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Serial No.

Specification No.

Waukesha® VGF™

F18/H24 G/GL/GLD/GSID Repair & Overhaul Manual

Third Edition

PLEASE NOTE: If grey lines appear instead of words, please do the following. In Acrobat Reader go to --> File --> Preferences --> General. Make sure "Use Greek Text Below _____ Pixels" is deselected.

DRESSER®
Waukesha

FORM 6243

Waukesha Engine
Dresser, Inc.
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Your purchase of a **VGF** inline series engine was a wise investment. In the industrial engine field the name, Waukesha Engine, stands for quality and durability. With normal care and maintenance this engine will provide many years of reliable service.

Before placing the engine in service read Chapters 1 and 2 very carefully. These chapters cover Safety, General Information and Engine Operation.

Section 1.00 – *Warning Tags And Decal Location* – Provides the location of all warning tags and decals and shows a duplicate of each in case the decals or tags have been lost or damaged.

Section 1.05 – *Safety Section* – Provides a list of warnings and cautions to make you aware of the dangers present during operation and maintenance of the engine. – READ THEM CAREFULLY AND FOLLOW THEM COMPLETELY –

Section 1.15 – *General Information* – Provides basic data on the **VGF** series engines such as; nameplate data, component weights, torque specifications and clearances. This section also supplies torque values of metric and standard capscrews as well as conversion data.

Section 2.00 – *Engine Startup And Shutdown* – Provides prestart inspection, troubleshooting, routine startup and shutdown.

This manual contains both operation and maintenance instructions for the **VGF** series engines. There are five chapters within the manual and each chapter contains one or more sections. The title of each chapter or section appears at the top of each page. To locate information on a specific topic, refer to the Table of Contents at the front of the manual or the Index at the back of the manual.

ALWAYS BE ALERT FOR THE SPECIAL WARNINGS WITHIN THE MANUAL TEXT. THESE WARNINGS PRECEDE INFORMATION THAT IS CRUCIAL TO YOUR SAFETY AS WELL AS OTHER PERSONNEL WORKING ON OR NEAR THE ENGINE. CAUTIONS OR NOTES IN THE MANUAL CONTAIN INFORMATION THAT RELATES TO POSSIBLE DAMAGE TO THE ENGINE OR ITS COMPONENTS DURING ENGINE OPERATION OR MAINTENANCE PROCEDURES.

Recommendations and data contained in the manual are the latest information available at the time of this printing and are subject to change without notice. Since engine accessories may vary due to customer specifications consult your local distributor or Waukesha Engine Service Operations Department for any information on subjects beyond the scope of this manual.

SECTION 1.00

WARNING TAG AND DECAL LOCATIONS

WARNING TAG AND DECAL LOCATIONS

⚠ WARNING

All warning tags and decals must be visible and readable to the operator when the engine is running. Make sure all warning tags and decals remain legible and attached. Likewise, all warning tags and decals removed during any repair work must be replaced in their original position before the engine is placed back into service. Old or badly worn decals and tags should also be replaced. Failure to properly replace these important tags and decals can result in severe injury or death.

NOTE: *The decals and tags shown in this manual are for the current production engine. Your engine may have the previous tags or decals that are not shown. The previous tags will contain similar wordage and will be located very close to the position of the new tags.*

The warning labels on the VGF F18/H24G/GSID/GL/GLD engines are in a specific location, and must be replaced if they are defaced or removed for any reason. Table 1.00-1 will describe where each label is located. Figure 1.00-1 and Figure 1.00-2 will show exact location of each label. Figure 1.00-3 through Figure 1.00-15 show illustrations of the warning tags and decals.

