AND NEW BUSHING WITH CLEAN ENGINE OIL PRIOR TO PRESSING IN. BE SURE THE OIL HOLE IN THE BUSHING IS ALIGNED WITH THE CORRESPONDING ORIFICE IN THE CONNECTING ROD. REFER TO FIGURE 6.33.

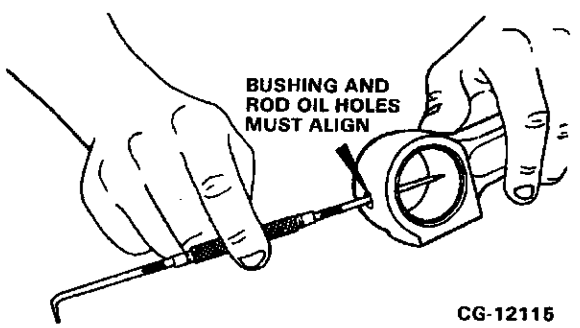

Figure 6.33. Check Bushing and Rod Oil Hole Alignment

2. After bushing installation, it must be honed to the proper I.D. (See **"SPECIFICATIONS"**). Use appropriate honing equipment.

BEARING FITTING PROCEDURE

1. If bearing–to–crankshaft running clearances exceed specifications because of wear, replace or regrind the crankshaft and install undersize precision type bearing shells.

IMPORTANT

DO NOT ATTEMPT TO REDUCE JOURNAL–TO–BEARING RUNNING CLEARANCES BY REWORKING BEARING CAP, BEARINGS OR BOTH. REGRIND OR REPLACE THE CRANKSHAFT. REFER TO SECTION 7.

CAUTION !

REWORKING THE BEARING CAP AND/OR BEARINGS WILL DESTROY THE ENGINEERED FIT OF THE BEARING SHELLS IN THEIR BORES.

2. Tighten the connecting rod bolts and nuts alternately and evenly to the specified torque, using an accurate torque wrench. (See **"TORQUE SPECIFICATIONS"**.)

NOTE: ABOUT BEARING CRUSH AND SPREAD! Bearing shells must fit tightly in the bore. When bearing shells are inserted into the connecting rod and cap, they protrude above the parting line. This protrusion is required to achieve "BEARING CRUSH". Bearing shells are designed with "SPREAD". That is, the width across the open ends are slightly larger than the diameter of the connecting rod bore into which they are assembled, as shown in Figure 6.34. This condition is designed into the bearing shell causing it to spread outward at the parting line when "CRUSH" load is applied by tightening the bolts. Some snap may be lost in normal use, but bearing replacement is not required because of a nominal loss of snap.

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CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CONNECTING RODS — Continued

When the assembly is drawn up tight, the bearing is compressed, assuring a positive contact between the bearing back and the bore as shown in **Figure 6.35.**

3. Fit connecting rod bearings and measure bearing running clearance as follows:

    a. With bearing cap removed, wipe oil from the face of the bearing insert and exposed portion of the crankshaft journal.

    b. Place a piece of "Plastigage®" across the full width of the bearing about 1/4 in. off center.

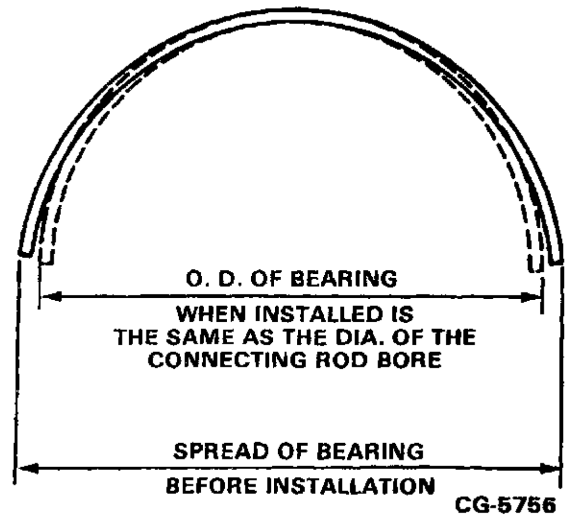

Figure 6.34. Bearing Spread

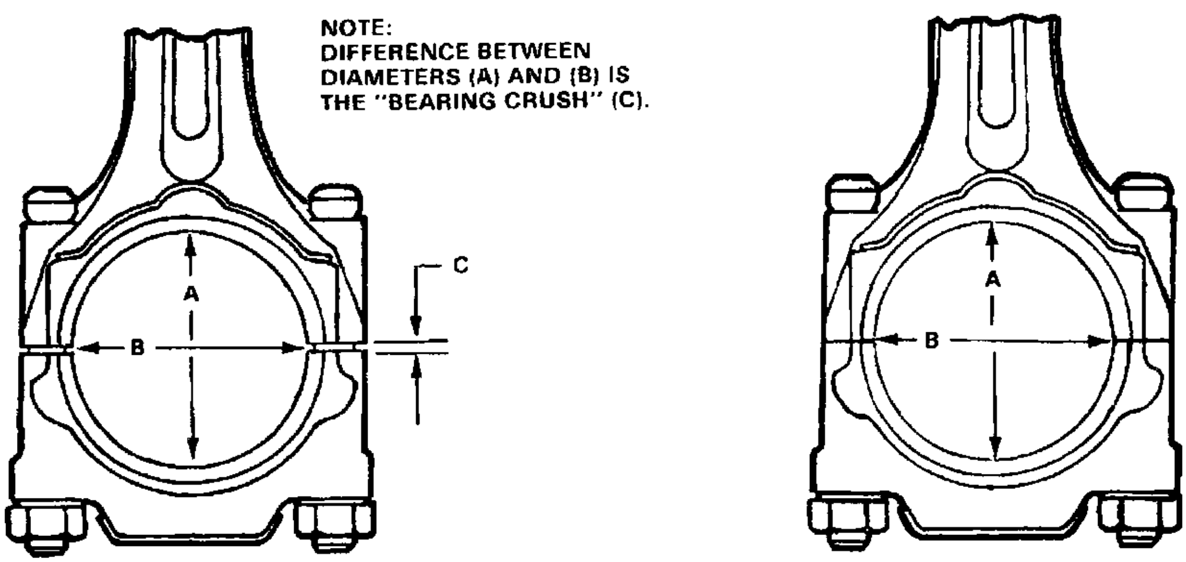

Figure 6.35. Bearing Crush

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CONNECTING RODS — Continued

c. Install the cap and tighten bolts and nuts evenly and alternately to specified torque.

NOTE: Do not turn the crankshaft during running clearance check.

d. Remove bearing cap. The "Plastigage®" material will be found adhering to either the bearing shell or the crankshaft. DO NOT REMOVE "PLASTIGAGE®". Use "Plastigage®" scale to measure widest point of flattened plastic material, **Figure 6.36**. The number within the graduated marks on the scale indicates the clearance in thousandths of an inch and millimeters (see "**SPECIFICATIONS**").

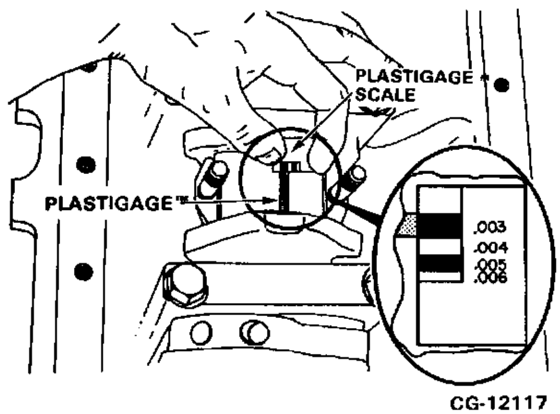

Figure 6.36. Check Connecting Rod Bearing Clearance

e. Remove the test material and the repeat test for each connecting rod bearing.

NOTE: With the precision bearings used, no problem should be encountered. However, if proper clearance is <u>NOT</u> achieved, a problem with the crankshaft may exist which requires regrinding and the use of undersize bearings. (Refer to Section 7 for Crankshaft Rework Information.) Bearing cap torque is very important. Use a torque wrench which is known to be accurate. Repeat running clearance check procedure before condemning the crankshaft.

4. Check connecting rod side clearance using a dial indicator as follows:

   a. Place the tip of the dial indicator on the connecting rod cap as shown in **Figure 6.37**.

   b. Pry the connecting rod towards the rear of the engine and "zero" the dial indicator.

   c. Pry the connecting rod toward the front of the engine and read the indicator. Refer to **"SPECIFICATIONS"** and repeat for all connecting rods.

NOTE: The connecting rod side clearance must be checked to be certain that the specified clearance exists.

a. Lack of clearance could indicate a damaged rod or a rod bearing out of position. Correct as required.

b. Excessive clearance may require replacement of the rods or crankshaft. Correct as required.

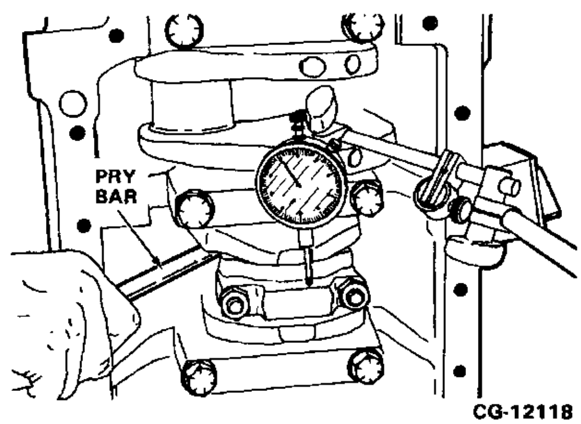

Figure 6.37. Check Connecting Rod Side Clearance

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE

1. Check the crankcase counterbore depth using the surface gauge (ZTSE–2515) or a depth micrometer as follows:

   SURFACE GAUGE METHOD (Refer to Figure 6.38)

   a. "Zero" the dial indicator on the crankcase deck.

   b. Move the indicator onto the counterbore ledge and check the depth at four points.

   c. Refer to "SPECIFICATIONS" for counterbore depth and maximum variation between the four measurement points.

   d. If maximum variation between the four points exceeds specifications, surface the counterbore.

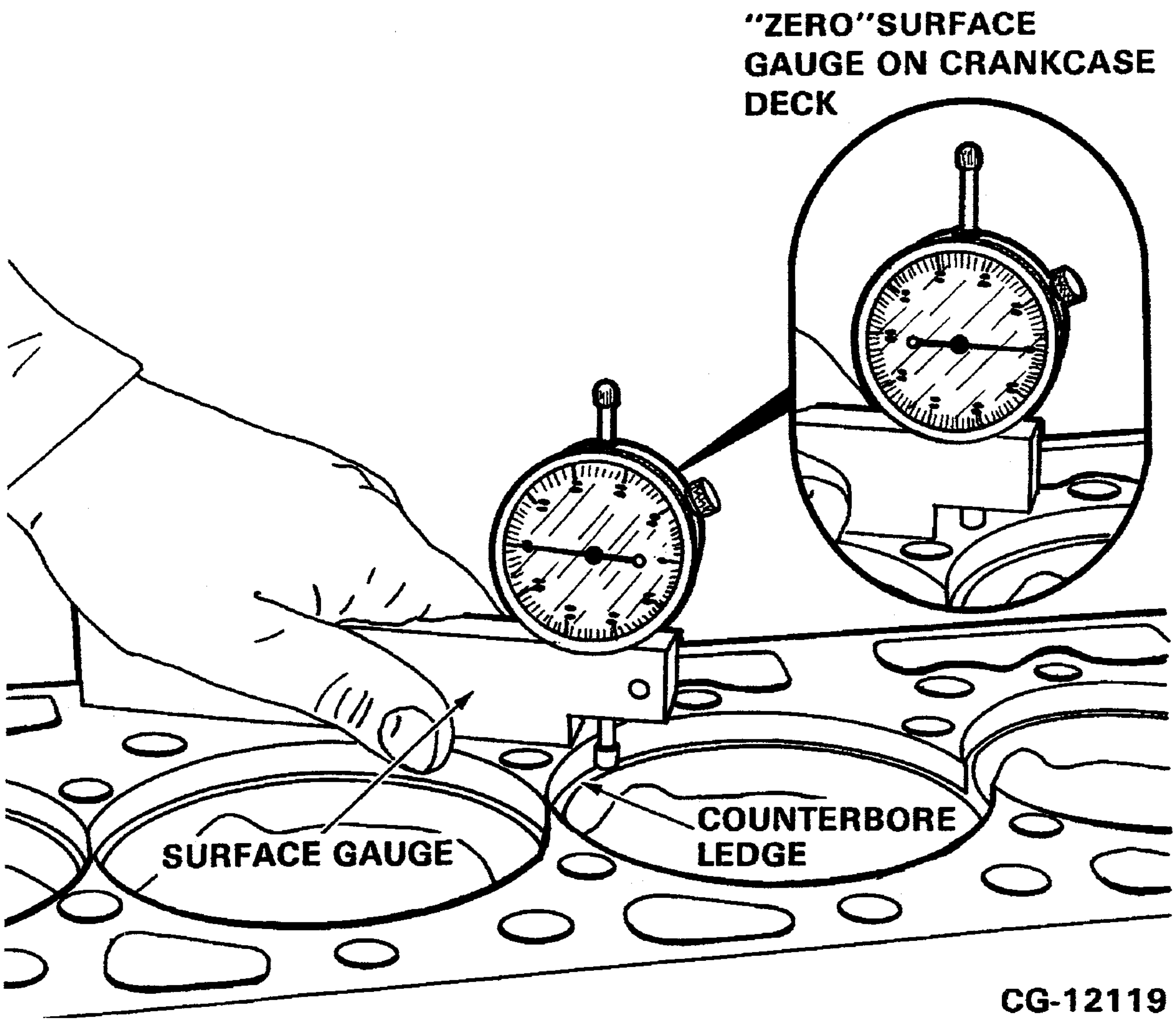

Figure 6.38. Check Clearance Counterbore Depth Using Surface Gauge (ZTSE–2515)

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE — Continued

DEPTH MICROMETER METHOD (Refer to Figure 6.39)

a. Check the counterbore depth at four points around the crankcase counterbore.

b. Record the measurements.

c. Refer to **"SPECIFICATIONS"**, and resurface the counterbore if the maximum variation between measurement points is exceeded.

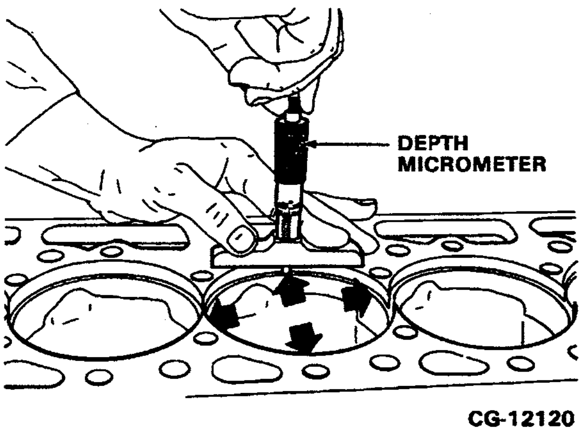

Figure 6.39. Check Crankcase Counterbore Depth Using a Depth Micrometer

2. Resurface the counterbore using the counterboring tool along with the appropriate cutter head as follows:

NOTE: The counterboring tool is currently being redesigned. Contact your Local Dealer regarding availability of this speciality tool. The following instructions are general in nature and are shown as a guide.

a. PRE–SET TOOL BIT by placing a 0.008 in. to 0.010 in. feeler gauge on the O.D. of the cutter head. Push the tool bit out until it touches the feeler gauge. Lock the tool bit in place using an Allen wrench as shown in **Figure 6.40**.

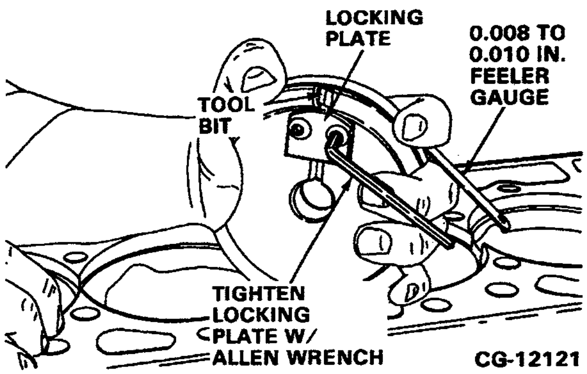

Figure 6.40. Pre–Set Tool Bit

b. INSTALL THE CUTTER HEAD onto the driver unit and adapter plate of the counterboring tool. Refer to **Figure 6.41**.

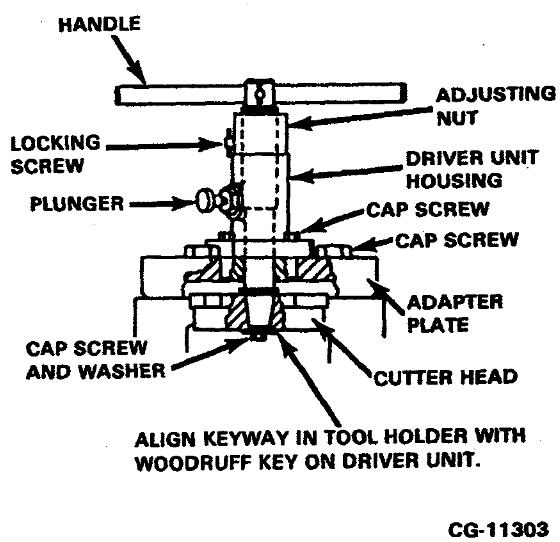

Figure 6.41. Counterboring Tool Components

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE — Continued

c. RAISE THE CUTTER HEAD by pulling the plunger **Figure 6.41** and lifting up on the handle. Mount the counterboring tool assembly to the crankcase as shown in **Figure 6.42**. Tighten the cap screw with washers finger–tight then apply 33 lbf–ft. torque.

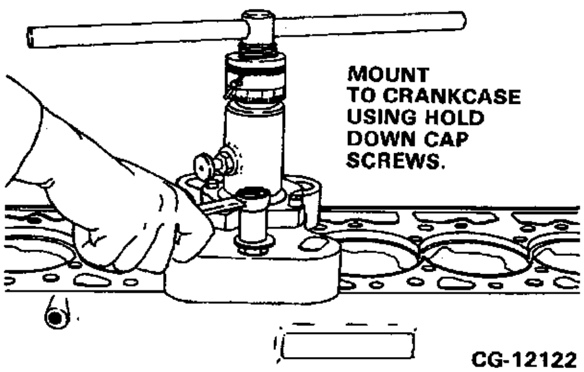

Figure 6.42. Mount Counterboring Tool to the Crankcase

d. LOWER THE CUTTING HEAD by pulling the plunger and SLOWLY lower the drive unit handle until the cutter head contacts the counterbore ledge. (Refer to **Figure 6.43.**)

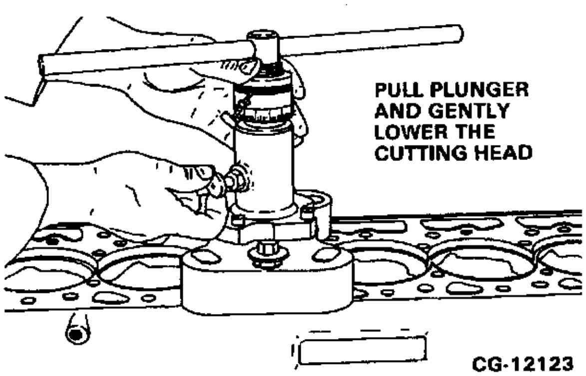

Figure 6.43. Lower Cutting Head into Counterbore

e. SET THE DEPTH OF THE CUT using one—of two methods.

METHOD ONE (Use Graduated Marks on Tool) (See Figure 6.44)

1. Loosen locking screw.
2. Rotate the adjusting nut in a counter–clockwise direction until the nut contacts the driver unit housing.
3. Backoff the adjusting nut by the amount of cut desired.

NOTE: Each graduated marking equals 0.001 in. If 0.002 in. material is to be removed, you must back off the adjusting nut two marks.

4. Tighten the adjusting nut lock screw.

IMPORTANT

NEVER ATTEMPT TO REMOVE MORE THAN 0.002 IN. MATERIAL AT A TIME.

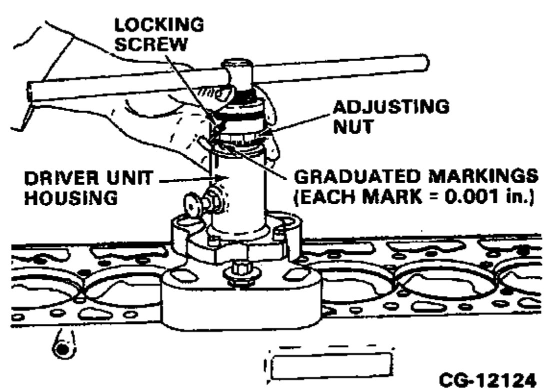

Figure 6.44. Set Cutting Tool Depth Method One

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CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE — Continued

METHOD TWO (Use Feeler Gauge) (See Figure 6.45)

1. Loosen locking screw.
2. Insert an appropriate size feeler gauge (0.002 in. max.) between the adjusting nut and driver unit housing. Rotate the adjusting nut until the feeler gauge is just held in place.
3. Tighten the locking screw and remove the feeler gauge.

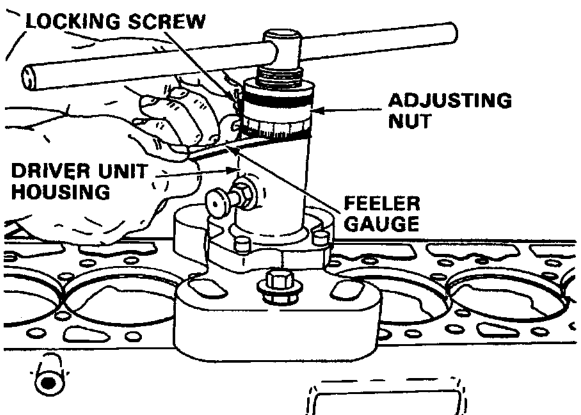

Figure 6.45. Set Cutting Tool Depth Method Two (Using Feeler Gauge)

f. CUT THE COUNTERBORE by rotating the handle smoothly in a clockwise direction until the unit turns freely and is bottomed out between the adjusting nut and the top of the driver unit housing. Refer to **Figure 6.46.**

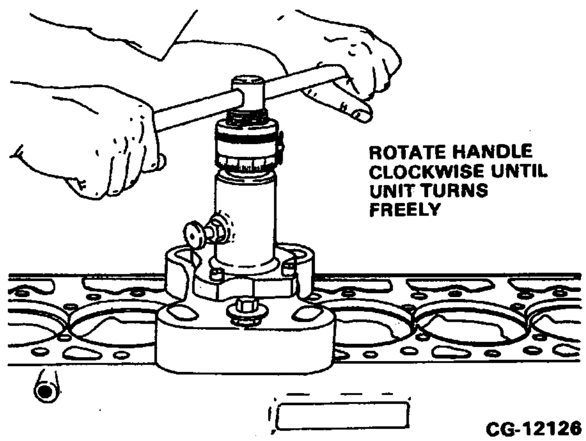

Figure 6.46. Cut the Counterbore

IMPORTANT

TO AVOID DAMAGE TO THE TOOL BIT, NEVER ROTATE COUNTERCLOCKWISE WHEN THE TOOL BIT IS IN CONTACT WITH THE COUNTERBORE LEDGE.

3. Remeasure the counterbore depth once the counterbore has been resurfaced and cleaned up. Refer to "Cylinder Sleeve Fitting Procedure", step one in this section.

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CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE — Continued

4. Check cylinder sleeve protrusion as follows:
   a. Clean the cylinder bore and crankcase counterbore area.
   b. Place each sleeve in the crankcase without O–rings. Clamp the sleeve down using three holding adapters (made locally). Refer to **Figure 6.47.**

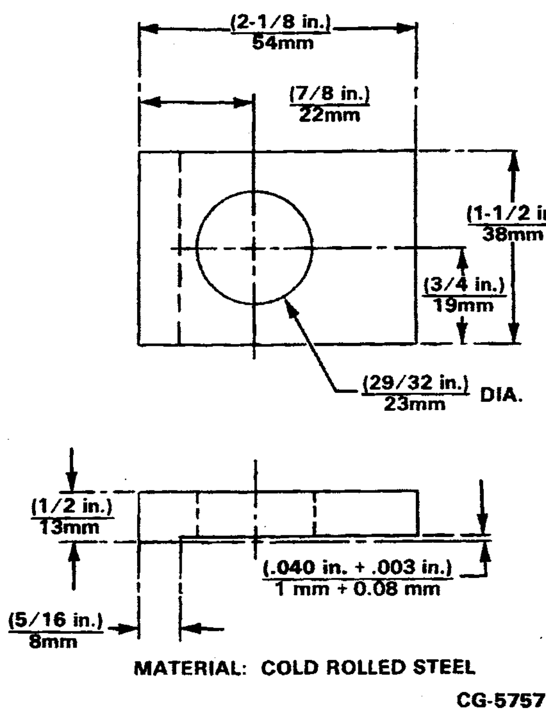

Figure 6.47. Cylinder Sleeve Holding Adapter Specifications

   c. Install the sleeve into its bore and install the holding adapters as shown in **Figure 6.48.** Fasten the holding adapters using grade 8 bolts and hardened washers. Tighten the bolts in two stages as follows:

      40 lbf–ft. (55 Nm)
      80 lbf–ft. (110 Nm)

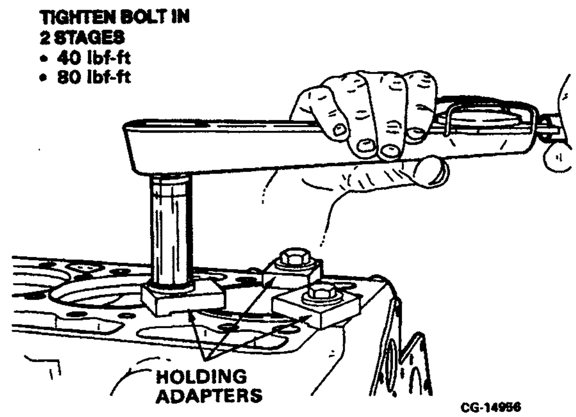

Figure 6.48. Tighten Holding Adapters

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CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE — Continued

d. Using surface gauge ZTSE–2515, place the dial indicator tip on the cylinder sleeve flange. "Zero" the indicator and move the block until the indicator tip drops off the flange to the crankcase deck. Record the reading. Refer to **Figure 6.49**.

NOTE: Take readings at three points around the sleeve and use the average reading to determine which shim(s), if any, is needed to bring the cylinder sleeve protrusion within the specification.

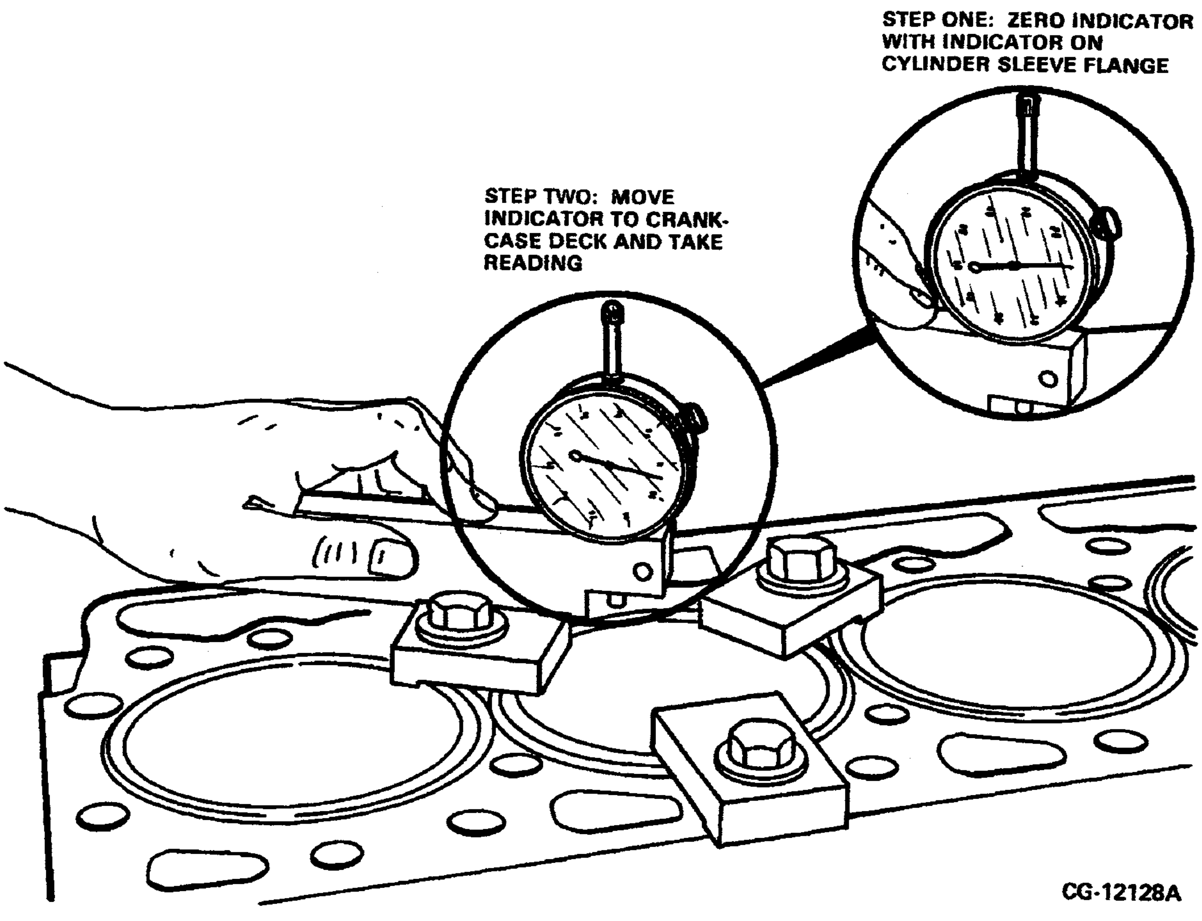

Figure 6.49. Measure Sleeve Protrusion

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE — Continued

5. Adjust the sleeve protrusion, as follows:
   a. Remove the holding adapters and cylinder sleeve.
   b. Clean the top deck of the crankcase and the cylinder sleeve counterbore.
   c. Install the shim(s), as required to bring the protrusion above the crankcase deck within specifications. Refer to **Figure 6.50**.

NOTE: Shims are available as a package consisting of the the following:

Quantity	Shim Size
2	.002 in.
2	.004 in.
1	.010 in.
1	.020 in.
2	.032 in.

   d. Follow cylinder sleeve installation instructions.

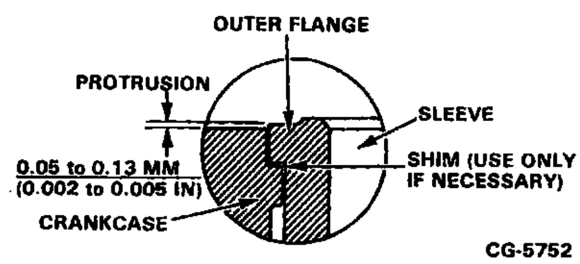

Figure 6.50. Install Shim(s) Reassembly

Reassembly

CONNECTING RODS, PISTONS & RINGS

1. Install the rings onto the pistons using a piston ring expander tool as follows: Refer to **Figure 6.51.**
   a. Install the rings in order.

      Oil control ring
      2nd compression ring
      Top compression ring

   b. Identification marks must face up. (Top ring has one dot. 2nd ring has two dots.)

NOTE: The oil ring does NOT have identification marks. There is no top or bottom, it may be installed in either direction.

   c. Stagger the ring gaps 120° apart.

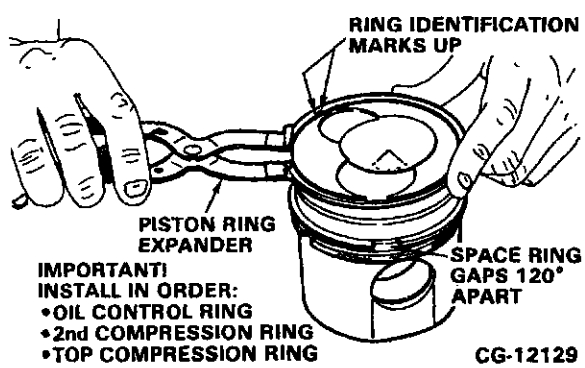

Figure 6.51. Install Piston Rings

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVE FITTING PROCEDURE — Continued

2. Assemble the piston and connecting rod as follows: Refer to **Figure 6.52.**

IMPORTANT

IF OLD PISTONS ARE BEING REPLACED WITH NEW, BE SURE TO VERIFY THAT THE CORRECT PISTONS ARE BEING INSTALLED. REFER TO CURRENT PARTS CATALOG FOR PROPER SERVICE NUMBERS.

a. Lubricate the connecting rod piston pin bushing with clean engine oil.
b. Install the retaining ring at one end of the piston pin bore.
c. Insert the connecting rod into the piston with the lug facing the "camside" of the piston.
d. Align the pin bores and insert the piston pin.
e. Install the second retaining ring.

NOTE: Rod and cap matching numbers must be opposite the camside of the piston.

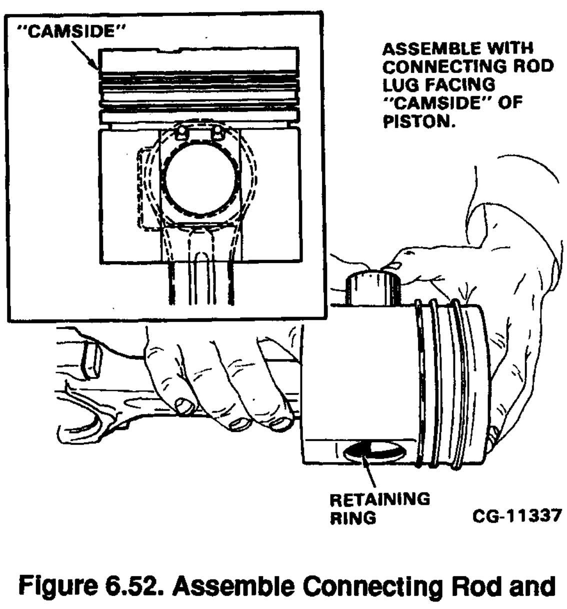

Figure 6.52. Assemble Connecting Rod and Piston

CYLINDER SLEEVES

1. Lubricate the O–rings with clean engine oil and install one into each cylinder sleeve groove. Refer to **Figure 6.53.**

NOTE: Each cylinder sleeve uses three O–rings.

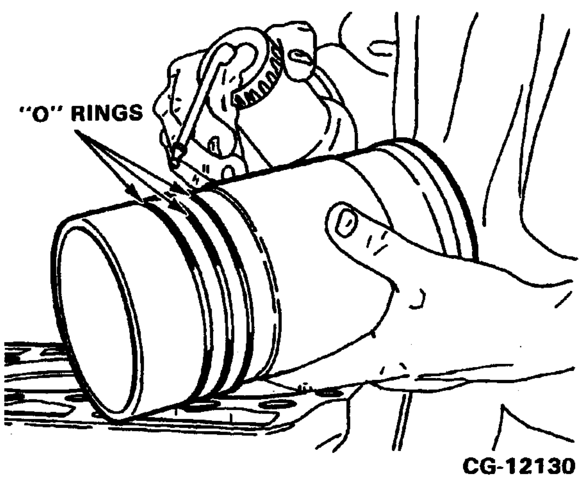

Figure 6.53. Install Cylinder Sleeve O–Rings

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Reconditioning — Continued

CYLINDER SLEEVES — Continued

2. If required, assure the proper shim(s) is installed, in the crankcase counterbore, so cylinder sleeve protrusion is within specifications. Refer to "Cylinder Sleeve Fitting Procedure", **Figure 6.50.**

Installation

CYLINDER SLEEVES

1. Be sure the O–rings are properly aligned in the grooves.
2. Lubricate the lower crankcase counterbore, then install the sleeve carefully into the same bore from which it was removed. Press into place by hand. Apply even pressure on each side. Refer to **Figure 6.54.**

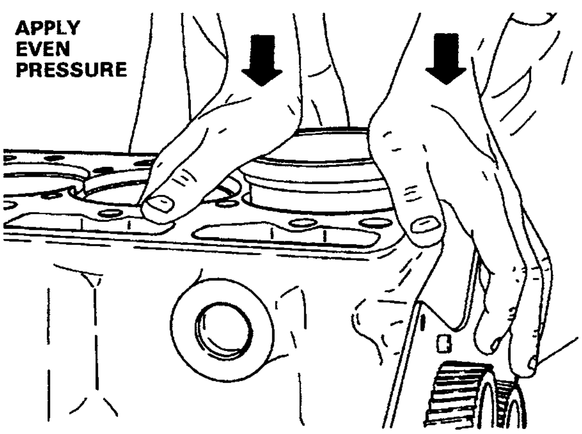

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Figure 6.54. Install Cylinder Sleeve

PISTON & ROD ASSEMBLY

1. Lubricate the piston rings with clean engine oil and stagger the ring gaps 120° apart.
2. Install the piston ring compressor over the piston rings.
3. Lubricate the cylinder sleeve with clean engine oil.
4. Protect the crankshaft and rod bolt threads by inserting pieces of rubber hose over the bolt threads prior to installing the piston and rod assembly into the crankcase. Refer to **Figure 6.55.**

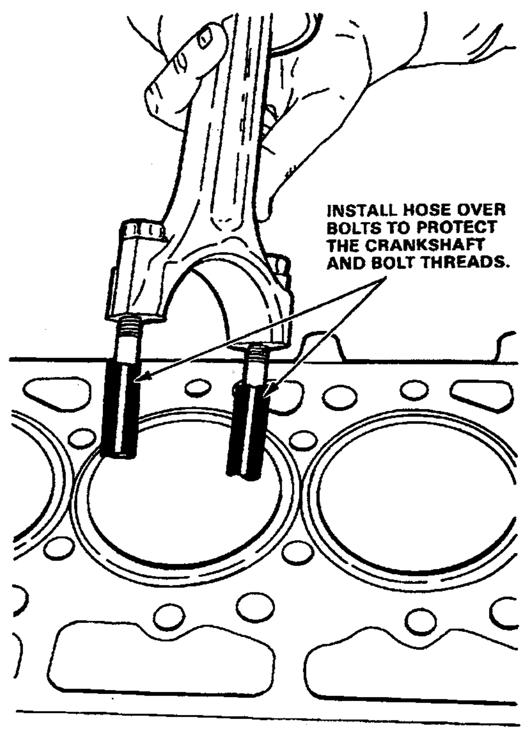

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Figure 6.55. Install Protective Hose Over Bolts

NOTE: Turn the crankshaft to position the crankpins at the bottom of their stroke prior to inserting the piston and rod.

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Installation — Continued

PISTON & ROD ASSEMBLY — Continued

5. Insert the piston and rod assembly into the sleeve. Refer to **Figure 6.56.**

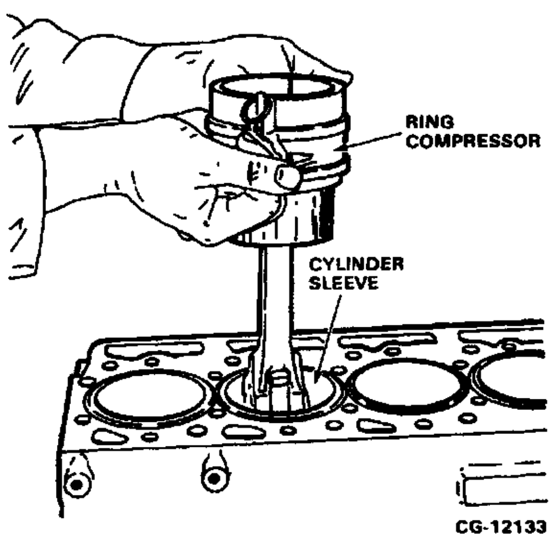

Figure 6.56. Place Piston and Rod Into Cylinder Sleeve

6. Push the piston into the sleeve with a wooden handle. Refer to **Figure 6.57.**

7. Guide the connecting rod into place on the crankpin, then remove the rubber hose from the bolts. Refer to **Figure 6.58.**

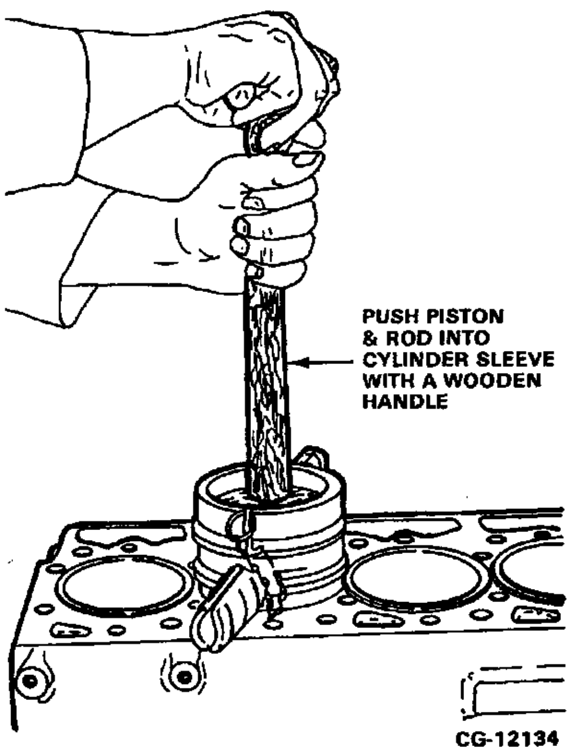

Figure 6.57. Insert Piston and Rod into Sleeve

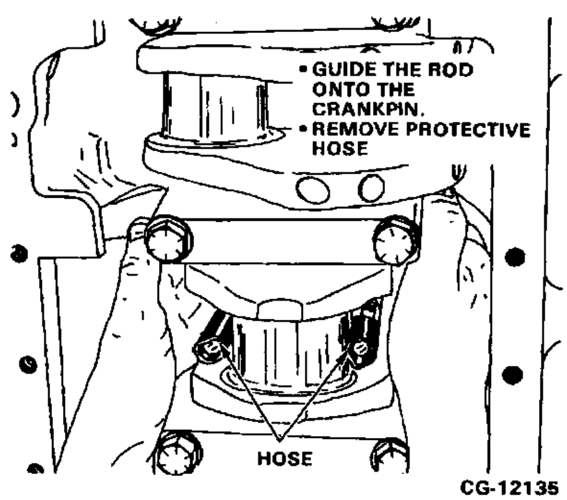

Figure 6.58. Guide Rods onto Crankpin

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Installation — Continued

CONNECTING ROD BEARING INSERTS & CAPS

IMPORTANT

PERFORM THE "BEARING FITTING PROCEDURE" AS DESCRIBED EARLIER IN THIS SECTION.

1. With the bearing inserts lubricated, install the connecting rod cap so the numbers on the cap and rod match. Refer to **Figure 6.59.**

NOTE: Matching numbers are opposite "camside".

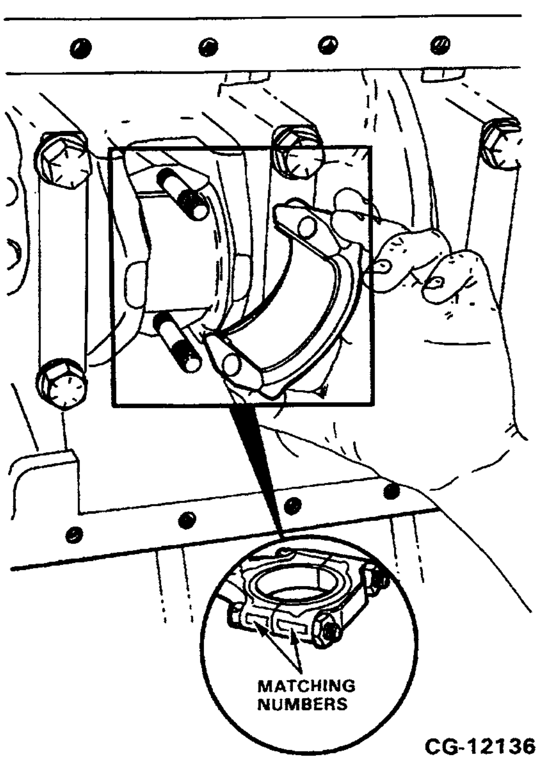

Figure 6.59. Install Connecting Rod Cap and Bearing

2. Install the nuts by hand onto the rod bolts finger–tight. Tighten the nuts to the specified torque. Refer to **Figure 6.60.**
3. Check connecting rod side clearance. (See **"SPECIFICATIONS"**.) Refer to **Figure 6.37**.

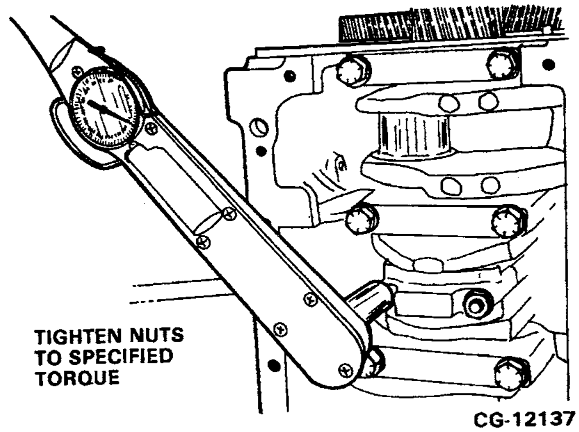

Figure 6.60. Tighten Connecting Rod Nuts

Reinstall the following components. Refer to the appropriate manual section for installation procedures.

- Oil pickup tube
- Oil pan
- Vibration damper and pulley
- Cylinder head assembly (with intake manifold, exhaust manifold, thermostat housing and turbocharger attached)
- Rocker arm assembly
- Fuel injection nozzles
- Turbocharger oil inlet and drain tubes
- Thermostat housing to water pump hose
- Adjust valve lash
- Valve cover and new gasket
- Aneroid tube
- Fuel leak–off lines (low pressure)
- Fuel injection lines (high pressure)
- Crossover pipe (DT–360 only)

CONNECTING RODS, PISTONS, RINGS AND SLEEVES — Continued

Installation — Continued

PRIME THE LUBRICATING SYSTEM

NOTE: Install new lube oil filters.

1. Pressure prime the lubrication system with oil, prior to starting as follows:

   a. Using oil leak detector ZTSE–1632, attach the line from the oil leak detector to the oil cooler at the pipe plug. Refer to **Figure 6.61.**

   b. Inject sufficient oil into the engine to fill the oil filters and charge the entire system.

NOTE: If oil enters the engine at other than the cooler, oil will be blocked by the oil filter and will not flow to the lube oil pump.

WARNING

DO NOT rotate any diesel engine when priming with oil to prevent accidental engine start up. Verify fuel injection pump shut–off is in No–Fuel position.

   c. After priming, check the oil level before the engine is put back into service. Do not fill past 17 quarts with filter change or 14 quarts without a filter change.

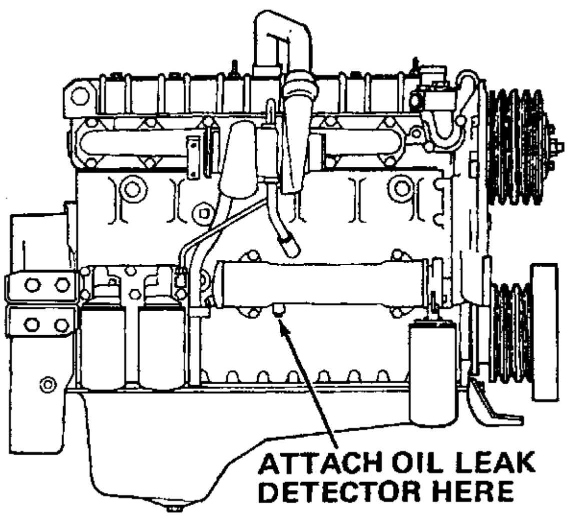

Figure 6.61. Location for Oil Leak Detector Installation

ENGINE RUN–IN PROCEDURE

IMPORTANT

AFTER INSTALLING NEW PISTONS AND/OR NEW RINGS, THE ENGINE MUST BE "RUN–IN" AS FOLLOWS:

1. Operate engine at low idle (no load) for 5 minutes.

   a. Check for leaks in the water, lube oil, fuel and air induction systems.

2. Operate engine at 3/4 rated speed (RPM) and 1/2 to 3/4 throttle for 10 minutes.
3. Operate engine at rated speed and full throttle for 30 minutes. Recheck for lube oil, fuel, water and air leaks.

SERVICE MANUAL
VIBRATION DAMPER, CRANKSHAFT, MAIN BEARINGS, FLYWHEEL & CRANKCASE

SECTION 7 INDEX

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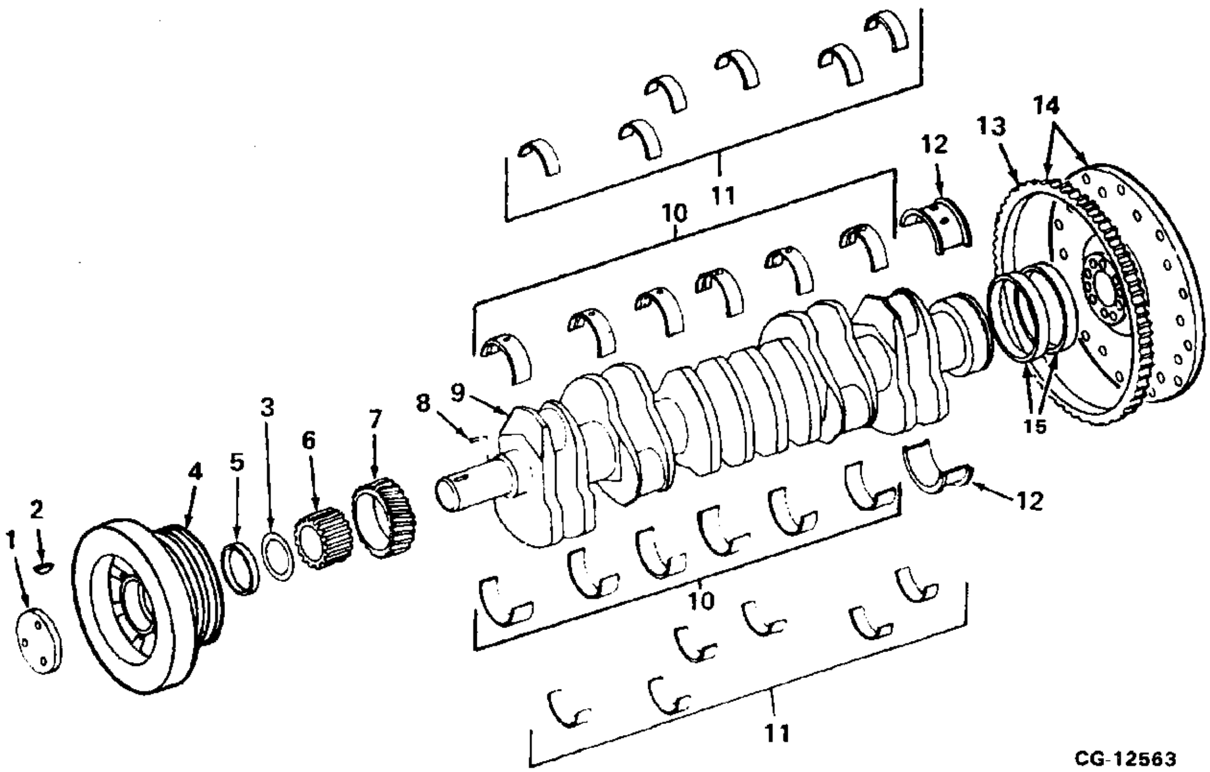

Figure 7.1. Crankshaft, Bearings, Flywheel and Related Components

1. Plate, Damper Retaining
2. Key, Woodruff
3. Washer, Seal
4. Pulley and Damper Assembly
5. Sleeve, Wear
6. Spline, Oil Pump Drive
7. Gear, Crankshaft
8. Pin, Roll
9. Crankshaft
10. Bearings, Crankshaft # 1–6
11. Bearings, Connecting Rod
12. Bearing, Crankshaft Thrust #7
13. Gear, Ring
14. Flywheel
15. Rear Oil Seal and Wear Sleeve, Crankshaft

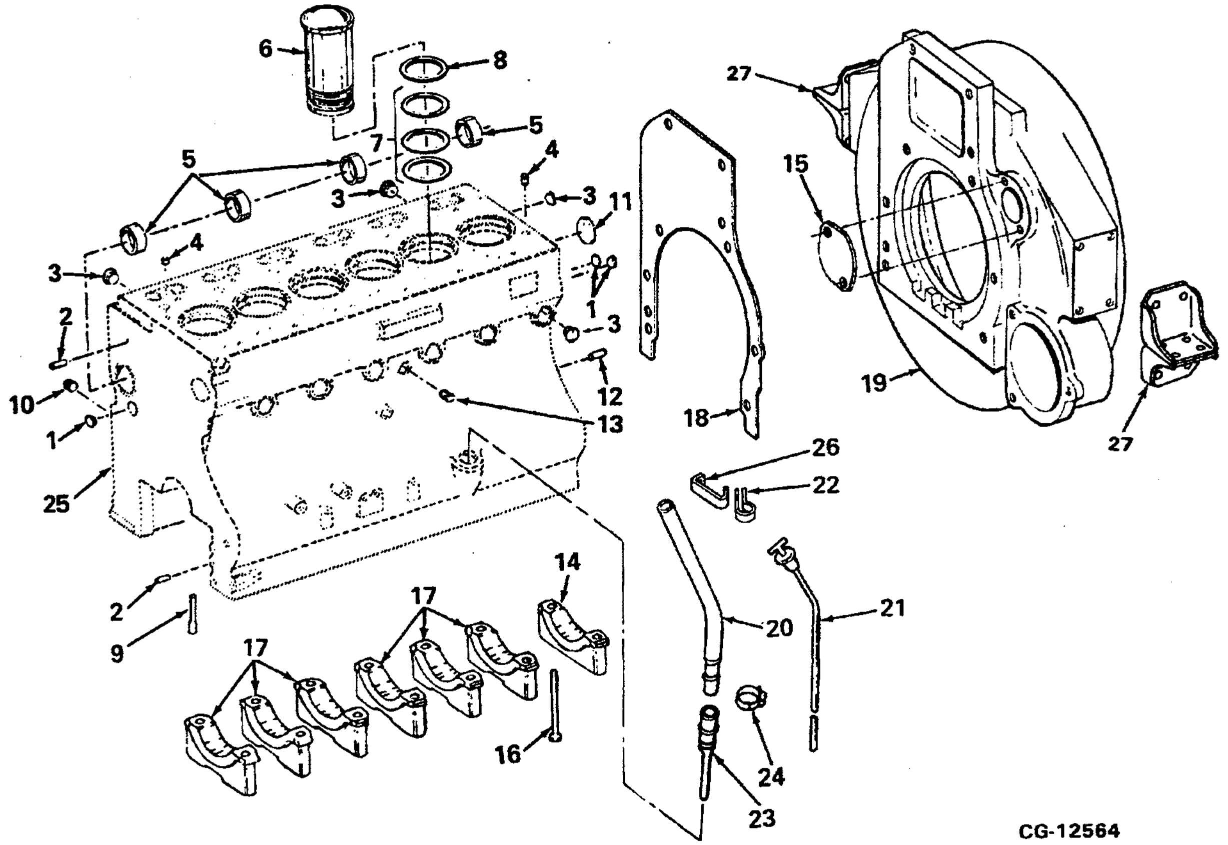

Figure 7.2. Crankcase and Related Parts

1. Plug, Cup
2. Dowel
3. Plug, Cup
4. Dowel, Bushing
5. Bearing Set, Camshaft
6. Sleeve, Cylinder
7. O–Rings, Cylinder Sleeve
8. Shim, Cylinder Sleeve (As Req'd)
9. Tube, Oil Jet
10. Plug, Hex–Socket
11. Ring, Camshaft Rear Seal
12. Dowel
13. Plug, Hex–Head Pipe
14. Cap, Main Bearing Rear Thrust
15. Plate, Flywheel Housing Cover
16. Bolt w/Flange, Main Bearing Cap
17. Cap, Main Bearing #1–6
18. Gasket, Flywheel Housing
19. Housing, Flywheel
20. Tube, Oil Fill
21. Gauge, Oil Level
22. Clamp, Oil Fill Tube
23. Tube, Lower Oil Level Gauge
24. Clamp, Tube
25. Crankcase
26. Brace, Oil Fill Tube
27. Rear Engine Mounting Brackets (Right and Left)

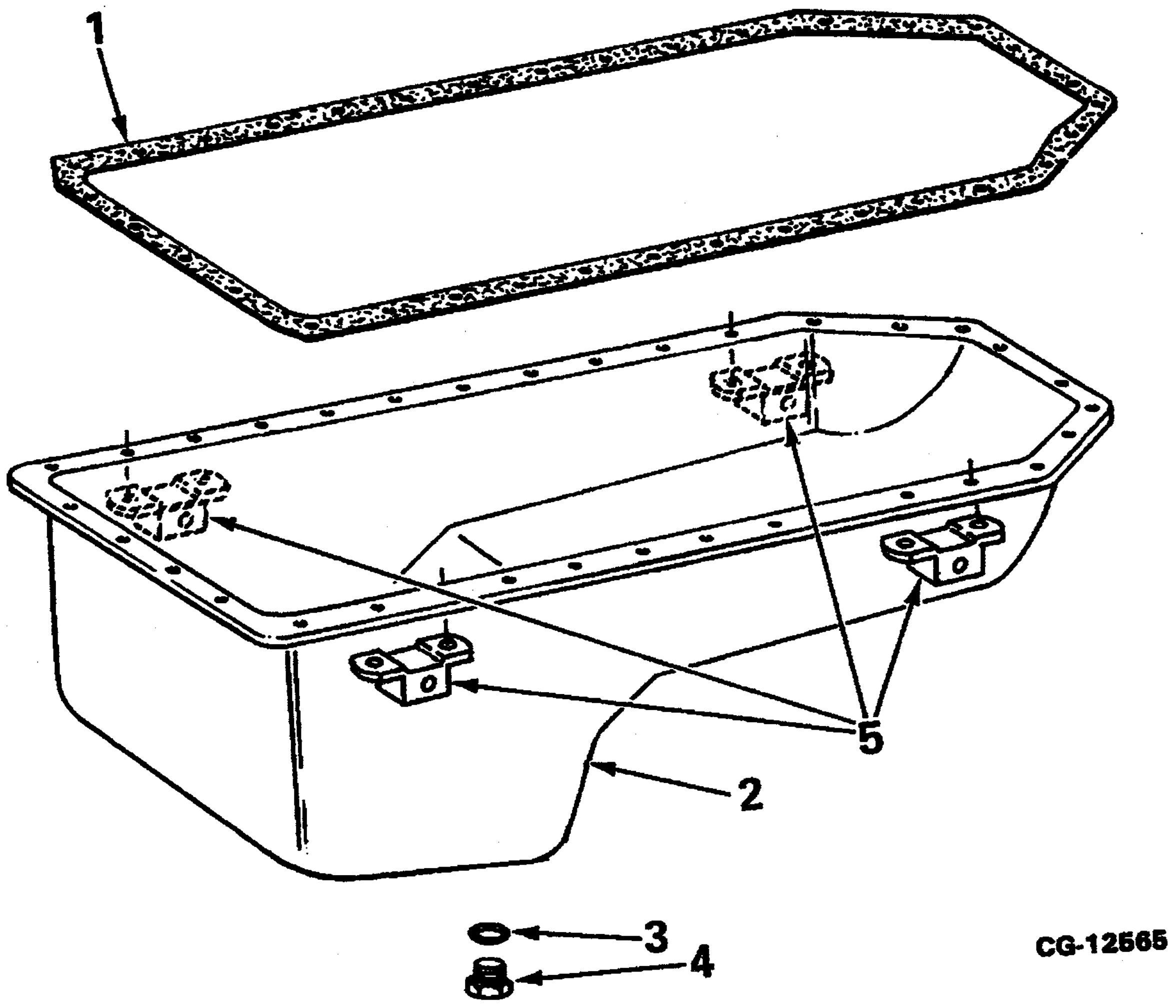

Figure 7.3. Oil Pan Assembly

1. Gasket, Oil Pan
2. Pan, Oil
3. Gasket, Drain Plug
4. Plug, Oil Pan Drain
5. Oil Pan Acoustic Cover Bracket (If Applied)

NOTE: Acoustic cover not shown.

SPECIFICATIONS

DIMENSION TITLE	VALUES
CRANKSHAFT:	
Type	Steel Forging, Induction Hardened, Grindable
Main Bearing Journal Diameter	
Standard Size	3.3742–3.3755 in. (85.705–85.737 mm)
.010" Undersize	3.3642–3.3655 in. (85.450–85.483 mm)
.020" Undersize	3.3542–3.3555 in. (85.196–85.230 mm)
.030" Undersize	3.3442–3.3455 in. (84.942–84.975 mm)
Main Bearing Journal Max. Out–of–Round	0.0013 in. (0.033 mm)
Main Bearing Thrust Face Runout (TIR Max.)	0.001 in. (0.025 mm)
Main Bearing Journal Taper (Max./In.)	0.00015"/in. (0.0038 mm/25.4 mm)
Main Journal Fillet Radius	0.220–0.235 in. (5.59–5.97 mm)
Rod Journal Fillet Radius	0.153–0.160 in. (3.89–4.06 mm)
Rear Oil Seal Journal Runout (Max.)	0.003 in. (0.08 mm)
Damper Mounting Area Runout (Max.)	0.0005 in. (0.013 mm)
Flywheel Mounting Surface Runout (Max.)	0.002 in. (0.05 mm)
Number of Main Bearings	7
Thrust Taken by	Rear Main
Thrust Bearing Journal Length (Std. to 0.020" U/S)	1.4415–1.4445 in. (36.614–36.690 mm)
Thrust Bearing Journal Length (0.030"U/S)	1.4535–1.4565 in. (36.919–36.995 mm)
Main Bearing to Crankshaft Clearance	0.0018–0.0051 in. (0.046–0.013 mm)
Connecting Rod Journal Diameter	
Standard Size	2.5182–2.5197 in. (63.962–64.000 mm)
.010" Undersize	2.5082–2.5097 in. (63.708–63.746 mm)
.020" Undersize	2.4982–2.5397 in. (63.454–64.508 mm)
.030" Undersize	2.4882–2.4897 in. (63.200–63.238 mm)
Connecting Rod Journal Max. Out–of–Round	0.0013 in. (0.033 mm)
Connecting Rod Journal Taper (Max./In.)	0.00015"/in. (0.0038 mm/25.4 mm)
Connecting Rod Bearing to Crankshaft Running Clearance	0.0018–0.0051 in. (0.013–0.046 mm)
Crankshaft Flange O.D.	4.9984–5.0000 in. (126.959–127.000 mm)
Crankshaft End Play	0.006–0.012 in. (0.15–0.30 mm)
Crankshaft End Play Max. Wear Limit	0.020 in. (0.51 mm)
Rod to Crankshaft Side Clearance	0.009–0.015 in. (0.23–0.38 mm)
Crankshaft Gear Backlash	0.003–0.016 in. (0.08–0.41 mm)

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SPECIFICATIONS

DIMENSION TITLE	VALUES
CRANKSHAFT — Continued:	
Flywheel Runout (Max.)	0.008 in. (0.20 mm)
Flywheel Concentricity (Max.)	0.008 in. (0.20 mm)
Flywheel Housing Bore Concentricity (Max.)	0.008 in. (0.20 mm)
Flywheel Housing Face Runout (Max.)	0.008 in. (0.20 mm)
Vibration Damper Max. Allowable Member Misalignment	0.060 in. (1.52 mm)
Vibration Damper Wobble (Max.)	0.060 in. (1.52 mm)
CRANKCASE:	
Crankcase Deck Flatness	0.003 in. (0.076 mm)
Crankcase Deck Finish (Micro Inches)	125 AA
Centerline of Main Bearing Bore to Head Deck	13.3985–13.4015 in. (340.322–340.398 mm)
Crankcase Main Bearing Bore Diameter	3.6885–3.6895 in. (93.688–93.713 mm)
Tappet Bore Diameter	1.1225–1.2350 in. (28.511–28.536 mm)
Valve Lifter O.D.	1.1195–1.1200 in. (28.435–28.448 mm)
Oil Jet Tube Orifice Diameter (Spray Hole Dia.)	0.048–0.049 in. (1.22–1.24 mm)
Main Bearings	
Type	Precision Replaceable
Material	Steel–Backed Copper/Lead
Thrust Taken by	No. 7 Rear
Cap Attachment	2 Bolts per Cap
Camshaft Bushing Bore Diameter in Crankcase (Without Bushing Installed)	
Front	2.5005–2.5020 in. (63.512–63.550 mm)
Intermediate Front	2.4805–2.4820 in. (63.005–63.043 mm)
Intermediate Rear	2.4605–2.4620 in. (62.496–62.535 mm)
Rear	2.4405–2.4420 in. (61.988–62.026 mm)
CYLINDER SLEEVES:	
Counterbore Dimension in Crankcase	0.348–0.350 in. (8.84–8.89 mm)
Maximum Allowable Variation of Counterbore Depth (Between Four Points)	0.001 in. (0.025 mm)
Maximum Cylinder Sleeve Counterbore Allowable Depth	0.413 in. (10.49 mm)
Flange Thickness	0.352–0.353 in. (8.94–8.97 mm)
Protrusion Above Crankcase Deck	0.002–0.005 in. (0.05–0.13 mm)

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SPECIAL TORQUES

Connecting Rod Nuts	85 lbf–ft. (115 Nm)
Crankshaft Main Bearing Cap Bolts	115 lbf–ft. (155 Nm)
Crankshaft Vibration Damper Retainer Bolts	105 lbf–ft. (142 Nm)
Flywheel Bolts	110 lbf–ft. (150 Nm)
Flywheel Housing Mounting Bolts	105 lbf–ft. (142 Nm)
Oil Pan Bolts	20 lbf–ft. (47 Nm)
Oil Pan Drain Plug	27 lbf–ft. (37 Nm)
Oil Level Gauge Tube Clamp	30 lbf–in. (3 Nm)

SPECIAL SERVICE TOOLS

Tool No.	Description
ZTOEM–4125	Lifting Sling
ZTSE–4272	Rear Oil Seal Installing Tool
ZTSE–3004A	Vibration Damper Wear Sleeve Installing Tool

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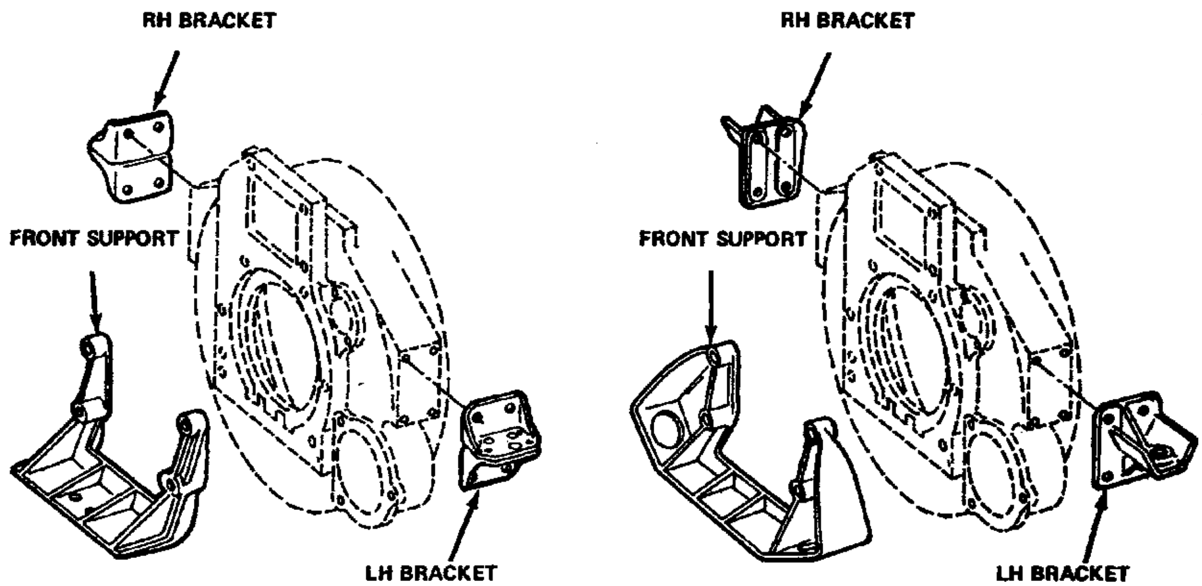
COMPONENT CHANGES

FRONT ENGINE SUPPORT AND REAR MOUNTING BRACKETS

Effective with S/N 054459 (1989 Model Year) the front engine support and rear mounting brackets are redesigned to improve on eliminating engine vibration. The new front engine support is designed to bolt directly to the crankcase replacing the earlier support which bolted to the front cover plate. The rear mounting brackets have been increased in length and reinforced in design. Refer to **Figure 7.4.**

NOTE: To accept the new direct crankcase bolt–on configeration, either modifications to the existing front cover plate and plate gasket are required or installation of a new front cover plate and gasket (as described in Section 8) are needed.



1988 and Prior Model Years

1989 and Later Model Years

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Figure 7.4 Front Engine Support and Rear Mounting Brackets Comparison

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REAR OIL SEAL & WEAR SLEEVE (Removal and Reassembly)

NOTE: The rear oil seal can be serviced in chassis. The procedure is performed as part of the engine overhaul and separately, when required.

REMOVAL

1. Remove two bolts from the flywheel and install two guide studs. Refer to **Figure 7.5**.

NOTE: Engines equipped to accommodate automatic transmissions will have a flex plate and a reinforcing plate, which must be removed.

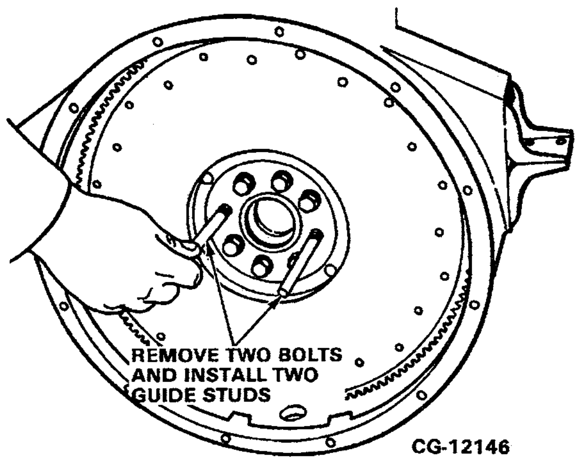

Figure 7.5. Install Guide Studs

2. Remove the remaining flywheel bolts and slide the flywheel out of the housing and off the guide studs to remove it from the crankshaft. Refer to **Figure 7.6.** With the flywheel removed, the guide studs can be removed from the crankshaft flange.

NOTE: Two methods are available to remove the rear oil seal. Method One uses rear seal remover tool ZTSE–4272. Method Two uses sheet metal screws and a pry bar.

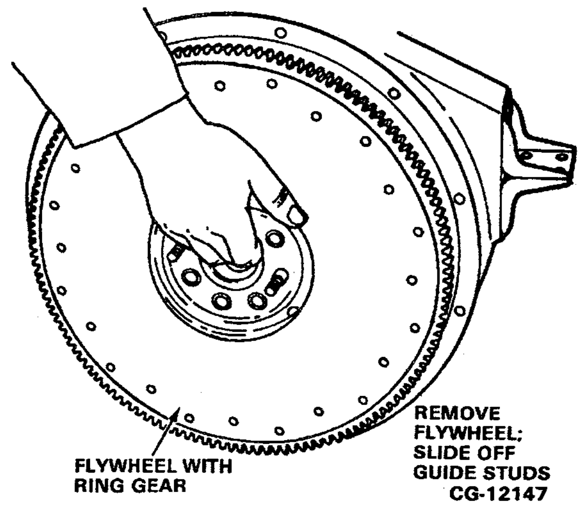

Figure 7.6. Remove Flywheel

Rear Oil Seal Removal (Method One)

1. Assemble the puller plate with forcing screw from ZTSE–4272 onto the crankshaft flange using the two guide studs from the tool. With the plate attached, use a punch and hammer to make four holes in the rear oil seal. Refer to **Figure 7.7.**

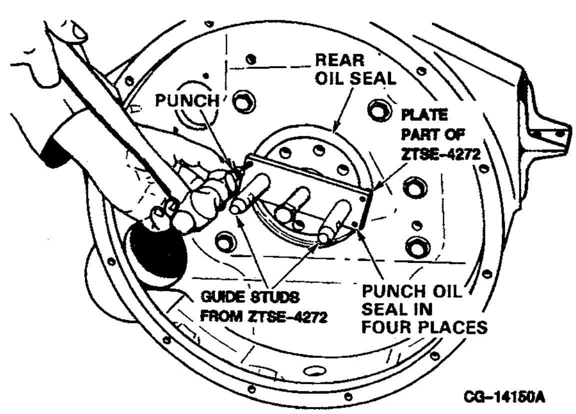

Figure 7.7. Punch Holes in Oil Seal

REAR OIL SEAL & WEAR SLEEVE (Removal and Reassembly) —Continued

REMOVAL — Continued

Rear Oil Seal Removal (Method One) — Continued

2. Insert hex head sheet metal screws into each of the punch holes. Turn the center forcing screw in the puller plate and the seal will be removed from the flywheel housing. Refer to **Figure 7.8.**

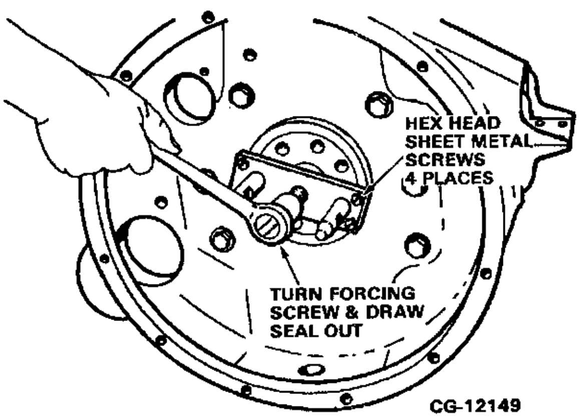

Figure 7.8. Remove Rear Oil Seal (Method One)

3. Discard oil seal.

Rear Oil Seal Removal (Method Two)

NOTE: Use Method Two if the rear seal remover tool ZTSE–4272 is not available.

1. Punch two holes into the rear oil seal and insert two hex head sheet metal screws.
2. Use a small pry and pry alternately on the screws to remove the seal from the flywheel housing. Refer to **Figure 7.9.**
3. Discard oil seal.

NOTE: It is not necessary to remove the flywheel housing if all that is required is to replace the crankshaft rear oil seal or wear sleeve.

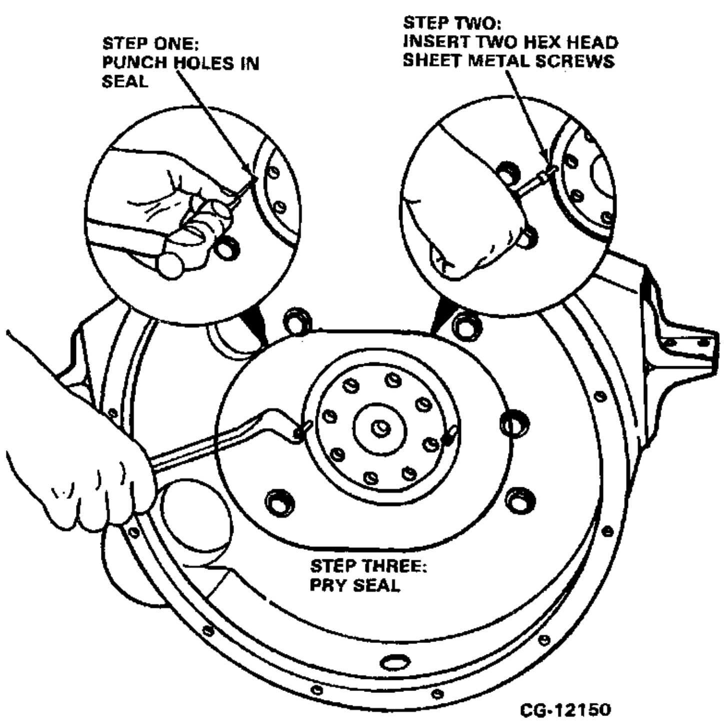

Figure 7.9. Remove Rear Oil Seal (Method Two)

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REAR OIL SEAL & WEAR SLEEVE (Removal and Reassembly) —Continued

REMOVAL — Continued

Wear Sleeve Removal (In Chassis)

1. With the rear oil seal removed, the wear sleeve can be removed using a muffler chisel and air hammer. Refer to **Figure 7.10.**

IMPORTANT

BE CAREFUL NOT TO NICK THE CRANKSHAFT FLANGE DURING THIS PROCEDURE. USE THIS METHOD ONLY WHEN THE REPAIR IS TO BE DONE IN CHASSIS WITH THE FLYWHEEL HOUSING IN PLACE.

2. Discard wear sleeve.

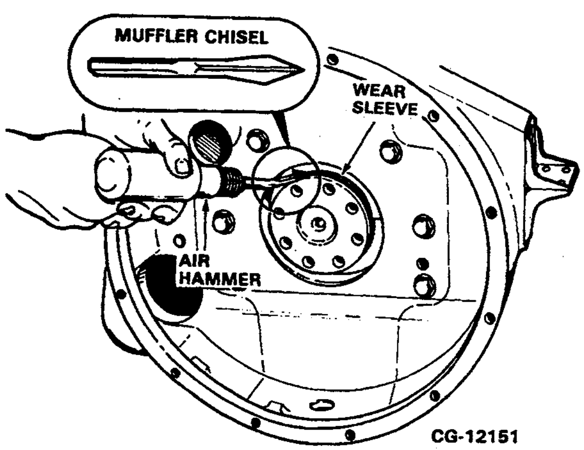

Figure 7.10. Remove Wear Sleeve with Air Hammer and Muffler Chisel

Wear Sleeve Removal (Out of Chassis)

1. With the flywheel housing removed, use a hammer and tap the O.D. of the wear sleeve. Refer to **Figure 7.11.**

NOTE: This causes the wear sleeve to expand and slide off easily.

2. Discard the wear sleeve.

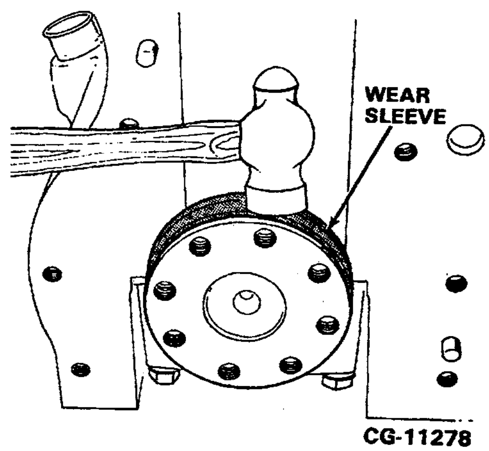

Figure 7.11. Tap to Expand Wear Sleeve

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REAR OIL SEAL & WEAR SLEEVE (Removal and Reassembly) —Continued

REASSEMBLY

Rear Oil Seal and Wear Sleeve Installation

NOTE: Flywheel housing bore concentricity and flywheel housing face runout should be checked to ensure proper engine to transmission alignment.

1. Check flywheel housing bore concentricity as follows:
   a. Attach a dial indicator to the crankshaft and place the indicator tip against the flywheel housing pilot bore. Refer to **Figure 7.12.**

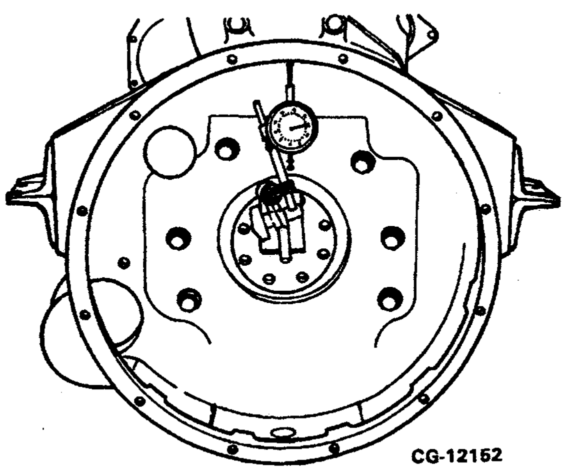

Figure 7.12. Check the Concentricity of the Flywheel Housing Bore in Relation to the Axis of the Crankshaft

   b. "Zero" the dial indicator.
   c. Rotate the crankshaft slowly and record the total indicator variation. Refer to **"SPECIFICATIONS"** for housing bore concentricity tolerance.

2. Check flywheel housing face runout as follows:
   a. Attach a dial indicator to the crankshaft flange, and place the indicator tip against the flywheel housing face. Refer to **Figure 7.13.**

IMPORTANT

"ZERO" THE CRANKSHAFT END PLAY BY PUSHING THE CRANKSHAFT IN THE SAME DIRECTION FOR ALL MEASUREMENTS.

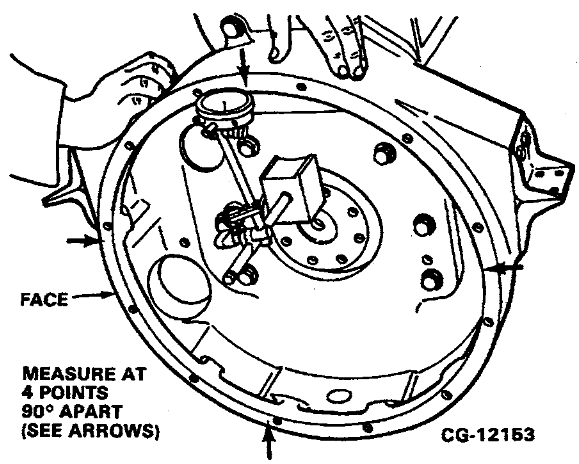

Figure 7.13. Check Flywheel Housing Face Runout

   b. Measure at four points, 90° apart, for total face variation.
   c. Refer to **"SPECIFICATIONS"** for flywheel housing face runout tolerance.

REAR OIL SEAL & WEAR SLEEVE (Removal and Reassembly) —Continued

REASSEMBLY — Continued

Rear Oil Seal and Wear Sleeve Installation — Continued

IMPORTANT

INSTALL THE REAR OIL SEAL AND WEAR SLEEVE AS A UNIT. DO NOT REMOVE THE SEAL FROM THE WEAR SLEEVE PRIOR TO INSTALLATION.

3. Install a new rear oil seal and crankshaft wear sleeve assembly using the installer tool ZTSE–4272 as follows:
   a. Clean the crankshaft flange and flywheel housing bore thoroughly. Remove any debris.
   b. Install the centering plate from ZTSE–4272 to the crankshaft flange using the two studs provided with the installer tool. Refer to **Figure 7.14.**
   c. Coat the I.D. of wear sleeve and O.D. of oil seal with a thin film of R.T.V. liquid gasket (Dow 732, General Electric 1473 or equivalent). DO NOT get any of this liquid on the seal lip or O.D. of the wear sleeve. Refer to **Figure 7.14.**
   d. Position the oil seal and wear sleeve over the centering plate and onto the crankshaft flange. Place the installer portion of ZTSE–4272 over the centering plate and studs. Turn the forcing nut on the installer tool until the seal and sleeve is seated in the bore. Refer to **Figure 7.15.**

NOTE: Proper use of this tool will assure that the seal and wear sleeve are pressed onto the crankshaft flange to the proper depth.

   e. Remove the installer tool.

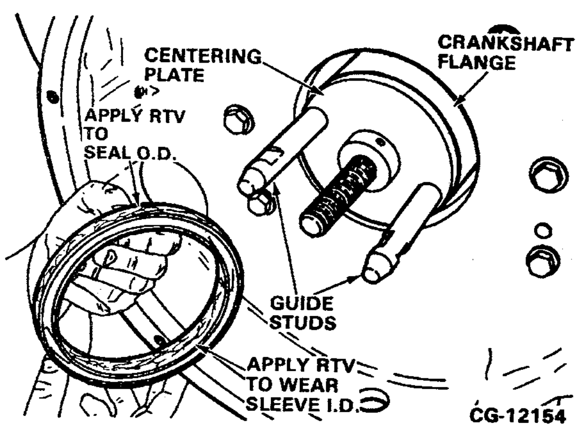

Figure 7.14. Install Centering Plate and apply R.T.V. to Seal and Sleeve

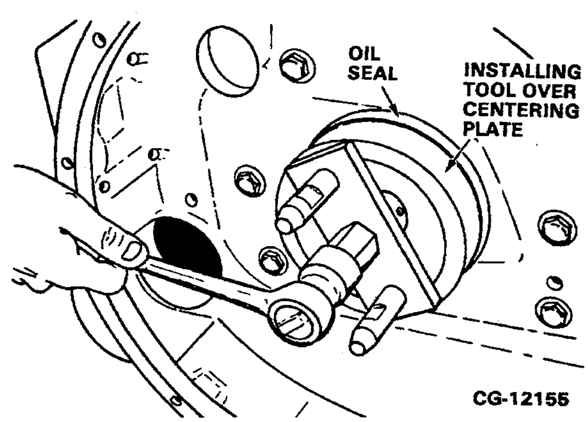

Figure 7.15. Install Seal and Wear Sleeve

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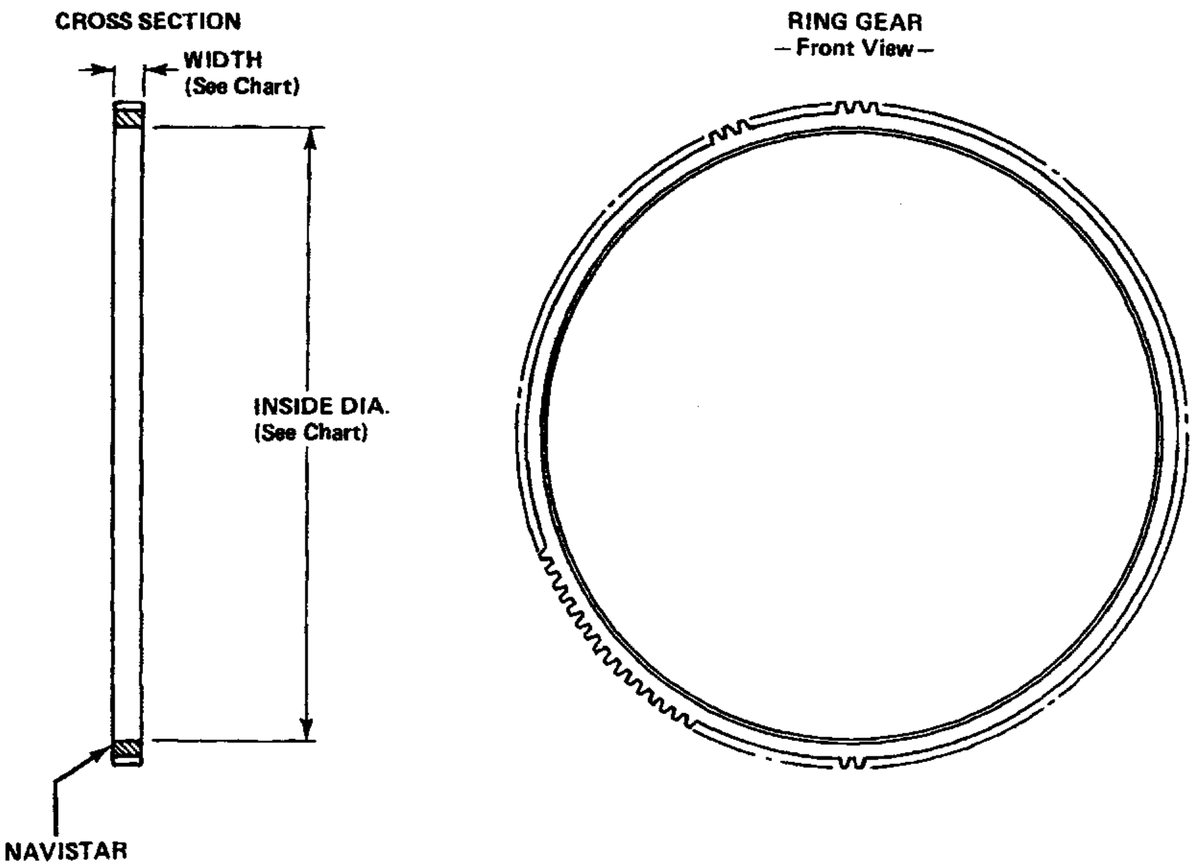
FLYWHEEL
(Reconditioning)

NOTE: Current production flywheel and ring gear have the following changes:

Ring gear width is REDUCED from .750 in. to .625 in. and I.D. INCREASED from 16.124 in. to 16.240 in. (before assembly). Refer to Figure 7.16.



PART NO.	WIDTH	I.D. BEFORE ASS'Y	I.D. AFTER ASS'Y
1 815 440 C1	.625 in.	16.240 in.	16.260 in.
1 813 752 C1	.750 in.	16.124 in.	16.144 in.
681 926 C2	.750 in.	16.124 in.	16.144 in.

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Figure 7.16. Flywheel Ring Gear Comparison

Flywheel seat diameter is INCREASED from 16.144 in. to 16.260 in. Refer to Figure 7.17.

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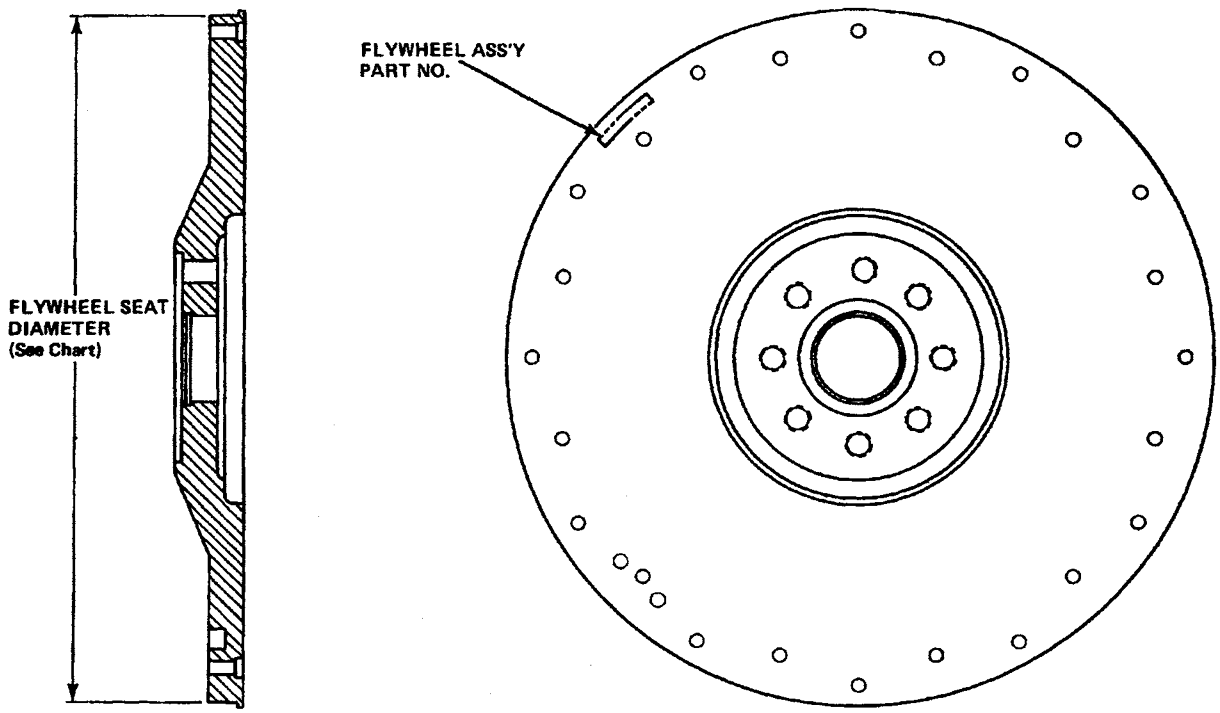
FLYWHEEL
(Reconditioning) — Continued



FLYWHEEL ASS'Y PART NO.	FLYWHEEL SEAT DIA.	USE RING GEAR PART NO.
673 565 C93	16.260 in.	1 815 440 C1
673 565 C92	16.144 in.	1 813 752 C1
678 520 C93	16.260 in.	1 815 440 C1
678 520 C92	16.144 in.	1 813 752 C1
681 905 C95	16.260 in.	1 815 440 C1
681 905 C94	16.144 in.	681 926 C2
683 961 C93	16.260 in.	1 815 440 C1
683 961 C92	16.144 in.	1 813 752 C1
690 602 C93	16.260 in.	1 815 440 C1
690 602 C92	16.144 in.	681 926 C2

CG-14570

Figure 7.17. Flywheel Seat Diameter Comparison

IMPORTANT

When replacing a damaged ring gear, be sure to identify the ring gear number (Figure 7.16.) or the flywheel assembly part number (Figure 7.17.) so the correct ring gear is ordered. Do not install a narrow ring gear on a flywheel with a narrow seat or a wide width ring gear on a wide seat flywheel. Refer to current Parts Catalog for proper service number.

CLEANING

1. Clean the flywheel with a non–caustic solvent and dry with filtered, compressed air.

INSPECTION

1. Visually inspect the flywheel for cracks heat checks and extensive scoring which would make it unfit for further service. Replace or resurface as required.
2. Inspect the ring gear for worn, chipped or cracked teeth. If teeth are damaged, replace the ring gear.

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FLYWHEEL
(Reconditioning) — Continued

REPAIR

Flywheel Resurfacing

1. The flywheel may be resurfaced to correct minor wear and scoring of clutch facing.

IMPORTANT

DO NOT RESURFACE FLYWHEELS USED WITH AUTOMATIC TRANSMISSIONS.

CAUTION !

This flywheel resurfacing information is provided for guidance only. Navistar International Transportation Corp. assumes no responsibility either for the results of any work performed in accordance with this information or for the ability of service personnel to detect heat checks. Any crack or heat check in the flywheel could cause it to separate, creating the possibility of injury to the operator or bystanders. Carefully examine the flywheel, after resurfacing, for any cracks or heat checks. If there is any question, do not use the flywheel.

2. When resurfacing the flywheel, refer to dimension "A" (**Figure 7.18**), to determine if the flywheel was previously refaced or if it has adequate stock for refacing.

NOTE: If the dimensions depicted in Figure 7.18 cannot be maintained, the flywheel must be replaced.

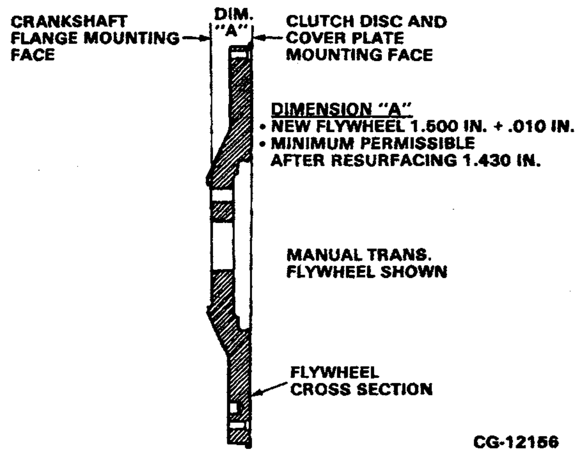

Figure 7.18. Flywheel Resurfacing Specifications

Ring Gear Replacement

NOTE: Effective with S/N 043930 all flywheels are equipped with a chamfered ring gear. The chamfer facilitates the engagement of the starter pinion into the flywheel. The new ring gear will replace the old and is a direct interchange without modification of existing parts or components.

1. Remove any damaged ring gear from the flywheel as follows:
   a. Heat the ring gear with a torch to expand the gear.
   b. Once heated, knock the gear off the flywheel. <u>DO NOT</u> HIT THE FLYWHEEL WHEN REMOVING THE RING GEAR.

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FLYWHEEL
(Reconditioning) — Continued

REPAIR — Continued

2. Install a new ring gear as follows:

   a. Heat the new ring gear evenly until the gear expands enough to slip onto the flywheel.

   b. Make sure the ring gear is seated properly against the flywheel shoulder.

IMPORTANT

DO NOT HEAT THE RING GEAR TO A TEMPERATURE HIGHER THAN 500°F (278°C). HEATING BEYOND 500°F WILL ADVERSELY AFFECT RING GEAR HARDNESS.

REASSEMBLY

1. Check flywheel housing bore concentricity and flywheel housing face runout, as described under "Rear Oil Seal and Wear Sleeve Installation". See **Figures 7.12 and 7.13.**
2. Install the flywheel and ring gear assembly as follows:
   a. Install the two guide studs on the crankshaft flange and slide the flywheel onto the guide studs. **NOTE: Be sure the flywheel bolt holes are in line with their mating bolt holes in the crankshaft flange.**
   b. Install six of the eight mounting bolts. Remove the guide studs and install the two remaining bolts. Refer to **Figure 7.19.**
   c. Tighten the flywheel mounting bolts to specified torque. Refer to **Figure 7.20.**

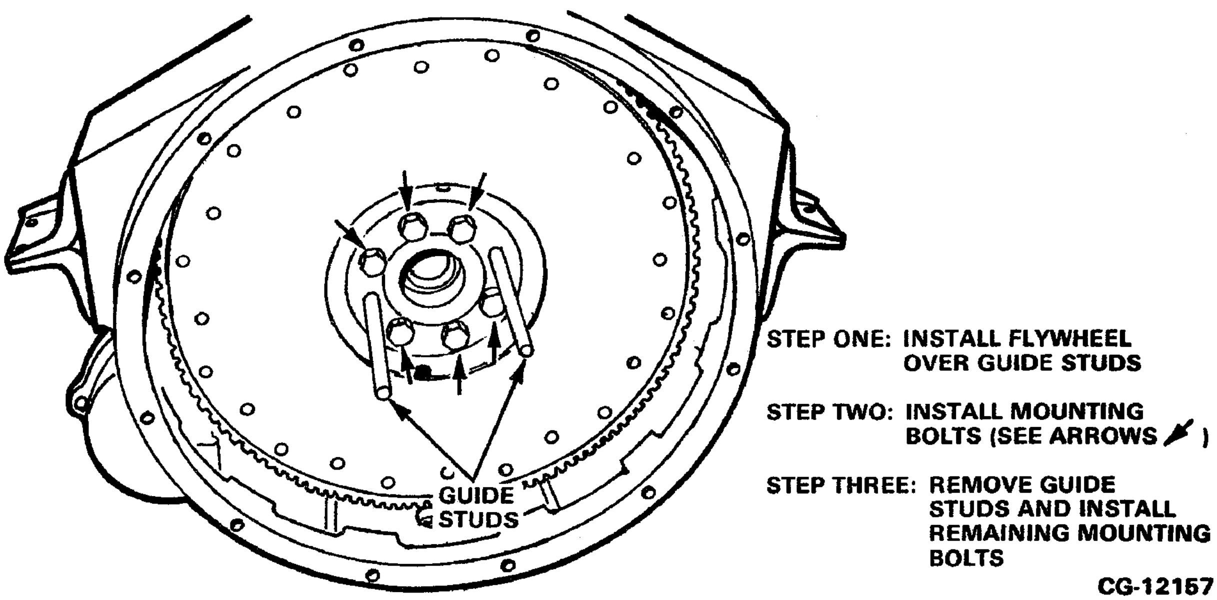

Figure 7.19. Install Flywheel with the Aid of Guide Studs

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FLYWHEEL
(Reconditioning) — Continued

REASSEMBLY — Continued

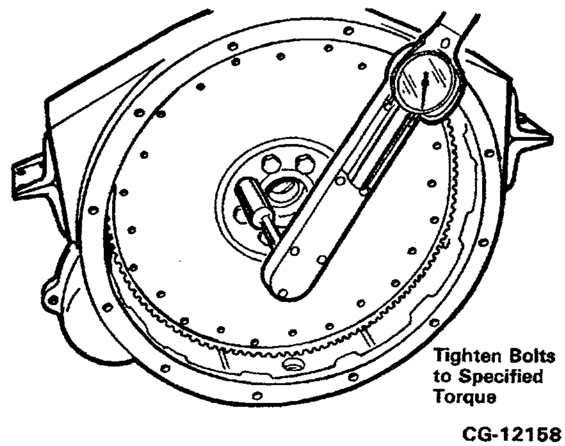

Figure 7.20. Tighten to Specified Torque

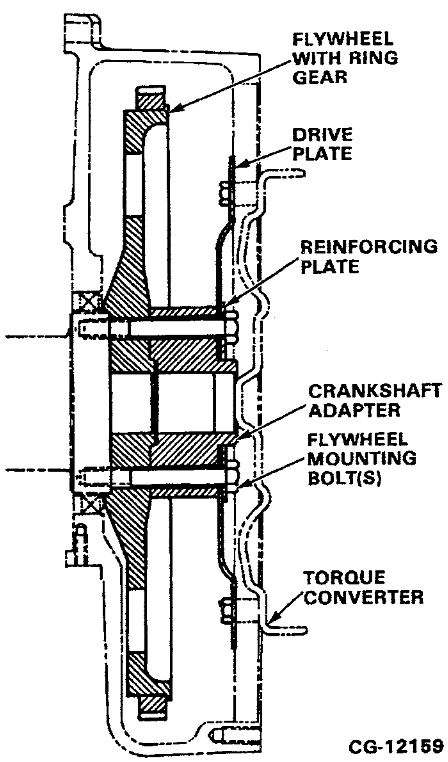

Figure 7.21. Flywheel Installation for Vehicles with AT–545 Transmission

NOTE: Engines equipped with either the AT–545, MT–640 or MT–650 transmission must have the flywheel installed in conjunction with the parts specified in Figures 7.21 and 7.22.