Table 1.00-1. VGF 6 And 8 Cylinder Engine Safety Labels

P/N	DECAL TYPE	TAG/PLATE TYPE	SUBJECT	LOCATION
209107M	Caution	-	To Service Heater	• On the jacket water heater body on the right side of engine
211900	Danger	-	Disconnect Power Source	• On the jacket water heater body on the right side of engine
211900B	Danger	-	Gas Shutoff	• On air connection next to Deltec carburetor
211910K	Warning	-	Safety Guard	• On the rear lifting eye or on bracket on intercooler [1]
211910L	Warning	-	Safety Guard	• On camshaft cover on front of engine
211910N	Warning	-	Maximum Gas Inlet Pressure	• Near the fuel gas connection on the rear of engine [2]
211910T	Warning	-	Maximum Gas Inlet Pressure	• On starter bracket on rear of engine
211910W	Warning	-	Vent Flammable Gas	• On plate mounted on butterfly housing and air/gas starter
211911B	-	Warning	Built Without Engine Protection	• Attached with two (2) nytyes to the throttle shaft
211911J	Warning	-	Barring Device	• On the last connecting rod cover in front of flywheel housing
211920B	Caution	-	Eye/Ear Protection	• On the plate mounted on intake manifold
211920E	Caution	-	Hot Components	• On turbocharger heat shield On the plate mounted on intake manifold
211930A	Safety	-	Lifting Instructions	• On camshaft cover on front of engine and rear lifting eye or on bracket on intercooler [3]
211930C	Safety	-	Lifting Instructions	• On camshaft cover on front of engine and rear lifting eye or on bracket on intercooler [3]

NOTE:
[1] *Place label on rear lifting eye when the intercooler is not specified. Use P/N 305885 label plate with M10 fasteners to attach to intercooler.*
[2] *Place label on regulator bracket when regulator is mounted.*
[3] *Place label on rear lifting eye when the intercooler is not specified. Use P/N 305885 label plate with M10 fasteners to attach to intercooler.*

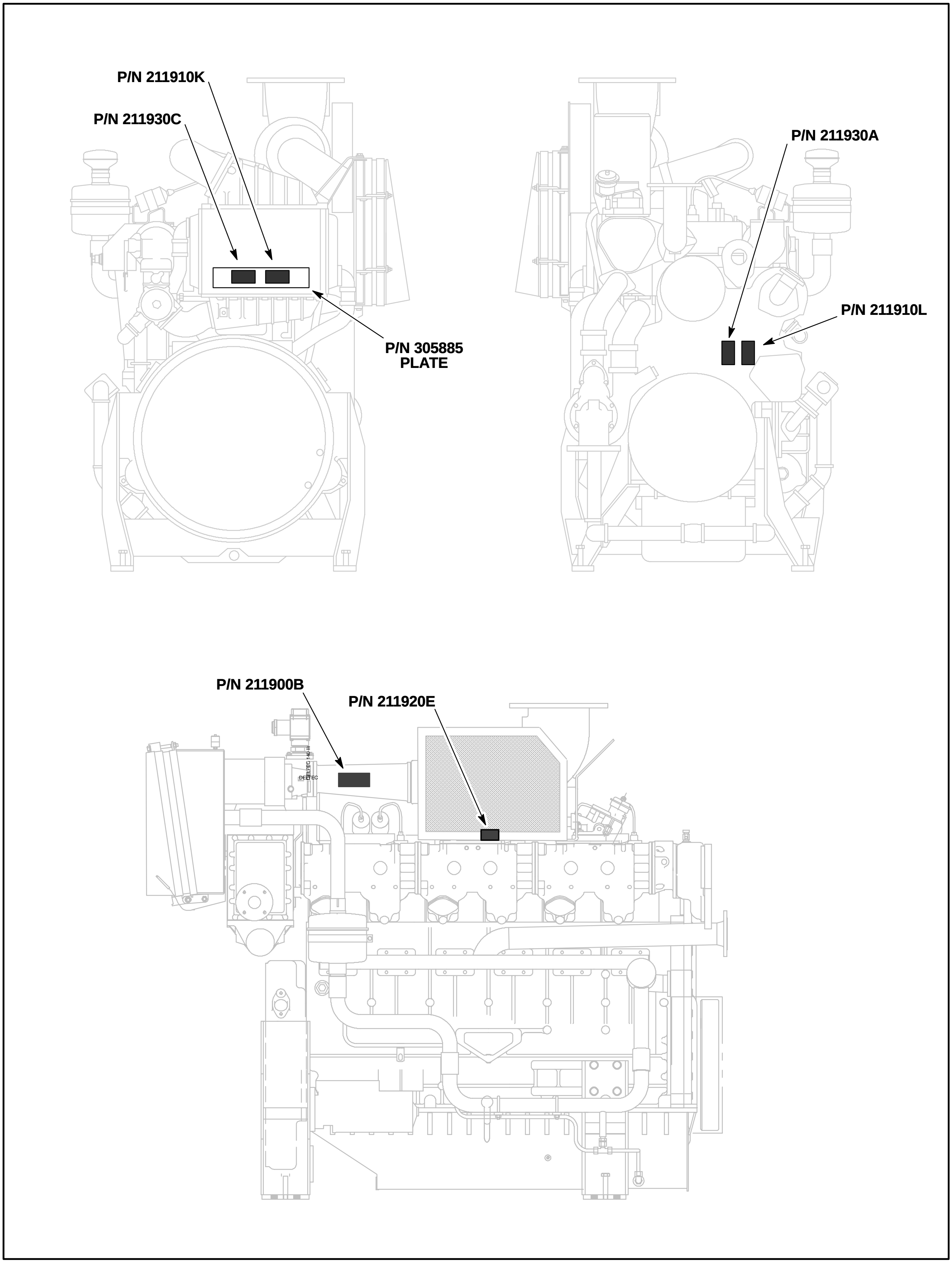


Figure 1.00-1. Warning Tag And Decal Locations

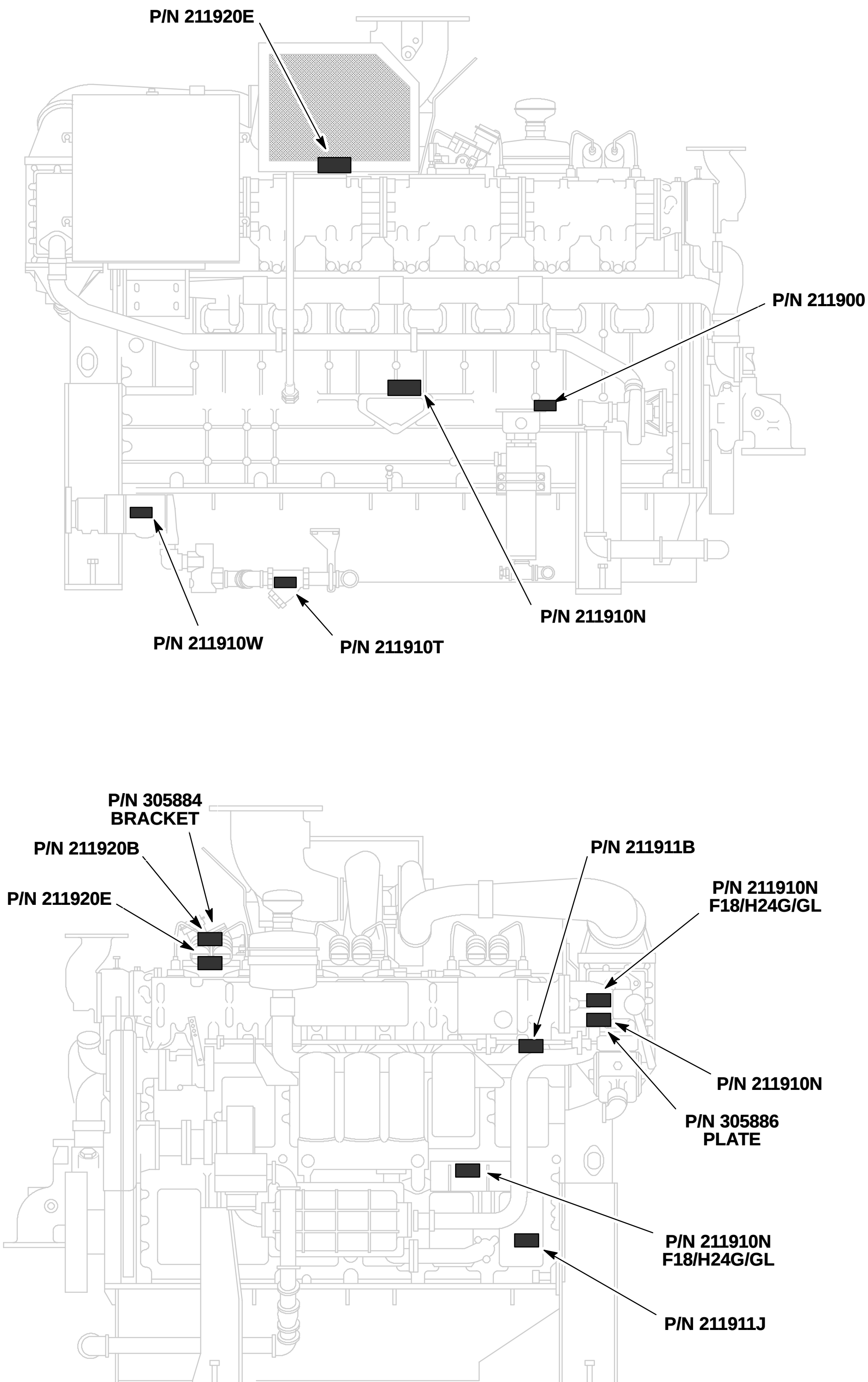


Figure 1.00-2. Warning Tag And Decal Locations

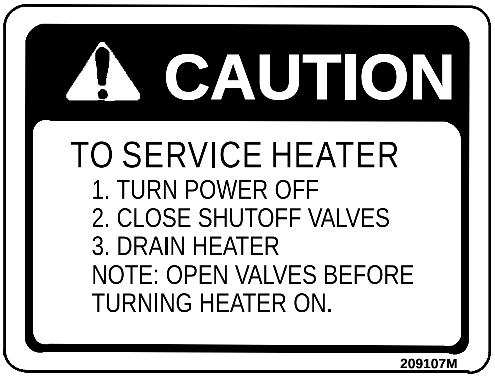


Figure 1.00-3. Caution Label – P/N 209107M – To Service Heater

Figure 1.00-4. Danger Label – P/N 211900 – Disconnect Power Source

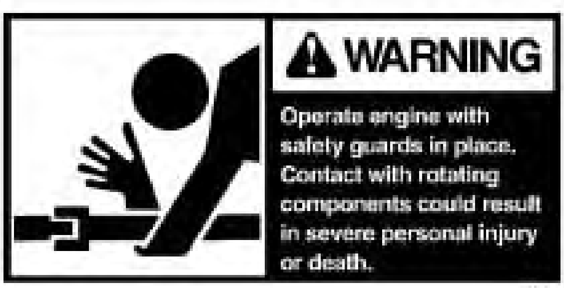


Figure 1.00-5. Warning Label – P/N 211910K – Safety Guard

Figure 1.00-6. Warning Label – P/N 211910L – Safety Guard

Figure 1.00-7. Warning Label – P/N 211910N – Maximum Gas Inlet Pressure

Figure 1.00-8. Warning Label – P/N 211910T– Maximum Gas Inlet Pressure

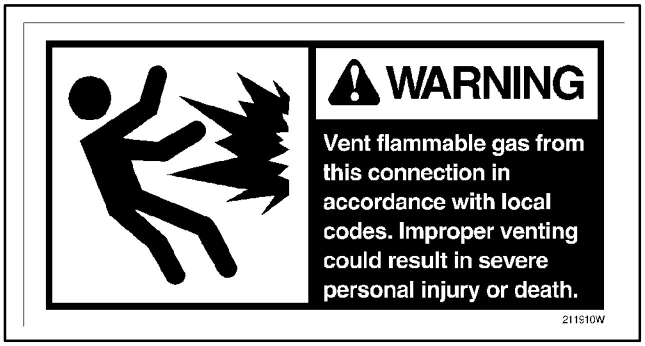


Figure 1.00-9. Warning Label – P/N 211910W – Vent Flammable Gas

Figure 1.00-10. Warning Label – P/N 211911B – Built Without Engine Protection

Figure 1.00-11. Warning Label – P/N 211911J – Barring Device

Figure 1.00-12. Caution Label – P/N 211920B – Eye/Ear Protection

Figure 1.00-13. Caution Label – P/N 211920E – Hot Components

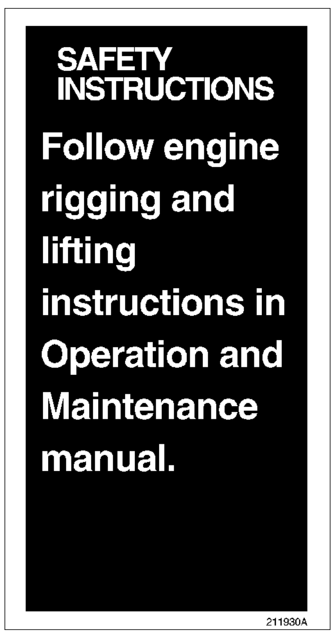


Figure 1.00-14. Safety Label – P/N 211930A – Lifting Instructions

Figure 1.00-15. Caution Label – P/N 211930C – Lifting Instructions

SECTION 1.05

SAFETY

SAFETY INTRODUCTION

The following safety precautions are published for your information. Waukesha Engine, Dresser, Inc., does not, by the publication of these precautions, imply or in any way represent that they are the sum of all dangers present near industrial engines or fuel rating test units. If you are installing, operating or