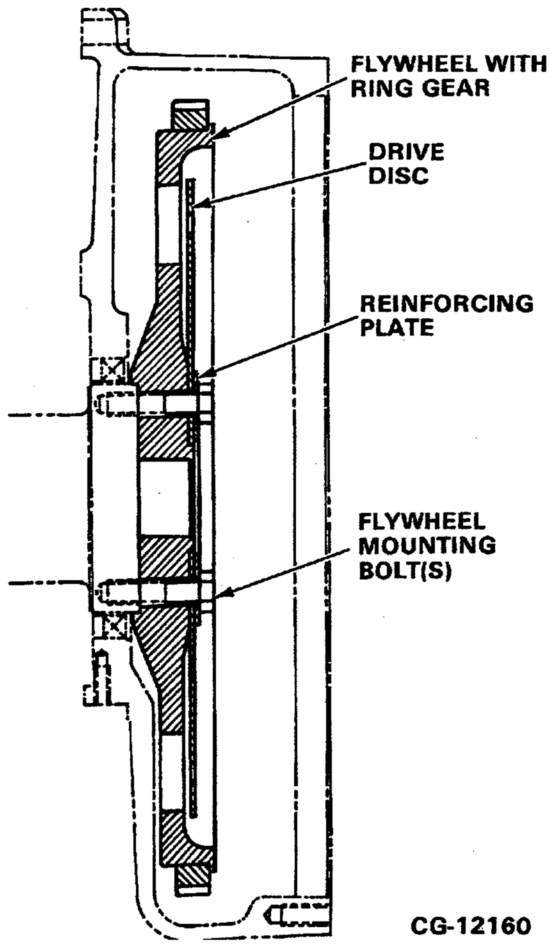

Figure 7.22. Flywheel Installation for Vehicles with MT–640 or MT–650 Transmissions

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CRANKCASE BREATHER
(Removal and Reassembly)

IDENTIFICATION (Refer to Figure 7.23)

A revised crankcase breather housing and tube assembly is released on engines with serial numbers above 37296. The new breather tube and housing are brazed parts and serviced as an assembly only. The new design positions the breather tube at the top side of the housing, which reduces oil carry–over.

NOTE: Crankcase pressure specifications are the same for new and former style crankcase breather assemblies.

IMPORTANT

THE O–RING USED FOR CONNECTING THE FORMER BREATHER TUBE AND HOUSING IS NOT REQUIRED WITH THE NEW ASSEMBLY. HOWEVER, THE NEW BREATHER HOUSING AND TUBE ASSEMBLY USES LONGER MOUNTING BOLTS THAN THE PRIOR HOUSING DESIGN.

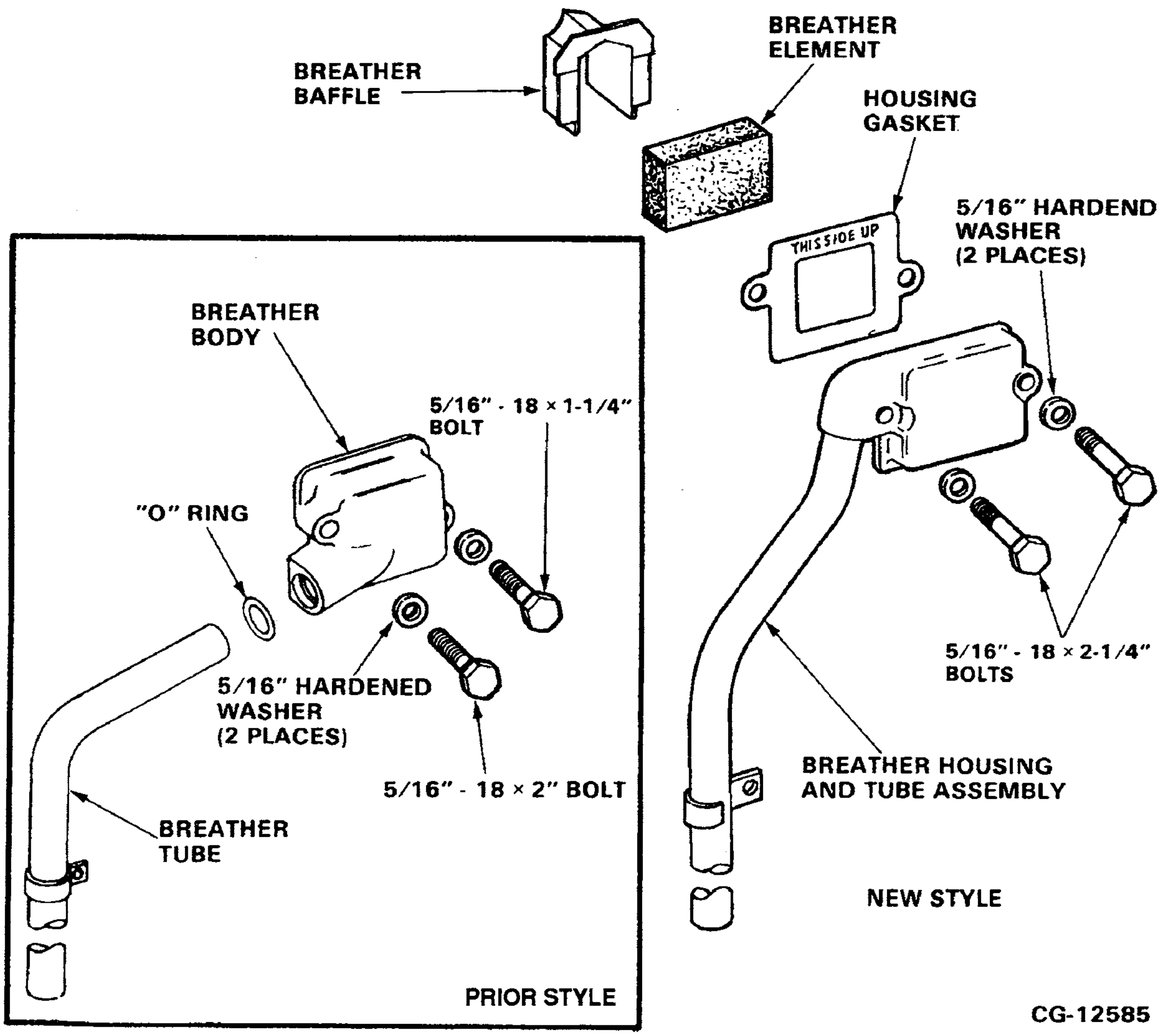

Figure 7.23. Crankcase Breather Identification

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CRANKCASE BREATHER
(Removal and Reassembly) — Continued

REMOVAL

1. Remove the bolt and washer at the breather tube. Refer to **Figure 7.24.**

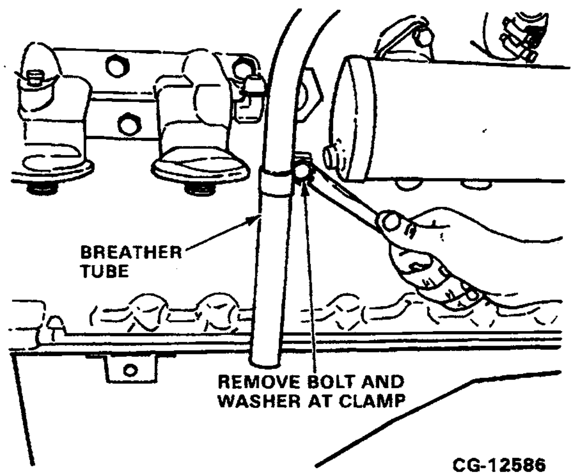

Figure 7.24. Remove Breather Tube Clamp Hardware

2. Remove the bolts and washers which retain the breather housing. Refer to **Figure 7.25.**

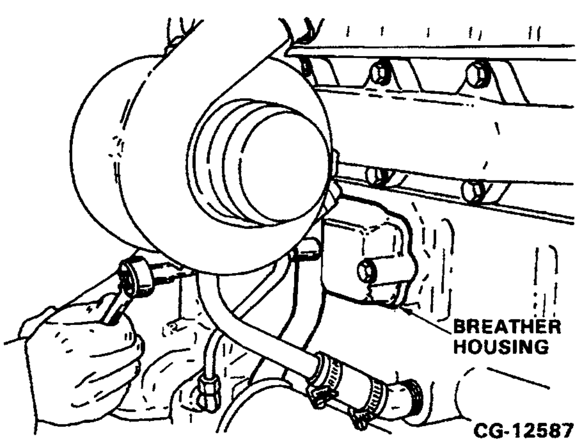

Figure 7.25. Remove Breather Housing Hardware

3. With the breather tube and housing assembly removed, remove and discard the gasket and breather element. Refer to **Figure 7.26.**

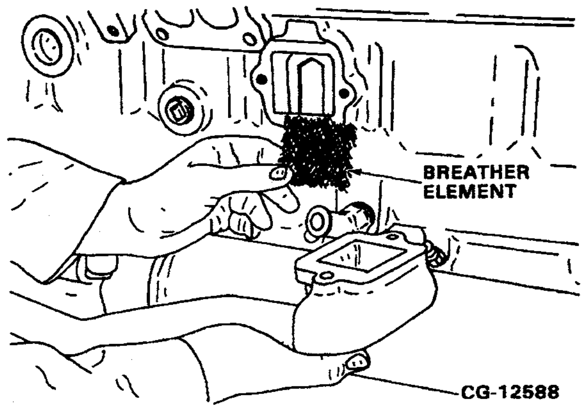

Figure 7.26. Remove Breather Element

4. Remove the breather baffle from the crankcase. Use a pick to break the R.T.V. seal. Refer to **Figure 7.27.**

NOTE: The baffle is designed to divert oil away from the crankcase breather to keep oil carry–over to a minimum.

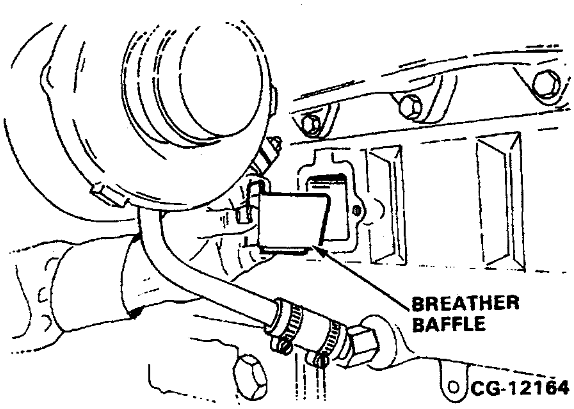

Figure 7.27. Remove Breather Baffle

NOTE: Clean old R.T.V. sealant from breather baffle.

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CRANKCASE BREATHER
(Removal and Reassembly) — Continued

REASSEMBLY

1. Apply fresh R.T.V. sealant to the breather baffle and insert it into the crankcase. Refer to **Figure 7.28.**

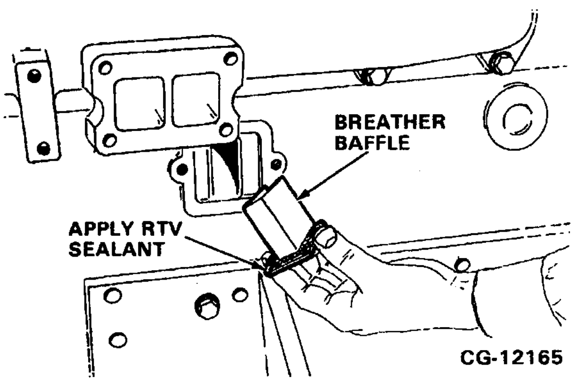

Figure 7.28. Install Breather Baffle

IMPORTANT

WHEN INSTALLING THE BREATHER BAFFLE INTO THE CRANKCASE OPENING, BE SURE THE BAFFLE SIDES ARE PARALLEL WITH THE SIDES OF THE CRANKCASE OPENING. THE BAFFLE MUST NOT BE SQUEEZED TO MAKE IT FIT OVER ANY CASTING FLASH OR BURRS. IF FLASH OR BURRS EXIST WHICH IMPEDE CORRECT BAFFLE INSTALLATION, REMOVE WITH A FILE AND CLEAN DEBRIS FROM THE CRANKCASE OPENING. REFER TO FIGURE 7.29.

2. Install a new breather element into the breather baffle. Refer to **Figure 7.30.**

NOTE: The breather element has two sides (one side with mesh and one side without mesh). Install with the mesh facing inside (towards the baffle).

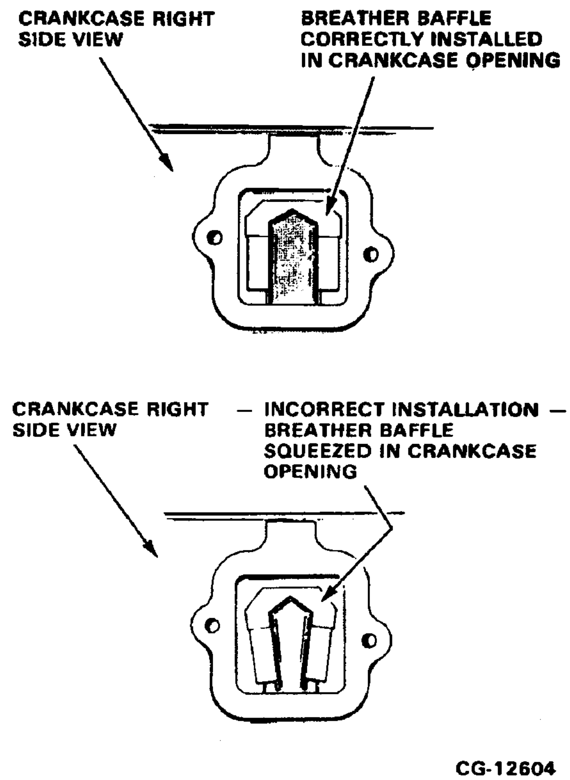

Figure 7.29. Breather Baffle (Installed View) Correct vs. Incorrect

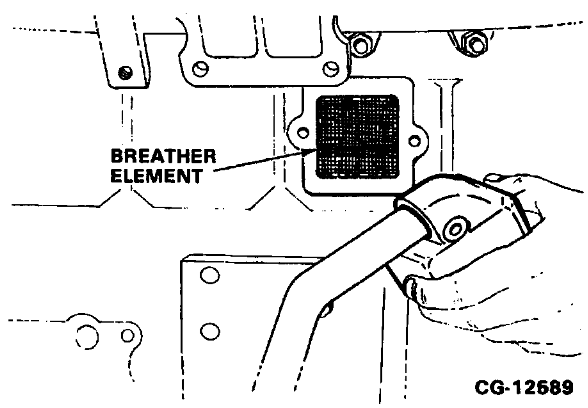

Figure 7.30. Install Breather Element

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CRANKCASE BREATHER
(Removal and Reassembly) — Continued

REASSEMBLY — Continued

3. Using a new gasket, install the breather housing on the crankcase. Use the appropriate length bolts (**Figure 7.31**) with washers and tighten to the standard torque.

4. For early style breather tubes, use a new O–ring and assemble the breather tube to the housing.

5. Secure the tube to the crankcase by installing the bolt and washer at the breather tube bracket.

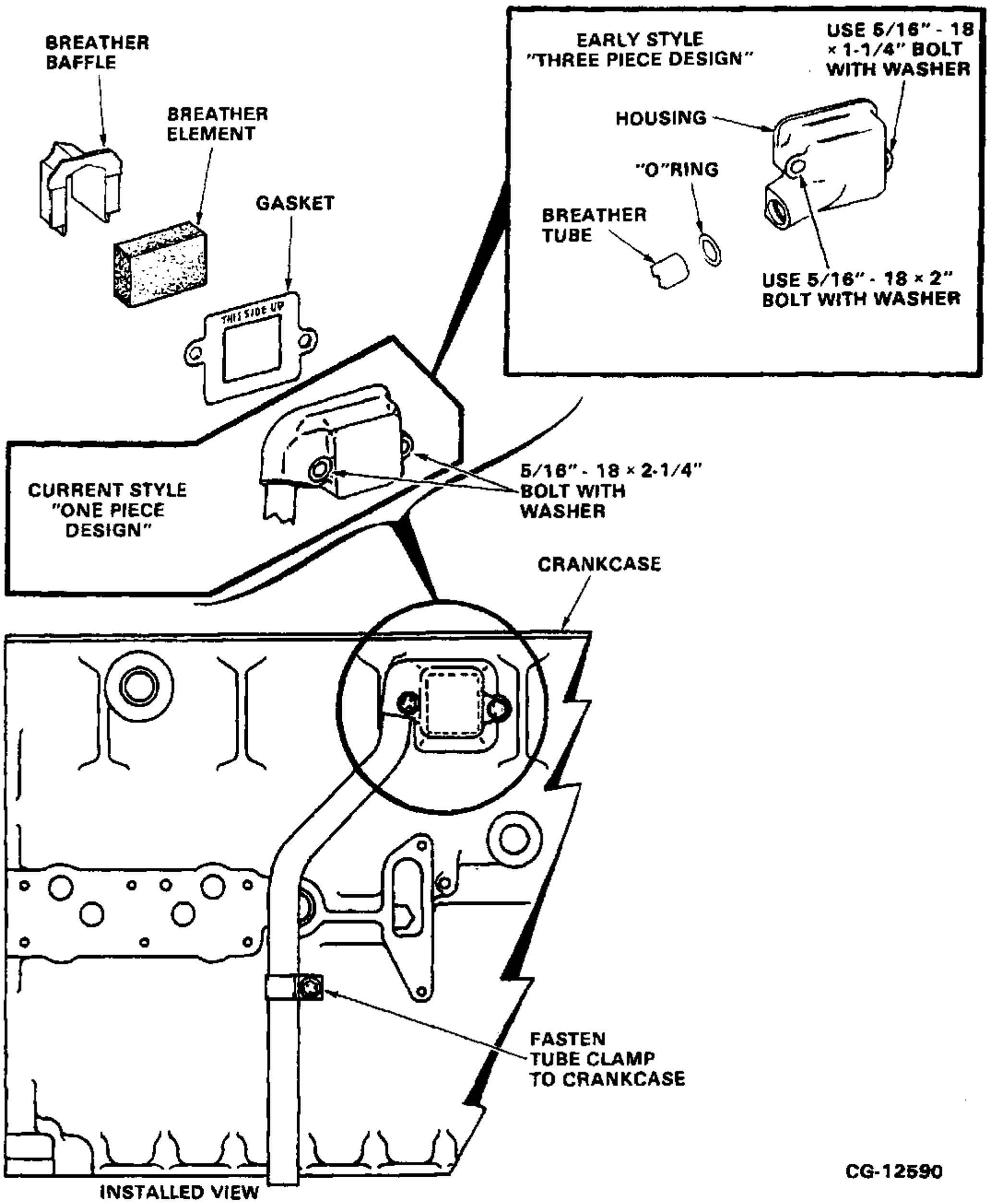

Figure 7.31. Crankcase Breather Installation

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OIL LEVEL GAUGE TUBE ASSEMBLY (Removal and Reassembly)

REMOVAL (Refer to Figure 7.32 or 7.33)

1. Loosen and remove the nut and washers which fasten the oil fill tube bracket to the intake manifold stud.
2. Loosen the tube clamp screw at the lower end of the upper oil level gauge tube.
3. Remove the oil level gauge, upper tube bracket, clamps and gasket from the lower oil level gauge tube in the crankcase, as an assembly.
4. Discard the gasket.
5. If required, remove the lower oil level gauge tube using a brass drift and a hammer, when the oil pan is removed.

CLEANING

1. Thoroughly clean both tubes.
2. Remove all old Loctite® from the lower oil level gauge tube and crankcase casting area which mates with the tube.
3. Dry with filtered, compressed air.

INSPECTION

1. Visually inspect the components for kinks, bends or restrictions.
2. Replace components as required.

REASSEMBLY (Refer to Figure 7.32 or 7.33)

1. Install the lower oil level gauge tube into the crankcase orifice as follows:
   a. Apply Loctite® 601 around the entire circumference of the tube and casting.
   b. Press tube in until the bead is seated in the chamfer of the crankcase.

NOTE: Dimensions in Figures 7.32 and 7.33 are for reference only. Also, the slots in the lower tube need not be oriented in any special manner.

2. Install a new gasket onto the upper oil level gauge tube.
3. Insert the upper tube into the lower tube and orient tube so the bracket assembly aligns with the intake manifold stud.
4. Fasten the bracket assembly to the intake manifold using the appropriate hardware.
5. Tighten the tube clamp screw (at the lower end of the upper oil level gauge tube) to the specified special torque.

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OIL LEVEL GAUGE TUBE ASSEMBLY
(Removal and Reassembly) — Continued

REASSEMBLY — Continued

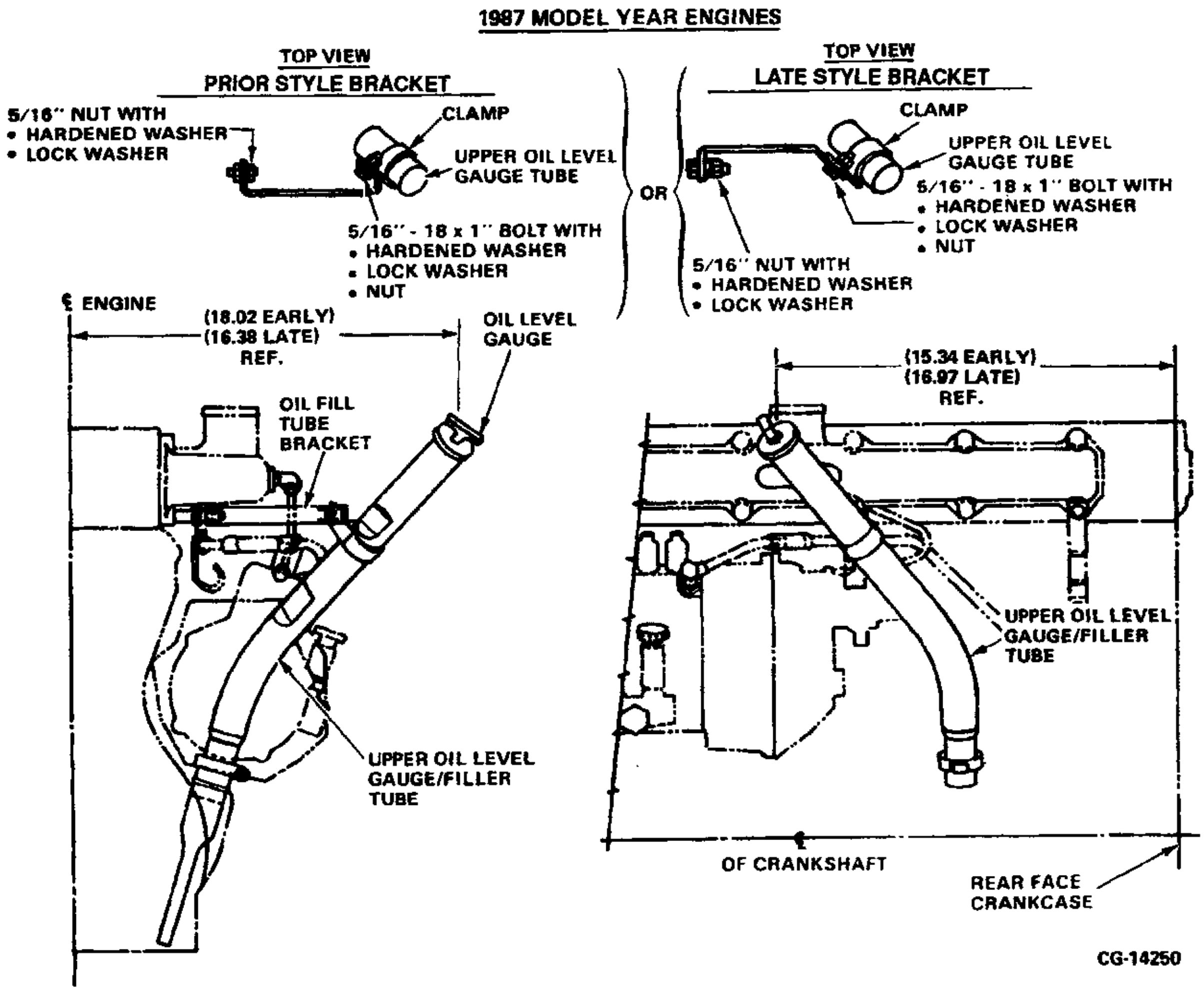

Figure 7.32. Early Oil Level Gauge Tube Installation

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OIL LEVEL GAUGE TUBE ASSEMBLY
(Removal and Reassembly) — Continued

REASSEMBLY — Continued

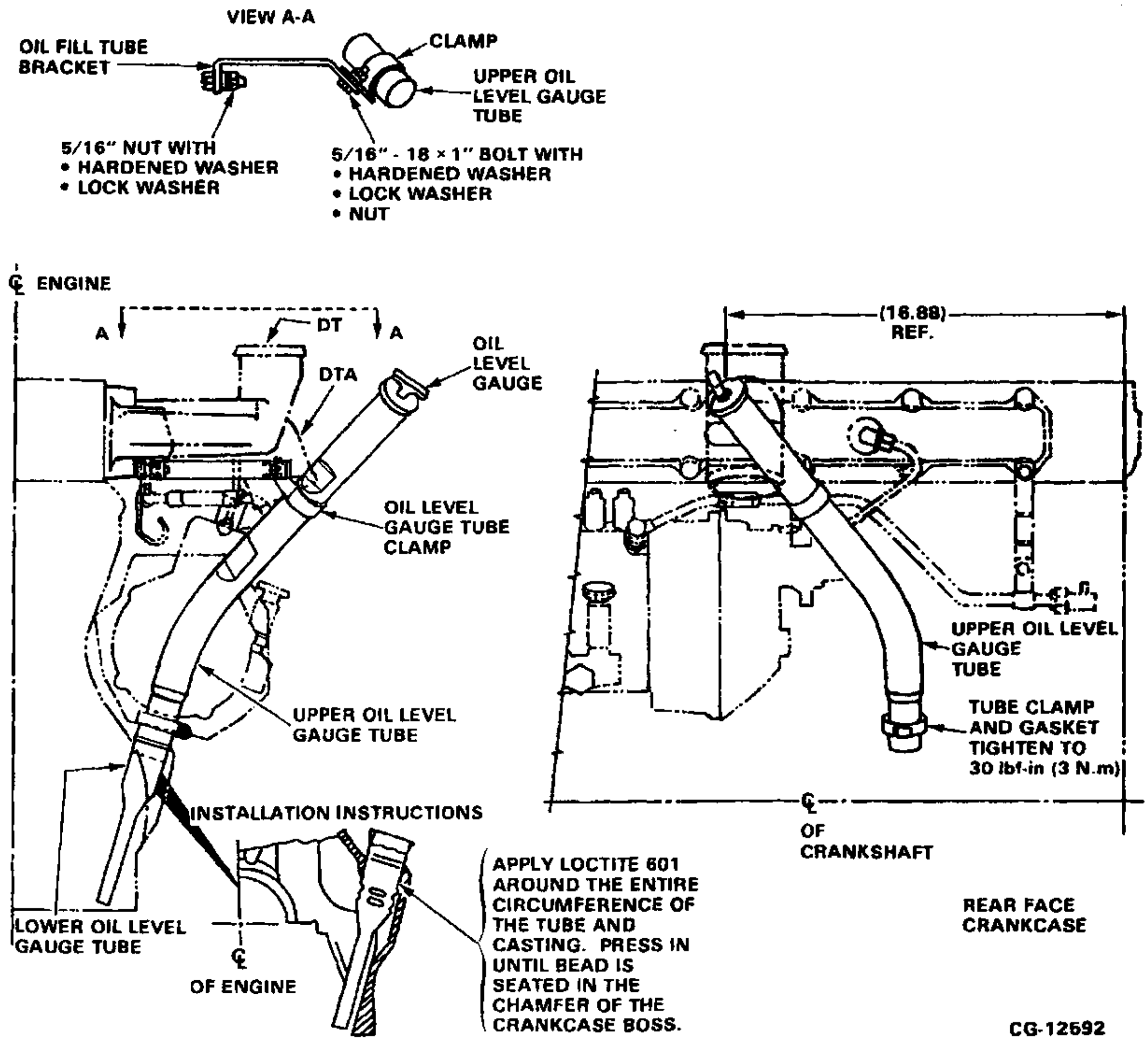

Figure 7.33. Typical Oil Level Gauge Tube Installation

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning)

REMOVAL (For Engine Overhaul)

1. Prior to crankshaft removal, remove the following components:

NOTE: Refer to the appropriate manual section for detailed removal procedures.

- Crossover pipe (DT–360 only)
- Fuel injection lines (high pressure)
- Fuel leak–off lines (low pressure)
- Aneroid tube
- Valve cover
- Thermostat housing to water pump hose
- Turbocharger oil inlet and oil drain tubes
- Rocker arm assembly
- Fuel injection nozzles
- Cylinder head assembly (with intake manifold, exhaust manifold, thermostat housing and turbocharger attached)
- Fuel injection pump
- Fuel filter and header
- Oil cooler
- Oil filters and header

2. Remove the crankcase breather assembly, oil level gauge tube assembly, flywheel, rear oil seal and wear sleeve as described in this section.

Oil Pan

3. Remove the oil pan as follows:

NOTE: The oil pan must be removed prior to removing the flywheel housing due to the studs in the housing which are used to retain the oil pan.

a. Remove the four nuts from the studs at the rear of the oil pan. Refer to **Figure 7.34.**

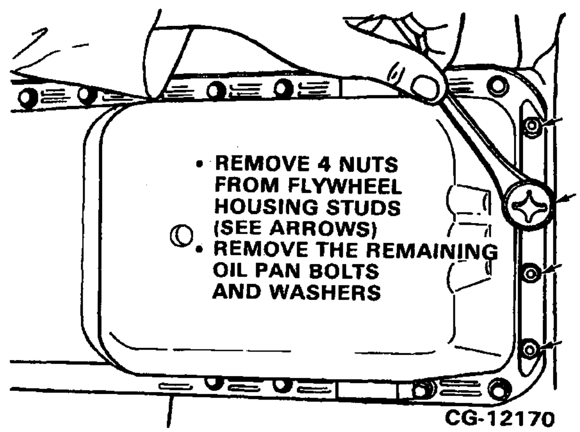

Figure 7.34. Remove Oil Pan Fasteners

NOTE: 1988 model year DTA–360 Diesel Engines were equipped with an oil pan sump acoustic cover to reduce noise levels in accordance with government standards. 1988 DT–360's and 1987 DT/DTA–360's did not require an acoustic cover; consequently, those engines were not built with oil pan cover brackets. The four oil pan cover brackets (two on each side) are fastened to the engine using eight 1–1/8 in. long screw and conical washer assemblies. Do not substitute hardware. Refer to your parts catalog when ordering. Refer to Figure 7.35.

DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

REMOVAL (For Engine Overhaul) — Continued

Oil Pan — Continued

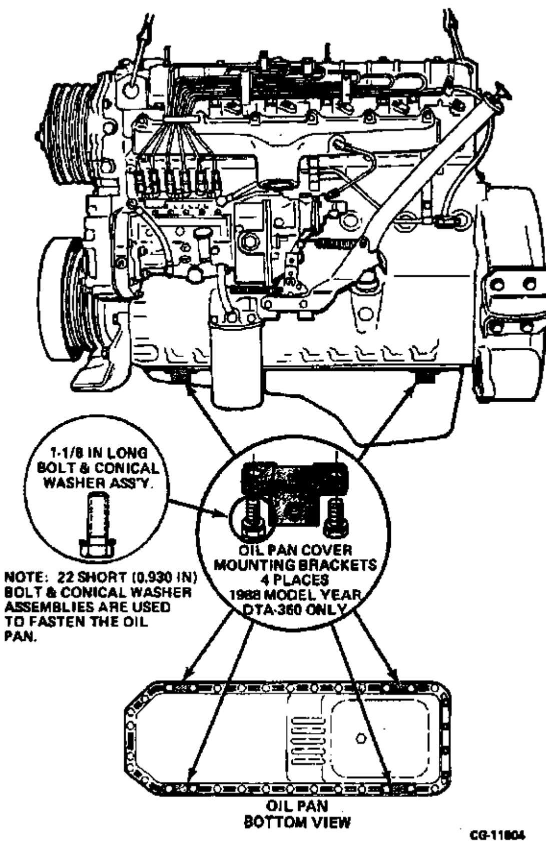

Figure 7.35. Oil Pan Cover Bracket Location

b. Remove the remaining oil pan bolt and washer assemblies and oil pan cover brackets, if equipped.

c. Remove oil pan and gasket from the crankcase. Discard the gasket. Refer to **Figure 7.36.**

NOTE: Effective with Serial Number 071931 oil pans have been installed using a robotically–applied liquid gasket.

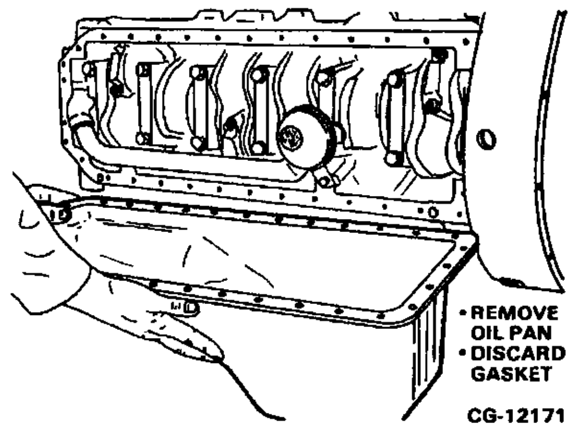

Figure 7.36. Remove Oil Pan

Flywheel Housing

4. With the oil pan and flywheel removed, remove the flywheel housing as follows:

   a. Remove the six bolts and washers which support the housing. Refer to **Figure 7.37.**

   b. Remove the housing from the crankcase.

NOTE: The housing is supported by two alignment dowels.

   c. Remove the flywheel housing gasket and discard.

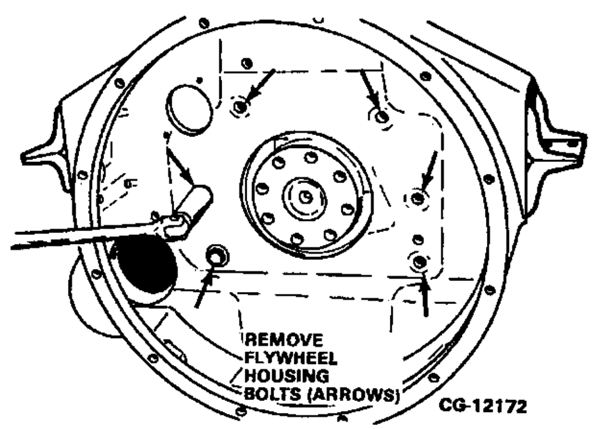

Figure 7.37. Remove Flywheel Housing and Gasket

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

REMOVAL (For Engine Overhaul) — Continued

Vibration Damper

5. Prior to vibration damper and pulley removal, inspect the vibration damper for wobble as follows: (Refer to **Figure 7.38**)
   a. Remove paint from the face of the damper at 4 points 90° apart.
   b. Attach a magnetic base dial indicator to the front cover. Position the indicator point on the unpainted surface and "zero" the indicator.
   c. Pry the crankshaft pulley forward and read the indicator.
   d. Repeat at each unpainted surface. If wobble exceeds specification, replace the damper.

IMPORTANT

DO <u>NOT</u> PRY THE CRANKSHAFT PULLEY BACK AND FORTH. PRY ONLY IN ONE DIRECTION, TO ELIMINATE THE POSSIBILITY OF REPLACING A DAMPER FOR EXCESSIVE WOBBLE WHEN THE CRANKSHAFT END PLAY WAS BEING READ BY MISTAKE.

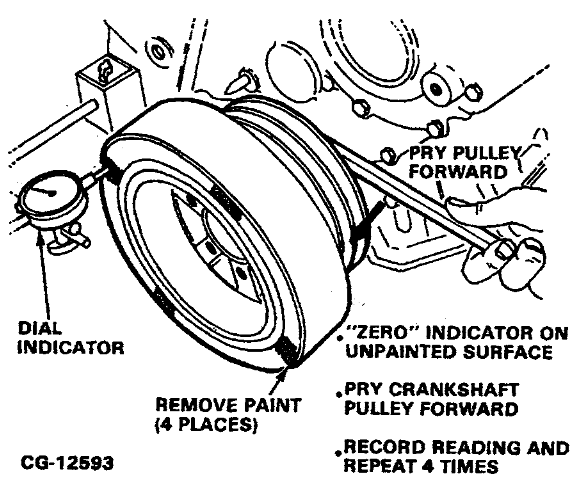

Figure 7.38. Check Vibration Damper for Wobble

6. Remove the vibration damper as follows:
   a. Loosen and remove the three bolts and retainer. Refer to **Figure 7.39.**

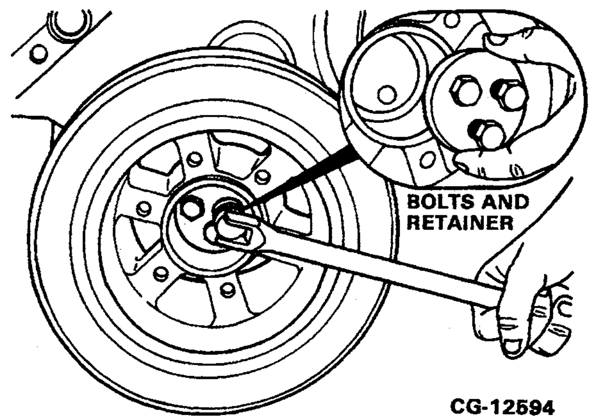

Figure 7.39. Remove Damper Retainer

   b. Install a universal puller using 3/8 in. bolts long enough to hold the puller in place. Turn the forcing screw and remove the damper and pulley assembly. Refer to **Figure 7.40.**

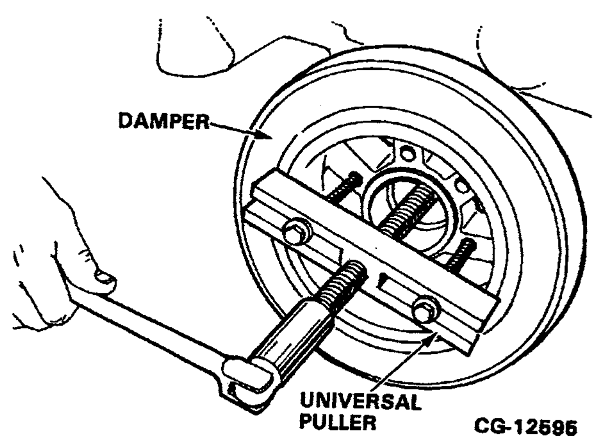

Figure 7.40. Remove Damper and Pulley Assembly

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

REMOVAL (For Engine Overhaul) — Continued

Oil Pickup Tube

7. With the vibration damper removed, remove the oil pickup tube as follows: (Refer to **Figure 7.41**)

   a. Loosen and remove the two retaining bolts at the front cover.

   b. Support the oil pickup tube and remove the retaining bolt at the support bracket.

   c. Remove the pickup tube and gasket. Discard the gasket.

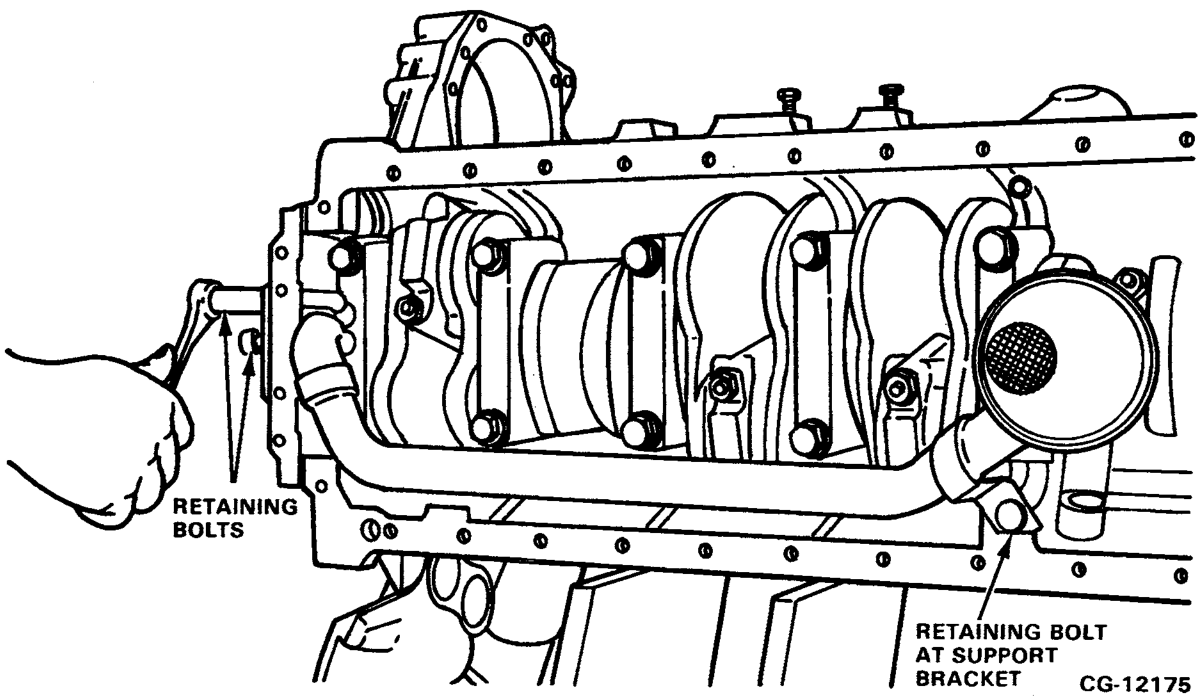

Figure 7.41. Remove Oil Pickup Tube

DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

REMOVAL (For Engine Overhaul) — Continued

Miscellaneous Components

8. Remove the oil pump assembly as outlined in Section 9.
9. Remove the water pump pulley and water pump as directed in Section 10.
10. Remove the engine front cover. Refer to Section 8.
11. Remove the piston and rod assemblies as described in Section 6.
12. Remove the rear crankshaft flange wear sleeve. Refer to **Figure 7.11**.

Crankshaft and Main Bearings

13. Rotate the engine stand so the crankshaft is facing up.
14. Verify main bearing bolt torque as follows: (Refer to **Figure 7.42**)

PULL–UP–TO–THE–MARK METHOD

a. Place a socket over the main bearing bolt, and pull the socket in the tightening direction to remove "SLACK" between the socket and the bolt head. Mark the socket and a point on the main bearing cap so the marks are aligned.

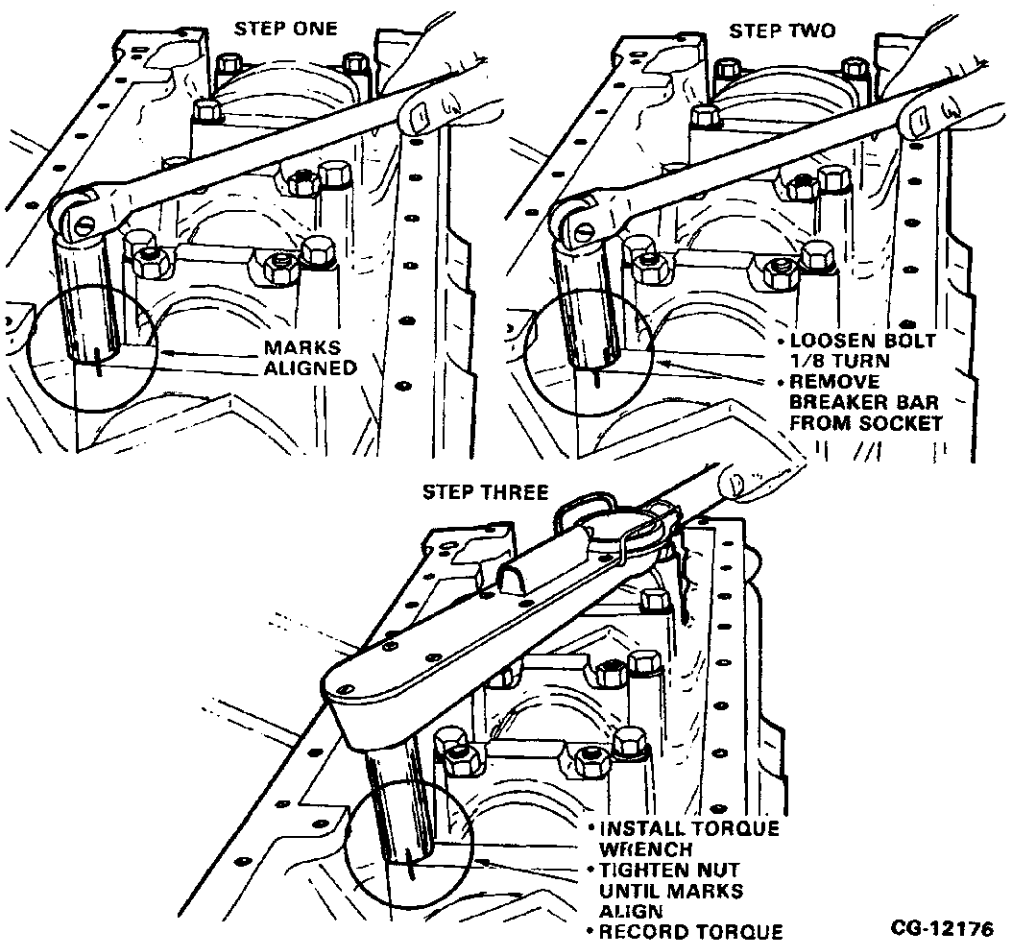

Figure 7.42. Check Bolt Torque (Using Pull–to–the–Mark Method)

DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

REMOVAL (For Engine Overhaul) — Continued

Crankshaft and Main Bearings — Continued

b. Using a breaker–bar, loosen the bolt 1/8 of a turn.

c. Without disturbing the socket location, remove the breaker–bar and install a torque wrench in its place.

d. Turn the bolt until the socket mark and main bearing cap mark are aligned.

e. With marks aligned, record the torque reading.

f. Repeat this procedure for all main bearing cap bolts and record all readings. This information can be useful during bearing inspection.

15. Remove the #1 through #6 main bearing caps as follows:

a. Loosen the main bearing cap bolts.

b. Grasp the bolts and rock the bearing cap back and forth to loosen and remove the cap. Refer to **Figure 7.43**.

c. Remove the lower bearing shell from the cap and keep in order for inspection.

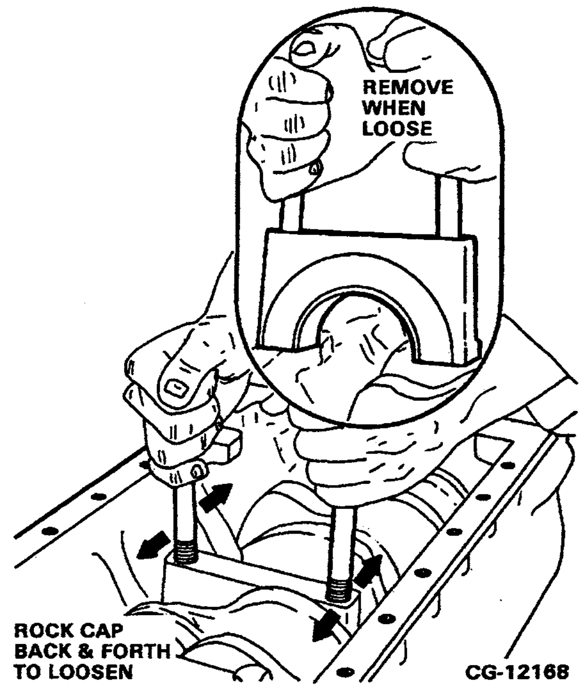

Figure 7.43. Remove Main Bearing Caps

16. Remove the #7 rear (thrust) bearing cap as follows:

a. Loosen the two mounting bolts.

b. Grasp the two bolts and rock the thrust bearing from side to side to loosen. Refer to **Figure 7.43.**

DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

REMOVAL (For Engine Overhaul) — Continued

Crankshaft and Main Bearings — Continued

c. Once loosened, remove the cap and bearing shell from the crankshaft. Refer to **Figure 7.44**.

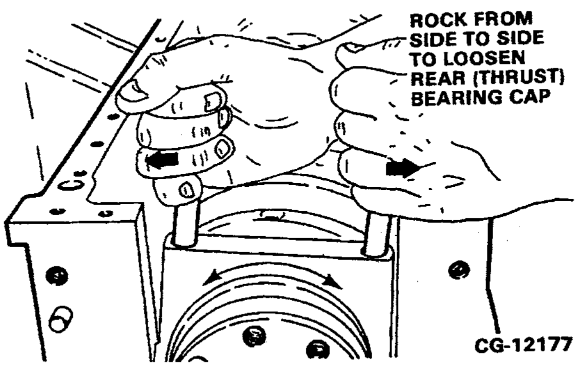

Figure 7.44. Remove Rear (Thrust) Bearing Cap

17. Remove the crankshaft from the crankcase using ZTOEM–4125 lifting sling, as shown in **Figure 7.45.**

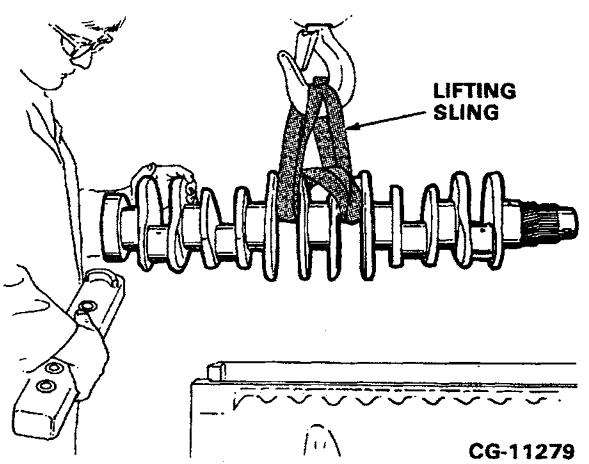

Figure 7.45. Remove Crankshaft

IMPORTANT

BE CAREFUL NOT TO DAMAGE THE CRANKSHAFT WHEN REMOVED.

18. Remove the upper main bearing shells by pushing them out of the main bearing saddle with your thumbs as shown in **Figure 7.46.** Mark the upper shells and put with the lower shells until a proper inspection can be done.

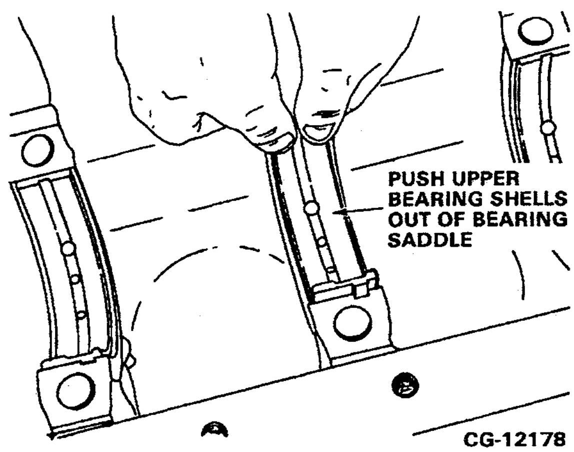

Figure 7.46. Remove Upper Bearing Shells

CLEANING

Vibration Damper

1. Clean the damper using a suitable solvent.
2. Dry with filtered compressed air.

Crankshaft and Main Bearings

1. Clean the bearing caps thoroughly in solvent and dry with compressed air.
2. Clean all the internal oil passages of the crankshaft using a stiff nylon brush. Loosen all dirt, sludge and deposits which may have accumulated. Flush the oil passages with a suitable solvent.
3. Blow the passages dry with filtered compressed air.

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

INSPECTION AND REPAIR

Vibration Damper

1. Visually inspect the vibration damper alignment marks.

NOTE: The damper has an inner member and an outer member separated by a rubber insert.

2. If the marks (**Figure 7.47**) are misaligned by more than the specified maximum, REPLACE THE DAMPER. Refer to **"SPECIFICATIONS"**.

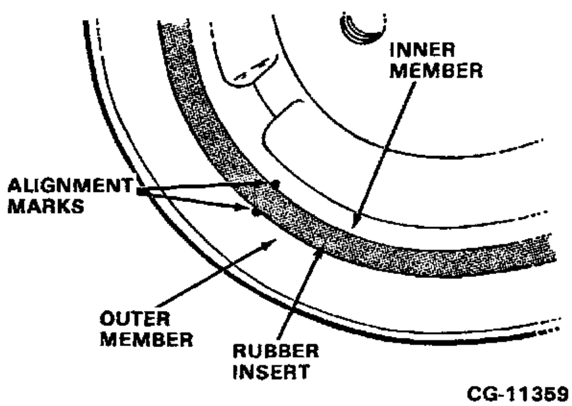

Figure 7.47. Vibration Damper Alignment Marks

3. Whenever the vibration damper or oil pump assembly is removed, replace the crankshaft front oil seal wear sleeve as follows:

   a. Split the wear sleeve with a muffler chisel to remove. Be careful not to damage the damper. Refer to **Figure 7.48**. Discard sleeve.

   b. Apply Aviation Permatex™ No. 3 to the I.D. of a new wear sleeve and press into the vibration damper using wear sleeve installer ZTSE–3004–A. Refer to **Figure 7.49**.

NOTE: Install so the chamfer on the wear sleeve O.D. is facing out when viewing the front end of the damper.

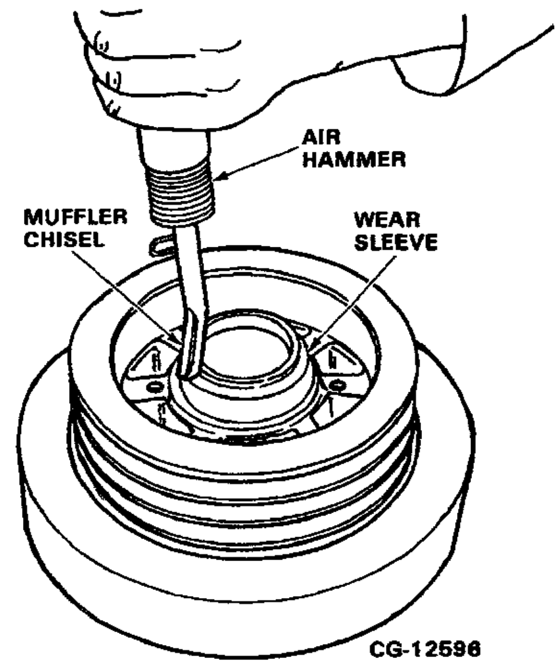

Figure 7.48. Remove Wear Sleeve from Damper

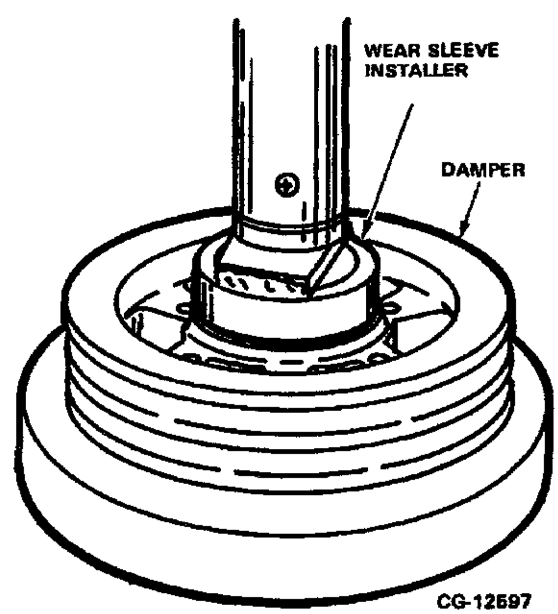

Figure 7.49. Install a New Vibration Damper Wear Sleeve

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

Crankshaft and Main Bearings

1. Visually inspect the crankshaft journals (main and rod) for scratches, grooves and scoring. Use dye penetrant methods to check for cracks.
2. Visually inspect all bearing inserts. Replace bearings, as required.
3. Measure the diameter of each journal using a micrometer. (See **"SPECIFICATIONS"**). Measure each journal at two points, at right angles to each other. Move the micrometer over the entire width of the journal. Refer to **Figure 7.50**.

NOTE: If the journals exceed the maximum out-of-round specification, the crankshaft must be reground or replaced.

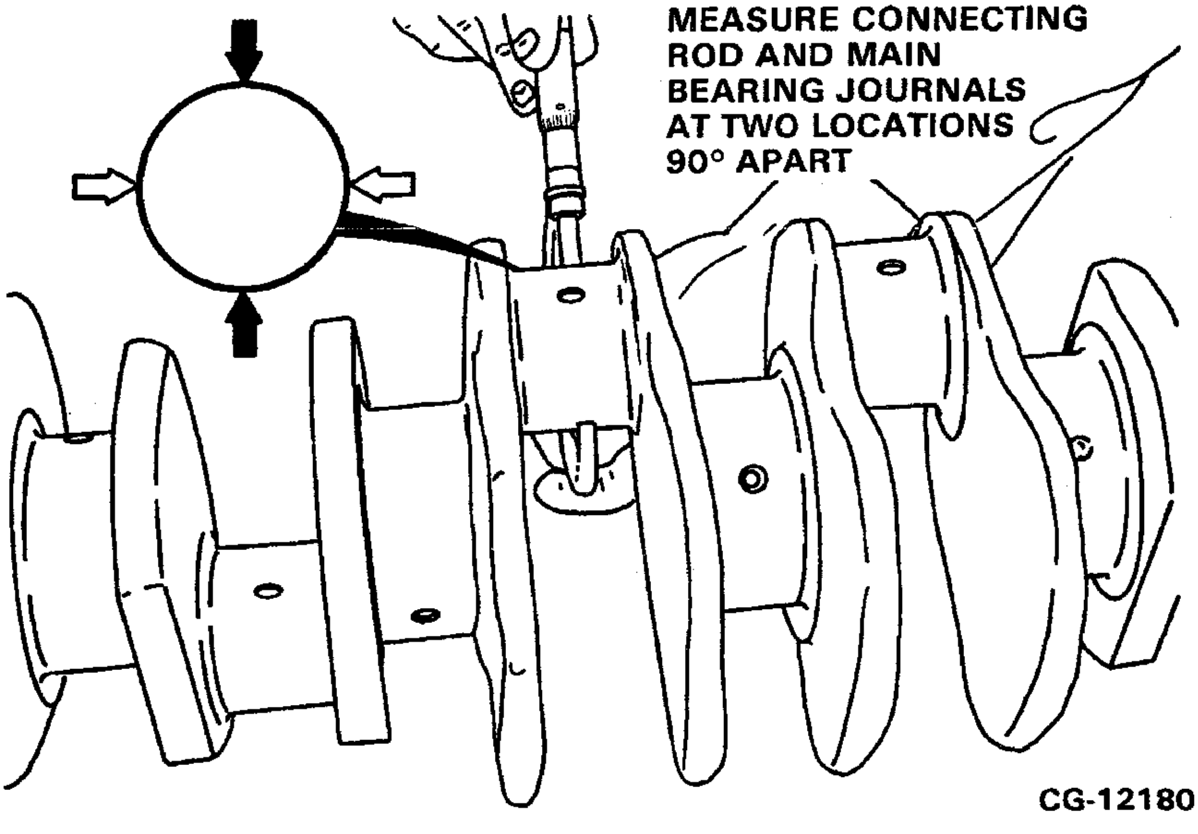

Figure 7.50. Measure Crankshaft Bearing Journals

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

Crankshaft and Main Bearings — Continued

4. The crankshaft can be ground 0.010 in., 0.020 in. or 0.030 in. undersize as follows:

NOTE: An induction–hardened fillet and journal crankshaft can be reground similar to any precision crankshaft. However, these shafts require special treatment when grinding.

NOTE: Bearing failures can cause overheating of crankshaft journals and reduction of hardness. When this occurs, the crankshaft strength may be unacceptably reduced. Whenever bluing is found on the journal or fillet area, the crankshaft must be replaced.

IMPORTANT

THE SUPERIOR STRENGTH OF THE CRANKSHAFT IS DUE TO THE INDUCTION HARDENING PROCESS OF THE BEARING JOURNALS AND FILLETS. THIS LOCALIZED HARDENING GREATLY INCREASES THE BENDING STRENGTH OF THE CRANKSHAFT; IN ORDER TO MAINTAIN THIS STRENGTH, SPECIAL PRECAUTIONS MUST BE TAKEN WHEN REGRINDING THE SHAFT. IF SPECIAL PRECAUTIONS ARE NOT TAKEN, THE CRANK–SHAFT CAN BE SEVERELY WEAKENED. THE METALLURGICAL CHARACTERISTICS OF THE SHAFT DEMAND EXACTING STANDARDS AND CONTROL WHEN REGRINDING JOURNALS. HOWEVER, IT CAN BE REGROUND LOCALLY WHERE EQUIPMENT AND EXPERIENCE CAN PRODUCE QUALITY STANDARDS OUTLINED IN THE FOLLOWING INSTRUCTIONS.

5. Grind the crankshaft as any other precision crankshaft using the following guidelines:

   The crankshafts are reground similar to any precision crankshaft with the following precautions:

   — A mechanical or an automatic wheel dresser is mandatory to prevent chatter, burning and poor surface finish. A hand stone should NEVER be used to rough or fine dress the face or radii of the wheel. The radii should blend evenly into the journal.

   — The selection of the grinding wheel is important because too hard a wheel will increase the possibility of burning. An aluminum–oxide wheel with a grit size of approximately 5O and a maximum hardness of M will produce satisfactory results, with other conditions being suitable.

   — The coolant must be such that is minimizes burning. This requires a fluid with high lubricity properties. The straight–cutting oils appear to be the best for grinding crankshafts and are strongly recommended.

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

Crankshaft and Main Bearings — Continued

IMPORTANT

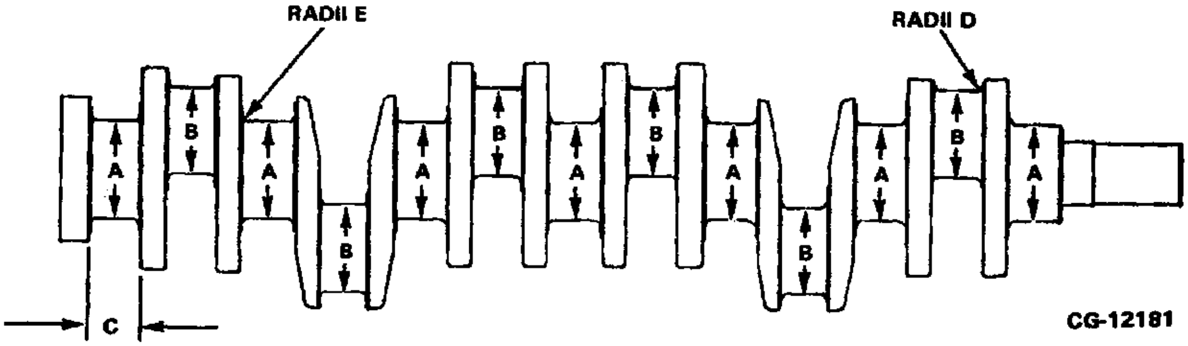
USE EVERY PRECAUTION TO AVOID BURNS ON THE SHAFT DURING THE GRINDING OPERATION.

— A grinding wheel speed of 6500 surface feet per minute with a work spindle speed of approximately 40 to 45 revolutions per minute is usually satisfactory.

— Grind all journals with crankshaft rotating in a counterclockwise direction (viewed from front of crankshaft), lap all journals with crankshaft rotating in clockwise direction. DO NOT REFINISH REAR SEAL FLANGE.

— Feed rates should be slower than normal to prevent any burning.

— Maintain the undersize grinding limits specified in **Figure 7.51**.



.010 Inch Undersize Crankshaft	A Main Journal	B Rod Journal	C Width	Rod Journal Radii D	Main Journal Radii E
DT/DTA–360	3.3642–3.3655 (85.451 –85.484)	2.5081 2.5097 (63.706–63.746)	1.441 5–1.4445 (36.614–36.6990)	0.220–0.235 (5.59–5.97)	0.153–0.160 (3.89–4.06)

.020 Inch Undersize Crankshaft	A Main Journal	B Rod Journal	C Width	Rod Journal Radii D	Main Journal Radii E
DT/DTA–360	3.3542–3.3555 (85.197–85.230)	2.4981–2.4497 (63.452–63.492)	1.441 5–1.4445 (36.614–36.690)	0.220–0.235 (5.59–5.97)	0.153–0.160 (3.89–4.06)

.030 Inch Undersize Crankshaft	A Main Journal	B Rod Journal	C Width	Rod Journal Radii D	Main Journal Radii E
DT/DTA–360	3.3442–3.3455 (84.943–84.976)	2.4881–2.4897 (63.198–63.238)	1.4535–1.4565 (36.91 9–36.995)	0.220–0.235 (5.59–5.97)	0.153–0.160 (3.89–4.06)

Figure 7.51. Limits for Undersize Crankshaft Grinding

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

Crankshaft and Main Bearings — Continued

— Maximum allowable taper on crankpins (rod journals) and main journals .00015 per inch of length (.013 mm per 25.4 mm) of length. Crankpins and journals must be polished to 12 Micro–inch maximum (20 Micro–inch maximum on fillets) and must not be over 0.0005 inch (0.003 mm) out– of–round.

NOTE: Do not grind the crankshaft flange.

CAUTION !

It is a good practice to keep a type ABC fire extinguisher near any grinding equipment which cools with oil and produces heat.

— Inspection of the crankshaft for dimensional tolerances is the same as for conventionally hardened crankshafts, except that extra care must be taken to be sure the shaft is cool before inspecting. Scrap only crankshafts which do not meet the specified tolerances.

— In addition to inspecting the dimensional tolerances, the crankshaft must also be carefully checked for surface defects, particularly for grinding cracks and burns. It is advisable to spray check the crankshaft (using dye penetrant methods) after grinding and lapping to insure that there is no surface cracking. Scrap any flange which cannot pass these inspections.

6. TARASOV ETCH: In order to establish the acceptability of a regrind procedure, crankshaft should be etched before lapping to determine whether the crankshaft was burned during the regrinding procedure. The best etch to use is the Tarasov etch, which will show both the rehardened and the overtempered areas. The etching procedure is as follows:

CAUTION !

Due to the sharp odor and flammability of the Tarasov etch, the etching should be done in a well. ventilated area, away from any open flame.

— Clean surface with a scouring powder and water or a good solvent.

— Wash thoroughly and rinse with alcohol.

— Apply etchant No. 1 (4 parts nitric acid in 96 parts water) for approximately 16 seconds with a cotton swab.

— Rinse with water and dry.

— Apply etchant No. 2 (2 parts hydrochloric acid in 98 parts acetone) for approximately 15 seconds with a cotton swab.

CAUTION !

Acetone is highly flammable.

— Rinse with alcohol and dry thoroughly with compressed air.

IMPORTANT

IF THE CRANKSHAFT HAS BEEN BURNED, IT WILL SHOW UP AS A CHANGE OF COLOR AFTER THE ETCH. AREAS REHARDENED BY EXCESSIVE HEAT APPEAR NEARLY WHITE, WHILE SOFTENED AREAS TURN DARK GRAY OR BLACK. AREAS UNAFFECTED BY THE HEAT OF GRINDING ETCH A LIGHT GRAY.

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DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

Crankshaft and Main Bearings — Continued

IMPORTANT

IF ANY BURNS SHOW UP AFTER THE ETCH IS USED, THE PHYSICAL PROPER. TIES OF THE CRANKSHAFT WILL HAVE BEEN SERIOUSLY REDUCED, AND THE CRANKSHAFT SHOULD NOT BE USED.

NOTE: If burning becomes a serious problem, it can usually be eliminated by reducing the infeed rate, using a softer grade of wheel, or increasing the work spindle speed. Sometimes, a combination of these factors, along with the recommendations mentioned above, will be necessary to overcome the problem.

7. After the crankshaft passes the Tarasov etch test, it may be lapped.

IMPORTANT

THOROUGHLY CLEAN THE CRANKSHAFT OIL PASSAGES WITH A NYLON BRISTLE BRUSH, SOAP AND WATER TO REMOVE ALL DEBRIS WHICH MAY HAVE ACCUMULATED DURING THE REGRINDING PROCEDURE. ANY DEBRIS LEFT IN THE CRANKSHAFT OIL PASSAGES CANNOT BE REMOVED BY THE OIL FILTERS AND WILL DAMAGE BEARINGS IMMEDIATELY UPON ENGINE START-UP. ONCE CLEANED, WRAP THE CRANKSHAFT, TO PROTECT IT FROM CONTAMINATION, UNTIL IT IS INSTALLED.

8. Visually inspect the crankshaft gears for chipping or wear. If replacement is required, the gears can be replaced as follows:

GEAR REPLACEMENT

a. Place a chisel between the gear teeth and strike the chisel with a hammer to split the gear.

b. Remove the oil pump drive spline first then the crankshaft gear, if required. Refer to **Figure 7.52.**

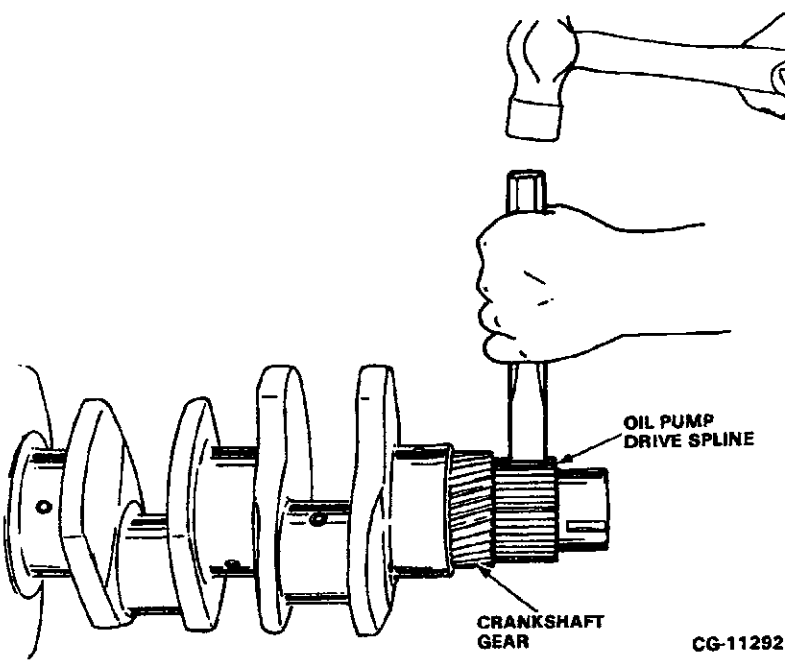

Figure 7.52. Remove Gears, if Required

DAMPER, CRANKSHAFT AND MAIN BEARINGS (Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

Crankshaft and Main Bearings — Continued

c. Be careful not to damage the crankshaft during gear removal.

d. With gears removed, heat the crankshaft gear and oil pump drive spline to 370–395° F

e. Install the crankshaft gear first. Be sure the locating pin on the crankshaft gear aligns with the crankshaft properly. Refer to **Figure 7.53**. Press the gear into place.

f. Install the hot oil pump drive spline onto the crankshaft until flush with the crankshaft gear. See **Figure 7.53**.

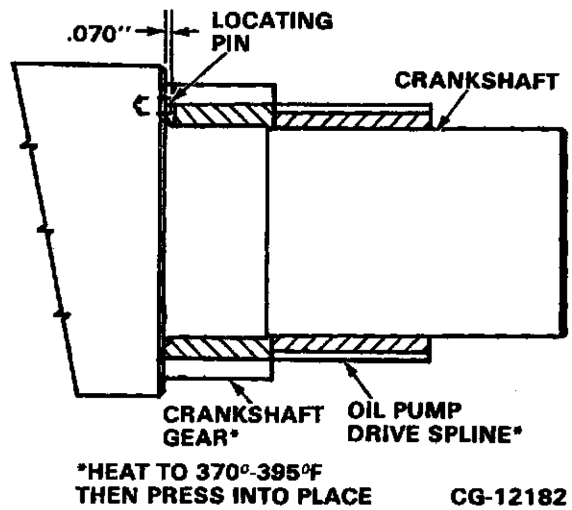

Figure 7.53. Crankshaft Gear Installation

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CRANKCASE
(Reconditioning)

CLEANING

NOTE: The best way to clean the crankcase during engine overhaul is in a chemical bath or "HOT TANK". This removes all carbonous material and mineral deposits which collect in the cooling passages. However, when a "HOT TANK" is not available, use the following cleaning procedure.

1. Clean all old gasket material from the machined surfaces of the crankcase.
2. Clean the cylinder bore using soap, water and a nylon brush.
3. Remove the main oil gallery cup plugs, at the front and rear of the crankcase, as follows:

NOTE: Oil gallery cup plugs are 13/16" in diameter. Occasionally, engines are built with oversized galleries requiring 7/8" cup plugs. These plugs can be identified by a diamond with an MP stamped on it. When replacing these cup plugs, be sure to determine if the plug is a standard 13/16" or an oversize 7/8". Refer to the Parts Catalog for the correct service number.

a. Drill a small hole into the cup plug and insert a self tapping sheet metal screw into the plug.

b. Using a small pry bar, pry the plug out. Refer to **Figure 7.54.**

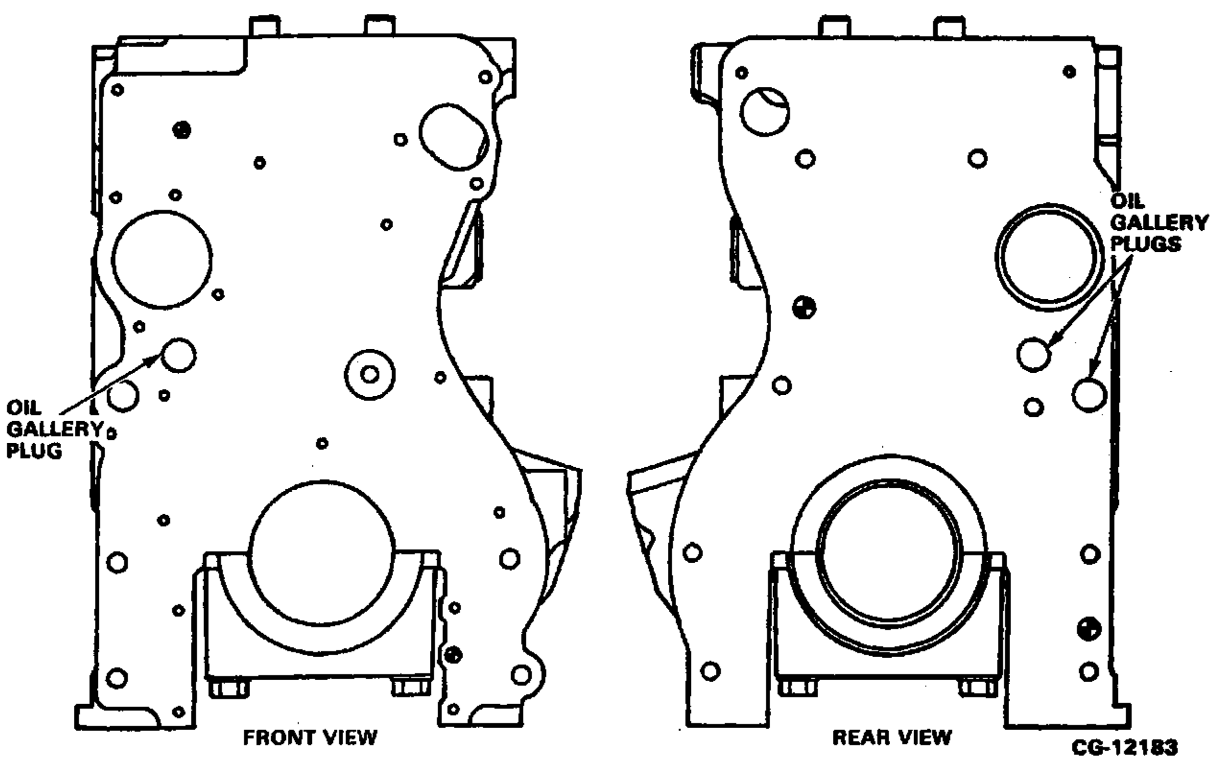

Figure 7.54. Main Oil Gallery Plug Locations

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CRANKCASE
(Reconditioning) — Continued

CLEANING — Continued

4. Remove the four hex–socket plugs located on the right side of the crankcase. Refer to **Figure 7.55.**

5. With the plugs removed from the crankcase, clean the crankcase as follows:

   a. Use a 13/16" nylon brush and solvent to clean the oil galleries.

   b. Clean the cross drillimgs using a nylon brush and solvent.

   c. Blow out all oil galleries and cross drillings using filtered compressed air.

   d. Clean all threaded holes using a tap of appropriate size.

   e. Reinstall the four hex–socket plugs on the right side of the crankcase. Use Loctite® to seal the threads.

6. Install new main oil gallery cup plugs as follows:

   a. Clean mating surfaces on plug and crankcase.

   b. Apply Loctite® to the outside edge of the cup plug.

   c. Drive the cup plug in using an arbor approximately 1/4 in. smaller in diameter than the plug being installed.

   d. Recess the plug 1/8 in.

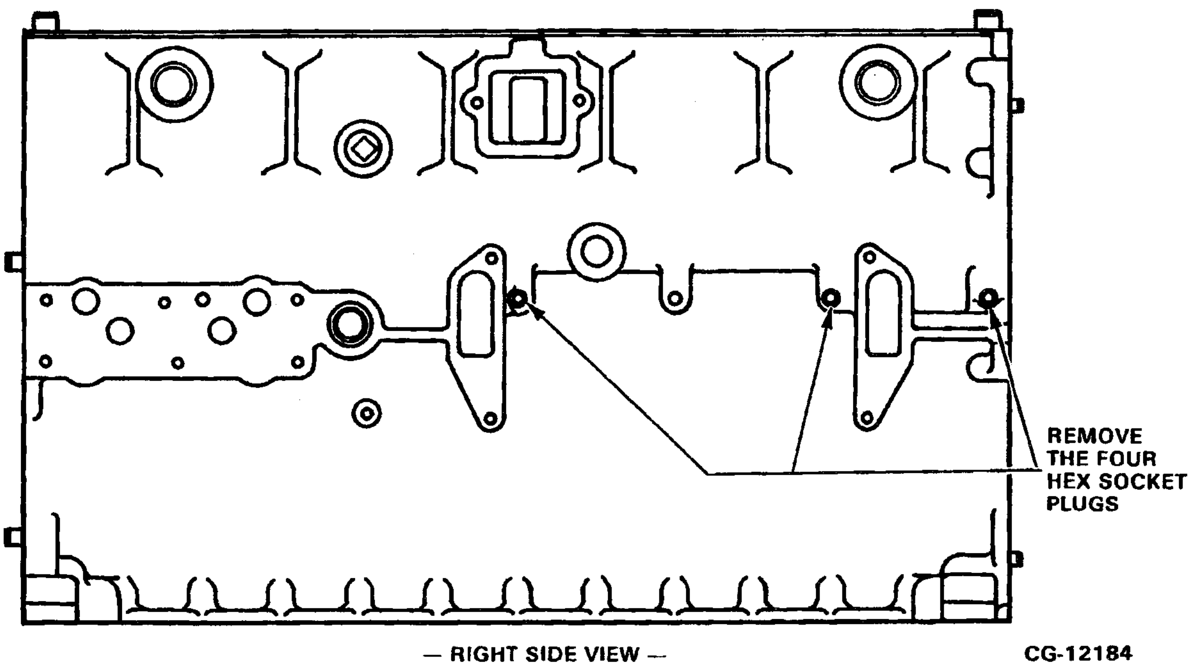

Figure 7.55. Cross Drilling Plug Locations

CRANKCASE
(Reconditioning) — Continued

INSPECTION AND REPAIR

NOTE: Threaded holes with damaged threads may be salvaged with the use of a "Heli–Coil repair".

1. Inspect the crankcase deck for flatness using a straightedge and feeler gauge. Use the checking pattern shown in **Figure 7.56.** If a 0.003 in. feeler gauge can pass, the crankcase must be replaced.

IMPORTANT

DO NOT RESURFACE THE CRANKCASE. SURFACE DEFECTS BEYOND THOSE LISTED IN STEP ONE, ABOVE, ARE NOT CORRECTABLE. REPLACE THE CRANKCASE.

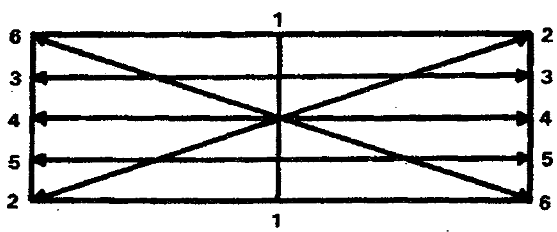

Figure 7.56. Crankcase Deck Flatness Checking Pattern

2. Repairs for coolant and oil leaks in the crankcase casting can be performed with certain restrictions as follows:

Restrictions:

a. No repairs may be made within one inch of an internal rib, wall or boss casting. Repairs are only allowed in the shaded areas. (Refer to **Figure 7.57**)

b. Casting cracks cannot be repaired.

c. Leak to be repaired must be within tap drill diameter.

d. Maximum plug size allowed for repair is1/4–18NPTF.

e. Leaks to be plugged (repaired) must be at least 3 inches apart.

Procedure:

a. Locate the leak. Drill through using a 1/8–27 NPTF or 1/4–18 NPTF tap drill, depending on size. Drill hole square with surface being repaired.

b. Tap 1/8–27 NPTF or 1/4–18 NPTF. **CAUTION: Do not over tap. Plug head must be above casting surface when installed.**

c. Clean chips and dirt from the internal passages.

d. Apply Loctite® No. 601 to the O.D. of the pipe plug; then install the plug.

e. Allow 4 hours cure time.

f. Grind protruding portion of plug flush with casting surface, if desired.

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CRANKCASE
(Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

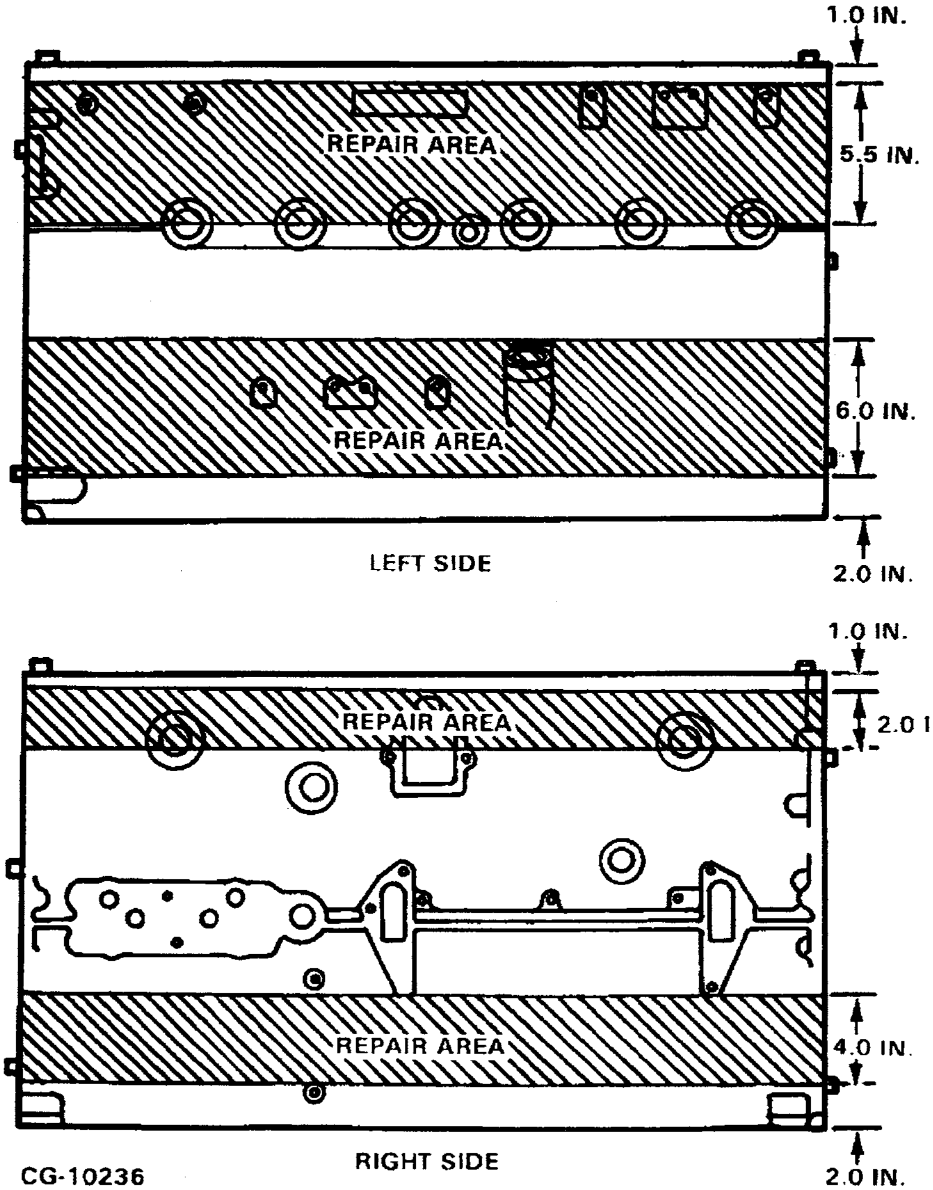

Figure 7.57. Crankcase Casting — Leak Repair Areas

3. Visually inspect the piston oil jet tubes for blockage as follows: (Refer to **Figure 7.58**)

   a. Shine a light source under the small orifice in the tube end which protrudes into the crankcase from its insertion point in the bearing saddle.

   b. Position your eye to align with the large orifice of the piston cooling jet. If the light source is visible, the jet tube is clear and requires no further service.

   c. If the light source is <u>not</u> visible, the piston cooling jet tube is blocked. Clean the tube to remove any blockage.

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CRANKCASE
(Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

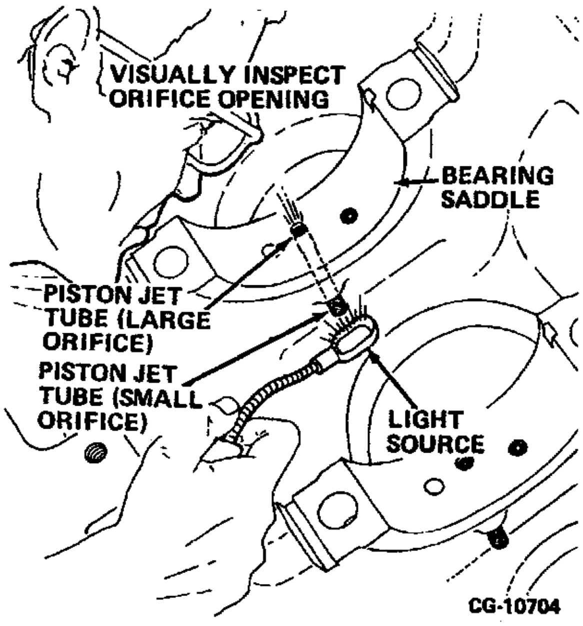

Figure 7.58. Visually Inspect Piston Oil Jet Tubes

4. Clean any piston oil jet tube blockage as follows: (Refer to **Figure 7.59**)
   a. Run an appropriately sized wire or torch tip cleaner through the tube orifice to remove blockage.

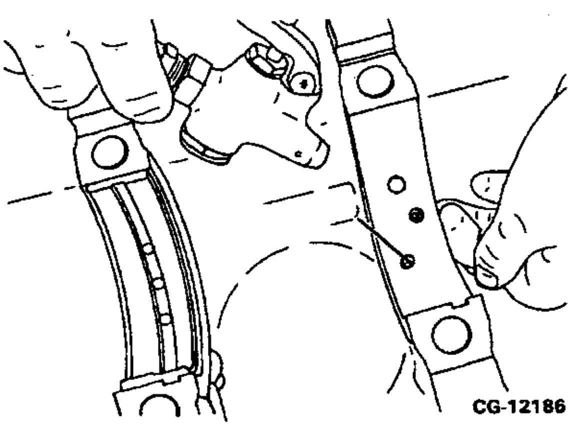

Figure 7.59. Clean Piston Oil Jet Tubes

   b. Using filtered compressed air, blow loosened debris out from the jet tube orifice.
   c. Reinspect piston cooling jet tube using a light source as previously described.

NOTE: Do not remove piston cooling jet tubes unless they are damaged or cannot pass the visual inspection after cleaning.

CAUTION !

Always wear safety glasses when using compressed air.

5. If the tubes are damaged or blockage cannot be removed, replace as follows:
   a. Use a pilot driver to remove the tube. Refer to **Figure 7.60.**

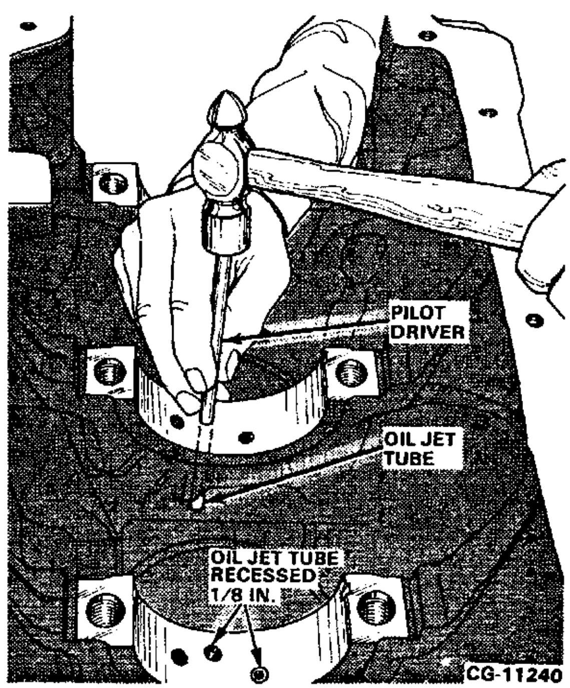

Figure 7.60. Piston Oil Jet Tube Removal/Installation

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CRANKCASE
(Reconditioning) — Continued

INSPECTION AND REPAIR — Continued

b. Install the new oil jet tubes using the same pilot driver.

NOTE: Lubricate the oil jet tube O.D. prior to installing into the bearing saddle.

c. Recess the oil jet tube 1/8 in. below the bearing saddle. Refer to **Figure 7.60.**

IMPORTANT

WHEN INSTALLED, THE OIL JET TUBE MUST NOT PROJECT ABOVE THE CRANKCASE BEARING SADDLE SURFACE.

6. Refer to Section 6 under "Cylinder Sleeve Fitting Procedure" for crankcase upper counterbore reconditioning procedures.
7. For camshaft bushing service procedures, refer to Section 5, "Rocker Arm Assembly, Camshaft, Tappets and Push Rods".

DAMPER, CRANKSHAFT AND MAIN BEARINGS

INSTALLATION

Crankshaft and Main Bearings

IMPORTANT

PRIOR TO CRANKSHAFT INSTALLATION, INSPECT THE CRANKCASE AS DESCRIBED LATER IN THIS SECTION.

Check Crankcase Integrity as follows:

1. Rotate the engine so the main bearing saddles are facing upward.
2. Wipe the main bearing supports using a lint–free cloth. The supports must be free of oil. DO NOT LUBRICATE THE BACK SIDE OF THE BEARING INSERTS.
3. Install the upper bearing inserts into the bearing saddle. Be sure the locking tangs on the bearings are snapped into the crankcase. Install with the large oil hole toward the cam side. Refer to **Figure 7.61.**

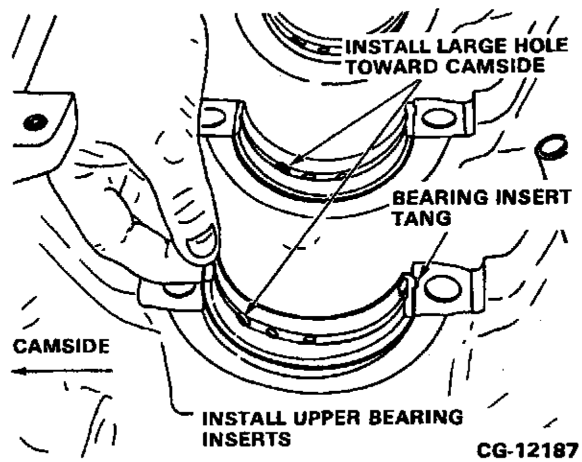

Figure 7.61. Install Main Bearing Inserts

4. Apply Prussian Blue® to the crankshaft main bearing journals. Carefully lower the crankshaft onto the main bearing inserts in the crankcase.

NOTE: Do not install the main bearing caps and lower bearing inserts at this time.

5. Rotate the crankshaft 1/2 turn.
6. Carefully remove the crankshaft and inspect the upper bearing inserts for an even transfer of bluing from the journals to the bearings.

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DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Crankshaft and Main Bearings — Continued

IMPORTANT

IF VOIDS APPEARED IN THE BLUING TRANSFER, THE CRANKCASE INTEGRITY IS QUESTIONABLE.

7. When satisfied that the crankcase is in good order and free of distortion and burrs around the upper bearing insert seats, clean all Prussian Blue® from the bearings and crankshaft journals.

8. Lubricate the upper main bearing inserts with clean engine oil. Refer to **Figure 7.62.**

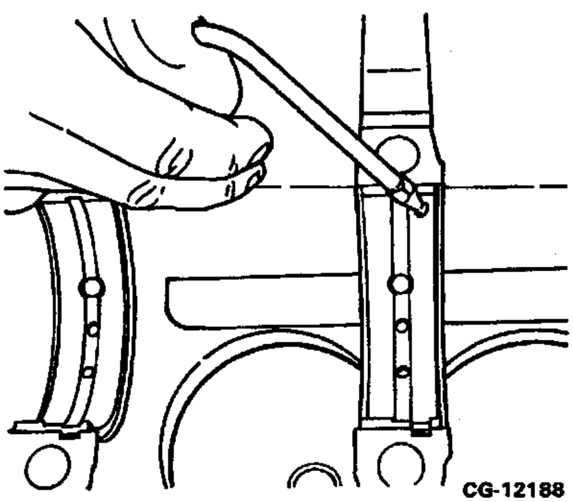

Figure 7.62. Lubricate Upper Bearing Inserts

9. Carefully install the crankshaft into the main bearing saddle. Use the ZTOEM–4125 lifting sling to lower the crankshaft. Refer to **Figure 7.63.**

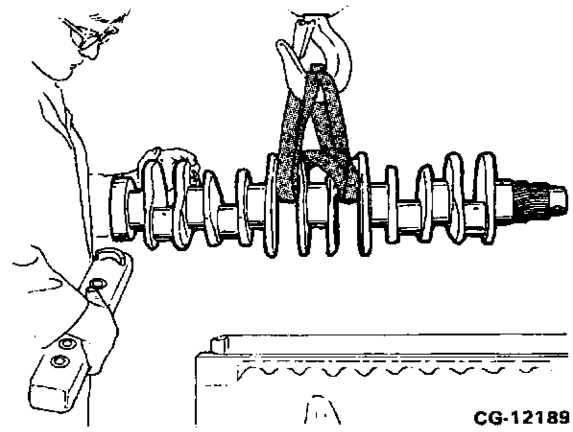

Figure 7.63. Install Crankshaft

New Main Bearing Cap Fitting Procedure for Service

A crankcase can usually be salvaged even if a main bearing cap has been damaged. Replacement main bearing caps are available for service. The bore of these caps is finish machined, which eliminates the need of line boring after installation. However, the face and sides of the caps must be modified to the dimensions of the old cap to assure a perfect fit in the crankcase. Enough material has been left on the face and sides of the caps to allow for this modification.

Following are detailed instructions for modifying the caps.

1. Replacement main bearing caps require the face and sides of the caps to be machined to the dimension of the old cap. We will refer to the face and sides as surfaces "A","B" and "C". Refer to **Figure 7.64.**

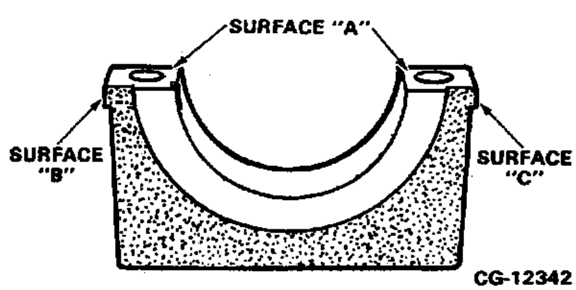

Figure 7.64. Surfaces to be Machined

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DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

New Main Bearing Cap Fitting Procedure for Service — Continued

2. Surface "A" modification:

   a. Measure the distance from the face of the cap to the saddle. We refer to this as dimension No. 1. See **Figure 7.65.**

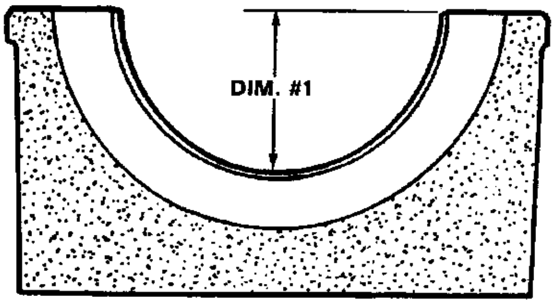

Figure 7.65. Dimension No. 1

   b. Measuring the old cap first, place a drill rod or a new drill of any size from 1/4" to 1/2" (6 to 13 mm) on the cap saddle. Measure the distance from the face of the cap (**Figure 7.66**) to the drill rod shank with a depth gauge as shown and record the reading.

NOTE: Repeat this procedure on the service cap and record the reading. If the old cap is broken and dimension No. 1 cannot be determined, use one of the other caps as a pattern.

IMPORTANT

USE THE SAME DRILL BIT FOR ALL MEASUREMENTS OF DIMENSIONS NO. 1, 2 AND 3.

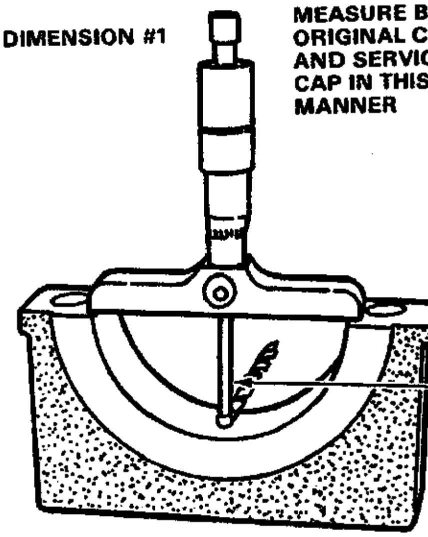

Figure 7.66. Measure Dimension No. 1

   c. Calculate dimension No.1 as follows: Subtract the original cap dimension from the service cap dimension. Then subtract an additional 0.002 in.

FORMULA

(Service Cap Dim. – Original Cap Dim.) – 0.002 in. = Material to be removed from surface "A".

NOTE: Two thousandths of an inch is subtracted to allow enough stock for a finish cut.

   d. Mill or grind the back of the cap until the surface is flat. Verify flatness after machining.

DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

New Main Bearing Cap Fitting Procedure for Service — Continued

e. Now modify surface "A" by machining the appropriate amount of material calculated in step c above. Refer to **Figure 7.67.**

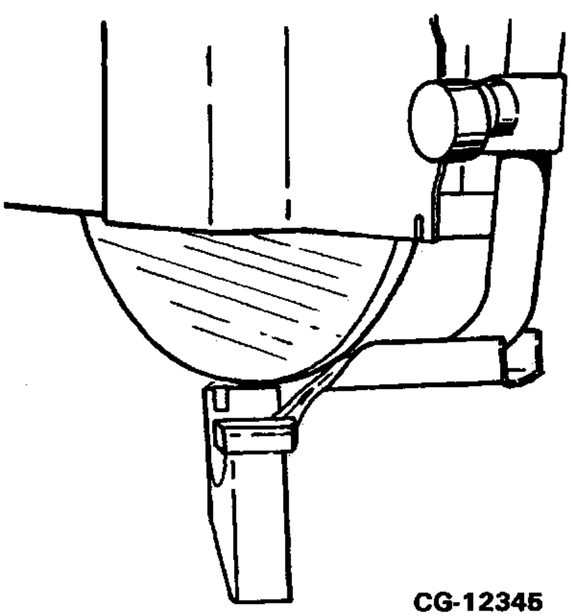

Figure 7.67. Machine Surface "A"

IMPORTANT

VERIFY THAT THE PROPER AMOUNT OF MATERIAL WAS REMOVED AND CHECK FOR FLATNESS.

3. Surface "B" modification: (Notched side of cap)

   a. Calculate dimension No. 2 prior to modifying surface "B". Refer to **Figure 7.68.**

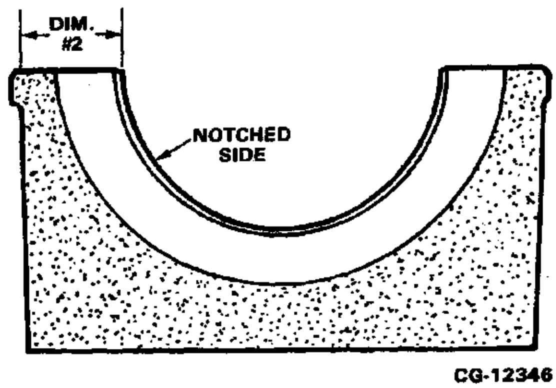

Figure 7.68. Dimension No. 2

   b. Clamp the old main bearing cap to a surface plate. Place a drill rod of any size from 1/4" to 1/2" (6 to 13 mm) on the inside of the cap (against the notched side). Measure the distance with a micrometer as shown in **Figure 7.69.** Record the reading.

NOTE: Repeat this procedure on the service cap.

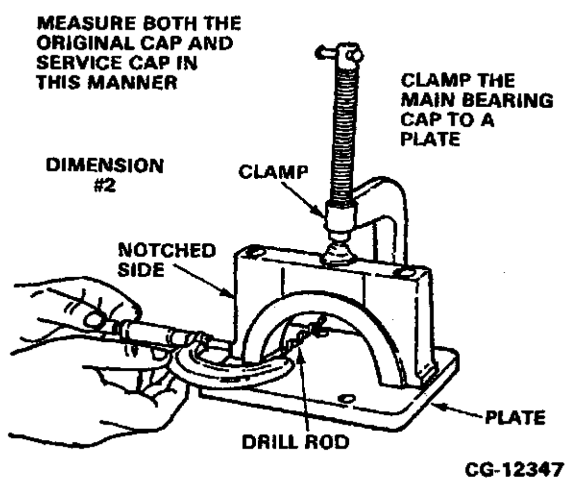

Figure 7.69. Measure Dimension No. 2

   c. Calculate dimension No. 2 as follows: Subtract the original cap dimension from the service cap dimension.

FORMULA

Service Cap Dim. – Original Cap Dim. = Material to be removed from surface "B".

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DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

New Main Bearing Cap Fitting Procedure for Service — Continued

d. Modify surface "B" by clamping the service main bearing cap to an angle plate with surface "B" facing up. Mill or grind the appropriate amount of material, calculated in step c, from surface "B". Refer to **Figure 7.70.**

IMPORTANT

SURFACE "B" MUST BE HELD SQUARE WITH SURFACE "A" AND PARALLEL TO THE BEARING BORE.

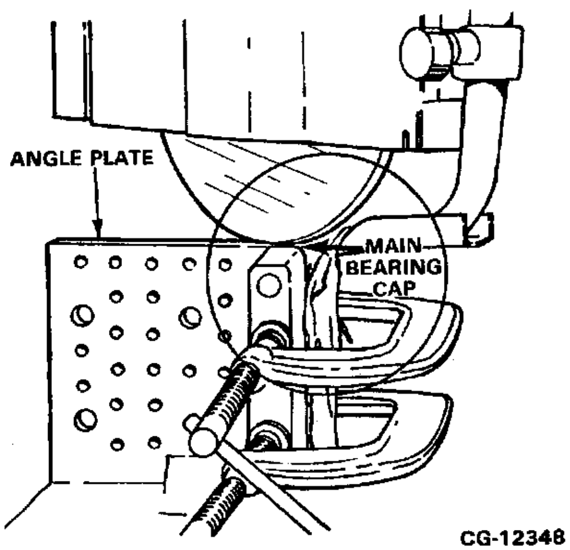

Figure 7.70. Machine Surface "B"

4. Surface "C" modification:

   a. Calculate dimension No.3, prior to modifying surface "C". Refer to **Figure 7.71.**

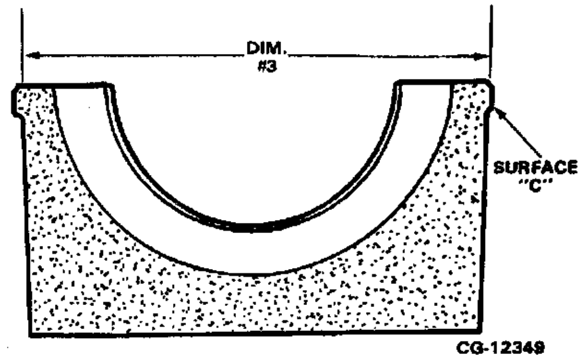

Figure 7.71. Dimension No. 3 (Bearing Cap Width)

   b. Using a 7 in. micrometer, measure the width of the service cap as shown in **Figure 7.72.**

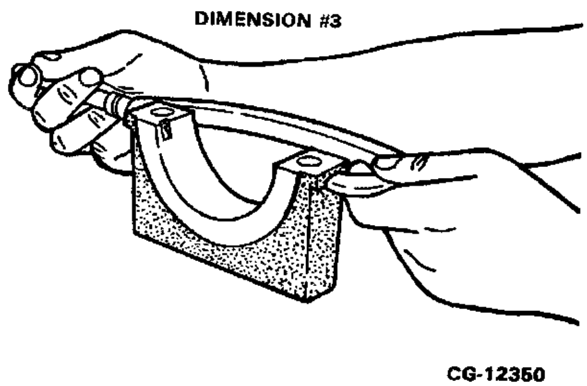

Figure 7.72. Measure Dimension No. 3 (Bearing Cap Width)

NOTE: The specification for dimension No. 3 is 6.051 in. +/− 0.001 in.).

   c. Calculate the amount of material to be removed to obtain dimension No. 3 as follows: Subtract the specification 6.051 in. from the service cap width.

FORMULA

Service Cap Width − 6.051 in. (153.69 mm) = Material to be removed from Surface "C".

DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

New Main Bearing Cap Fitting Procedure for Service — Continued

d. Modify surface "C" by clamping the service main bearing to an angle plate with surface "C" facing up. Mill or grind the appropriate amount of material, calculated in step c, from surface "C". Refer to **Figure 7.73.**

IMPORTANT

SURFACE "C" MUST BE HELD SQUARE WITH SURFACE "A" AND PARALLEL TO THE BEARING BORE.

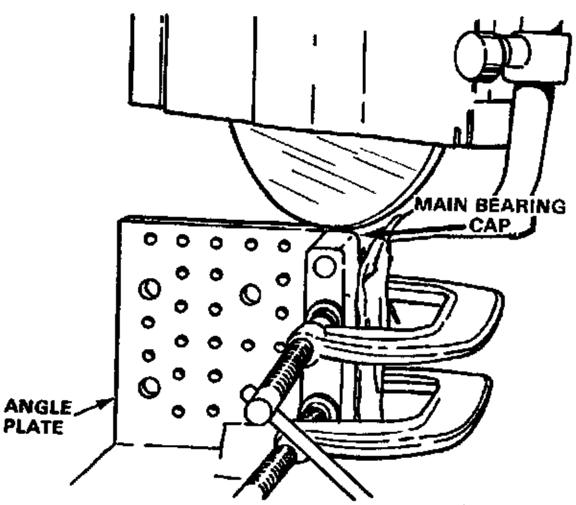

Figure 7.73. Machine Surface "C"

5. Demagnetize the bearing cap after machining.
6. Remove all burrs and sharp edges with a file or a deburring tool. Clean the cap in solvent to remove all machining oil.

Bearing Fitting Procedure

1. Install a new bearing in a new bearing cap in the original bearing cap, as required. Be sure the locking tangs on the bearing inserts are snapped into the bearing cap notch.
2. Check bearing clearance as follows:
   a. Clean the bearing surface and the exposed half of the crankshaft journal. Be sure these surfaces are free of oil.
   b. Install the bearing caps and lower inserts and tighten to the specified torque.
   c. Remove one bearing cap and insert one at a time. Remaining caps are left tight while checking the fit of the bearing with the cap removed.
   d. Wipe the oil from all contact surfaces of the exposed journal and bearing insert and cap removed.
   e. Place a piece of Plastigage® across the full width of the bearing surface on the crankshaft journal (or bearing cap insert) approximately 1/4 in. off center. Install bearing cap and tighten cap bolt to "specified" torque.

NOTE: Do not turn crankshaft while making check with Plastigage®.

NOTE: IN CHASSIS SERVICE ONLY — When bearing clearance is checked, the crankshaft will have to be supported and held against the upper main bearing halves to get a correct Plastigage® reading. Use a jack at counterweight next to each main bearing being checked to support the crankshaft. Failure to support the crankshaft will result in inaccurate readings.

   f. Remove bearing cap and insert.

DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Bearing Fitting Procedure — Continued

g. Do not disturb Plastigage®. Using the Plastigage® envelope, measure the widest point of the Plastigage®, **Figure 7.74.** This reading indicates the bearing clearance in thousandths of an inch or millimeters.

h. If the bearing clearance is not within specifications, the crankshaft must be reground and undersize bearings installed (as described earlier in this section).

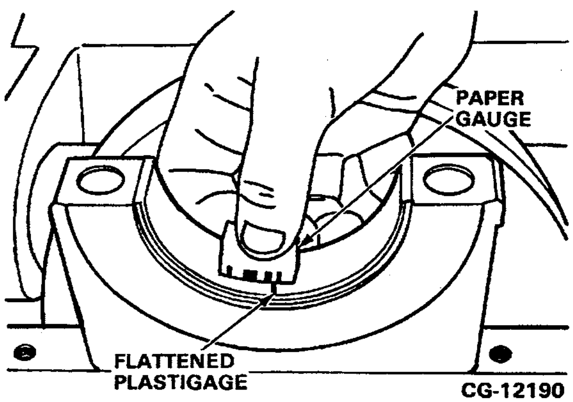

Figure 7.74. Check Main Bearing Clearance

Main Bearing and Cap

3. When acceptable bearing clearance is achieved, proceed as follows:

   a. Clean Plastigage® from the bearing or crankshaft journal surface.

   b. Coat all bearing surface journals and bolts with clean engine oil.

   c. Place the #1–6 bearing caps with lower bearing inserts over the crankshaft in the proper location.

IMPORTANT

THE MAIN BEARING CAPS MUST BE INSTALLED IN THE LOCATION AND POSITION FROM WHICH THEY WERE REMOVED. THE CAPS AND THE CRANKCASE ARE STAMPED TO IDENTIFY LOCATION AS SHOWN IN FIGURE 7.75. TO AID IN PROPER INSTALLATION, AN ARROW IS CAST IN THE CAPS. (SEE FIGURE 7.75). WHEN INSTALLING THE CAPS, BE SURE THE NUMBERS MATCH AND THE ARROW IS POINTING TOWARD THE CAMSHAFT SIDE. IF INSTALLING A NEW BEARING CAP, STAMP THE NEW CAP AS SHOWN IN FIGURE 7.75.

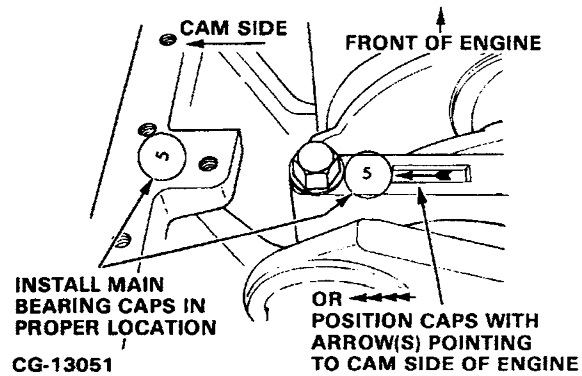

Figure 7.75. Verify Proper Bearing Cap Location

   d. Tighten the #1–6 main bearing cap bolts to the specified torque. Refer to **Figure 7.76.**

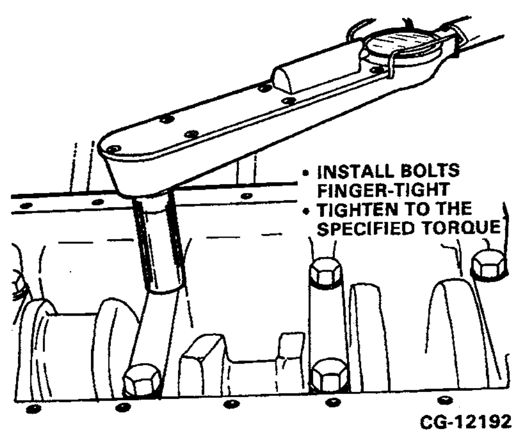

Figure 7.76. Tighten Bolts to Specified Torque

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DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Main Bearing and Cap — Continued

e. Install the rear thrust bearing as follows:

1. Insert the main bearing cap with the rear thrust bearing in position as shown in **Figure 7.77.**

2. Center the rear thrust bearing by moving the crankshaft rearward, then forward.

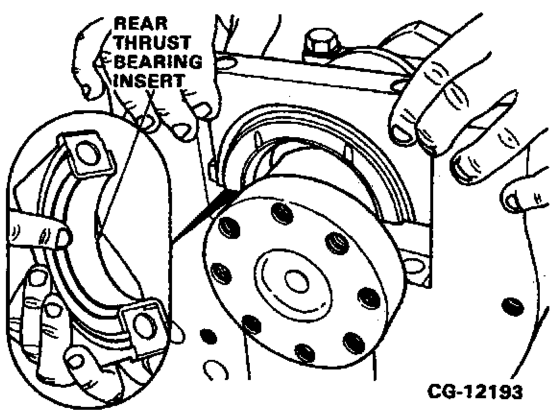

Figure 7.77. Install Rear Thrust Bearing Cap and Insert

3. Tighten the two rear thrust bearing bolts finger–tight then tighten to the specified torque. Refer to **Figure 7.78.**

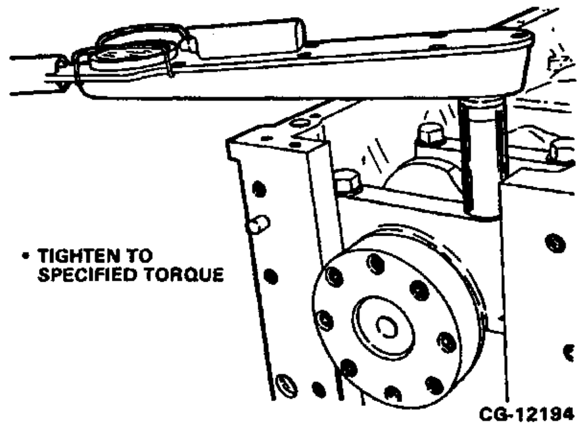

Figure 7.78. Tighten Rear Thrust Bearing

f. Check crankshaft end play using a dial indicator as follows: Refer to **Figure 7.79.**

1. Mount the dial indicator on the crankcase with the indicator tip on the crankcase flange face.

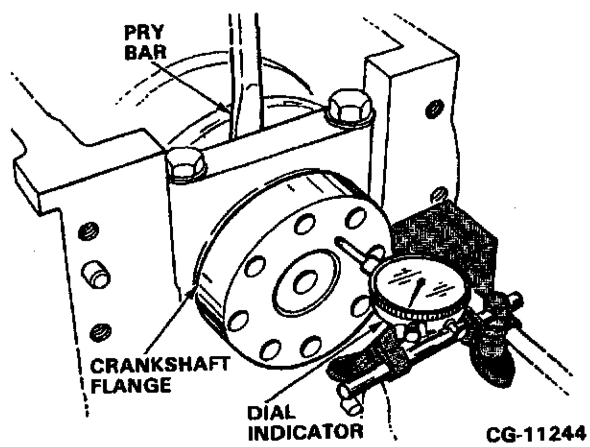

Figure 7.79. Check Crankshaft End Play

DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Main Bearing and Cap — Continued

2. Lightly pry the crankshaft forward and "zero" the indicator.

3. Then pry the crankshaft rearward and record the dial indicator reading. Repeat to assure an accurate reading.

NOTE: If end play exceeds the specifications, replace the thrust bearing and recheck crankshaft end play.

4. Install the piston and rod assemblies. Refer to Section 6.

5. Install the front plate and front cover. Refer to Section 8.

6. Install the oil pump assembly. Refer to Section 9.

Flywheel Housing and Flywheel

7. Install the flywheel housing as follows:

   a. Install a new square cut O–ring to seal the camshaft and a new flywheel housing gasket over the locating dowels. Use grease to hold the gasket in place. Refer to **Figure 7.80.**

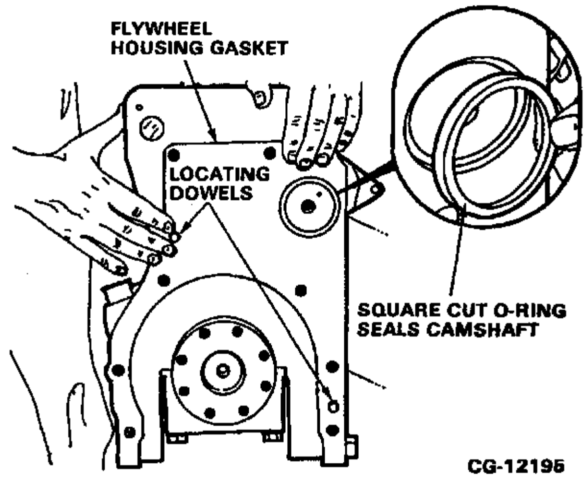

Figure 7.80. Install Flywheel Housing Gasket and Camshaft O–Ring

   b. Install the flywheel housing on the crankcase locating dowels and tighten the mounting bolts to the specified torque. Refer to **Figure 7.81.**

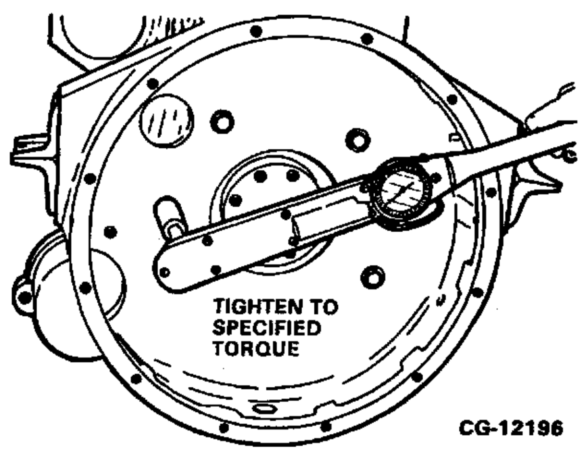

Figure 7.81. Tighten Flywheel Housing Bolts

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DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Flywheel Housing and Flywheel — Continued

8. Check flywheel housing bore concentricity and face runout Refer to **Figures 7.12 and 7.13**, which appear earlier in this section.
9. Install the rear seal and wear sleeve. Refer to the "Rear Oil Seal and Wear Sleeve Installation" procedure which appears earlier in this section.
10. Install the flywheel and ring gear assembly. Refer to "Flywheel (Reconditioning)", in this section, for the installation procedure.
11. Install the front cover. Refer to Section 8.
12. Remove the gasket material which overhangs the edge of the front cover (**Figure 7.82**) and the flywheel housing (**Figure 7.83**), at the oil pan rail.

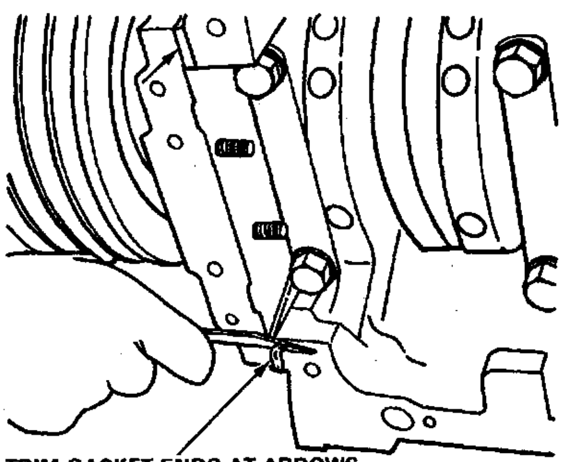

Figure 7.82. Remove Excess Front Cover Gasket

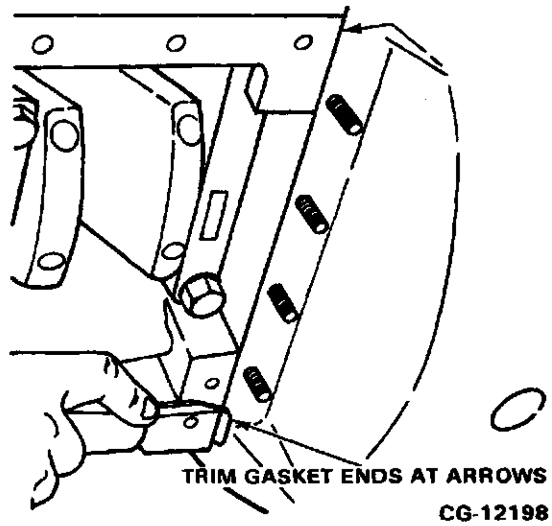

Figure 7.83. Remove Excess Flywheel Housing Gasket

Oil Pickup Tube

13. Install the oil pickup tube assembly as follows:
    a. Wipe oil from the front cover inlet tube gasket surface.
    b. Using a new gasket, remove the release paper and apply the gasket to the front cover.

NOTE: Be sure the gasket is properly aligned before applying it to the front cover. Once applied, the gasket will stick to the front cover. An out of position gasket can cause low or no oil pressure and bearing damage.

DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Oil Pickup Tube — Continued

c. Loosely install the two mounting bolts and washers through the front cover and fasten the oil pickup tube. Refer to **Figure 7.84.**

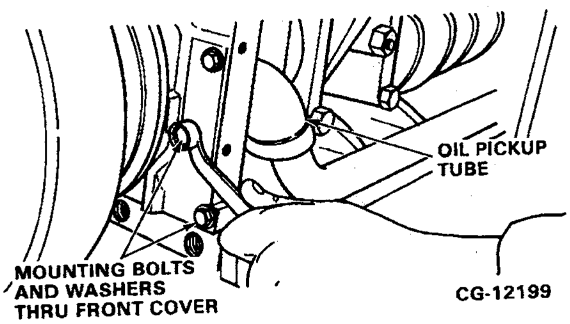

Figure 7.84. Fasten Oil Pickup Tube to Front Cover

d. Align the pickup tube bracket with the crankcase mounting pad and loosely install the mounting bolt with the lock washer and hardened washer. Refer to **Figure 7.85.** Once aligned, tighten the front bolts alternately until secured (**Figure 7.84**). Once the oil pickup tube to front cover bolts are tightened, secure the pickup tube bracket (**Figure 7.85**).

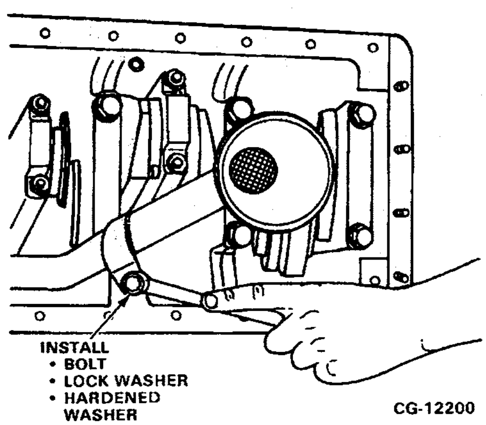

Figure 7.85. Install Pickup Tube Bracket

Oil Pan

NOTE: Effective with Serial Number 071931 oil pans have been installed using a robotically–applied liquid gasket. When replacing the oil pan use a fiber oil pan gasket and R.T.V. sealant as described below.

14. Install the oil pan, using a new gasket and R.T.V. as follows:

a. Scrape or wire brush all of the old liquid gasket from the pan rail, flywheel housing, front cover and oil pan. Use a commercially available brake cleaner to remove all oil and solvent from these surfaces.

b. Apply a 1/4" bead of R.T.V. sealant (P/N 446 839 C1) to the mating areas of the front cover to pan rail and pan rail to flywheel housing as shown in **Figure 7. 86.**

CAUTION !

Do not apply excessive amounts of R.T.V. which could end up in the pickup screen, restricting lube oil flow.

DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Oil Pan — Continued

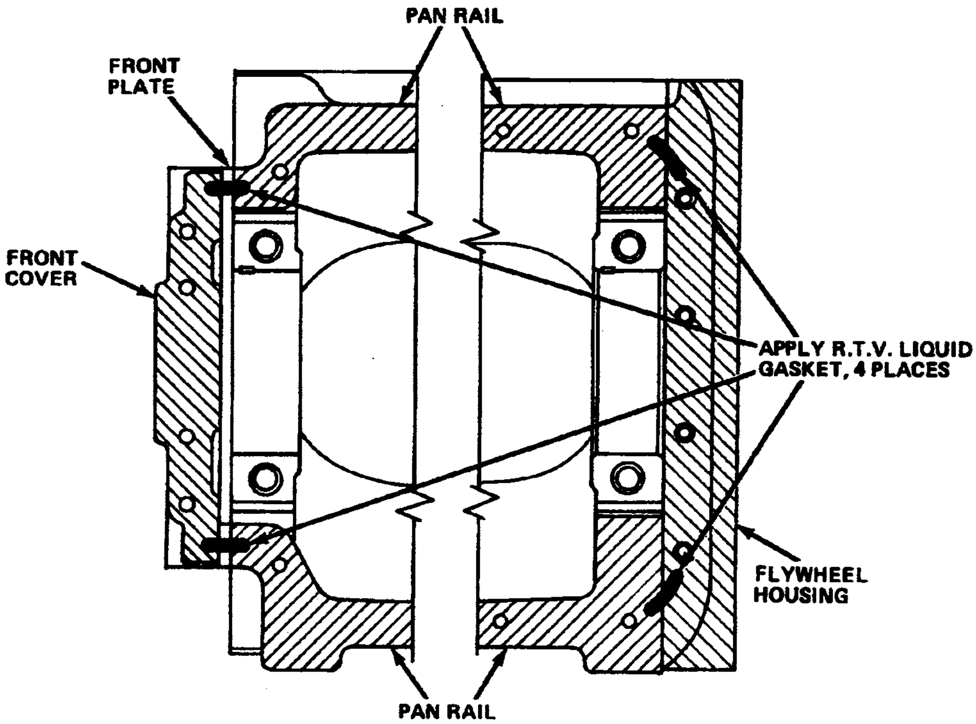

Figure 7.86. R.T.V. Sealant Installation Locations

c. Using guide studs, install the oil pan gasket and oil pan onto the crankcase within 10 minutes of R.T.V. application.

d. Install the four cover spacers (if applied) and tighten the oil pan bolts and washers to the specified special torque. Also, tighten the four nuts and washers on the studs at the rear of the oil pan to the specified torque. Refer to **Figure 7.87.**

e. Install the oil pan drain plug, using a new plastic seal washer. Tighten to the specified torque.

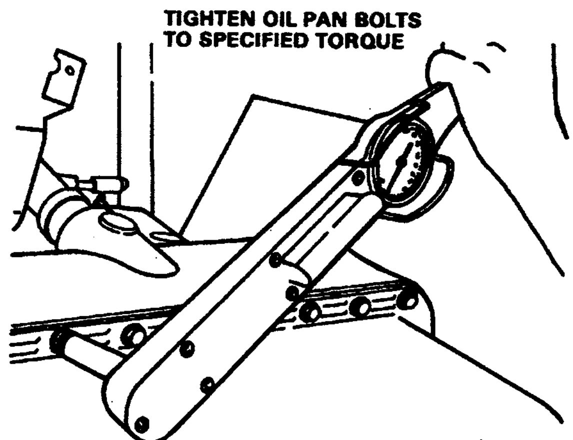

Figure 7.87. Install the Oil Pan

DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Vibration Damper

15. Install the vibration damper as follows:
    a. Heat the damper in water. Do not exceed 212°F when heating the damper and DO NOT install the damper when cold (room temperature).
    b. Align the keyway on the damper with the key on the crankshaft. Use bolts which are longer than the damper retainer bolts to draw the damper onto the crankshaft. Remove the long bolts and install the damper retainer using the correct bolts.
    c. Prevent the crankshaft from turning and tighten the bolts to the specified special torque. Refer to **Figure 7.88.**

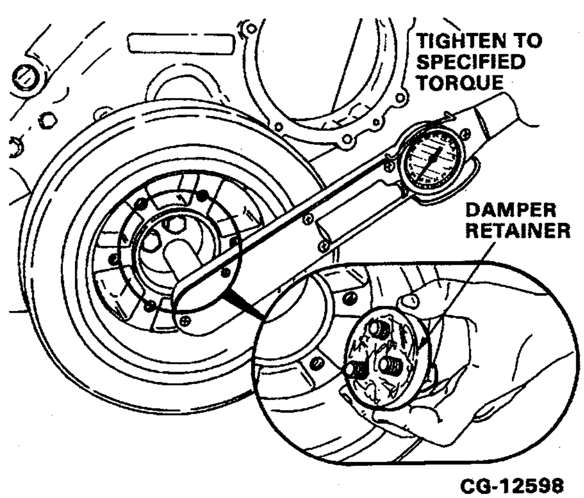

Figure 7.88. Install Vibration Damper

NOTE: The vibration damper assembly was simplified for the 1988 and later model years by reducing the number of crankshaft pulley grooves from four (in 1987) to three. The reduction in pulley grooves for the crankshaft pulley is a direct result of a simplified accessory drive, which eliminates two accessory drive belts. The current vibration damper is designed with six center ribs as shown in Figure 7.89. The current design differs from the early design, which has a solid center. Refer to Figure 7.89.

IMPORTANT

DO NOT MIX VIBRATION DAMPERS. USE THE SOLID CENTER DAMPER ON 1987 MODEL YEAR ENGINES ONLY AND THE DAMPER WITH SIX CENTER RIBS ON 1988 AND LATER MODEL ENGINES ONLY. REFER TO CURRENT PARTS CATALOG FOR SERVICE PART NUMBERS.

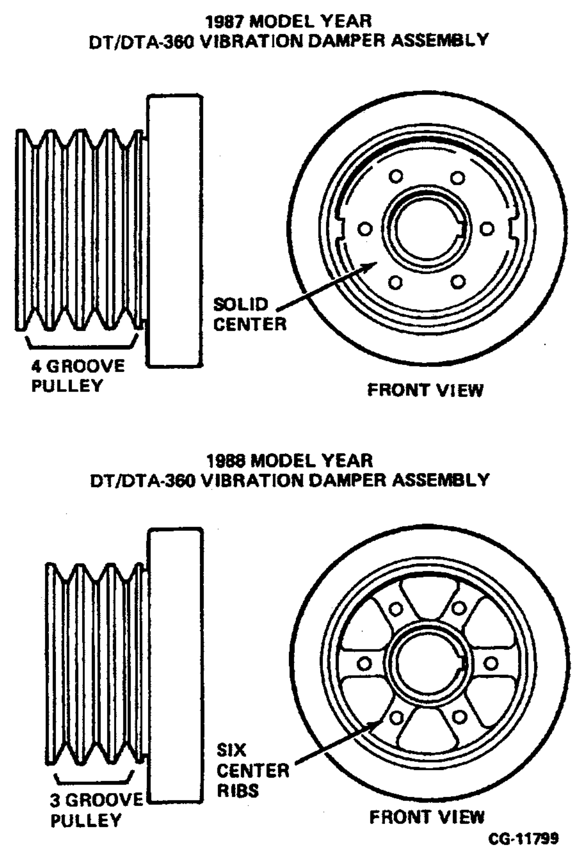

Figure 7.89. Vibration Damper Assembly Identification

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DAMPER, CRANKSHAFT AND MAIN BEARINGS — Continued

INSTALLATION — Continued

Vibration Damper — Continued

16. Refer to the appropriate manual sections an install the following:

 - Fuel injection pump
 - Oil cooler
 - Water pump and pulley
 - Cylinder head assembly (with intake manifold, exhaust manifold, thermostat housing and turbocharger attached)
 - Rocker arm assembly

IMPORTANT

ADJUST VALVE LASH AS SPECIFIED IN SECTION 4.

 - Oil level gauge tube assembly
 - Turbocharger oil inlet and oil drain tubes
 - Thermostat housing to water pump hose
 - Valve cover w/new gasket
 - Aneroid tube
 - Fuel leak–off lines (low pressure)
 - Fuel injection lines (high pressure)
 - Crossover pipe (DT–360 only)

NOTE: Install new lube oil filters and fuel filter.

17. Prime the lubricating system as specified Section 6.

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SERVICE MANUAL
TIMING GEAR TRAIN AND FRONT COVER

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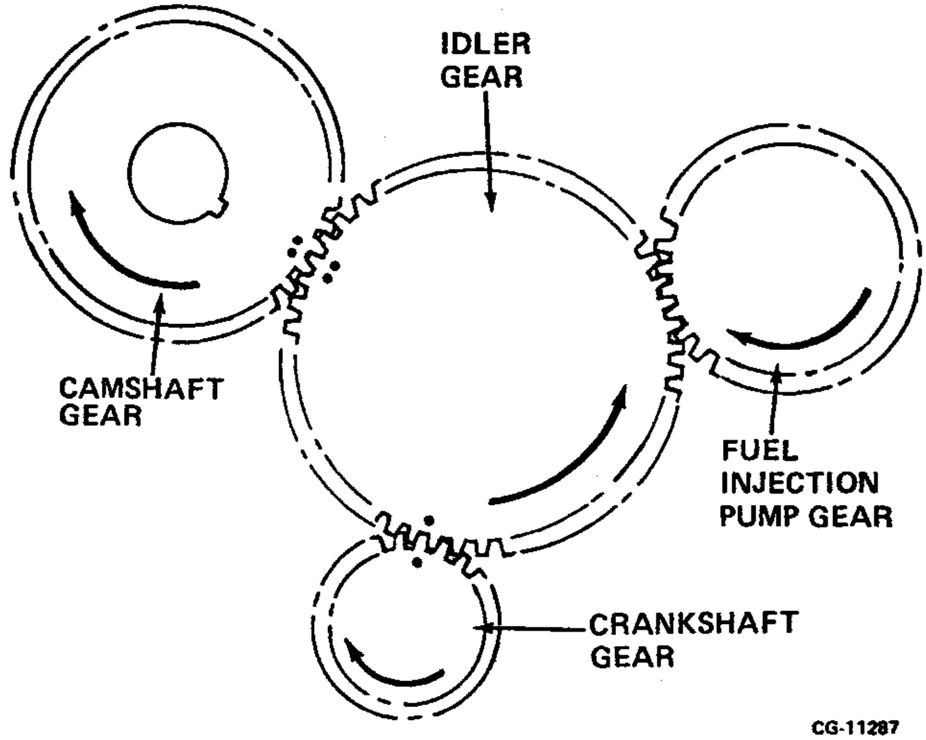

Figure 8.1. Timing Gear Train

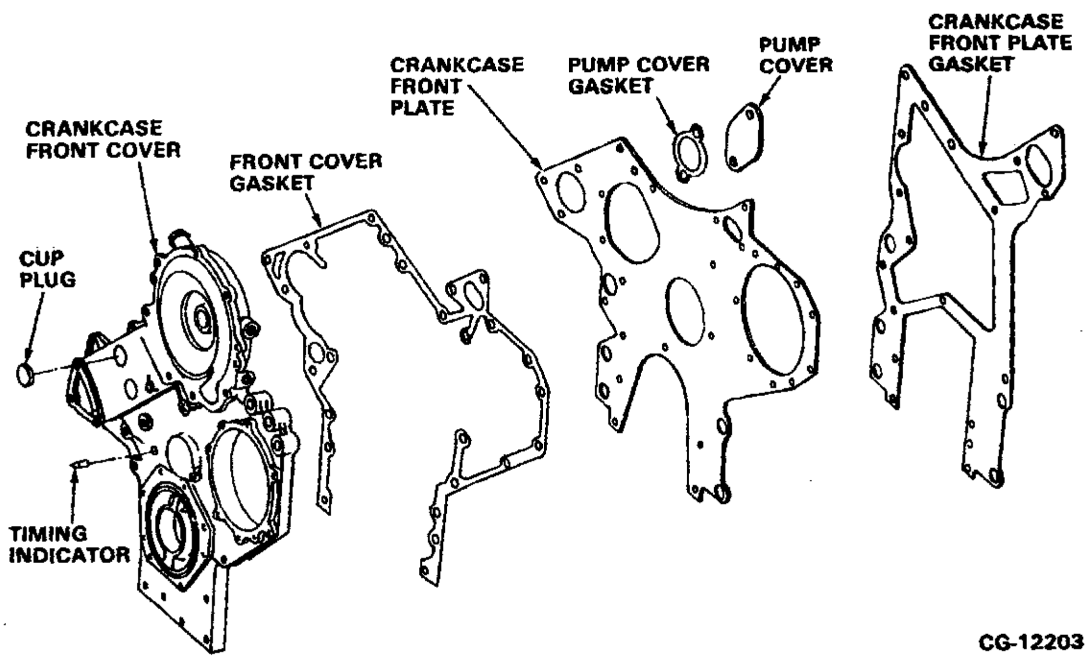

Figure 8.2. Crankcase Front Cover and Related Parts

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SPECIFICATIONS

DIMENSION TITLE	VALUES
TIMING GEARS:	
Crankshaft to Idler Backlash	0.003 in. (0.08 mm) / 0.016 in. (0.41 mm)
Idler to Crankshaft Backlash	0.003 in. (0.08 mm) / 0.016 in. (0.41 mm)
Idler to Injection Pump Backlash	0.003 in. (0.08 mm) / 0.016 in. (0.41 mm)

SPECIAL TORQUES

Crankcase Front Plate Bolts .... 20 lbf–ft. (27 Nm)
Idler Gear Retaining Bolt .... 85 lbf–ft. (115 Nm)
Injection Pump Drive Gear Bolts .... 35 lbf–ft. (47 Nm)

SPECIAL SERVICE TOOLS

None required for this section

ENGINE GEAR TRAIN TIMING VERIFICATION

Valve train failures of broken or bent push rods, valves, rocker arms and worn valve keepers and/or rotators in many instances have been found to be caused by improper timing of the gear train. Depending on valve lash setting, if the camshaft gear is improperly timed by one (1) tooth early, the engine pistons will strike the intake valve heads or if the timing is set one (1) tooth late, the exhaust valve may contact pistons.

CHECKING ENGINE GEAR TRAIN TIMING WITHOUT REMOVING FRONT COVER AND/OR ENGINE TEAR DOWN

1. Adjust the #1 intake valve with the #1 piston set at TDC (Top Dead Center) compression stroke as follows: rotate the crankshaft until the #1 piston is on the compression stroke and the timing pointer on the front cover is in line with the TDC mark on the vibration damper. Confirm that the #1 piston is on the compression stroke by turning both push rods by hand to verify that both valves are closed. The valves are closed when the push rods are loose and can be turned easily.

2. Adjust only #1 intake valve by loosening lock nut and turning the valve adjusting screw until you can place a .029" feeler gauge between the valve lever and valve stem of the #1 intake valve. Tighten the valve adjustment screw until a slight drag is felt on the feeler gauge. Tighten the lock nut once the valve adjustment is set. Refer to **Figure 8.3**.

NOTE: Only adjust #1 intake valve.

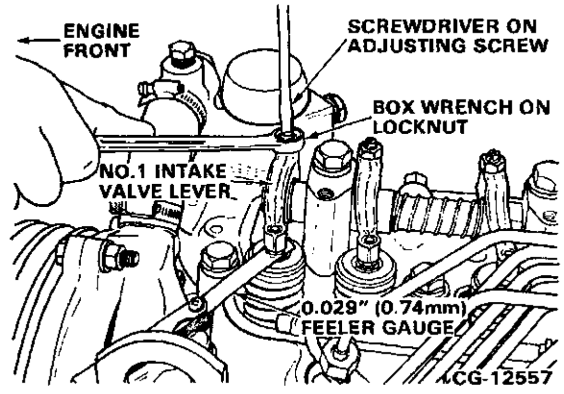

Figure 8.3. Adjust #1 Intake Valve Lever to .029" Clearance

3. Remove .029" feeler gauge, and place a .004" feeler gauge between the valve lever and valve stem of the #1 intake valve and slowly bar the crankshaft in engine rotation until a slight drag is felt on the feeler gauge. Refer to **Figures 8.4 and 8.5**.

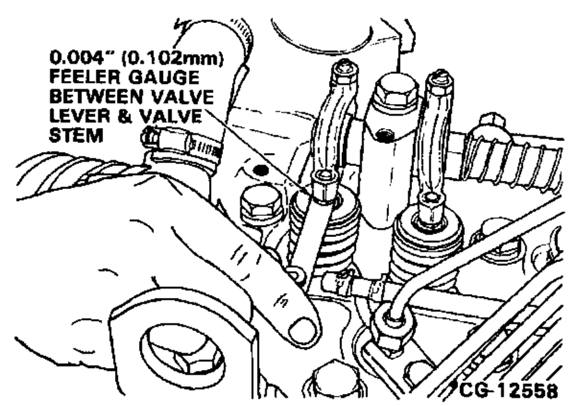

Figure 8.4. Insert.004" Feeler Gauge at #1 Valve Lever

CHECKING ENGINE GEAR TRAIN TIMING WITHOUT REMOVING FRONT COVER AND/OR ENGINE TEAR DOWN — Continued

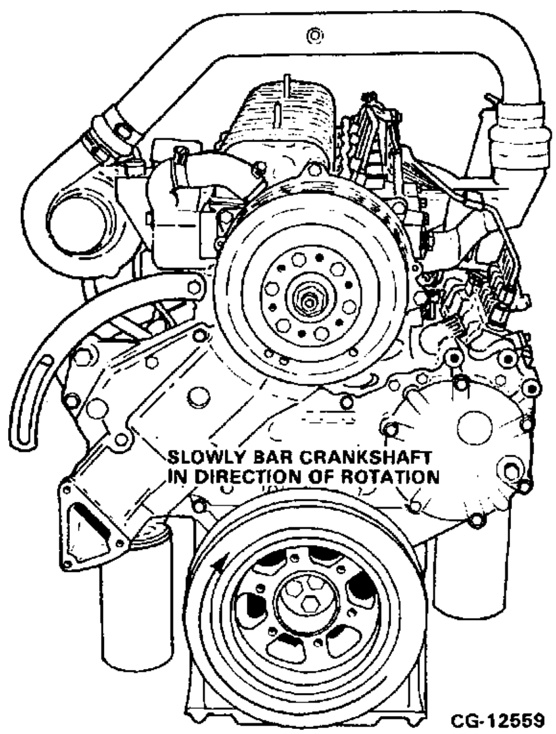

Figure 8.5. Bar Engine Until .004" Feeler Gauge is Snug

4. This is now the point which the #1 intake valve starts to open BTDC (Before Top Dead Center). The following degree reading should be read on the vibration damper:

ENGINES	READINGS BTDC
DT–360	22° ± 3°
DTA–360	22° ± 3°

5. Rotate crankshaft approximately 360° or one full revolution in engine rotation to TDC (Top Dead Center) #1 compression stroke. Reset valve lash to specifications (.025"), as described in Section 4.

6. If timing is found to be incorrect, removal of the engine's front cover is required to inspect punch marks and gear tooth positions.

NOTE: One (1) tooth "out of time" on gear train equals approximately 11 degrees movement of vibration damper. Figure 8.6. shows a properly timed gear train.

NOTE: If the timing on the #1 valve is within specifications, the other valves barring extreme camshaft lobe wear or poor adjustment will also be in time.

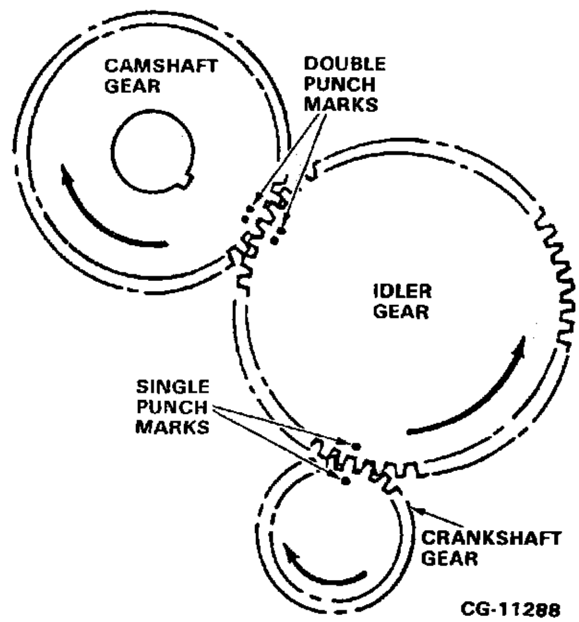

Figure 8.6. Properly Timed Gear Train

NOTE: The single punch marks on the crankshaft and idler gears must align, while the two punch marks on the camshaft and idler gears must align.

NOTE: As many as 14 revolutions may be required to bring the marks into alignment.

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FRONT COVER

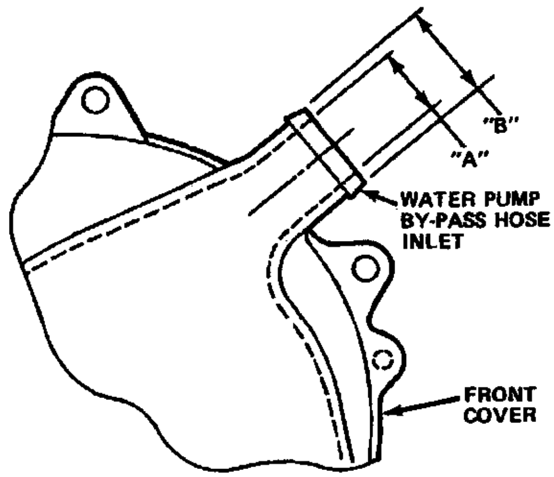
COMPONENT CHANGES

Crankcase Front Cover

Effective with S/N 054459, the crankcase front cover has an increased sized water pump by–pass hose inlet. Refer to **Figure 8.7.** for dimensions. Refer to current parts catalog when replacing the front cover or by–pass hose.

Front Cover Plate

Effective with S/N 054459, the front cover plate and gasket have been decreased in size to accept the new direct crankcase mounting front engine support. Refer to **Figure 8.8.** for current layout.



		1988	1989
"A"	INSIDE DIAMETER	0.83" I.D.	1.00" I.D.
"B"	OUTSIDE DIAMETER	1.29" O.D.	1.46" O.D.

CG-14473

Figure 8.7. Crankcase Water Pump By–Pass Inlet Location

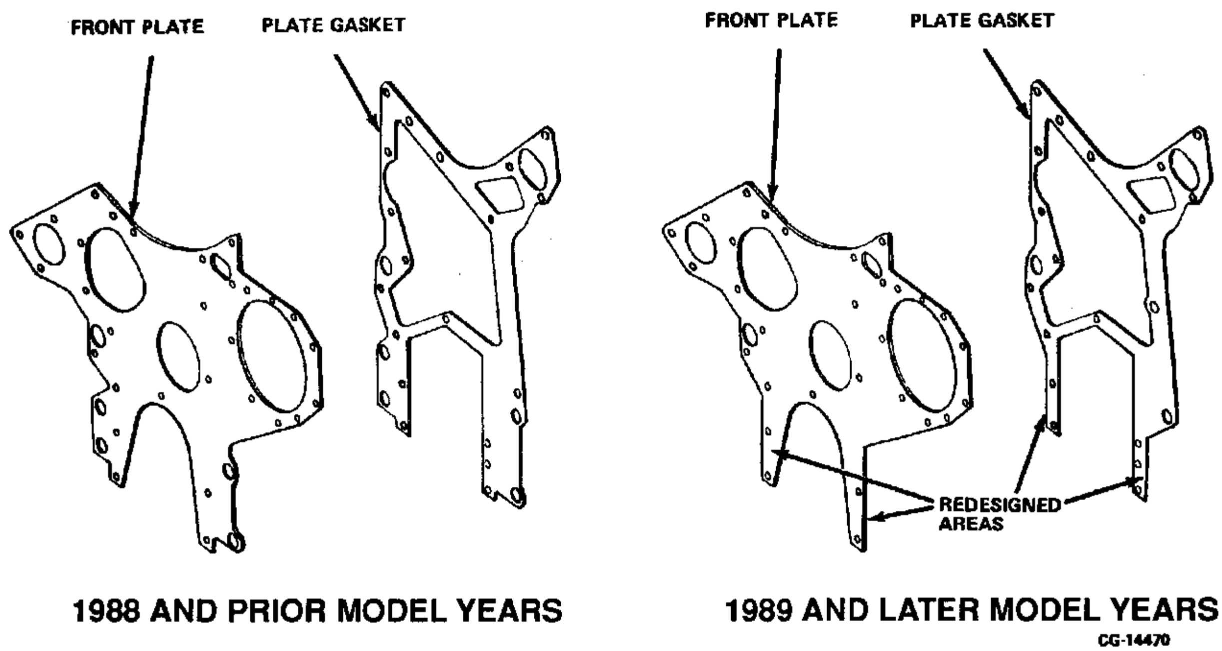


Figure 8.8. Front Cover Plate and Cover Plate Gasket Comparison

FRONT COVER

REMOVAL

1. Prior to front cover removal, remove the following components:

NOTE: Refer to the appropriate manual section for detailed removal procedures.

- Vibration damper
- Oil pump assembly
- Water pump to thermostat housing hose
- Water pump and pulley
- Oil pan
- Oil pickup tube
- Fuel injection lines (high pressure)
- Fuel return tube at injection pump
- Fuel filter to supply pump tube
- Throttle return springs
- Aneroid tube

2. Remove the injection pump drive gear access cover as follows:

   a. Loosen and remove the six fasteners which secure the access cover. Refer to **Figure 8.9.**

NOTE: Three thru bolts with nuts and washers secure the access cover to the injection pump adapter housing and three bolts with washers secure the access cover to the housing casting. 1987 and later model years access covers are of different designs and require different length hardware. Refre to Figure 8.25 for hardware location.

   b. Remove the access cover and gasket. Discard gasket.

3. Remove the injection pump drive gear and the injection pump as described in Section 11.

IMPORTANT

PRIOR TO REMOVING THE INJECTION PUMP, FOLLOW THE INJECTION PUMP TO ENGINE TIMING PROCEDURE TO FACILITATE REASSEMBLY. REFER TO SECTION 11.

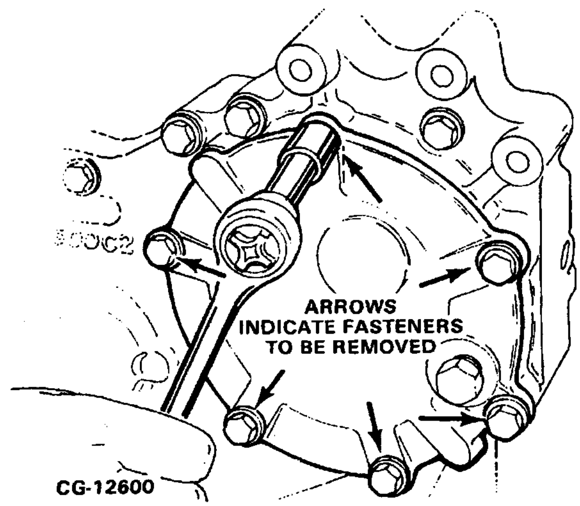


Figure 8.9. Remove Injection Pump Drive Gear Access Cover

4. Remove the front cover as follows:

   a. Remove the two nuts which secure the power steering pump or cover at the rear of the front cover and front plate. Remove the cover and discard the gasket. Refer to **Figure 8.10.**

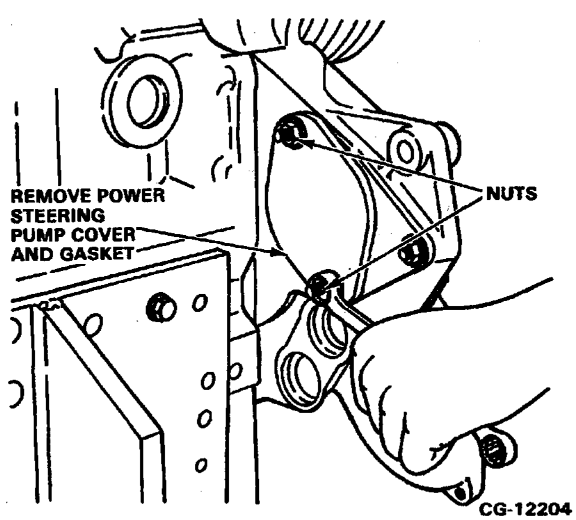


Figure 8.10. Remove Power Steering Pump or Cover and Gasket

FRONT COVER — Continued

REMOVAL — Continued

b. Remove all the front cover mounting bolts which secure the front cover to the crankcase. Refer to **Figure 8.11.**

c. Remove the front cover from the crankcase and set aside.

d. Remove front cover gasket and discard.

CLEANING

1. Remove all gasket material from the following mating surfaces:
   - Injection pump drive gear access cover
   - Water pump
   - Oil pan
   - Oil pickup tube
   - Crankcase front cover
2. Clean all bolt threads prior to reassembly.

INSPECTION

1. Visually inspect the front cover for damage.

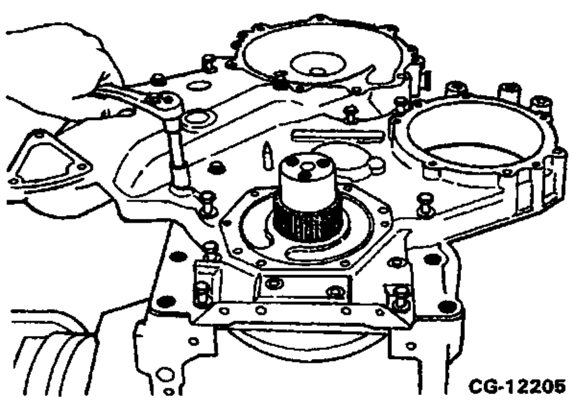


Figure 8.11. Remove Crankcase Front Cover (With Engine In Vertical Position)

TIMING GEAR TRAIN

INSPECTION PRIOR TO REMOVAL

1. Prior to removing any gear, check the backlash of the idler gear and camshaft gear as follows:

Idler Gear to Crankshaft Gear Backlash (Refer to **Figure 8.12.**)

1. Mount a magnetic base dial bore indicator to the crankcase at a suitable location.
2. Position the dial indicator tip at a gear tooth and remove lash.
3. "Zero" the dial indicator.
4. Hold the camshaft gear and move the idler gear by hand. Read the indicator and record the backlash.
5. If backlash exceeds **"SPECIFICATIONS"**, inspect the gear for misassembly or wear. If worn, replace the gear.

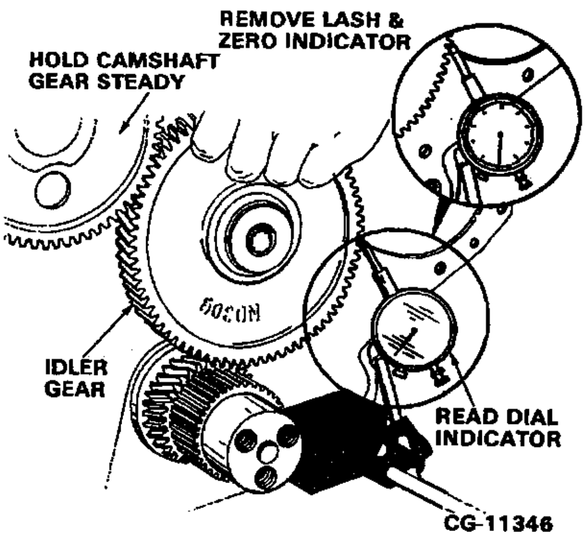


Figure 8.12. Measure Idler Gear to Crankshaft Gear Backlash

TIMING GEAR TRAIN — Continued

INSPECTION PRIOR TO REMOVAL — Continued

Camshaft Gear to Idler Gear Backlash (Refer to **Figure 8.13**)

1. Attach a magnetic base dial indicator to the crankcase at a suitable location.
2. Position the dial indicator tip at a gear tooth and remove lash.
3. "Zero" the dial indicator.
4. Hold the idler gear steady and move the camshaft gear by hand. Read the indicator and record backlash.
5. If backlash exceeds **"SPECIFICATIONS"**, replace the camshaft gear.

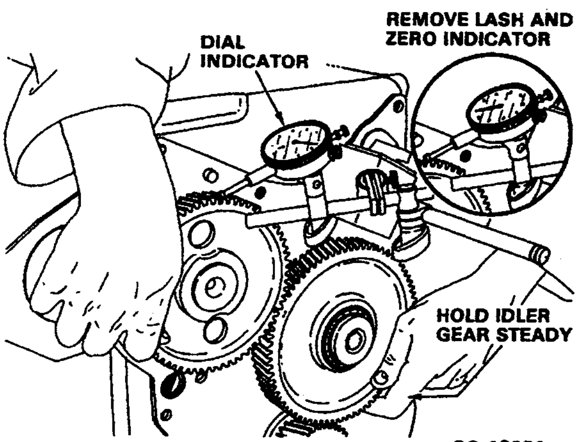


Figure 8.13. Measure Camshaft Gear to Idler Gear Backlash

NOTE: At this stage of disassembly, it is advantageous to measure camshaft end play, refer to Section 5.

2. Visually inspect the oil pump drive gear spline and the crankshaft gear for nicks, chips or wear. Replace as necessary.

REMOVAL

Idler Gear Assembly

1. Remove the idler gear as follows: (Refer to **Figure 8.14**)

   a. Loosen and remove the idler gear retaining bolt.

   b. Remove the idler gear assembly and spacer (thin washer) from the crankcase.

NOTE: The idler gear is supported on two tapered roller bearings and a shaft. The roller bearings are serviced as an assembly.

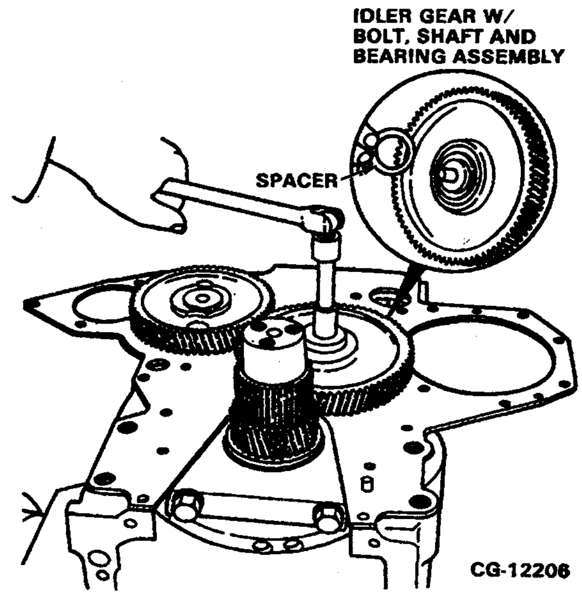


Figure 8.14. Remove Idler Gear

Camshaft Gear

2. Refer to Section 5 for the camshaft gear removal procedure.

NOTE: The camshaft gear must be pressed off the camshaft since it is a shrink fit. Remove only if damaged or worn.

Crankshaft Gear and Oil Pump Drive Spline

3. Refer to Section 7 for the crankshaft gear and oil pump drive spline removal procedure.

NOTE: These gears should be removed only if they fail visual inspection.

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TIMING GEAR TRAIN — Continued

REMOVAL — Continued

Injection Pump Drive Gear

NOTE: The injection pump drive gear must be removed when removing the engine front cover.

4. The drive gear can be removed without removing the engine front cover, by removing the injection pump drive gear access cover. Refer to Section 11 for the injection pump drive gear removal procedure.

Front Plate

5. With the camshaft assembly and idler gear removed, remove the front plate as follows:
   a. Remove the four retaining bolts which secure the front plate to the crankcase. Refer to **Figure 8.15.**
   b. Lift the front plate off the alignment dowels on the crankcase.
   c. Discard the gasket and clean any gasket material from the front plate or crankcase.

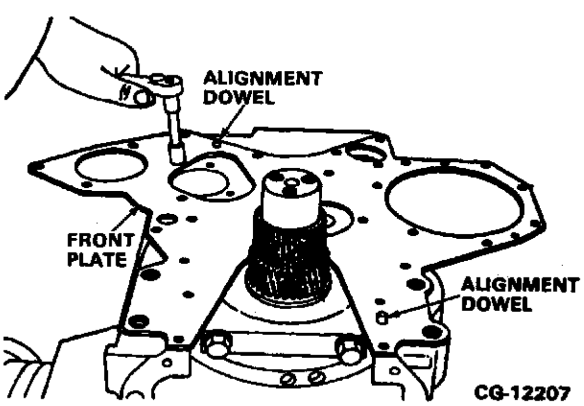

Figure 8.15. Remove Front Plate and Gasket

CLEANING

1. Clean all gears and related components, which are to be reinstalled, as follows:
   a. Clean all components in a suitable solvent.
   b. Dry with filtered compressed air.

INSPECTION

Idler Gear Assembly

1. Visually inspect the bearings and shaft for wear or damage. Replace as required.

NOTE: The bearings are serviced as an assembly consisting of two tapered roller bearings held together by a retaining ring. Refer to Figure 8.16.

2. Visually inspect the gear teeth for chips or nicks. Replace as required.

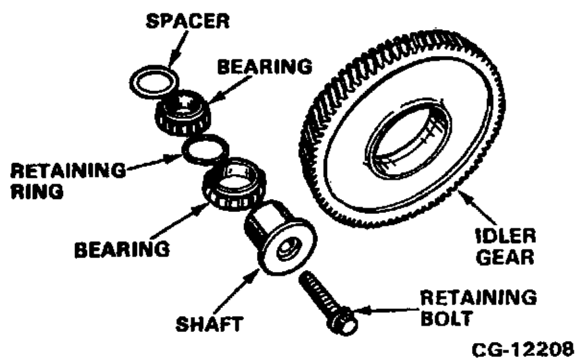

Figure 8.16. Inspect Idler Gear Components

NOTE: Inspection of the camshaft, crankshaft and oil pump spline gears is performed prior to gear removal or disassembly. Refer to Section 11 for Injection Pump Drive Gear Inspection.

TIMING GEAR TRAIN — Continued

INSTALLATION

1. Install the crankcase front plate as follows:
   a. Install a new front plate gasket over the crankcase alignment dowels.
   b. Mount the front plate to the crankcase using four lock bolts. Tighten the bolts to the specified **"SPECIAL TORQUE"**. Refer to **Figure 8.17**.

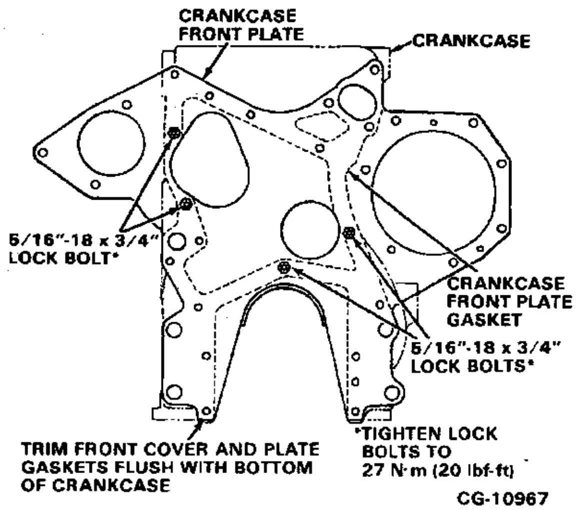

Figure 8.17. Front Plate and Front Plate Gasket Installation to Crankcase

2. Install a new crankshaft gear and oil spline gear, if required, as specified in Section 7.
3. If required, press on a new camshaft gear as explained in Section 5.
4. Install the camshaft and gear assembly as specified in Section 5.

NOTE: Check camshaft end play and be sure the tappets move freely in their bores.

5. Install the idler gear as follows: (Refer to **Figure 8.18**)
   a. Assemble the bearing assembly, shaft and retainer bolt in the gear.

NOTE: Use grease to hold the spacer in place against the crankcase.

   b. Install the gear with the timing marks facing out.
   c. Tighten the retaining bolt to the specified **"SPECIAL TORQUE"**.

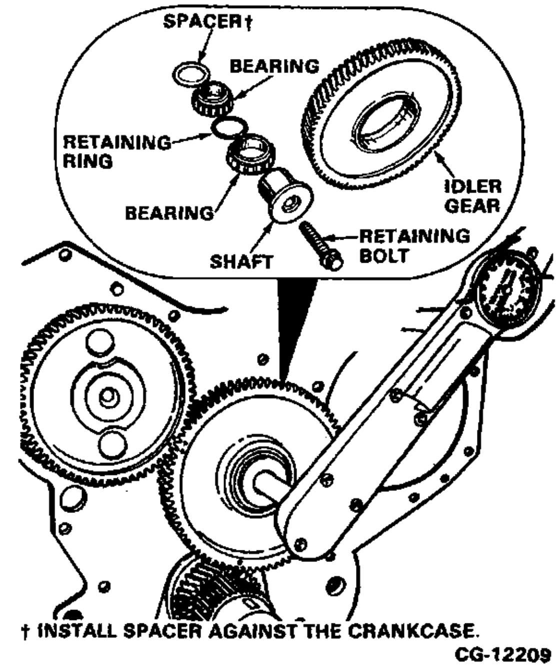

Figure 8.18. Install Idler Gear Assembly

IMPORTANT

IDLER GEAR COMPONENTS MUST BE ASSEMBLED AS SHOWN IN FIGURE 8.18 OR GEAR TRAIN DAMAGE COULD OCCUR.

TIMING GEAR TRAIN — Continued

INSTALLATION — Continued

6. When an engine has been disassembled and the camshaft, crankshaft or idler gear removed, the gears must be assembled with the timing marks properly aligned, as shown in **Figure 8.19**.

NOTE: The single punch marks on the crankshaft and idler gears must align, while the two punch marks on the camshaft and idler gears must align.

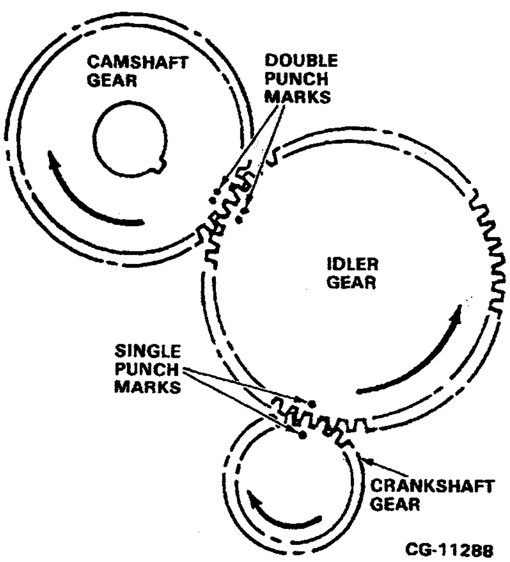

Figure 8.19. Align Gear Timing Marks

NOTE: As many as 14 revolutions may be required to bring the marks into alignment.

IMPORTANT

REMEASURE CAMSHAFT TO IDLER GEAR AND CRANKSHAFT TO IDLER GEAR BACKLASH, AFTER INSTALLATION, TO CONFIRM PROPER REASSEMBLY.

FRONT COVER

INSTALLATION

1. Install the front cover as follows:
   a. Install a new gasket over the front plate. Hold the gasket in place using the locating dowel pins.
   b. Install the front cover on the locating dowel pins and install the mounting hardware in the correct locations, as shown in **Figure 8.20**.
   c. Tighten the front cover mounting bolts to the standard torque. See Appendix.
2. Install the oil pickup tube and oil pan using new gaskets. Refer to Section 7.
3. Install the oil pump assembly with a new front seal. Refer to Section 9.
4. Install the vibration damper, see Section 7.

NOTE: Be sure the oil pickup tube mounting bolts are installed prior to installing the vibration damper.

5. Install the water pump using a new gasket. Refer to Section 10.
6. Install the water pump to thermostat housing hose.
7. Install the power steering pump or cover using a new gasket. Refer to **Figure 8.10.**

FRONT COVER — Continued

INSTALLATION — Continued

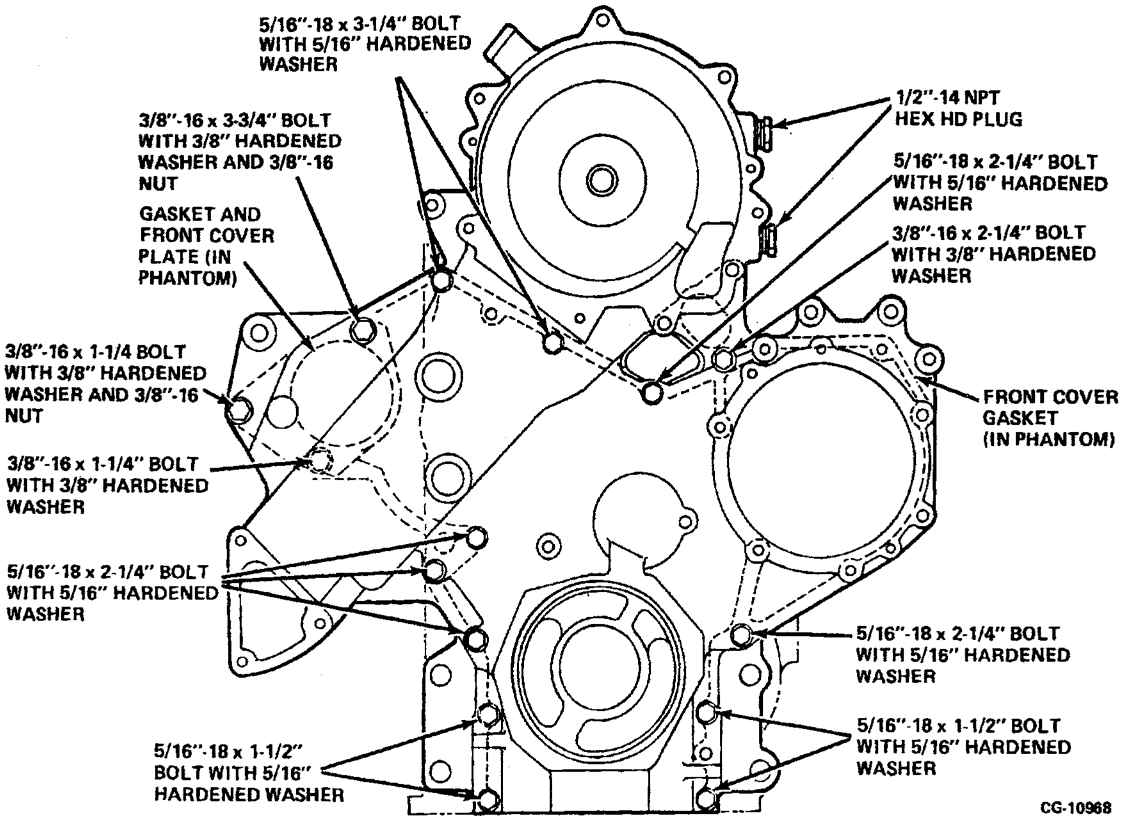

Figure 8.20. Front Cover Installation

INJECTION PUMP DRIVE GEAR

INSTALLATION

1. Install the injection pump and adapter housing to the front cover. Refer to Section 11.

2. Install the injection pump drive gear as follows:

   a. **IMPORTANT: Verify that the engine #1 cylinder is at TDC (compression stroke) and the front cover timing pointer and damper pulley are aligned at the specified static timing. Refer to Chart 1 (Page 14).**

   b. Loosely install the injection pump drive gear to the injection pump drive hub. **DO NOT TIGHTEN BOLTS.** Refer to **Figure 8.21.**

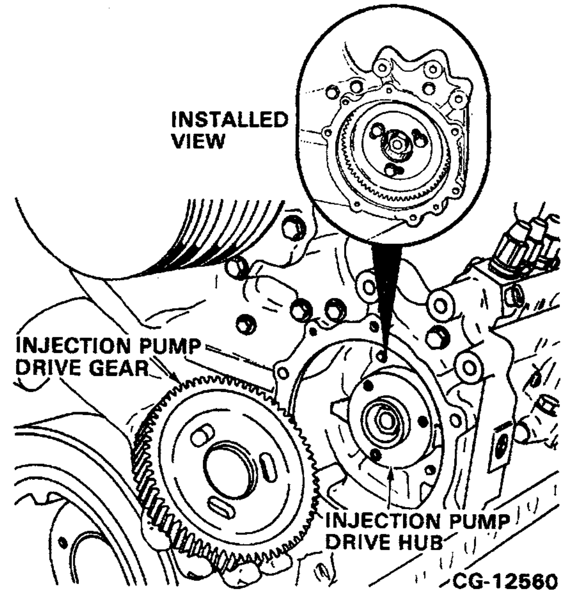

Figure 8.21. Install Injection Pump Drive Gear

INJECTION PUMP DRIVE GEAR — Continued

INSTALLATION — Continued

c. Verify the alignment of the injection pump timing pointer to the drive hub scribe line through the adapter housing sight plug. Refer to **Figure 8.22**. Rotate the pump gear and hub as required for proper alignment.

d. Tighten the three pump drive gear mounting bolts to the specified **"SPECIAL TORQUE"**.

e. Verify timing after injection pump drive gear installation by rotating the engine crankshaft counterclockwise at least 90° to remove gear train backlash. Then rotate the crankshaft clockwise until the timing pointer and scribe line are aligned. Refer to **Figure 8.22**.

f. Observe engine front cover timing pointer and crankshaft pulley degree alignment. The engine to static injection pump timing should be as specified in Chart I (Page 14). Refer to **Figure 8.23**.

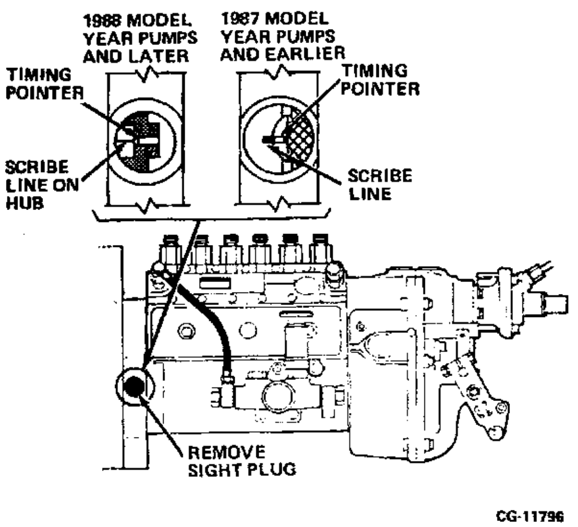

Figure 8.22. Injection Pump Timing Marks (Model PES6A pump shown)

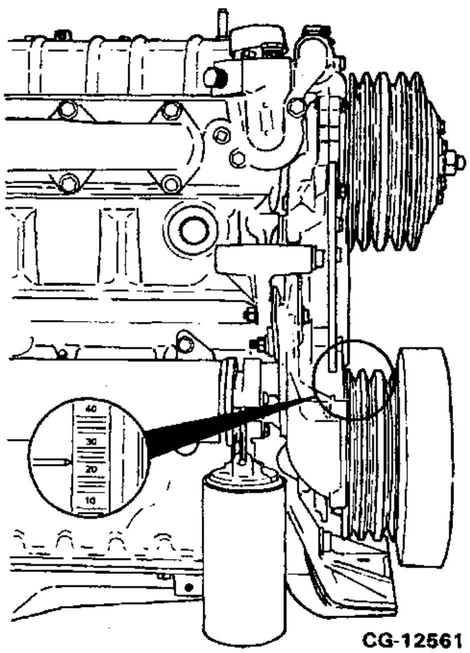

Figure 8.23. Engine to Injection Pump Timing on Pulley

INJECTION PUMP
DRIVE GEAR — Continued

INSTALLATION — Continued

CHART I

Model Year	Engine Model	Emission Standard	Horsepower Rating*	Static Timing Degrees**
1987	DT–360	Federal	165	20° BTDC
1987	DTA–360	Federal	180	22° BTDC
1987	DTA–360	California	175	13° BTDC
1988/1989	DT–360	Federal	170	21° BTDC
1988/1989	DTA–360	Federal	180	24° BTDC
1988/1989	DTA–360	California	175	17° BTDC
1990	DT–360	50 State	170	15° BTDC
1990	DTA–360	50 State	185	19° BTDC
1991	DT–360	Federal	170	12° BTDC
1991	DT–360	California	170	9° BTDC
1991	DTA–360	Federal	185	16° BTDC
1991	DTA–360	California	185	13° BTDC

* @ 2700 RPM
** ± 1° BTDC

3. Install the injection pump drive gear access cover using a new gasket (**Figure 8.24**) as follows:

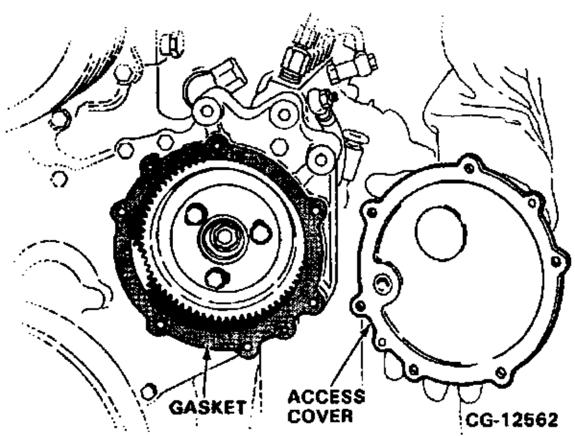

Figure 8.24. Install New Access Cover Gasket

a. Secure the three bolts and washers which fasten into the front cover casting.

b. Secure the bolts, washers and nuts which mount through the access cover, front cover and adapter housing. Refer to **Figure 8.25.** for bolt location on early and late model access covers.

c. Tighten the fasteners to the standard torque. See Appendix.

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INJECTION PUMP DRIVE GEAR — Continued

INSTALLATION — Continued

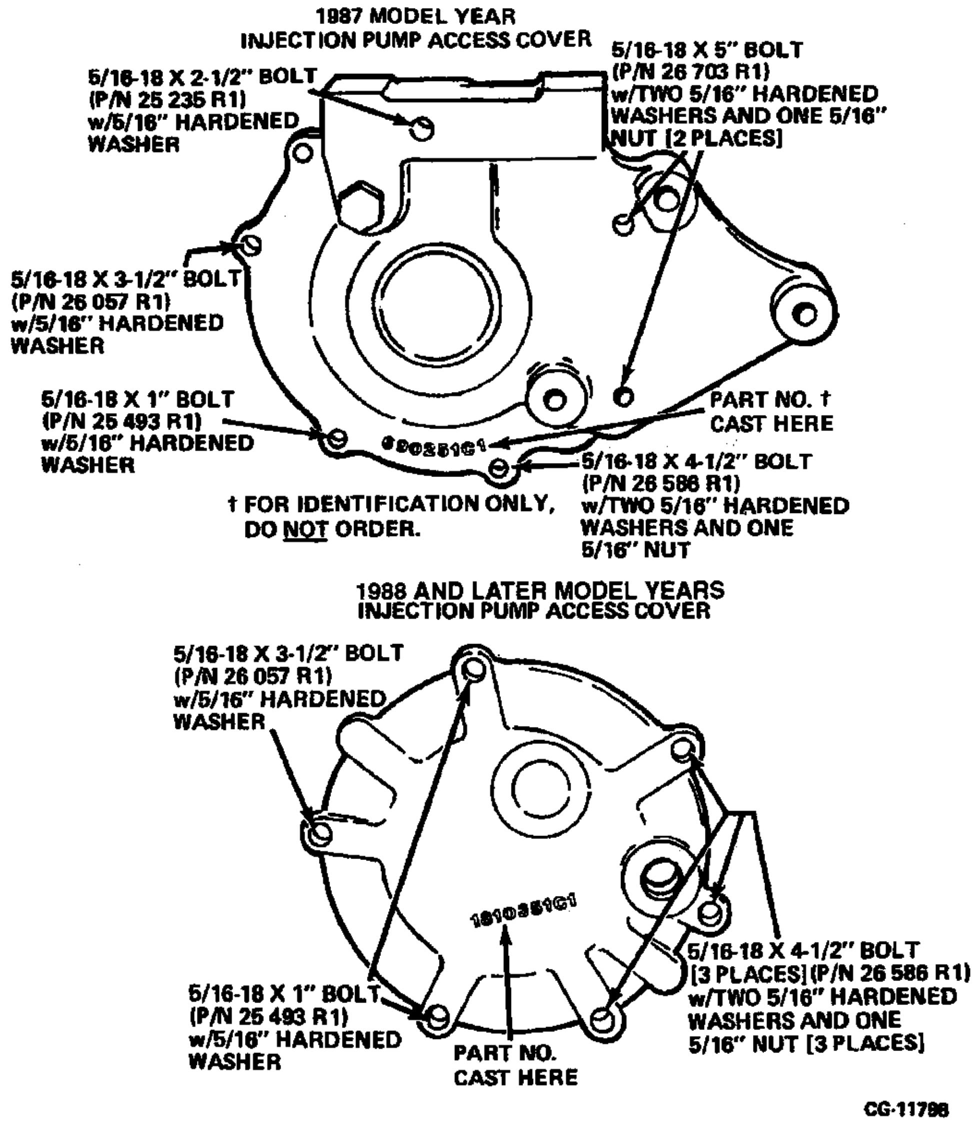

Figure 8.25. Install Injection Pump Drive Gear Access Cover Using the Correct Hardware

4. Reinstall the following components: Refer to Section 11 for installation procedures.
   - Fuel injection lines (high pressure)
   - Fuel return tube at injection pump
   - Fuel filter to supply pump tube
   - Aneroid tube
   - Throttle return springs
5. Prime the lubricating system as specified in Section 6.

SERVICE MANUAL

LUBRICATING OIL PUMP, OIL FILTERS & COOLER

SECTION 9 INDEX

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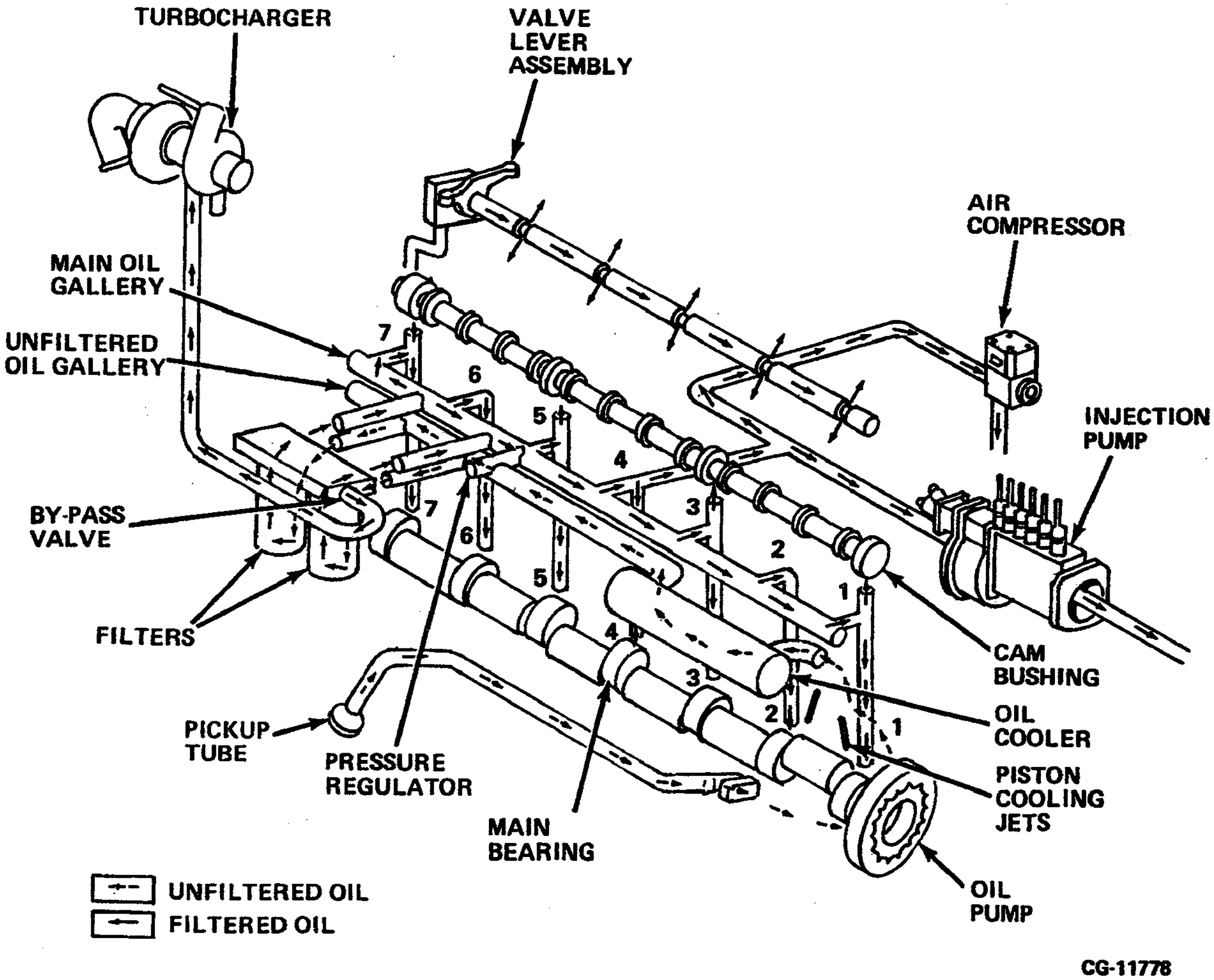

Figure 9.1. Engine Lubrication System

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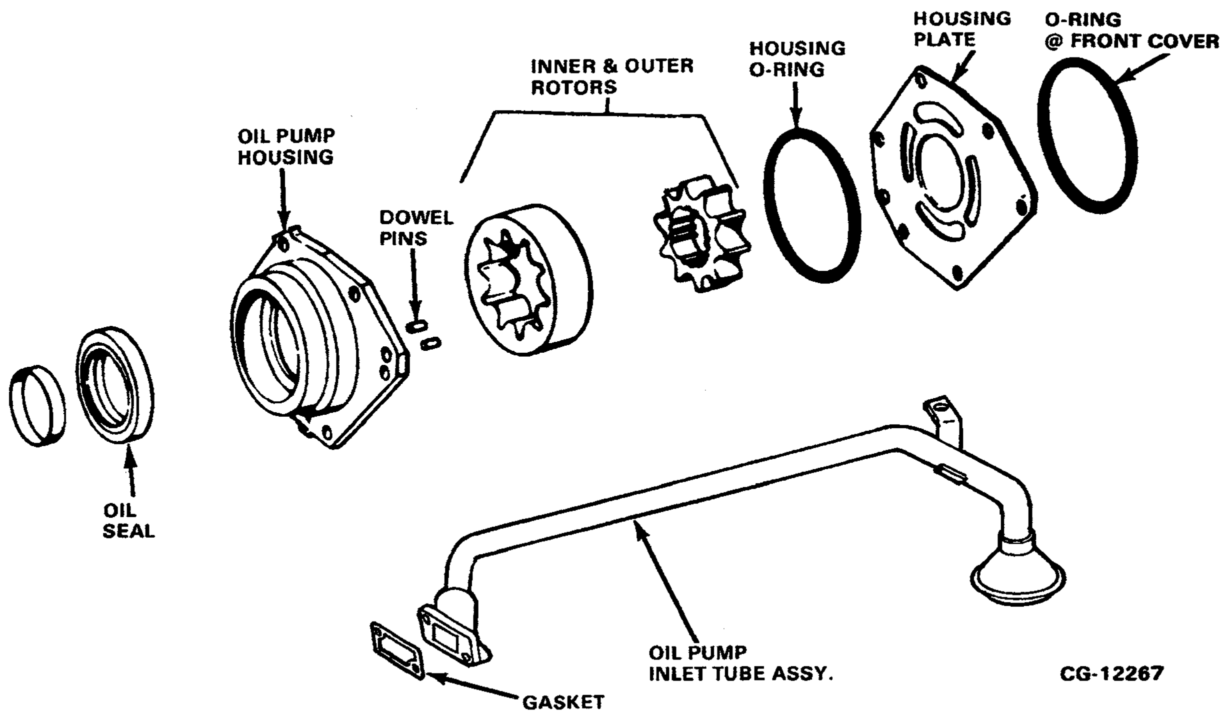

Figure 9.2. Lubricating Oil Pump and Pick–Up Tube

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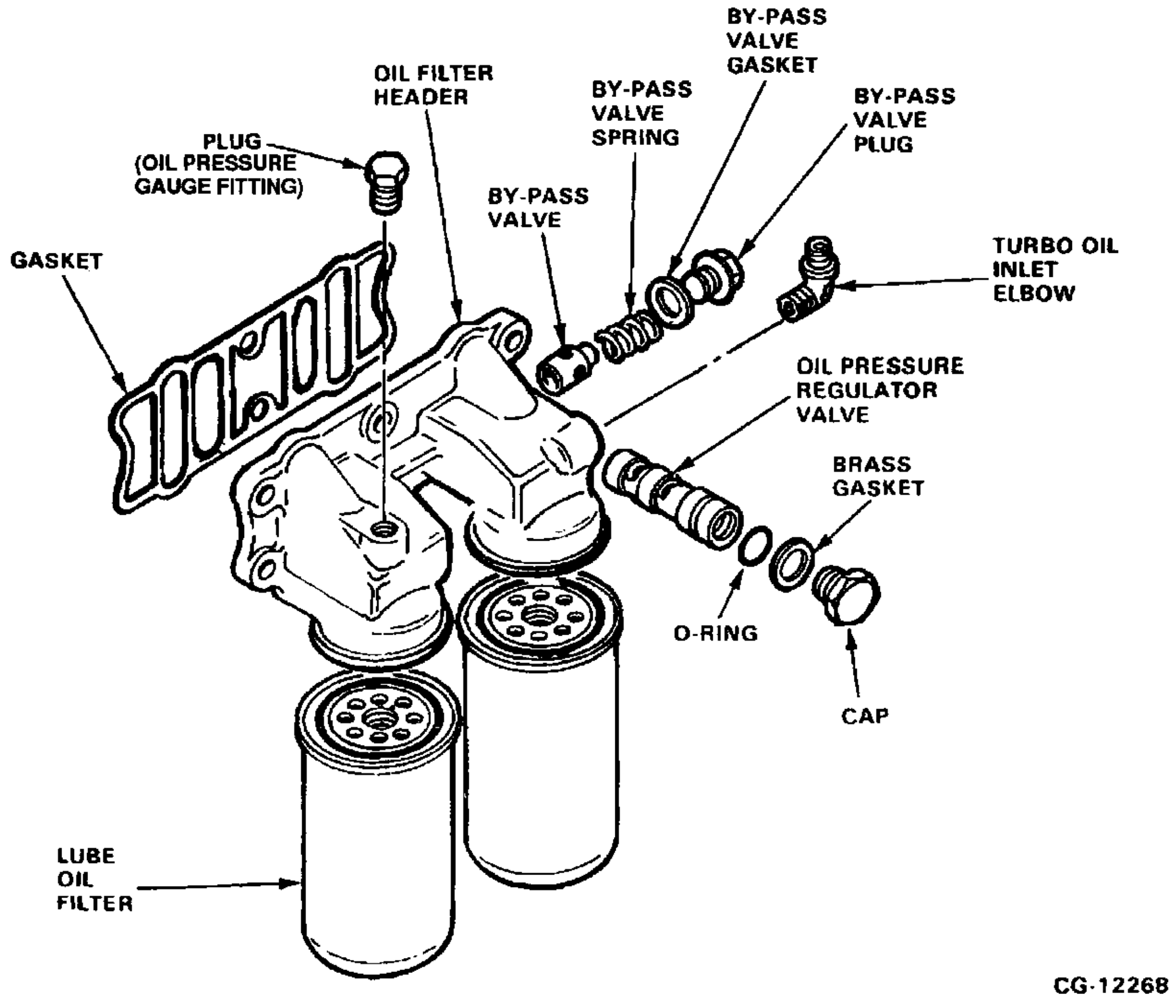

Figure 9.3. Oil Filter Header, Filters, Bypass Valve and Pressure Regulating Valve

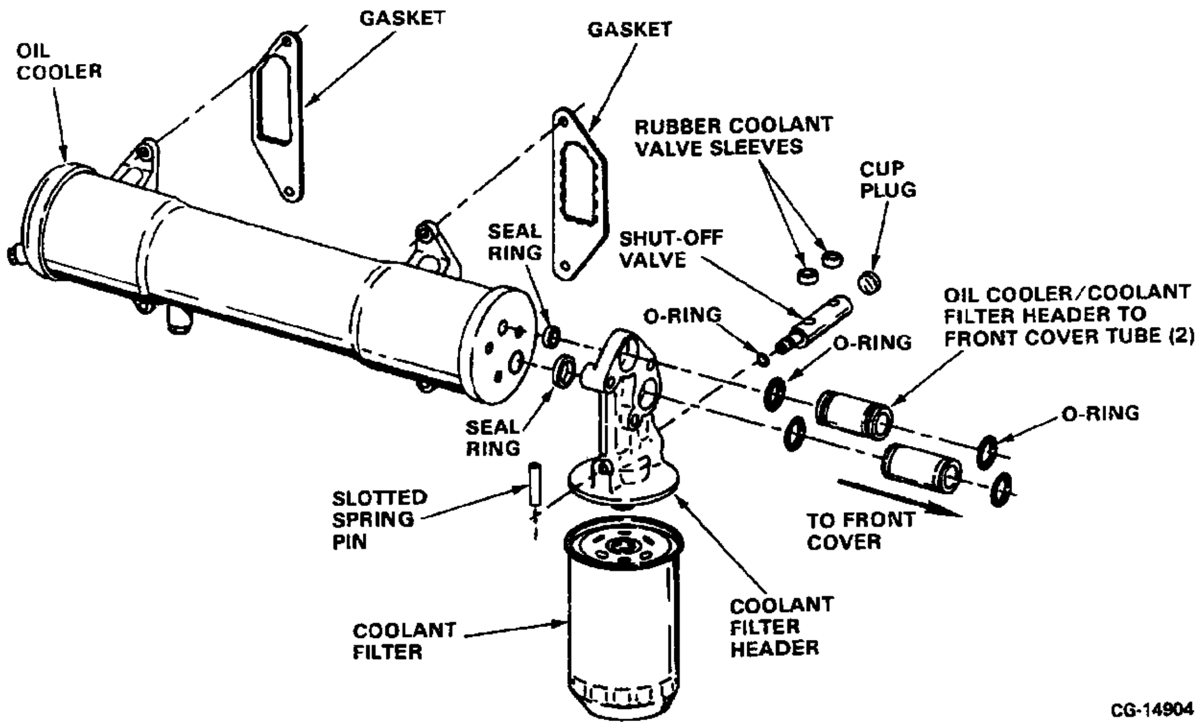

Figure 9.4. Oil Cooler Assembly

SPECIFICATIONS

DIMENSION TITLE	VALUES
OIL PUMP:	
Type	"GEROTOR"
Drive	Crankshaft
End Clearance, Inner and Outer Rotor to Housing	0.0002 in. (0.051 mm) 0.0048 in. (0.122 mm)
Radial Clearance, between Outer Rotor Housing	0.0055 in. (0.140 mm) 0.0095 in. (0.241 mm)
Engine Oil Pressure* (Run engine until normal operating temperatures are reached)	
At Low Idle Speed (700 RPM)	10 psi (69 kPa) Minimum
At High Idle Speed	40 to 65 psi (276 to 448 kPa)
ENGINE OIL FILTER:	
Type	"EXTENDERt — HIGH EFFICIENCY — SPIN–ON"
Number	2
Filter Bypass Location	In Oil Filter Header
COOLANT FILTER:	
Type	"SPIN–ON"
Number	1
BYPASS VALVE SPRING:	
Free Length	2.075 in. (52.71 mm)
Test Length	0.927 in. (23.55 mm)
Test Load	6.12 lbs. (27.2 N)
PRESSURE REGULATOR VALVE SPRING:	
Free Length	2.172 in. (55.17 mm)
Test Length	1.230 in. (31.24 mm)
Test Load	15.3 lbs. (68.1 N) ± 5%
Outside Diameter	0.500 in. (12.70 mm)

*Oil pressure measurement should be made utilizing an oil gallery tap.

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SPECIFICATIONS — Continued

DIMENSION TITLE	VALUES
PRESSURE REGULATOR VALVE ASSEMBLY:	
Location	In Crankcase, Forward of Oil Filter
Setting	48 psi (331 kPa) 52 psi (359 kPa)
Valve Assembly Diameter	.9985 in. (25.362 mm) .9975 in. (25.336 mm)
Valve Clearance in Bore	0.002 in. (0.05 mm) 0.004 in. (0.10 mm)
Crankcase Bore I.D.	1.002 in. (25.45 mm) 0.999 in. (25.37 mm)

SPECIAL TORQUES

Oil Filter Bypass Valve Cap	50 lbf–ft. (68 Nm)
Oil Pan Drain Plug	27 lbf–ft. (37 Nm)
Oil Pan Bolts	20 lbf–ft. (27 Nm)
Oil Pressure Regulator Valve Cap Nut	170 lbf–ft. (230 Nm)
Oil Pickup Tube Mounting Bolts	18 lbf–ft. (25 Nm)

SPECIAL SERVICE TOOLS

Tool No.	Description
ZTSE–2241	Spring Load Tester

NOTE

Refer to Operations and Maintenance manual for Lubricating Oil System Specifications, Capacities and Maintenance Instructions.