servicing a Waukesha product, it is your responsibility to ensure full compliance with all applicable safety codes and requirements. All requirements of the Federal Occupational Safety and Health Act must be met when Waukesha products are operated in areas that are under the jurisdiction of the United States of America. Waukesha products operated in other countries must be installed, operated and serviced in compliance with any and all applicable safety requirements of that country.

For details on safety rules and regulations in the United States, contact your local office of the Occupational Safety and Health Administration (OSHA).

The words “danger,” “warning,” “caution” and “note” are used throughout this manual to highlight important information. Be certain that the meanings of these alerts are known to all who work on or near the equipment.

NOTE: *This symbol identifies information which is NECESSARY TO THE PROPER OPERATION, MAINTENANCE OR REPAIR OF THE EQUIPMENT.*

⚠ CAUTION

This symbol identifies information about hazards or unsafe practices. Disregarding this information *could* result in PRODUCT DAMAGE AND/OR PERSONAL INJURY.

⚠ WARNING

This symbol identifies information about hazards or unsafe practices. Disregarding this information *could* result in SEVERE PERSONAL INJURY OR DEATH.

⚠ DANGER

This symbol identifies information about immediate hazards. Disregarding this information *will* result in SEVERE PERSONAL INJURY OR DEATH.

SAFETY TAGS AND DECALS

⚠ WARNING