LUBRICATING OIL PUMP

REMOVAL

1. Remove the vibration damper as described in Section 7.
2. Using a hammer and chisel, remove the woodruff key from the crankshaft as shown in **Figure 9.5.**

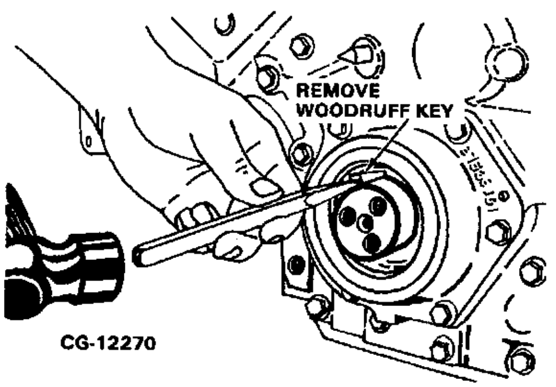

Figure 9.5. Remove Woodruff Key from Crankshaft

3. Remove the six oil pump housing retaining bolts and washers as shown in **Figure 9.6**.

NOTE: Whenever the oil pump housing is removed from the crankcase front cover, be careful not to mix the six oil pump housing bolts with any other hardware. These bolts have a nylon patch mounted in the threads to seal through tapped holes which go into the oil cavity behind the crankcase front cover. Installation of cap screws not so equipped will result in oil leaks around these cap screws. The leaks will not be obvious until after the engine has been put back into service. To prevent the possible loss of the bolts' sealing characteristic, the prevailing torque bolts should not be reinstalled more than three times.

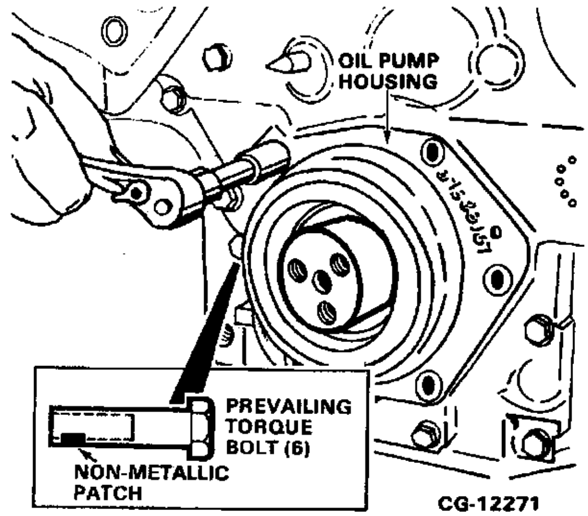

Figure 9.6. Remove Oil Pump Housing Bolts

4. Remove the oil pump housing with O–ring seal from the front cover. Refer to **Figure 9.7.** Discard the O–ring seal.

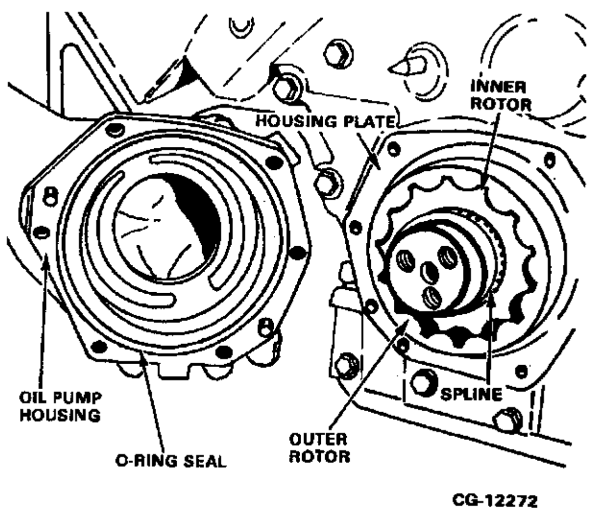

Figure 9.7. Remove Oil Pump Housing

LUBRICATING OIL PUMP — Continued

REMOVAL — Continued

5. Remove the inner and outer rotors from the oil pump drive spline. Refer to **Figure 9.4**.
6. Remove the oil pump housing plate. With the plate removed, remove the sealing O–ring from the front cover. Refer to **Figure 9.8**. Discard the O–ring seal.

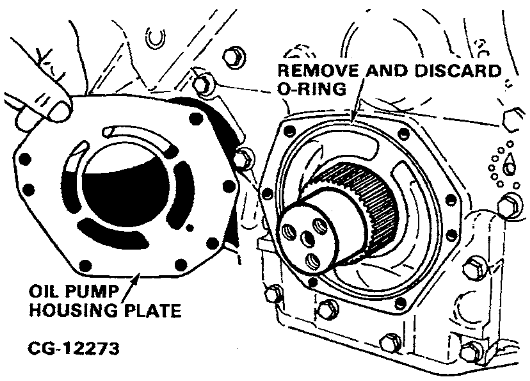

Figure 9.8. Remove Oil Pump Plate and O–Ring

7. Remove the oil seal from the oil pump housing. Discard the seal.

CLEANING

1. Wash all parts thoroughly in a suitable solvent.
2. Dry with filtered compressed air.

INSPECTION AND REPAIR

1. Visually inspect the rotors, housing and plate for nicks, burrs or scoring.
2. Replace any damaged components.

NOTE: The inner and outer rotors are a matched set and cannot be replaced separately.

Inspect for wear as follows:

3. Check the radial clearance between the outer rotor and the pump housing using a feeler gauge as shown in **Figure 9.9.** Refer to **"SPECIFICATIONS"**. If radial clearance exceeds the specifications, check housing to rotor clearance (see step 4).

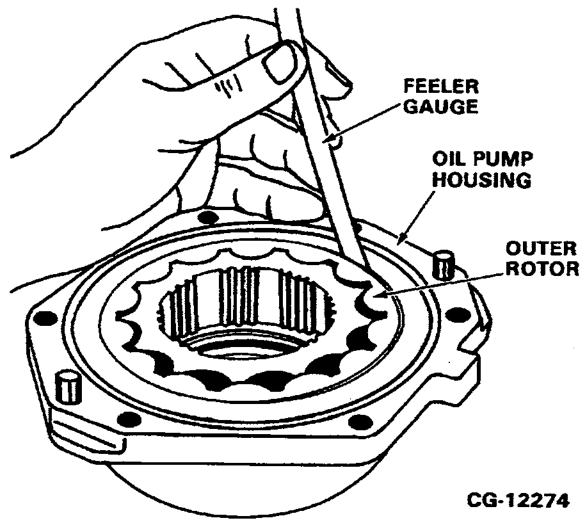

Figure 9.9. Check Outer Rotor to Housing Clearance

4. Check housing to rotor clearance as follows:

METHOD ONE (Refer to **Figure 9.10**)

a. With the O–ring removed from the oil pump housing, place a straightedge across the housing.

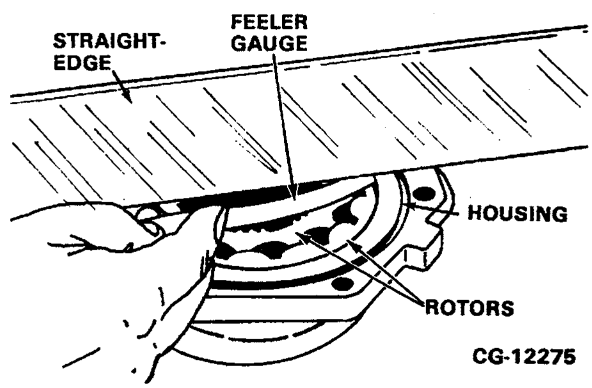

Figure 9.10. Check Housing to Rotor Clearance (Method One)

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LUBRICATING OIL PUMP — Continued

INSPECTION AND REPAIR — Continued

b. Insert an appropriate feeler gauge under the straightedge at the housing and outer rotors. (See **"SPECIFICATIONS"**.)

c. If not within specifications, check the inner housing and rotors for wear. Replace worn components, as required.

METHOD TWO (Refer to **Figure 9.11**)

NOTE: An alternate method of measuring the housing to rotor clearance is the use of Plastigage® just before assembling the oil pump to the front cover.

a. Place a strip of Plastigage® onto the rotors (side facing out from engine).

b. Install a new O–ring in the oil pump housing and install the housing to the front cover.

c. Remove the housing and measure the Plastigage®. (See **"SPECIFICATIONS"**.)

d. If not within specifications, check the rotors and inner housing for wear. Replace worn components, if necessary.

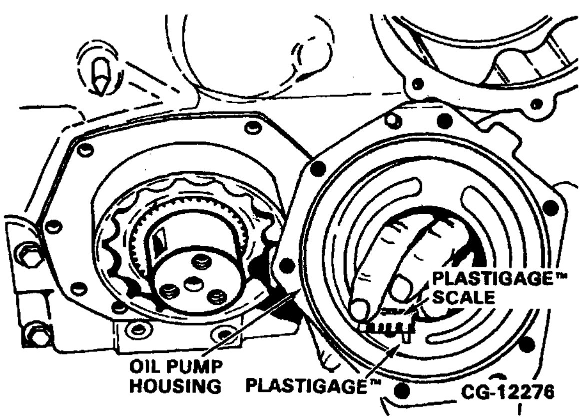

Figure 9.11. Check Housing to Rotor Clearance (Method Two)

e. If components are to be reused, clean the Plastigage® from the rotors or housing.

NOTE: The Plastigage® may stick to either the rotors or the oil pump housing.

REASSEMBLY

1. Install a new crankshaft front oil seal into the lubricating oil pump housing as follows:

   a. Apply gasket eliminator #515 to the O.D. of the oil seal.

   b. Press the seal into the oil pump housing so the front of the seal is flush with the front of the oil pump housing. Refer to **Figure 9.12.**

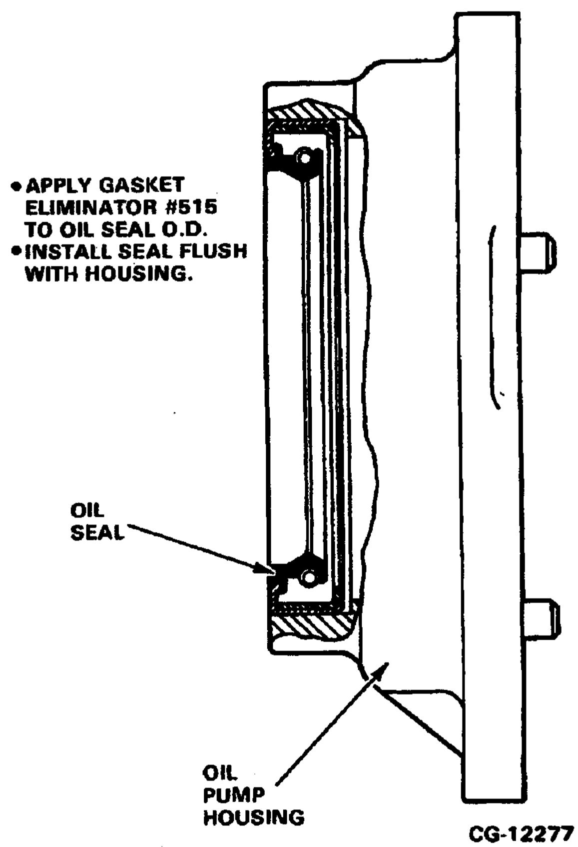

Figure 9.12. Oil Seal Installation Diagram

LUBRICATING OIL PUMP — Continued

REASSEMBLY — Continued

2. Install a new O–ring on the front cover, then install the housing plate. Refer to **Figure 9.13.**

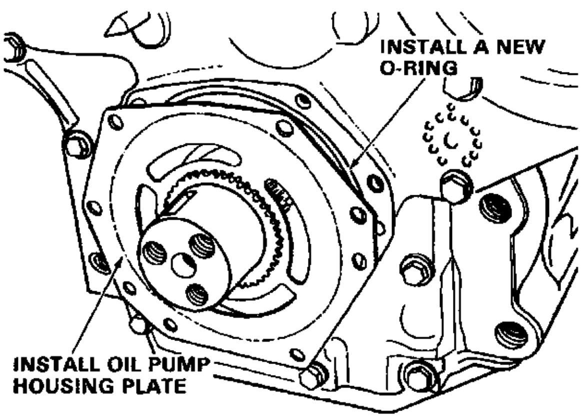

Figure 9.13. Install O–Ring and Plate

3. Install the inner rotor onto the gear spline. With the inner rotor installed, tap in the crankshaft key with a plastic hammer. Refer to **Figure 9.14.**

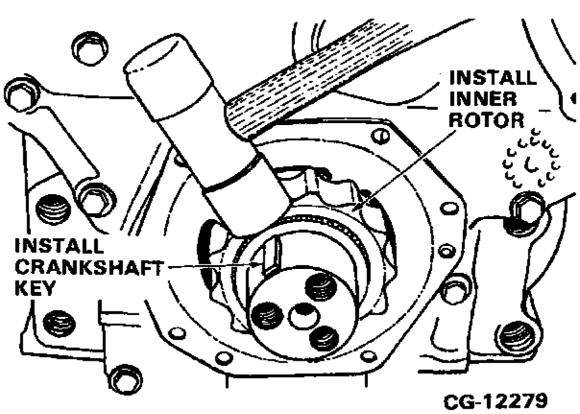

Figure 9.14. Install Inner Rotor and Crankshaft Key

4. Assemble a new O–ring and the outer rotor into the housing. Lubricate the rotator with clean engine oil. Refer to **Figure 9.15.**

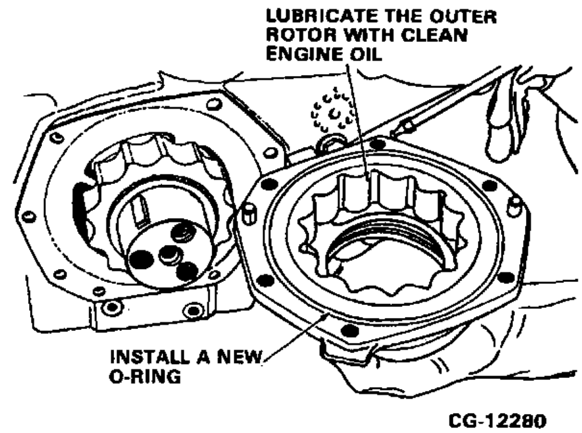

Figure 9.15. Assemble Housing Components

5. Install the outer rotor and housing over the inner rotor. Align the bolt holes and install the "patch" bolts. Tighten the bolts to the standard torque. Refer to **Figure 9.16. NOTE: "Patch" bolts must be used to prevent leakage.**

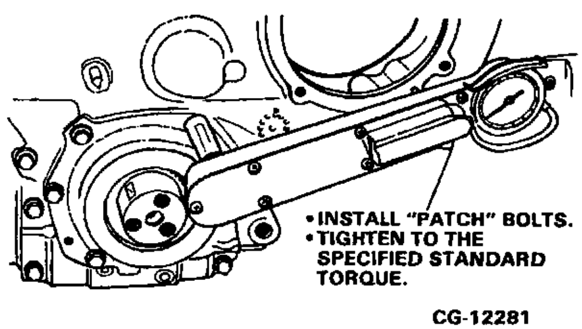

Figure 9.16. Tighten Oil Pump Mounting Bolts

6. Install the vibration damper as specified in Section 7.

IMPORTANT

BE SURE TO INSTALL THE SEAL WASHER WHICH IS POSITIONED BETWEEN THE OIL PUMP DRIVE GEAR SPLINE AND THE VIBRATION DAMPER. REFER TO SECTION 7, FIGURE 7.1.

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OIL FILTERS AND HEADER

REMOVAL

1. Remove the oil filters using an appropriate filter wrench. Refer to **Figure 9.17**. Discard the filters.

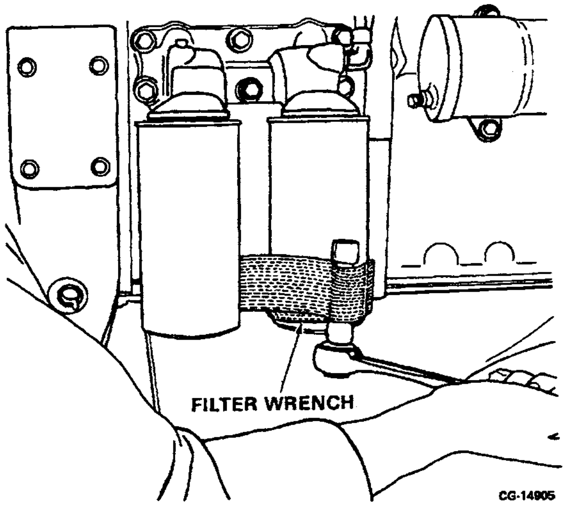

Figure 9.17. Remove Oil Filters

2. Disconnect the turbocharger oil inlet tube nut at the filter header elbow. Cap the elbow after disconnecting the oil inlet tube. Refer to **Figure 9.18.**

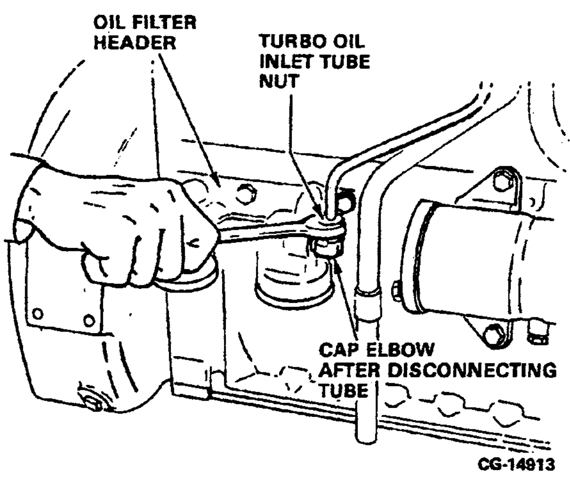

Figure 9.18. Disconnect Turbo Oil Inlet Tube

NOTE: If further engine disassembly is required, remove the turbocharger oil inlet tube as described in Section 2.

3. Loosen and remove the six retaining bolts and washers which secure the header to the crankcase. Refer to **Figure 9.19.**

NOTE: The header retaining bolts are "patch" bolts. They are required at these locations for their sealing capability.

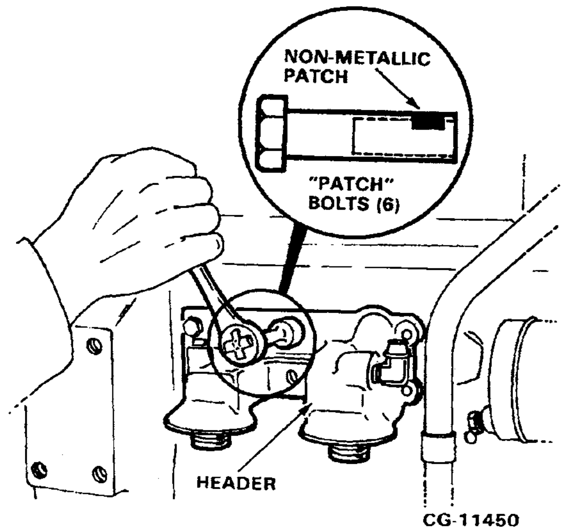

Figure 9.19. Remove Header Retaining Bolts

4. Remove the filter header and gasket from the crankcase. Refer to **Figure 9.20.**

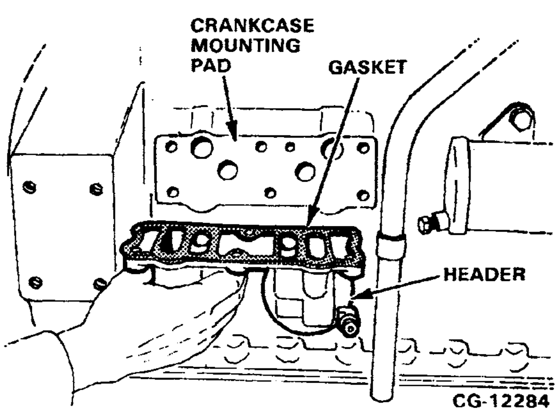

Figure 9.20. Remove Filter Header and Gasket

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OIL FILTERS AND HEADER — Continued

REMOVAL — Continued

5. Remove the oil filter bypass valve from the filter header as follows: (Refer to **Figure 9.21**)
   a. Loosen and remove the bypass valve plug.
   b. Remove the brass sealing gasket and discard.
   c. Remove the bypass valve spring.
   d. Remove the bypass valve.

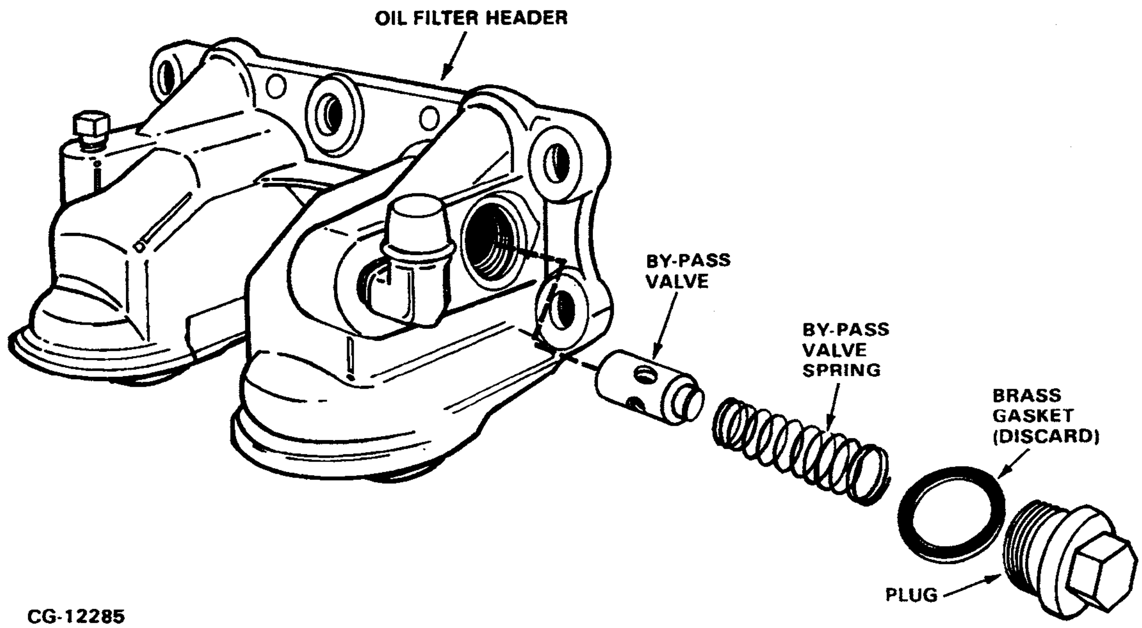

Figure 9.21. Remove Oil Filter Bypass Valve

CLEANING

1. Clean the oil filter header (with the bypass valve removed) using a suitable oil solvent.
2. Clean the bypass valve components using a suitable solvent.
3. Dry all components using filtered compressed air.

INSPECTION AND REPAIR

Oil Filter Header

1. Visually inspect the header for blocked orifices or damaged threads at the oil filter threaded inserts.
2. Remove any debris which may be blocking the oil flow passages.
3. If thread damage is apparent, replace the header.

Oil Filter Bypass Valve

1. Visually inspect the bypass valve for debris or scoring which could cause the valve to stick open. Replace as required.

NOTE: Bypass valve inspection is especially important any time an engine failure is experienced. If the valve sticks in the open position, unfiltered oil will go directly to the crankshaft and other vital engine parts.

2. Visually inspect the bypass valve spring for wear.
3. Measure by–pass valve spring tension using valve spring tester ZTSE–2241. Refer to "SPECIFICATIONS".
   a. Measure maximum spring length in use (valve closed).
   b. Measure minimum spring length in use (valve open).

NOTE: Apply the appropriate test load to each spring and determine if test length is achieved.

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OIL FILTERS AND HEADER — Continued

Oil Filter

New Design Description

A new larger capacity lubricating oil filter is available for service. This new filter is designated as an "EXTENDER™" oil filter and is constructed of a special paper media and additional media capacity to retain contaminants.

The larger capacity "EXTENDER™" oil filter requires an additional one (1) quart of oil added to the lubrication oil system to compensate for the increased dimensions of the oil filter.

The major feature of the new "EXTENDER™" oil filter provides for an extended time interval between changes of oil, fuel and coolant filters.

**WITHOUT "EXTENDER™"
CHANGE INTERVAL**

FILTER	HOURS	MILES
OIL	200	6,000
FUEL	400	12,000
COOLANT	600	18,000

WARNING

WHEN USING AN OIL FILTER OTHER THAN "EXTENDER™", THE OLD 6,000 MILES/200 HOURS OIL DRAIN INTERVAL MUST BE RETAINED.

**WITH "EXTENDER™"
EXTENDED CHANGE INTERVAL**

FILTER	HOURS	MILES
OIL	300	8,000
FUEL	600	16,000
COOLANT	900	24,000

IMPORTANT

ALWAYS REPLACE BOTH OLD OIL FILTERS WITH TWO (2) NEW "EXTENDER™" OIL FILTERS. DO NOT MIX OLD AND NEW FILTERS ON ANY ONE ENGINE.

REASSEMBLY

1. Install the bypass valve and spring into the header. Refer to **Figure 9.21.**

2. Using a new brass gasket, install the bypass valve plug and tighten to the specified special torque.

3. Using a new gasket, install the filter header assembly to the crankcase. Fasten the header using special "patch" bolts to assure proper sealing. Refer to **Figure 9.19.** Tighten to the standard torque. (See Appendix.)

4. Reconnect the turbocharger oil inlet tube to the oil filter header elbow. Use a new sealing ring at the oil inlet tube nut.

NOTE: For all engines built prior to S/N 054459, (prior to installation of "EXTENDER™" oil filters) check for possible contact between "EXTENDER™" filter can and manufacture's tab at lower right hand corner of crankcase. If necessary, chamfer tab back 15° as shown in Figure 9. 22. so that a .25" clearance is present between filter can and tab.

5. Install two new lube oil filters as follows:

   a. Lubricate the filter gasket with clean engine oil.

   b. Hand tighten the filters 1/2–3/4 turn after the gasket contacts the header. **DO NOT OVERTIGHTEN.**

NOTE: For all engines built prior to S/N 054459, after installing two (2) new "EXTENDER™" oil filters, ADD one (1) extra quart of oil. This will bring the total capacity of the lubrication system from 17 quarts to 18 quarts of oil [crankcase capacity (with filters)]. Dipstick oil level MUST be brought up to "FULL" mark.

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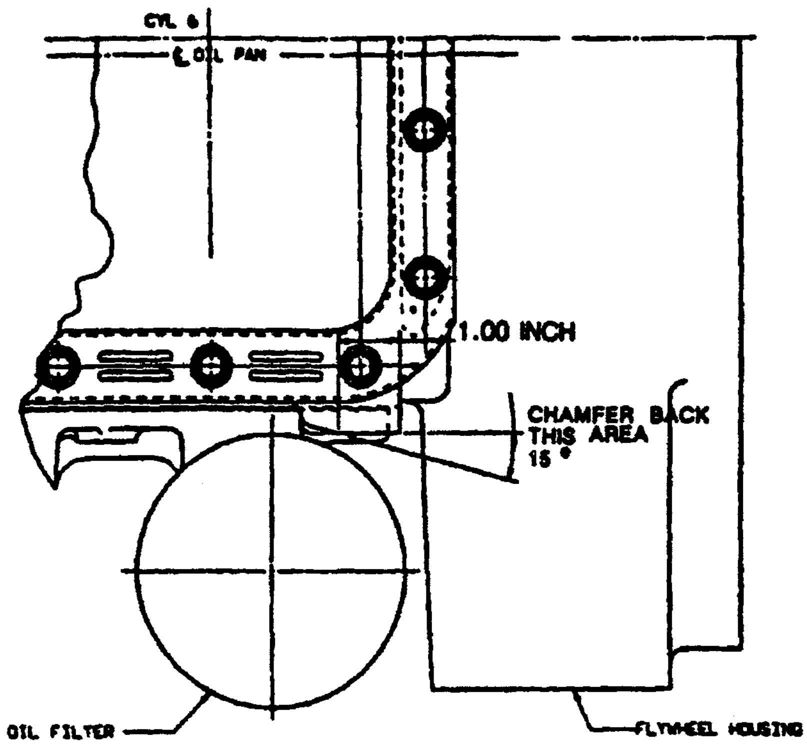
OIL FILTERS AND HEADER — Continued

REASSEMBLY — Continued



BOTTOM VIEW OF CRANKCASE

CG-13368

Figure 9. 22. Manufacture's Tab Location
(For engine Serial Numbers 054459 and Below)

OIL COOLER AND COOLANT FILTER ASSEMBLY

REMOVAL

Remove the oil cooler as follows:

NOTE: Engine cooling system must be drained.

1. Prior to oil cooler removal, the cooler itself must be drained of oil and coolant.

OIL COOLER AND COOLANT FILTER ASSEMBLY — Continued

REMOVAL — Continued

a. Drain the oil from the oil cooler. Refer to **Figure 9.23.**

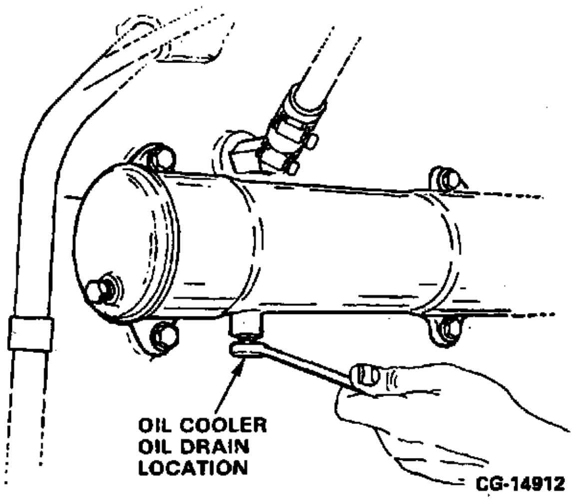


Figure 9.23. Drain Oil from the Oil Cooler

b. Drain the coolant from the oil cooler. Refer to **Figure 9.24.**

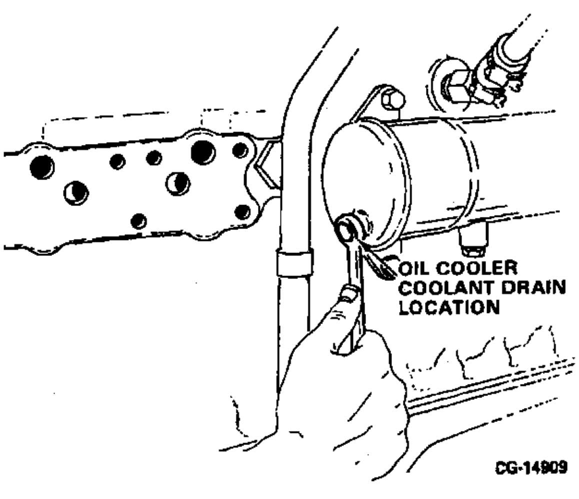


Figure 9.24. Drain Coolant from the Oil Cooler

c. Reinstall oil and coolant drain plugs after draining the oil cooler.

d. Remove the "spin–on" coolant filter and discard.

2. Loosen and remove the four "patch" bolts and washers which secure the oil cooler and coolant filter to the crankcase. Refer to **Figure 9.25.**

NOTE: Support the oil cooler when mounting bolts are removed.

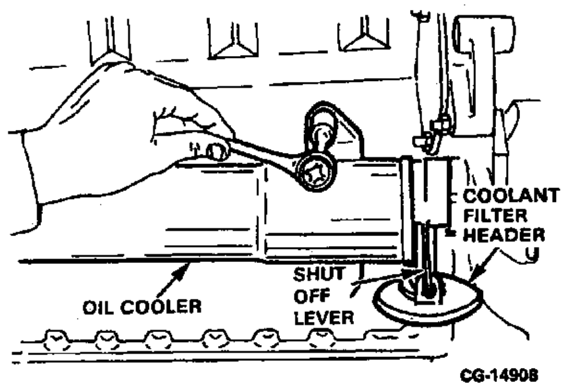


Figure 9.25. Remove Oil Cooler Mounting Bolts

IMPORTANT

THE COOLANT FILTER HEADER IS EQUIPPED WITH A SHUT–OFF VALVE WHICH IS ACTIVATED BY A SHUT–OFF LEVER (FIGURE 9.25). WHEN THE MANUALLY OPERATED SHUT–OFF LEVER IS IN THE VERTICAL POSITION, THE VALVE IS OPEN AND THE COOLANT FILTER IS OPERATIONAL. WHEN THE LEVER IS IN THE HORIZONTAL POSITION THE VALVE IS CLOSED AND THE COOLANT FILTER IS BY–PASSED. BE SURE THE LEVER IS IN THE VERTICAL POSITION DURING ENGINE OPERATION.

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OIL COOLER AND COOLANT FILTER ASSEMBLY — Continued

REMOVAL — Continued

3. Remove the oil cooler and coolant filter header assembly from the crankcase. Discard the oil cooler gaskets. **NOTE: The used oil cooler gaskets may be retained for use when pressure checking the oil cooler.**

NOTE: It will be necessary to move the oil cooler and coolant filter header assembly rearward to free it from the front cover. Refer to Figure 9.26. Discard O–rings at front cover.

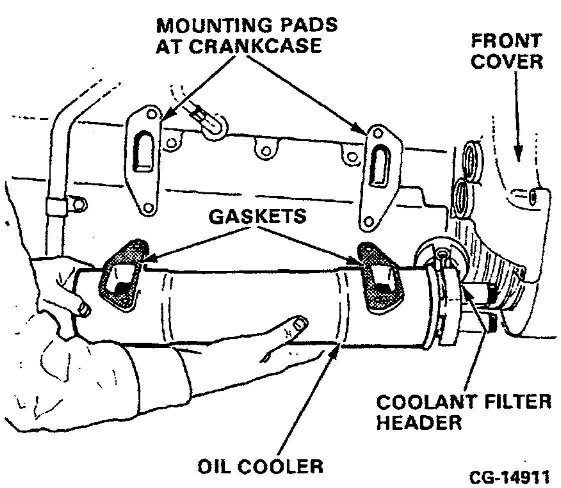

Figure 9.26. Remove Oil Cooler

4. Remove the coolant filter header from the oil cooler as follows:
   a. Remove the two oil cooler/coolant filter header tubes and O–rings from the coolant filter header. Discard the O–rings. Refer to **Figure 9.4**.
   b. Loosen and remove the three coolant filter headers to oil cooler mounting bolts and hardened washers. Refer to **Figure 9.27**. Discard the large and small seal rings at the oil cooler. Refer to **Figure 9.4**.

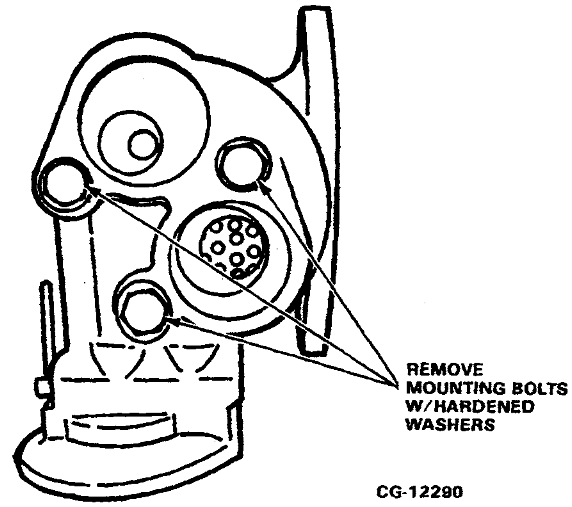

Figure 9.27. Coolant Filter Header Removal

COOLANT FILTER HEADER RECONDITIONING (Refer to Figure 9.28)

NOTE: Coolant filter header disassembly is only required when external valve leakage is present (which indicates the need for O–ring replacement) or when leakage is found during coolant filter replacement. When the shut–off valve is in the "OFF" position and coolant leaks past the valve, this indicates the need for coolant shut–off valve sleeve replacement.

1. Remove the slotted spring pin (shut–off valve handle) from the valve.
2. Mount the header in a soft jawed vise and drive the shut–off valve out of the casting, from the pin end.

NOTE: The cup plug will pop out when the shut–off valve is driven out of the header. Discard the cup plug.

3. Remove the O–ring from the shut–off valve and discard.

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OIL COOLER AND COOLANT FILTER ASSEMBLY — Continued

COOLANT FILTER HEADER RECONDITIONING — Continued

4. Use a pick to remove the two rubber sealing sleeves which are located in the filter header casting above the shut–off valve. Discard the sleeves.
5. Visually inspect the shut–off valve for wear, replace as required.
6. Lubricate the O–ring, shut–off valve and sleeves prior to assembly into the header using NLGI #2 multi–purpose lithium grease.
7. Install new sleeves in the header and a new O–ring on the shut–off valve.
8. Press the valve into the header until the holes in the valve are aligned with the holes in the header (as viewed from the bottom of the header).
9. Press the spring pin into the shut–off valve shaft until the pin bottoms.

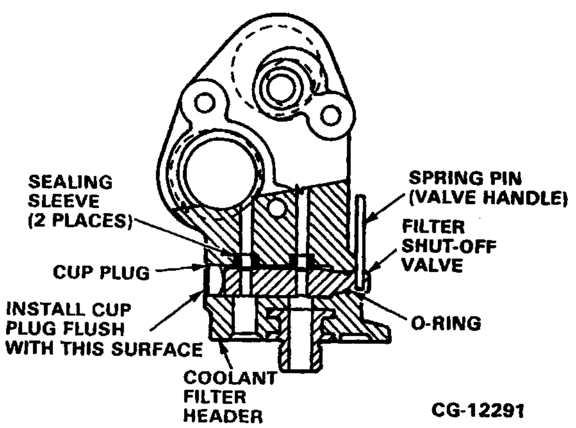

Figure 9.28. Coolant Filter Header Assembly

10. Install a new cup plug flush with the header casting surface.

CLEANING

1. Immerse the oil cooler into a suitable (non–caustic) cleaning solvent.
2. Shake the oil cooler vigorously, with it partially filled with cleaning solvent. Rinse the cooler with solvent repeatedly until the solvent which is drained comes out clear.
3. After cleaning and draining the cooler of solvent, blow out any remaining debris and solvent inside the oil cooler passages.

NOTE: <u>DO NOT</u> use wire brushes or steel scrapers for removing deposits.

INSPECTION AND REPAIR

NOTE: Replace the oil cooler after a catastrophic or hard–part failure of engine.

1. Construct two plates, as illustrated in **Figure 9.29**, one with a 1/4" NPT hole and one without.

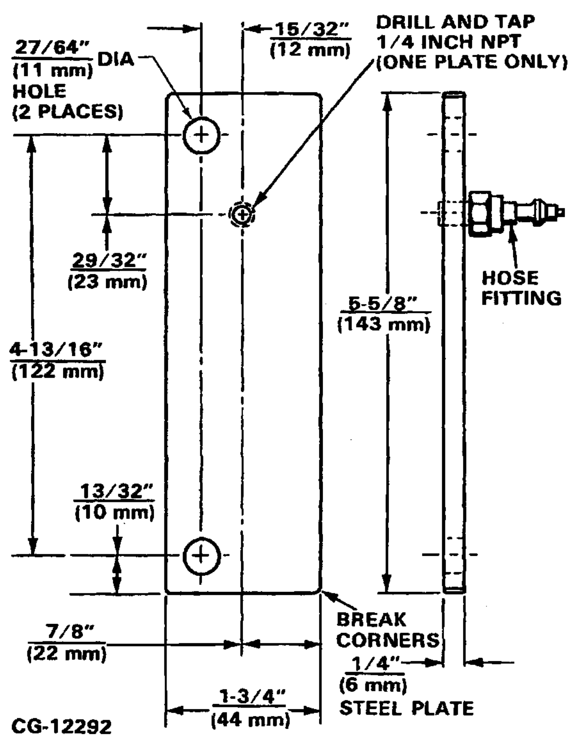

Figure 9.29. Pressure Plate Fabrication

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OIL COOLER AND COOLANT FILTER ASSEMBLY — Continued

INSPECTION AND REPAIR — Continued

CAUTION !

USE ADEQUATE SAFETY PRECAUTIONS WHEN PERFORMING THE FOLLOWING TEST.

2. Fasten the plates, using the old oil cooler gaskets, to the oil cooler.
3. Install a regulated air supply to the pressure plate fitting. Refer to **Figure 9.30**.
4. Immerse the assembly in a container of water, heated to 120°F (49°C).

NOTE: The heated water stabilizes the metal parts of the cooler.

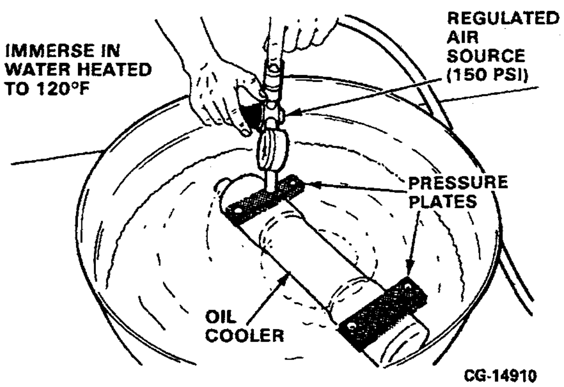

Figure 9.30. Oil Cooler Pressure Test for Leakage

5. Apply 150 psi (935 kPa) air pressure while immersed in the water tank.
6. Visually inspect the cooler for moving or growing bubbles after one minute.

NOTE: The oil cooler cannot be repaired. If bubbling is found, replace the oil cooler.

REASSEMBLY

1. Assemble the coolant filter header to the oil cooler as follows:
   a. Install new square cut seal rings (one large and one small) at the coolant filter header. Refer to **Figure 9.31**. Hold in place with grease.

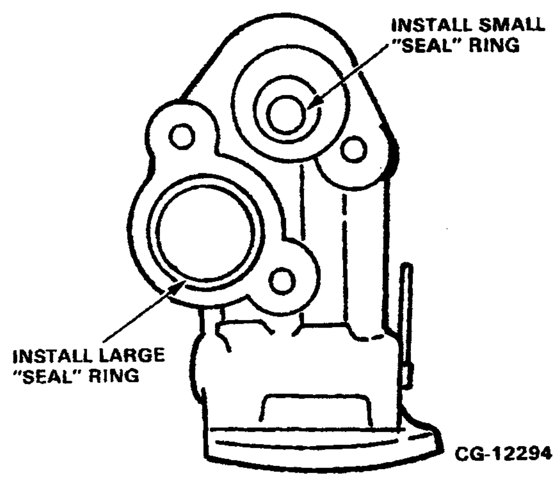

Figure 9.31. Coolant Filter Header Seal Ring Locations

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OIL COOLER AND COOLANT FILTER ASSEMBLY — Continued

REASSEMBLY — Continued

2. Fasten the coolant filter header to the oil cooler using the three "patch" bolts with hardened washers. Tighten to the standard torque. Refer to **Figure 9.32**.
3. Install new O–rings on the coolant filter header to front cover tubes. Refer to **Figure 9.4.**
4. Lubricate the O–rings and the front cover and header tube mating surfaces with a suitable grease.
5. Install the tubes into the header.

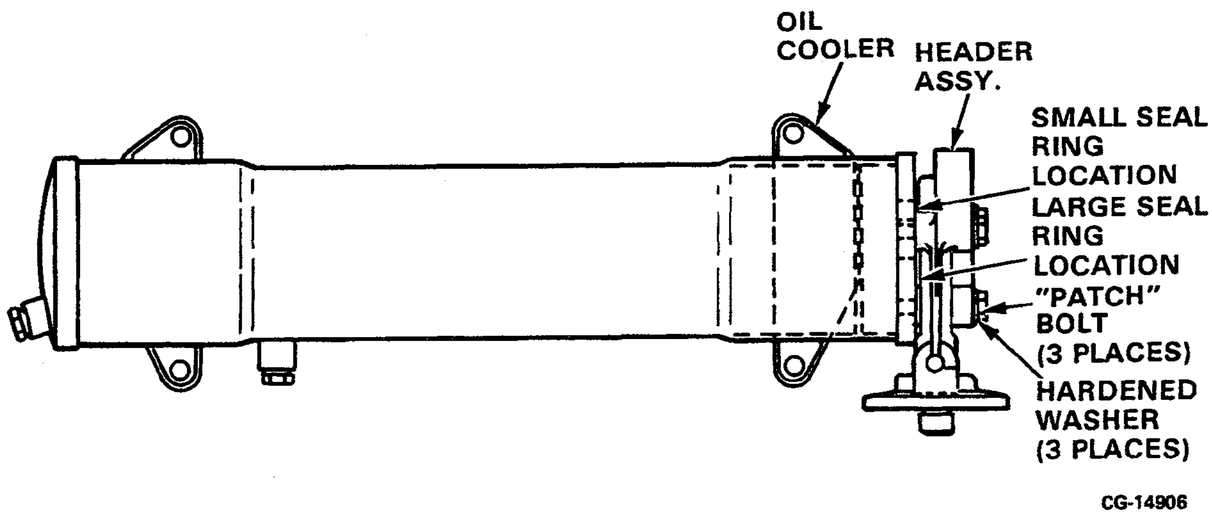

Figure 9.32. Coolant Filter Header to Oil Cooler Installation

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OIL COOLER AND COOLANT FILTER ASSEMBLY — Continued

REASSEMBLY — Continued

6. Using new gaskets, install the oil cooler and coolant filter assembly to the crankcase and front cover. Fasten the oil cooler to the crankcase using the special "patch" bolts and hardened washers to avoid leakage at the cooler. Tighten the bolts to the standard torque. (See Appendix.) Refer to **Figure 9.33.**

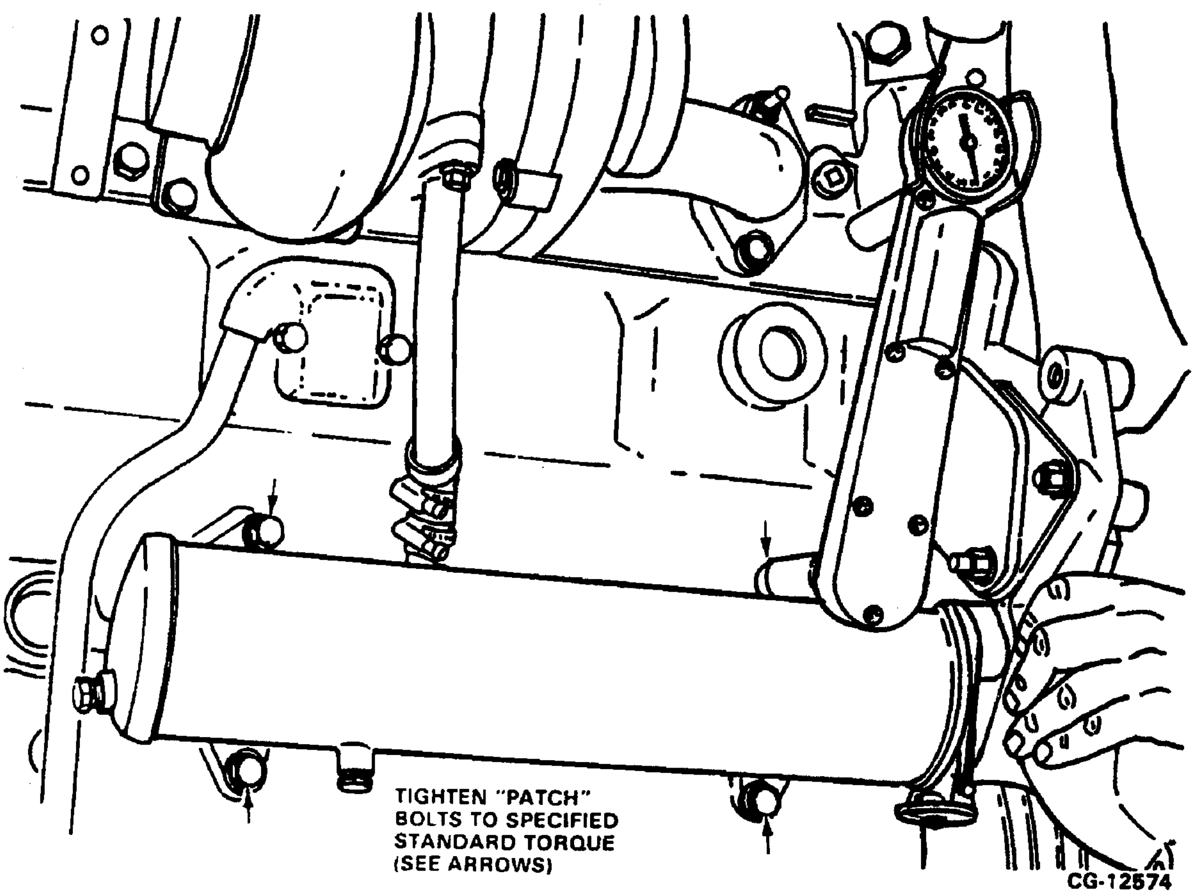

Figure 9.33. Install Oil Cooler and Coolant Filter Header (Early Style Oil Cooler Shown)

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OIL PRESSURE REGULATING VALVE (OPRV)

NEW DESIGN DESCRIPTION

1. The oil pressure regulating valve (OPRV) has been revised by adding two 0.042 in. dia. holes as shown in **Figure 9.34**. The new design allows oil to flow into the regulating valve spring chamber, displacing any air in the chamber. The oil filled chamber dampens the regulating valve operation, acting as a hydraulic damper for the valve. This improved design eliminates regulating valve "pounding".

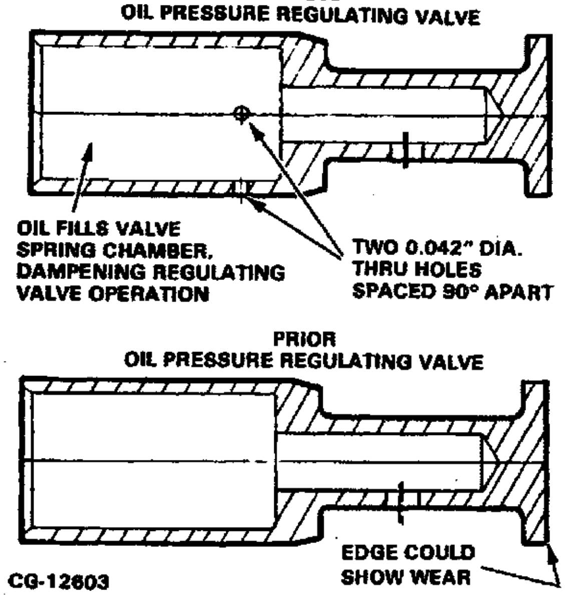

Figure 9.34. Oil Pressure Regulating Valve Design Comparison

IMPORTANT

THE REVISED OIL PRESSURE REGULATING VALVE ASSEMBLY IS SHOWN IN FIGURE 9.35. AN O-RING AND REGULATING VALVE CAP GASKET ARE FURNISHED WITH THE ASSEMBLY IN A SERVICE PACKAGE. THE OIL PRESSURE REGULATING VALVE ASSEMBLY IS NOT SERVICED SEPARATELY. REFER TO THE LATEST PARTS CATALOG WHEN ORDERING SERVICE PARTS.

NOTE: Late model production engines and all service use the revised design OPRV assembly (Figure 9.35.). When confronted with an OPRV or bearing failure, replace the OPRV with the revised design OPRV assembly.

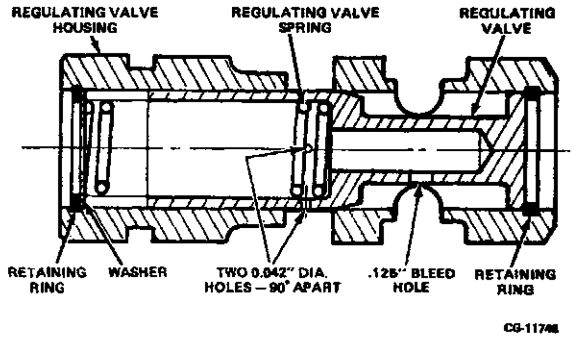

Figure 9.35. Revised Oil Pressure Regulating Valve Assembly

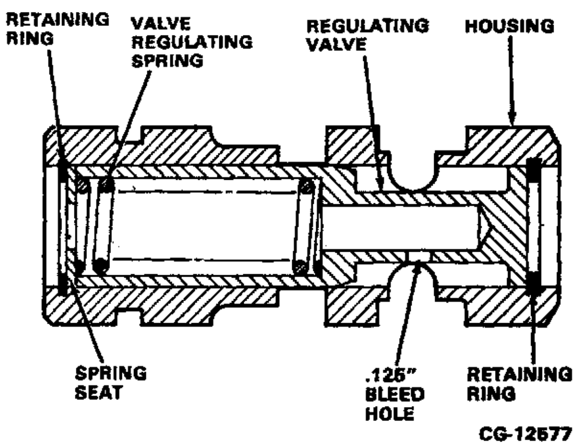

Figure 9.36. Prior Oil Pressure Regulating Valve Assembly

OIL PRESSURE REGULATING VALVE (OPRV) — Continued

REMOVAL

NOTE: Prior to removing the oil pressure regulating valve from the crankcase, the crankcase breather tube must be removed. Refer to Section 7.

1. Loosen and remove the oil pressure regulating cap. Refer to **Figure 9.37**.
2. Pull the regulating valve assembly out of the crankcase. Refer to **Figure 9.37**. Discard the cap gasket.

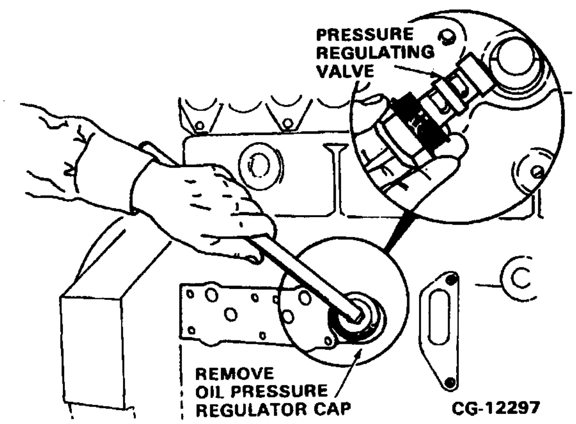

Figure 9.37. Remove Oil Pressure Regulating Valve

CLEANING

1. Clean with a suitable solvent.
2. Blow dry using filtered compressed air.

INSPECTION AND REPAIR

1. Move the regulating valve, by hand, to ensure it moves freely in the housing. Refer to **Figure 9.35 and 9.36.**
2. Place the OPRV assembly on a hard, flat surface. Using a wooden dowel, depress the valve plunger until it bottoms. While holding the plunger in position, insert a wire such as a paper clip, through the valve housing and valve as shown in **Figure 9.38.**

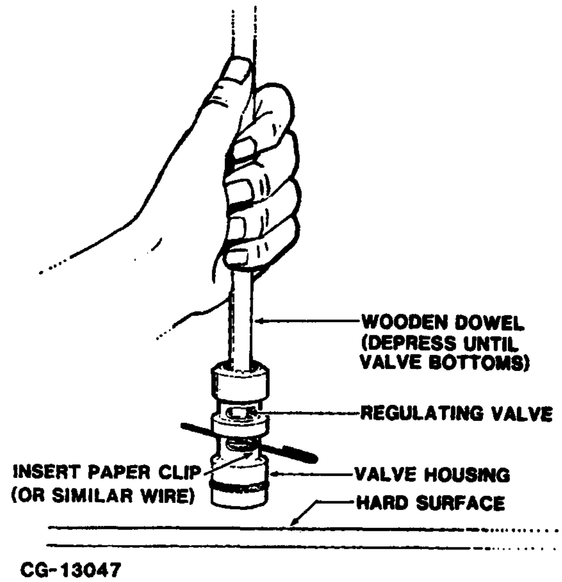

Figure 9.38. Positioning OPRV Assembly for Inspection

NOTE: The following inspections can be performed without oil pressure regulating valve disassembly.

3. Visually inspect the retaining ring, ring groove and front edge of the oil pressure regulating valve. If parts show the following, replace the OPRV assembly with the revised design. Refer to **Figure 9.39**.
   - Broken or missing retaining ring.
   - Loose retaining ring.
   - Distorted retaining ring groove.
   - A deep groove from the outline of the retaining ring on the regulating valve.
   - Valve distortion.
4. Replace the oil pressure regulating valve assembly if any of the conditions listed exist.

OIL PRESSURE REGULATING VALVE (OPRV) — Continued

INSPECTION AND REPAIR — Continued

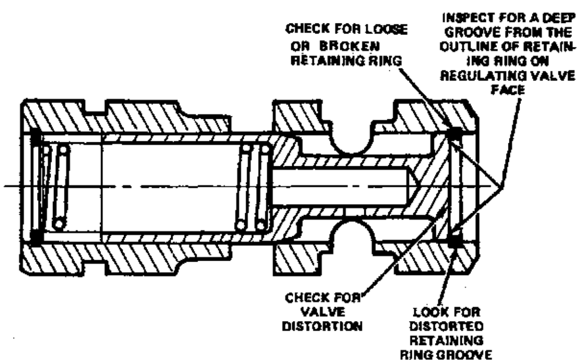

Figure 9.39. OPRV Assembly Inspection Check Points

IMPORTANT

IF THE OIL PRESSURE REGULATING VALVE HAS A BROKEN OR MISSING RETAINING RING, IT IS RECOMMENDED THAT THE ENGINE BEARINGS AND CRANKSHAFT BE INSPECTED FOR POSSIBLE DAMAGE.

5. If the OPRV assembly shows no signs of fatigue or wear, apply pressure to the valve plunger with a wooden dowel and remove the wire inserted in step 2.

REASSEMBLY

IMPORTANT

WHEN REPLACING THE OPRV ASSEMBLY OR REINSTALLING IT AFTER INSPECTION, ALWAYS INSTALL THE OPRV USING A NEW O-RING AND REGULATING VALVE CAP GASKET.

1. Insert the pressure regulating valve assembly into the crankcase. See **Figure 9.37 (Insert).**
2. Using a new regulating cap gasket, install the cap and tighten to the specified special torque. Refer to **Figure 9.40.**

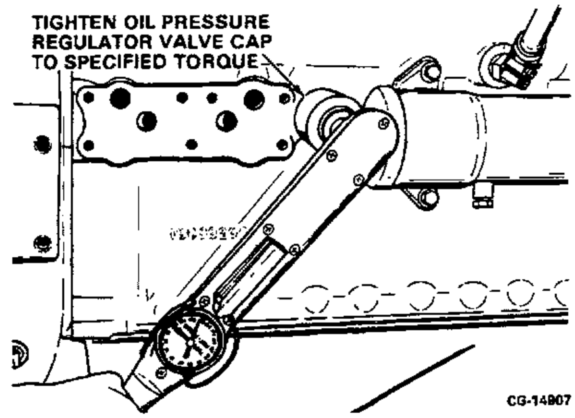

Figure 9.40. Install Oil Pressure Regulating Valve Assembly

OIL PICKUP TUBE

REMOVAL

Refer to Section 7 for removal instructions.

CLEANING

1. Clean the oil pickup tube assembly in a suitable solvent.
2. Dry using filtered compressed air.

INSPECTION AND REPAIR

Check the oil pickup tube for cracks (leakage) as follows:

1. Verify the oil pickup tube mounting bolt torque using the "Pull-Up-to-the-Mark Method" Refer to "SPECIFICATIONS".
2. Remove the oil cooler oil drain plug. Refer to **Figure 9.10.**
3. Install a 0–50 psi (0–350 kPa) air pressure gauge and air pressure regulator at the oil cooler oil drain location using the appropriate fittings.
4. Apply a 4 in. square by 1 in. thick foam rubber pad to seal off the oil pickup tube screen.
5. Connect an air supply to the regulating valve.

NOTE: Keep the air regulating valve closed when connecting the air supply hose to the regulator.

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OIL PICKUP TUBE

INSPECTION AND REPAIR — Continued

6. Gradually open the regulating valve and apply 20–30 psi (140–2O5 kPa) at the air gauge (mounted at the outlet of the air regulating valve) to maintain 3 to 5 psi (20–33 kPa) air pressure in the pipe.
7. Check the oil pickup tube using a soap solution at the following locations: (Look for bubbles.) (Refer to **Figure 9.41**)
   a. Tube — Check for cracks.
   b. Housing w/Inlet Screen — Check seams and brazed connection to tube.
   c. Support Bracket — Check for leaks where the bracket is brazed to the tube.
   d. Mounting Flange Elbow — Check where the mounting flange is brazed to the pickup tube.
   e. Mounting Flange Mating Surface — Check the mounting flange to the front cover mating surfaces.

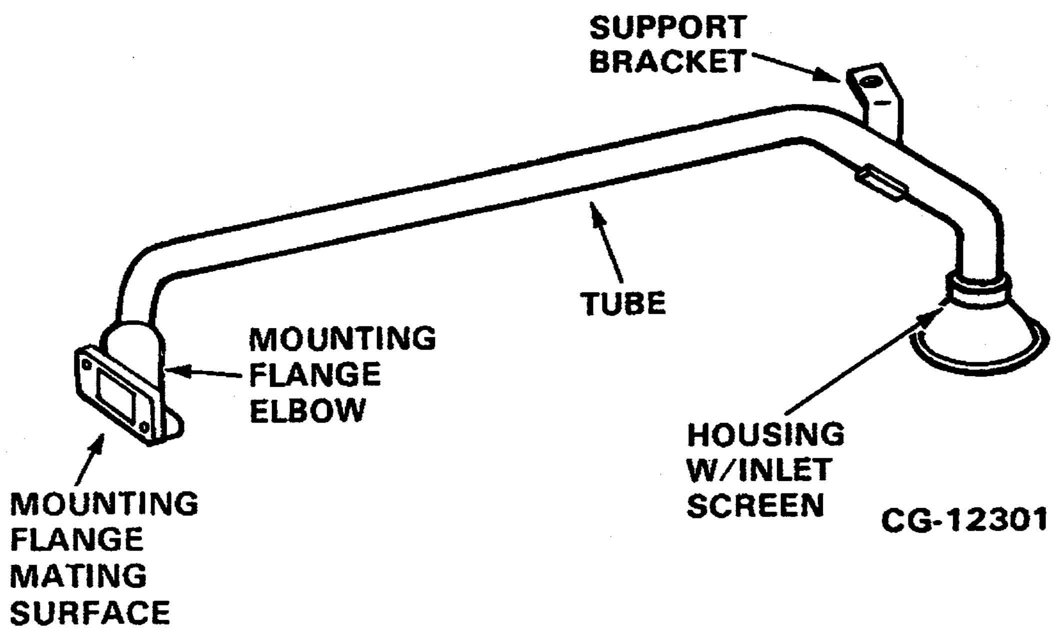

Figure 9.41. Oil Pump Pickup Tube Leak Check Areas

8. If leakage is found at the tube, housing with inlet screen, support bracket or mounting flange elbow, replace the oil pickup tube assembly.
9. If leakage is found at the mounting flange mating surface, remove the assembly and investigate the cause. Check for a damaged or missing gasket or damaged mounting flange mating surface.

NOTE: If the mounting flange mating surface is found to be damaged, replace the oil pickup tube assembly. Refer to Section 7 for installation instructions if the oil pickup tube must be replaced.

10. Remove the test gauge and reinstall the oil drain plug at the oil cooler.
11. Reinstall the oil pan using a new gasket. Refer to Section 7.
12. Install the vibration damper as described in Section 7.

SERVICE MANUAL

WATER PUMP AND THERMOSTAT

SECTION 10 INDEX

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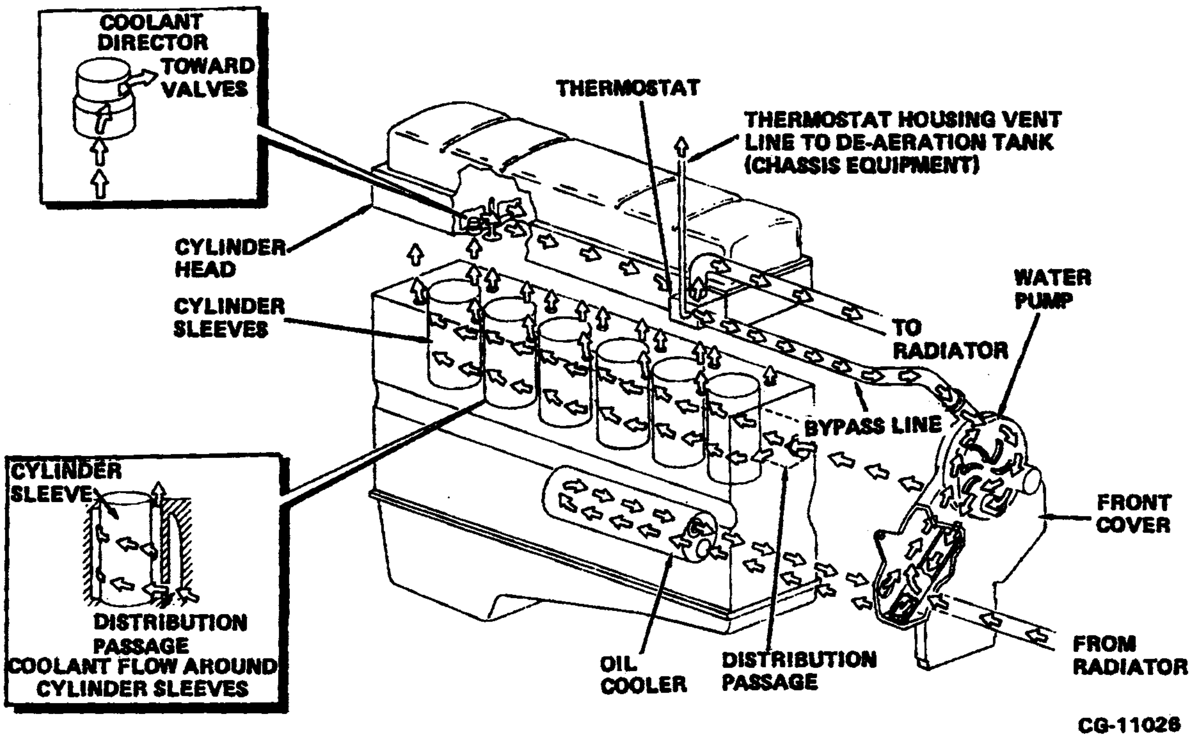

Figure 10.1. Engine Coolant Flow

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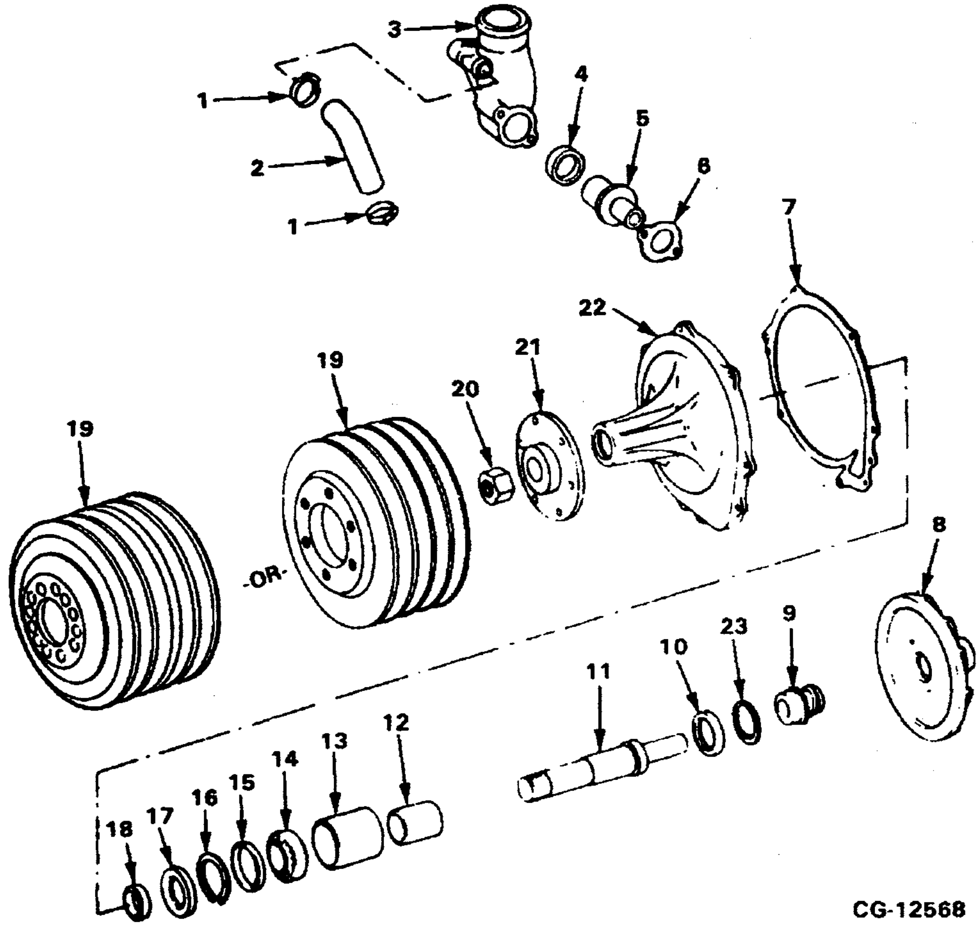

Figure 10.2. Water Pump, Thermostat and Related Parts

1. Hose Clamp
2. Hose, Thermostat Housing to Front Cover
3. Thermostat Housing
4. Thermostat Seal
5. Thermostat
6. Thermostat Gasket
7. Water Pump Housing Gasket
8. Impeller
9. Seal Assembly
10. Bearing Seal (Rear Grease)
11. Shaft
12. Inner Spacer
13. Outer Spacer
14. Bearing
15. Spacer, Retaining Ring
16. Retaining Ring
17. Bearing Seal (Front Grease)
18. Wear Sleeve
19. Pulley(Current Production — 4–Groove)
20. Nut
21. Hub
22. Pump Housing
23. O–Ring

SPECIFICATIONS

DIMENSION TITLE	VALUES	
WATER PUMP:		
Clearance between Housing and Back Face of Impeller	0.010 in. (0.25 mm) 0.046 in. (1.17 mm)	
Bearing End Play	0.0015 in. (0.038 mm) 0.0095 in. (0.241 mm)	
THERMOSTAT:		
Type	Poppet Valve, Pellet Operated	
Operating Temperature Range	Start to Open Temp.	Full Open Temp.
	180° F	202° F

SPECIAL TORQUES

Water Pump Hub Nut .... 150 lbf–ft. (203 Nm)

SPECIAL SERVICE TOOLS

Any special service tools required are to be made locally as specified in this section.

NOTE

Refer to Operations and Maintenance manual for Cooling System Specifications, Capacities and Maintenance Instructions.

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WATER PUMP

CHECK BEARING END PLAY

1. Verify end play by grasping the water pump pulley hub and moving the pulley back and forth.
2. If end play appears to be excessive, completely loosen all bolts and measure end play using a dial indicator.
3. If maximum end play exceeds the **"SPECIFICATIONS"**, repair or replace the assembly, as required. Refer to **"SPECIFICATIONS"**.

REMOVAL

1. Remove the six water pump pulley bolts and lock washers. Refer to **Figure 10.3**.

NOTE: Use a pry bar to keep the pulley from turning when loosening the pulley bolts.

2. Remove the pulley from the water pump hub.

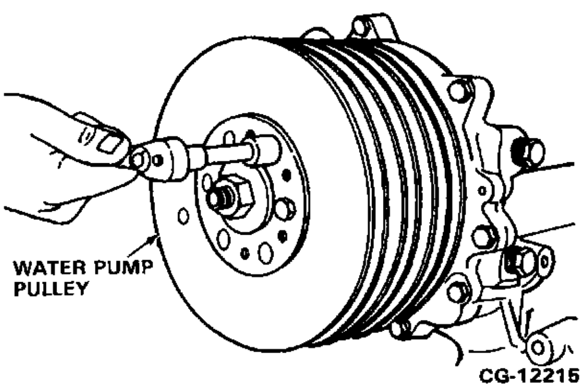

Figure 10.3. Remove the Water Pump Pulley Bolts (Six Groove Pulley Shown)

FOUR GROOVE FAN PULLEY

NOTE: A new 4 groove water pump pulley is released with the 1988 and later model years, replacing the 6 groove pulley which was used on the 1987 model year engines. The reduction in pulley grooves is a direct result of a simplified accessory drive which eliminates two accessory drive belts. Refer to Figure 10.4. for water pump pulley identification. DO <u>NOT</u> INTERMIX PULLEYS.

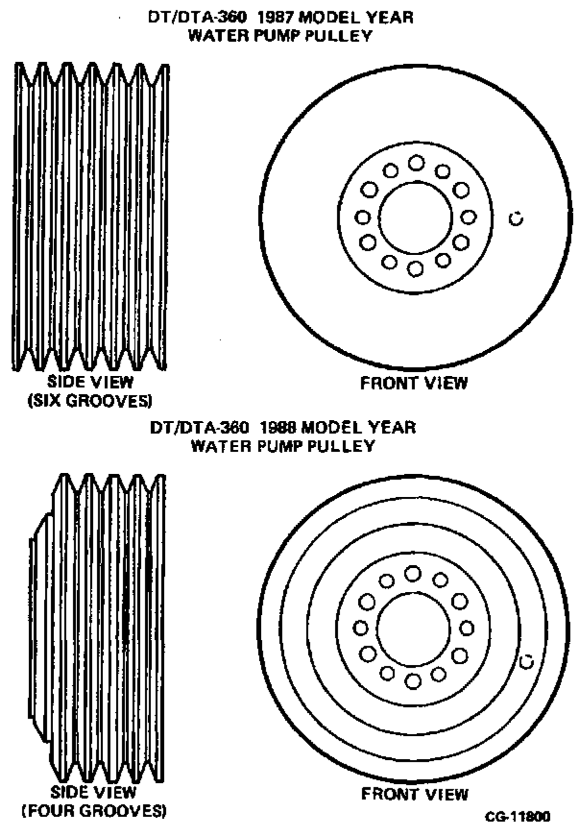

Figure 10.4. Water Pump Pulley Identification

WATER PUMP — Continued

REMOVAL — Continued

SHEET METAL FAN PULLEY

NOTE: Effective with S/N 059327 a three-piece spun sheet metal fan pulley arrangement (rather than one-piece cast iron) is used for production and service on all engines equipped with a four groove fan pulley. Those early engines equipped with a six groove fan pulley are still serviced with the six groove, one-piece cast iron pulley. Do not intermix pulleys on any engine, as belt groove center distances as well as pulley diameters are different. Refer to Parts Catalog for service item part numbers. Refer to Figure 10.5.

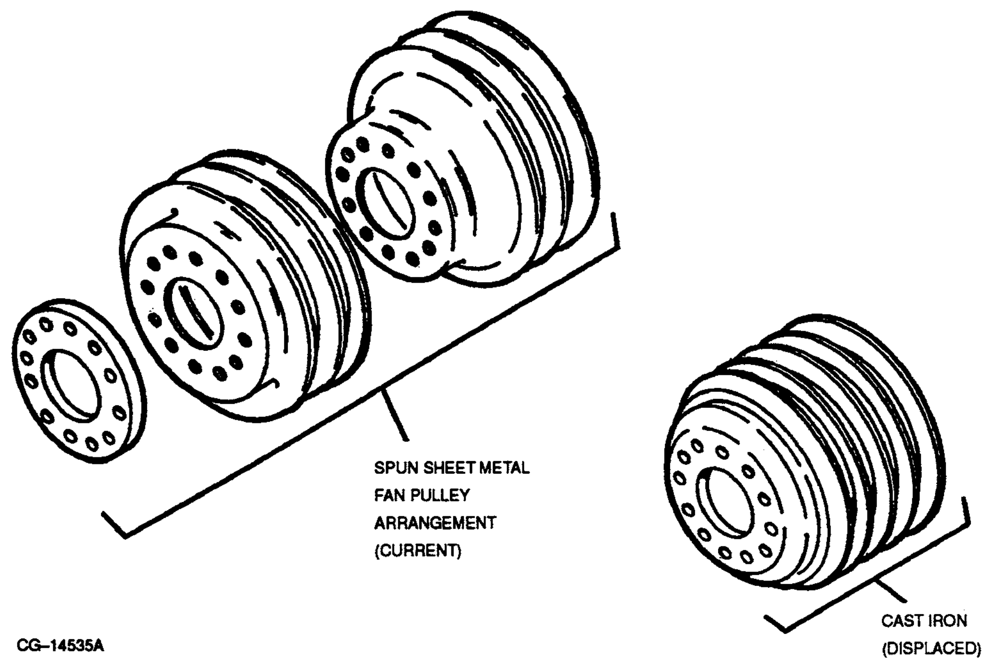

Figure 10.5. Fan Pulley Comparison

WATER PUMP — Continued

REMOVAL — Continued

3. Remove the bolts and washers which secure the water pump to the front cover. Refer to **Figure 10.6**.
4. Remove the water pump from the front cover. Discard the gasket.

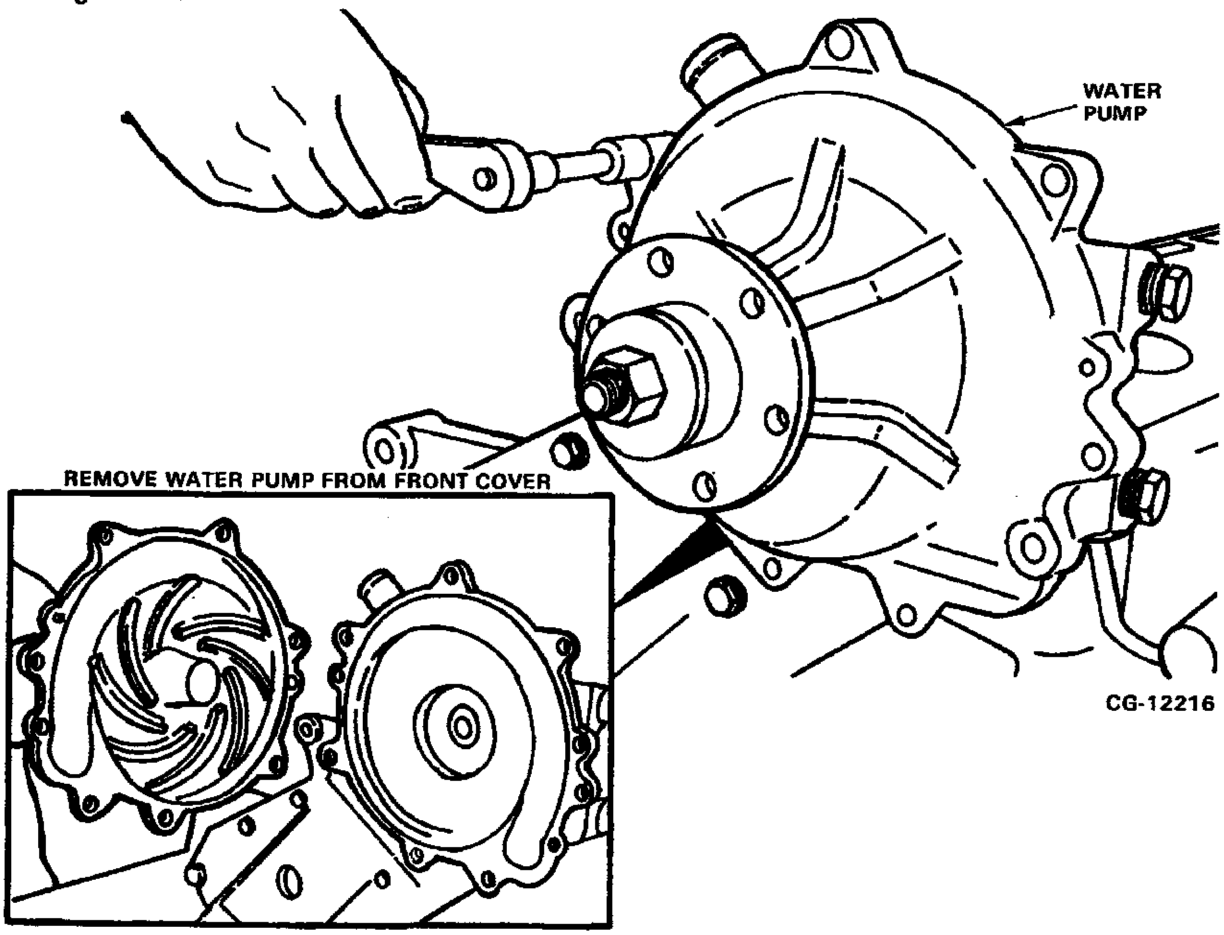

Figure 10.6. Remove Water Pump Mounting Bolts

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WATER PUMP — Continued

CLEANING

1. Scrape or wire brush the water pump and front cover gasket surfaces to remove all gasket material.
2. Clean the water pump surfaces using a suitable solvent and dry with filtered compressed air.

DISASSEMBLY

1. Remove the water pump impeller as follows:
   a. Mount the water pump in a vise.
   b. Install a suitable puller with the pulling jaws inserted into the 1/2 in. holes of the impeller and the forcing screw on the shaft. Refer to **Figure 10.7.**
   c. Turn the forcing screw to remove the impeller from the shaft.

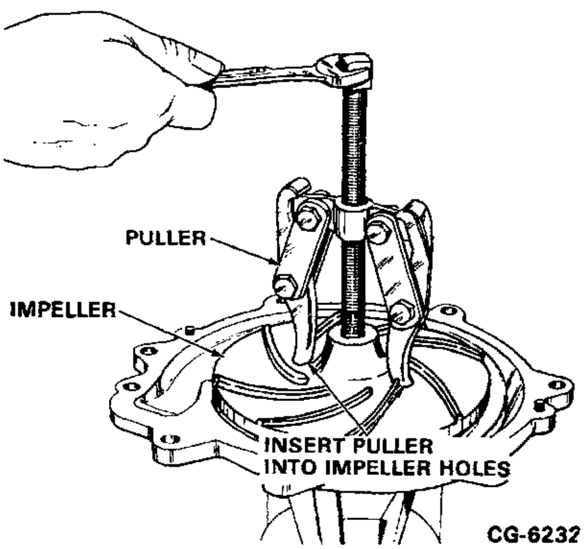

Figure 10.7. Remove Water Pump Impeller

   d. Remove the impeller from the housing to expose the water pump seal. Remove the seal from the shaft and discard. Refer to **Figure 10.8.**

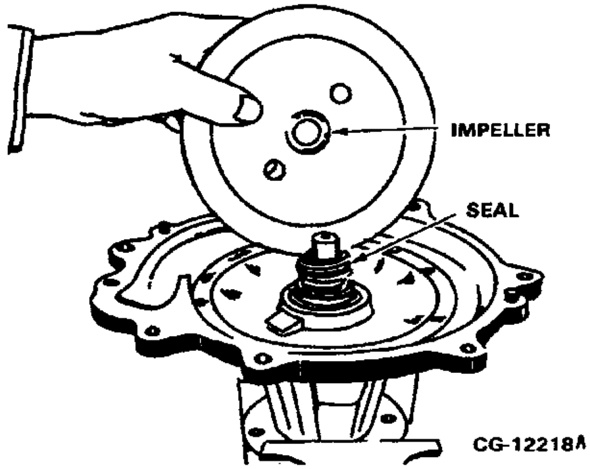

Figure 10.8. Remove Water Pump Seal

2. Remove the hub retaining nut and pulley hub. Refer to **Figure 10.9.**

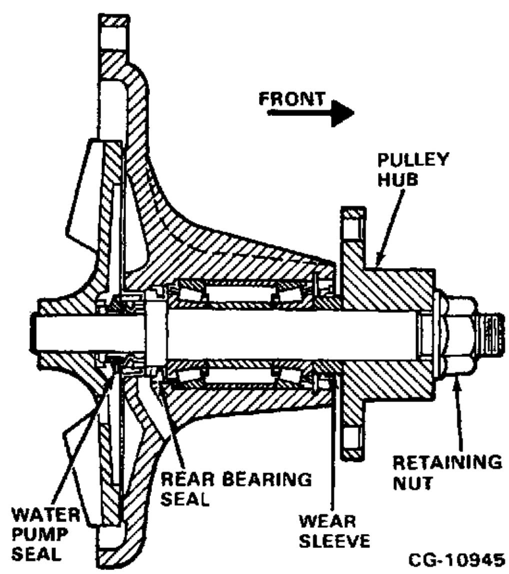

Figure 10.9. Water Pump Cross-Section

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WATER PUMP — Continued

DISASSEMBLY — Continued

3. Remove the front bearing seal and wear sleeve. Discard the bearing seal. Refer to **Figure 10.10**.

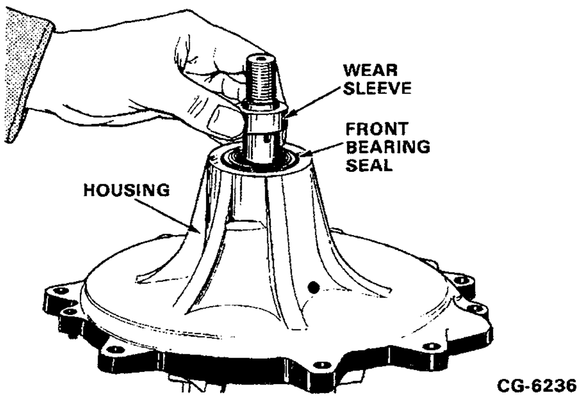

Figure 10.10. Remove Wear Sleeve and Front Bearing

4. Remove the retaining ring using a ring expander as shown in **Figure 10.11**.

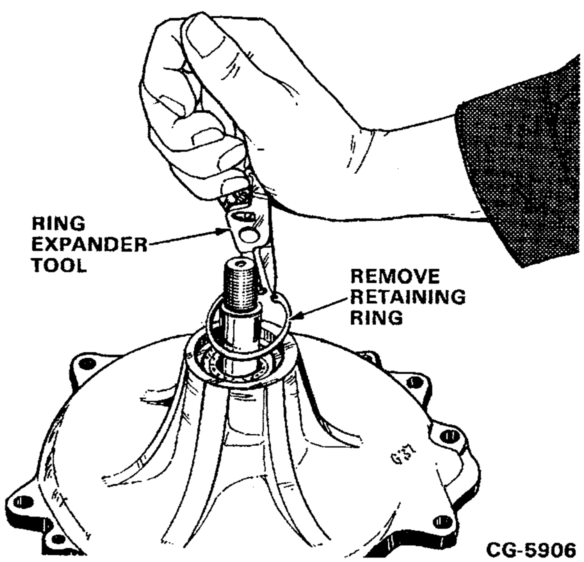

Figure 10.11. Remove Retaining Ring

5. Press out the shaft from the rear of the housing, as shown in **Figure 10.12**.

NOTE: The bearings and spacers will come out with the shaft. The bearings must be pressed from the shaft.

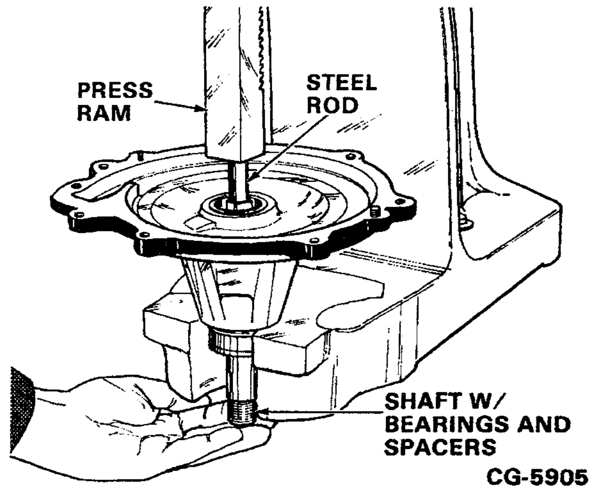

Figure 10.12. Press out Shaft and Bearings

6. Drive out (from the front of the housing) the metal part of the water pump seal. Refer to **Figure 10.10**. for component location. Discard the part.
7. Drive out (from the rear of the housing) the rear bearing seal and discard the part. Refer to **Figure 10.9**. for component location.

CLEANING (Water Pump Components)

1. Wash all parts thoroughly in a suitable solvent.
2. Dry with filtered compressed air.

INSPECTION

Inspect and repair the water pump as follows: (Reference numbers refer to **Figure 10.13**.)

1. Visually inspect the shaft wear sleeve (12) and spacers (7, 8, 9 and 15) for wear and corrosion. Replace as required.
2. Visually inspect the bearing housing (4) for wear or damage. Replace as necessary.

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WATER PUMP — Continued

INSPECTION — Continued

3. Inspect the impeller vanes (2) for erosion, nicks, burrs or roughness around the edges. Replace as required.

RECONDITIONING

4. When servicing the water pump, always replace the water pump seal (3), O–ring (16), bearing assembly (6), and front and rear bearing seals (5 and11).

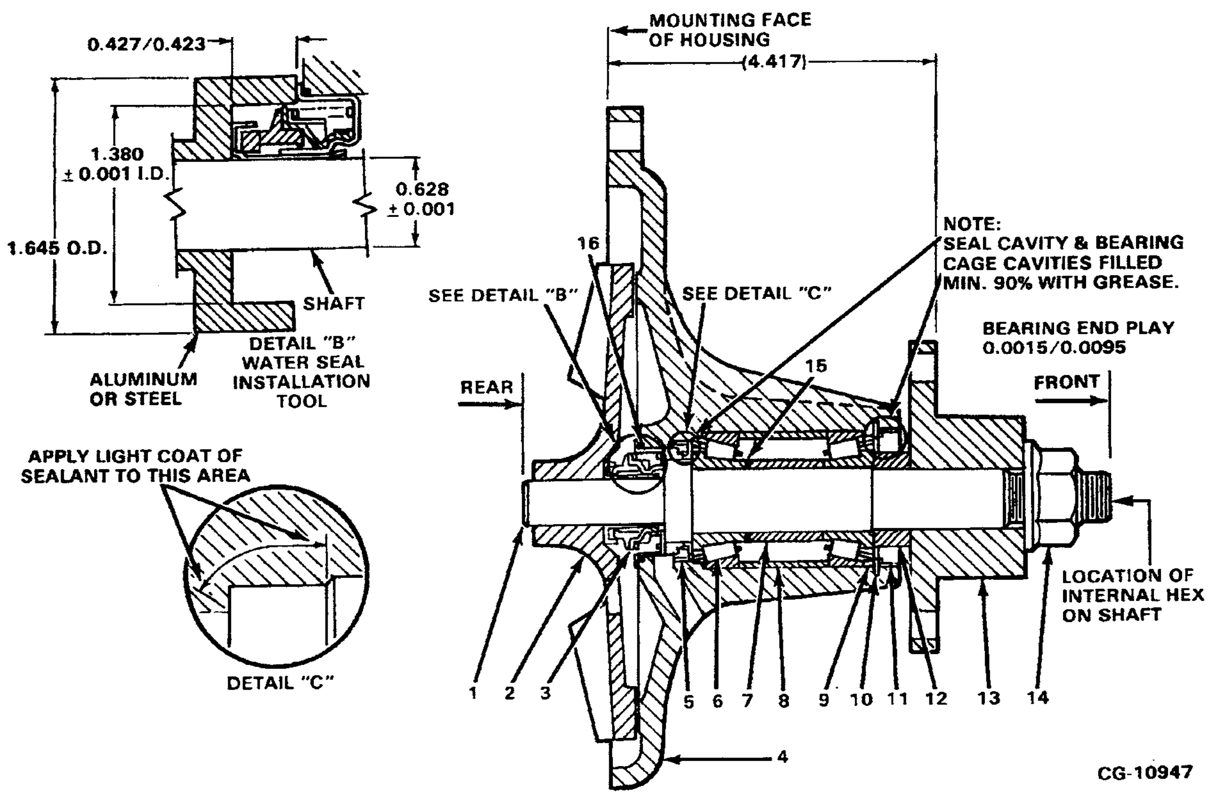

Figure 10.13. Cross Section of Water Pump

1. Shaft
2. Impeller
3. Water Pump Seal
4. Bearing Housing
5. Rear Bearing Seal
6. Bearing Assembly
7. Inner Spacer
8. Outer Spacer
9. Retaining Ring Spacer
10. Retaining Ring
11. Bearing Front Seal
12. Wear Sleeve
13. Pulley Hub
14. Flange Lock Nut (3/4–16 Hex.)
15. Spacer (Part of Item 6)
16. O–Ring

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WATER PUMP — Continued

RECONDITIONING — Continued

Reassembly

Reassemble the water pump as follows: (Reference numbers refer to **Figure 10.13.**)

IMPORTANT

A HIGH TEMPERATURE GREASE MUST BE USED DURING REASSEMBLY. THE GREASE SPECIFICATION (EMS B27–5004 TYPE 1) IS MET BY AMOCO'S RYKON PREMIUM GREASE NO. 2 COLOR RED AND MAY BE OBTAINED LOCALLY. IF A LOCAL DISTRIBUTOR CANNOT BE FOUND, CONTACT:

AMOCO OIL COMPANY
200 E. RANDOLPH DRIVE
CHICAGO, IL 60601
PHONE: (312) 856–5111

1. Apply a coat of Aviation Permatex™ No. 3 to the rear bearing seal (5). See Detail "C", **Figure 10.13.**
2. Pack the new rear seal (5) cavity full of grease.* Lubricate the rear seal O.D. and seal lip with grease.* Press the new rear seal into the housing (4).
3. Prepack the rear roller bearing inner race assembly with grease.* Support the shaft (1) at the impeller end and press the inner race assembly to bottom on the shoulder of the shaft.
4. Lightly lubricate the seal surface on the shaft (1) and the O.D. of the shaft installation sleeve with grease.* Install the shaft into the front of the pump with the installation sleeve. Refer to **Figure 10.14.**

IMPORTANT

FABRICATE THE SHAFT INSTALLATION SLEEVE LOCALLY AS SHOWN IN FIGURE 10.14. ALWAYS INSTALL THE SHAFT USING THE INSTALLATION SLEEVE.

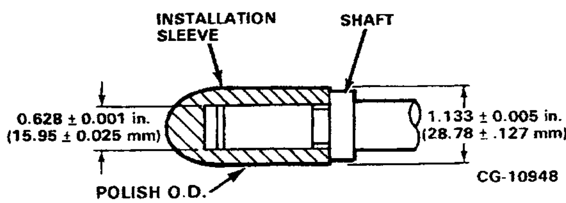

Figure 10.14. Shaft Installation Sleeve Fabrication

5. Remove the shaft installation sleeve.
6. Grease* the rear roller bearing (6) outer race and press into the housing (4) against the shoulder.
7. Install the outer spacer (8).
8. Press in outer race of the front bearing and make sure that outer bearing races and spacers are bottomed.
9. Install the spacers (7 and 15).
10. Fill in the cavity between the spacers with 0.6 oz. (17 cc) of grease.*
11. Prepack front roller bearing inner race assembly with grease.* Support shaft at impeller end and press inner race assembly until it bottoms on shaft.
12. Install the retaining ring spacer (9) and the retaining ring (10).
13. Pack the spring area of the front seal (11) full of grease* and lubricate the seal lip with grease.*

* Use Amoco Rykon Premium Grease No. 2 Color Red.

WATER PUMP — Continued

RECONDITIONING — Continued

Reassembly — Continued

14. Install the front seal (11) and the housing (4) against the retaining ring (10).
15. Lightly lubricate the seal surface of the wear sleeve (12).
16. Install the wear sleeve (12).
17. Install the pulley hub (13) onto the shaft (1).
18. Apply clean engine oil to the threads and install the flange lock nut (14). Tighten the shaft to the **"SPECIAL TORQUES"** by turning the internal hex at the end of the shaft, while holding the nut.
19. Install a new O–ring (16) on the water pump seal (3) and press into the bearing housing (4) using the water pump seal installation tool. (**See Detail "B", Figure 10.13.**)
20. Apply two small drops of Loctite™ 290 to the shaft/coolant seal joint. Space each drop 180° apart.
21. Support the shaft at the front end and push the housing down by hand.
22. Press the impeller onto the shaft supported on the front end as shown in **Figure 10.15**.

NOTE: Prior to full installation of the impeller, place two 0.028 in. (0.71 mm) feeler gauges under the impeller.

23. Verify impeller to housing clearance as follows:

IMPORTANT

USE A SLEEVE (FIGURE 10.14) UNDER THE PRESS RAM WHEN PRESSING ON THE IMPELLER BECAUSE THE SHAFT WILL PROTRUDE SLIGHTLY ABOVE THE IMPELLER.

a. With the feeler gauge in place, press the impeller until the feeler gauges are snug. Refer to **Figure 10.15**.

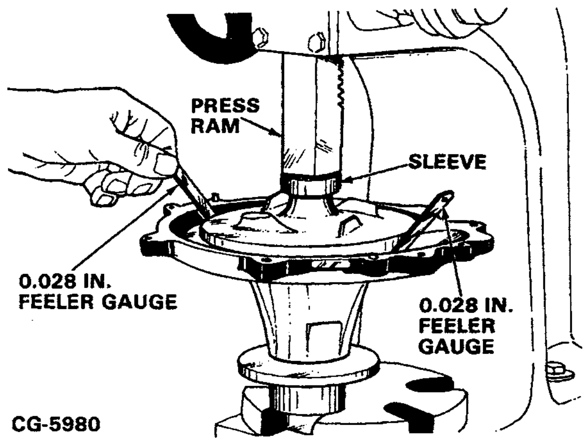

Figure 10.15. Press on Impeller and Check Impeller to Housing Clearance

b. Refer to the **"SPECIFICATIONS"** for impeller to housing clearance.

INSTALLATION

1. Using a new gasket, place the gasket over the water pump housing dowels. Refer to **Figure 10.16.**

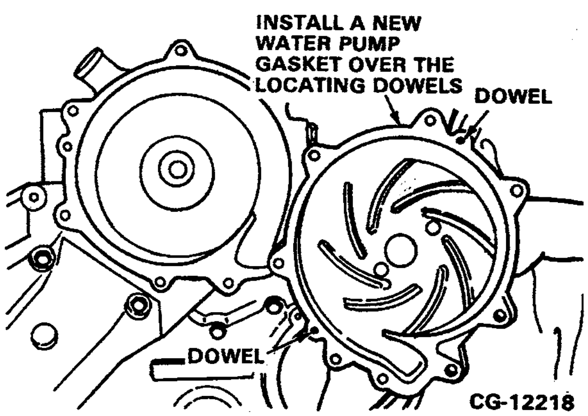

Figure 10.16. Align Gasket onto Water Pump Dowels

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WATER PUMP — Continued

INSTALLATION — Continued

2. Install the water pump to the front cover. Tighten the mounting bolts and washers to the specified standard torque. Refer to **Figure 10.17**.

NOTE: Be sure the water pump rotates freely after installation.

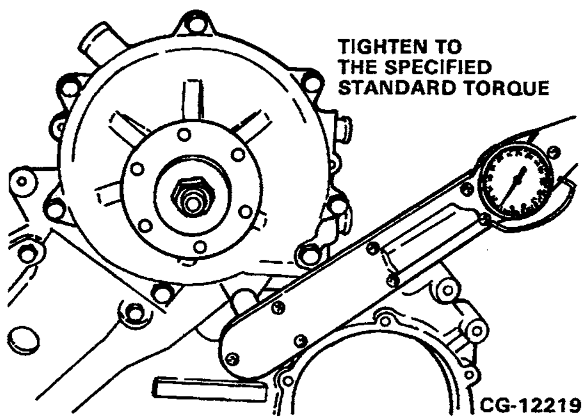


Figure 10.17. Install the Water Pump

3. Slide the water pump pulley over the water pump hub. Fasten the pulley to the hub using the six mounting bolts and washers. Refer to **Figure 10.18**.

NOTE: Tighten to the standard torque while using a pry bar to prevent pulley movement.

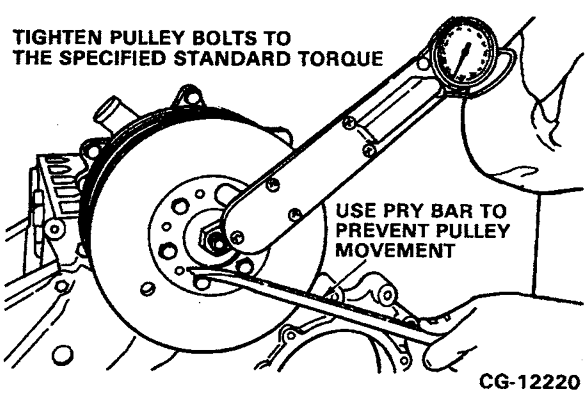


Figure 10.18. Install Water Pump Pulley (Six Groove Pulley Shown)

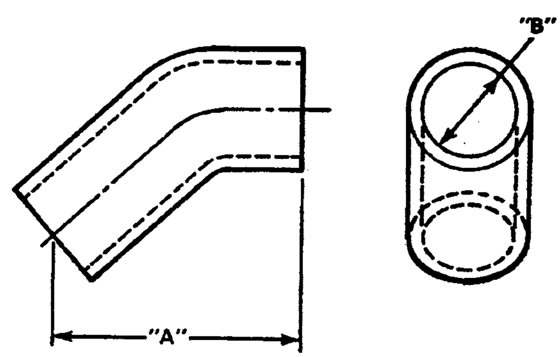
THERMOSTAT

COMPONENT CHANGES

Effective with Engine S/N 054459 changes were made to the cooling system to increase cab heat and engine warm–up. With the increased sized water pump by–pass inlet, as described in Section 8, is a change to the thermostat by–pass hose and housing.