To avoid severe personal injury or death, all warning tags and decals must be visible and legible to the operator while the equipment is operating.

EQUIPMENT REPAIR AND SERVICE

Proper maintenance, service and repair are important to the safe, reliable operation of the unit and related equipment. Do not use any procedure not recommended in the Waukesha Engine manuals for this equipment.

⚠ WARNING

To prevent severe personal injury or death, always stop the unit before cleaning, servicing or repairing the unit or any driven equipment.

Place all controls in the OFF position and disconnect or lock out starters to prevent accidental restarting. If possible, lock all controls in the OFF position and take the key. Put a sign on the control panel warning that the unit is being serviced.

Close all manual control valves, disconnect and lock out all energy sources to the unit, including all fuel, electric, hydraulic, and pneumatic connections.

Disconnect or lock out driven equipment to prevent the possibility of the driven equipment rotating the disabled engine.

⚠ WARNING

To avoid severe personal injury or death, ensure that all tools and other objects are removed from the unit and any driven equipment before restarting the unit.

⚠ WARNING

Allow the engine to cool to room temperature before cleaning, servicing or repairing the unit. Hot components or fluids can cause severe personal injury or death.

Some engine components and fluids are extremely hot even after the engine has been shut down. Allow sufficient time for all engine components and fluids to cool to room temperature before attempting any service procedure.