Thermostat By–pass Hose

The thermostat by–pass hose has been increased in diameter and length. Refer to Engine Parts Catalog for the proper number for service as the hoses do NOT interchange. Refer to **Figure 10.19** for dimensions.



		1987/88	1989 & UP
"A"	LENGTH	3.20"	3.65"
"B"	INSIDE DIAMETER	1.19"	1.36"

CG-14472

Figure 10.19. Thermostat By–Pass Hose Comparison

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THERMOSTAT—Continued

COMPONENT CHANGES

Thermostat Housing

Changes to the thermostat housing are:
(Refer to **Figure 10.20**)

a. The water deaeration 1/8"–27 NPTF tapped hole and pipe plug located on top of the 1987/1988 model year's thermostat housing is relocated to the front side of the thermostat housing.

b. A new 1/2"–14 NPTF tapped hole and hex–plug replace the water deaeration 1/8"–27 NPTF tapped hole and plug on top of the thermostat housing. This new hole is used for additional sensor mountings.

c. The inside and outside diameters of the thermostat housing water pump by–pass hose inlet are increased to coincide with the enlargements to the water pump by–pass hose and crankcase front cover.

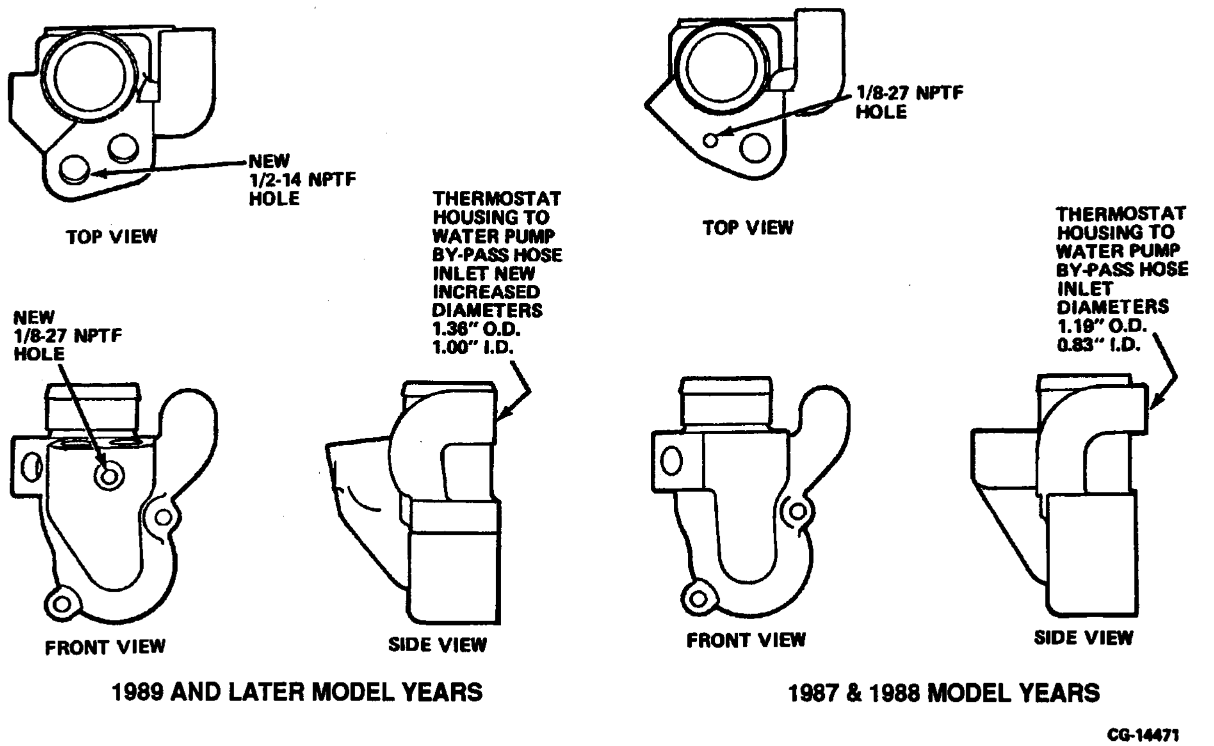

Figure 10.20. Thermostat Housing Comparison

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THERMOSTAT—Continued

OPERATION

The thermostat is used to direct coolant flow in the cooling system so engine coolant temperature may be controlled. The thermostat is located in a thermostat housing attached to the cylinder head. The housing is arranged to return coolant to the radiator or to bypass the radiator and direct coolant to the water pump.

In the cold position (thermostat closed), coolant from the engine is routed through the center of the thermostat and into the bypass passage where it is returned to the water pump. Refer to **Figure 10.21**.

When the coolant is at a temperature greater than 180°F (82°C), the thermostat starts to open, becoming fully open at 202°F (94°C). In the hot position (thermostat open), the thermostat port opens to allow coolant to flow to the radiator, at the same time the thermostat reduces flow through the bypass passage. Refer to **Figure 10.21**. A small amount of coolant always flows to the deaeration tank.

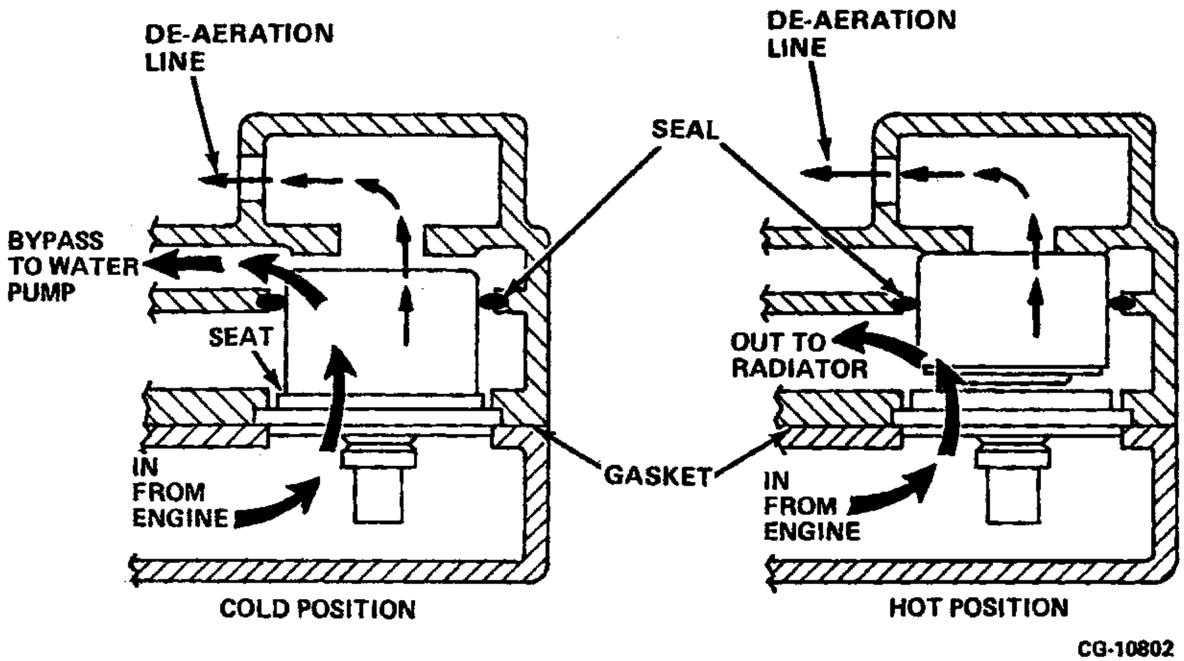

Figure 10.21. Thermostat Operation

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THERMOSTAT — Continued

REMOVAL

1. Loosen the worm clamp at the water outlet hose which connects to the front cover. Refer to **Figure 10.22.**
2. Loosen and remove the two thermostat housing bolts and washers which secure the housing to the cylinder head. Refer to **Figure 10.22.**

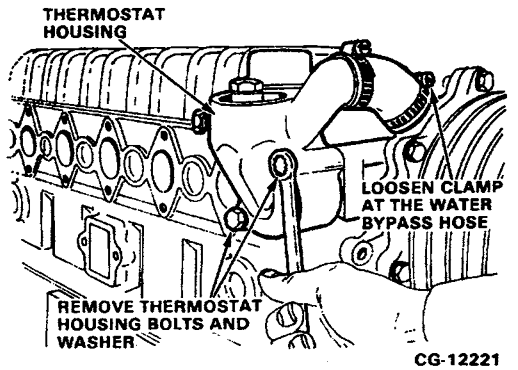

Figure 10.22. Remove Thermostat Housing Fasteners

3. Remove the thermostat housing and hose assembly to expose the thermostat. Remove the thermostat and gasket from the cylinder head. Discard the gasket. Refer to **Figure 10.23.**

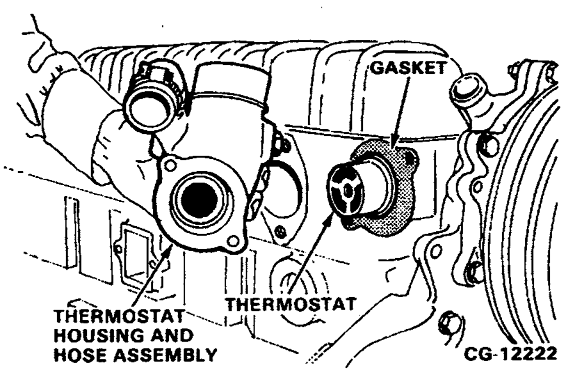

Figure 10.23. Remove Housing and Thermostat

CLEANING

1. Clean the thermostat housing and mating cylinder head gasket surfaces with a scraper.
2. Remove all old gasket material.
3. Wash the housing prior to inspection.
4. Dry with filtered compressed air.

INSPECTION AND REPAIR

1. Visually inspect the thermostat seal, located in the thermostat housing, for lip damage. Refer to **Figure 10.24.** for seal location.

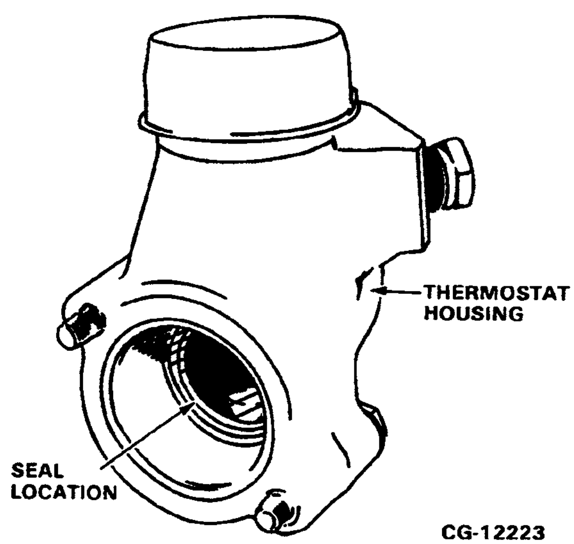

Figure 10.24. Inspect Thermostat Seal in Housing

2. Replace the seal, if required, as follows:
   a. Pry the damaged seal from the housing using a suitable pry bar.
   b. Install a new seal into the housing using a suitable disc, drift and hammer.

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THERMOSTAT — Continued

INSPECTION AND REPAIR — Continued

c. Install the seal flush as shown in **Figure 10.25**.

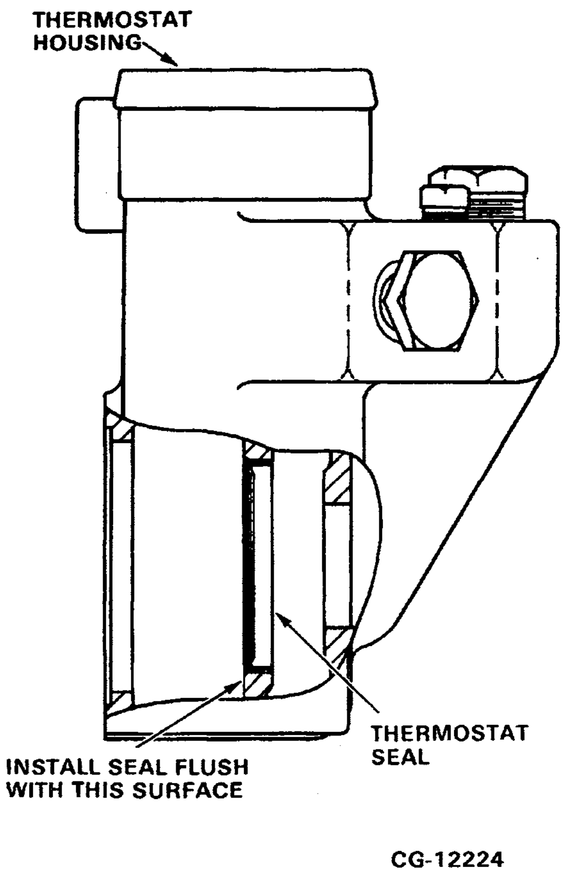

Figure 10.25. Thermostat Seal Installation

3. Visually inspect the thermostat for the following conditions, which may cause improper closure: Replace as required. (Refer to **Figure 10.26**.)

   - Debris or loose fit at seat.
   - Wrong seal location (look for witness mark).
   - Rough or uneven wear at the seal seat location.
   - Uneven seat.

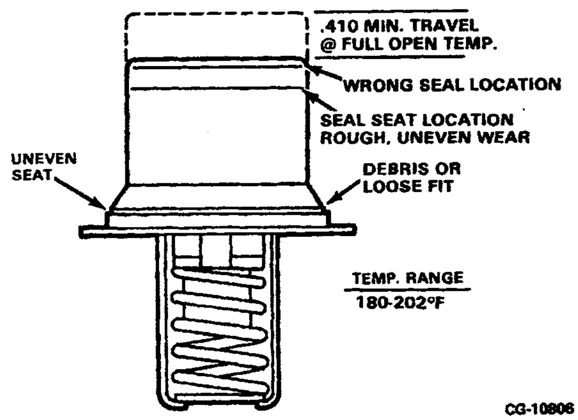

Figure 10.26. Visually Inspect Thermostat

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THERMOSTAT — Continued

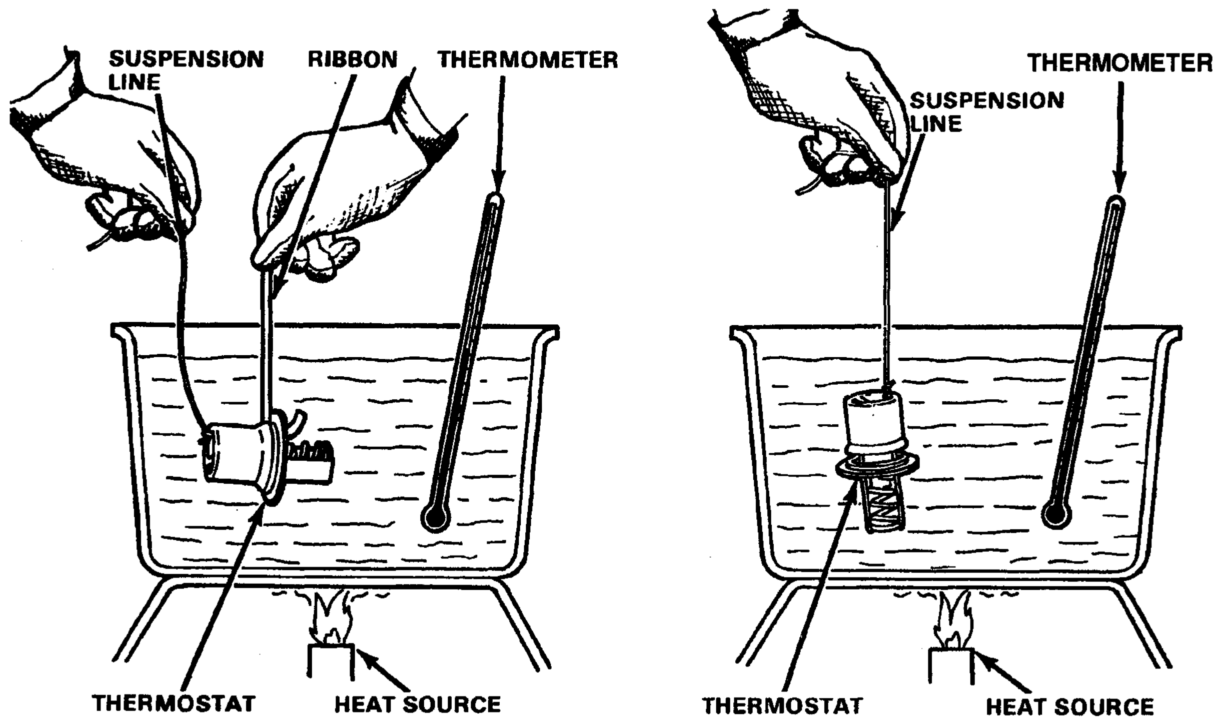
INSPECTION AND REPAIR — Continued

Check thermostat operation as follows: (Refer to **Figure 10.27.**)

CAUTION !

Exercise caution and good judgment to avoid injury when dealing with hot water and objects during the thermostat operation check. Use heat resistant gloves and wear appropriate eye protection.

1. Manually open the thermostat enough to insert a nylon ribbon under the thermostat seat. Suspend the thermostat in the container so that the thermostat does not touch the bottom of the container.
2. Heat the container filled with water to the "Start–to–Open" temperature of 180°F. Observe the thermometer and record the temperature as soon as the thermostat drops from the nylon ribbon. THIS READING IS THE "START–TO–OPEN" TEMPERATURE.
3. Continue to heat the water to the "Full–Open" temperature of 202°F. Observe the thermometer and the movement of the thermostat sleeve. Observe the thermostat sleeve movement when "Full–Open" temperature is achieved. Minimum sleeve travel at "Full–Open" temperature is .410 in.
4. While the sleeve is off of the seat, inspect the seat area for pitting and foreign deposits. Remove the thermostat from the water.
5. Replace the thermostat if it does not operate as described above.



"START TO OPEN" TEMPERATURE (RIBBON TEST)

"FULL OPEN" TEMPERATURE (MINIMU M SLEEVE TRAVEL TEST)

CG-10846

Figure 10.27. Thermostat Functional Test

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THERMOSTAT — Continued

INSTALLATION

1. Install the thermostat into the thermostat housing and place a new gasket onto the housing. Refer to **Figure 10.28**.

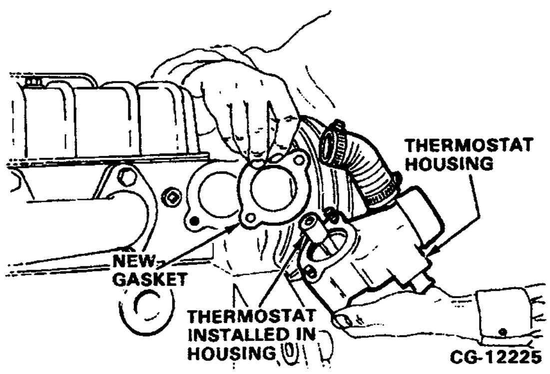

Figure 10.28. Assemble the Thermostat and Housing

2. Attach the thermostat housing to the cylinder head using the two bolts and washers. Connect the hose to the front cover. Refer to **Figure 10.29**.

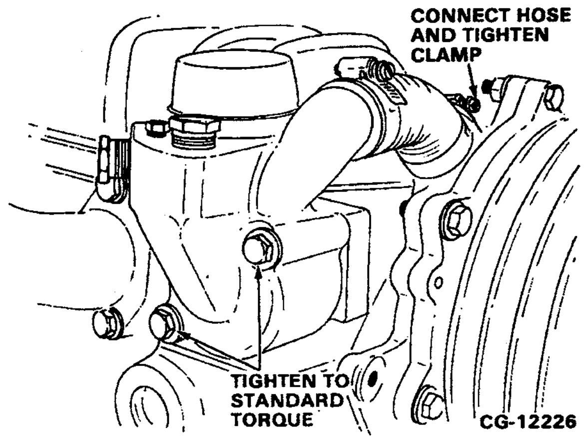

Figure 10.29. Install the Thermostat and Housing

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SERVICE MANUAL

FUEL INJECTION PUMP

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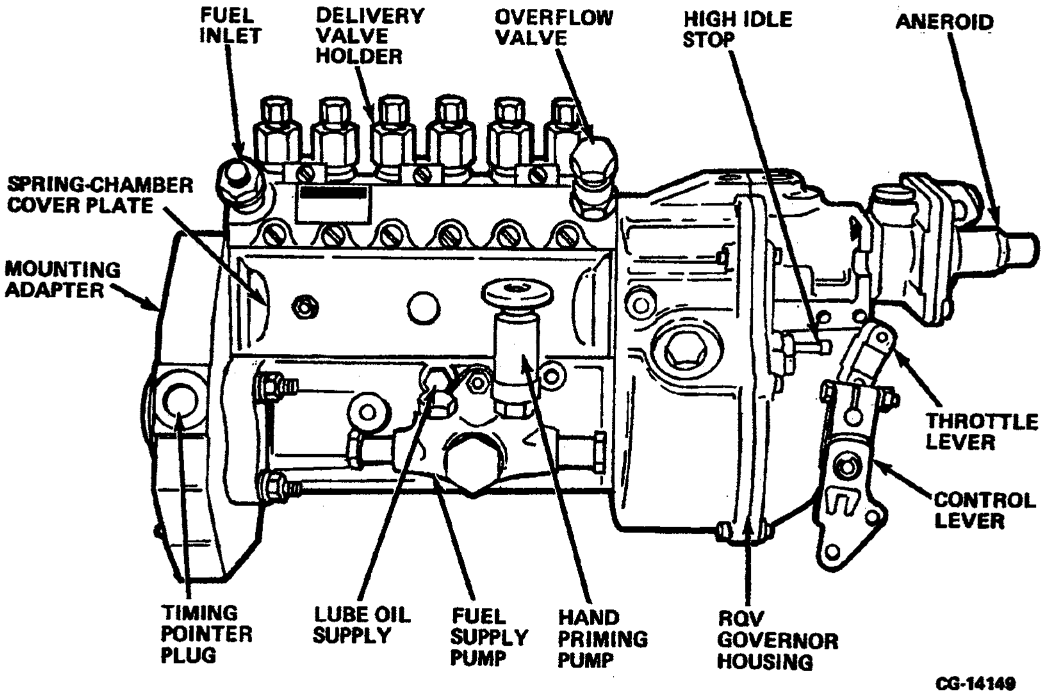

Figure 11.1. Fuel Injection Pump (Model PES–6A)

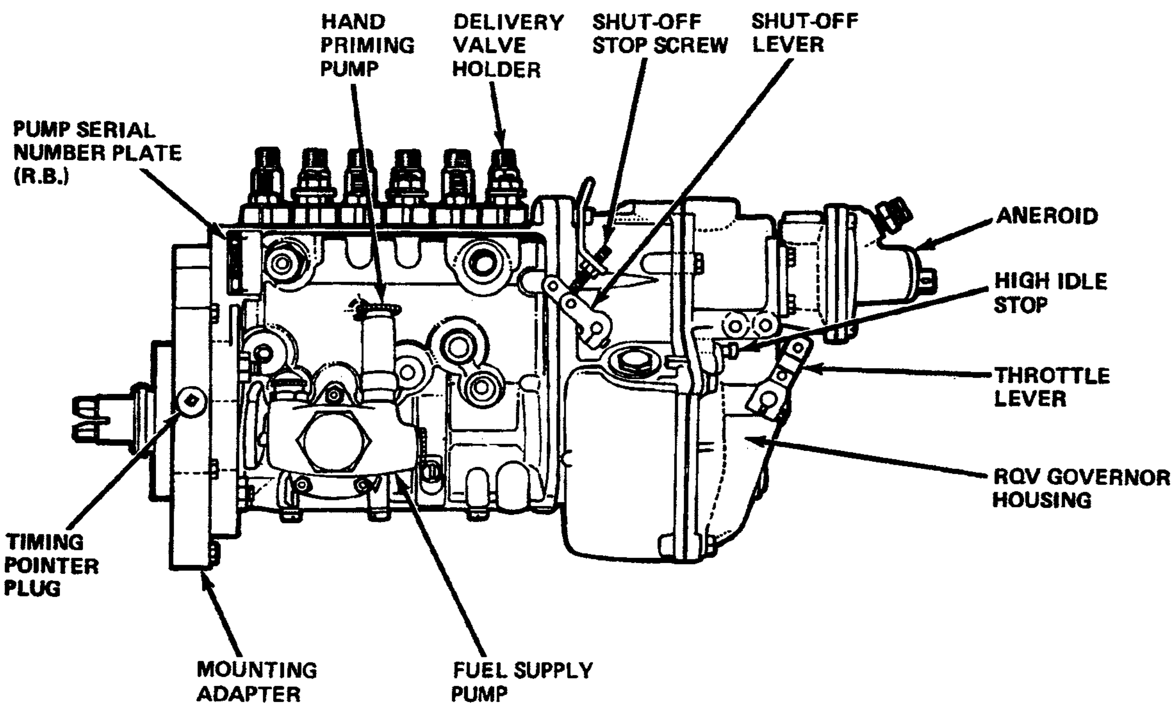

Figure 11.2. Fuel Injection Pump (Model MW)

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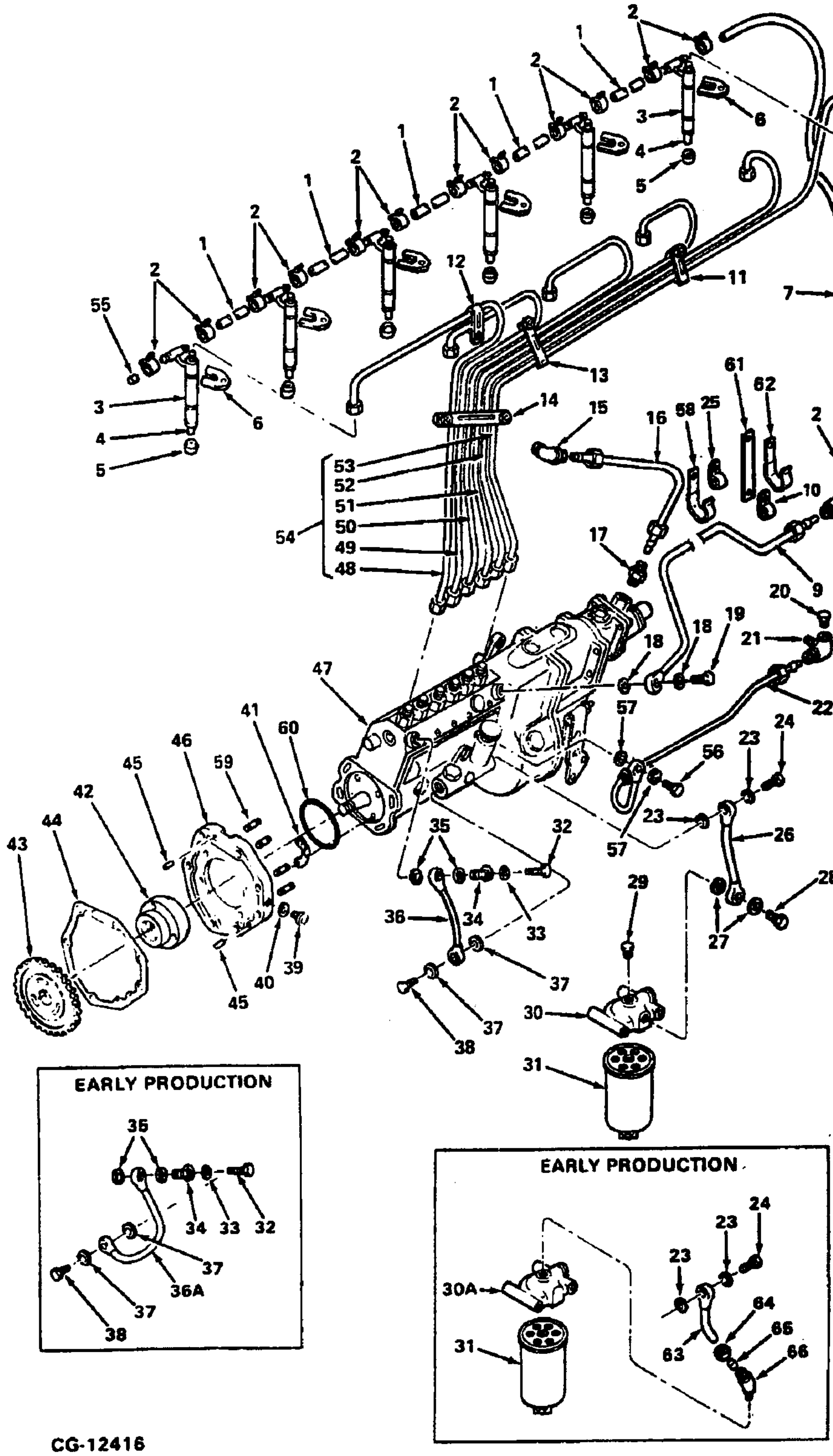

Figure 11.3. Typical Fuel Injection Pump Piping, Nozzles, Drive and Fuel Filter Header (1987/1988 Model Year Engines Shown w/ PES 6A Pump and Suction Side Filtering)

Legend for Figure 11.3

(1987/1988 Model Year Engines Shown)

1. Hose, Fuel Return
2. Clip, Fuel Return Hose
3. Nozzle Assembly
4. Nozzle Tip
5. Grommet, Dust Seal
6. Crab, Injector Nozzle
7. Hose, Fuel Return
8. Tee, Fuel Leak–Off
9. Tube Assembly, Fuel Return
10. Clamp, Fuel Return Tube
11. Clamp Assembly (3 Pipes)
12. Clamp Assembly (2 Pipes)
13. Clamp Assembly (5 Pipes)
14. Clamp Assembly (6 Pipes)
15. Elbow, Aneroid Tube
16. Tube, Aneroid
17. Connector, Tube
18. Washer, Overflow Valve
19. Screw, Hollow
20. Plug, 1/8–27 Pipe
21. Elbow, Injection Pump Lube Oil
22. Tube, Injection Pump Lube Oil
23. Gasket, Supply Pump Hollow Screw
24. Screw, Supply Pump Hollow
25. Clamp, Fuel Return Tube
26. Hose, Fuel Filter to Injection Pump (Current Production)
27. Washer, Fuel Filter Hose Fitting (Current Production)
28. Screw, Fuel Filter Hose Fitting (Current Production)
29. Plug, Pipe (Current Production)
30. Header, Fuel Filter (Current Production)

30A. Header, Fuel Filter (Early Production)

31. Filter, Fuel
32. Screw, Fuel Inlet Fitting Bleed
33. Gasket, Bleed Screw
34. Screw, Fuel Inlet Fitting Hollow
35. Gasket, Fuel Inlet Fitting Hollow Screw
36. Hose, Fuel Inlet (Current Production)

36A. Tube, Fuel Inlet (Early Production)

37. Gasket, Supply Pump Hollow Screw
38. Screw, Fuel Supply Pump Hollow
39. Plug, 3/4–16, Pump Adapter
40. Gasket, Pump Adapter Plug
41. Pointer, Timing
42. Hub, Injection Pump Gear
43. Gear, Injection Pump
44. Gasket, Injection Pump Mounting Adapter
45. Pin, Special Hardened Dowel
46. Adapter, Injection Pump Mounting
47. Pump Assembly, Fuel Injection
48. Pipe, Injection (# 1 Cylinder)
49. Pipe, Injection (#2 Cylinder)
50. Pipe, Injection (#3 Cylinder)
51. Pipe, Injection (#4 Cylinder)
52. Pipe, Injection (#5 Cylinder)
53. Pipe, Injection (#6 Cylinder)
54. Pipe Assembly, Fuel Injection
55. Cap, Fuel Return
56. Screw, Injection Pump Lube Oil Line Hollow
57. Washer, Injection Pump Lube Oil Line Hollow
58. Clip, Open
59. Stud Bolts, Injection Mounting
60. O–Ring, Injection Pump Mounting Adapter
61. Extension Clamp
62. Clip, Open
63. Tube, Fuel Filter to Injection Pump (Early Production)
64. Nut, Fuel Tube Fitting (Early Production)
65. Sleeve, Fuel Tube (Early Production)
66. Elbow, Fuel Filter Header (Early Production)

NOTE: Location of Clamp Assemblies, Quantity of Pipes held by Clamp Assemblies, Length and Diameter of Injection Pipes may vary between Model Years. Refer to Parts Catalog for Correct Service Parts.

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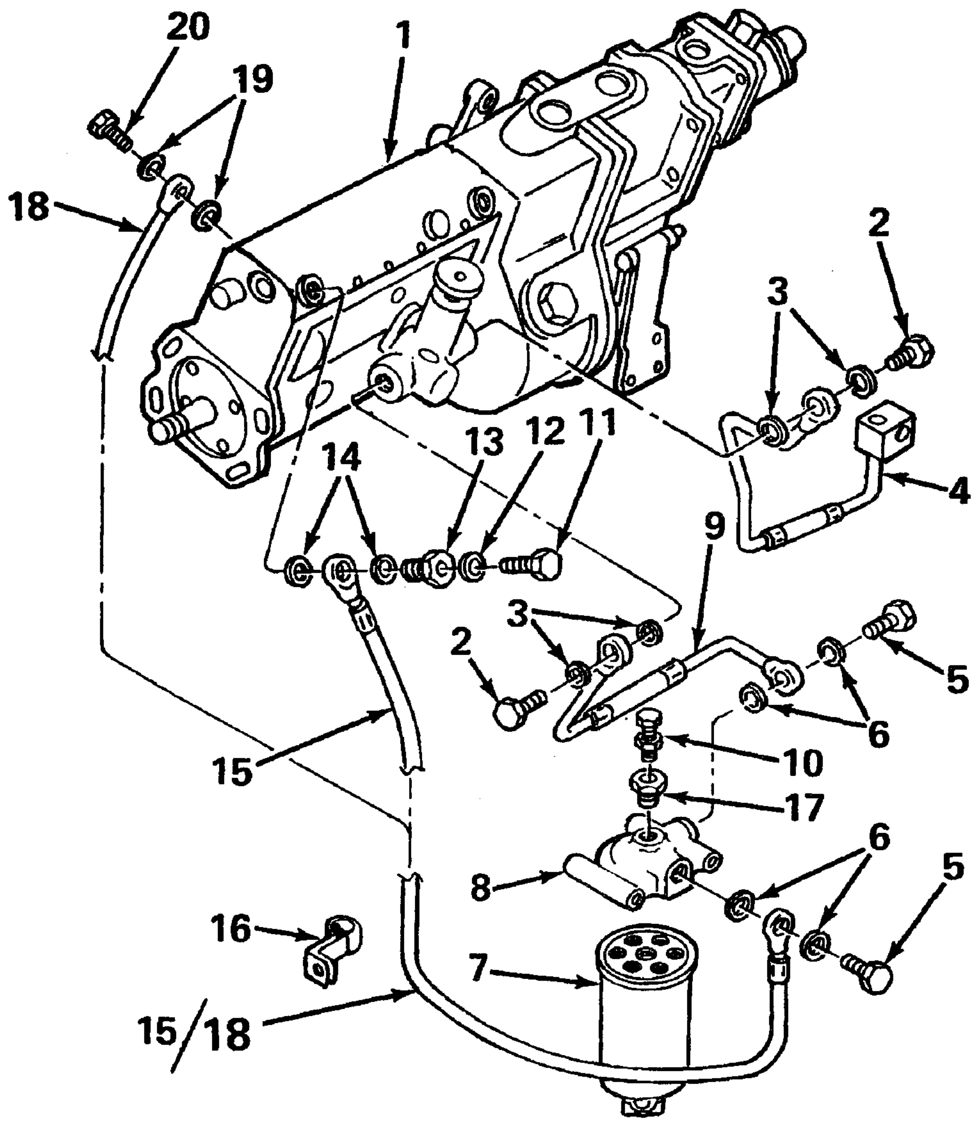

Figure 11.4. Typical Fuel Filter and Injection Pump Piping w/ Pressure Side Filtering (Model A or MW Injection Pump)

1. Pump Assembly, Fuel Injection
2. Screw, Hollow
3. Gasket, Supply Pump Hollow Screw
4. Tube and Hose, Fuel Inlet
5. Screw, Hollow
6. Gasket, Fuel Filter Hollow Screw
7. Filter, Fuel
8. Header, Fuel Filter
9. Tube and Hose, Supply Pump to Fuel Filter
10. Plug (Model A Pump)
10. Valve, Filter Bleed (Model MW Pump)
11. Screw, Hollow(Model A Pump)
12. Gasket, Bleed Screw (Model A Pump)
13. Screw w/Bleed, Fuel Inlet (Model A Pump)
14. Gasket, Fuel Inlet Fitting (Model A Pump)
15. Hose, Fuel Filter to Inj Pump(Model A Pump)
16. Clamp, Filter to Inj Pump Hose
17. Bushing, Reducer (Model MW Pump)
18. Tube and Hose, Fuel Filter to Inj Pump (Model MW Pump)
19. Gasket, Fuel Inlet Fitting (Model MW Pump)
20. Screw, Hollow (Model MW Pump)

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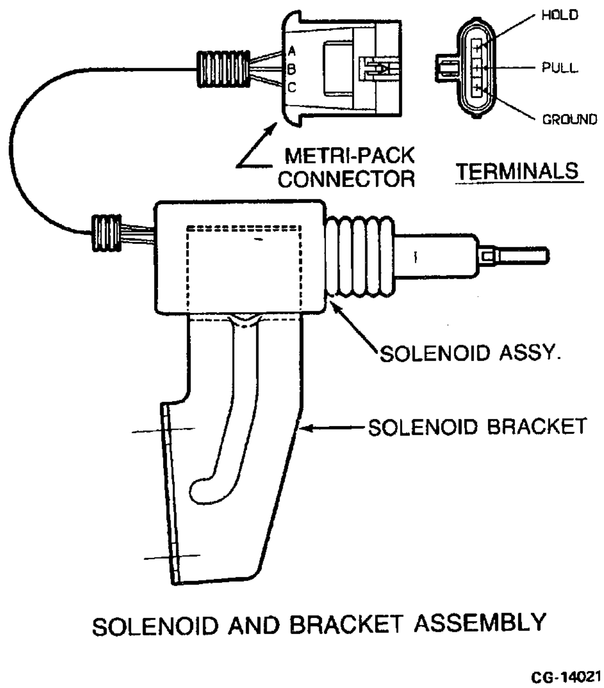

Figure 11.5. Electric Shut–Off Solenoid and Bracket for Model PES6A Pump

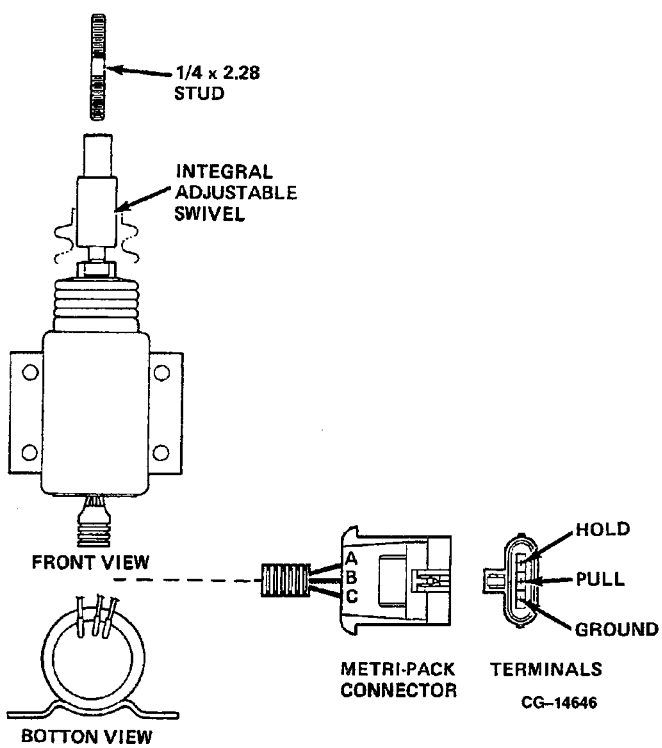

Figure 11.6. Electric Shut–Off Solenoid and Bracket for Model MW Pump

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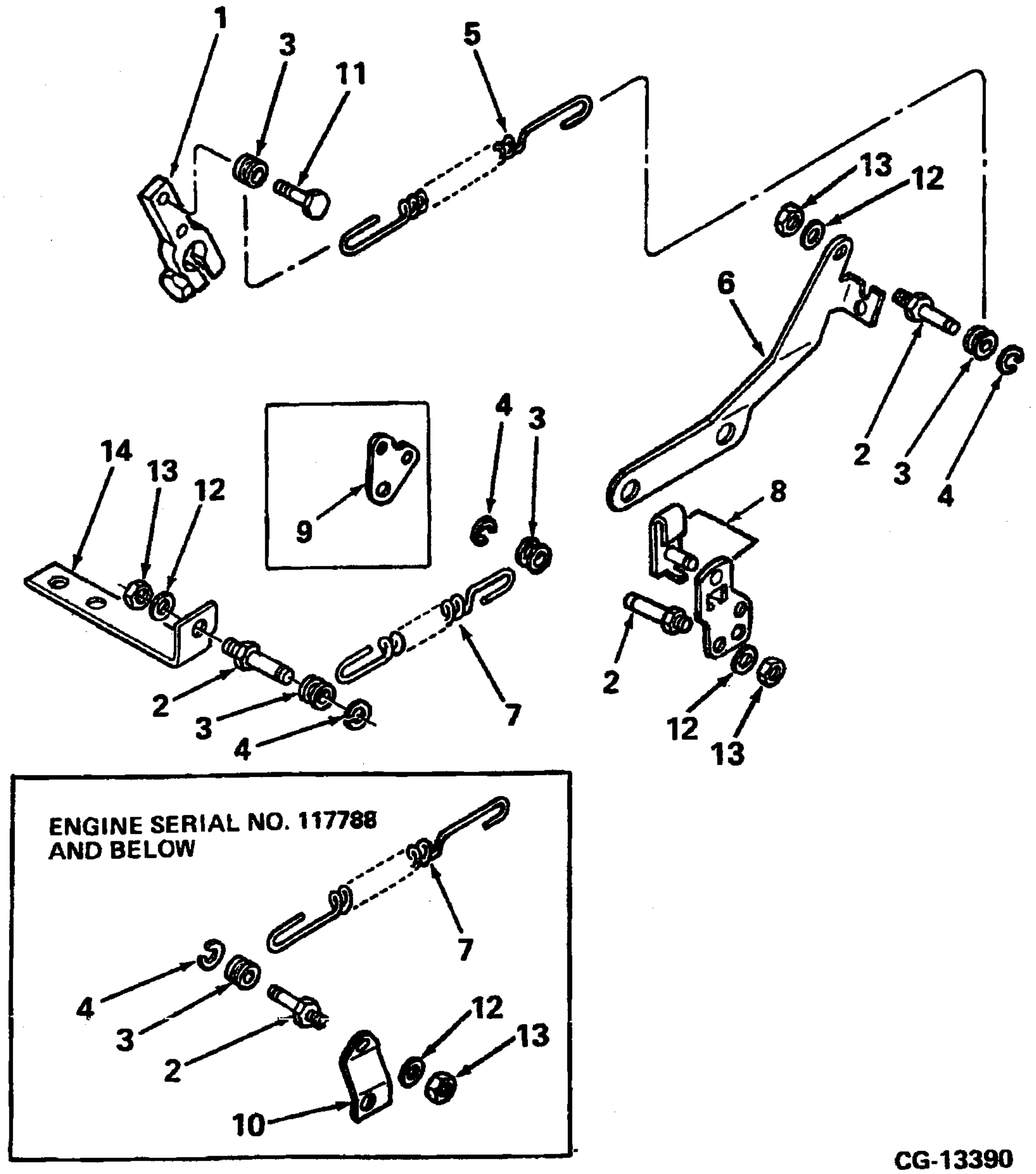

Figure 11.7. Typical Fuel Injection Pump Linkage.

1. Lever, Injection Pump Throttle
2. Post, Spring Anchor
3. Roller, Spring
4. Ring, Retaining
5. Spring, Upper Throttle Lever
6. Bracket, Throttle Cable (Mounted to Crankcase)
7. Spring, Lower Throttle Control Lever
8. Lever, Injection Pump Control
9. Plate, Throttle Extension
10. Bracket, Extension (Return) Spring
11. Bolt, Spring Roller
12. Washer, Lock
13. Nut
14. Bracket, Extension (Return) Spring

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SPECIFICATIONS

DIMENSION TITLE	VALUES
INJECTION PUMP:	
Model	Robert Bosch PES6A–2000 or MW
Drive	Gear — Steel Forging
Static Timing: (1987 Model Year)	
165 HP (DT–360 Federal)	20° ± 1 BTDC
180 HP (DTA–360 Federal)	22° ± 1 BTDC
175 HP (DTA–360 California)	13° ± 1 BTDC
Static Timing: (1988 & 1989 Model Year)	
170 HP (DT–360 Federal)	21° ± 1 BTDC
180 HP (DTA–360 Federal)	24° ± 1 BTDC
175 HP (DTA–360 California)	17° ± 1 BTDC
Static Timing: (1990 Model Year)	
170 HP (DT–360)	15° ± 1 BTDC
185 HP (DTA–360)	19° ± 1 BTDC
Static Timing: (1991 Model Year)	
170 HP (DT–360 Federal)	12° ± 1 BTDC
170 HP (DT–360 California) #	9° ± 1 BTDC
185 HP (DTA–360 Federal)	16° ± 1 BTDC
185 HP (DTA–360 California) #	13° ± 1 BTDC
# Equipped with Model MW Fuel Injection Pump	
FUEL FILTER:	
Type	Spin–on

SPECIAL TORQUES

Injection Pump Drive Gear Bolts	35 lbf–ft. (47 Nm)
Adapter Housing Nuts	24 lbf–ft. (33 Nm)
Injection High Pressure Line Connector Nut (A Pump) *	18 lbf–ft. (24 Nm)
Injection High Pressure Line Connector Nut (MW Pump)	30 lbf–ft. (40 Nm)
Banjo Fuel Oil Connections (14 mm)	25 lbf–ft. (34 Nm)
Banjo Lube Oil Connections (10 mm)	16 lbf–ft. (21 Nm)
Nozzle Retainer Bolt (Crab Bolt)	20 lbf–ft. (27 Nm)
Governor Housing Plug (10 mm Internal Hex)	20 lbf–ft. (27 Nm)

* A back–up wrench must be used on the delivery valve holder nut to prevent movement of the delivery valve holder on Model PES6A fuel injection pump.

NOTE: Injection line fittings at the pump and nozzle are frequently overtightened due to the fitting size (3/4"). This swedges the injection line, often partly closing the ends. This alters fuel delivery characteristics, raises injection line pressures and may cause performance problems or injection pump failure. Inspect the ends of the injection lines and discard any with swedged or damaged fittings or holes.

SPECIAL SERVICE TOOLS

None Required for this Section

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FUEL INJECTION PUMP

REMOVAL

NOTE: FUEL INJECTION PUMP MODELS PES6A AND MW REMOVAL AND REASSEMBLY PROCEDURES ARE SIMILAR. THOSE PROCEDURES LISTED BELOW ARE THE SAME FOR BOTH PUMPS. WHERE THE SPECIFIC PROCEDURES ARE DIFFERENT THE INSTRUCTIONS ARE GIVEN BY PUMP AND SERIAL NUMBER.

IMPORTANT

CLEANLINESS IS OF UTMOST IMPORTANCE WHEN SERVICING FUEL INJECTION SYSTEMS. ALWAYS CLEAN ENGINE BEFORE INJECTION PUMP IS REMOVED OR DISCONNECTING FUEL LINES. ALWAYS PLUG OR CAP ANY OPENING TO PREVENT DIRT, PAINT CHIPS OR OTHER FOREIGN MATERIAL FROM ENTERING THE FUEL SYSTEM. DO NOT CLEAN WITH ENGINE RUNNING.

Set Injection Pump to Engine Timing Prior to Pump Removal as Follows:

1. Disconnect battery cables.
2. Disconnect accelerator cable from outer injection pump control lever.
3. Remove injection pump timing pointer plug and gasket from left side of pump mounting adapter.

WARNING

Shut–off must be in no–fuel position before proceeding.

4. Rotate the engine in the normal operating direction until the engine front cover timing pointer is on the degree mark on the damper pulley for the particular application. Refer to **Chart 1**.
5. Visually inspect the hub scribe line and timing pointer for alignment. If the scribe line and timing pointer are aligned, the #1 piston is on the compression stroke. Refer to **Figure 11.8**.

NOTE: The above procedure establishes the accuracy of the previous timing and avoids the necessity of removing the valve cover to establish the # 1 compression stroke during reassembly.

Verify Injection Pump to Engine Timing as Follows, if Gear Train was Disassembled:

1. Verify that the #1 piston is on the compression stroke by:
   a. Removing the valve cover.
   b. Check to see if the #1 cylinder intake and exhaust valve levers are loose by turning the push rods by hand.
   c. If loose, the #1 piston is on the compression stroke and the injection pump may be removed.
   d. If the # 1 cylinder valve levers are <u>NOT</u> loose, set the pump to engine static timing as described in steps 2 and 3.
2. Rotate the engine (in the normal direction of rotation) one complete revolution. The engine should now be on the #1 compression stroke.
3. Observe the engine front cover timing pointer and damper pulley degree alignment. To ensure an accurate reading, view the pointer straight on. Refer to **Figure 11.8**.

The engine should now be positioned at specified static pump to engine timing (see **Chart 1**).

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FUEL INJECTION PUMP — Continued

REMOVAL — Continued

CHART 1

Engine Model	Emission Standard	Horse-Power Rating	Static Timing — Degrees
1987 Model Year			
DT-360	Federal	165	20° ± 1 BTDC
DTA-360	Federal	180	22° ± 1 BTDC
DTA-360	California	175	13° ± 1 BTDC
1988 & 1989 Model Year			
DT-360	Federal	170	21° ± 1 BTDC
DTA-360	Federal	180	24° ± 1 BTDC
DTA-360	California	175	17° ± 1 BTDC
1990 Model Year			
DT-360	50 State	170	15° ± 1 BTDC
DTA-360	50 State	185	19° ± 1 BTDC
1991 Model Year			
DT-360	Federal	170	12° ± 1 BTDC
DT-360	California	170	9° ± 1 BTDC
DTA-360	Federal	185	16° ± 1 BTDC
DTA-360	California	185	13° ± 1 BTDC

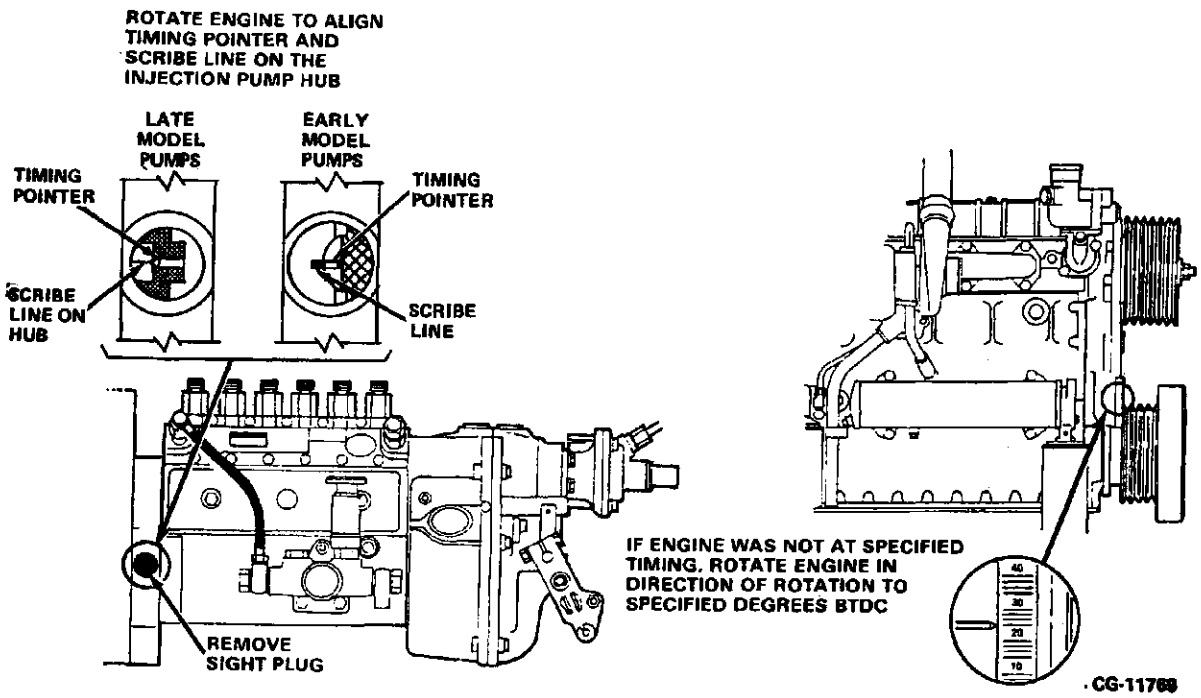

Figure 11.8. Injection Pump to Engine Timing (Prior to Pump Removal)
(PES6A Injection Pump Shown)

NOTE: If timing is not within specifications, rotate engine to correct crankshaft position (specified degrees before top dead center) before removing injection pump. If it is necessary to rotate engine in opposite direction of normal rotation to achieve specified timing, rotate engine to 90 degrees before top dead center and then rotate engine to specified timing. This procedure takes up gear backlash.

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

COMPONENT CHANGES

FUEL SUPPLY PLUMBING REVISED

The fuel supply plumbing was revised for engines equipped with a model PES6A fuel injection pump with serial number 084779 and above. The current design pulls the fuel [under suction] from the tank to the supply pump. The fuel then moves [under pressure] from the supply pump, through the filter and into the fuel injection pump inlet. Refer to **Figure 11.9.**

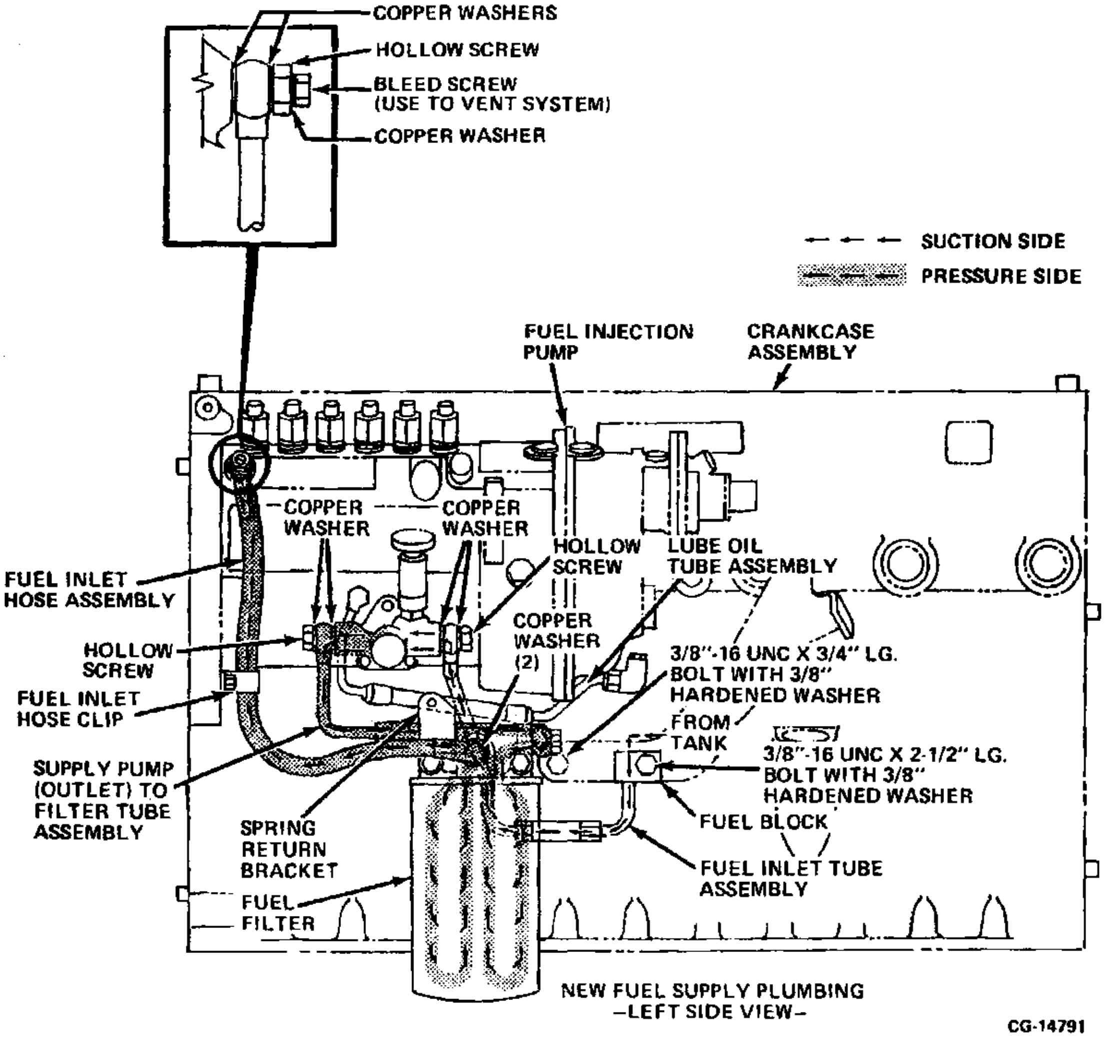

Figure 11.9. New PES6A Fuel Supply Plumbing

The prior plumbing system pulls the fuel [under suction] from the tank, through the filter and into the supply pump where the fuel is delivered [under pressure] into the fuel injection pump inlet.

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

Remove the Injection Pump as Follows:

1. Using a 3/4 in. wrench, loosen the six fuel injection line nuts at the nozzles. Refer to **Figure 11.10.**

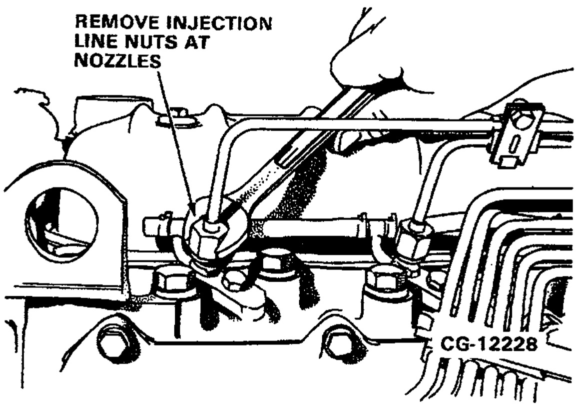

Figure 11.10. Remove Injection Line Nuts at Nozzles

2. Loosen and remove the fuel injection line nuts at the pump while holding the delivery valve holder with a modified 12 pt. 7/8 in. box wrench to prevent delivery valve movement (which could affect rack travel). Refer to **Figure 11.11.**

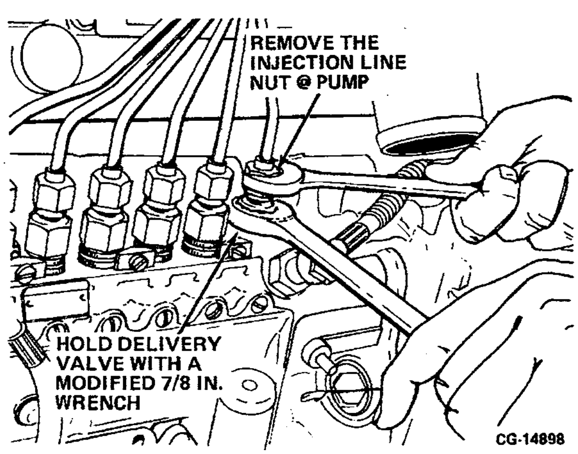

Figure 11.11. Remove Injection Line Nuts at Pump

NOTE: The 7/8 in. wrench used to hold the delivery valve must be modified by cutting a slot which allows it to pass over the fuel line. Refer to Figure 11.42. for details.

3. Remove the fuel injection lines as an assembly. Refer to **Figure 11.12.**

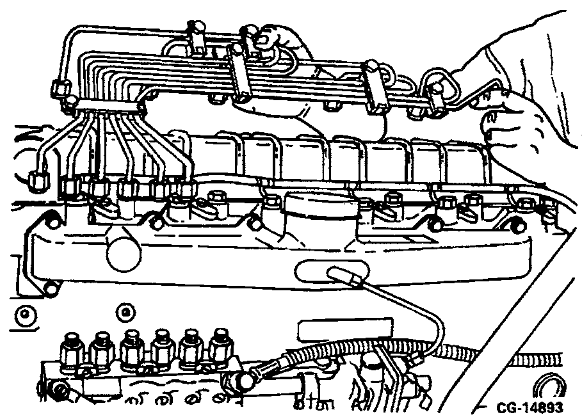

Figure 11.12. Remove Fuel Injection Lines as an Assembly

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

IMPORTANT

CAP ALL FUEL INJECTION LINES, DISCHARGE FITTING AT THE PUMP AND NOZZLE INLETS WITH PLASTIC CAPS. DO NOT USE TAPE. TAPE COLLECTS DIRT AND LEAVES A GUMMY RESIDUE ON MATING SURFACES. REFER TO FIGURES 11.13 THROUGH 11.15.

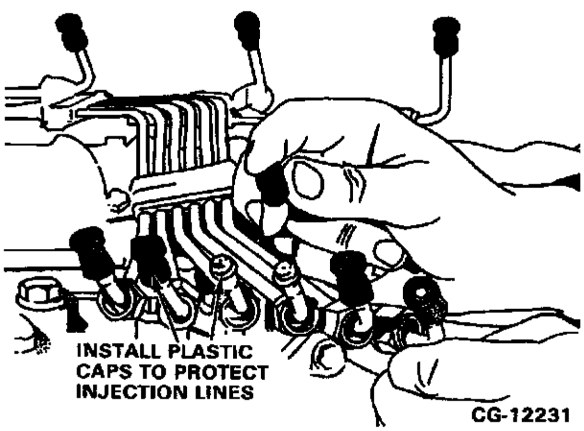

Figure 11.13. Cap Injection Lines

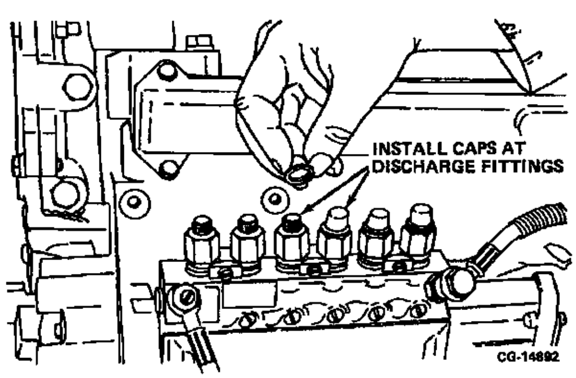

Figure 11.14. Cap Pump Discharge Fittings

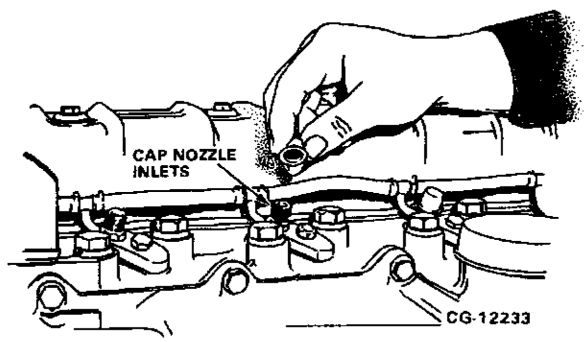

Figure 11.15. Cap Nozzle Inlets

4. Remove the aneroid tube as follows: (Refer to **Figure 11.16**)
   a. Remove the connecting nuts at the pump aneroid and at the intake manifold elbow.
   b. Remove the rubber sealing sleeves at each end and discard.
   c. Cap the openings at the aneroid and the intake manifold.

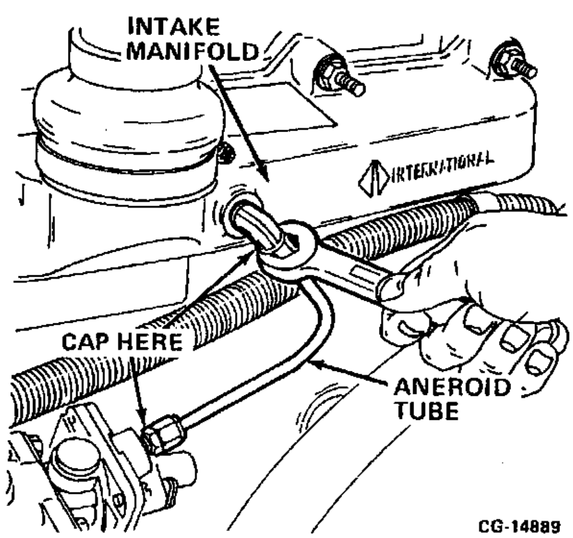

Figure 11.16. Remove Aneroid Tube

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

5. Remove the fuel inlet (fuel header to injection pump) hose assembly as follows: (Refer to **Figure 11.17**)

   a. Remove nut and washer holding hose clip to pump mounting adapter.

   b. Loosen and remove the hollow screw at the fuel filter header banjo fitting.

   c. Loosen and remove the hollow screw (with bleed screw) at the injection pump inlet.

   d. Cap the injection pump inlet and fuel filter header outlet.

NOTE: Copper gaskets are used to seal the banjo fittings at each end of the fuel inlet tube.

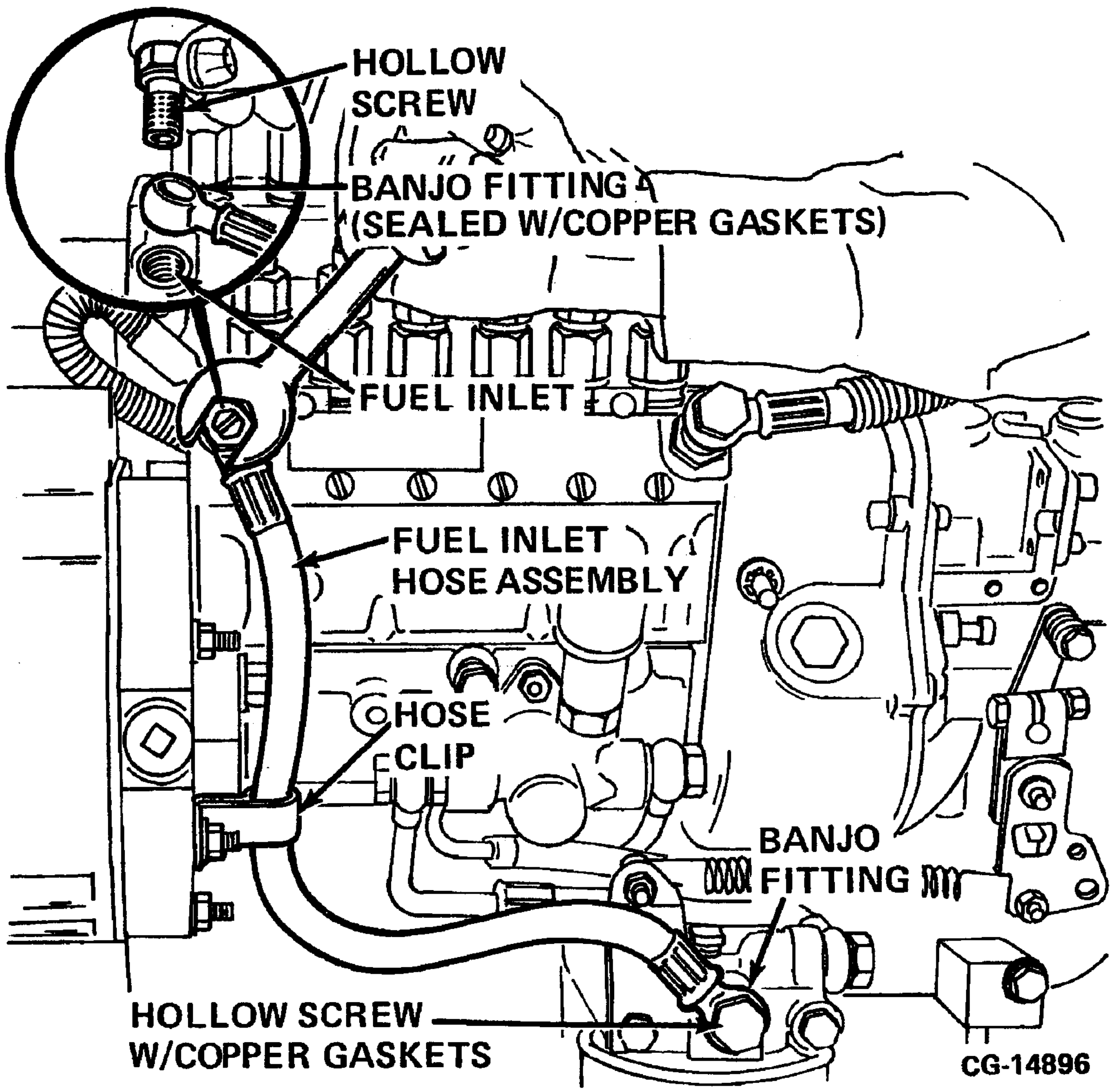

Figure 11.17. Remove the Fuel Inlet Hose Assembly

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

6. Remove the upper and lower throttle return springs. Refer to **Figure 11.18.**

NOTE: The lower spring is a small diameter while the upper spring is a large diameter. Do NOT switch spring location during reassembly.

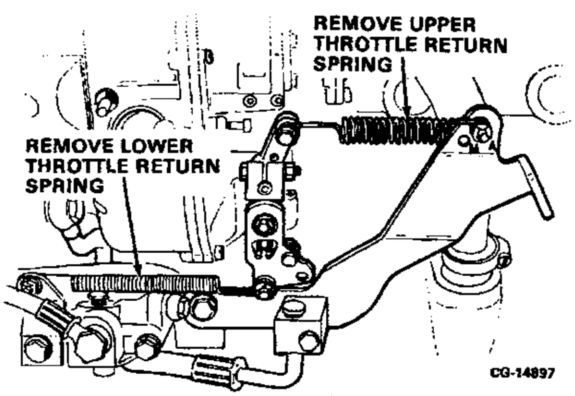

Figure 11.18. Remove Upper and Lower Throttle Return Springs

7. Remove the fuel outlet (supply pump to fuel filter) tube as follows: (Refer to **Figure 11.19**)
   a. Remove the hollow screw and copper sealing gaskets at the fuel filter header.
   b. Remove the hollow screw and copper sealing gaskets at the supply pump banjo fitting.
   c. Remove the tube assembly and cap the fuel filter header and supply pump openings.

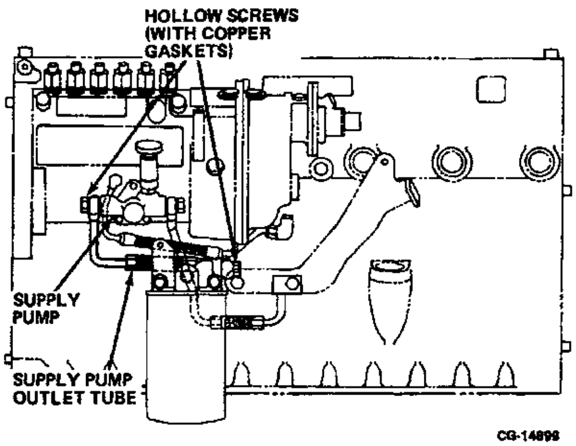

Figure 11.19. Remove Fuel Outlet Tube

8. Remove the supply pump inlet tube assembly as follows: Refer to **Figure 11.20**
   a. Remove the hollow screw and copper sealing gaskets at the supply pump banjo fitting.
   b. Remove the bolt and washer at the fuel block (which also retains throttle cable bracket).
   c. Remove the tube assembly and cap the opening at the supply pump inlet.

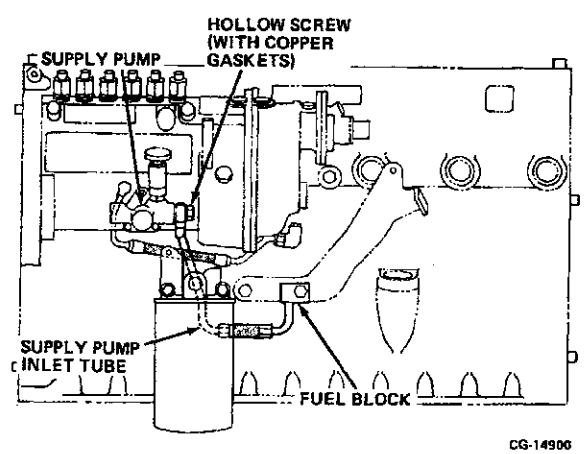

Figure 11.20. Remove Supply Pump Inlet Tube

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

9. Remove the fuel return line as follows:

STEP ONE — Refer to **Figure 11.21**

a. Disconnect the fuel leak–off hose from the return tube leak–off tee using pliers.

b. Remove the intake manifold stud bolt nut and hose clamp (at the #6 cylinder, bottom hole position).

STEP TWO — Refer to **Figure 11.21**

a. Remove the hex head hollow screw and washers from the fuel return tube banjo fitting at the fuel injection pump.

b. Remove the fuel return line as an assembly. Keep the hardware together to facilitate reassembly.

c. Cap the fuel return inlet at the pump.

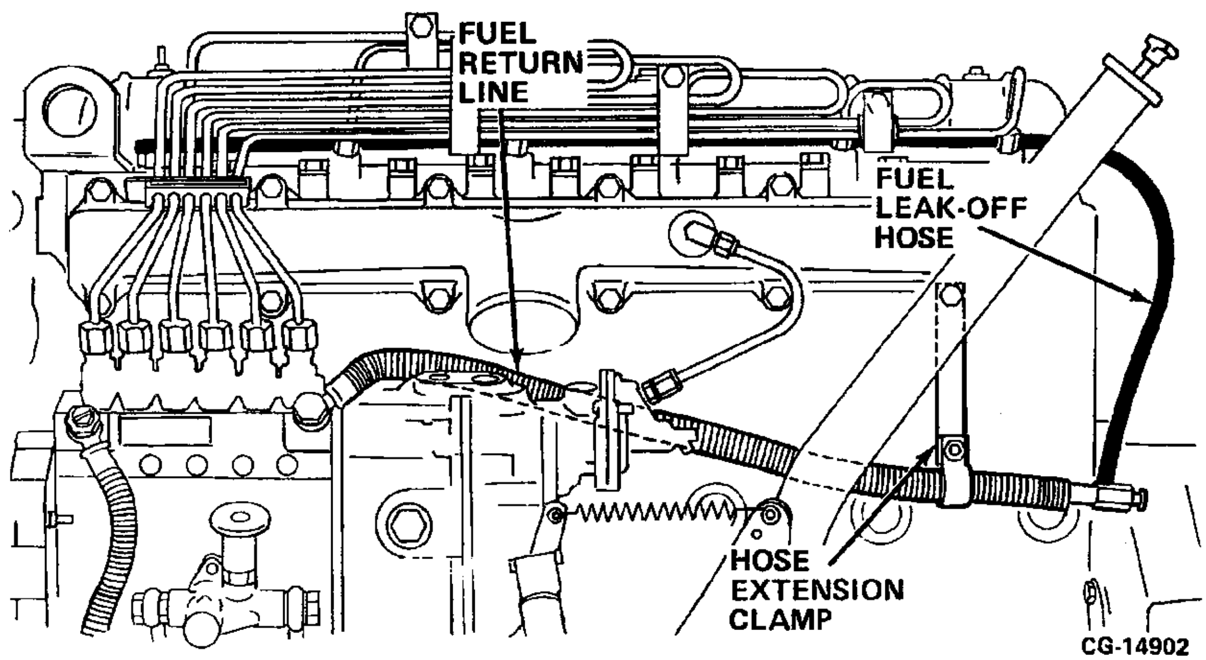

Figure 11.21. Fuel Return Tube Removal

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

10. Remove the lube oil supply line as follows: (Refer to **Figure 11.22**)
   a. Loosen and remove the compression nut
   b. Remove the hex head hollow screw and copper gaskets from the banjo fitting at the fuel injection pump oil inlet.
   c. Remove the tube assembly and discard the sealing sleeve at the compression nut end of the tube.
   d. Cap the pump oil inlet and the elbow at the crankcase.

NOTE: IF THE FUEL INJECTION PUMP IS EQUIPPED WITH AN ELECTRIC SHUTOFF SOLENOID, DISCONNECT THE HARNESS FROM THE PACKARD CONNECTOR AT THE SOLENOID, PRIOR TO INJECTION PUMP REMOVAL.

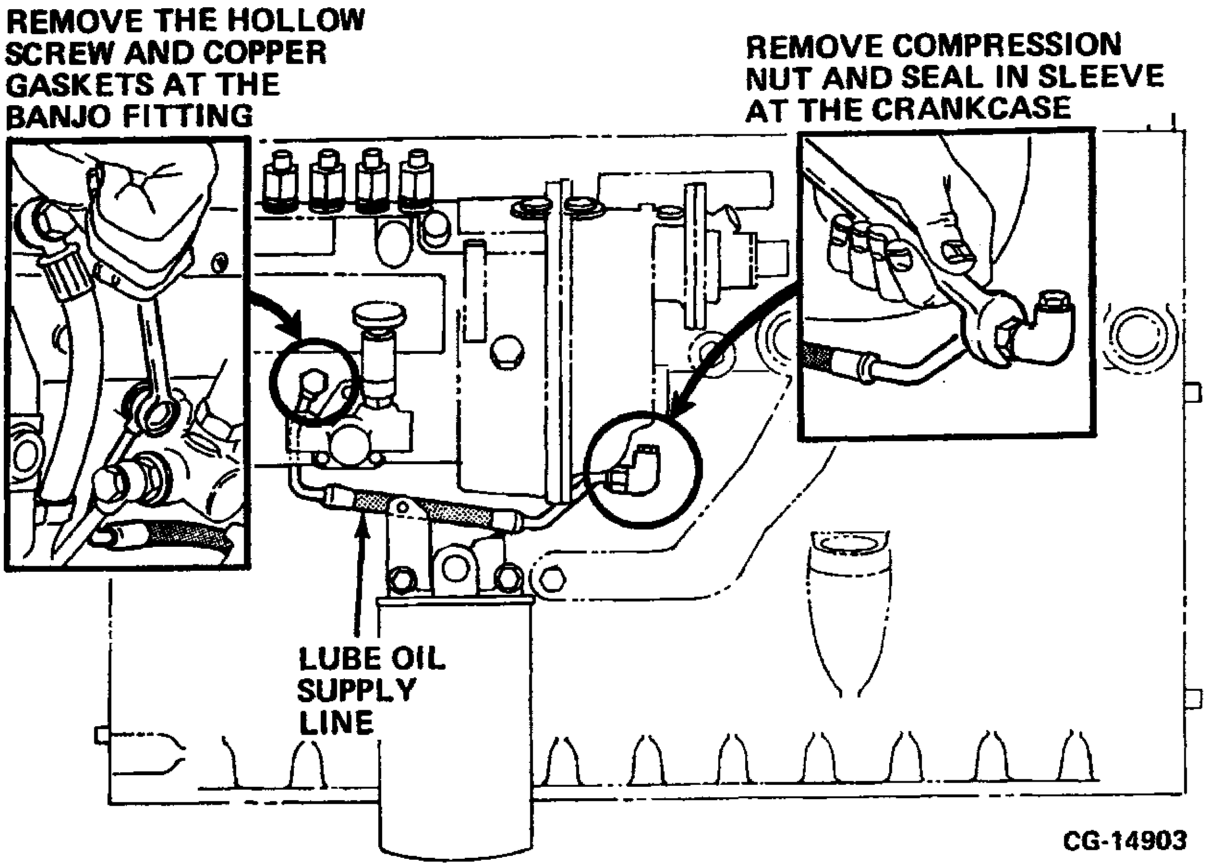

Figure 11.22. Remove Lube Oil Supply Line

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

11. Remove the injection pump drive gear access cover as follows:
    a. Loosen and remove the six fasteners which secure the access cover. Refer to **Figure 11.23.**

NOTE: Three thru bolts and nuts with washers secure the access cover to the injection pump adapter housing and three bolts with washers secure the access cover to the housing casting.

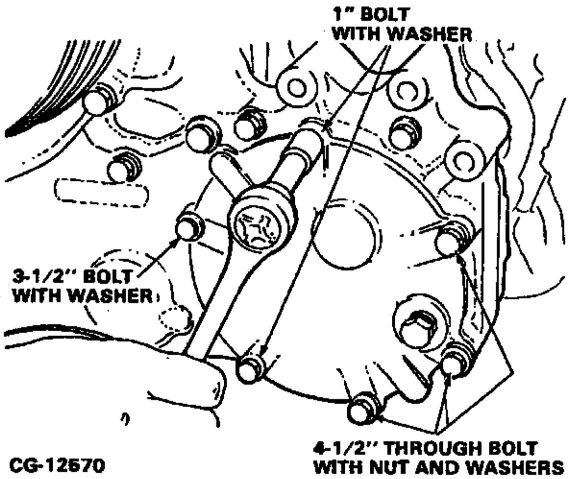

Figure 11.23. Remove Injection Pump Drive Gear Access Cover Bolts

b. Remove the access cover and gasket from the front cover to expose the injection pump drive gear. Discard the gasket. Refer to **Figure 11.24.**

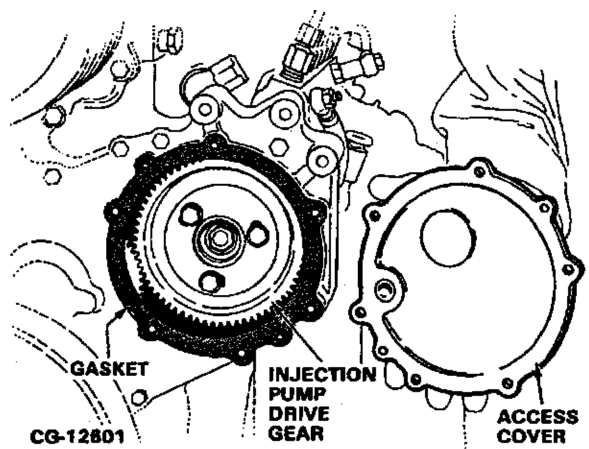

Figure 11.24. Remove Access Cover

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

12. Remove the injection pump drive gear bolts and hardened washers. Refer to **Figure11.25.**

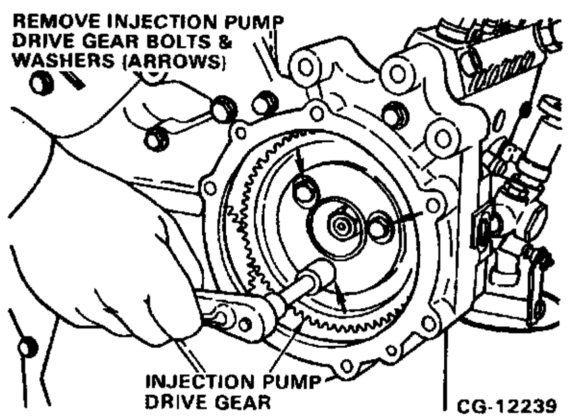

Figure 11.25. Remove Injection Pump Drive Gear Bolts

13. Remove the injection pump drive gear from the pump hub. Refer to **Figure 11.26.**

NOTE: The polished side of the drive gear faces the hub.

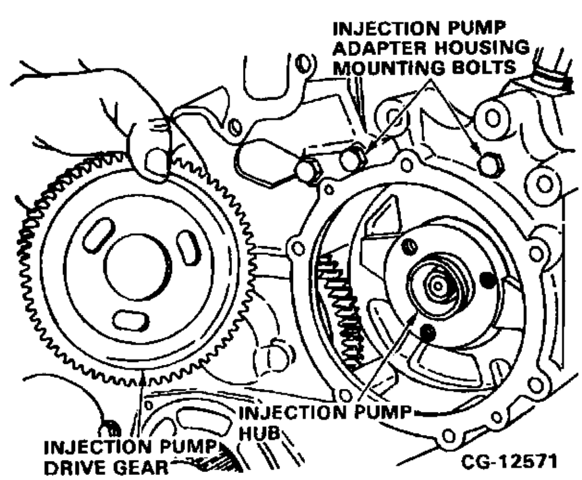

Figure 11.26. Remove the Injection Pump Drive Gear

14. Remove the two adapter housing bolts which go through the front cover. Refer to **Figure 11.26.**
15. Remove the adapter housing bolt and washer located at the bottom/rear (in–board) side of the adapter housing. Refer to **Figure 11.27.**

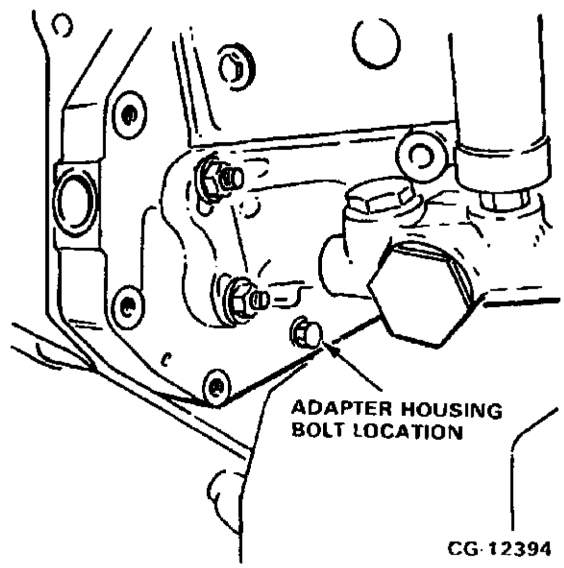

Figure 11.27. Remove Bottom/Rear (In–Board) Adapter Housing Bolt

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

16. Remove the injection pump and mounting adapter as an assembly. Discard the gasket. Refer to **Figure 11.28**.

IMPORTANT

IF THE INJECTION PUMP MOUNTING ADAPTER (46, FIGURE 11.3) REQUIRES REPLACEMENT, THE SERVICE ADAPTER COMES WITH A TIMING POINTER (41, FIGURE 11.3) PRESSED IN THE ADAPTER.

IF THE INJECTION PUMP MOUNTING ADAPTER IS REMOVED FROM THE PUMP AND A NEW ADAPTER IS INSTALLED, THE PUMP MUST BE FLOW TIMED. AFTER FLOW TIMING, STRIKE A NEW MARK ON THE REPLACEMENT MOUNTING ADAPTER TO ALIGN WITH THE SCRIBE MARK LOCATED ON THE INBOARD SIDE OF THE PUMP MOUNTING FLANGE. (REFER TO FIGURE 11.29). IF THE MOUNTING ADAPTER IS REMOVED TO PERFORM INJECTION PUMP REPAIRS, THE ORIGINAL MOUNTING ADAPTER MUST BE REINSTALLED WITH THE FACTORY SET SCRIBE MARKS ALIGNED, AFTER THE PUMP IS FLOW TIMED. (REFER TO FIGURE 11.29).

NOTE: Dowels on the adapter housing hold the pump assembly to the front plate.

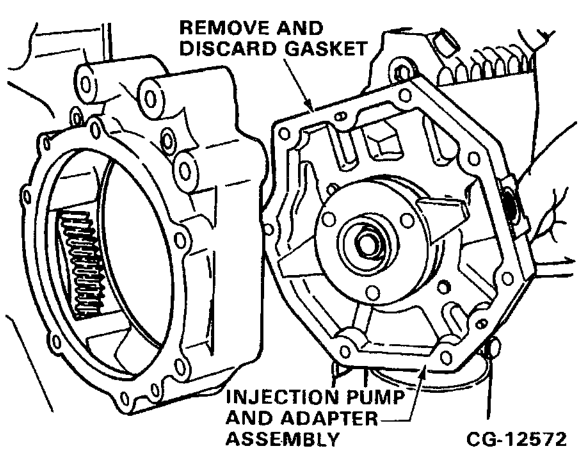

Figure 11.28. Remove Injection Pump Assembly

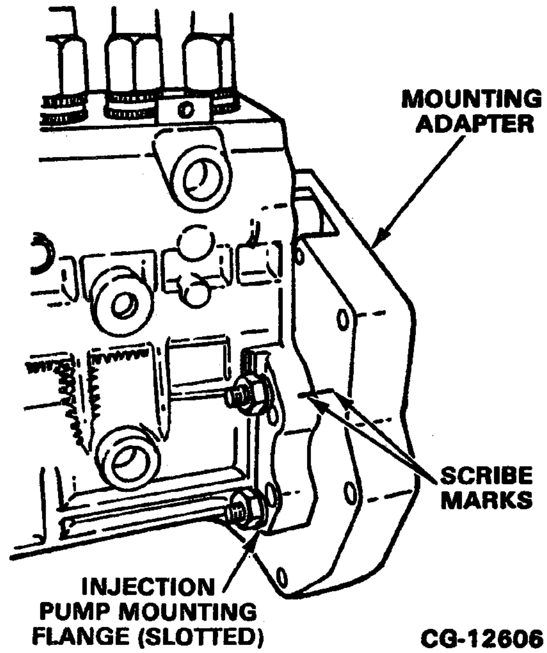

Figure 11.29. Mounting Adapter Installation

Fuel Filter Header and Throttle Linkage Assembly

1. Using an appropriate filter wrench, remove the fuel filter from the header and discard.
2. Loosen and remove the two mounting bolts which secure the fuel filter header to the crankcase, then remove the header. Refer to **Figure 11.30**.

NOTE: The lower throttle return spring bracket assembly is retained by the front filter header bolt.

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REMOVAL — Continued

Fuel Filter Header and Throttle Linkage Assembly — Continued

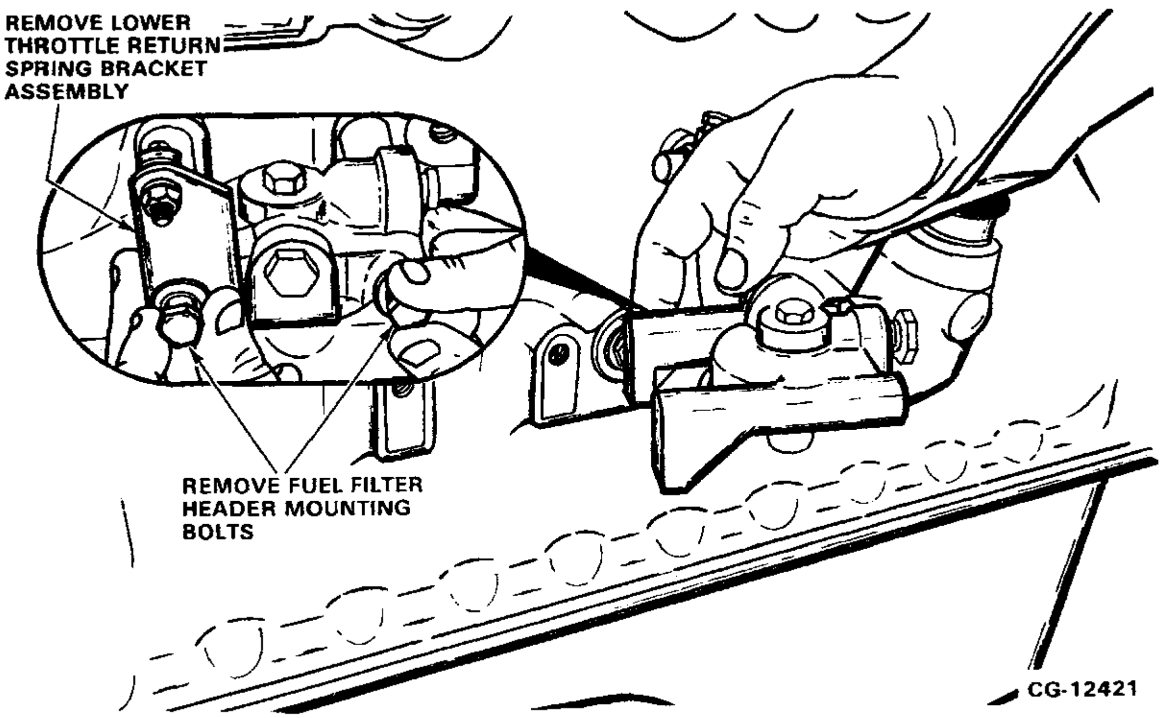

Figure 11.30. Remove Fuel Filter Header and Lower Throttle Return Spring Bracket Assembly

3. Remove the throttle cable bracket assembly from the crankcase. The bolt for the supply pump inlet tube assembly fuel block/throttle cable bracket was removed at step 8 (Page 15). Refer to **Figure 11.31**.

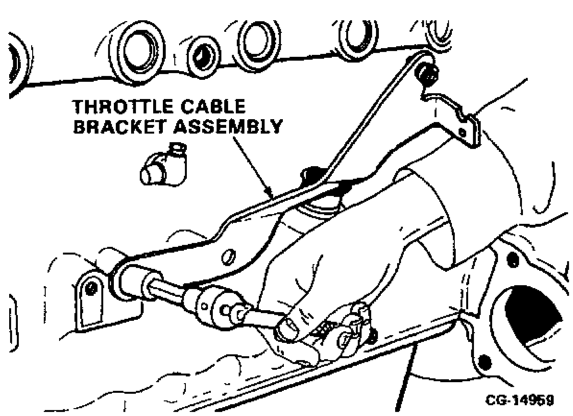

Figure 11.31. Remove the Throttle Cable Bracket Assembly

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY

1. Install the injection pump and adapter housing assembly to the engine front cover plate using a new adapter housing gasket. Refer to **Figure 11.32.**

NOTE: Adapter housing dowel pins will align the gasket and the adapter housing to the engine front plate.

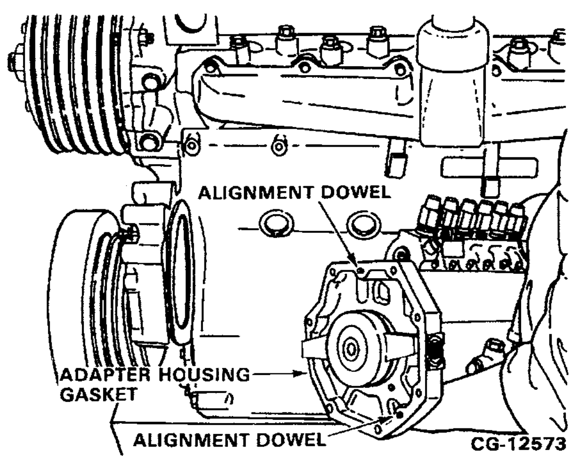

Figure 11.32. Install Injection Pump and Adapter Housing Assembly to the Front Plate

2. Tighten the adapter housing bolts (depicted in **Figures 11.26 and 11.27**) to the specified special torque (see "**SPECIFICATIONS**").
3. Install the injection pump drive gear as follows:
   a. **IMPORTANT! Verify that the engine #1 cylinder is on the compression stroke (TDC). Also verify static timing by checking the timing pointer and degree marks on the damper pulley. Refer to "Set Injection Pump to Engine Timing Prior to Pump Removal", in this section for a detailed procedure.**
   b. Loosely install the injection pump drive gear to the injection pump drive hub. DO NOT TIGHTEN BOLTS. Refer to **Figure 11.33.**

NOTE: Position bolts in the center of the kidney slot.

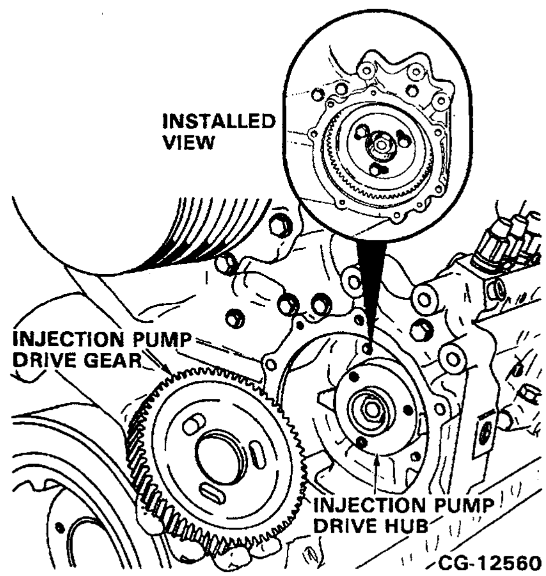

Figure 11.33. Install Injection Pump Drive Gear

   c. Verify the alignment of the injection pump timing pointer to the drive hub scribe line through the adapter housing sight plug. Refer to **Figure 11.34**. Rotate the pump hub as required for proper alignment.

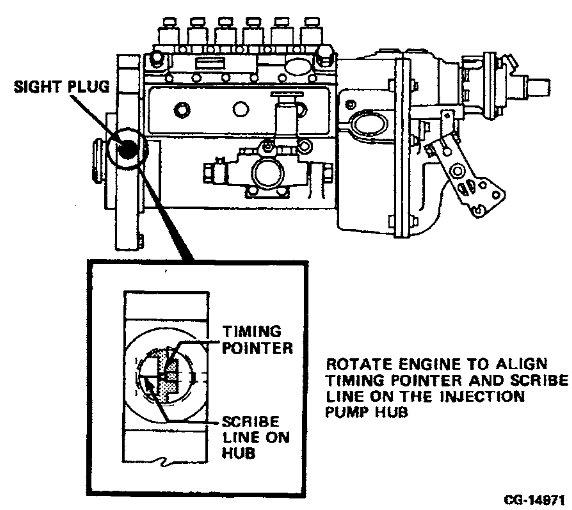

Figure 11.34. Injection Pump Timing Marks

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

d. Tighten the three pump drive gear mounting bolts to the specified **"SPECIAL TORQUE"**.

IMPORTANT

BE SURE THE TIMING POINTER AND SCRIBE LINE ARE STILL ALIGNED AFTER THE BOLTS ARE TIGHTENED.

e. Reinstall sight plug using a new copper gasket.

4. Install the injection pump drive gear access cover **(Figure 11.35.)** using a new gasket as follows:

a. Secure the three bolts and washers which fasten into the front cover casting. Tighten to the standard torque. See Appendix.

b. Secure the bolts, washers and nuts which mount through the access cover, front cover and adapter housing. Tighten to the standard torque. See Appendix.

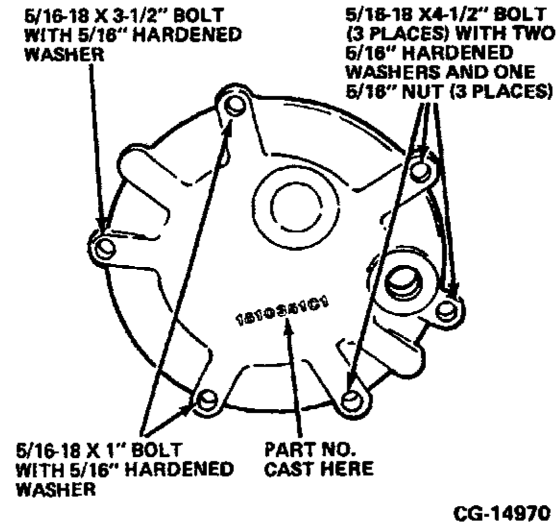

Figure 11.35. Injection Pump Access Cover Mounting Hardware Location

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

5. Install the fuel return line as follows:

NOTE: The fuel return tube mounting clamp is located at the #6 cylinder intake manifold bottom bolt location.

a. Remove protective cap from pump at fuel return outlet.

b. Install the clamps, washers, spacers and fuel return tube. Tighten the "patch" stud bolts to the specified special torque. Refer to **Figure 11.36.**

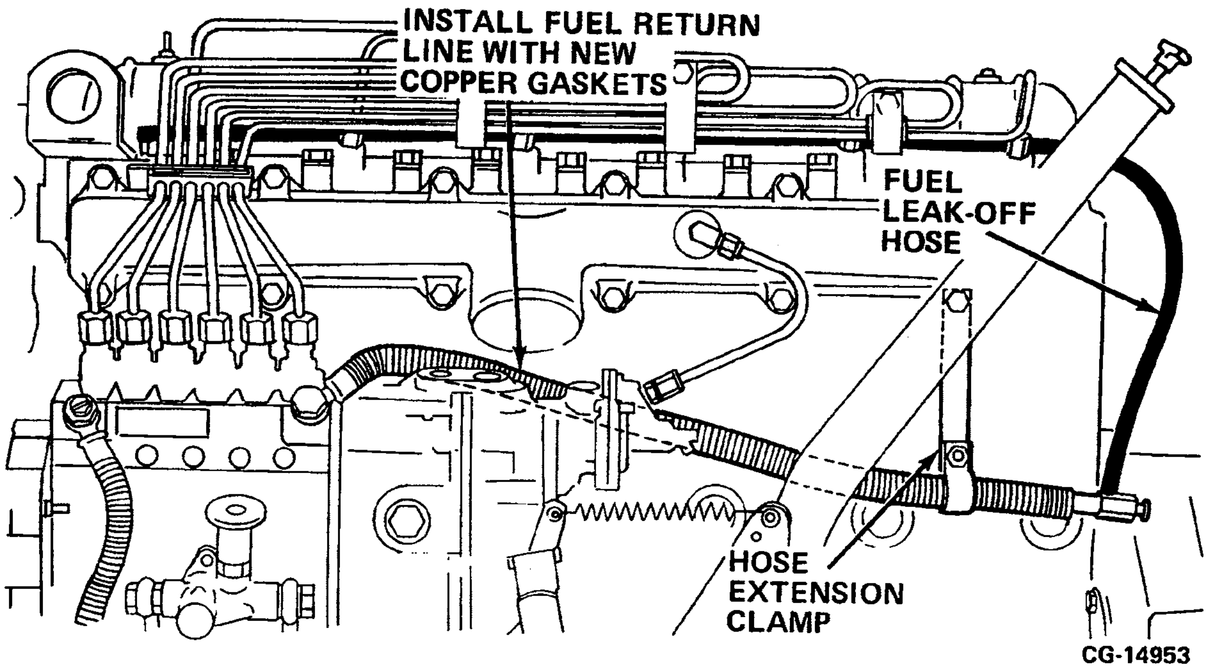

Figure 11.36. Fuel Return Tube and Clamp Installation

c. Reconnect the fuel return tube to the pump using new copper gaskets and hollow screws at the banjo fitting. Refer to **Figure 11.36.**

d. Reconnect the fuel leak–off hose to the return tube tee.

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

6. Install the fuel injection line assembly as follows:
   a. Remove the protective caps from the lines, nozzles and delivery valve holders at the pump.

IMPORTANT

PRIOR TO INSTALLING THE FUEL INJECTION LINE ASSEMBLY, CLEAN WITH FILTERED COMPRESSED AIR AND VISUALLY INSPECT FOR CONTAMINATION OR DAMAGE. REPLACE AS REQUIRED.

   b. Install the connector nuts at the nozzles using a 3/4 in. "Crow Foot" socket, as shown in **Figure 11.41**. Tighten each nut to the specified **"SPECIAL TORQUE"**.

NOTE: Injection line fittings at the pump and nozzle are frequently over tightened due to the fitting size 3/4 in. This swedges the injection line, often partly closing the ends. This alters fuel delivery characteristics, raises injection line pressures and may cause performance problems or injection pump failure. Visually inspect the ends of the injection lines and replace any with swedged or damaged fittings or holes.

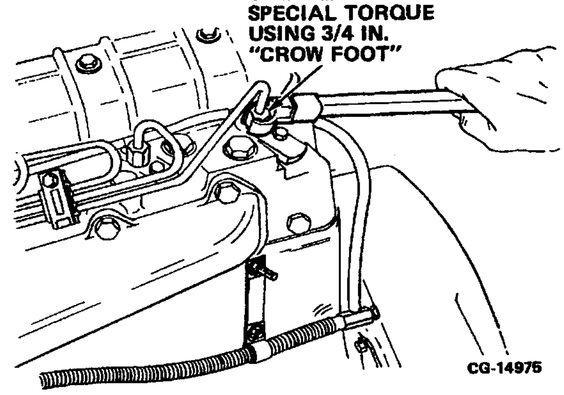

Figure 11.41. Install Injection Line Connector Nuts to each Nozzle

   c. Tighten the fuel injection line connecting nuts to the delivery valve holders at the pump. Tighten to the specified **"SPECIAL TORQUE"** using a 3/4 in. "Crow Foot" wrench at the connector nut while holding the delivery valve holder nut with a modified 12 pt. 7/8 in. wrench. Refer to **Figure 11.42.** Do not allow the delivery valve holder to move.

NOTE: Modify the 12 pt. 7/8 in. wrench by cutting a section wide enough to allow the injection pipe to pass so the delivery valve may be held.

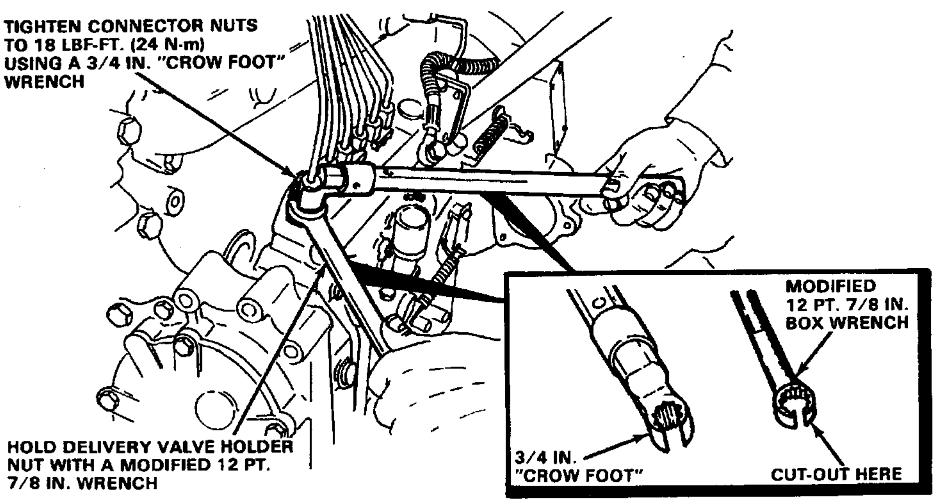

Figure 11.42. Install Injection Line Connector Nuts to the Pump Delivery Valve Holders

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

7. Install the aneroid tube as follows:

   a. Remove the protective caps from the intake manifold elbow and the aneroid.

   b. Install new rubber sealing sleeves at each end of the aneroid tube.

   c. Tighten the connecting nuts at each end of the tube as shown in **Figure 11.43**.

IMPORTANT

REUSE OF OLD SEALING SLEEVES CAN CAUSE LEAKAGE, AFFECTING ANEROID OPERATION.

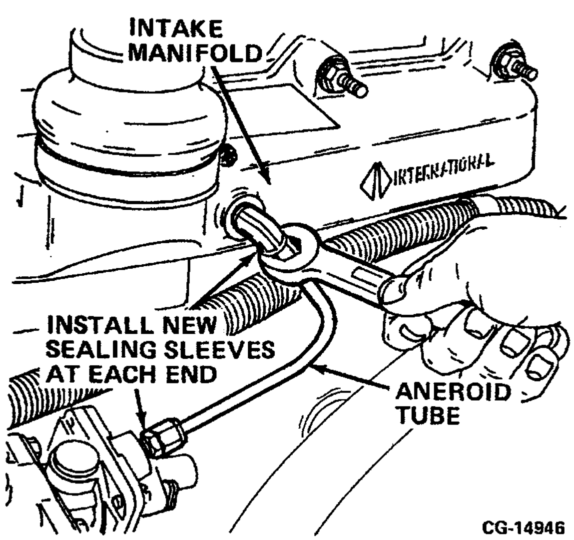

Figure 11.43. Install Aneroid Tube

8. Install the fuel filter header as follows: (Refer to **Figure 11.44**)

   a. Mount the header at the crankcase mounting pad. Fasten the header using the two mounting bolts and washers.

   b. Tighten the fasteners to the standard torque. See Appendix.

NOTE: Be sure to install the lower throttle return spring bracket on the mounting bolt which faces the front of the engine.

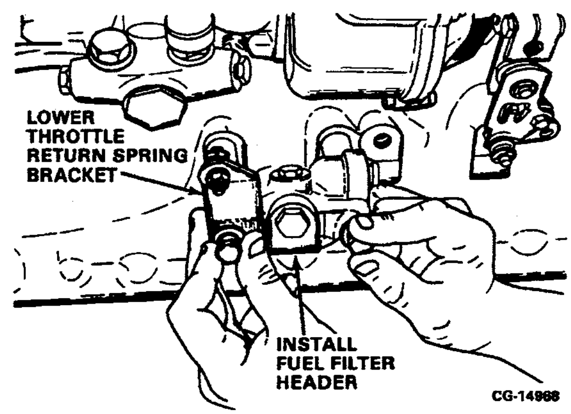

Figure 11.44. Install the Fuel Filter Header

9. Install the lube oil supply line as follows: (Refer to **Figures 11.45**)

   a. Remove the protective caps at the crankcase oil outlet elbow and the pump oil inlet.

   b. Install a new rubber sealing sleeve at the compression nut end of the tube.

   c. Fasten the tube to the crankcase oil outlet tube and tighten the nut.

   d. Using new copper gaskets, fasten the banjo fitting to the pump oil inlet with the hollow screw.

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

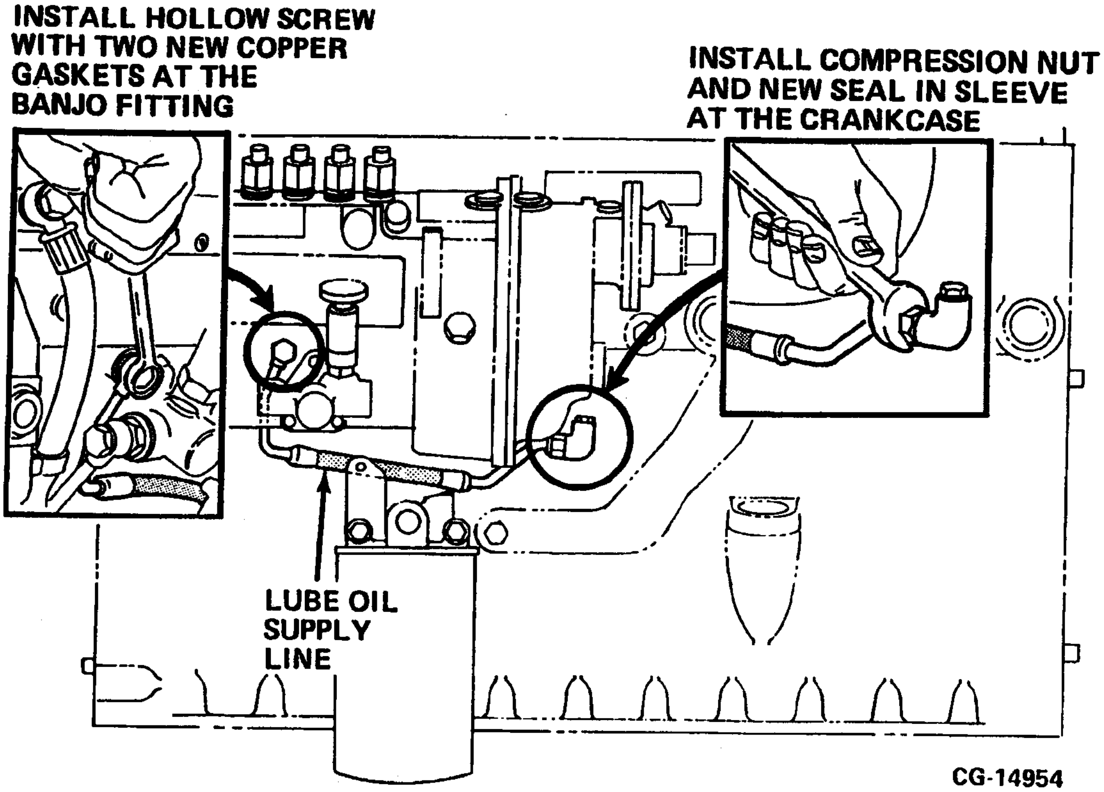

Figure 11.45. Install Lube Oil Supply Line

10. Mount the throttle lever return spring bracket to the crankcase using the two mounting bolts and washers. Refer to **Figure 11.46.**

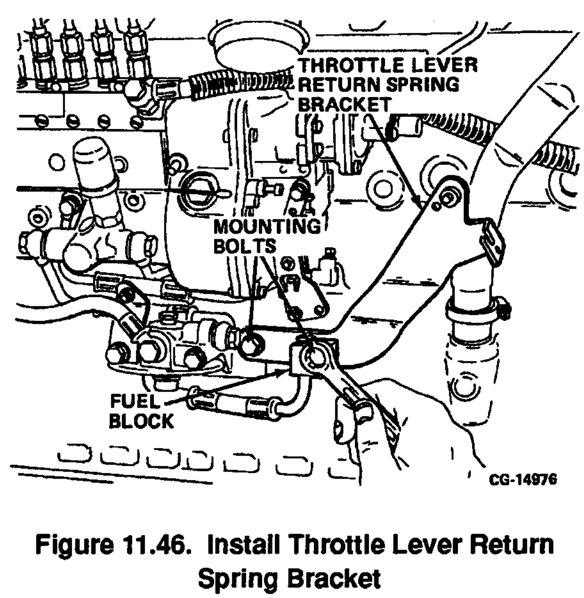

Figure 11.46. Install Throttle Lever Return Spring Bracket

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

11. Install the fuel outlet (supply pump to fuel filter) tube as follows: (Refer to **Figure11.47.**)
   a. Remove the supply pump outlet and fuel filter header protective caps.
   b. Install the hollow screw and copper sealing gaskets at the fuel filter header.
   c. Install the hollow screw and copper sealing gaskets at the supply pump banjo fitting.

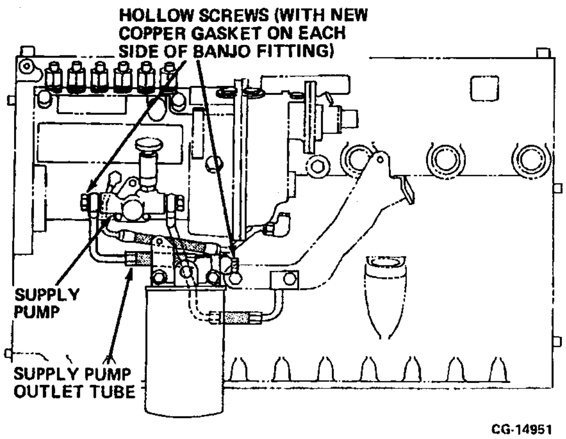

Figure 11.47. Install Fuel Inlet Tube

12. Install the supply pump inlet tube assembly as follows: Refer to **Figure 11.48**.
   a. Remove the supply pump inlet protective caps.
   b. Install the hollow screw and copper sealing gaskets at the supply pump banjo fitting.
   c. Install the bolt and washer at the fuel block.

NOTE: The bolt and washer at the fuel block also mounts the throttle lever return spring bracket (rear mounting position).

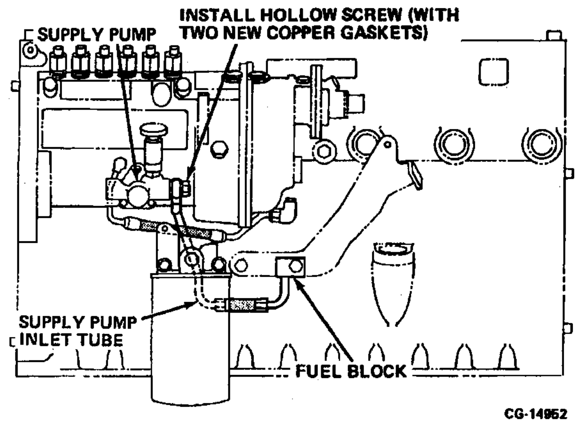

Figure 11.48. Install Supply Pump Inlet Tube

13. Install the fuel inlet (fuel header to injection pump) hose assembly as follows: (Refer to **Figure 11.49.**)
   a. Remove the injection pump inlet and fuel filter header outlet protective caps.
   b. Install the hollow screw (with bleed screw) at the injection pump inlet.
   c. Install the hollow screw at the fuel filter header banjo fitting.
   d. Install the nut and washer holding the hose clip to pump mounting adapter.

NOTE: Copper gaskets are used to seal the banjo fittings at each end of the fuel inlet tube.

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

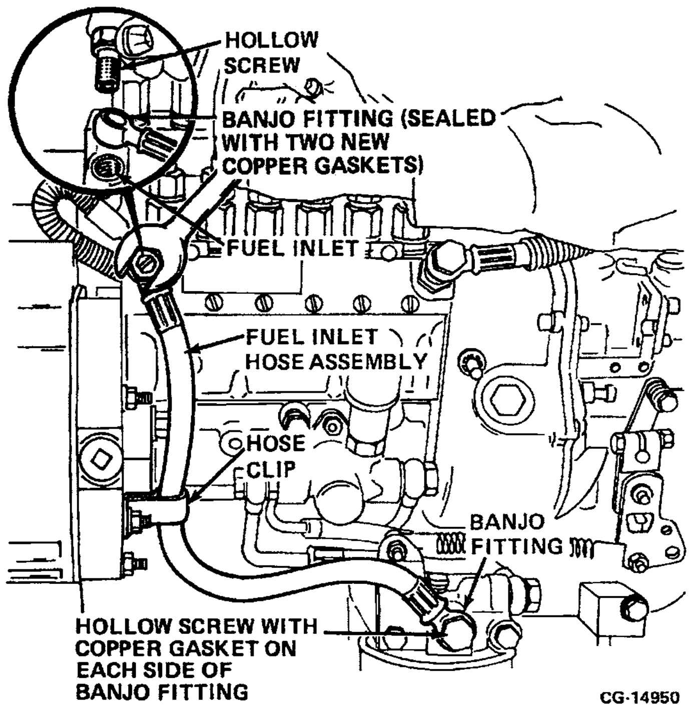

Figure 11.49. Installing the Fuel Inlet Hose Assembly

14. Connect the throttle return springs as shown in **Figure 11.50.**

IMPORTANT

THE LARGE DIAMETER SPRING MUST BE INSTALLED IN THE TOP POSITION WHILE THE NARROW DIAMETER SPRING IS INSTALLED IN THE LOWER POSITION. DO NOT INTERMIX SPRINGS!

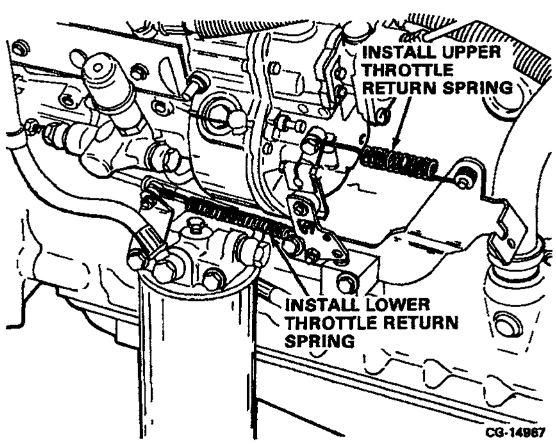

Figure 11.50. Install the Throttle Return Springs

NOTE: Refer to CGES–445–* (DT/DTA–360 Diesel Enginet Diagnostic Manual) for throttle linkage inspection and/or adjustment procedures.

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP EFFECTIVE WITH ENGINE S/N 84779

REASSEMBLY — Continued

15. Install a new fuel filter as follows: (Refer to **Figure 11.51**)
    a. Lubricate the filter gasket with clean diesel fuel.
    b. Tighten until the gasket touches the filter header.
    c. Tighten by hand an additional 1/2 turn.

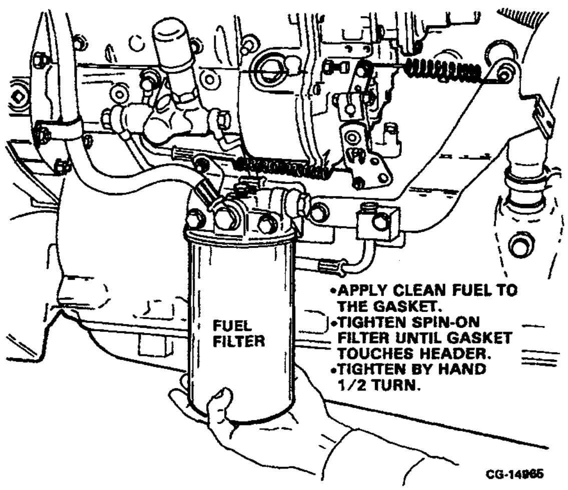

Figure 11.51. Install a New Fuel Filter

NOTE: Do not add fuel to the new filter.

PRIMING FUEL INJECTION SYSTEM

After replacing fuel injection pump or replacing fuel supply lines, prime fuel system using these procedures:

1. Loosen the bleed screw at the pump fuel inlet.
2. Loosen hand priming pump handle.
3. Operate priming pump until pump action provides solid fuel at the bleed screw. Close the screw.
4. Position injection pump shut–off lever in run position with electric shut–off or mechanical cable.
5. Crank engine for fifteen seconds.
6. Tighten priming pump handle.
7. Start engine and operate until engine runs smoothly.

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COMPONENT CHANGES

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

Effective with Engine S/N 090976, California application engines are equipped with Robert Bosch Model "MW" fuel injection pumps.

IMPORTANT

Fuel injection pump and filter piping, electric shut–off solenoids and mounting hardware are different between model "PES6A" and "MW" fuel injection pumps. DO NOT intermix fuel system components between fuel systems. Refer to Parts Catalog for proper service part numbers.

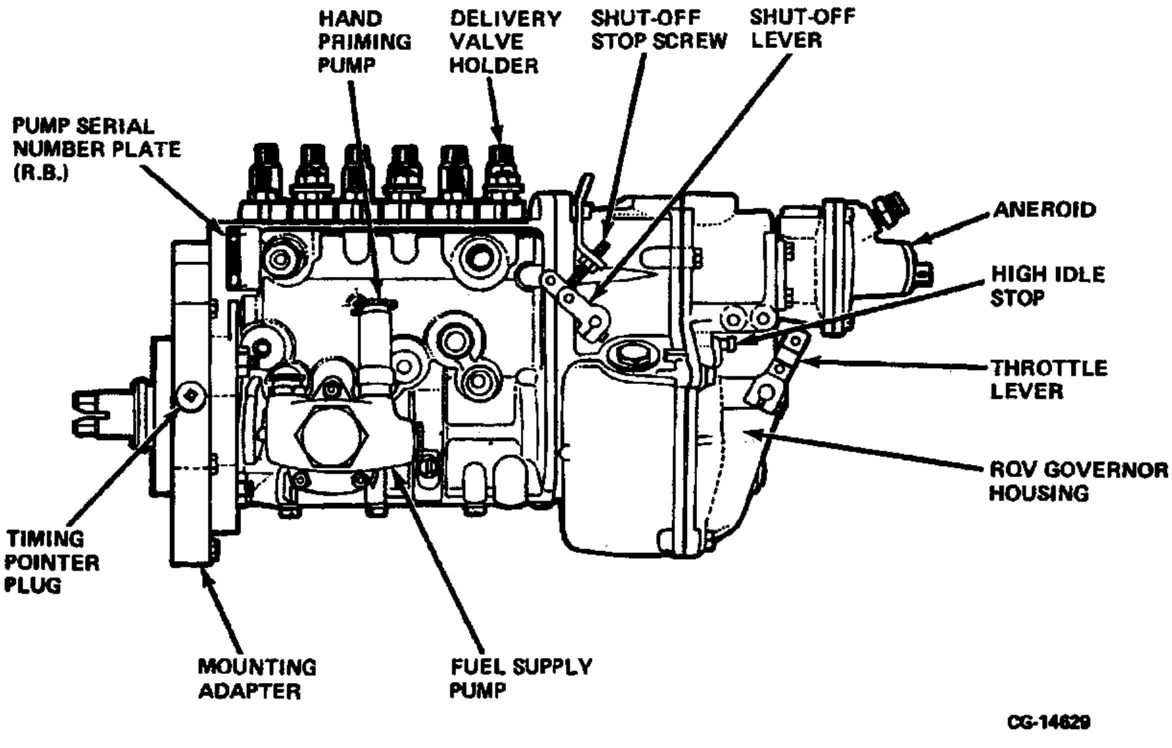

Figure 11.52. Fuel Injection Pump (Model MW)

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

Remove the Injection Pump as Follows:

1. Using a 3/4 in. wrench, loosen the six fuel injection line nuts at the nozzles. Refer to **Figure 11.53.**

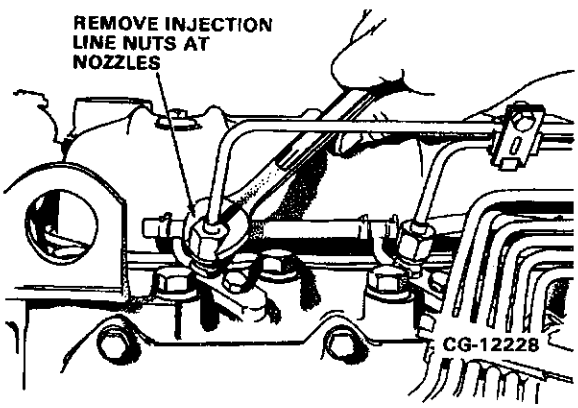

Figure 11.53. Remove Injection Line Nuts at Nozzles

2. Loosen and remove the fuel injection line nuts at the pump. Refer to **Figure 11.54.**

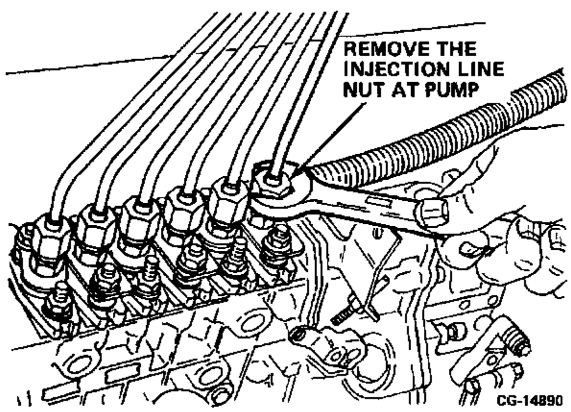

Figure 11.54. Remove Injection Line Nuts at Pump

3. Remove the fuel injection lines as an assembly. Refer to **Figure 11.55.**

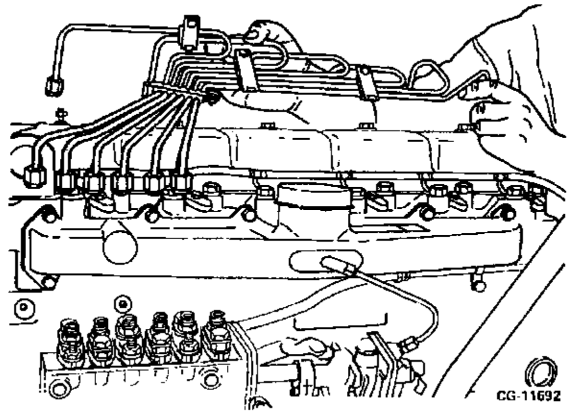

Figure 11.55. Remove Fuel Injection Lines as an Assembly

IMPORTANT

CAP ALL FUEL INJECTION LINES, DISCHARGE FITTING AT THE PUMP AND NOZZLE INLETS WITH PLASTIC CAPS. DO NOT USE TAPE. TAPE COLLECTS DIRT AND LEAVES A GUMMY RESIDUE ON MATING SURFACES. REFER TO FIGURES 11.56. THROUGH 11.58.

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

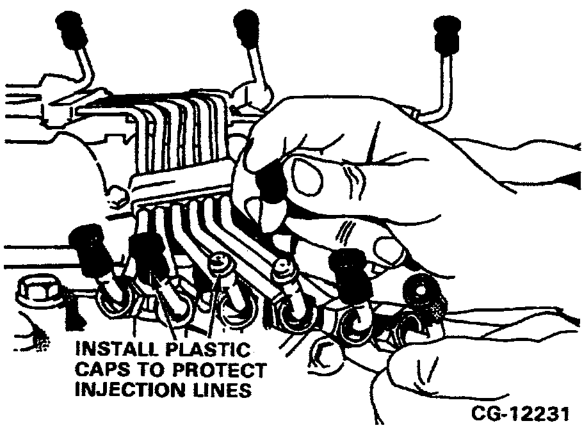

Figure 11.56. Cap Injection Lines

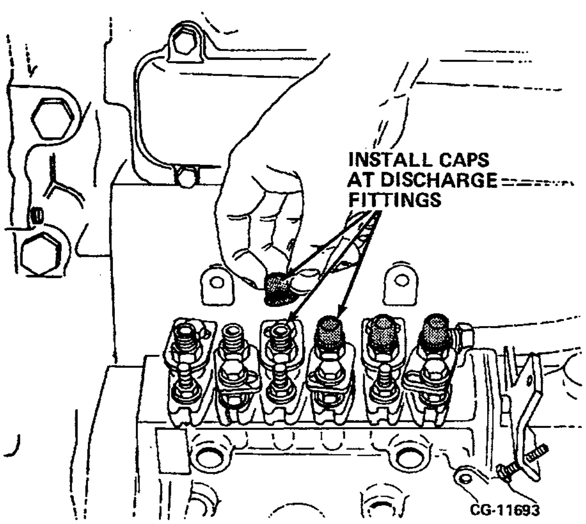

Figure 11.57. Cap Pump Discharge Fittings

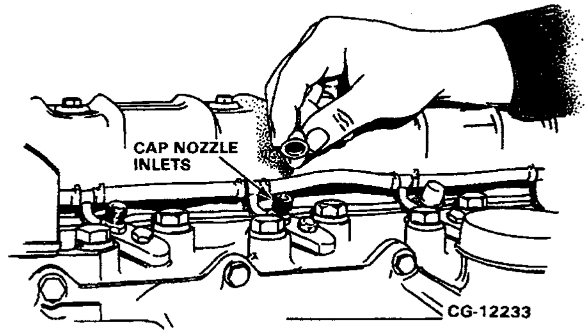

Figure 11.58. Cap Nozzle Inlets

4. Remove the aneroid tube as follows: (Refer to **Figure 11.59**)
   a. Remove the connecting nuts at the pump aneroid and at the intake manifold elbow.
   b. Remove the rubber sealing sleeves at each end and discard.
   c. Cap the openings at the aneroid and the intake manifold.

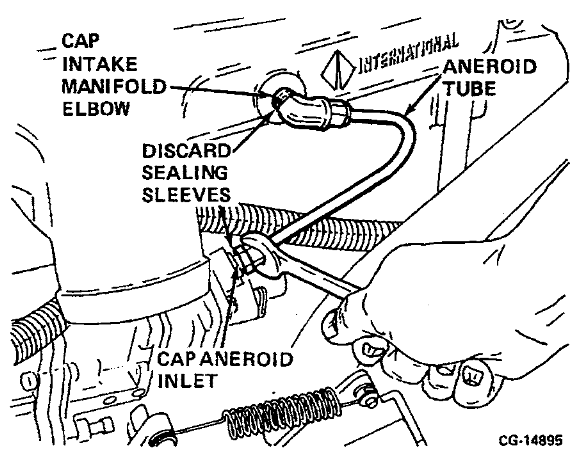

Figure 11.59. Remove Aneroid Tube

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

5. Remove the supply pump fuel inlet (fuel block to supply pump) tube assembly as follows: (Refer to **Figure 11.60**)
   a. Remove the hollow screw and copper sealing gaskets at the supply pump banjo fitting.
   b. Remove the bolt and washer at the fuel block.
   c. Remove the tube assembly and cap the opening at the supply pump inlet.

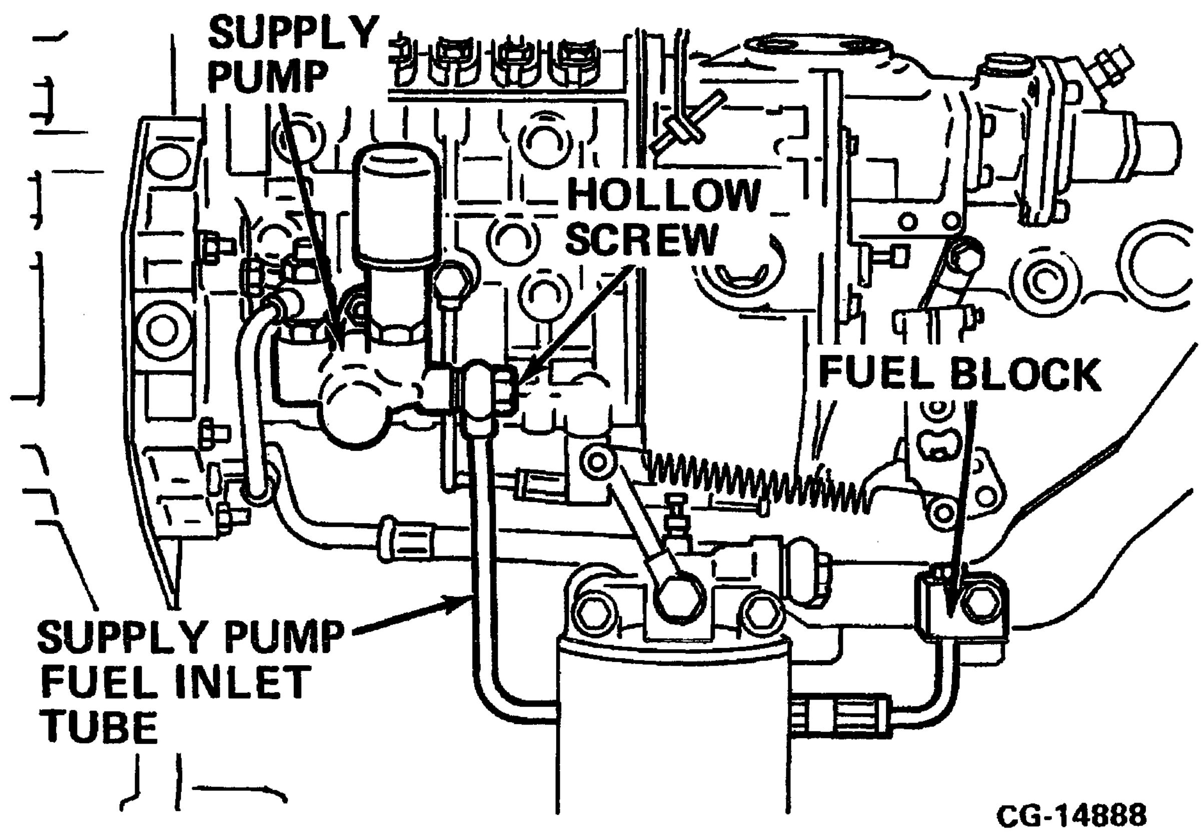

Figure 11.60. Remove the Supply Pump Fuel Inlet Tube Assembly

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

6. Remove the fuel filter inlet (supply pump to fuel filter) tube as follows: (Refer to **Figure 11.61**)
   a. Remove the hollow screw and copper sealing gaskets at the fuel filter header.
   b. Remove the hollow screw(with bleed screw) and copper sealing gaskets at the supply pump banjo fitting.
   c. Remove the tube assembly and cap the fuel filter header and supply pump openings.

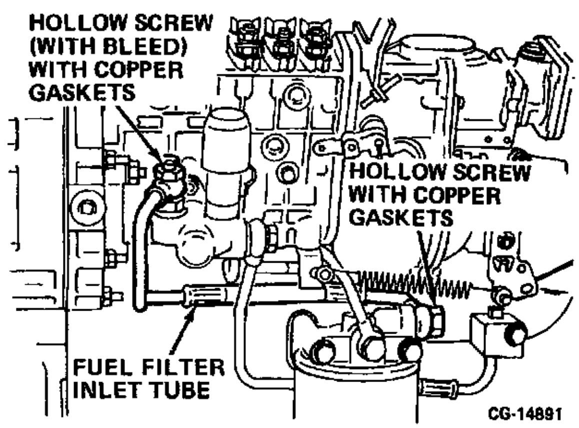

Figure 11.61. Remove Fuel Filter Inlet Tube

7. Remove the upper and lower throttle return springs. Refer to **Figure 11.62**.

NOTE: The lower spring is a small diameter while the upper spring is a large diameter. Do <u>NOT</u> switch spring location during reassembly.

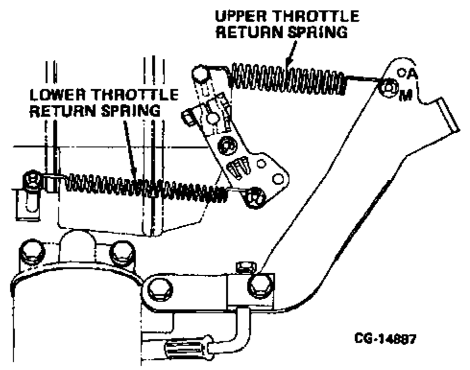

Figure 11.62. Remove Upper and Lower Throttle Return Springs

8. Remove the injection pump supply (filter header to injection pump) tube assembly as follows: Refer to **Figure 11.63**.
   a. Remove the hollow screw and copper sealing gaskets at the supply pump banjo fitting.
   b. Remove the hollow screw and copper sealing gaskets at the injection pump inlet.
   c. Cap the injection pump inlet and fuel filter header outlet.

NOTE: Copper gaskets are used to seal the banjo fittings at each end of the fuel inlet tube.

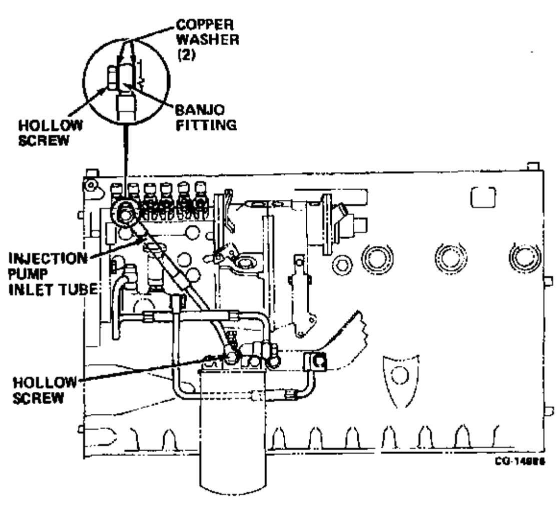

Figure 11.63. Remove Injection Pump Inlet Tube

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

9. Remove the fuel return line as follows:

STEP ONE — Refer to **Figure 11.64**

a. Disconnect the fuel leak–off hose from the return tube leak–off tee using pliers.

b. Remove the intake manifold stud bolt nut and hose clamp (at the #6 cylinder, bottom hole position).

STEP TWO — Refer to **Figure 11.64**

a. Remove the hex head hollow screw and washers from the fuel return tube banjo fitting at the fuel injection pump.

b. Remove the fuel return line as an assembly. Keep the hardware together to facilitate reassembly.

c. Cap the fuel return inlet at the pump.

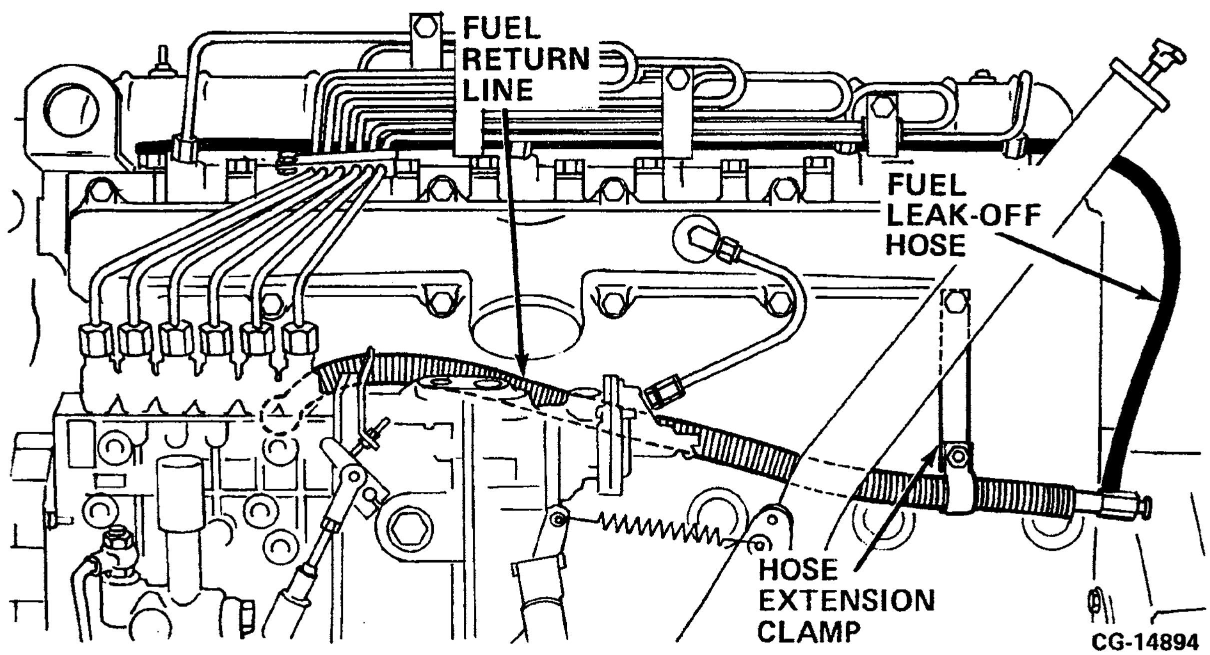

Figure 11.64. Fuel Return Tube Removal

FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

10. Remove the lube oil supply line as follows: (Refer to **Figure 11.65**)

    a. Loosen and remove the compression nut at the crankcase elbow.

    b. Remove the hex head hollow screw and copper gaskets from the banjo fitting at the fuel injection pump oil inlet.

    c. Remove the tube assembly and discard the sealing sleeve at the compression nut end of the tube.

    d. Cap the pump oil inlet and the elbow at the crankcase.

NOTE: IF THE FUEL INJECTION PUMP IS EQUIPPED WITH AN ELECTRIC SHUTOFF SOLENOID, DISCONNECT THE HARNESS FROM THE PACKARD CONNECTOR AT THE SOLENOID, PRIOR TO INJECTION PUMP REMOVAL.

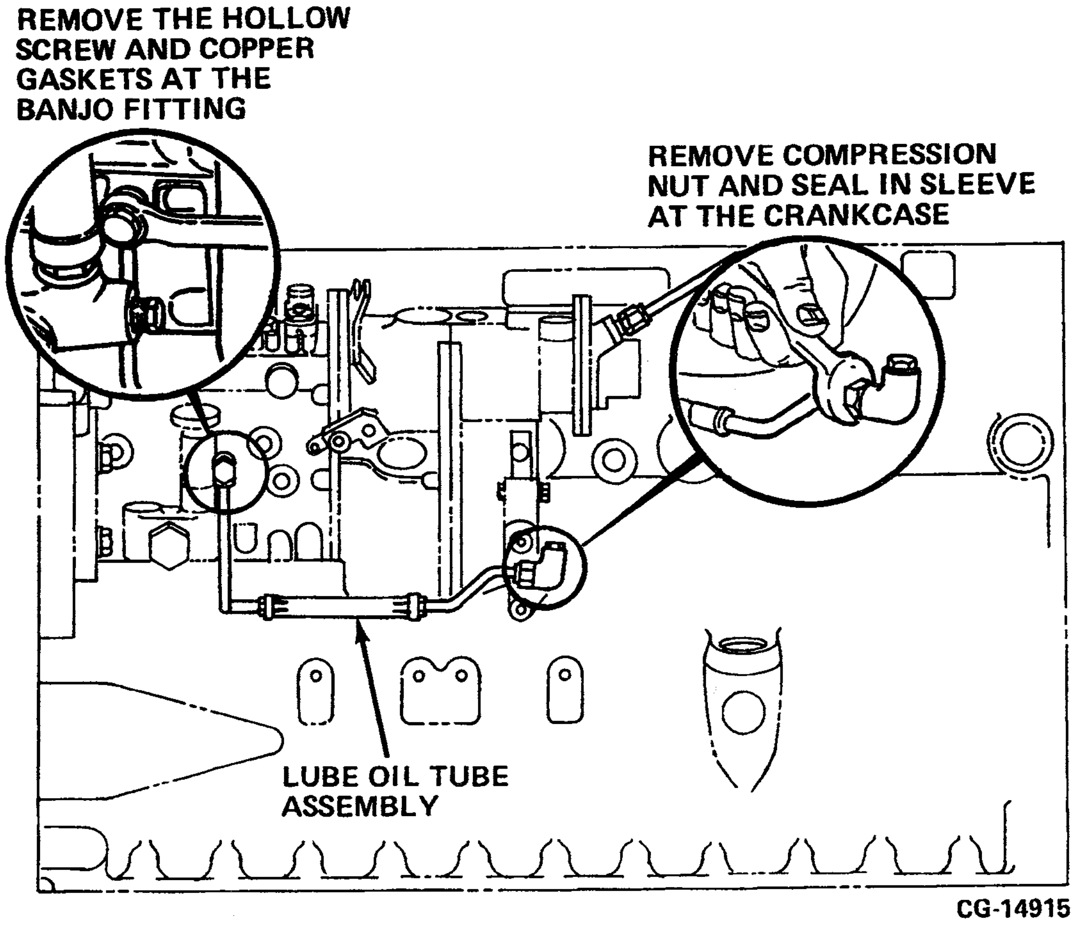

Figure 11.65. Remove Lube Oil Supply Line

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

11. Remove the injection pump drive gear access cover as follows:
   a. Loosen and remove the six fasteners which secure the access cover. Refer to **Figure 11.66**.

NOTE: Three thru bolts and nuts with washers secure the access cover to the injection pump adapter housing and three bolts with washers secure the access cover to the housing casting.

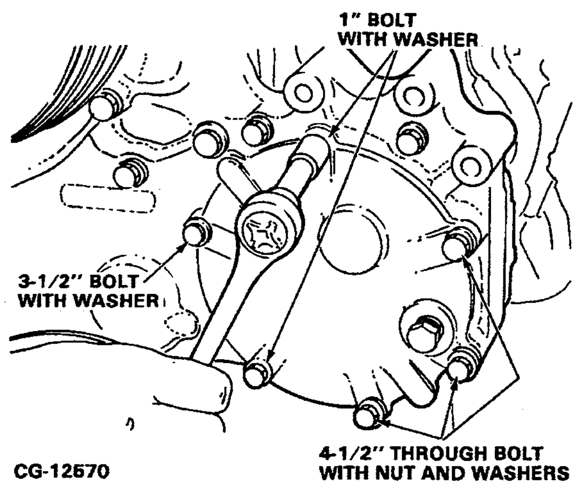

Figure 11.66. Remove Injection Pump Drive Gear Access Cover Bolts

   b. Remove the access cover and gasket from the front cover to expose the injection pump drive gear. Discard the gasket. Refer to **Figure 11.67**.

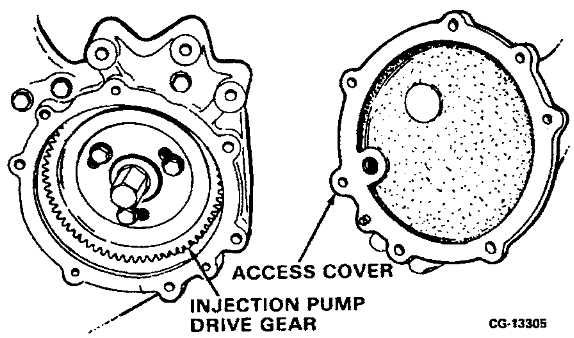

Figure 11.67. Remove Access Cover

FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

12. Remove the injection pump drive gear bolts and hardened washers. Refer to **Figure 11.68.**

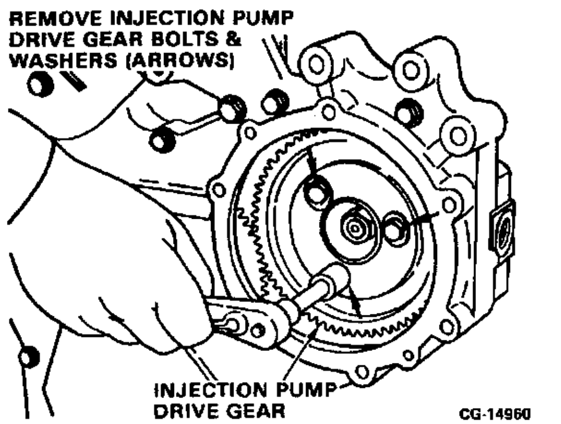

Figure 11.68. Remove Injection Pump Drive Gear Bolts

NOTE: The injection pump and adapter assembly can be removed without removing the injection pump drive gear. Drive gear removal is shown at this time for procedural purposes only.

13. Remove the injection pump drive gear from the pump hub. Refer to **Figure 11.69.**

NOTE: The polished side of the drive gear faces the hub.

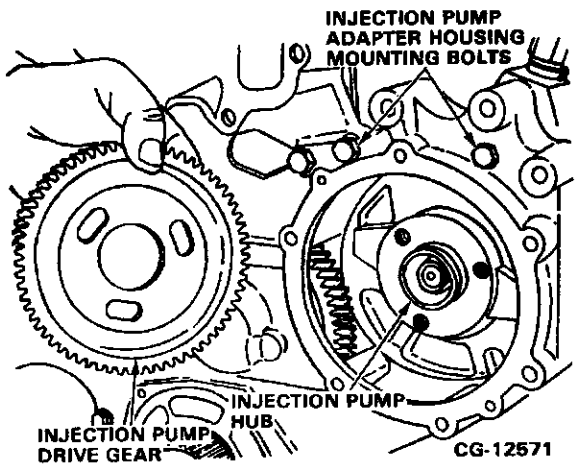

Figure 11.69. Remove the Injection Pump Drive Gear

14. Remove the two adapter housing bolts which go through the front cover. Refer to **Figure 11.69.**
15. Remove the adapter housing bolt and washer located at the bottom/rear (in–board) side of the adapter housing. Refer to **Figure 11.70.**

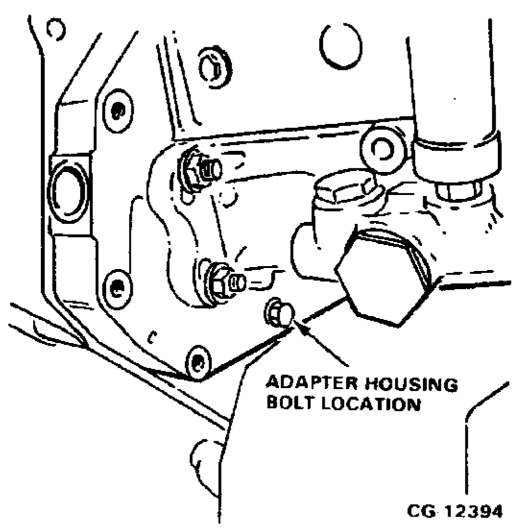

Figure 11.70. Remove Bottom/Rear (In–Board) Adapter Housing Bolt

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

16. Remove the injection pump and mounting adapter as an assembly. Discard the gasket. Refer to **Figure 11.71**.

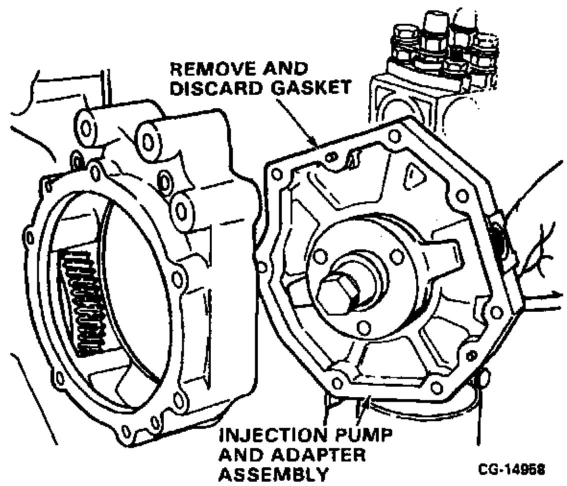

Figure 11.71. Remove Injection Pump Assembly

NOTE: Dowels on the adapter housing hold the pump assembly to the front cover.

IMPORTANT

IF THE FUEL INJECTION PUMP MOUNTING ADAPTER IS REMOVED FROM THE PUMP TO PERFORM REPAIRS, REINSTALL THE ADAPTER WITH THE FACTORY SET SCRIBE MARKS ALIGNED ONLY AFTER THE PUMP IS FLOW-TIMED. IF THE FUEL INJECTION PUMP MOUNTING ADAPTER IS REMOVED FROM THE PUMP AND A NEW ADAPTER IS INSTALLED, THE PUMP MUST BE FLOW-TIMED. AFTER FLOW TIMING, STRIKE A NEW MARK ON THE REPLACEMENT MOUNTING ADAPTER TO ALIGN WITH THE SCRIBE MARK LOCATED ON THE INBOARD SIDE OF THE PUMP MOUNTING FLANGE. (REFER TO FIGURE 11.72). REFER TO ROBERT BOSCH FUEL INJECTION PUMP SERVICE MANUAL FORM CGES-375 FOR FLOW TIMING PROCEDURES FOR MW INJECTION PUMPS.

NOTE: Dowels on the adapter housing hold the pump assembly to the front plate.

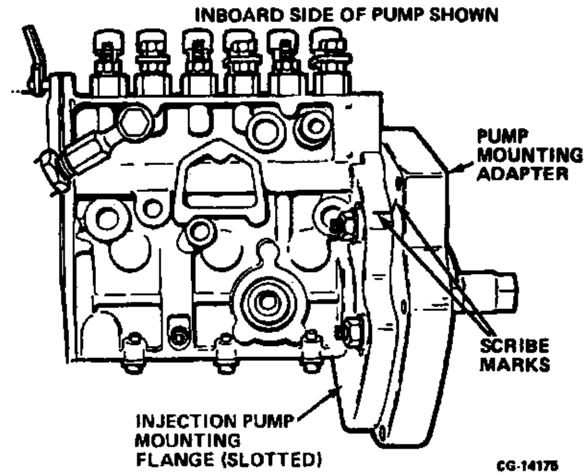

Figure 11.72. Mounting Adapter Installation

Fuel Filter Header and Throttle Linkage Assembly

1. Using an appropriate filter wrench, remove the fuel filter from the header and discard.
2. Loosen and remove the two mounting bolts which secure the fuel filter header to the crankcase, then remove the header. Refer to **Figure 11.73.**

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REMOVAL — Continued

Fuel Filter Header and Throttle Linkage Assembly — Continued

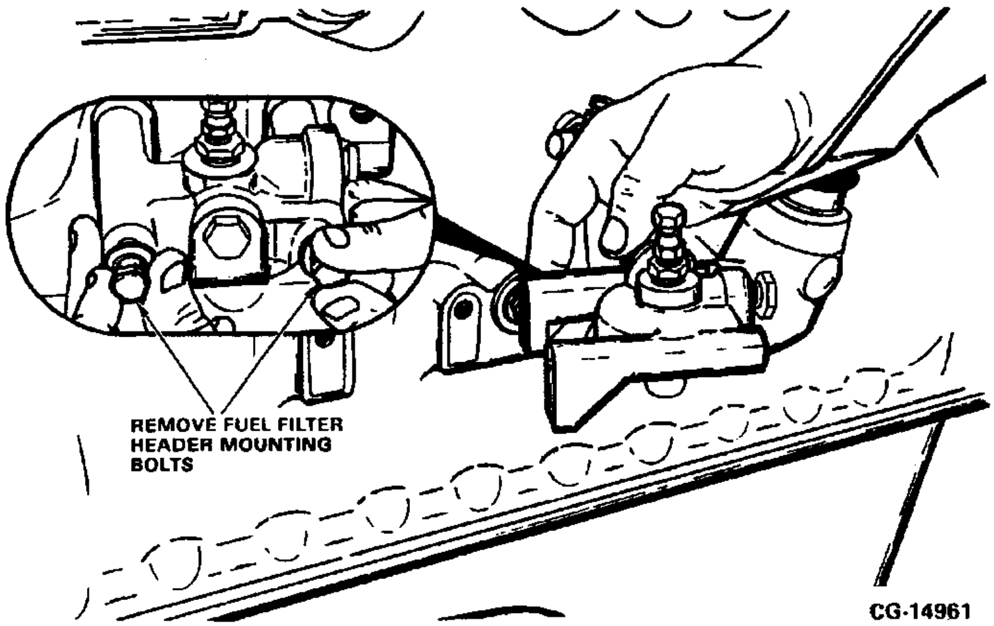

Figure 11.73. Remove Fuel Filter Header

3. Remove the throttle cable bracket assembly from the crankcase. Refer to **Figure 11.74**.

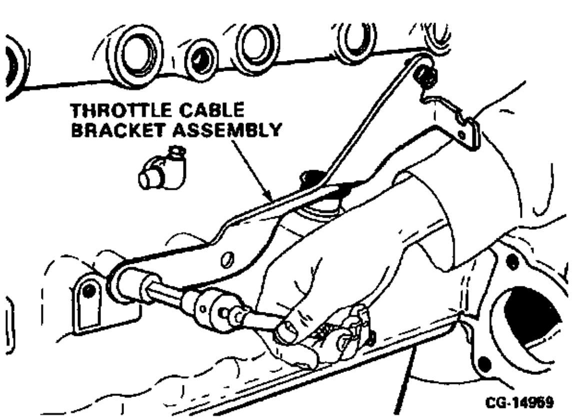

Figure 11.74. Remove the Throttle Cable Bracket Assembly

FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY

1. Install the injection pump and adapter housing assembly to the engine front cover plate using a new adapter housing gasket. Refer to **Figure 11.75.**

NOTE: Adapter housing dowel pins will align the gasket and the adapter housing to the engine front plate.

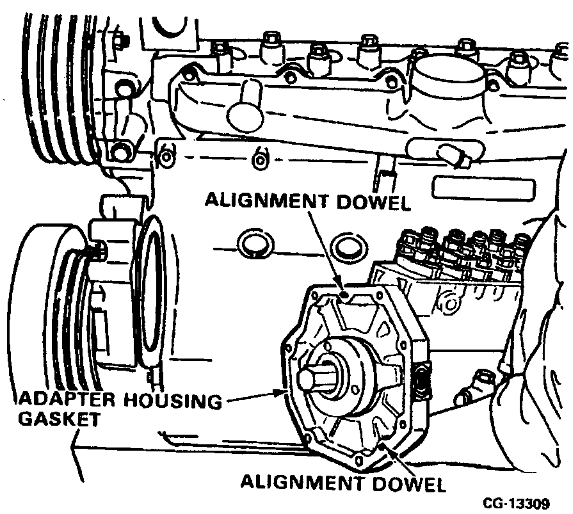

Figure 11.75. Install Injection Pump and Adapter Housing Assembly to the Front Plate

2. Tighten the adapter housing bolts (depicted in **Figures 11.69 and 11.70**) to the specified special torque (see "**SPECIFICATIONS**").
3. Install the injection pump drive gear as follows:
   a. **IMPORTANT! Verify that the engine #1 cylinder is on the compression stroke (TDC). Also verify static timing by checking the timing pointer and degree marks on the damper pulley. Refer to "Set Injection Pump to Engine Timing Prior to Pump Removal", in this section for a detailed procedure.**
   b. Loosely install the injection pump drive gear to the injection pump drive hub. DO NOT TIGHTEN BOLTS. Refer to **Figure 11.76.**

NOTE: Position bolts in the center of the kidney slot.

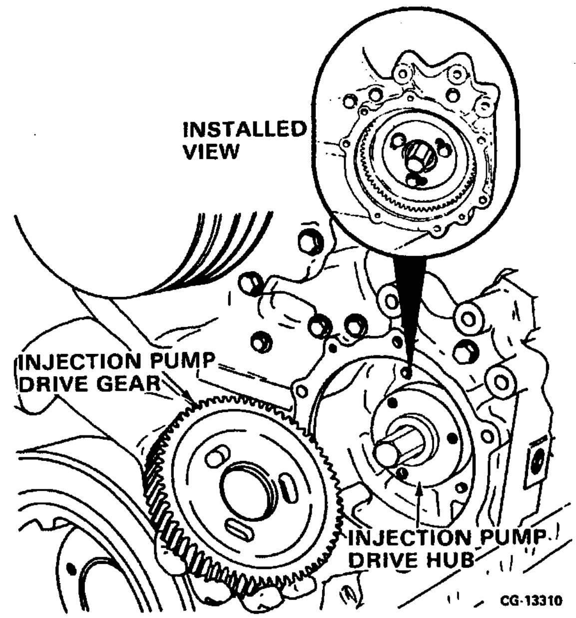

Figure 11.76. Install Injection Pump Drive Gear

   c. Verify the alignment of the injection pump timing pointer to the drive hub scribe line through the adapter housing sight plug. Refer to **Figure 11.77**. Rotate the pump hub as required for proper alignment.
   d. Tighten the three pump drive gear mounting bolts to the specified "**SPECIAL TORQUE**".

IMPORTANT

BE SURE THE TIMING POINTER AND SCRIBE LINE ARE STILL ALIGNED AFTER THE BOLTS ARE TIGHTENED.

   e. Reinstall sight plug using a new copper gasket.

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

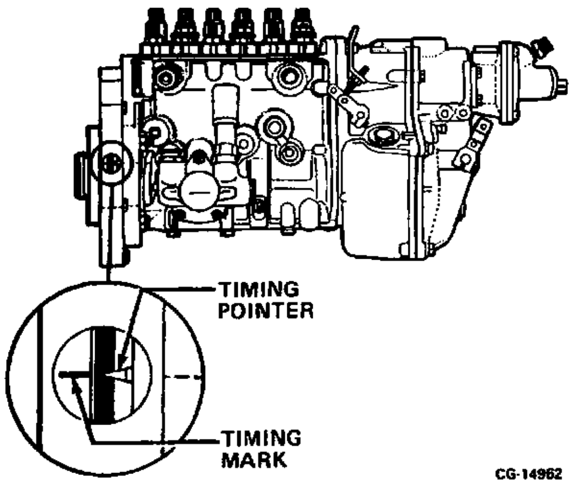

Figure 11.77. Injection Pump Timing Marks

4. Install the injection pump drive gear access cover using a new gasket as follows (Refer to **Figure 11.78.**):

   a. Secure the three bolts and washers which fasten into the front cover casting. Tighten to the standard torque. See Appendix.

   b. Secure the bolts, washers and nuts which mount through the access cover, front cover and adapter housing. Tighten to the standard torque. See Appendix.

   c. Tighten the fasteners to the standard torque. See Appendix.

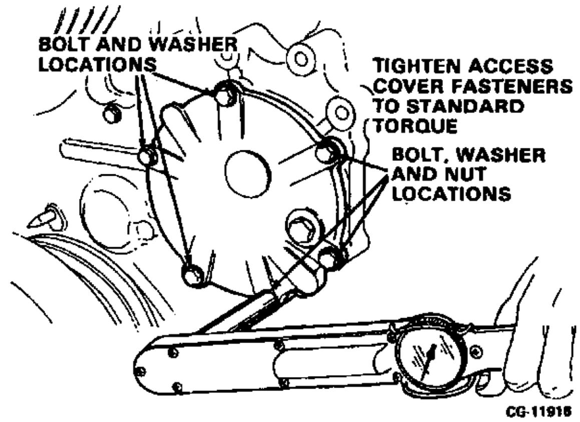

Figure 11.78. Install Injection Pump Drive Gear Access Cover

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

5. Install the fuel return line as follows:

NOTE: Mount the fuel return tube clamp at the #6 cylinder bottom intake manifold bolt.

a. Remove protective cap from pump at fuel return outlet.

b. Install the clamp, washers, spacers and fuel return tube. Tighten the "patch" stud bolts to the specified special torque. Refer to **Figure 11.79**.

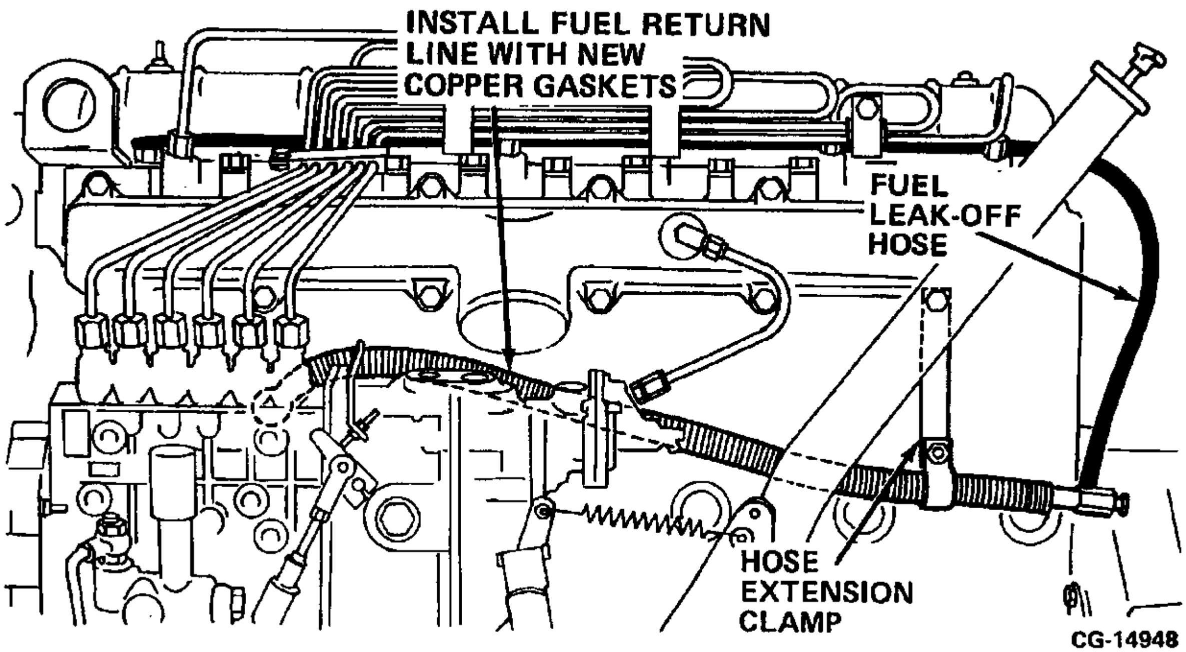

Figure 11.79. Fuel Return Tube and Clamp Installation

c. Reconnect the fuel return tube to the pump using the hollow screw and new copper gaskets at the banjo fitting. Refer to **Figure 11.79**. Tighten the hollow screw to the specified special torque.

d. Reconnect the fuel leak–off hose to the return tube tee.

FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

6. Install the lube oil supply line as follows: (Refer to **Figure11.80**)
   a. Remove the protective caps at the crankcase oil outlet elbow and the pump oil inlet.
   b. Install a new rubber sealing sleeve at the compression nut end of the tube.
   c. Fasten the tube to the crankcase oil outlet tube and tighten the nut.
   d. Using new copper gaskets, fasten the banjo fitting to the pump oil inlet with the hollow screw to the specified special torque.

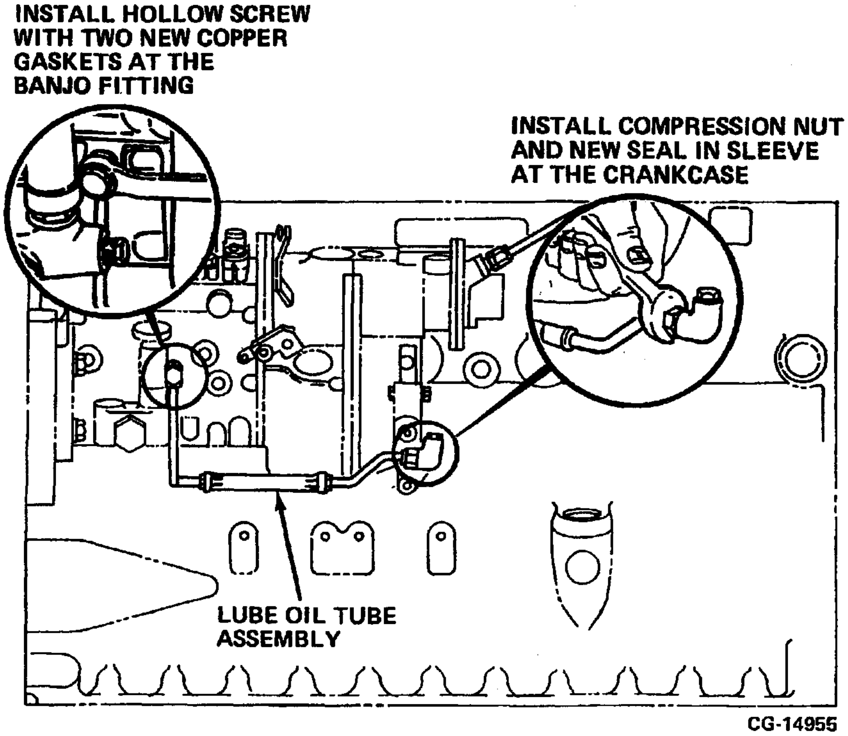

Figure 11.80. Install Lube Oil Supply Line

FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

7. Install the fuel filter header as follows: (Refer to **Figure 11.81**)
   a. Mount the header at the crankcase mounting pad. Fasten the header using the two mounting bolts and washers.
   b. Tighten the fasteners to the standard torque. See Appendix.

NOTE: Be sure to install the lower throttle return spring bracket on the mounting bolt which faces the front of the engine.

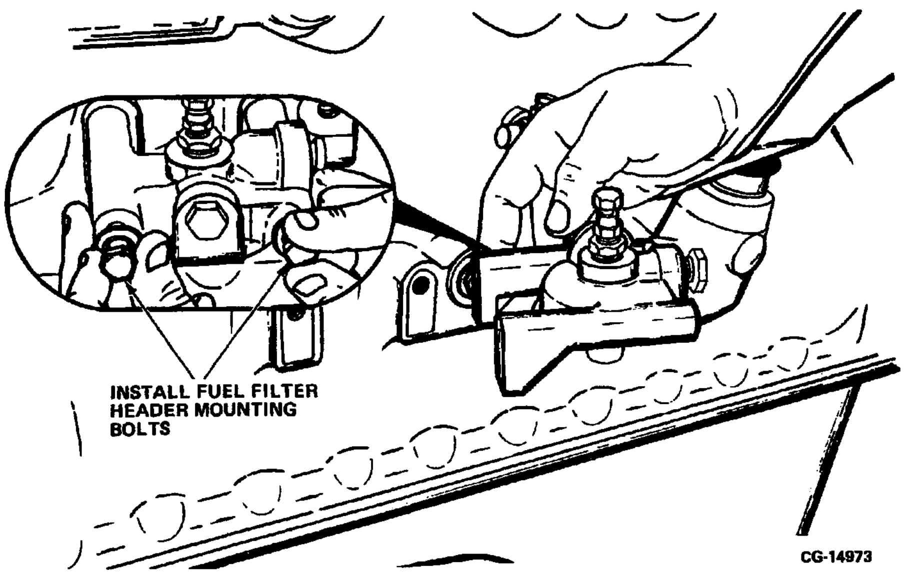

Figure 11.81. Install Fuel Filter Header

8. Install the injection pump fuel supply (filter header to injection pump) tube assembly as follows: (Refer to **Figure 11.82.**)

NOTE: Remove protective cap at the fuel injection pump and fuel filter header prior to installation.

   a. Connect the banjo fitting at the supply pump using the hollow screw and new copper gaskets.
   b. Connect the hollow screw with the built–in bleed screw at the injection pump fuel inlet using new copper gaskets.
   c. One copper gasket is installed on each side of the banjo fittings and the hollow screws are to be tightened to the special specied torque.

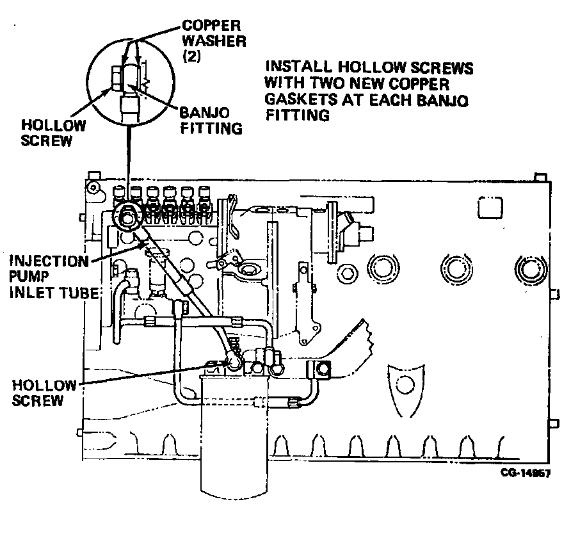

Figure 11.82. Install Injection Pump Inlet Tube

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

9. Install the fuel filter inlet (supply pump to fuel filter) tube as follows: (Refer to **Figure 11.83.**)
   a. Remove the protective caps from the fuel filter header and supply pump inlet.
   b. Connect the banjo fitting at the supply pump using the hollow screw (with bleed screw) and new copper gaskets.

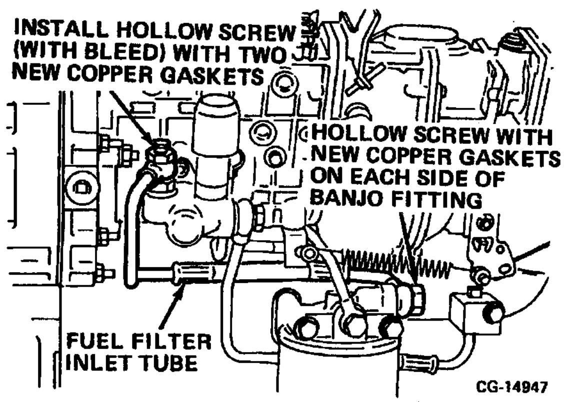

Figure 11.83. Install Fuel Inlet Tube (Fuel Filter to Supply Pump)

   c. Connect the banjo fitting at the fuel filter header using the hollow screw and copper sealing gaskets on each side of the fitting.
   d. Torque each hollow screw to the specified special torque.

NOTE: Use one new copper gasket on each side of the banjo fitting.

10. Install the supply pump fuel inlet (fuel block to supply pump) tube assembly as follows: (Refer to **Figure 11.84.**)
    a. Remove protective cap from supply pump inlet.
    b. Install the hollow screw and copper sealing gaskets at the supply pump banjo fitting. Tighten the hollow screw to the specified special torque.
    c. Install the bolt and washer at the fuel block. Tighten the fastener to the standard torque (see Appendix).

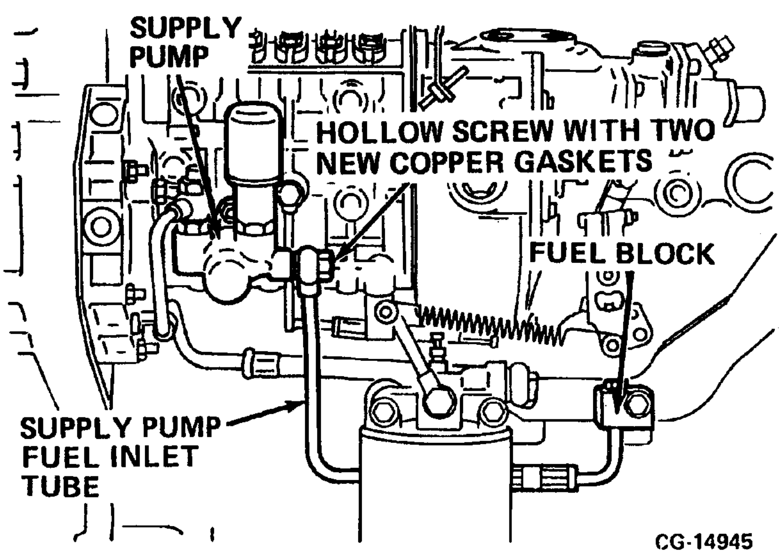

Figure 11.84. Install the Supply Pump Fuel Inlet Tube Assembly

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

11. Install the fuel injection line assembly as follows:

IMPORTANT

PRIOR TO INSTALLING THE FUEL INJECTION LINE ASSEMBLY, CLEAN WITH FILTERED COMPRESSED AIR AND VISUALLY INSPECT FOR CONTAMINATION OR DAMAGE. REPLACE AS REQUIRED.

a. Remove the protective caps from the lines, nozzles and delivery valve holders at the pump.

b. Install the connector nuts at the nozzles using a 3/4 in. "Crow Foot" socket, as shown in **Figure 11.85.** Tighten each nut to the specified **"SPECIAL TORQUE"**.

NOTE: Injection line fittings at the pump and nozzle are frequently over tightened due to the fitting size 3/4 inch. This swedges the injection line, often partly closing the ends. This alters fuel delivery characteristics, raises injection line pressures and may cause performance problems or injection pump failure. Visually inspect the ends of the injection lines and replace any with swedged or damaged fittings or holes.

c. Tighten the fuel injection line connecting nuts to the delivery valve holders at the pump. Tighten to the specified **"SPECIAL TORQUE"** using a 3/4 in. "Crow Foot" wrench at the connector nut. Refer to **Figure 11.86.**

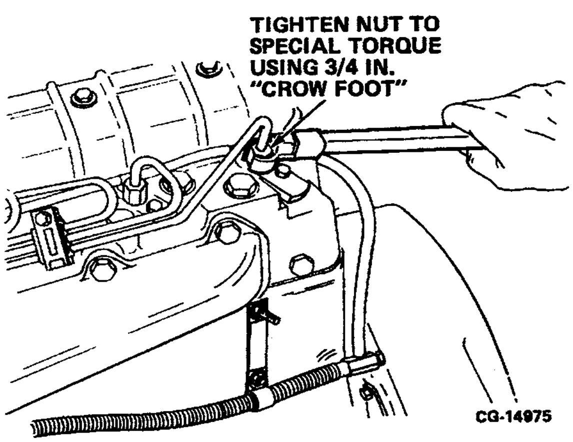

Figure 11.85. Install Injection Line Connector Nuts to each Nozzle

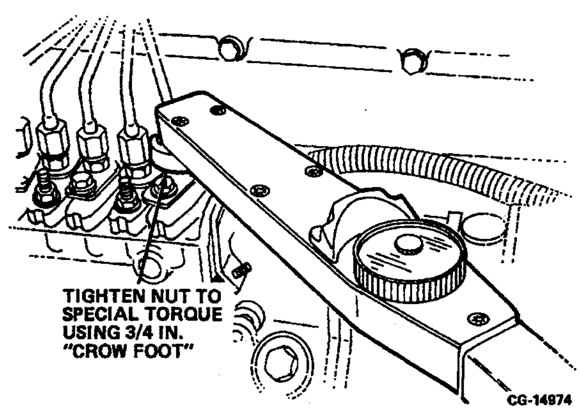

Figure 11.86. Install Injection Line Connector Nuts to the Pump Delivery Valve Holders

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

12. Install the aneroid tube as follows:

   a. Remove the protective caps from the intake manifold elbow and the aneroid.

   b. Install new rubber sealing sleeves at each end of the aneroid tube.

   c. Tighten the connecting nuts at each end of the tube as shown in **Figure 11.87**.

IMPORTANT

REUSE OF OLD SEALING SLEEVES CAN CAUSE LEAKAGE, AFFECTING ANEROID OPERATION.

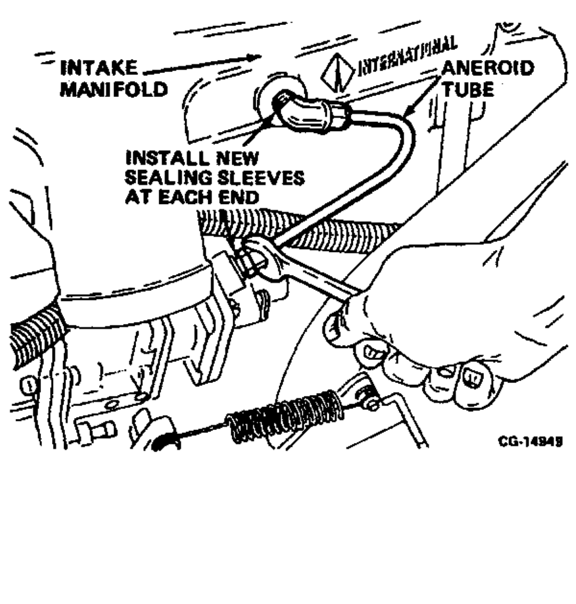

Figure 11.87. Install Aneroid Tube

13. Mount the throttle lever return spring bracket to the crankcase using the two mounting bolts and washers. Refer to **Figures 11.88.**

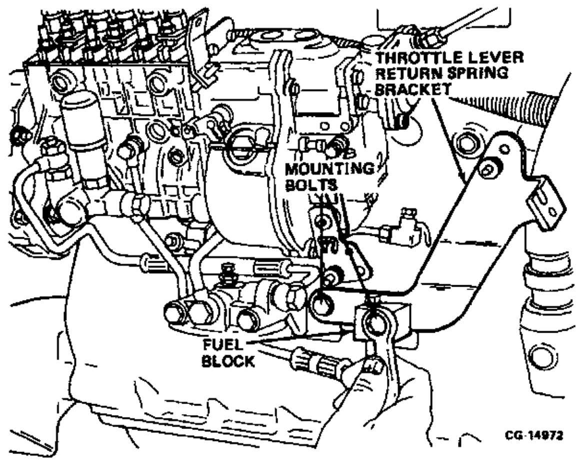

Figure 11.88. Install Throttle Lever Return Spring Bracket

14. Connect the throttle return springs as shown in Figure 11.89.

IMPORTANT

THE LARGE DIAMETER SPRING MUST BE INSTALLED IN THE TOP POSITION WHILE THE NARROW DIAMETER SPRING IS INSTALLED IN THE LOWER POSITION. DO NOT INTERMIX SPRINGS! THIS APPLIES TO BOTH CURRENT AND EARLY PRODUCTION MODELS.

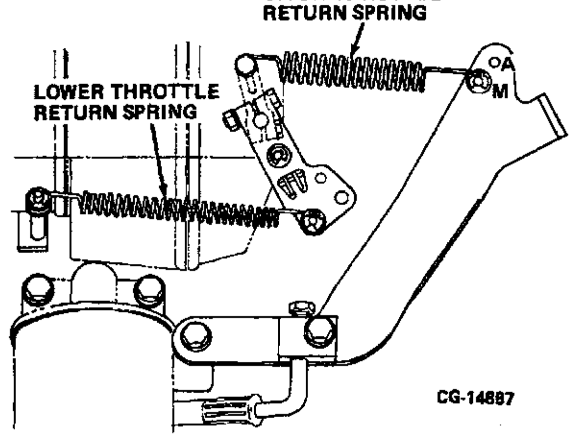

Figure 11.89. Install the Throttle Return Springs

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FUEL INJECTION PUMP — Continued

WITH MODEL MW PUMP EFFECTIVE WITH ENGINE S/N 90976

REASSEMBLY — Continued

NOTE: Refer to CGES–445–* (DT/DTA–360 Diesel Engine Diagnostic Manual) for throttle linkage inspection and/or adjustment procedures.

15. Install a new fuel filter as follows: (Refer to **Figure 11.90**)
    a. Lubricate the filter gasket with clean diesel fuel.
    b. Tighten until the gasket touches the filter header.
    c. Tighten by hand an additional 1/2 turn.

NOTE: Do not add fuel to the new filter.

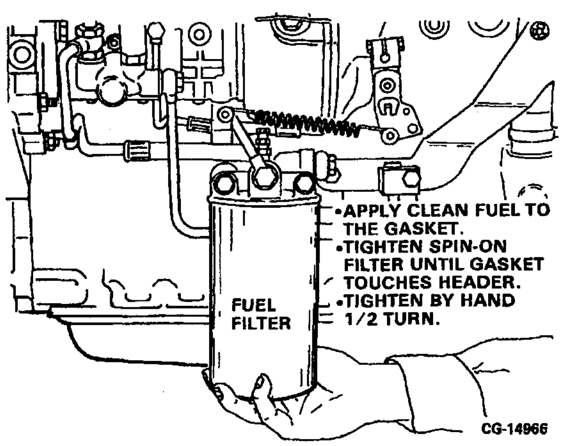

Figure 11.90. Install a New Fuel Filter

16. Install throttle cable linkage to the control lever and adjust linkage as specified in the current DT/DTA–360 operation and maintenance manual.
17. Connect electric shut–off harness connector to the packard connector on the ESO solenoid, if equipped.

PRIMING FUEL INJECTION SYSTEM

After replacing fuel injection pump or replacing fuel supply lines, prime fuel system using these procedures: (Refer to **Figure 11.90.A.**)

1. Loosen fuel bleed screw located on plunger type hand priming pump.
2. Operate plunger type hand priming pump until pump action provides solid fuel at the bleed screw. Close bleed screw.
3. Loosen bleed screw on fuel filter header. Operate plunger type hand priming pump until pump action provides solid fuel at the filter header bleed screw. Close bleed screw.
4. Crank engine for fifteen seconds.
5. Start engine and operate until engine runs smoothly.

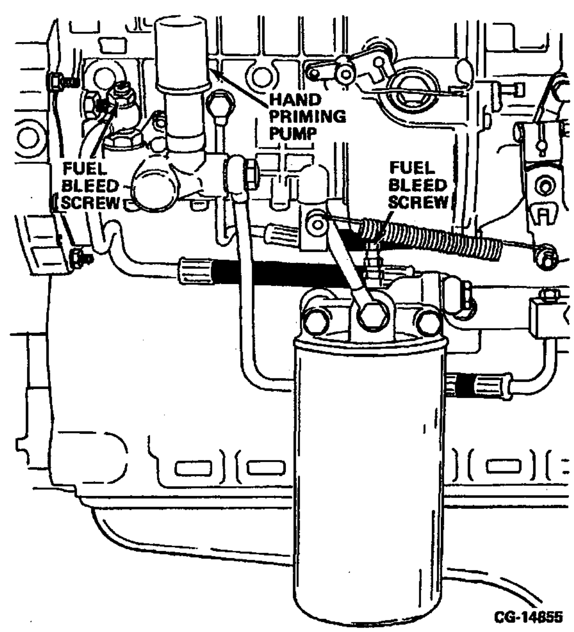

Figure 11.90.A. Priming Fuel Injection System

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

Remove the Injection Pump as Follows:

1. Using a 3/4 in. wrench, loosen the six fuel injection line nuts at the nozzles. Refer to **Figure 11.91.**

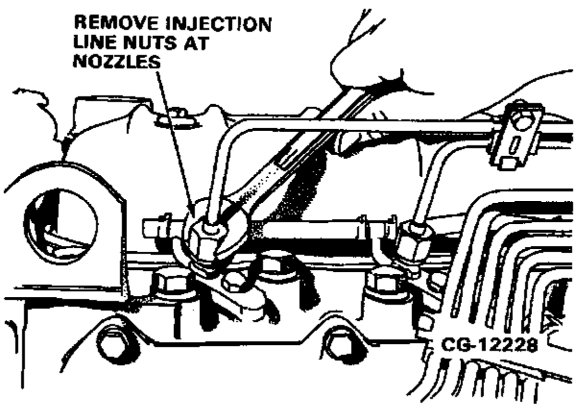

Figure 11.91. Remove Injection Line Nuts at Nozzles

2. Loosen and remove the fuel injection line nuts at the pump while holding the delivery valve holder with a modified 12 pt. 7/8 in. box wrench to prevent delivery valve movement (which could affect rack travel). Refer to **Figure 11.92.**

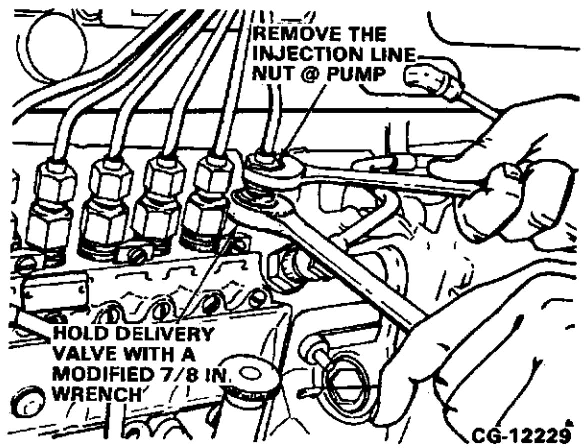

Figure 11.92. Remove Injection Line Nuts at Pump

NOTE: The 7/8 in. wrench used to hold the delivery valve must be modified by cutting a slot which allows it to pass over the fuel line. Refer to Figure 11.128 for details.

3. Remove the fuel injection lines as an assembly. Refer to **Figure 11.93.**

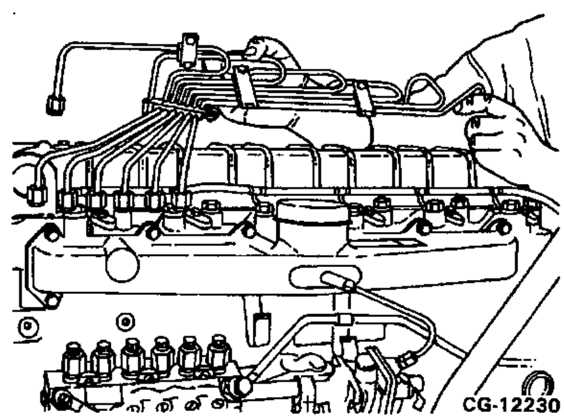

Figure 11.93. Remove Fuel Injection Lines as an Assembly

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

IMPORTANT

CAP ALL FUEL INJECTION LINES, DISCHARGE FITTING AT THE PUMP AND NOZZLE INLETS WITH PLASTIC CAPS. DO NOT USE TAPE. TAPE COLLECTS DIRT AND LEAVES A GUMMY RESIDUE ON MATING SURFACES. REFER TO FIGURES 11.94 THROUGH 11.96.

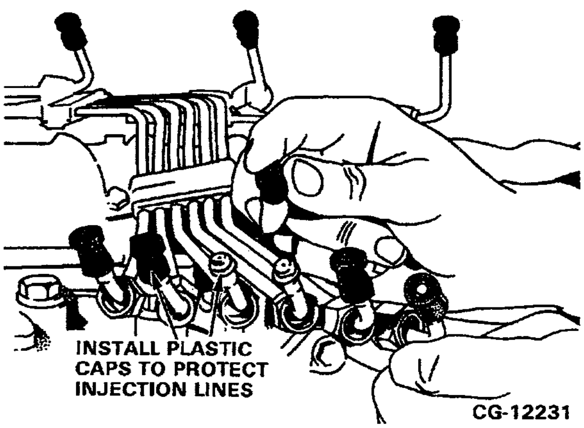

Figure 11.94. Cap Injection Lines

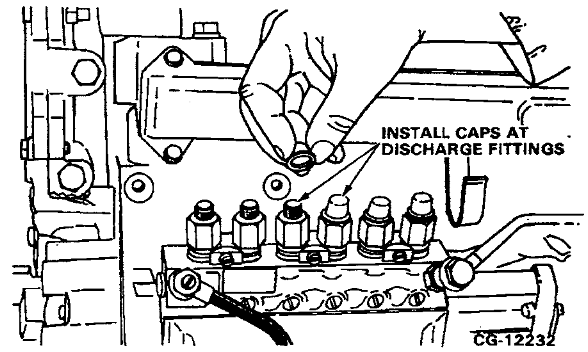

Figure 11.95. Cap Pump Discharge Fittings

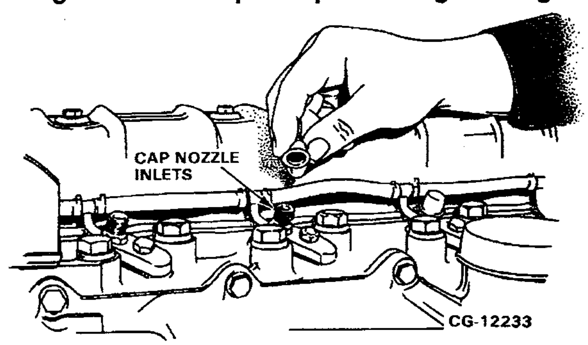

Figure 11.96. Cap Nozzle Inlets

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

4. Remove the aneroid tube as follows: (Refer to **Figure 11.97**)

   a. Remove the connecting nuts at the pump aneroid and at the intake manifold elbow.

   b. Remove the rubber sealing sleeves at each end and discard.

   c. Cap the openings at the aneroid and the intake manifold.

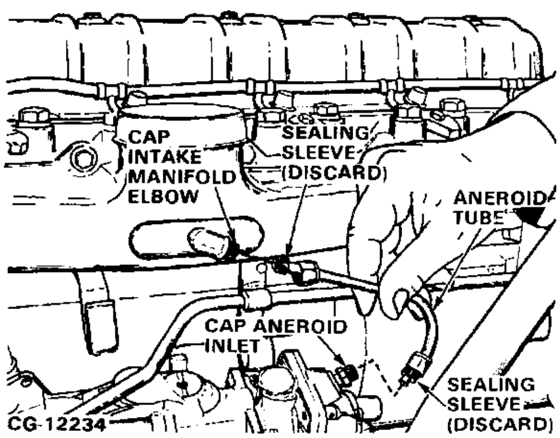


Figure 11.97. Remove Aneroid Tube

IMPORTANT

ANEROID TUBE ASSEMBLIES HAVE BEEN CHANGED TO ACCOMMODATE REVISED INTAKE MANIFOLD DESIGNS AND MODEL YEAR CHANGES. REFER TO FIGURE 11.98 FOR TYPICAL ARTWORK IDENTIFICATION. SERVICE PROCEDURES ARE THE SAME FOR ALL ANEROID TUBE ASSEMBLIES.

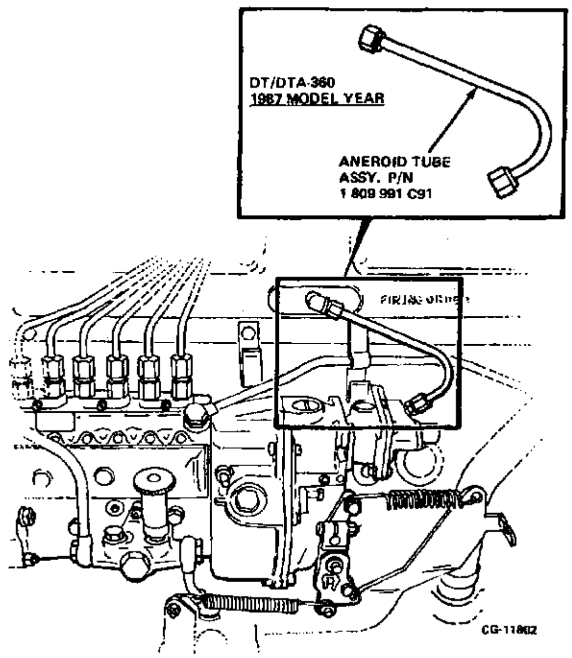


Figure 11.98. Aneroid Tube Assembly Identification

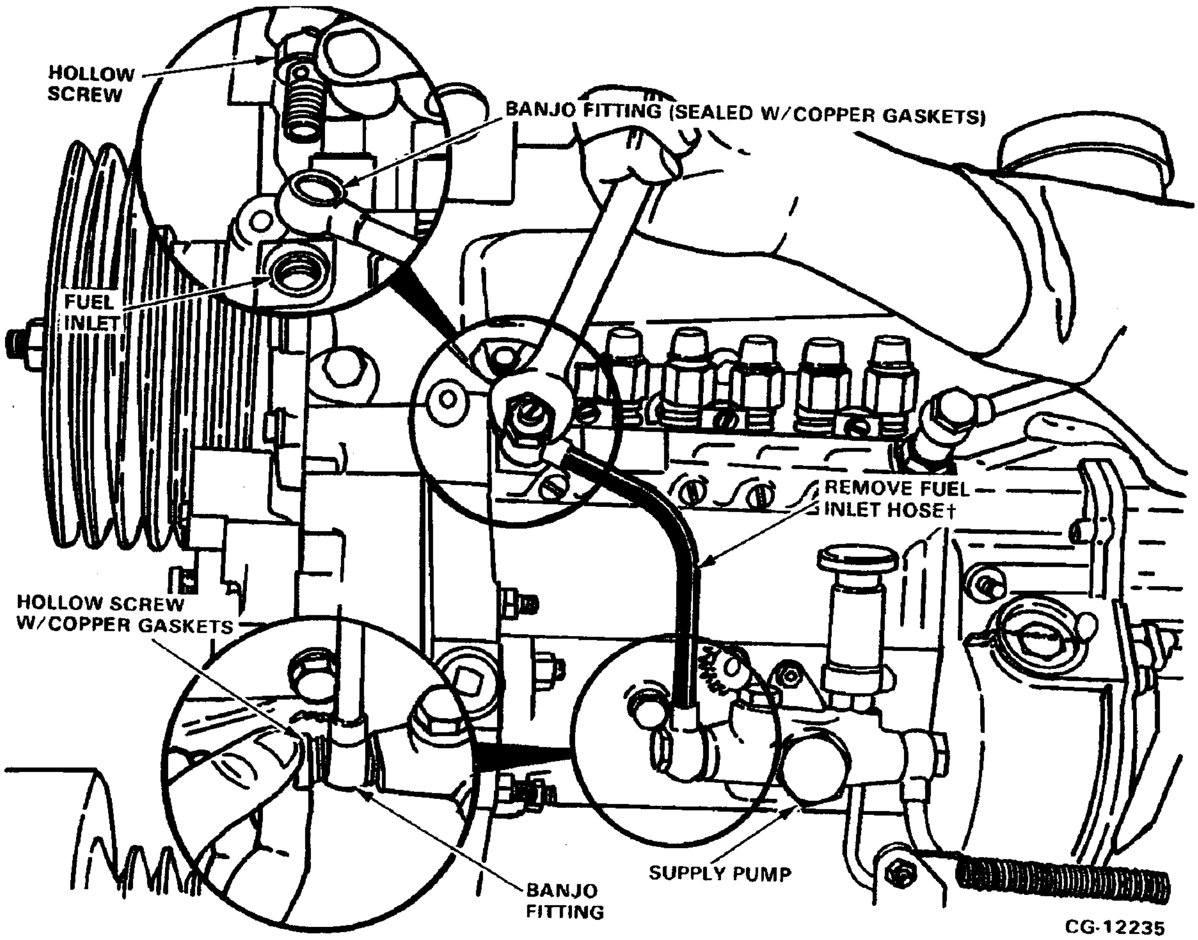
FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

5. Remove the fuel inlet (supply to injection pump) tube as follows: (Refer to **Figure 11.99**)
   a. Loosen and remove the hollow screw at the supply pump banjo fitting.
   b. Loosen and remove the hollow screw (with bleed screw) at the injection pump inlet.
   c. Cap the injection pump inlet and supply pump inlet.

NOTE: Copper gaskets are used to seal the banjo fittings at each end of the fuel inlet tube.



†CURRENT PRODUCTION FUEL INLET HOSE IS SHOWN. EARLY PRODUCTION USED A FUEL INLET TUBE.

Figure 11.99. Remove the Fuel Inlet Tube (1987 Model Year Engine Shown)

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

6. Remove the upper and lower throttle return springs. Refer to **Figures 11.100 and 11.101**.

NOTE: The lower spring is a small diameter while the upper spring is a large diameter. Do <u>NOT</u> switch spring location during reassembly.

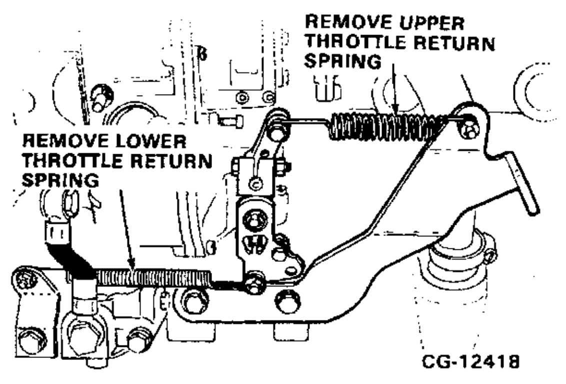

Figure 11.100. Remove Upper and Lower Throttle Return Springs (Current Production)

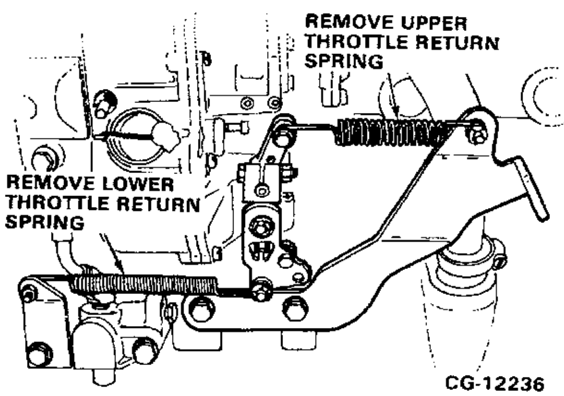

Figure 11.101. Remove Upper and Lower Throttle Return Springs (Early Production)

7. Remove the fuel inlet (fuel filter to supply pump) hose or tube as follows: (Refer to **Figures 11.102 and 11.103**)

(Current Production)

a. Remove the hollow screw and copper sealing gaskets at the fuel filter header.
b. Remove the hollow screw and copper sealing gaskets at the supply pump banjo fitting.
c. Remove the hose assembly and cap the fuel filter header and supply pump openings.

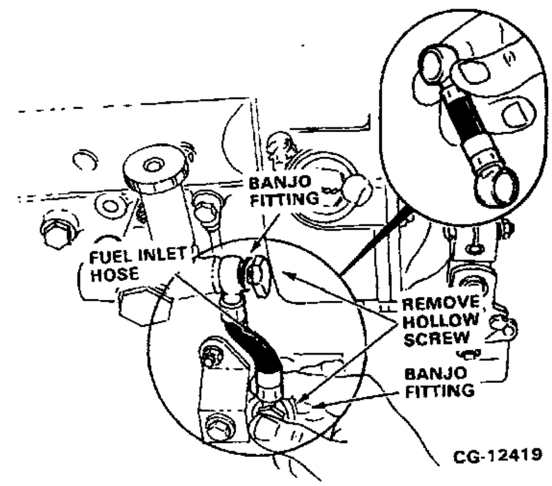

Figure 11.102. Remove Fuel Inlet Tube (Current Production)

(Early Production)

a. Loosen and remove the nut at the fuel filter header. Remove and discard the sealing sleeve from the inlet tube.
b. Remove the hollow screw and copper sealing gaskets at the supply pump banjo fitting.
c. Remove the tube assembly and cap the fuel filter header and supply pump openings.

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

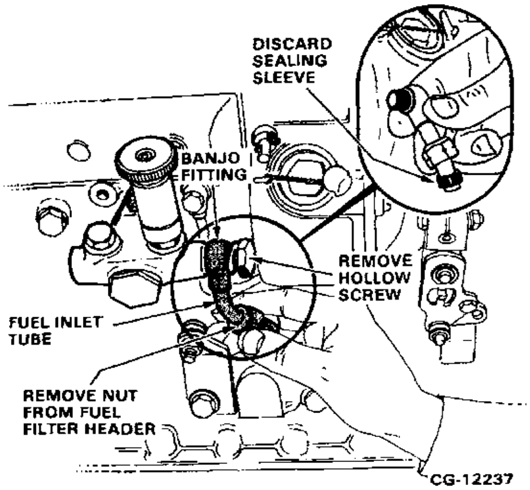

Figure 11.103. Remove Fuel Inlet Tube (Early Production)

8. Remove the fuel return line as follows:

STEP ONE — Refer to **Figure 11.104**

a. Disconnect the fuel leak–off hose from the return tube leak–off tee using pliers.

b. Remove the intake manifold bolt at the #6 cylinder, bottom bolt position.

NOTE: This bolt retains a washer, spacer, wiring harness clamp, extension clamp, bolt, nut, washer and fuel return tube clamp, for 1987 model year engines. 1988 model year engines have the same components except for the spacer.

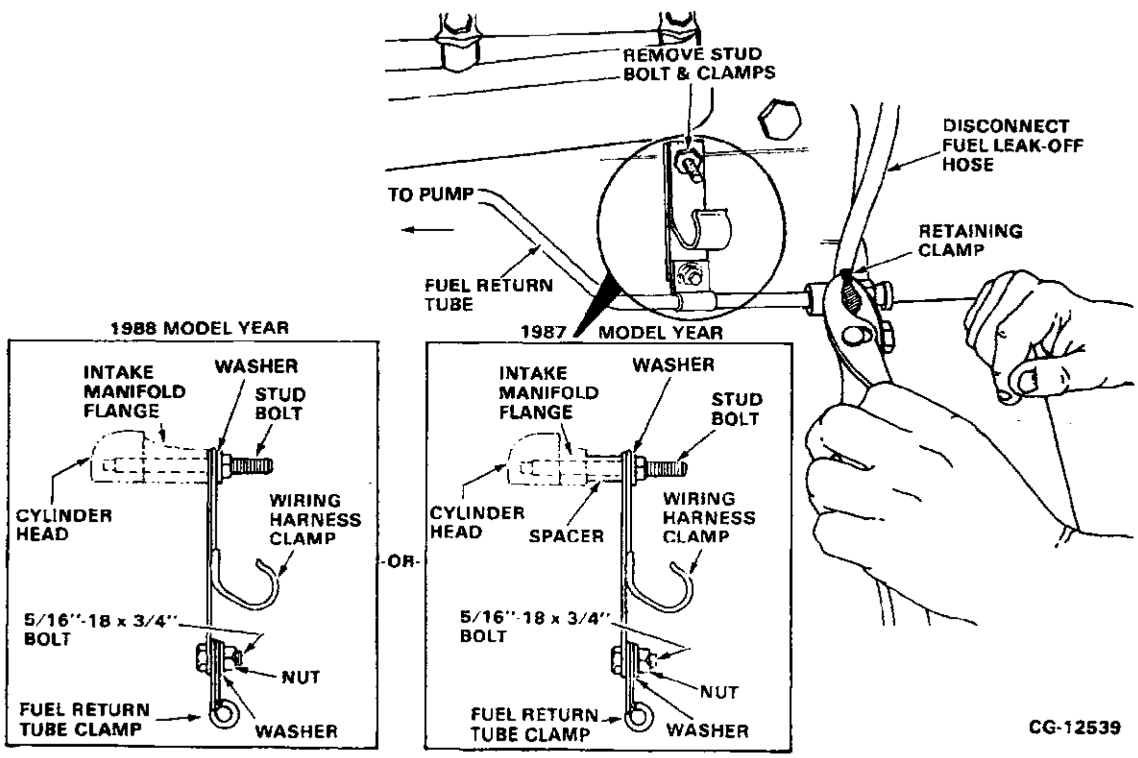

Figure 11.104. Fuel Return Tube Removal (Step One)

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

STEP TWO — Refer to **Figure 11.105.**

a. Remove the intake manifold stud bolt (at the #4 cylinder, bottom bolt position).

NOTE: The stud bolt retains a washer, fuel return tube clamp, wiring harness clamp, washer and a spacer, for 1987 model year engines. 1988 model year engines have the same components except for the spacer.

b. Remove the hex head hollow screw and washers from the fuel return tube banjo fitting at the fuel injection pump.

c. Remove the fuel return line as an assembly. Keep the hardware together to facilitate reassembly.

d. Cap the fuel return inlet at the pump.

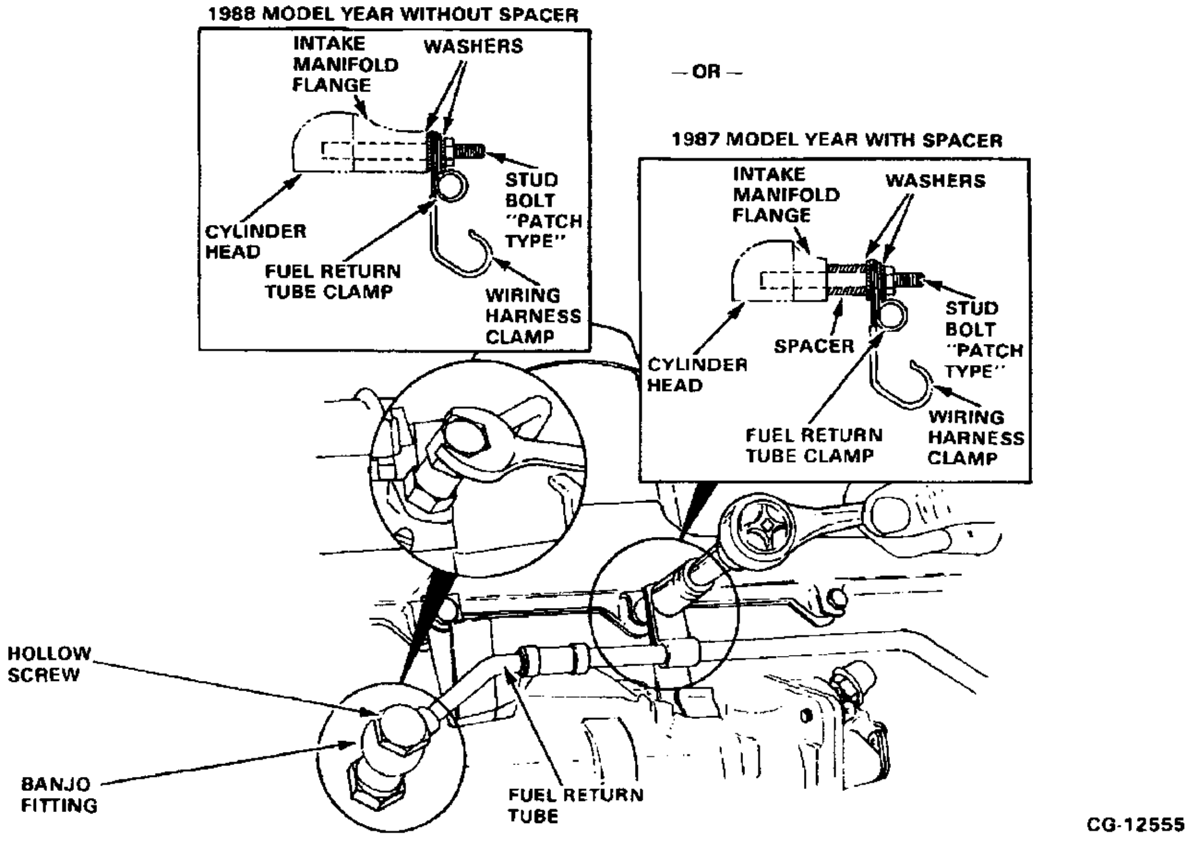

Figure 11.105. Fuel Return Tube Removal (Step Two)

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

9. Remove the lube oil supply line as follows: (Refer to **Figure 11.106**)

NOTE: The procedure applies to both the 1987 and 1988 model year lube oil tube assemblies.

a. Loosen and remove the compression nut

b. Remove the hex head hollow screw and copper gaskets from the banjo fitting at the fuel injection pump oil inlet.

c. Remove the tube assembly and discard the sealing sleeve at the compression nut end of the tube.

d. Cap the pump oil inlet and the elbow at the crankcase.

NOTE: IF THE FUEL INJECTION PUMP IS EQUIPPED WITH AN ELECTRIC SHUTOFF SOLENOID, DISCONNECT THE HARNESS FROM THE PACKARD CONNECTOR AT THE SOLENOID, PRIOR TO INJECTION PUMP REMOVAL.

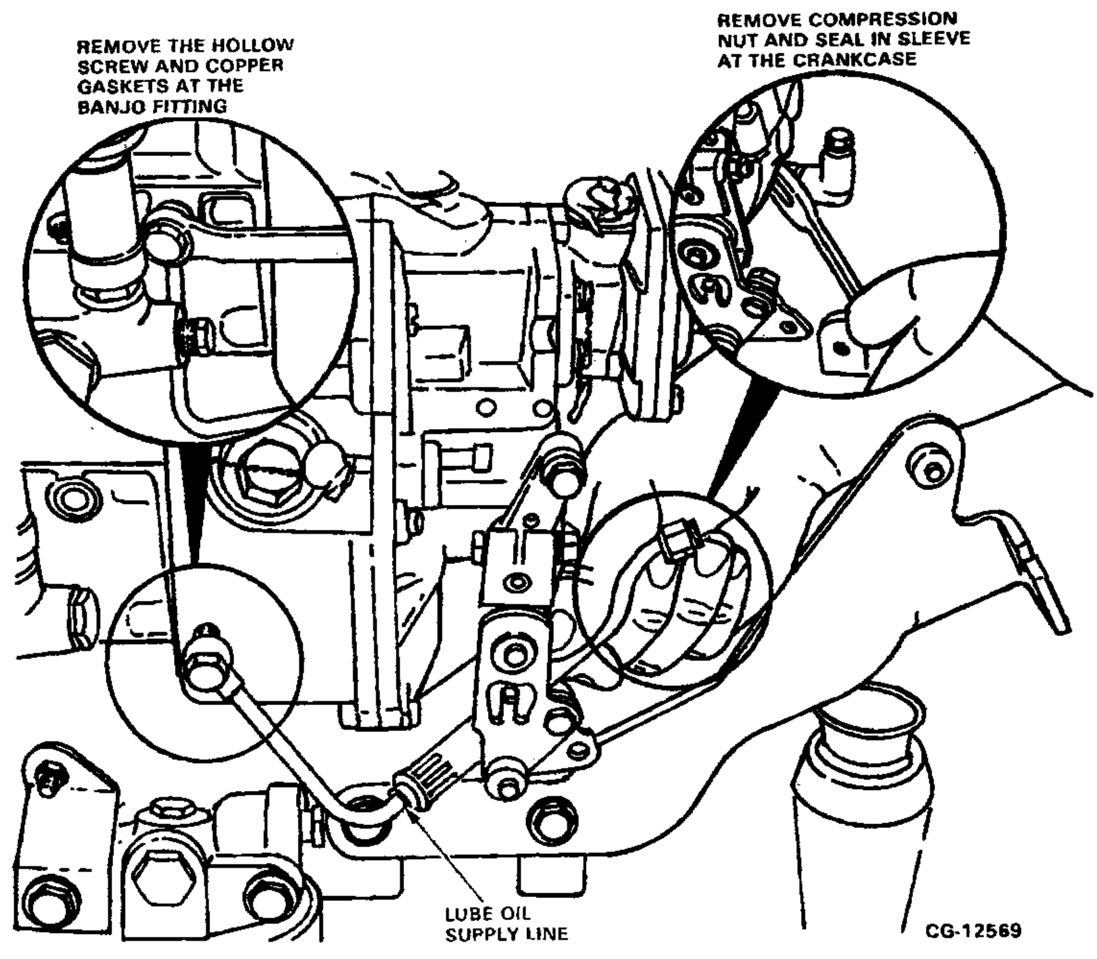

Figure 11.106. Remove Lube Oil Supply Line

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

IMPORTANT

THE 1988 MODEL YEAR ENGINES USE A REVISED LUBE OIL SUPPLY TUBE ASSEMBLY WHICH HAS A REVISED CONFIGURATION. REFER TO FIGURE 11.107 FOR 1988 VS. 1987 LUBE OIL TUBE ASSEMBLY IDENTIFICATION. THE REVISED CONFIGURATION FOR 1988 IS NECESSARY TO ACCOMMODATE THE NEW FUEL INJECTION PUMP, WHICH HAS THE LUBE OIL INLET RELOCATED IN FRONT OF THE SUPPLY PUMP ON THE INJECTION PUMP HOUSING. REFER TO FIGURE 11.108. THE LUBE OIL TUBE ASSEMBLIES FOR 1987 AND 1988 ARE NOT INTERCHANGEABLE.

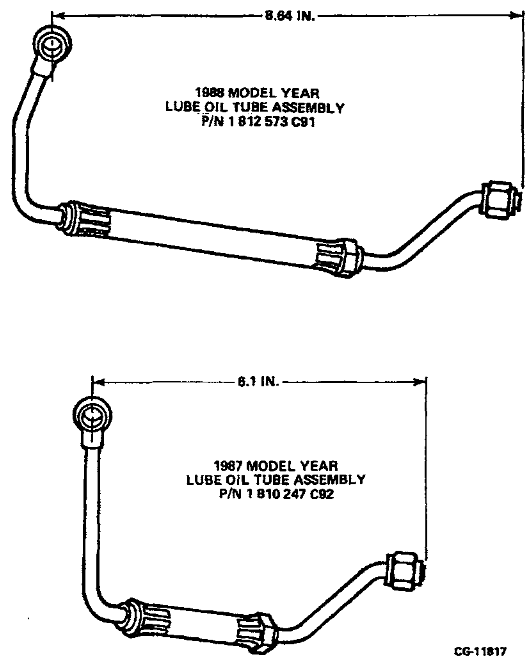
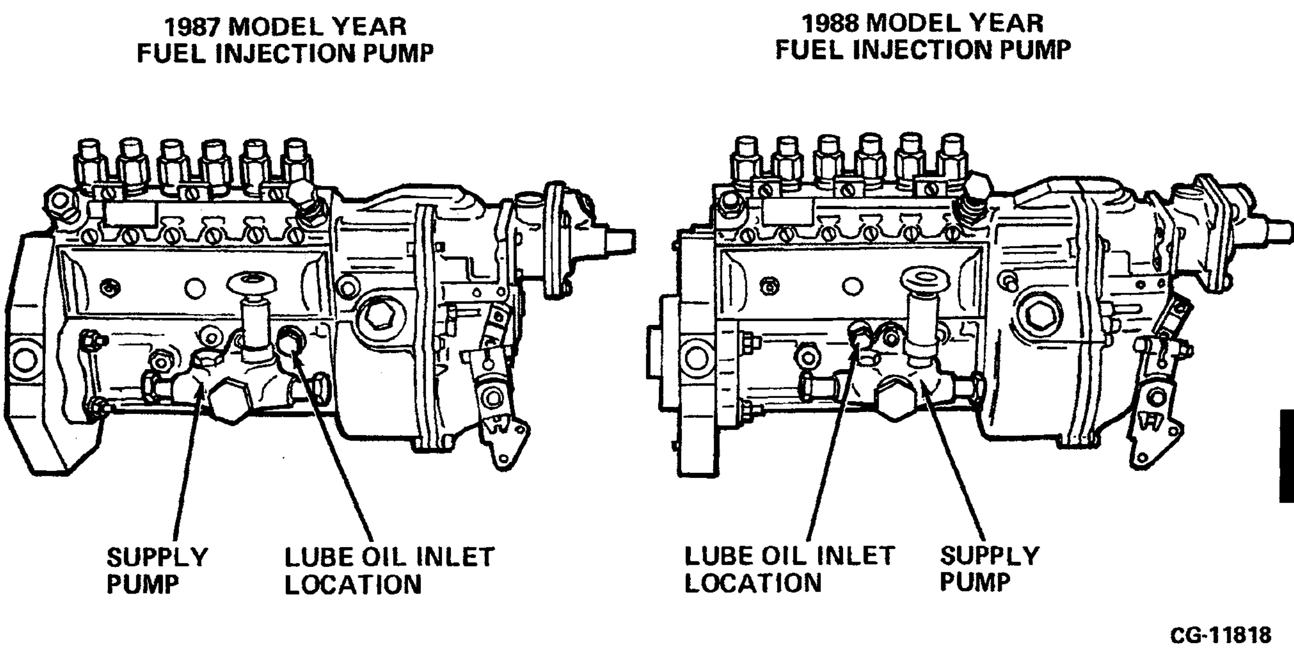


Figure 11.107. Lube Oil Tube Assembly Identification Figure



11.108. Revised Fuel Injection Pump Lube Oil Inlet Location

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

10. Remove the injection pump drive gear access cover as follows:
    a. Loosen and remove the six fasteners which secure the access cover. Refer to **Figures 11.109 and 11.110**.

NOTE: Three thru bolts and nuts with washers secure the access cover to the injection pump adapter housing and three bolts with washers secure the access cover to the housing casting.

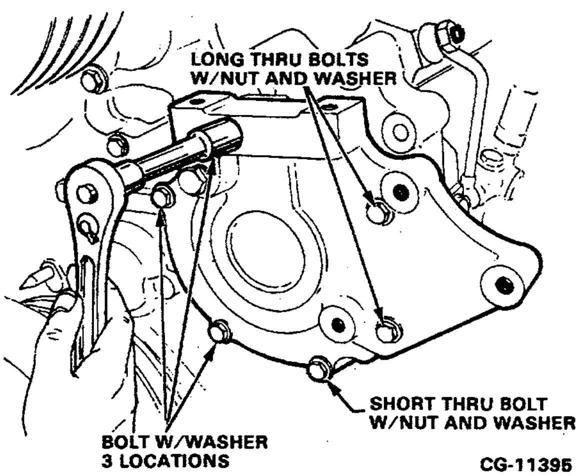


Figure 11.109. Remove Injection Pump Drive Gear Access Cover Bolts (1987 Model Year Shown)

NOTE: 1988 and later model year engines incorporate a simplified injection pump access cover (Refer to Figure 11.110.) as part of a revised accessory drive for 1988. Mounting hardware for the 1987 and 1988 access cover is different while the gasket is the same.

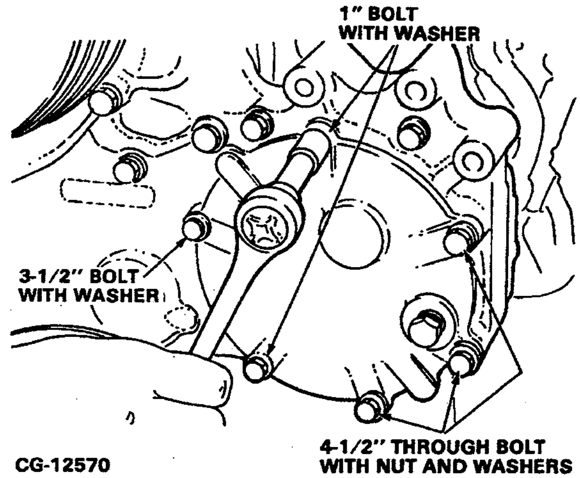


Figure 11.110. Remove Injection Pump Drive Gear Access Cover Bolts (Current Production Cover Shown)

b. Remove the access cover and gasket from the front cover to expose the injection pump drive gear. Discard the gasket. Refer to **Figure 11.111**.

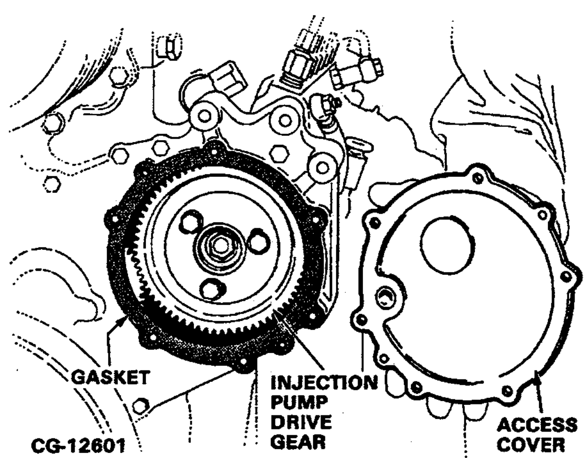


Figure 11.111. Remove Access Cover

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

11. Remove the injection pump drive gear bolts and hardened washers. Refer to **Figure 11.112**.

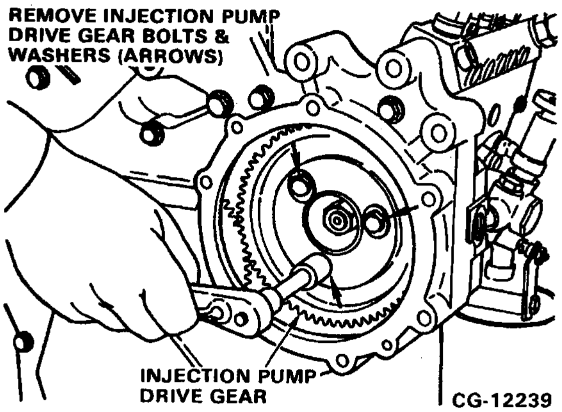

Figure 11.112. Remove Injection Pump Drive Gear Bolts

NOTE: The injection pump and adapter assembly can be removed without removing the injection pump drive gear. Drive gear removal is shown at this time for procedural purposes only.

12. Remove the injection pump drive gear from the pump hub. Refer to **Figure 11.113**.

NOTE: The polished side of the drive gear faces the hub.

13. Remove the two adapter housing bolts which go through the front cover. Refer to **Figure 11.113**.

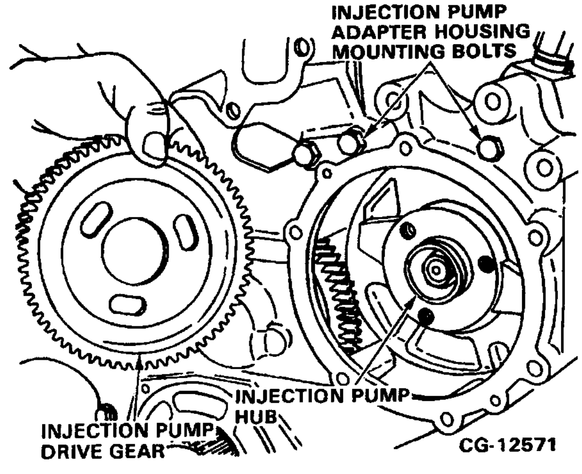

Figure 11.113. Remove the Injection Pump Drive Gear

14. Remove the adapter housing bolt and washer located at the bottom/rear (in–board) side of the adapter housing. Refer to **Figure 11.114**.

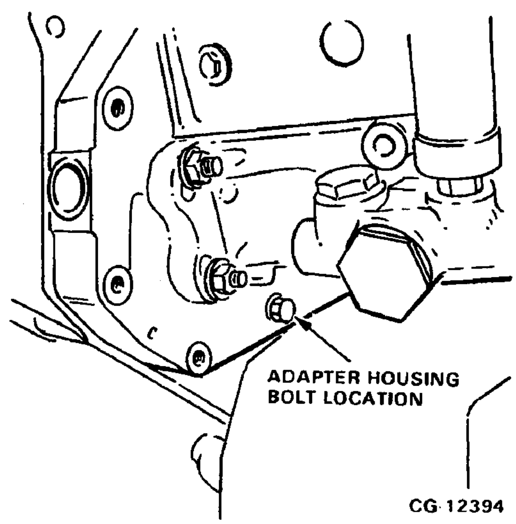

Figure 11.114. Remove Bottom/Rear (In–Board) Adapter Housing Bolt

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

15. Remove the injection pump and mounting adapter as an assembly. Discard the gasket. Refer to **Figure 11.115**.

IMPORTANT

IF THE INJECTION PUMP MOUNTING ADAPTER (46, FIGURE 11.3) REQUIRES REPLACEMENT, THE SERVICE ADAPTER COMES WITH A TIMING POINTER (41, FIGURE 11.3) PRESSED IN THE ADAPTER. IF SERVICING AN ENGINE WITH A 1988 OR LATER MODEL YEAR FUEL INJECTION SYSTEM, USE THE SERVICE MOUNTING ADAPTER AS FURNISHED. HOWEVER, IF SERVICING AN ENGINE WITH A 1987 MODEL YEAR FUEL INJECTION SYSTEM, GRIND THE TIMING POINTER OFF THE ADAPTER AND USE THE EXISTING TIMING POINTER (41, FIGURE 11.3) WHICH IS MOUNTED TO THE 1987 MODEL YEAR FUEL INJECTION PUMP.

IF THE INJECTION PUMP MOUNTING ADAPTER IS REMOVED FROM THE PUMP AND A NEW ADAPTER IS INSTALLED, THE PUMP MUST BE FLOW TIMED. AFTER FLOW TIMING, STRIKE A NEW MARK ON THE REPLACEMENT MOUNTING ADAPTER TO ALIGN WITH THE SCRIBE MARK LOCATED ON THE INBOARD SIDE OF THE PUMP MOUNTING FLANGE. (REFER TO FIGURE 11.116). IF THE MOUNTING ADAPTER IS REMOVED TO PERFORM INJECTION PUMP REPAIRS, THE ORIGINAL MOUNTING ADAPTER MUST BE REINSTALLED WITH THE FACTORY SET SCRIBE MARKS ALIGNED, AFTER THE PUMP IS FLOW TIMED. (REFER TO FIGURE 11.116).

NOTE: Dowels on the adapter housing hold the pump assembly to the front plate.

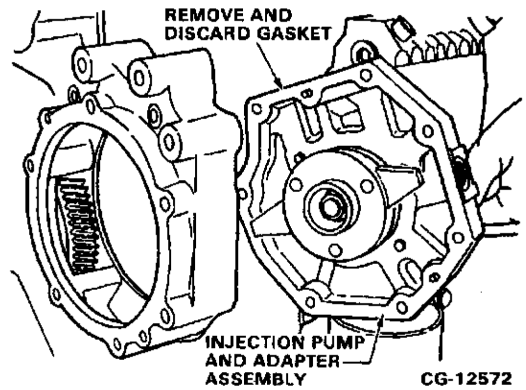

Figure 11.115. Remove Injection Pump Assembly

IN BOARD SIDE OF PUMP SHOWN

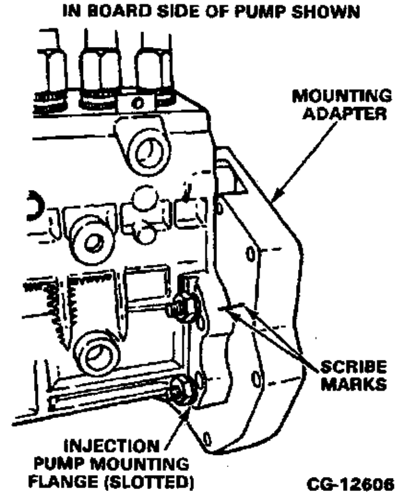

Figure 11.116. Mounting Adapter Installation

Fuel Filter Header and Throttle Linkage Assembly

1. Using an appropriate filter wrench, remove the fuel filter from the header and discard.
2. Loosen and remove the two mounting bolts which secure the fuel filter header to the crankcase, then remove the header. Refer to **Figures 11.117 and 11.118**.

NOTE: The lower throttle return spring bracket assembly is retained by the front filter header bolt.

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

Fuel Filter Header and Throttle Linkage Assembly — Continued

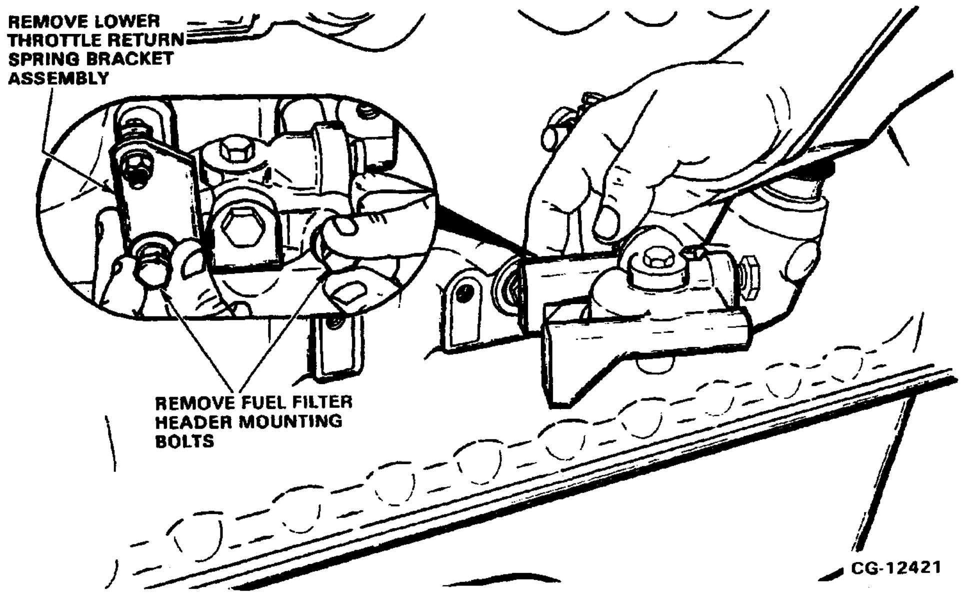

Figure 11.117. Remove Fuel Filter Header and Lower Throttle Return Spring Bracket Assembly (Current Production Shown)

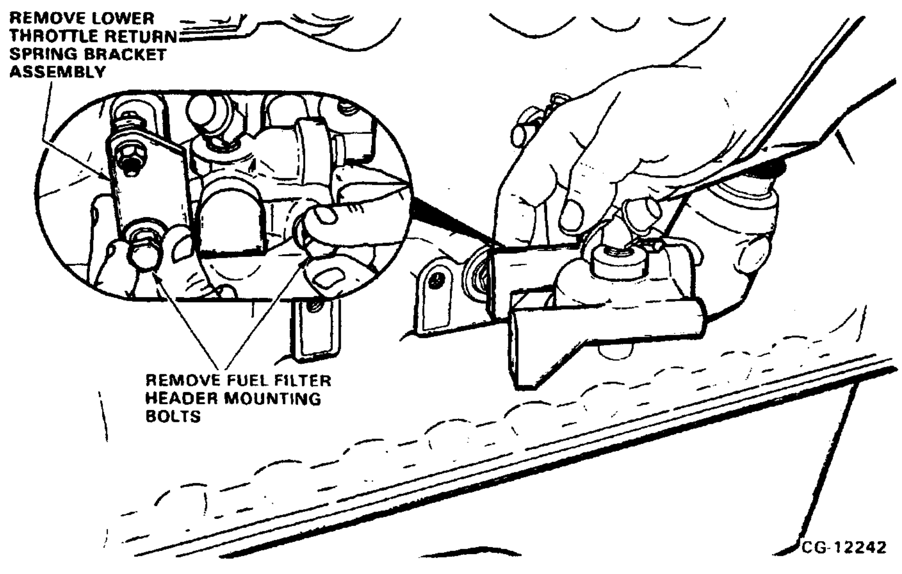

Figure 11.118. Remove Fuel Filter Header and Lower Throttle Return Spring Bracket Assembly (Early Production Shown)

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REMOVAL — Continued

Fuel Filter Header and Throttle Linkage Assembly — Continued

3. Remove the throttle cable bracket assembly from the crankcase. Refer to **Figure 11.119.**

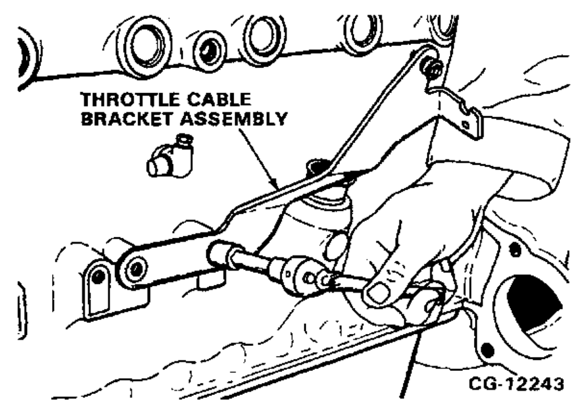

Figure 11.119. Remove the Throttle Cable Bracket Assembly

REASSEMBLY

1. Install the injection pump and adapter housing assembly to the engine front cover plate using a new adapter housing gasket. Refer to **Figure 11.120.**

36NOTE: Adapter housing dowel pins will align the gasket and the adapter housing to the engine front plate.

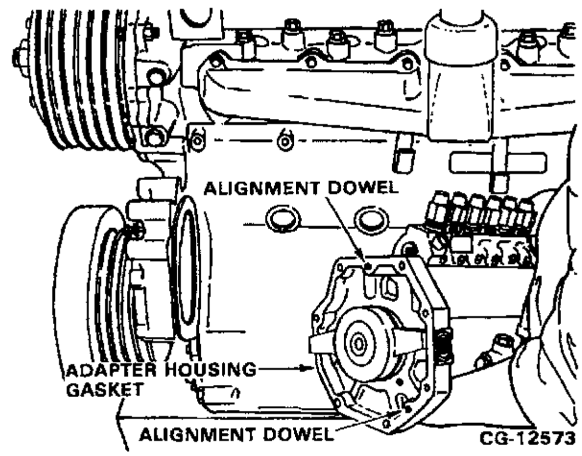

Figure 11.120. Install Injection Pump and Adapter Housing Assembly to the Front Plate

2. Tighten the adapter housing bolts (depicted in **Figures 11.113 and 11.114**) to the specified special torque (see "**SPECIFICATIONS**").
3. Install the injection pump drive gear as follows:
   a. **IMPORTANT! Verify that the engine #1 cylinder is on the compression stroke (TDC). Also verify static timing by checking the timing pointer and degree marks on the damper pulley. Refer to "Set Injection Pump to Engine Timing Prior to Pump Removal", in this section for a detailed procedure.**

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

b. Loosely install the injection pump drive gear to the injection pump drive hub. DO NOT TIGHTEN BOLTS. Refer to **Figure 11.121.**

NOTE: Position bolts in the center of the kidney slot.

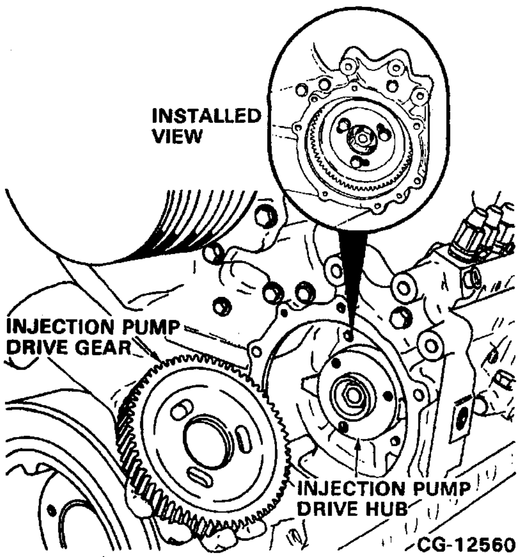

Figure 11.121. Install Injection Pump Drive Gear

c. Verify the alignment of the injection pump timing pointer to the drive hub scribe line through the adapter housing sight plug. Refer to **Figure 11.122**. Rotate the pump hub as required for proper alignment.

NOTE: The injection pump drive hub for 1988 has wings which allow for better timing mark visibility. Refer to Figure 11.123.

d. Tighten the three pump drive gear mounting bolts to the specified **"SPECIAL TORQUE"**.

IMPORTANT

BE SURE THE TIMING POINTER AND SCRIBE LINE ARE STILL ALIGNED AFTER THE BOLTS ARE TIGHTENED.

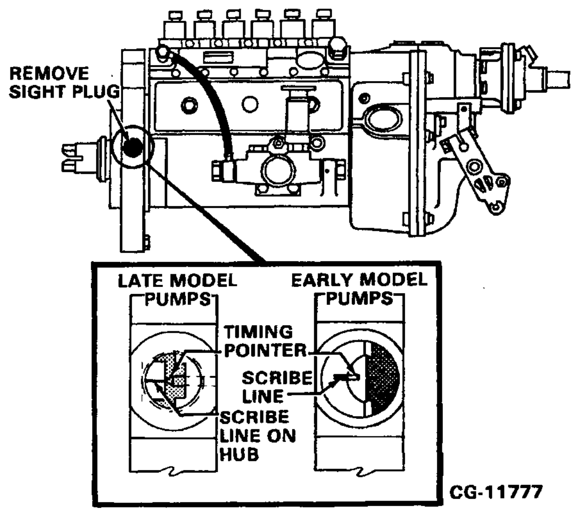

Figure 11.122. Injection Pump Timing Marks

e. Reinstall sight plug using a new copper gasket.

4. Install the injection pump drive gear access cover using a new gasket as follows:

   a. Secure the three bolts and washers which fasten into the front cover casting. Tighten to the standard torque. See Appendix.

   b. Secure the bolts, washers and nuts which mount through the access cover, front cover and adapter housing. Tighten to the standard torque. See Appendix.

IMPORTANT

1987 AND 1988 MODEL YEAR ENGINES USE DIFFERENT INJECTION PUMP ACCESS COVERS AND HARDWARE. REFER TO FIGURE 11.124. FOR MOUNTING HARDWARE LOCATION.

   c. Tighten the fasteners to the standard torque. See Appendix.

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

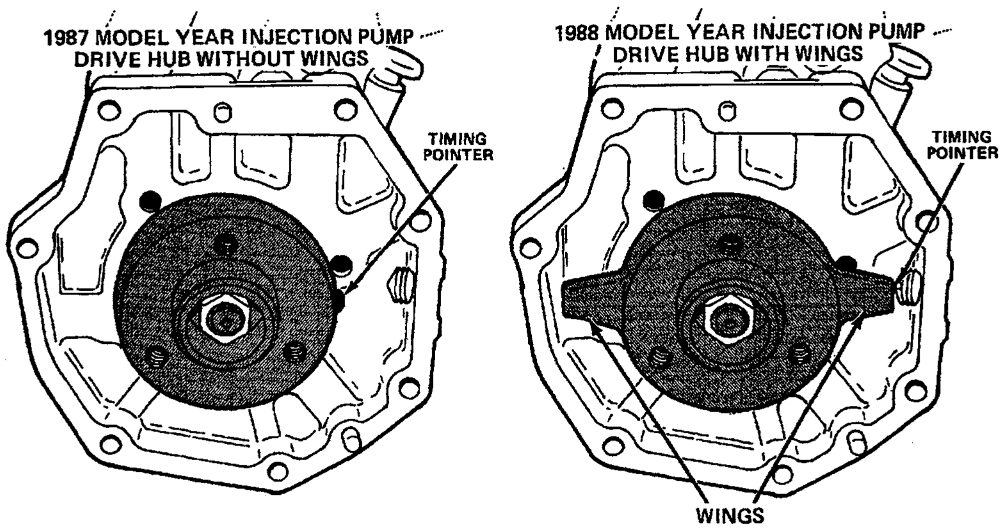

Figure 11.123. Injection Pump Drive Hub Identification

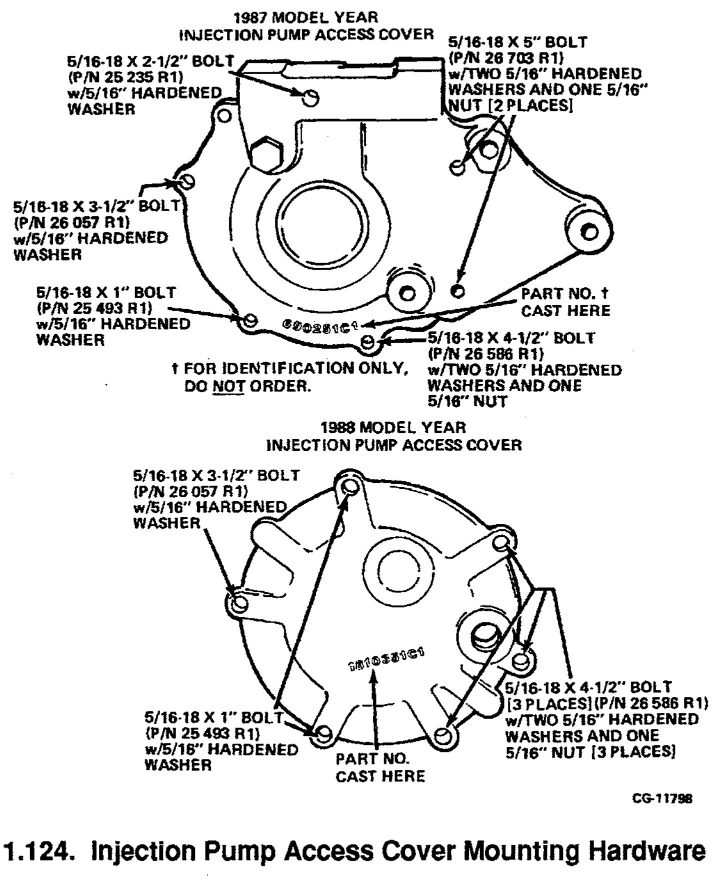

Figure 11.124. Injection Pump Access Cover Mounting Hardware Location

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

5. Install the fuel return line as follows:

NOTE: The following intake manifold bolt locations incorporate fuel return tube and/or engine wiring harness clamps.

#4 cylinder bottom bolt. (Refer to **Figure 11.105**.)

#6 cylinder bottom bolt. (Refer to **Figure 11.104**.)

a. Remove protective cap from pump at fuel return outlet.

b. Install the clamps, washers, spacers and fuel return tube. Tighten the "patch" stud bolts to the specified special torque. Refer to **Figure 11.125.**

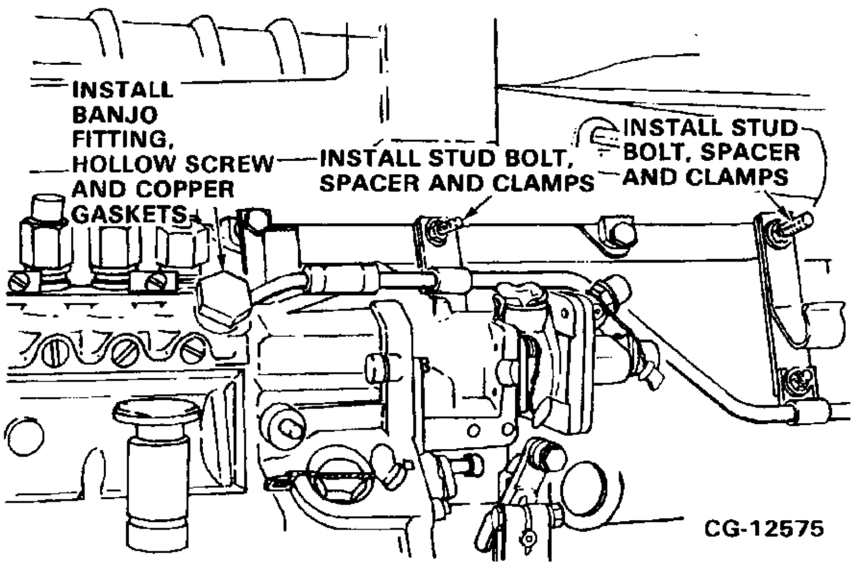

Figure 11.125. Fuel Return Tube and Clamp Installation

NOTE: 1988 model year engines do not use spacers. Refer to Figures 11.104 and 11.105 for details.

c. Reconnect the fuel return tube to the pump using new copper gaskets and hollow screws at the banjo fitting. Refer to **Figure 11.125.**

d. Reconnect the fuel leak–off hose to the return tube tee.

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

6. Install the fuel inlet (supply to pump) hose as follows:

NOTE: Remove protective cap at the fuel injection pump prior to installation.

a. Connect the banjo fittings at the supply pump and the injection pump inlet using the hollow screws and new copper gaskets.

b. Note copper gasket location in **Figure 11.126**. One gasket is located on each side of the banjo fitting.

c. The hollow screw with the built-in bleed screw is located at the injection pump fuel inlet.

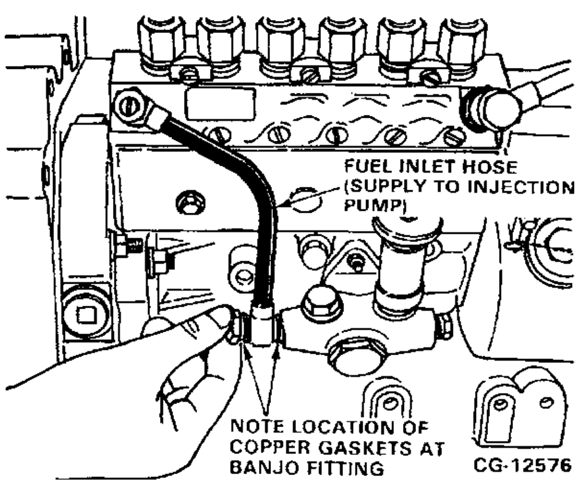

Figure 11.126. Install Fuel Inlet Hose (Supply Pump to Injection Pump) (Current Production Shown)

NOTE: Early production fuel inlet uses a steel tube instead of a hose. The method of service for the tube or hose is the same.

7. Install the fuel injection line assembly as follows:

a. Remove the protective caps from the lines, nozzles and delivery valve holders at the pump.

IMPORTANT

PRIOR TO INSTALLING THE FUEL INJECTION LINE ASSEMBLY, CLEAN WITH FILTERED COMPRESSED AIR AND VISUALLY INSPECT FOR CONTAMINATION OR DAMAGE. REPLACE AS REQUIRED.

b. Install the connector nuts at the nozzles using a 3/4 in. "Crow Foot" socket, as shown in **Figure 11.127**. Tighten each nut to the specified **"SPECIAL TORQUE"**.

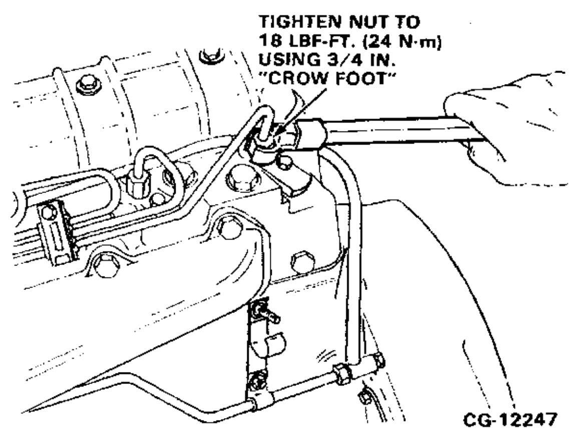

Figure 11.127. Install Injection Line Connector Nuts to each Nozzle (1987 Model Year Shown)

NOTE: Injection line fittings at the pump and nozzle are frequently over tightened due to the fitting size 3/4 in. This swedges the injection line, often partly closing the ends. This alters fuel delivery characteristics, raises injection line pressures and may cause performance problems or injection pump failure. Visually inspect the ends of the injection lines and replace any with swedged or damaged fittings or holes.

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

c. Tighten the fuel injection line connecting nuts to the delivery valve holders at the pump. Tighten to the specified "**SPECIAL TORQUE**" using a 3/4 in. "Crow Foot" wrench at the connector nut while holding the delivery valve holder nut with a modified 12 pt. 7/8 in. wrench. Refer to **Figure 11.128**. Do not allow the delivery valve holder to move.

NOTE: Modify the 12 pt. 7/8 in. wrench by cutting a section wide enough to allow the injection pipe to pass so the delivery valve may be held.

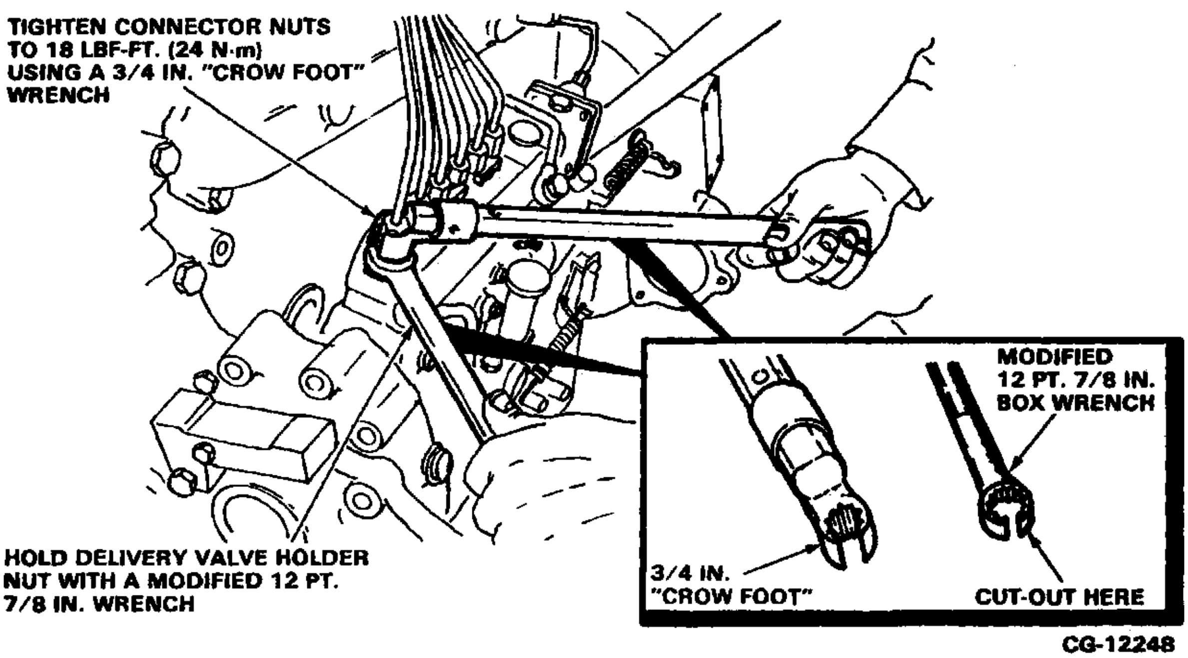

Figure 11.128. Install Injection Line Connector Nuts to the Pump Delivery Valve Holders

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

IMPORTANT

1988 MODEL YEAR FUEL INJECTION PIPES HAVE A SMALLER I.D. (0.072 IN.) TO MEET THE 1988 MODEL YEAR EXHAUST EMISSION STANDARDS. THE 1987 MODEL YEAR PIPES HAVE A 0.082 IN. I.D.

IMPORTANT

THE FUEL INJECTION PIPE ASSEMBLY CONFIGURATION AND CLAMPS WERE REVISED FOR 1988 TO ACCOMMODATE THE LARGE INTAKE MANIFOLD, WHICH NECESSITATED THE INCREASE IN LENGTH FROM 28 IN. TO 34 IN. THE PIPE ASSEMBLIES ARE NOT INTERCHANGEABLE.

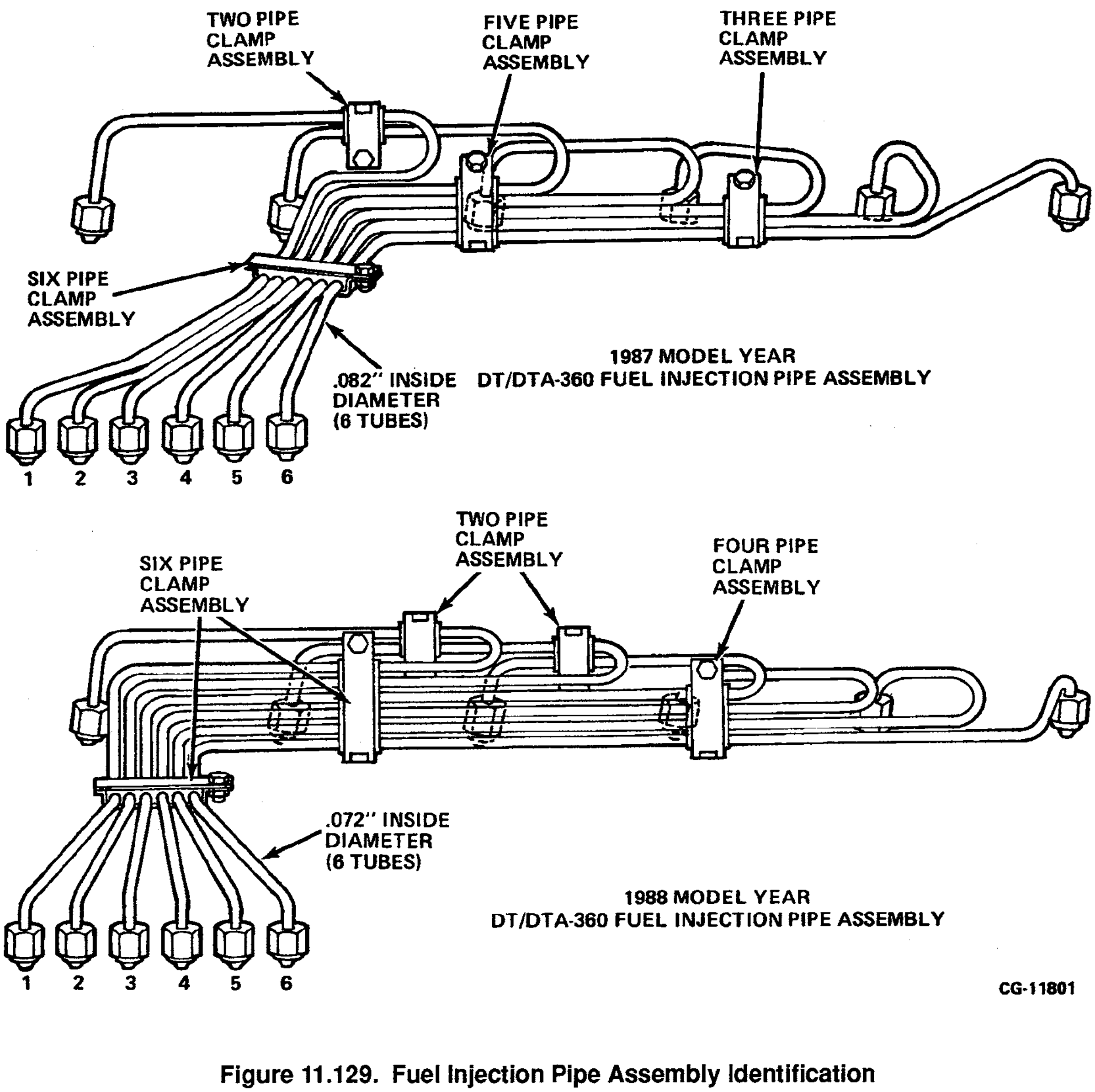

Figure 11.129. Fuel Injection Pipe Assembly Identification

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

8. Install the aneroid tube as follows:
   a. Remove the protective caps from the intake manifold elbow and the aneroid.
   b. Install new rubber sealing sleeves at each end of the aneroid tube.
   c. Tighten the connecting nuts at each end of the tube as shown in **Figure 11.130**.

IMPORTANT

REUSE OF OLD SEALING SLEEVES CAN CAUSE LEAKAGE, AFFECTING ANEROID OPERATION.

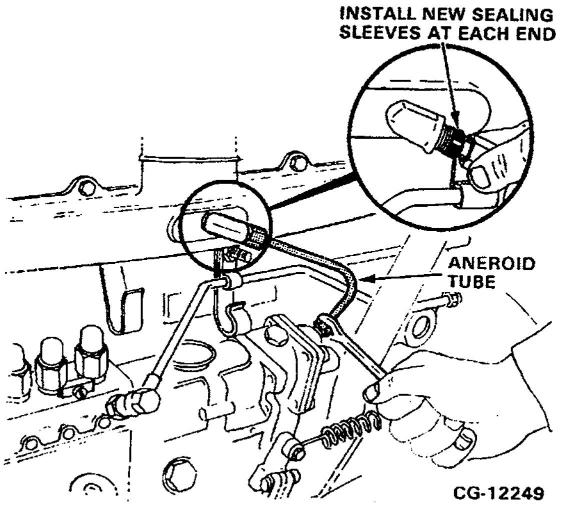

Figure 11.130. Install Aneroid Tube (1987 Model Year Shown, 1988 Similar)

9. Install the fuel filter header as follows: (Refer to **Figure 11.131**)
   a. Mount the header at the crankcase mounting pad. Fasten the header using the two mounting bolts and washers.
   b. Tighten the fasteners to the standard torque. See Appendix.

NOTE: Be sure to install the lower throttle return spring bracket on the mounting bolt which faces the front of the engine.

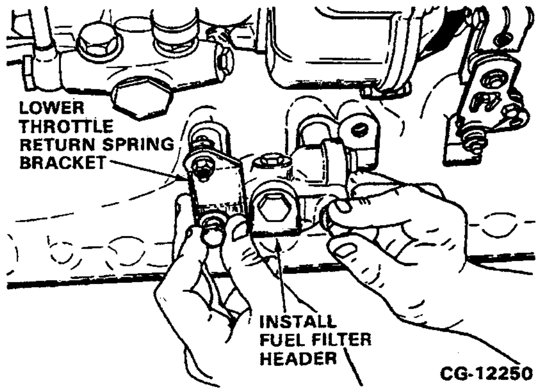

Figure 11.131. Install the Fuel Filter Header (Current Production Header Shown)

10. Install the lube oil supply line as follows: (Refer to **Figures 11.132 and 11.133**)
    a. Remove the protective caps at the crankcase oil outlet elbow and the pump oil inlet.
    b. Install a new rubber sealing sleeve at the compression nut end of the tube.
    c. Fasten the tube to the crankcase oil outlet tube and tighten the nut.
    d. Using new copper gaskets, fasten the banjo fitting to the pump oil inlet with the hollow screw.

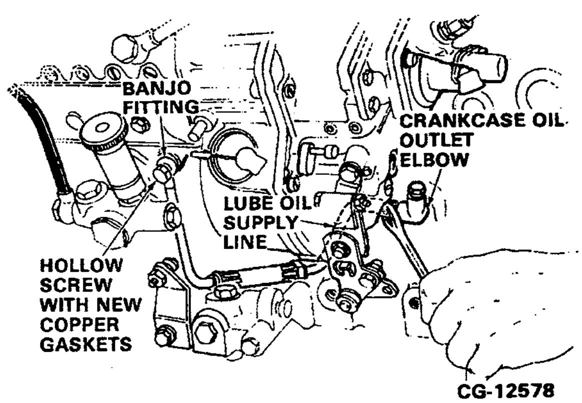

Figure 11.132. Install Lube Oil Supply Line (1987 Model Year Shown)

FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

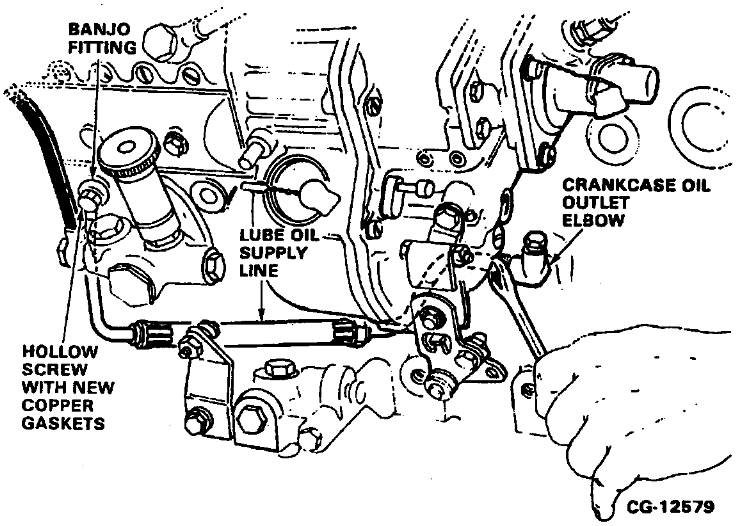

Figure 11.133. Install Lube Oil Supply Line (1988 Model Year Shown)

11. Install the fuel inlet (fuel filter to supply pump) hose or tube as follows: (Refer to **Figures 11.134 and 11.135**)

   a. Remove the protective caps from the fuel filter header and supply pump inlet.

(Current Production)

   b. Connect the banjo fittings at the supply pump and the fuel filter header using the hollow screws and new copper gaskets.

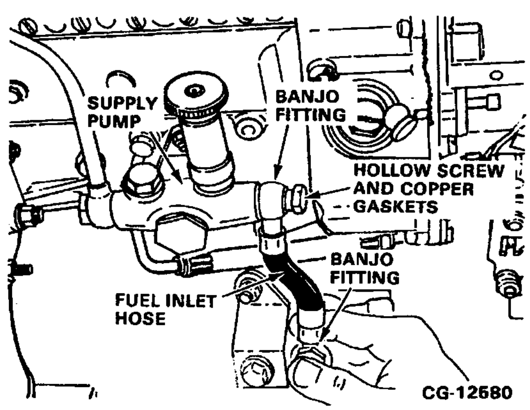

Figure 11.134. Install Fuel Inlet Tube (Fuel Filter to Supply Pump) (Current Production)

(Early Production)

   b. Install a new rubber sealing sleeve at the compression nut end of the tube.

   c. Fasten the tube to the header and tighten the nut.

   d. Using new copper gaskets, fasten the banjo fitting to the supply pump inlet with the hollow screw.

NOTE: Use one new copper gasket on each side of the banjo fitting.

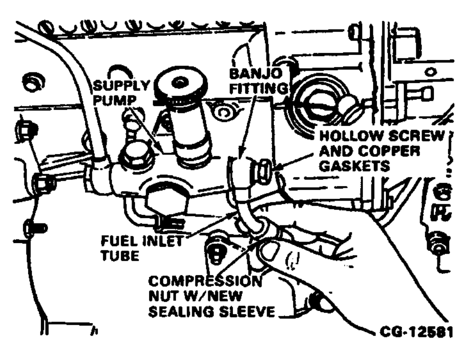

Figure 11.135. Install Fuel Inlet Tube (Fuel Filter to Supply Pump) (Early Production)

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

12. Mount the throttle lever return spring bracket to the crankcase using the two mounting bolts and washers. Refer to **Figures 11.136 and 11.137**.

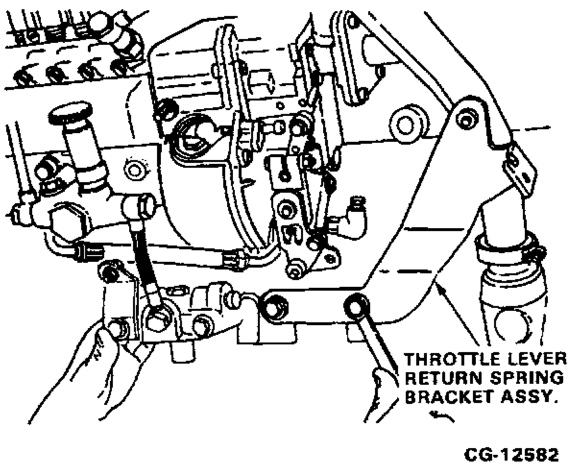

Figure 11.136. Install Throttle Lever Return Spring Bracket (Current Production)

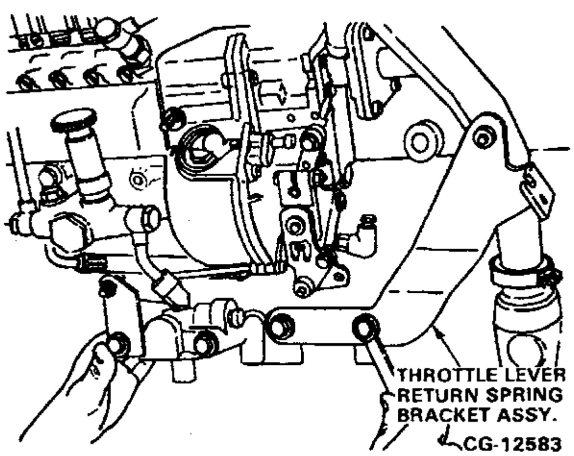

Figure 11.137. Install Throttle Lever Return Spring Bracket (Early Production)

13. Connect the throttle return springs as shown in **Figure 11.138**.

IMPORTANT

THE LARGE DIAMETER SPRING MUST BE INSTALLED IN THE TOP POSITION WHILE THE NARROW DIAMETER SPRING IS INSTALLED IN THE LOWER POSITION. DO NOT INTERMIX SPRINGS! THIS APPLIES TO BOTH CURRENT AND EARLY PRODUCTION MODELS.

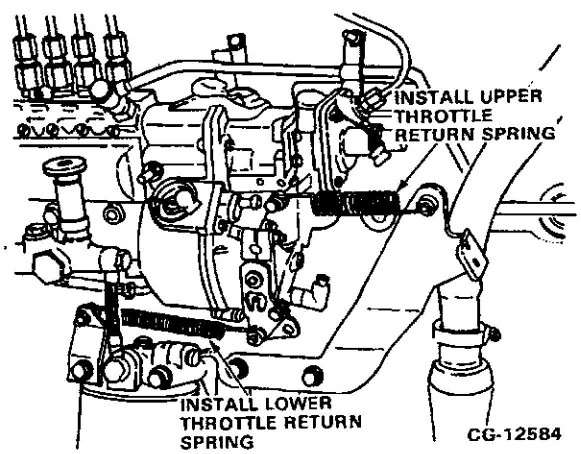

Figure 11.138. Install the Throttle Return Springs (Current Production Shown)

NOTE: Refer to CGES–445–* (DT/DTA–360 Diesel Engine Diagnostic Manual) for throttle linkage inspection and/or adjustment procedures.

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FUEL INJECTION PUMP — Continued

MODEL PES6A PUMP PRIOR TO ENGINE S/N 84779

REASSEMBLY — Continued

14. Install a new fuel filter as follows: (Refer to **Figure 11.139**)
    a. Lubricate the filter gasket with clean diesel fuel.
    b. Tighten until the gasket touches the filter header.
    c. Tighten by hand an additional 1/2 turn.

NOTE: Do not add fuel to the new filter.

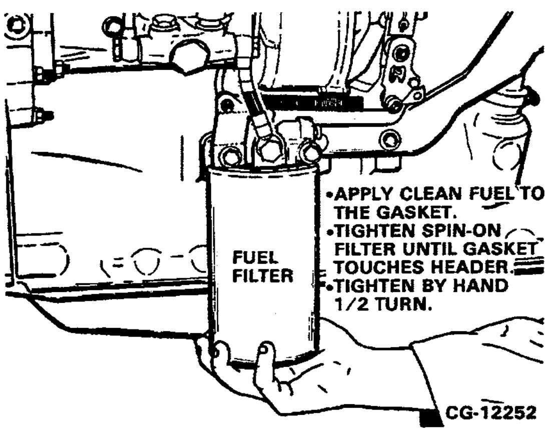

Figure 11.139. Install a New Fuel Filter

15. Install throttle cable linkage to the control lever and adjust linkage as specified in the current DT/DTA–360 operation and maintenance manual.
16. Connect electric shut–off harness connector to the packard connector on the ESO solenoid, if equipped.

PRIMING FUEL INJECTION SYSTEM

After replacing fuel injection pump or replacing fuel supply lines, prime fuel system using these procedures:

1. Loosen the bleed screw at the pump fuel inlet.
2. Loosen hand priming pump handle.
3. Operate priming pump until pump action provides solid fuel at the bleed screw. Close the screw.
4. Position injection pump shut–off lever in run position with electric shut–off or mechanical cable.
5. Crank engine for fifteen seconds.
6. Tighten priming pump handle.
7. Start engine and operate until engine runs smoothly.

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COMPONENT CHANGES

ELECTRIC SHUT–OFF SOLENOID (For Engines So Equipped)

Effective with Engine S/N 054459 and all service requirements, the ESO features a new "switchless" operation. The new ESO is equipped with a three wire lead connector which connects directly into the cranking motor circuit for plunger "pull in". The hold coil, which keeps the plunger depressed, is activated by the ignition key "ON" position only after "pull in" has been achieved. Refer to **Figure 11.140**

Refer to **"ELECTRIC SHUT–OFF (ESO) SOLENOID REMOVAL AND REINSTALLATION (IN CHASSIS)** in this section for instructions.

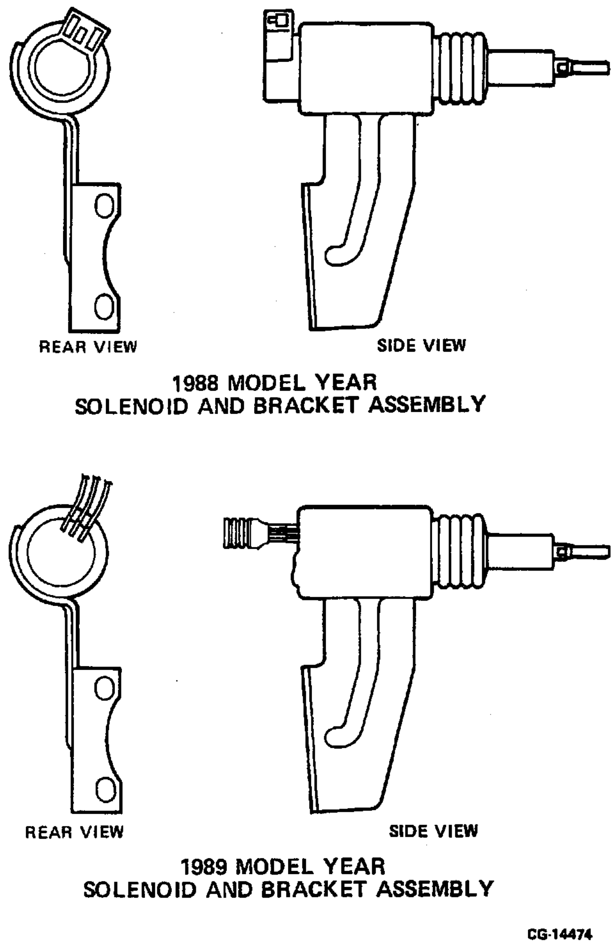

Figure 11.140. Electric Shut–Off Solenoid (ESO) Comparison

ELECTRIC SHUT–OFF (ESO) SOLENOID REMOVAL AND REINSTALLATION (IN CHASSIS)

Removal

IMPORTANT

TO AVOID FUEL AND PUMP CONTAMINATION, DO NOT REMOVE THE FUEL INJECTION LINES TO ACCESS THE ESO SOLENOID.

IMPORTANT

The following instructions are to be used if the electric "Internal Switch" solenoid is reinstalled on an PES6A pump. The current service solenoid is designated as "Switchless" and requires different installation instructions which begin on the following page.

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FUEL INJECTION PUMP — Continued

ELECTRIC SHUT–OFF (ESO) SOLENOID REMOVAL AND REINSTALLATION (IN CHASSIS) — Continued

Removal — Continued

NOTE: Follow these procedures step by step to prevent solenoid burn out or internal damage to injection pump.

1. Remove the two mounting bolts which secure the ether injector mounting plate to the radiator frame and place the assembly (with electrical wiring and fluid supply tube still connected) on the lower hood pivot support.
2. Remove all supply and discharge lines at the rear of the air brake system compressor. Using a 9/16 in. socket and ratchet or a box wrench, remove the four bolts which secure the compressor.
3. Slide the compressor inward and remove both fan belts. Lift the compressor and support it on its side on the upper pulley. Remove the six mounting bolts securing the lower compressor bracket and remove the bracket.

IMPORTANT

FOR DETAILED INFORMATION ON CHASSIS RELATED COMPONENTS, REFER TO THE APPROPRIATE CHASSIS RELATED SERVICE MANUAL.

4. Remove the electric shut–off (ESO) solenoid as follows: (Refer to **Figure 11.141**)

   a. Loosen the jam nut at the female end rod.

   b. Unscrew the swivel from the female rod end.

   c. Access the injection pump to adapter housing mounting nuts from underneath the vehicle. Remove the inboard nuts and washers using a 9/16 in. box wrench.

   d. Remove the solenoid and bracket assembly from the engine. Disconnect the harness from the packard connector at the solenoid after the solenoid is removed.

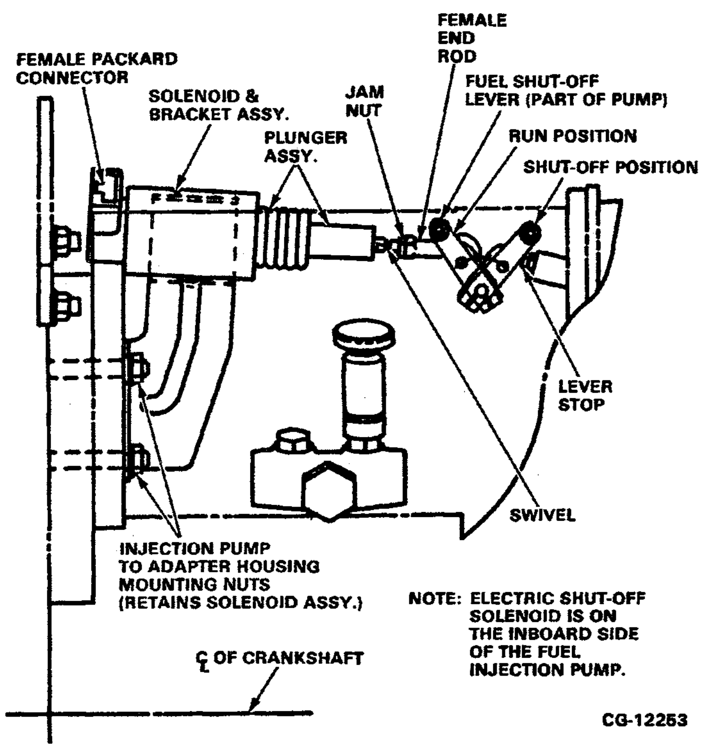

Figure 11.141. Electric Shut–Off Solenoid (Installed View)

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FUEL INJECTION PUMP — Continued

ELECTRIC SHUT-OFF (ESO) SOLENOID REMOVAL AND REINSTALLATION (IN CHASSIS) — Continued

Reinstallation and Adjustment (Refer to Figure 11.142)

1. Install the solenoid and bracket assembly onto the inboard injection pump mounting studs.
2. Working from beneath the vehicle, hold the solenoid bracket firmly against the pump mounting flange and install the inboard washers and nuts by hand. Once in place, use a 9/16 in. swivel socket with a 5 in. extension and tighten the injection pump mounting bolts.
3. Install the wiring harness connector into the female packard connector at the rear of the solenoid.

WARNING

The adjustment procedure (steps 4–9) must be completed as specified to prevent solenoid burn–out or internal damage to the injection pump.

4. Energize the solenoid by turning the ignition key to the "ON" position. **NOTE: The plunger should be fully depressed when energized.**
5. Depress the plunger to the bottom of its travel and move the shut–off lever to the "RUN" position.
6. Screw the solenoid swivel into the female end rod until the shut–off lever stops its forward movement.
7. Turn the swivel <u>two full</u> turns in the opposite direction. (This moves the shut–off lever back towards the shut–off position.)
8. Tighten the jam nut, then de–energize the solenoid.
9. Cycle the solenoid several times making sure the shut–off lever travel is adequate to achieve the run and shut–off positions.

CAUTION !

Do not cycle more than 6 times within one minute. Additional cycling may cause pull–in coil over–heating resulting in burnout.

INSTALLATION INSTRUCTIONS FOR "SWITCHLESS" TYPE SOLENOID ASSEMBLIES ON ENGINES WITH AN PES6A INJECTION PUMP AND PREVIOUSLY EQUIPPED WITH AN "INTERNAL SWITCH" SOLENOID

IMPORTANT

FOR INSTALLATION AND ADJUSTMENT INSTRUCTIONS OF "SWITCHLESS" TYPE SOLENOID ASSEMBLIES ON ENGINES EQUIPPED WITH AN PES6A INJECTION PUMP WITH THE "SWITCHLESS" SOLENOID FOLLOW "INSTALLATION OF NEW "SWITCHLESS" ELECTRIC SHUT–OFF AS DESCRIBED BELOW AND "ADJUSTMENT OF NEW ELECTRIC "SWITCHLESS" SHUT–OFF SOLENOID" AS DESCRIBED ON PAGE 81.

INSTALLATION OF NEW "SWITCHLESS" ELECTRIC SHUT–OFF FOR PES6A INJECTION PUMP

1. Assemble solenoid and bracket assembly onto the inboard injection pump mounting studs.
2. Working from beneath the vehicle, hold the solenoid bracket firmly against the pump mounting flange and install the inboard washers and nuts by hand. Once in place, use a 9/16" swivel socket with a five inch extension and tighten the injection pump mounting bolts.
3. Assemble rod end to shut–off lever and tighten bolt. **DO NOT** connect rod end to adjusting rod at this time.
4. Thread stud into solenoid swivel until stud bottoms and tighten locknut against the swivel.

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FUEL INJECTION PUMP — Continued

INSTALLATION OF NEW "SWITCHLESS" ELECTRIC SHUT–OFF FOR PES6A INJECTION PUMP — Continued

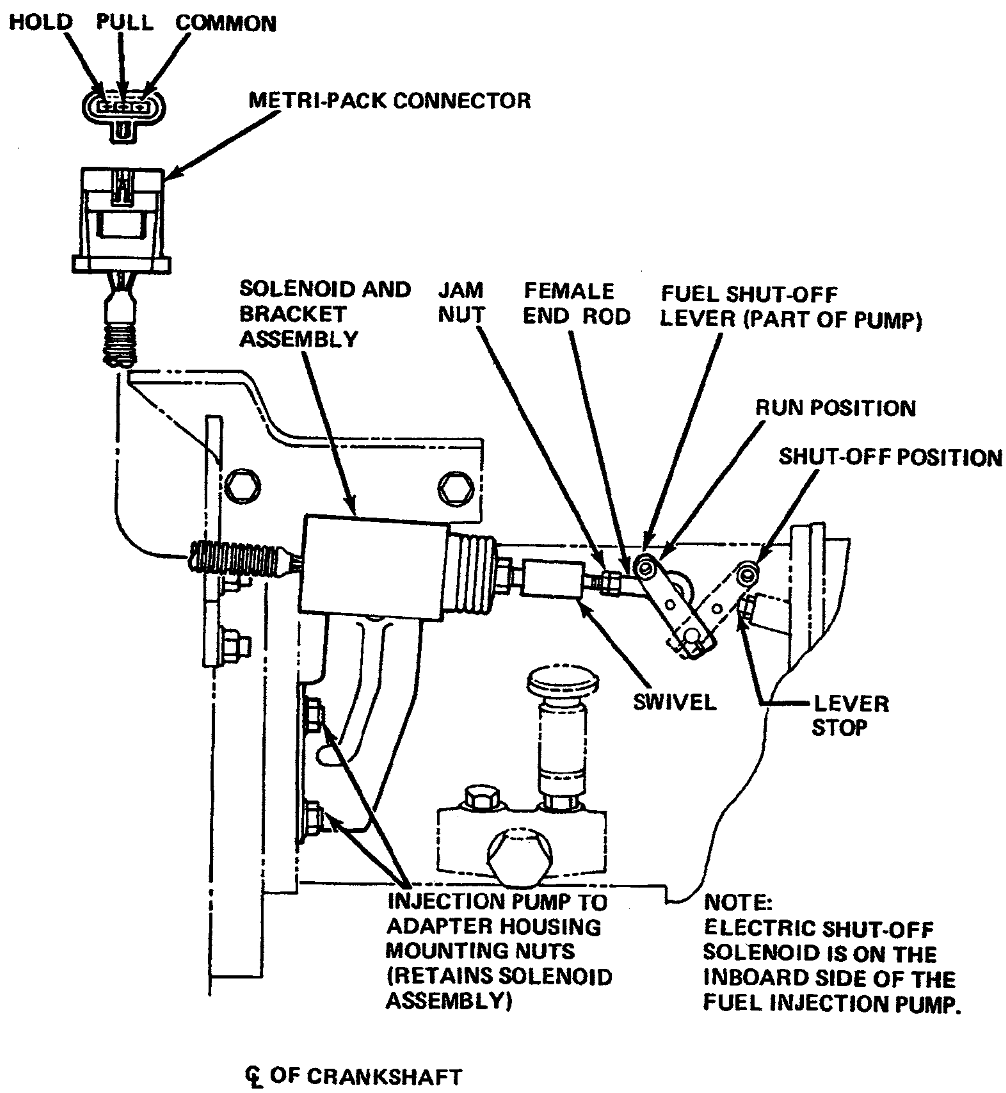

Figure 11.142. Solenoid Installation for PES6A Injection Pump

INSTALLATION OF NEW SOLENOID WIRING HARNESS ASSEMBLY

1. Assemble the metri–pack connector between the engine and the solenoid wiring harness.
2. Route conduit–covered wire with engine harness to starting motor magnetic switch mounted on cowl.
3. Connect eyelet terminal to same stud on starting motor magnetic switch that circuit 17 (HOT DURING START CYCLE ONLY) is connected. **DO NOT** tighten nut at this time as adjustment will require removal.

FUEL INJECTION PUMP — Continued

INSTALLATION OF NEW "SWITCHLESS" ELECTRIC SHUT–OFF FOR PES6A INJECTION PUMP — Continued

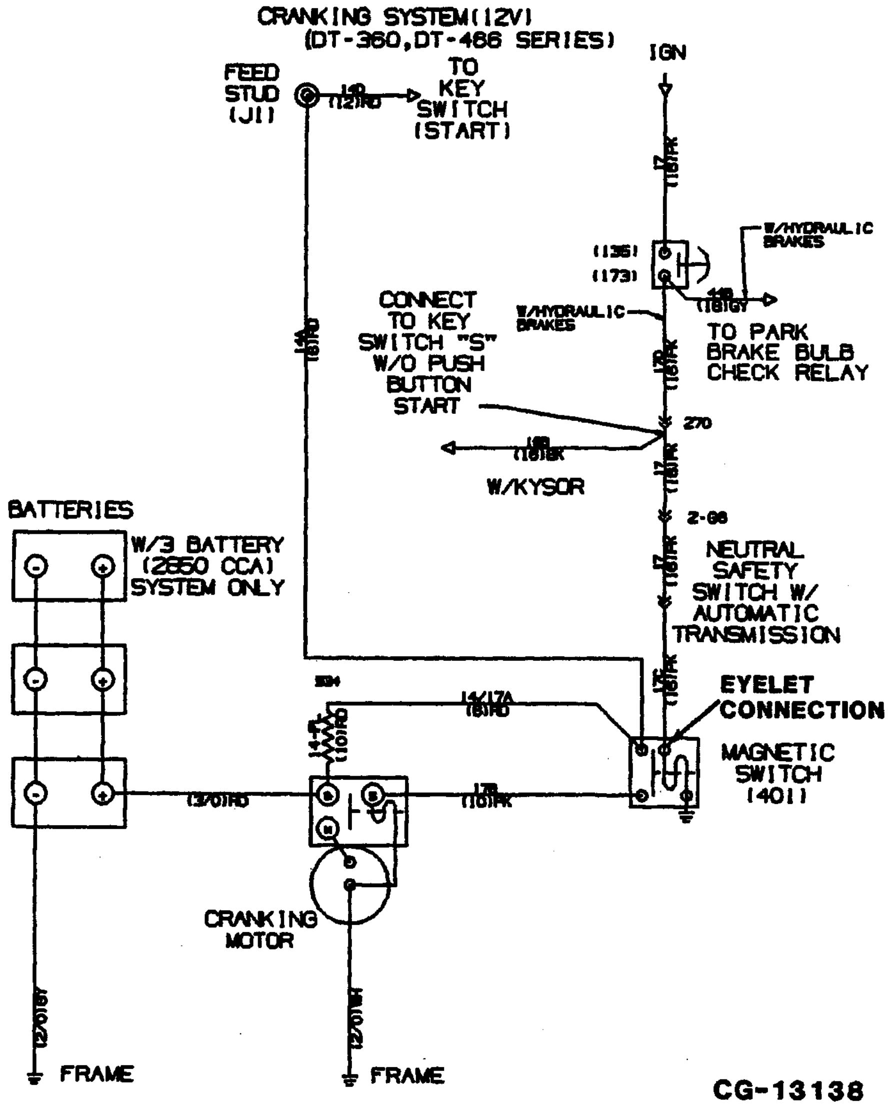

Figure 11.143. Cranking System Wiring Diagram

4. Shorten the green and yellow wires that were connected to the old fuel shut–off solenoid so that the ends are near the ends of the green and yellow wires in the adapter harness assembly

5. Use butt splices to connect the green wires (Hold–in circuit) together and the yellow wires (Ground circuit) together.

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FUEL INJECTION PUMP — Continued

INSTALLATION OF NEW "SWITCHLESS" ELECTRIC SHUT-OFF FOR PES6A INJECTION PUMP — Continued

NOTE: IF VEHICLE HAS A KYSOR SHUTDOWN SYSTEM, THEN SPLICE CIRCUIT 19E TO GREEN WIRE (HOLD–IN CIRCUIT) AND CIRCUIT 19–GB TO YELLOW WIRE (PULL–IN CIRCUIT). REFER TO FIGURE 11.144.

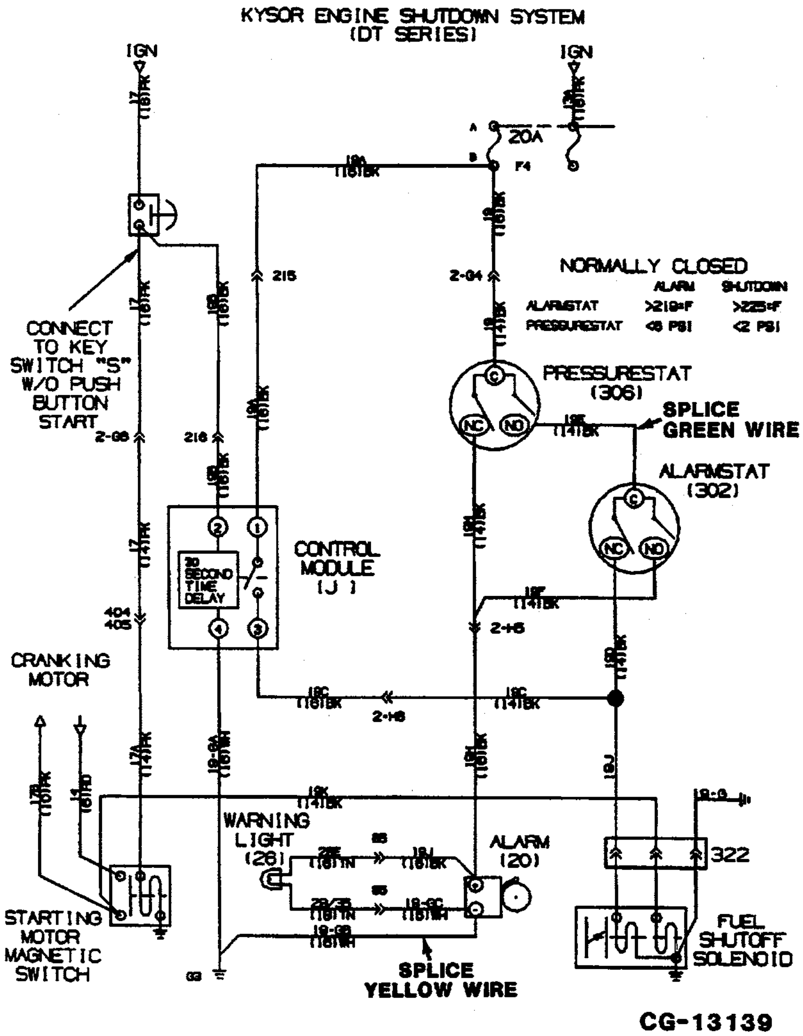

Figure 11.144. KYSOR Engine Shutdown System Wiring Diagram

6. To test wiring and solenoid, turn key switch to "ON" position (energize circuit) and then disconnect eyelet terminal (installed in step 3). Momentarily touch the eyelet terminal to the terminal opposite Circuit 17. This will cause the solenoid to energize and depress plunger to the bottom. When eyelet is removed, solenoid plunger will return.
7. Reconnect eyelet terminal to Circuit 17 and tighten nut.

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FUEL INJECTION PUMP — Continued

ADJUSTMENT OF NEW ELECTRIC "SWITCHLESS" SHUT–OFF SOLENOID FOR PES6A INJECTION PUMP (Refer to Figure 11.142)

NOTE: The adjustment procedure must be completed as specified to prevent solenoid burn–out or internal damage to the injection pump.

1. Energize the solenoid by turning the ignition key to the "ON" or "RUN" position. (RUN position for those vehicles equipped with push–button start).

NOTE: The solenoid plunger will not depress when energized.

2. Manually depress the plunger to the bottom (rear) of its travel.
3. While holding the plunger in, move the shut–off lever toward the RUN position and screw the solenoid swivel (with stud) into the rod end until the shut–off lever stops its forward movement.
4. Turn the swivel TWO FULL TURNS in the opposite direction. This moves the shut–off lever back towards the shut–off position.
5. Tighten the jam nut, then de–energize the solenoid.
6. Cycle the solenoid 2–3 times making sure the shut–off lever travel is adequate to achieve the "RUN" and "SHUT–OFF" positions. This can be done by cranking the engine to activate the "pull" coil causing the plunger to depress and turn the ignition off allowing the plunger to return under spring load.

CAUTION !

DO NOT cycle more than 3 times within one minute. Additional cycling may cause pull–in coil overheating resulting in burnout.

7. Secure wire and harnesses with strap locks to make sure that they will not interfere with solenoid operation or rub injection piping.

Reinstall the following:

- Lower compressor bracket
- Compressor (air brake system)
- Connect supply and discharge lines to the compressor
- Ether injector mounting plate

FUEL INJECTION PUMP – Continued

INSTALLATION OF ELECTRIC SHUT–OFF FOR MW INJECTION PUMP (Refer to Figure 11.145)

1. Assemble solenoid to bracket and tighten bolts.
2. Assemble bracket to engine at front cover and crankcase mounting locations.
3. Assemble rod end to shut–off lever and tighten bolt. **DO NOT** connect rod end to adjusting rod at this time.
4. Thread stud into solenoid swivel until stud bottoms and tighten locknut against the swivel.

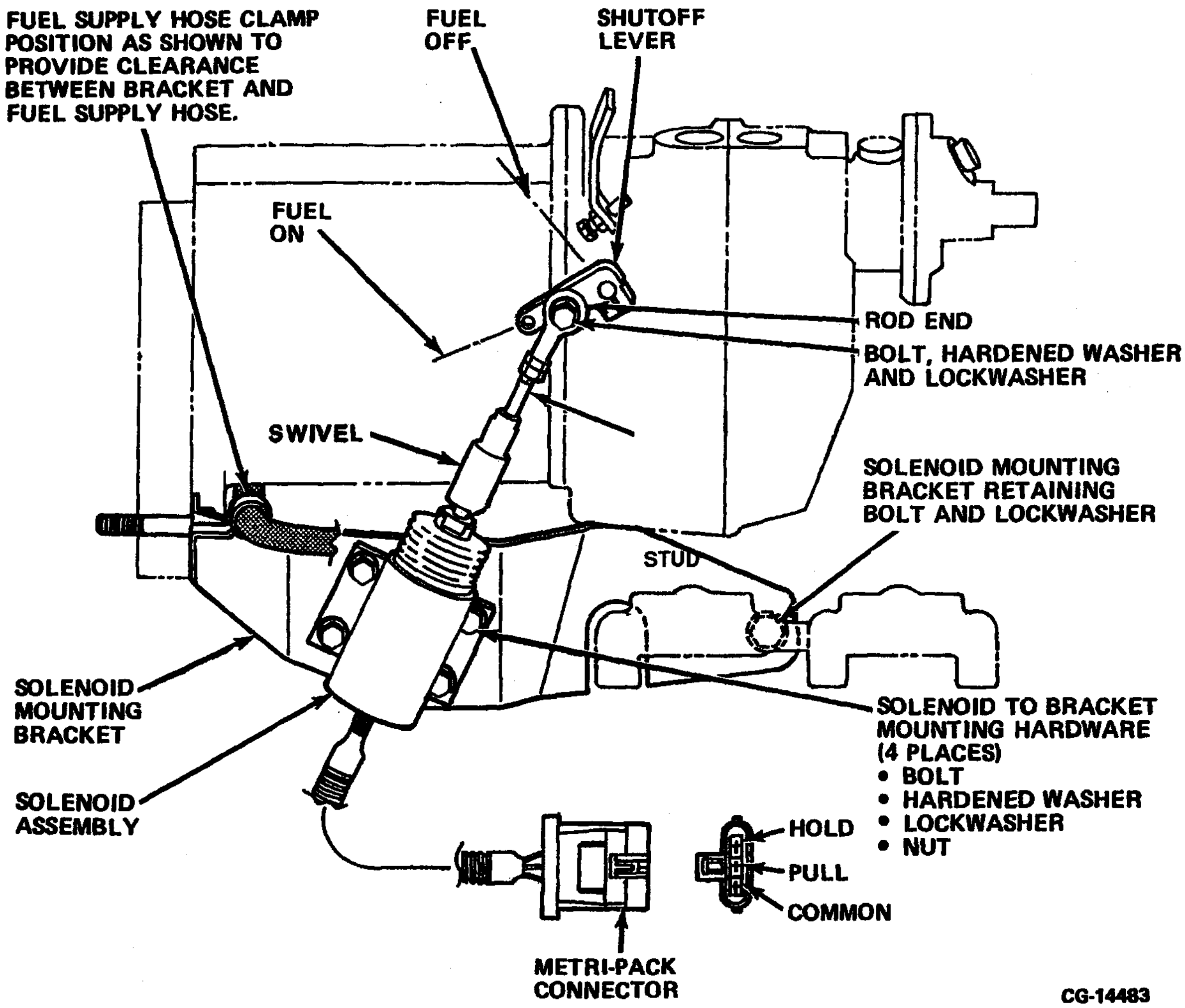

Figure 11.145. Solenoid Installation for MW Injection Pump

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FUEL INJECTION PUMP – Continued

ADJUSTMENT OF ELECTRIC SHUT–OFF SOLENOID FOR MW INJECTION PUMP (Refer to Figure 11.145)

1. Assemble the metri–pack connector between the engine and the solenoid wiring harness.

NOTE: The adjustment procedure must be completed as specified to prevent solenoid burn–out or internal damage to the injection pump.

a. Energize the solenoid by turning the ignition key to the **"ON"** or **"RUN"** position. (**RUN** position for those units equipped with push–button start).

NOTE: The solenoid plunger will not depress when energized.

b. Manually depress the plunger to the bottom of its travel.

c. While holding the plunger in, move the shut–off lever toward the **RUN** position and screw the solenoid swivel (with stud) into the rod end until the shut–off lever stops its downward movement.

d. Turn swivel **TWO FULL TURNS** in opposite direction (raising shut–off lever) and tighten locknut against rod end.

e. De–energize Solenoid

Following the installation and adjustment instructions will ensure that the solenoid plunger will be fully seated at bottom of stroke and internal injection pump shut–off lever will not contact interval housing stop tab nor interfere with injection pump fuel rack during "excess fuel" starting conditions. Shut–off stop screw has been factory preset limiting solenoid plunger total travel to approximately 1.00 inch from bottom of stroke (run position) to end of stroke (shut–off position).

f. Cycle the solenoid 2–3 times making sure the shut–off lever travel is adequate to achieve the "fuel" and "no fuel" positions. This can be done by cranking the engine to activate the "Pull" coil causing the plunger to depress and turn the ignition off allowing the plunger to return under spring load.

CAUTION !

Do not cycle more than 3 times within one minute. Additional cycling may cause pull–in coil over–heating resulting in burnout.

g. Secure wire and harnesses with strap locks to make sure that they will not interfere with solenoid operation or rub injection piping.

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SERVICE MANUAL

NOZZLES

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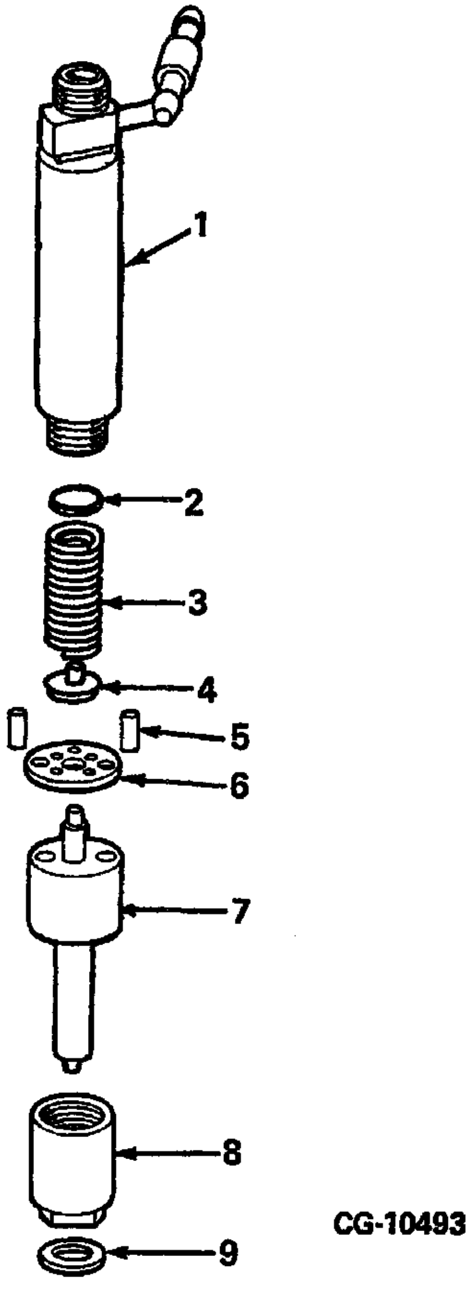

Figure 12.1. Fuel Injection Nozzle and Holder (Robert Bosch)

Legend for Figure 12.1

1. Body, Nozzle Holder
2. Spacer, Spring
3. Spring
4. Seat, Spring
5. Pins, Intermediate Plate
6. Plate, Intermediate
7. Nozzle (Tip), Injection (Nozzle Valve Body and Valve)
8. Nut, Nozzle Cap
9. Gasket, Injection Nozzle

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SPECIFICATIONS

DIMENSION TITLE	VALUES
NOZZLES:	
Type	Orifice
Code	
1987 Model Year	E
1988 & 1989 Model Year	G
1990 Model Year	10
1991 Model Year	18
Actuation	High Pressure Fuel from Injection Pump
Valve Opening Pressure (V.O.P.)	
New or Reconditioned (Codes E & G)	3075–3225 psi (21,201–22,236 kPa)
Min. V.O.P. before Reconditioning	2750 psi (18,961 kPa)
New or Reconditioned (Codes 10 & 18)	3600–3750 psi (24,820–25,855 kPa)
Min. V.O.P. before Reconditioning	2900 psi (20,000 kPa)

SPECIAL TORQUES

Nozzle Retainer Bolt (Crab Bolt)	20 lbf–ft. (27 Nm)
Injection High Pressure Line Connector Nut (A Pump)*	18 lbf–ft. (24 Nm)
Injection High Pressure Line Connector Nut (MW Pump)	30 lbf–ft. (40 Nm)

* A back–up wrench must be used on the delivery valve holder nut to prevent movement of the delivery valve holder on Model PES6A fuel injection pump.

SPECIAL SERVICE TOOLS

TOOL NO.	DESCRIPTION
ZTSE–1100	Injector Puller
ZTSE–4045A	Nozzle Hand Test Pump
ZTSE–4045	Nozzle Adapter Set
ZTSE–2752	Injection Nozzle Holding Fixture
ZTSE–2753	Holding Fixture Clamping Plate
ZTOEM–1068	Nozzle Cleaning Kit
ZTOEM–1070	Lapping Blocks

TROUBLESHOOTING

1. Where good combustion, specified engine temperature control and clean fuel prevail, nozzles require little attention.

Nozzle trouble is usually indicated by:

- Combustion knock

Other symptoms may include:

- Hard starting or failure to start
- Engine misses
- Excessive black smoke at idle
- Excessive black smoke under load
- Low power or loss of power
- Excessive fuel consumption
- Erratic idle speed
- Frequent engine stalls
- Surging at governed RPM

2. While the above symptoms may be caused by defective nozzles, they may also be caused by other engine related problems such as:
   - Incorrect fuel
   - Water in fuel
   - Dirty or damaged fuel filter
   - Incorrect maximum fuel setting
   - Faulty injection pump
   - Insufficient engine lubrication
   - Incorrect pump timing
   - Faulty engine valves
   - Air in fuel

3. Where faulty nozzle operation is suspected on an engine that is knocking, a simple test can be made to determine which cylinder is causing the difficulty.
4. With the engine running at a speed that makes the defect most pronounced, momentarily loosen the high pressure fuel inlet connection on one nozzle assembly sufficiently to "cut out" the cylinder.
5. Check each cylinder in the same manner. If one is found where loosening causes knocking to cease, the injection nozzle for that cylinder should be tested.
6. Nozzle testing, disassembly, cleaning and reconditioning must be done only by an authorized International Dealer or other diesel service outlet equipped and qualified to perform such services.

TROUBLESHOOTING — Continued

NOTE: When servicing injection nozzle assemblies, the necessity of cleanliness cannot be overemphasized. A clean workbench, clean washing fluid containers, clean tools and clean hands are all essential to produce satisfactory results. The use of suitable tools for this type of work is equally important.

TROUBLESHOOTING GUIDE

FAULT	POSSIBLE CAUSE	REMEDY
Nozzle bluing	1. Faulty installation or tightening. 2. Insufficient cooling.	Replace nozzle. Correct cooling system.
Spray pattern not well atomized	1. Carbon deposit on tip of nozzle valve. 2. Nozzle orifice(s) partially 3. Defective nozzle.	Clean nozzle. Clean nozzle. Replace nozzle.
Nozzle opening pressure too high	1. Incorrect shim adjustment 2. Nozzle valve dirty or sticky. 3. Seized nozzle	Readjust nozzle shims. Clean nozzle. Replace nozzle tip assembly.
Nozzle opening pressure too low	1. Shim/spacer wear. 2. Nozzle valve spring broken. 3. Nozzle seat worn.	Replace worn components and reset V.O.P.
Nozzle valve seat leakage	1. Nozzle leaks because of excessive carbon deposit or sticking nozzle 2. Defective nozzle.	Clean nozzle. Replace nozzle assembly.
Excessive leak–off	1. Dirt between pressure face of nozzle, valve stop spacer and holder body. 2. Loose nozzle cap nut. 3. Defective nozzle tip.	Clean nozzle. Inspect nozzle body and valve then tighten retainer nut to 45 Nm (33 lbf–ft.). Replace nozzle tip assembly.

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IDENTIFICATION

NOZZLE CHART

International® Nozzle and Holder Assy.	International® Nozzle Number	Code	Vendor Nozzle Identification Number Inscribed on Valve Body (See NOTE 1)	Dia. of Spray Holes mm/(in.)	Opening Pressure (New) (See NOTE 2)
1 810 398 C91+	1 810 397 C1	E	DLLA 150 P 147	4–0.300mm 0.0118 in.	21,200–22,235kPa (3075–3225 psi)
1 812 509 C91+	1 812 510 C1	G	DLLA 140 P 182	4–0.300mm 0.0187 in.	22,580–23,440kPa (3275–3400 psi)
1 813 859 C91	1 813 860 C1	G	NBM 770300	4–0.310mm 0.0122 in.	24,820–25,855kPa (3600–3750 psi)
1 815 409 C91	1 815 481 C1	10	NBM 770830	4–0.295mm 0.0116 in.	24,820–25,855kPa (3600–3750 psi)
1 817 418 C91	1 817 419 C1	18	NBM 770991	4–0.300mm 0.0118 in.	24,820–25,855kPa (3600–3750 psi)

NOTE 1: Nozzle identification number cannot be seen with nozzle assembled in the holder. (Refer to Figure 12.2)

NOTE 2: Recondition or replace the nozzle when opening pressure is below 2750 psi (18,961 kPa) for nozzles 1 810 397 C1 and 1 812 510 C1. For nozzle numbers: 1 813 860 C1, 1 815 481 C1 and 1 817 419 C1, recondition or replace the nozzle when opening pressure is below 2900 psi (19,995 kPa)

+ This International® nozzle and holder assembly part number DOES NOT appear on the nozzle holder. The following Robert Bosch nozzle holder part number does appear on the holder (KBAL 90 P 11). (Refer to Figure 12.2.)

NOTE: When performing the Nozzle Leakage Test and the nozzle is subjected to 3447 kPa (500 psi) hydraulic pressure below opening pressure for 5 seconds, wetting of the nozzle tip is permissible without the formation of a droplet.

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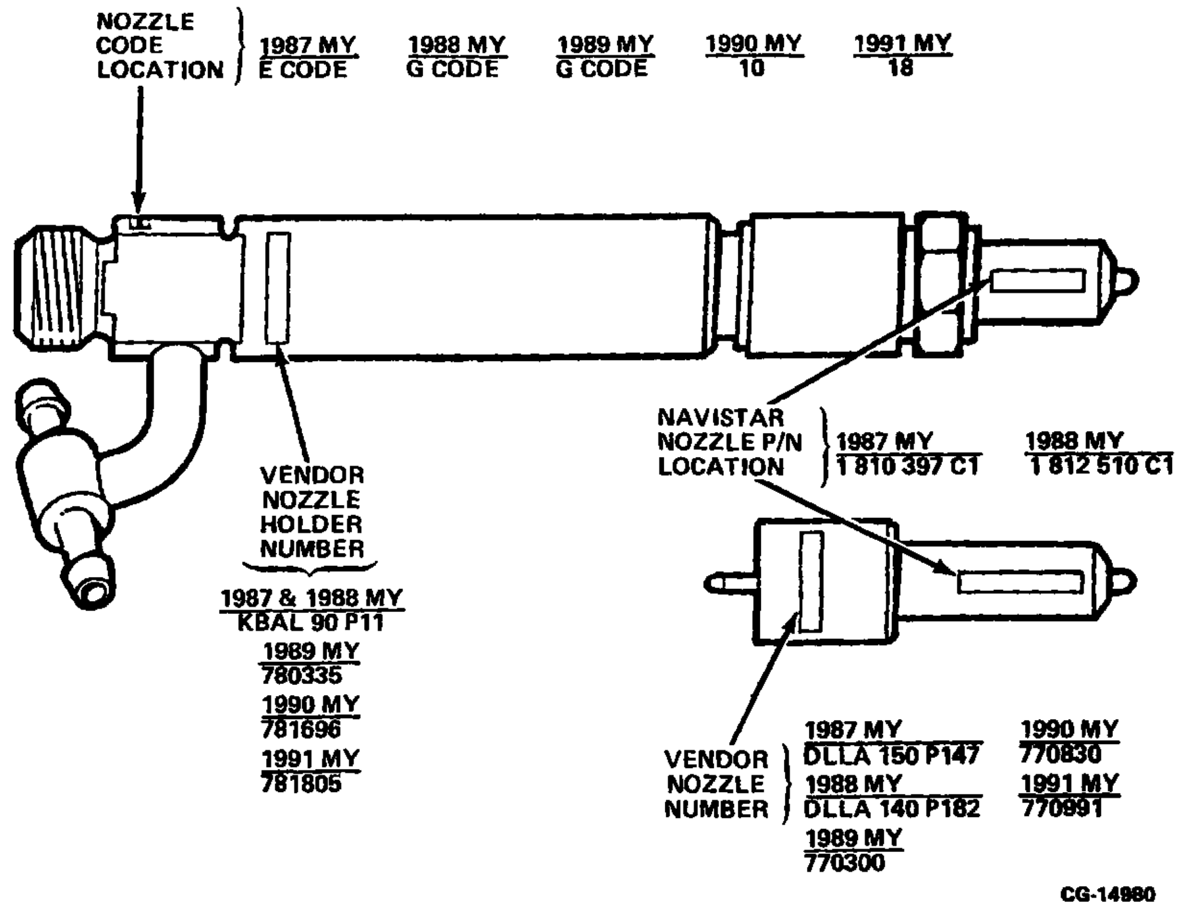

Figure 12.2. Nozzle and Holder Assembly Identification

IMPORTANT

NEW NOZZLE AND HOLDER ASSEMBLIES ARE RELEASED AND MATCHED FOR THE EACH MODEL YEAR. REFER TO THE CURRENT PARTS CATALOG FOR PROPER SERVICE NUMBER AND REFER TO THE NOZZLE CHART ON PAGE 5 FOR SPECIFICATIONS. DO NOT INTERMIX INJECTION NOZZLE ASSEMBLIES. INTERMIXING NOZZLES WILL RESULT IN POOR PERFORMANCE AND NON-COMPLIANCE WITH EMISSION STANDARDS.

REMOVAL

1. Clean the top of the engine to prevent dirt from entering any openings.

2. Remove the fuel injection lines as an assembly. Follow the directions in Section 11 under "Fuel Injection Pump Removal".

IMPORTANT

BE SURE TO CAP ALL NOZZLE, PUMP AND FUEL LINE OPENINGS TO PROTECT THE FUEL SYSTEM FROM CONTAMINATION.

3. Remove the injection nozzle hold–down bolt and clamp (crab). Refer to **Figure 12.3.**

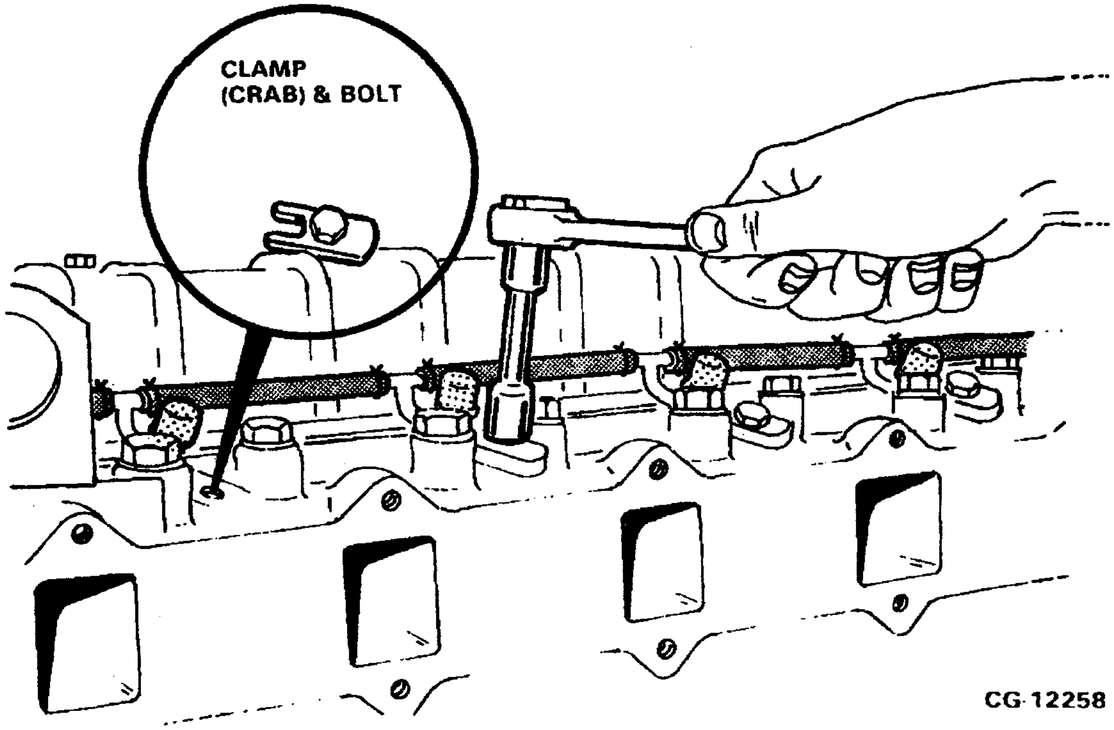

Figure 12.3. Remove Nozzle Hold–Downs

REMOVAL — Continued

4. Remove the nozzle as follows:
   a. If necessary, use nozzle injector puller (ZTSE–1100) to pull the nozzle straight out. Refer to **Figure 12.4**.

NOTE: Twisting the holder with a wrench will loosen the nozzle and the copper sealing gasket at the bottom of the nozzle but may also accidentally loosen or remove the injector sleeve.

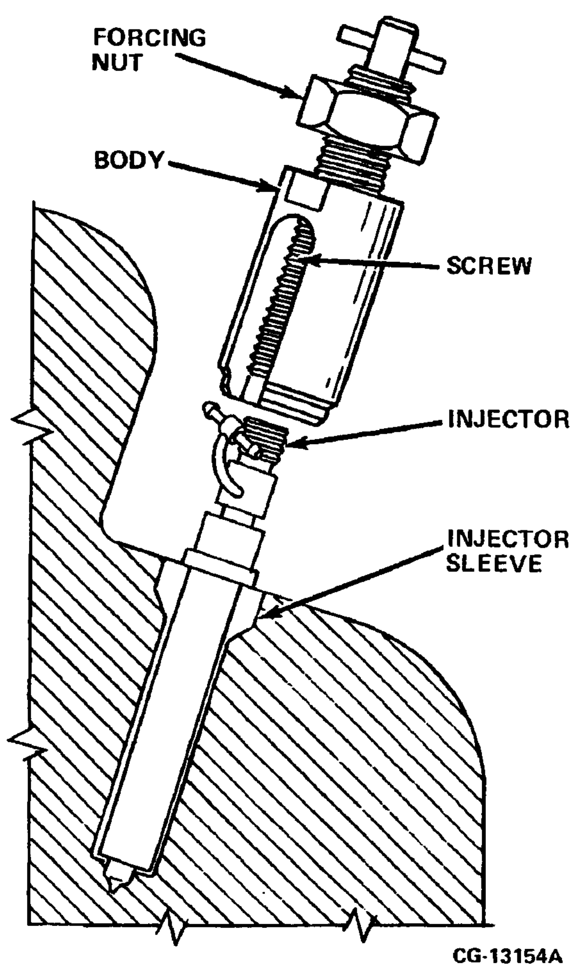

Figure 12.4. Injection Puller

5. Remove the nozzles and dust seal grommets from their sleeved bores in the cylinder head.

NOTE: The nozzles may be removed as an assembly (with the leak–off lines) or individually. Install plastic caps over the nozzle tips when removed from the cylinder head.

6. Remove the copper nozzle gaskets from the nozzle bores using an O–ring pick. Refer to **Figure 12.5.**

NOTE: The nozzle gasket(s) may adhere to the nozzle(s) when removed.

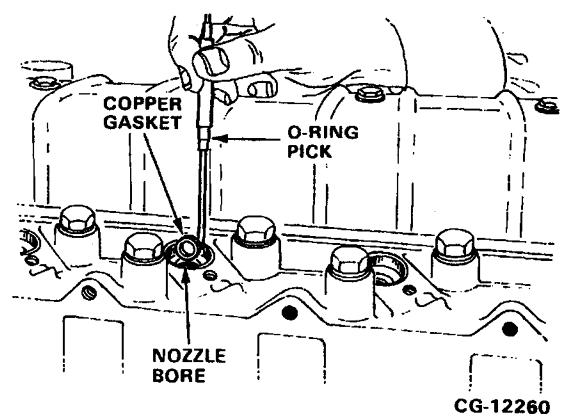

Figure 12.5. Remove Copper Sealing Gasket from Bore

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PRE–RECONDITIONING INSPECTION

1. The prime requirements for a satisfactory nozzle assembly are: pressure tight seats; no excessive valve stem leakage; satisfactory spray and atomization characteristics.
   a. After removal from engine, test nozzles for spray condition, opening pressure and leakage on a hand test pump ZTSE–4045A. **Figure 12.6** shows an injection nozzle mounted for testing on the hand test pump.

IMPORTANT

IT IS ADVISABLE TO TEST NOZZLES BEFORE CLEANING THEM. AFTER TESTING, PLACE NOZZLES IN A COLD DECARBONIZING SOLUTION FOR AT LEAST ONE HOUR. AFTER REMOVING NOZZLES FROM SOLUTION, WASH OFF THE OUTSIDE SURFACES.

   b. Prepare pump for making tests. Fill pump reservoir with Viscor 1487C calibration fluid. Open pump valve slightly and operate pump handle to expel air from pump and outlet pipe. Operate pump until solid fluid (without air bubbles) flows from the end of the outlet pipe. Close the pump valve.

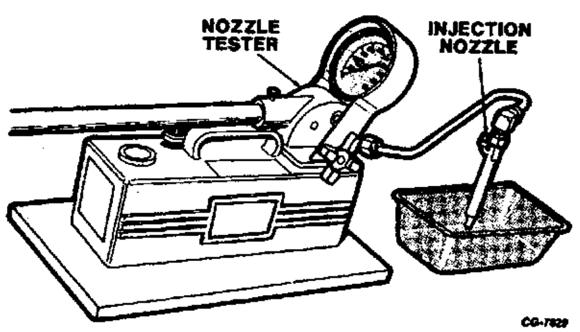

Figure 12.6. Mount Nozzle Assembly to the Hand Test Pump

   c. Connect injection nozzle to test pump. Avoid "cross–threading". Tighten connector nut securely with open end wrench.

NOTE: The gauge valve should be closed. Failure to close the gauge valve will lead to a damaged gauge. The gauge valve should only be opened to check opening pressure and tip leakage. A residual pressure should always be left in the pressure gauge.

   d. Bleed air from the nozzle. Open the pump valve and operate the pump for several quick strokes to expel (bleed) air from the injection nozzle. Fluid should discharge from the holes in the nozzle tip.

IMPORTANT

KEEP HANDS AWAY FROM NOZZLE DISCHARGE. FLUID DISCHARGING FROM THE NOZZLE UNDER HIGH PRESSURE CAN PENETRATE THE SKIN AND CAUSE INFECTION. MEDICAL ATTENTION SHOULD BE PROVIDED IMMEDIATELY IN THE EVENT OF SKIN PENETRATION.

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PRE–RECONDITIONING INSPECTION — Continued

e. OBSERVE THE DISCHARGE PATTERN. Operate the test pump in smooth, even strokes and observe the pattern of fluid discharging from the four (4) nozzle tip discharge holes. The discharge should be well atomized in an even pattern, free from solid streams and dribbling. Refer to **Figure 12.7.**

f. CHECK NOZZLE OPENING PRESSURE. Open the gauge valve, operate the test pump in slow, smooth, even strokes and observe gauge pressure to determine pressure at which nozzle opens (discharges fluid). The nozzle should operate within the specified opening pressure range. See **"SPECIFICATIONS"**.

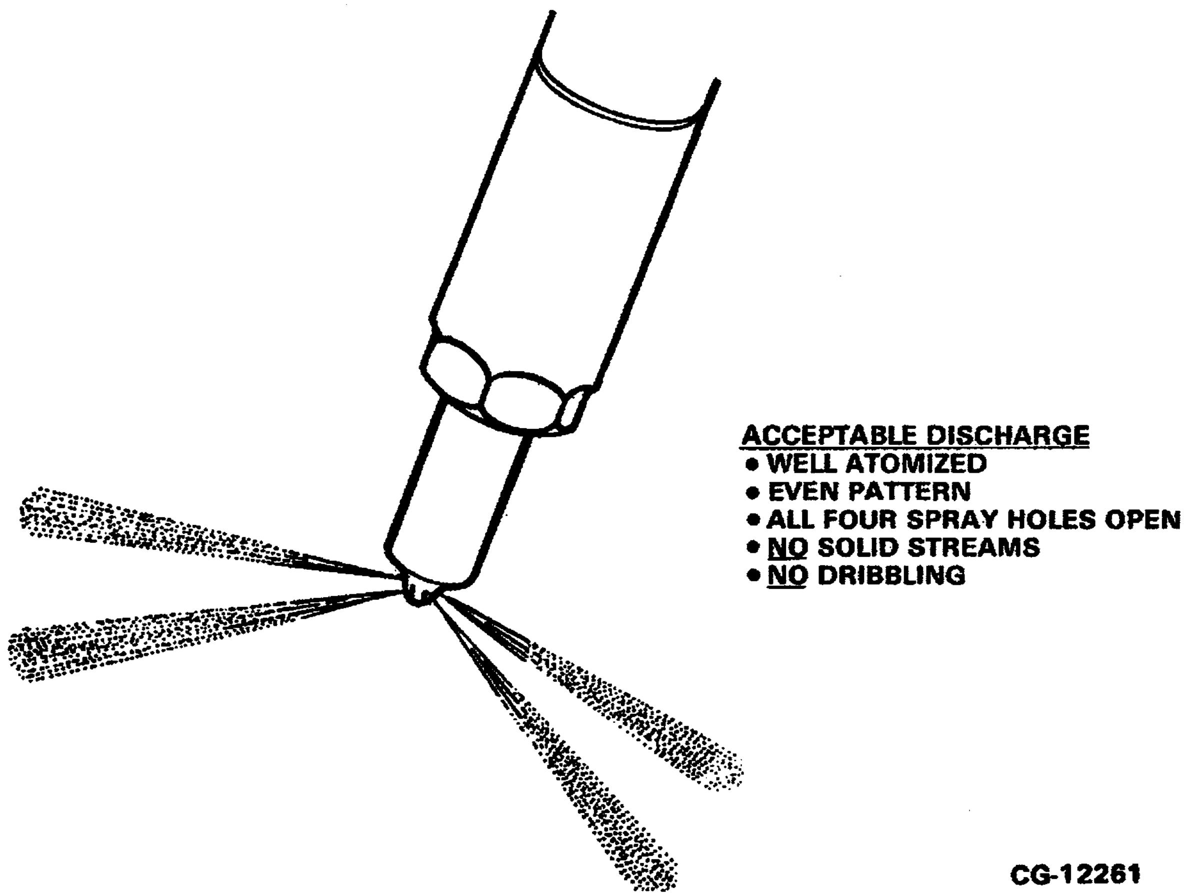

Figure 12.7. Acceptable Nozzle Discharge

PRE–RECONDITIONING INSPECTION — Continued

g. CHECK FOR TIP LEAKAGE. Blow nozzle tip dry using filtered compressed air. Operate test pump to maintain pressure at about 500 psi (3447 kPa) below opening pressure. Nozzle tip should remain dry without an accumulation of fluid drops at spray holes. A slight wetting after about 5 seconds is permissible if no droplets are formed. Refer to **Figure 12.8.**

IMPORTANT

DO NOT WIPE TIP WITH FINGERS AS THIS WILL TEND TO DRAW THE FLUID PRESENT IN THE SAC HOLE THROUGH THE ORIFICES AND FALSELY INDICATE A LEAK AND REJECTION OF A GOOD VALVE.

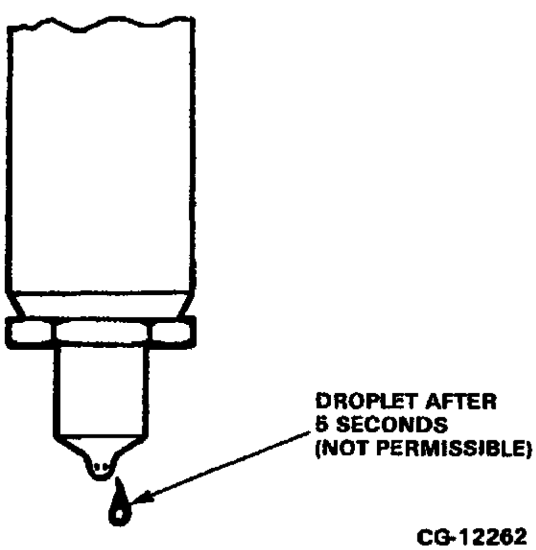

Figure 12.8. Unacceptable Nozzle Tip Leakage

h. CHECK FUEL LEAK–OFF. Operate test pump in quick strokes and observe for flow of fluid from leak–off part of nozzle. A very slight leak–off is normal. If more than 1.0 cc/min. of fluid is expelled or if fluid surges from leak–off port when nozzle pressure is held @ 500 psi below V.O.P., the nozzle is faulty.

2. If the nozzle passes the above tests, it is suitable for further service in the engine following cleaning and removal of accumulated carbon. Nozzles showing irregular spray pattern, leakage at nozzle tip spray holes, excessive fluid leak–off or opening pressure below minimum permissible limit should be replaced or reconditioned (disassembled, cleaned and rebuilt).

DISASSEMBLY

NOTE: Disassemble only those nozzle holder assemblies that fail to meet specifications.

When inspecting various components, reference can be made to test performance results as an aid in determining the extent of reconditioning necessary.

NOTE: Under no circumstances should nozzle valves and bodies be interchanged. To avoid interchanging, use numbered containers to keep nozzle components together.

1. Wash all external dirt, grease and carbon deposits from holder assembly with a suitable cleaning agent.

2. Remove nozzle gasket from nozzle, if not removed earlier.

3. A brass wire hand brush should be used to remove hardened deposits of dirt or carbon. DO NOT use a steel wire brush to clean the nozzles. Never use a power operated brush.

IMPORTANT

SOAK NOZZLE HOLDER ASSEMBLY IN A CARBON REMOVING CLEANING AGENT ("GUNK", "BENDIX CLEANER" OR EQUIVALENT) FOR AT LEAST FOUR HOURS BEFORE REMOVING NOZZLE CAP NUT, OTHERWISE, THE NOZZLE PLATE PINS MAY BE DAMAGED.

DISASSEMBLY — Continued

4. An ZTSE–2752 injector nozzle holding fixture and ZTSE–2753 injector nozzle clamping plate is required when disassembling a nozzle holder assembly; otherwise, the nozzle plate pins may be damaged.
   a. It is recommended that the ZTSE–2752 holding fixture be bolted to a workbench.
   b. Assemble the clamping plate (ZTSE–2753) to the guide pins on the holding fixture (ZTSE–2752). Refer to **Figure 12.9.**

NOTE: Wrench must be assembled prior to clamping nozzle in fixture.

   c. Insert the nozzle and holder assembly into the clamping plate as shown in **Figure 12.9.**
   d. Loosen the nozzle cap nut with an appropriate box end wrench until the nut can be turned by hand.
   e. Remove holder assembly from fixture.

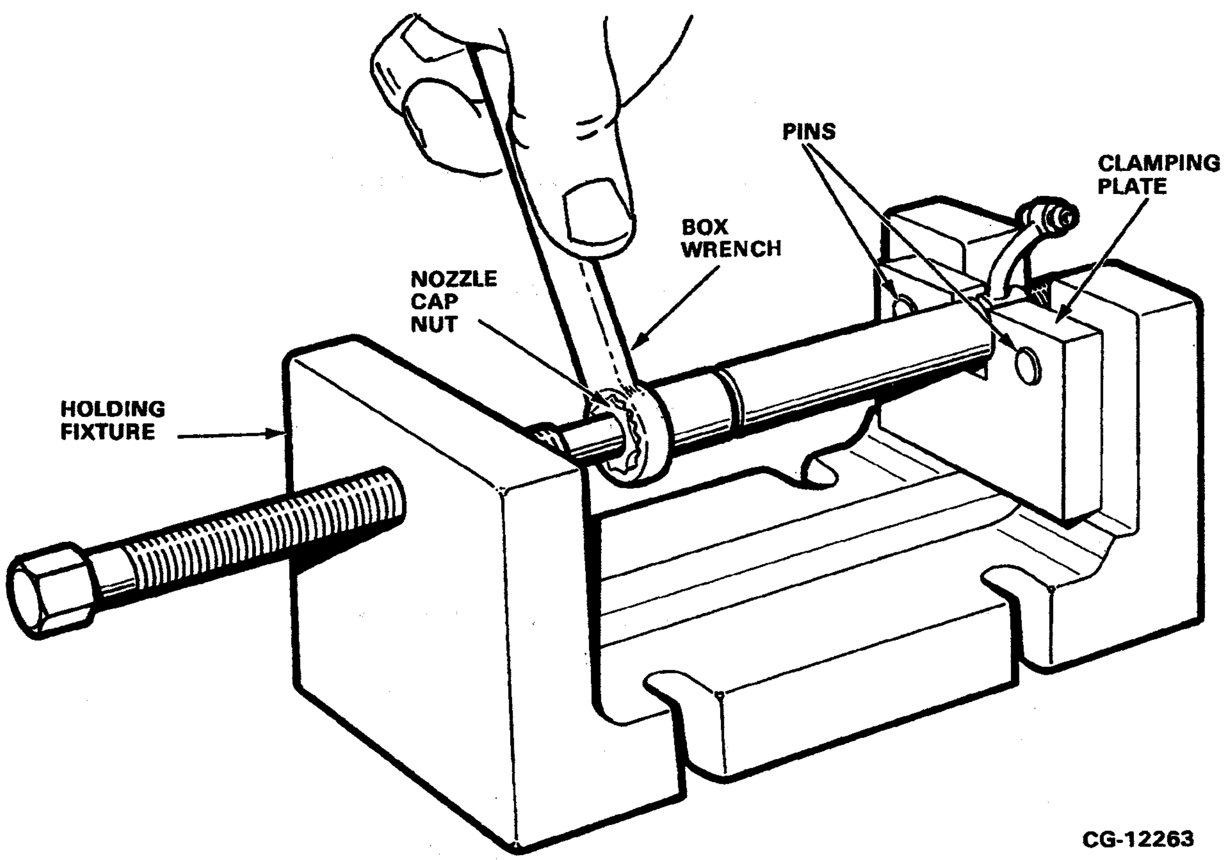

Figure 12.9. Mount Nozzle in Holding Fixture to Disassemble

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DISASSEMBLY — Continued

5. The nozzle may now be disassembled. Refer to **Figure 12.10** for component parts.

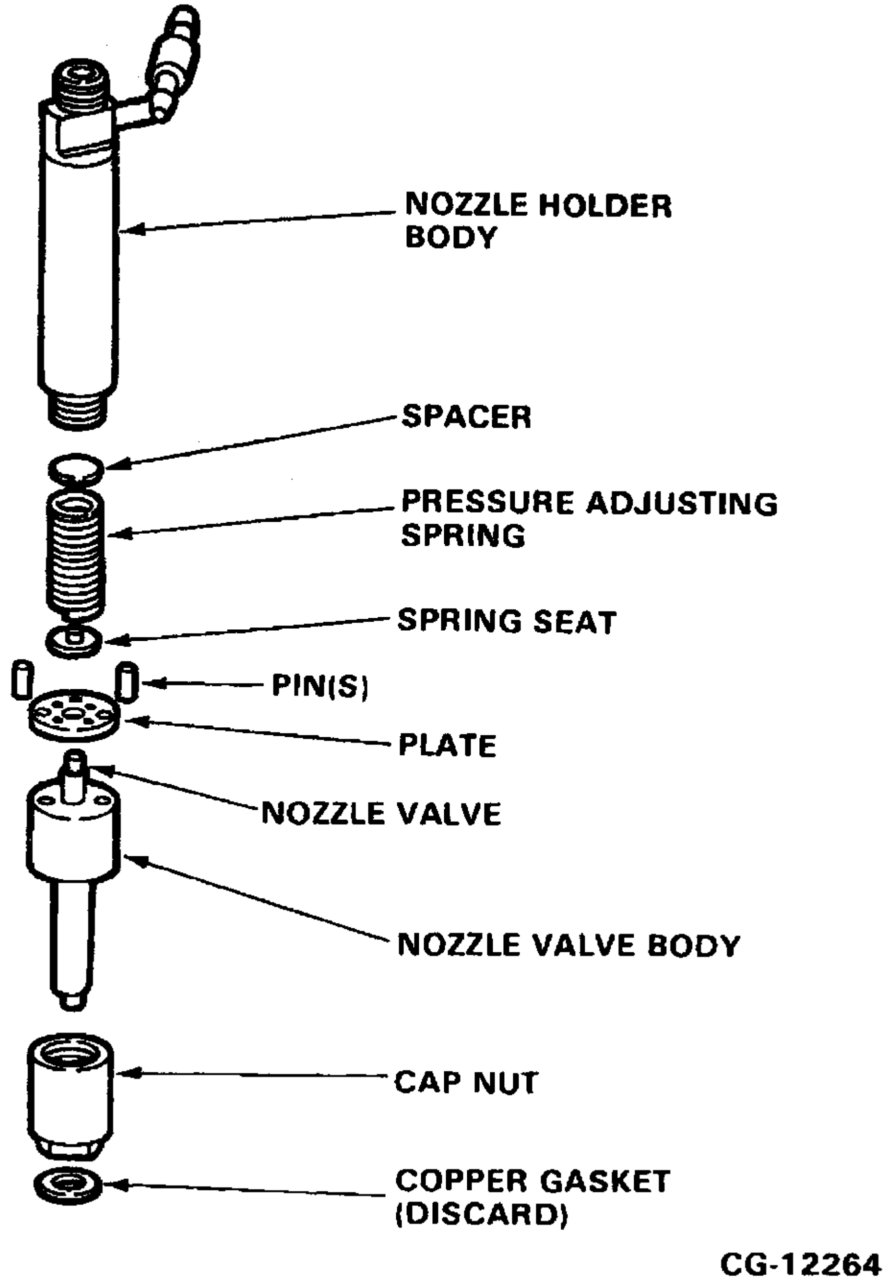

Figure 12.10. Fuel Injection Nozzle and Holder Components

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CLEANING, COMPONENT INSPECTION AND REPAIR

Cleaning

1. Wash all parts in a suitable cleaning agent.

NOTE: DO NOT intermix nozzle valves. Keep each valve with its original nozzle body.

2. Soak nozzle valve (tip) in a varnish removing cleaning agent.

3. Probe all nozzle spray holes with the appropriate size cleaning needle found in ZTOEM–1068 nozzle cleaning kit.

NOTE: The needle used must be smaller in diameter than the nozzle spray hole. See nozzle chart in this section for number and size of orifice holes.

4. Clean all ducts and nozzle spray holes with compressed air.

5. Thoroughly clean interior of nozzle cap nut. All carbon deposits must be removed (soak to loosen — brass brush to clean).

ZTOEM–1068 Nozzle Cleaning Set Consists of:

Description	Qty.
Honing Stone	1
Pin Vise, 0–.075"	1
Tallow, 1/2 oz. Tube	1
Brass Wire Brush, 1" x 3"	1
Tool Box (Wood, Sliding Lid)	1
Pressure Chamber Scraper	1
Polishing Sticks, 5 mm (60° Seat)	Set of 3
Valve Seat Scraper (60° Seat)	1
Inspection Magnifier (Loupe) 5x	1
Valve Seat Scraper (90° Seat)	1
Polishing Sticks, 5 mm (90° Seat)	Set of 3
Nozzle Sac Hole Reamers .046"	Set of 2
Nozzle Sac Hole Reamers .050"	Set of 2
Nozzle Sac Hole Reamers .069	Set of 2

ZTOEM–1068 Nozzle Cleaning Set — Continued

Description	Qty.
Spray Hole Cleaning Needles .010"	Set of 5
Spray Hole Cleaning Needles .011"	Set of 5
Spray Hole Cleaning Needles .012"	Set of 5
Spray Hole Cleaning Needles .013"	Set of 5
Spray Hole Cleaning Needles .014"	Set of 5
Spray Hole Cleaning Needles .015"	Set of 5
Spray Hole Cleaning Needles .021"	Set of 5

NOTE: Do not be too hasty in judging performance of a nozzle. It has been found that after soaking nozzles in a good carbon cleaner or carburetor cleaner for a day that many will meet specifications for leakage or opening pressure that might otherwise be rejected.

Component Inspection and Repair

1. Use a magnifying glass (part of ZTOEM–1068) to inspect the mating surfaces of the nozzle components, particularly the plate, nozzle valve body and valve for nicks, scratches or signs of corrosion. Refer to **Figure 12.11.**

NOTE: Failure of these surfaces to seal properly will result in leakage to the return or to the outside of the nozzle.

Recondition the mating surfaces by flat lapping or replace the components as required.

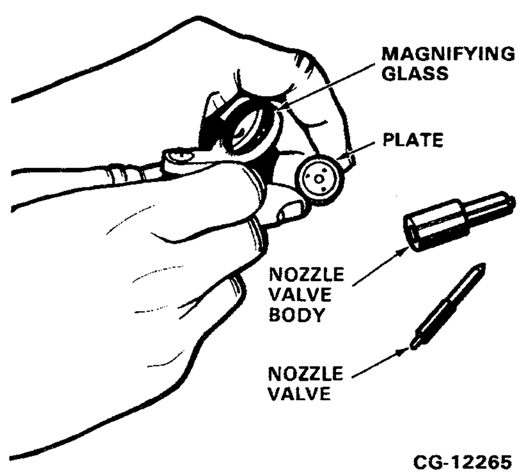

Figure 12.11. Inspect Mating Surfaces

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CLEANING COMPONENT INSPECTION AND REPAIR — Continued

Component Inspection and Repair — Continued

NOTE: Use Lapping Blocks Set ZTOEM–1070.

a. Prepare the lapping blocks for use by washing them in fuel oil and using a bristle brush. Dry off with filtered compressed air. DO NOT USE WIPING RAGS.

b. Mix a small amount of lapping compound (1000 grit) into a thin paste using diesel fuel.

NOTE: In some areas, prepared lapping compound can be obtained in small tubes.

c. Apply a very small amount of lapping compound (well spread out) to the lapped side of the block. Keep this amount at a minimum to obtain the best results.

NOTE: Blocks that are grooved on both sides are generally marked to indicate which side is the lapped surface.

d. The part to be lapped should be placed upon the lapping block and moved about in a figure eight pattern.

To equalize the wear in the lapping block, the series of figure eight strokes should start at one side and progress across the block as shown in **Figure 12.12.**

e. Apply only enough pressure to keep the part flat on the block. After four or five "passes", lift the part off the block and clean the compound off by rubbing the part across a clean sheet of paper placed on a flat surface. (Avoid excessive lapping.) If the surface of the lapped part does not appear uniform in reflected light or if there are any depressions around the sealing surfaces, repeat the lapping procedure above (see Note).

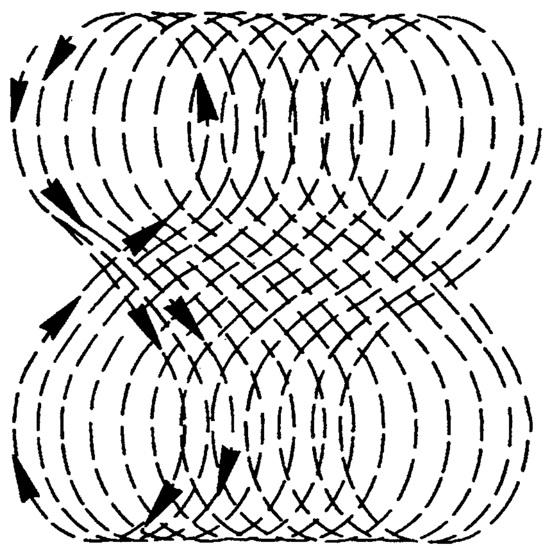

Figure 12.12. Pattern of Strokes Used for Flat Lapping

NOTE: One exception will be for the valve stop spacer. When the lapping process does not remove depressions around the center valve stem hole, the plate may be turned over in "Reassembly", provided good sealing surfaces are present. Otherwise the plate must be replaced with a new one.

f. Perform the last step, DRY LAPPING, which produces a mirror–like finish and provides an excellent sealing surface. Proceed as follows:

1. Clean the block in the same manner as described earlier and dry with filtered compressed air. The block used MUST BE FREE OF ANY LAPPING COMPOUND.
2. Place the part to be lapped on the block surface and move it about in a figure eight pattern across the whole area of the block (**Figure 12.12**). Make four or five passes, then inspect the finish before repeating (if necessary).

CLEANING COMPONENT INSPECTION AND REPAIR — Continued

Component Inspection and Repair — Continued

3. Apply only enough pressure to keep the part flat on the block.

NOTE: Do not handle parts on the lapped surfaces as corrosion will appear in the areas touched.

IMPORTANT

KEEP THE LAPPING BLOCKS COVERED WHEN NOT BEING USED, TO KEEP DUST OR OTHER FOREIGN MATTER FROM THE SURFACE.

NOTE: It will be necessary to perform a certain amount of maintenance on the lapping blocks to keep them in top condition. The wear will be gradual but, by continued use, worn or low spots in the block must be removed.

A short time spent each day in hand–lapping the blocks will be an effective way of maintaining the finish necessary for quality lapping.

g. Recondition the lapping blocks as follows:

The lapping blocks must be thoroughly cleaned before any reconditioning is started. Use a stiff bristle brush (not a wire brush) and scrub the blocks in a good solvent and blow dry with filtered compressed air.

All lapping blocks in a set involved in the reconditioning procedure outlined below:

Step 1. Spread a small amount of 1000 grit lapping compound (prepared in a paste) on a block number 1, assuming the blocks to be numbered 1, 2 and 3.

Step 2. Lap number 1 and 2 (face to face) together, using the figure eight pattern (Figure 12.12.). Then take 1 and 3; and finally 2 and 3. After working 1 and 3 together, wipe off number 2 on a clean sheet of paper placed on a flat surface. Low spots, if any, will appear as dark spots and high spots as bright spots. Continue the lapping procedure until the overall appearance is a uniform gray surface.

Step 3. After the blocks have been refinished, clean them thoroughly in a good solvent using a bristle brush, then blow dry with filtered compressed air.

1. Visually inspect the plate pins for deformity or breakage. Replace as required.
2. Visually inspect the nozzle cap nut for cracks, damaged threads or damaged copper gasket seating face. Replace as necessary.
3. Check the stem and the body of the valve. When both parts are wet with fuel oil, no sticking should be evident. Pull the valve out of the body about one–third of its length. When released, the valve should slide freely back to the seat. Foreign matter or scratches on the valve will cause it to stick. Carefully inspect before installing the valve.
4. OPENING PRESSURE ADJUSTMENT: The nozzle opening pressure is increased or decreased by the selection of the appropriately sized spacer.

REASSEMBLY (Refer to Figure 12.10.)

1. DO NOT touch lapped surfaces. To avoid interchanging of nozzle parts, reassemble one nozzle at a time.
2. Dip all parts in clean calibrating fluid.
3. Clamp the nozzle holder body upright in a vise, using the flats on the holder body to clamp onto.

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REASSEMBLY — Continued

4. Select an appropriate size spacer to achieve the correct opening pressure and insert it into the holder body.
5. Place the pressure adjusting spring and spring seat into the nozzle holder body.
6. Align the plate and pins with the dowel pin holes in the holder body and assemble to the nozzle holder body.
7. Dip the nozzle valve, located in the nozzle valve body, into clean calibrating fluid. Insert the nozzle valve into the valve body and move the valve up and down several times to insure free movement.
8. Apply a thin, even coat of "Lubriplate 630–AAA" or equivalent to the nozzle valve body seating shoulder; align the nozzle valve body locating pin holes with the plate pins and assemble to the two components.
9. Assemble the cap nut over the nozzle valve body and tighten the cap by hand to the holder.
10. Assemble nozzle holder assembly to injection nozzle holding fixture (ZTSE–2752) as described under "DISASSEMBLY" in this section.
11. Tighten the cap nut to the specified special torque.
12. Install a new copper gasket over the nozzle tip.
13. Cap the nozzles with plastic caps until retesting and adjusting is performed.

RETESTING AND ADJUSTING CLEAN NOZZLE ASSEMBLIES

CAUTION !

KEEP HANDS AWAY FROM THE NOZZLE DISCHARGE. FLUID DISCHARGING FROM THE NOZZLE UNDER HIGH PRESSURE CAN PENETRATE THE SKIN AND CAUSE INFECTION. MEDICAL ATTENTION SHOULD BE PROVIDED IMMEDIATELY IN THE EVENT OF SKIN PENETRATION.

1. Using VISCOR 1487C (SAE J967 Standard) calibration fluid and a standard hand test pump ZTSE–4045A, equipped with a pressure gauge having a capacity of at least 27,600 kPa (4000 psi), proceed as follows: (Refer to **Figure 12.13.**)

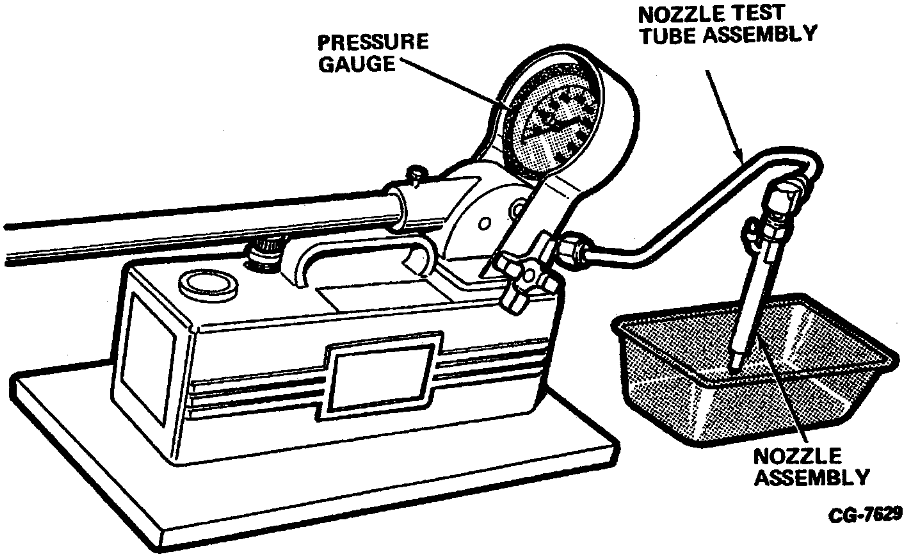

Figure 12.13. Nozzle Test Equipment

RETESTING AND ADJUSTING CLEAN NOZZLE ASSEMBLIES — Continued

a. Attach the nozzle tube assembly (part of Nozzle Adapter Set ZTSE–4045) to the nozzle hand test pump.

b. Attach the 90° adapter (part of Nozzle Adapter Set ZTSE–4045) to the nozzle tube.

c. Attach nozzle and holder assembly loosely to the test pump. Pump the handle several times to flush out the fittings, then tighten.

2. Test each nozzle for opening pressure as follows:

OPENING PRESSURE TEST: Pump the test pump handle a few strokes to clear the air from the nozzle and then raise the pressure steadily. Observe the gauge pressure at which the valve opens. Refer to the Nozzle Test Chart in this section for the specified opening pressure. If the pressure is incorrect, adjust by selecting a different size spacer.

NOTE: A .001 inch change in the spacer will result in a 55 psi (379 kPa) change in pressure.

3. Test each nozzle for seat leakage as follows:

SEAT LEAKAGE TEST: Wipe the nozzle tip dry. Bring the pressure up slowly to 500 psi (3447 kPa) below the nozzle opening pressure and maintain this pressure for 5 seconds. If fluid leaks or drips from the nozzle or a visible drop forms, the nozzle is leaking (slight moistening of the nozzle tip is permissible). Recondition or replace a leaking nozzle.

NOTE: Do not wipe the tip with the fingers as this will tend to draw the fuel present in the sac hole through the orifices and falsely indicate a leak resulting in the rejection of a good valve. Leakage at the seat may be caused by dirt or foreign material, carbon or gum deposits at the seat area or excessive wear of the seat. If the seat is worn, replace the nozzle body and nozzle valve.

NOTE: Never lap the valve–to–body seat. This will only widen the seat area and prevent sealing.

4. Test each nozzle for spray pattern as follows:

SPRAY PATTERN TEST: Close pressure gauge valve. Actuate test stand at a moderate rate and observe the spray pattern.

a. All of the fluid should be atomized and each hole should spray approximately the same amount of fuel.

b. The spray patterns for all holes should be uniform.

NOTE: Upon operating the test pump you will note a distinct and relatively regular nozzle chatter. A sharp pitched sound is not mandatory and an occasional skip or variation in sound may occur. In addition, chatter may vary from nozzle to nozzle. Lack of chatter is not a cause for rejection of a nozzle.

5. Test each nozzle for stem leakage as follows:

STEM LEAKAGE: Bring the pressure on the nozzle to 1500 psi. If there is any leakage from the return, collect it. To conserve time, nozzle may be in inverted position. The maximum allowable leakage is 1.0 cc in one minute at this pressure.

Excessive leakage at this point can be caused by scratches or poor sealing at the flat lapped surfaces of the nozzle body, intermediate plate or valve body. If this possibility has been already eliminated, there is excessive clearance between the valve stem and body. This condition necessitates replacement of the nozzle.

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RETESTING AND ADJUSTING CLEAN NOZZLE ASSEMBLIES — Continued

After nozzles meet testing standards and adjustments are made, you may install nozzle assemblies.

INSTALLATION

1. Thoroughly clean nozzle bore in cylinder head before reinserting nozzle holder assembly. Pay particular attention to seating surfaces, in order that no small particles or carbon will cause assembly to be cocked or permit blow–by of combustion gases. Don't use hard or sharp tools for cleaning. A round piece of brass properly shaped or a round steel bristle brush is permitted if used with care. Blow out with filtered compressed air.
2. Remove the nozzle tip protective caps and install the nozzle assemblies into each sleeved bore. Be sure a new copper gasket is in place. Use a dab of grease to hold the gasket in place.
3. Install the nozzle retainers (crabs) and tighten the bolts to the specified special torque. Refer to **Figure 12.14.**
4. Install the fuel return lines.
5. Remove the protective caps and install the high pressure fuel lines as described previously in this section. Tighten connector nuts to the specified special torque.

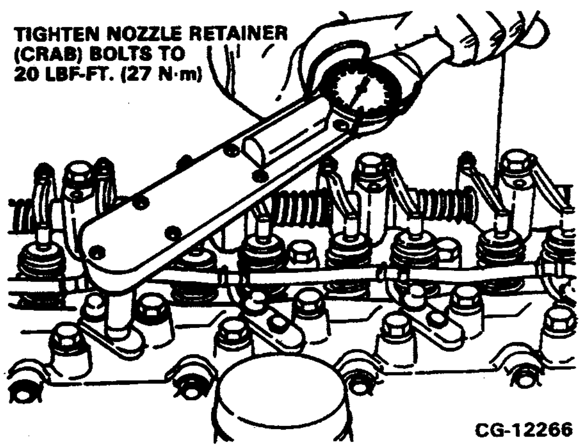

Figure 12.14. Install Injection Nozzles

6. Prime the fuel injection system as described in SECTION 11 under "Fuel Injection Pump".

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DT/DTA–360 ENGINE SPECIFICATIONS
1987 MODEL YEAR

ENGINE SPECIFICATIONS	DT–360	DTA–360
Number of Cylinders	6	6
Bore	4.010 in. (101.9mm)	4.010 in. (101.9mm)
Stroke	4.751 in. (116.4mm)	4.751 in. (116.4mm)
Displacement	360 cu. in. (5.9L)	360 cu. in. (5.9L)
Brake Horsepower (Max.)*	165 BHP @2700	175 & 180 BHP @2700
Torque (ft–lbs.) (Max)	380 ft–lbs @1700 RPM	175 BHP – 419 ft–lbs. @1700 RPM+ 180 BHP – 399 ft–lbs. @1700 RPM
Idle Speed (No Load)	600–700 RPM	600–700 RPM
Governed Speed (No Load)	3080 RPM (Max.)	175 BHP – 3085 RPM (Max.) 180 BHP – 3090 RPM (Max.)
Governed Speed (Full Load)	2700 RPM (Max.)	2700 RPM (Max.)
Compression Ratio	16.5:1	16.5:1
Firing Order	1–5–3–6–2–4	1–5–3–6–2–4
Valve Tappet Clearance (Hot/Cold)	Int. & Exh. .025 in. (.635 mm)	Int. & Exh. .025 in. (.635 mm)
Engine Lube Oil Pressure (Engine at Operating Temperature with SAE 30 Oil) Low Idle (700 RPM) High Idle	 10–30 psi (69–207 kPa) 40–65 psi (276–448 kpa)	 10–30 psi (69–207 kPa) 40–65 psi (276–448 kpa)
Crankcase Capacity (Without Filter)	14 quarts	14 quarts
Crankcase Capacity (With Filter)	17 quarts	17 quarts
Crankcase Capacity (With EXTENDER™ Filter	18 quarts	18 quarts
Thermostat Opening Temperature	180° F	180° F
Inital Injection Timing Degree BTDC ±1° (Static Timing)	20° BTDC	175 BHP – 13° BTDC 180 BHP – 22° BTDC

* Horsepower based on J1349 Standards at sea level and 77° F (25° C) ambient. No deration required up to 10,000 ft. (3048 meters).
+ California Emissions Certified Engine.

Printed in United States of America

DT/DTA–360 ENGINE SPECIFICATIONS 1988/1989 MODEL YEAR

ENGINE SPECIFICATIONS	DT–360	DTA–360
Number of Cylinders	6	6
Bore	4.010 in. (101.9mm)	4.010 in. (101.9mm)
Stroke	4.751 in. (116.4mm)	4.751 in. (116.4mm)
Displacement	360 cu. in. (5.9L)	360 cu. in. (5.9L)
Brake Horsepower (Max.)*	170 BHP @2700	175 & 180 BHP @2700
Torque (ft–lbs.) (Max)	400 ft–lbs @1700 RPM	175 BHP – 419 ft–lbs. @1700 RPM+ 180 BHP – 400 ft–lbs. @1700 RPM
Idle Speed (No Load)	600–700 RPM	600–700 RPM
Governed Speed (No Load)	3090 RPM (Max.)	175 BHP – 3085 RPM (Max.) 180 BHP – 3095 RPM (Max.)
Governed Speed (Full Load)	2700 RPM (Max.)	2700 RPM (Max.)
Compression Ratio	16.7:1	16.7:1
Firing Order	1–5–3–6–2–4	1–5–3–6–2–4
Valve Tappet Clearance (Hot/Cold)	Int. & Exh. .025 in. (.635 mm)	Int. & Exh. .025 in. (.635 mm)
Engine Lube Oil Pressure (Engine at Operating Temperature with SAE 30 Oil)		
Low Idle (700 RPM)	10–30 psi (69–207 kPa)	10–30 psi (69–207 kPa)
High Idle	40–65 psi (276–448 kpa)	40–65 psi (276–448 kpa)
Crankcase Capacity (Without Filter)	14 quarts	14 quarts
Crankcase Capacity (With Filter)	17 quarts	17 quarts
Crankcase Capacity (With EXTENDER™ Filter	18 quarts	18 quarts
Thermostat Opening Temperature	180° F	180° F
Inital Injection Timing Degree BTDC ±1° (Static Timing)	21° BTDC	175 BHP – 17° BTDC 180 BHP – 24° BTDC

* Horsepower based on J1349 Standards at sea level and 77° F (25° C) ambient. No deration required up to 10,000 ft. (3048 meters).
+ California Emissions Certified Engine.

DT/DTA–360 ENGINE SPECIFICATIONS
1990 MODEL YEAR

ENGINE SPECIFICATIONS	DT–360	DTA–360
Number of Cylinders	6	6
Bore	4.010 in. (101.9mm)	4.010 in. (101.9mm)
Stroke	4.751 in. (116.4mm)	4.751 in. (116.4mm)
Displacement	360 cu. in. (5.9L)	360 cu. in. (5.9L)
Brake Horsepower (Max.)*	170 BHP @2700	185 BHP @2700
Torque (ft–lbs.) (Max)	400 ft–lbs @1700 RPM	435 ft–lbs. @1700 RPM+
Idle Speed (No Load)	600–700 RPM	600–700 RPM
Governed Speed (No Load)	3100 RPM (Max.)	3100 RPM (Max.)
Governed Speed (Full Load)	2700 RPM (Max.)	2700 RPM (Max.)
Compression Ratio	16.2:1	16.2:1
Firing Order	1–5–3–6–2–4	1–5–3–6–2–4
Valve Tappet Clearance (Hot/Cold)	Int. & Exh. .025 in. (.635 mm)	Int. & Exh. .025 in. (.635 mm)
Engine Lube Oil Pressure (Engine at Operating Temperature with SAE 30 Oil)		
Low Idle (700 RPM)	10–30 psi (69–207 kPa)	10–30 psi (69–207 kPa)
High Idle	40–65 psi (276–448 kpa)	40–65 psi (276–448 kpa)
Crankcase Capacity (Without Filter)	14 quarts	14 quarts
Crankcase Capacity (With EXTENDER™ Filter	18 quarts	18 quarts
Thermostat Opening Temperature	180° F	180° F
Inital Injection Timing Degree BTDC ±1° (Static Timing)	15° BTDC	19° BTDC

* Horsepower based on J1349 Standards at sea level and 77° F (25° C) ambient. No deration required up to 10,000 ft. (3048 meters).
+ California Emissions Certified Engine.

Printed in United States of America

DT/DTA–360 ENGINE SPECIFICATIONS
1991 MODEL YEAR

ENGINE SPECIFICATIONS	DT–360	DTA–360
Number of Cylinders	6	6
Bore	4.010 in. (101.9mm)	4.010 in. (101.9mm)
Stroke	4.750 in. (120.7mm)	4.750 in. (120.7mm)
Displacement	360 cu. in. (5.9L)	360 cu. in. (5.9L)
Brake Horsepower (Max.)*	170 BHP @2700	185 BHP @2700
Torque (lb–ft.) (Max)	400 @1700 RPM	C185C – 445@1700 C185F – 445@1700 C185TC – 485@1700 C185TF – 485@1700
Idle Speed (No Load)	600–700 RPM	600–700 RPM
Governed Speed (No Load)	3100 RPM (Max.)	3100 RPM (Max.)
Governed Speed (Full Load)	2700 RPM (Max.)	2700 RPM (Max.)
Compression Ratio	17.5:1	17.5:1
Firing Order	1–5–3–6–2–4	1–5–3–6–2–4
Valve Tappet Clearance (Hot/Cold)	Int. & Exh. .025 in. (.635 mm)	Int. & Exh. .025 in. (.635 mm)
Engine Lube Oil Pressure (Engine at Operating Temperature with SAE 30 Oil) Low Idle (700 RPM) High Idle	 10–30 psi (69–207 kPa) 40–65 psi (276–448 kpa)	 10–30 psi (69–207 kPa) 40–65 psi (276–448 kpa)
Crankcase Capacity (Without Filter)	14 quarts	14 quarts
Crankcase Capacity (With EXTENDER™ Filter	18 quarts	18 quarts
Thermostat Opening Temperature	180° F	180° F
Inital Injection Timing Degree BTDC ±1° (Static Timing)	C170C – 9° BTDC C170F – 12° BTDC	C185C –16° BTDC C185F – 16° BTDC C185TC – 13° BTDC C185TF – 16° BTDC

* Horsepower based on J1349 Standards at sea level and 77° F (25° C) ambient. No deration required up to 10,000 ft. (3048 meters).
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TURBOCHARGER: (Model T04E)
- Turbine Shaft Axial End Play .... 0.001 – 0.004 in. (0.02–0.10 mm)
- Turbine Shaft Radial Shaft Movement (Play) ..... 0.003 – 0.006 in. (0.08–0.15 mm)

INTAKE MANIFOLD:
- No Service Specifications Required

EXHAUST MANIFOLD:
- Max. Allowable Warpage
  - (Manifold Installed w/o Gasket) .... 0.010 in. (0.25 mm)
- Max. Allowable Removal of Material .... 0.025 in. (0.64 mm)

EXHAUST VALVES:
- Stem Diameter (at Tip End) .... 0.3710 in. – 0.3720 in. (9.423 mm – 9.449 mm)
- Stem to Guide Clearance
  - (Max. Allowable Before Replacement)
  - (With Tapered Shaft) .... 0.007 in. (0.18 mm)
  - (With Straight Shaft) .... 0.006 in. (0.15 mm)
- Face to Stem Run–Out (T.I.R.) Max.) .... 0.0015 in. (0.038 mm)
- Valve Face Angle .... 45° –00' – 45° –15'
- Valve Face Margin (Min.) .... 0.045 in. (1.14 mm)
- Valve Lash .... 0.025 in. (0.64 mm)

INTAKE VALVE:
- Stem Diameter .... 0.3718 in. – 0.3725 in. (9.444 mm – 9.462 mm)
- Stem to Guide Clearance
  - (Max. Allowable Before Replacement) .... 0.006 in. (0.15 mm)
- Face to Stem Run–Out (T.I.R. Max.) .... 0.0015 in. (0.038 mm)
- Valve Face Angle .... 30° –00' – 30° –15'
- Valve Face Margin (Min.) .... 0.068 in. (1.73 mm)
- Valve Lash .... 0.025 in. (0.64 mm)

CYLINDER HEAD:
- Valve Guide Type .... Replaceable
- Valve Guide Length (Overall) (S/N 072707 & Above) .... 2.610 in. (66.29 mm)
- Valve Guide Length (Overall) (S/N 072706 & Below) .... 2.750 in. (69.85 mm)
- Valve Guide Bore Diameter in Cylinder Head for
  - Valve Guide Insert .... 0.6239 in. – 0.6252 in. (15.847 mm – 15.880 mm)
- Valve Guide O.D. .... 0.6260 in. – 0.6265 in. (15.900 mm – 15.913 mm)
- Valve Guide I.D.
  - (Reamed After Assembly) .... 0.3740 in. – 0.3750 in. (9.500 mm – 9.525 mm)
- Valve Guide Interference Fit Dim. ... 0.0008 in. – 0.0026 in. (0.020 mm – 0.066 mm)
- Valve Guide Bore Out–of–Round (Max.) .... 0.002 in. (0.05 mm)
- Valve Guide Bore Taper (Max.) .... 0.005 in. (0.13 mm)

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CYLINDER HEAD: Continued

Valve Guide Height from Top Deck Cylinder Head
Surface (Int.) (S/N 072707 & Above) . . . 1.090 in. – 1.110 in. (27.69 mm – 28.19 mm)
Valve Guide Height from Top Deck Cylinder Head
Surface (Int.) (S/N 072706 & Below) . . . 0.992 in. – 1.012 in. (25.20 mm – 25.70 mm)
Valve Guide Height from Top Deck Cylinder Head
Surface (Exh.) (S/N 072707 & Above) . . 1.090 in. – 1.110 in. (27.69 mm – 28.19 mm)
Valve Guide Height from Top Deck Cylinder Head
Surface (Exh.) (S/N 072706 & Below) . . 1.272 in. – 1.292 in. (32.31 mm – 32.83 mm)
Valve Seat Insert Angle (Int.) . . . . 30° –00' – 30° –15'
Valve Seat Insert Angle (Exh.) . . . . 45° –00' – 45° –15'
Valve Seat Width (Int. & Exh.) . . . . 0.075 in. – 0.085 in. (1.91mm – 2.26 mm)
Valve Seat Run–Out (T.I.R. Max.) . . . . 0.002 in. (0.05 mm)
Valve Seat insert O. D.
(Intake)
0.002" Oversize . . . . 1.7805 in. (45.225 mm)
0.015" Oversize . . . . 1.7955 in. (45.606 mm)
(Exhaust)
0.002" Oversize . . . . 1.5345 in. (38.976 mm)
0.015" Oversize . . . . 1.5495 in. (39.357 mm)
Valve Seat Insert Counterbore Diameter
Intake . . . . 1.777 in. – 1.778 in. (45.14 mm – 45.16 mm)
Exhaust . . . . 1.532 in. – 1.533 in. (38.91 mm – 38.94 mm)
Valve Head Recession Relative to Deck (Head Gasket
Surface) (Int. & Exh.) . . . . 0.000 in. – 0.014 in. (0.00 mm – 0.36 mm)
Gasket surface Flatness . . . . 0.004 in. (0.10 mm) in 6 inches
0.006 in. (0.15 mm) Overall
Deck to Deck Dimension (Head Thickness)
(New) . . . . 4.198 in. – 4.202 in (106.63 mm – 106.73 mm)
Minimum Deck to Deck Dimension After Rework . . . . 4.188 in. (106.38 mm)

VALVE SPRINGS:

Number of Springs per Valve 1
Intake & Exhaust
Free Length . . . . 2.340 in. (59.44 mm)
Test Length (Valve Closed) . . . . 2.007 in. (50.98 mm)
Test Load (Valve Closed) . . . . 66–70 lbs.
Test Load (Valve Open) . . . . 1.552 in. (39.42 mm)
Test Load (Valve Open) . . . . 156–164 lbs.

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CAMSHAFT:

Cam Lobe Lift (Total):

Intake .... 0.2705 in. (6.870 mm)

Exhaust .... 0.2829 in. (7.186 mm)

Maximum Permissible Cam Lobe Wear .... 0.020 in. (0.51 mm)

Camshaft Running Clearance .... 0.002 in. – 0.007 in. (0.05 mm – 0.18 mm)

Maximum Permissible Camshaft Running Clearance .... 0.008 in. (0.20 mm)

Bushing I.D. (Installed in Crankcase)2.2845 in. – 2.2880 in. (58.026 mm – 58.115 mm)

Bushing Journal Diameter .... 2.2814 in. – 2.2825 in. (57.948 mm – 57.976 mm)

Service Bushings Furnished to Size .... Yes

Thrust Plate Thickness (New) .... 0.274 in. – 0.276 in. (6.96 mm – 7. 01 mm)

End Clearance .... 0.005 in. – 0.013 in. (0.13 mm – 0.33 mm)

ROCKER ARM ASSEMBLY: (Valve Lever and Shaft Assembly)

Valve Lever Shaft Diameter .... 0.8491 in. – 0.8501 in. (21.567 mm – 21.593 mm)

Valve Lever Clearance on Shaft .... 0.0019 in. – 0.0049 in. (0.048 mm – 0.124 mm)

Valve Lever Bushing (I.D) .... 0.852 in. – 0.854 in. (21.64 mm – 21.69 mm)

Bracket Orifice I.D. .... 0.042 in. (1.07 mm)

TAPPETS:

Diameter .... 1.1195 in. – 1.1200 in. (28.435 mm – 28.448 mm)

Length .... 2.437 in. (61.90 mm)

Tappet Clearance in Crankcase .... 0.0025 in. – 0.0040 in. (0.064 mm – 0.102 mm)

PUSH ROD:

Maximum Run–Out (T.I.R.) .... 0.020 in. (0.51 mm)

ROCKER ARM SHAFT SPRINGS:

Number of Springs 5

Free Length .... 4.06 in. (103.1 mm)

Test Length .... 2.07 in. (52.6 mm)

Test Load .... 71 lbf–ft. (31 Nm)

I.D. .... 1.02 in. (25.9 mm)

CONNECTING RODS:

Center–to–Center Distance between Connecting Rod
Bearing and Piston Pin Bushing .. 8.419 in. – 8.421 in. (213.84 mm – 213.89 mm)

Bushing Bore Diameter (Pin End) ... 1.622 in. – 1.624 in. (41.198 mm – 41.249 mm)

Piston Pin Bushing I.D. (Installed) . 1.4971 in. – 1.4975 in. (38.026 mm – 38.036 mm)

Bearing Bore Diameter
(Crankshaft End) .... 2.6771 in. – 2.6779 in. (67.998 mm – 68.018 mm)

Maximum Out–of–Round .... 0.002 in. (0.05 mm)

Maximum Taper/Inch .... 0.0005 in. (0.013 mm)

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CONNECTING RODS: Continued

Connecting Rod Bearing I.D.
(Installed) . . . . 2.5215 in. – 2.5233 in. (64.046 mm – 64.092 mm)
Bearing Running Clearance . . . . 0.0018 in. – 0.0051 in. (0.046 mm – 0.103 mm)
Maximum Permissible Bearing Running Clearance
(Before Reconditioning) . . . . 0.007 in. (0.18 mm)
Connecting Rod Side Clearance on
Crankshaft . . . . 0.009 in. – 0.015 in.(0.23 mm – 0.38 mm)
Maximum Permissible Side Clearance on Crankshaft . . . . 0.018 in. (0.46 mm)
Connecting Rod Alignment (Max. Total Difference)
Twist . . . . 0.002"/in. (0.05 mm/25.4 mm)
Bend . . . . 0.001"/in. (0.03 mm/25.4 mm)

PISTONS:

Running Clearance between Piston and
Cylinder Sleeve . . . . 0.0035 in. – 0.0065 in. (0.089 mm – 0.165 mm)
Skirt Diameter (Measured 90° from pin bore and 1.146 in. below
bottom ring land) . . . . 4.0035 in. – 4.0045 in. (101.689 mm – 101.714 mm)
Number of Rings per Piston 3
Piston Ring Groove Widths:
Top Compression Ring — Measured Over
0.1150 in. Gauge Pins . . . . 4.0239 in. (102.207 mm) Upper Limit
(Full keystone) . . . . 3.9933 in. (101.430 mm) Replacement Limit
Intermediate Compression Ring – Measured Over
0.1150 in. Gauge Pins . . . . 4.0279 in. (102.309 mm) Upper Limit
(Full Keystone) . . . . 3.9964 in. (101.508 mm) Replacement Limit
Side Clearance:
Oil Control Ring . . . . 0.0015 in. – 0.0035 in. (0.038 mm – 0.089 mm)

PISTON RINGS – COMPRESSION:

Number of Rings per Piston 2
Type (Face and Finish):
Top Ring (Eff. with S/N 072706) . . . . Full Keystone (Barrel Face) – Plasma Coated
Top Ring (Prior to S/N 072706) . . . . Full Keystone (Barrel Face) – Chrome
Intermediate Ring . . . . Full Keystone (Tapered Face)
Ring Gap with New Sleeve: (With used sleeve, check above ring travel)
Top Ring . . . . 0.015 in. – 0.033 in. ((0.30 mm – 0.64 mm)
Intermediate Ring . . . . 0.060 in. – 0.078 in (1.52 mm – 1.98 mm)

PISTON RINGS – OIL CONTROL:

Number of Rings per Piston 1
Type . . . . One Piece Slotted – Chrome
Ring Gap . . . . 0.010 in. – 0.026 in. (0.25 mm – 0.66 mm)

PISTON PINS:

Diameter .... 1.4955 in. – 1.4957 in. ((37.986 mm – 37.991 mm)
Length .... 3.287 in. – 3.297 in. (83.49 mm – 83.74 mm)
Clearance in Rod .... 0.0014 in. – 00020 in. (0.036 mm – 0.051 mm)
Maximum Permissible Clearance in Rod,
    before Replacing .... 0.003 in. (0.08 mm)
Clearance in Piston (Measured in
    Vertical Plane) .... 0.0004 in. – 0.0008 in. (0.010 mm – 0.020 mm)
Clearance in Piston (Measured in
    Horizontal Plane) .... 0.0010 in. – 0.0018 in. (0.025 mm – 0.046 mm)
Maximum Permissible Clearance in Piston,
    before Replacing .... 0.0025 in. (0.064 mm)

CYLINDER SLEEVES:

Inside Diameter (New) .... 4.0095 in. – 4.0105 in. (101.841 mm – 101.870 mm)
Maximum Permissible Diameter Sleeve Wear, at Top of
  Ring Travel before Replacement (Sleeve Taper) .... 0.004 in. (0.10 mm)
Counterbore Dimension in Crankcase ..... 0.348 in. – 0.350 in. (8.84 mm – 8.89 mm)
Maximum Allowable Variation of Counterbore Depth
  (Between Four Points) .... 0.001 in. (0.03 mm)
Maximum Cylinder Sleeve Counterbore Allowable Depth .... 0.413 in. (10.49 mm)
Flange Thickness .... 0.352 in. – 0.353 in. (8.94 mm – 8.97 mm)
Protrusion Above Crankcase .... 0.002 in. – 0.005 in. (0.05 mm – 0.13 mm)

CRANKSHAFT:

Type .... Steel Forging, Induction Hardened, Grindable
Main Bearing Journal Diameter
    Standard Size .... 3.3742–3.3755 in. (85.705–85.737 mm)
    .010" Undersize .... 3.3642–3.3655 in. (85.450–85.483 mm)
    .020" Undersize .... 3.3542–3.3555 in. (85.196–85.230 mm)
    .030" Undersize .... 3.3442–3.3455 in. (84.942–84.975 mm)
Main Bearing Journal Max. Out–of–Round .... 0.0013 in. (0.033 mm)
Main Bearing Thrust Face Runout (T.I.R. Max.) .... 0.001 in. (0.03 mm)
Main Bearing Journal Taper (Max./In.) .... 0.00015"/in. (0.0038 mm/25.4 mm)
Main Journal Fillet Radius .... 0.220–0.235 in. (5.59–5.97 mm)
Rod Journal Fillet Radius .... 0.153–0.160 in. (3.89–4.06 mm)
Rear Oil Seal Journal Runout (Max.) .... 0.003 in. (0.076 mm)
Damper Mounting Area Runout (Max.) .... 0.0005 in. (0.013 mm)
Flywheel Mounting Surface Runout (Max.) .... 0.002 in. (0.05 mm)
Number of Main Bearings 7

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CRANKSHAFT: Continued

Thrust Taken by	Rear Main
Thrust Bearing Journal Length	
(Std. to 0.020" U/S)	1.4415–1.4445 in. (36.614–36.690 mm)
Thrust Bearing Journal Length (0.030 U/S)	1.4535–1.4565 in. (36.919–36.995 mm)
Main Bearing to Crankshaft Clearance	0.0018–0.0051 in. (0.046–0.013 mm)
Connecting Rod Journal Diameter	
Standard Size	2.5182–2.5197 in. (63.962–64.000 mm)
.010" Undersize	2.5082–2.5097 in. (63.708–63.746 mm)
.020" Undersize	2.4982–2.5397 in. (63.454–64.508 mm)
.030" Undersize	2.4882–2.4897 in. (63.200–63.238 mm)
Connecting Rod Journal Max. Out–of–Round	0.0013 in. (0.033 mm)
Connecting Rod Journal Taper (Max./In.)	0.00015"/in. (0.0038 mm/25.4 mm)
Connecting Rod Bearing to Crankshaft	
Running Clearance	0.0018–0.0051 in. (0.013–0.046 mm)
Crankshaft Flange O.D.	4.9984–5.0000 in. (126.959–127.000 mm)
Crankshaft End Play	0.006–0.012 in. (0.15–0.30 mm)
Crankshaft End Play Max. Wear Limit	0.020 in. (0.51 mm)
Rod to Crankshaft Side Clearance	0.009–0.015 in. (0.23–0.38 mm)
Crankshaft Gear Backlash	0.003–0.016 in. (0.08–0.41 mm)
Flywheel Runout (Max.)	0.008 in. (0.20 mm)
Flywheel Concentricity (Max.)	0.008 in. (0.20 mm)
Flywheel Housing Bore Concentricity (Max.)	0.008 in. (0.20 mm)
Flywheel Housing Face Runout (Max.)	0.008 in. (0.20 mm)
Vibration Damper Max. Allowable Member Misalignment	0.060 in. (1.52 mm)
Vibration Damper Wobble (Max.)	0.060 in. (1.52 mm)

CRANKCASE:

Crankcase Deck Flatness	0.003 in. (0.076 mm)
Crankcase Deck Finish (Micro inches)	125 AA
Centerline of Main Bearing	
Bore to Head Deck	13.3985–13.4015 in. (340.322–340.398 mm)
Crankcase Main Bearing Bore Diameter	3.6885–3.6895 in. (93.688–93.713 mm)
Tappet Bore Diameter	1.1225–1.2350 in. (28.511–28.536 mm)
Valve Lifter O.D.	1.1195–1.1200 in. (28.435–28.448 mm)
Oil Jet Tube Bore Orifice Diameter	
(Spray Hole Dia.)	0.048–0.049 in. (1.22–1.24 mm)
Main Bearings	
Type	Precision Replaceable
Material	Steel Backed Copper/ Lead
Thrust Taken by	No. 7 Rear
Cap Attachment	2 Bolts per Cap

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CRANKCASE: Continued

Camshaft Bushing Bore Diameter in Crankcase (without Bushing)

Front .... 2.5005–2.5020 in. (63.512–63.550 mm)
Intermediate Front. .... 2.4805–2.4820 in. (63.005–63.043 mm)
Intermediate Rear .... 2.4605–2.4620 in. (62.496–62.535 mm)
Rear .... 2.4405–2.4420 in. (61.988–62.026 mm)

CYLINDER SLEEVES:

Counterbore Dimension in Crankcase . . . 0.348 –in. – 0.350 in. (8.84 mm – 8.89 mm)
Maximum Allowable Variation of Counterbore Depth
(Between Four Points) .... 0.001 in. (0.03 mm)
Maximum Cylinder Sleeve Counterbore Allowable Depth ...... 0.413 in. (10.49 mm)
Flange Thickness .... 0.352 in. – 0.353 in. ((8.94 mm – 8.97 mm)
Protrusion Above Crankcase .... 0.002 in. – 0.005 in (0.05 mm – 0.13 mm)

TIMING GEARS:

Crankshaft to Idler Backlash .... 0.003 in. – 0.016 in (0.08 mm – 0.41 mm)
Idler to Crankshaft Backlash .... 0.003 in. – 0.016 in. (0.08 mm – 0.41 mm)
Idler to Injection Pump Backlash .... 0.003 in. – 0.016 in. (0.08 mm – 0.41 mm)

OIL PUMP:

Type .... "GEROTOR"
Drive .... Crankshaft
End Clearance, Inner and Outer
Rotor to Housing .... 0.0002 in. – 0.0048 in.(0.051 mm–0.122 mm)
Radial Clearance, between Outer
Rotor Housing .... 0.0055 in. – 0.0095 in (0.140 mm–0.241 mm)
Engine Oil Pressure* (Run engine until normal operating temperatures are reached)
At Low Idle Speed (@ 700 RPM) .... 10 psi (69 kPa) Min.
At High Idle .... 40 to 65 psi (276 to 448 kPa)

ENGINE OIL FILTER:

Type .... "EXTENDER — HIGH EFFICIENCY — SPIN–ON"
Number 2
Filter Bypass Location .... In Oil Filter Header

BYPASS VALVE SPRING

Free Length .... 2.075 in. (52.71 mm)
Test Length .... 0.927 in. (23.55 mm)
Test Load .... 6.12 lbs. (27.2 N)

*Oil pressure measurement should be made utilizing an oil gallery tap rather than a remote location.

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PRESSURE REGULATOR VALVE SPRING:

Free Length	2.172 in. (55.17 mm)
Test Length	1.230 in. (31.24 mm)
Test Load	15.3 lbs. (68.1 N ± 5%)
Outside Diameter	0.500 in. (12.70 mm)

PRESSURE REGULATOR VALVE ASSEMBLY:

Location	In Crankcase, forward of Oil Filter
Setting	48 psi – 52 psi ((331 kPa – 359 kpa)
Valve Assembly Diameter	0.9975 in. – 0.9985 in. (25.336 mm – 25.362 mm)
Valve Clearance in Bore	0.002 in. – 0.004 in. (0.05 mm) (0.10 mm)
Crankcase Bore I.D	0.999 in. – 1.002 in. (25.37 mm – 25.45 mm)

WATER PUMP:

Clearance between Housing and Back Face of Impeller	0.010 in. – 0.046 in. (0.25 – 1.17 mm)
Bearing End Play	0.0015 in. – 0.0095 in. (0.038 mm – 0.241 mm)

THERMOSTAT:

Operating Temperature Range	Start to Open 180° F – Full Open 202° F

INJECTION PUMP:

Model	Robert Bosch PES6A–2000 or MW
Drive	Gear – Steel Forging

Static Timing: (1987 Model Year)

165 HP (DT–360 Federal)	20°+1° BTDC
180 HP (DTA–360 Federal)	22°+1° BTDC
175 HP (DTA–360 California)	13°+1° BTDC

Static Timing: (1988 & 1989 Model Year)

170 HP (DT–360 Federal)	21°+1° BTDC
180 HP (DTA–360 Federal)	24°+1° BTDC
175 HP (DTA–360 California)	17°+1° BTDC

Static Timing: (1990 Model Year)

170 HP (DT–360)	15°+1° BTDC
185 HP (DTA–360)	19°+1° BTDC

Static Timing: (1991 Model Year)

170 HP (DT–360 Federal)	12°+1° BTDC
170 HP (DT–360 California)#	9°+1° BTDC
185 HP (DTA–360 Federal)	16°+1° BTDC
185 HP (DTA–360 California)#	13°+1° BTDC

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FUEL FILTER:
Type .... Spin–on

NOZZLES:
Type .... Orifice
Code
1987 Model Year .... E
1988 & 1989 Model Year .... G
1990 Model Year 10
1991 Model Year 18
Actuation .... High Pressure Fuel from Injection Pump
Valve Opening Pressure (V.O.P.)
New or Reconditioned (Codes E & G5) .... 3075–3225 psi (21,201–22,236 kPa)
Min. V.O.P. before Reconditioning .... 2750 psi (18,961 kPa)
New or Reconditioned (Codes 10 & 18) ...... 3600–3750 psi (24,820–25,855 kPa)
Min. V.O.P. before Reconditioning .... 2900 psi (20,000 kPa)

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GENERAL TORQUE GUIDELINES

Many conditions affect torque and the results of torque applications. The major purpose in tightening a fastener to a specified torque is to obtain tension in the fastener (i.e., bolt, nut, etc.), which in turn develops a clamping load which exceeds any possible loading imposed on parts due to engine RPM or vibration.

Tension Values for Standard Fasteners

The "Standard Nut and Bolt Torque Chart" provides tightening torque for general purpose applications using original equipment standard hardware as listed in the Parts Catalog for the application involved. **DO NOT SUBSTITUTE.** Original equipment standard hardware is defined as Type 8, coarse thread bolts and nuts and thru hardened flat washers (Rockwell "C" 38–45), all phosphate coated and assembled without supplemental lubrication (as received condition). **NOTE: Phosphate coating is a dry lubricant.**

Fastener Thread Condition

Threads that are dry, excessively rough, battered or filled with dirt require considerable effort just to rotate. Then when the clamping load is developed or the bolt tension is applied, the torque reading mounts rapidly (due to thread friction) to the specified torque value. However, the desired bolt tension and maximum clamping effect is not achieved. This condition can lead to failure of the fastener to maintain component integrity. The proper bolt tension and clamping effect can never be attained if the fastener is dry. The fastener threads must have a film of clean lubricant (engine oil) to be considered lubricated.

STANDARD NUT AND BOLT TORQUE CHART

Nominal Thread Diameter	Standard Torque — Grade 8			
	lbf–ft.		N•m	
	Minimum	Maximum	Minimum	Maximum
1/4	12	14	16	19
5/16	27	30	37	41
3/8	45	50	61	68
7/16	75	85	102	115
1/2	115	130	156	176
9/16	160	180	217	245
5/8	220	250	300	340
3/4	400	450	540	610
7/8	650	730	880	990
1	970	1090	1300	1480
1–1/8	1380	1550	1870	2100
1–1/4	1940	2180	2600	3000
1–1/2	3300	3700	4500	5000
1–3/4	5300	6000	7100	8100
2	8000	9000	10800	12200

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SPECIAL NUT AND BOLT TORQUE DATA*

Turbocharger Back Plate–to–Center Housing Capscrews	117.5 lbf–in. (13.3 N•m)
(Tighten finger–tight plus 90°)	
Turbocharger Impeller Shaft Lock Nut	19 lbf–in. (2.15 N•m)
(Use tee handle wrench only)	
Turbocharger Center Housing–to–Turbine Housing Capscrews	115 lbf–in. (13 N•m)
Turbocharger Center Housing–to–Compressor Housing Capscrews	150 lbf–in. (16.9 N•m)
Turbocharger Mounting Bolts/Nuts	35 lbf–ft. (47 N•m)
Turbocharger Air Hose Clamp	45 lbf–in. (5 N•m)
Intake Manifold Bolts	20 lbf–ft. (27 N•m)
(Use prevailing torque [patch type] fasteners)	
Exhaust Manifold Bolts	60 lbf–ft. (81 N•m)
Cylinder Head Valve Cover Bolts	26 lbf–in. (3 N•m)
Cylinder Head Bolts +	165 lbf–ft. (225 N•m)
Valve Adjusting Screw Nut	20 lbf–ft. (27 N•m)
Camshaft Thrust Plate Bolt	20 lbf–ft. (27 N•m)
Connecting Rod Nuts	85 lbf–ft. (115 N•m)
Crankshaft Main Bearing Cap Bolts	115 lbf–ft. (155 N•m)
Crankshaft Vibration Damper Retainer Bolts	105 lbf–ft. (142 N•m)
Crankcase Front Plate Bolts	20 lbf–ft. (27 N•m)
Idler Gear Retaining Bolt	85 lbf–ft. (115 N•m)
Flywheel Bolts	110 lbf–ft. (150 N•m)
Flywheel Housing Mounting Bolts	105 lbf–ft. (142 N•m)
Oil Pan Bolts	20 lbf–ft. (27 N•m)
Oil Pan Drain Plug	27 lbf–ft. (37 N•m)
Oil Level Gauge Tube Clamp	30 lbf–in. (3 N•m)
Oil Filter Bypass Valve Cap	50 lbf–ft. (68 N•m)
Oil Pressure Regulator Valve Cap Nut	170 lbf–ft. (230 N•m)
Oil Pickup Tube Mounting Bolts	18 lbf–ft. (25 N•m)
Water Pump Hub Nut	150 lbf–ft. (203 N•m)
Water Pump Mounting Bolts	35 lbf–ft. (47 N•m)

* Unless otherwise specified, torque values are with threads and washer faces coated with clean engine oil.

+ To be tightened in steps as shown on Page 17.

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SPECIAL NUT AND BOLT TORQUE DATA* – Continued

Injection Pump Drive Gear Bolts	35 lbf–ft. (47 N•m)
Adapter Housing Nuts	24 lbf–ft. (33 N•m)
Nozzle Retainer Bolt (Crab Bolt)	20 lbf–ft. (27 N•m)
Injection High Pressure Line Connector Nut (A Pump)#	18 lbf–ft. (24 N•m)
Injection High Pressure Line Connector Nut (MW Pump)	30 lbf–ft. (40 N•m)
Banjo Fuel Oil Connections (14 mm)	25 lbf–ft. (34 N•m)
Banjo Lube Oil Connections (10 mm)	16 lbf–ft. (21 N•m)
Governor Housing Plug (10 mm Internal Hex)	20 lbf–ft. (27 N•m)

NOTE: Injection line fittings at the pump and nozzle are frequently overtightened due to the fitting size (3/4"). This swedges the injection line, often partly closing the ends. This alters fuel delivery characteristics, raises injection line pressures and may cause performance problems or injection pump failure. Inspect the ends of the injection lines and discard any with swedged or damaged fittings or holes.

A back–up wrench must be used on the delivery valve holder nut to prevent movement of the delivery valve holder.
* Unless otherwise specified, torque values are with threads and washer faces coated with clean engine oil.

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CYLINDER HEAD TORQUE DATA

Tighten cylinder head bolts following the assembly steps listed:

1. **Lubricate bolt threads, bolt head seating areas and washers with clean engine oil.**
2. **Tighten bolts in three (3) stages:**

STAGE 1 – Following sequence "A" tighten bolts to 110 lbf–ft. (150 N•m).

STAGE 2 – Following sequence "A" tighten bolts to 155 lbf–ft. (210 N•m).

STAGE 3 – Following sequence "B" tighten bolts, in row, to 165 lbf–ft. (225 N•m).

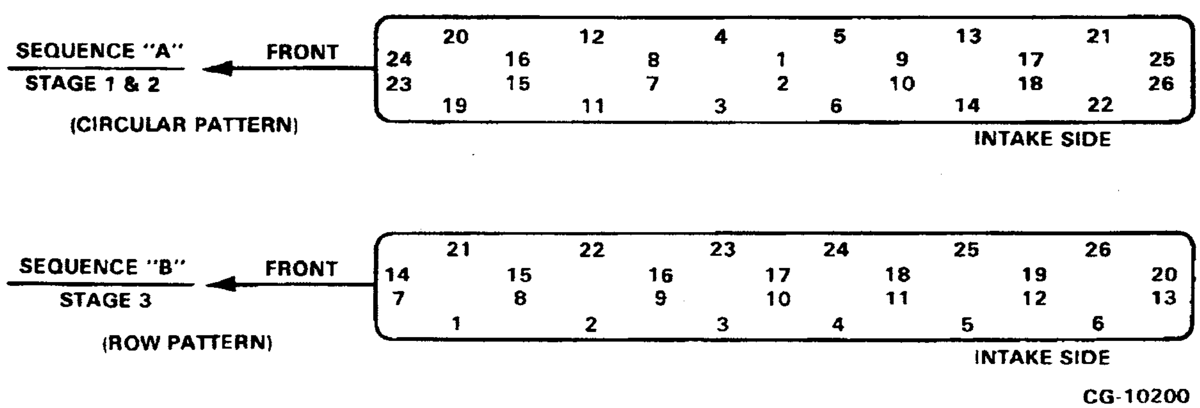

Figure 1. Sequence for Tightening Cylinder Head Bolts

SPECIAL SERVICE TOOL LIST

MANUAL SECTION	TOOL DESCRIPTION	TOOL ORDER NO.
One	Engine Stand Adapter Plate	ZT–206386
Two	No Special Tools Required	– – –
Three	No Special Tools Required	– – –
Four	Valve Guide Reamer (.3740" Dia.)	ZTSE–2215A
	Valve Seat Installer (Int./Exh.)	ZTSE–4164
	Nozzle Sleeve Puller Adapter	ZTSE–2587A
	Nozzle Sleeve Installing Tool	ZTSE–2534A
	Valve Guide Remover	ZTSE–1722
	Valve Guide Installer	ZTSE–1943
	Valve Spring Tester	ZTSE–2241
	Eccentric Valve Seat Grinder	ZTSE–1631A
	Valve Seat Grinding Kit	ZTSE–1631–46
	Valve Guide Cleaner	ZTSE–1300
	Valve Spring Compressor	ZTSE–1846
	Universal Valve Seat Extractor	ZTSE–1951B
	Exhaust Collet	ZTSE–1951–20
	Intake Collet	ZTSE–1951–21
	Cylinder Head Pressure Test Kit (Incl. ZTSE–4289–3 Plate and ZTSE–4289–1 Hardware Kit)	ZTSE–4289A
Five	Camshaft Bushing Puller & Installer	ZTSE–2893
	Spring Tester	ZTSE–2241
Six	Universal Wet Sleeve Puller	ZTSE–2536
	Piston Ring Expander	ZTSE–4220
	Piston Groove Wear Gauge Pins	ZTSE–3020
	Surface Gauge	ZTSE–2515
	Band Type Ring Compressor	ZTOEM–6269
	Oil Leak Detector	ZTSE–1632
	Counterbore Cutter Tool	– – –
Seven	Vibration Damper Wear Sleeve Installing Tool	ZTSE–3004A
	Lifting Sling	ZTOEM–4125
	Rear Oil Seal Installing Tool	ZTSE–4272

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SPECIAL SERVICE TOOL LIST – CONTINUED

MANUAL SECTION	TOOL DESCRIPTION	TOOL ORDER NO.
Eight	No Special Tools Required	– – –
Nine	Spring Tester	ZTSE–2241
Ten	No Special Tools Required	– – –
Eleven	No Special Tools Required	– – –
Twelve	Injector Puller Nozzle Adapter Set Nozzle Hand Test Pump Lapping Blocks Injection Nozzle Holding Fixture Holding Fixture Clamping Plate Nozzle Cleaning Kit	ZTSE–1100 ZTSE–4045 ZTSE–4045A ZTOEM–1070 ZTSE–2752 ZTSE–2753 ZTOEM–1068

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SERVICE MANUAL

ENGLISH/METRIC CONVERSION

CONVERSION TABLE

CONVERSION TABLE — INCH FRACTIONS AND DECIMALS TO MILLIMETER EQUIVALENTS											
INCHES		mm	INCHES		mm	INCHES		mm	INCHES		mm
Fract.	Dec.		Fract.	Dec.		Fract.	Dec.		Fract.	Dec.	
—	.0004	.01	—	.3	7.620	—	.7874	20	—	1.969	50
—	.001	.0250	5/16	.3125	7.938	51/64	.7969	20.241	2	2.000	50.8
—	.0039	.10	—	.3150	8	13/16	.8125	20.638	2 1/8	2.125	54
—	.005	.127	21/64	.3281	8.334	—	.8268	21	—	2.165	55
—	.0079	.2	—	.3346	8.5	53/64	.8281	21.034	2 1/4	2.250	57.2
—	.0098	.25	11/32	.3438	8.731	27/32	.8438	21.431	—	2.362	60
—	.01	.254	—	.3543	9	55/64	.8594	21.828	2 3/8	2.375	60.3
—	.0118	.3	23/64	.3594	9.128	—	.8662	22	2 1/2	2.500	63.5
1/64	.0156	.397	—	.3740	9.5	7/8	.8750	22.225	—	2.559	65
—	.0157	.4	3/8	.375	9.525	57/64	.8906	22.622	2 5/8	2.625	66.7
—	.0197	.5	25/64	.3906	9.922	—	.9	22.860	2 3/4	2.750	69.9
—	.0236	.6	—	.3937	10	—	.9055	23	—	2.756	70
—	.025	.635	—	.4	10.160	29/32	.9063	23.019	2 7/8	2.875	73
—	.0276	.7	13/32	.4062	10.319	59/64	.9219	23.416	—	2.953	75
—	.0295	.75	—	.4134	10.5	15/16	.9375	23.813	3	3.000	76.2
1/32	.0313	.794	27/64	.4219	10.716	—	.9449	24	—	3.150	80
—	.0315	.8	—	.4331	11	61/64	.9531	24.209	3 1/4	3.250	82.6
—	.0354	.9	7/16	.4375	11.113	31/32	.9688	24.606	—	3.346	85
—	.0394	1	29/64	.4531	11.509	—	.9843	25	3 1/2	3.500	88.9
3/64	.0469	1.191	15/32	.4688	11.906	1	1.000	25.400	—	3.543	90
—	.0472	1.2	—	.4724	12	—	1.024	26	—	3.740	95
—	.05	1.270	31/64	.4844	12.303	1 1/16	1.062	26.988	3 3/4	3.750	95.3
—	.0551	1.4	—	.4921	12.5	—	1.063	27	—	3.937	100
—	.0591	1.5	1/2	.5	12.700	—	1.102	28	4	4.000	101.6
1/16	.0625	1.588	—	.5118	13	1 1/8	1.125	28.575	—	4.331	110
—	.0669	1.7	33/64	.5156	13.097	—	1.142	29	4 1/2	4.500	114.3
—	.075	1.905	17/32	.5326	13.494	—	1.181	30	—	4.724	120
5/64	.0781	1.984	—	.5315	13.5	1 3/16	1.188	30.16	5	5.000	127
—	.0787	2	35/64	.5469	13.891	—	1.221	31	—	5.118	130
—	.0906	2.3	—	.5512	14	1 1/4	1.250	31.75	5 1/2	5.500	139.7
3/32	.0938	2.381	9/16	.5625	14.288	—	1.260	32	—	5.512	140
—	.0984	2.5	—	.571	14.5	—	1.299	33	—	5.906	150
—	.1	2.540	37/64	.5781	14.684	1 5/16	1.312	33.34	6	6.000	152.4
—	.1024	2.6	—	.5906	15	—	1.339	34	—	6.299	160
7/64	.1093	2.776	19/32	.5938	15.081	1 3/8	1.375	34.93	6 1/2	6.500	165.1
—	.1181	3	—	.6	15.240	—	1.378	35	7	7.000	177.8
1/8	.125	3.175	39/64	.6094	15.478	—	1.417	36	—	7.087	180
—	.1378	3.5	—	.6103	15.5	1 7/16	1.438	36.51	7 1/2	7.500	190.5
9/64	.1406	3.572	5/8	.6250	15.875	—	1.457	37	—	7.874	200
5/32	.1563	3.969	—	.6299	16	—	1.496	38	8	8.000	203.2
—	.1575	4	41/64	.6406	16.272	1 1/2	1.500	38.10	8 1/2	8.500	215.9
11/64	.1719	4.366	—	.6496	16.5	—	1.535	39	—	8.661	220
—	.1772	4.5	21/32	.6563	16.669	1 9/16	1.562	39.69	9	9.000	228.6
3/16	.1875	4.763	—	.6693	17	—	1.575	40	—	9.449	240
—	.1969	5	43/64	.6719	17.066	—	1.614	41	9 1/2	9.500	241.3
—	.2	5.080	11/16	.6875	17.463	1 5/8	1.625	41.28	—	9.843	250
13/64	.2031	5.159	—	.6890	17.5	—	1.654	42.	10	10.000	254
—	.2165	5.5	—	.7	17.780	1 11/16	1.688	42.86	—	10.236	260
7/32	.2188	5.556	45/64	.7031	17.859	—	1.693	43	11	11.000	279.4
15/64	.2344	5.953	—	.7087	18	—	1.732	44	—	11.024	280
—	.2362	6	23/32	.7188	18.256	1 3/4	1.750	44.45	—	11.811	300
1/4	.25	6.350	—	.7283	18.5	—	1.772	45	12	12.000	304.8
—	.2559	6.5	47/64	.7344	18.653	—	1.811	46	13	13.000	330.2
17/64	.2656	6.747	—	.7480	19	1 13/16	1.813	46.04	—	13.780	350
—	.2756	7	3/4	.75	19.050	—	1.850	47	14	14.000	355.6
9/32	.2813	7.144	49/64	.7656	19.447	1 7/8	1.875	47.63	15	15.000	381
—	.2953	7.5	—	.7677	19.5	—	1.890	48	—	15.748	400
19/64	.2969	7.541	25/32	.7813	19.844	—	1.929	49	16	16.000	406.4

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