ACIDS

⚠ WARNING

Comply with the acid manufacturer's recommendations for proper use and handling of acids. Improper handling or misuse could result in severe personal injury or death.

BATTERIES

⚠ WARNING

Comply with the battery manufacturer's recommendations for procedures concerning proper battery use and maintenance. Improper maintenance or misuse could result in severe personal injury or death.

BODY PROTECTION

⚠ WARNING

Always wear OSHA approved body, sight, hearing and respiratory system protection. Never wear loose clothing, jewelry or long hair around an engine. The use of improper attire or failure to use protective equipment may result in severe personal injury or death.

CHEMICALS

GENERAL

⚠ WARNING

Always read and comply with safety labels on all containers. Do not remove or deface the container labels. Improper handling or misuse could result in severe personal injury or death.

CLEANING SOLVENTS

⚠ WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners or other highly volatile fluids for cleaning.

LIQUID NITROGEN/DRY ICE

⚠ WARNING

Comply with the liquid nitrogen/Dry Ice manufacturer's recommendations for proper use and handling of liquid nitrogen/Dry Ice. Improper handling or use could result in severe personal injury or death.

COMPONENTS

HEATED OR FROZEN

⚠ WARNING

Always wear protective equipment when installing or removing heated or frozen components. Some components are heated or cooled to extreme temperatures for proper installation or removal. Direct contact with these parts could cause severe personal injury or death.

INTERFERENCE FIT

⚠ WARNING

Always wear protective equipment when installing or removing components with an interference fit. Installation or removal of interference components may cause flying debris. Failure to use protective equipment may result in severe personal injury or death.

COOLING SYSTEM

⚠ WARNING

Always wear protective clothing when venting, flushing or blowing down the cooling system. Operational coolant temperatures can range from 180 – 250° F (82 – 121° C). Contact with hot coolant or coolant vapor can cause severe personal injury or death.

⚠ WARNING

Do not service the cooling system while the engine is operating or when the coolant is hot. Operational coolant temperatures can range from 180° – 250° F (82° – 121° C). Contact with hot coolant or vapor can cause severe personal injury or death.

ELECTRICAL

GENERAL

⚠ WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

IGNITION

⚠ WARNING

Avoid contact with ignition units and wiring. Ignition system components can store electrical energy and if contacted can cause electrical shocks. Electrical shock can cause severe personal injury or death.

⚠ WARNING

Properly discharge any electrical component that has the capability to store electrical energy before connecting or servicing that component. Electrical shock can cause severe personal injury or death.

EXHAUST

⚠ WARNING

Do not inhale engine exhaust gases. Exhaust gases are highly toxic and could cause severe personal injury or death.

Ensure exhaust systems are leak free and that all exhaust gases are properly vented.

⚠ WARNING

Do not touch or service any heated exhaust components. Allow sufficient time for exhaust components to cool to room temperature before attempting any service procedure. Contact with hot exhaust system components can cause severe personal injury or death.

FIRE PROTECTION

⚠ WARNING

Refer to local and federal fire regulations for guidelines for proper site fire protection. Fires can cause severe personal injury or death.

FUELS

GENERAL

⚠ WARNING

Ensure that there are no leaks in the fuel supply. Engine fuels are highly combustible and can ignite or explode causing severe personal injury or death.

GASEOUS

⚠ WARNING

Do not inhale gaseous fuels. Some components of fuel gas are odorless, tasteless, and highly toxic. Inhalation of gaseous fuels can cause severe personal injury or death.

⚠ WARNING

Shut off the fuel supply if a gaseous engine has been cranked excessively without starting. Crank the engine to purge the cylinders and exhaust system of accumulated unburned fuel. Failure to purge accumulated unburned fuel in the engine and exhaust system can result in an explosion resulting in severe personal injury or death.

LIQUID

⚠ WARNING

Do not ingest liquid fuels or breathe in their vapors. Liquid fuels may be highly toxic and can result in severe personal injury or death.

⚠ WARNING

Use protective equipment when working with liquid fuels and related components. Liquid fuel can be absorbed into the body resulting in severe personal injury or death.

INTOXICANTS AND NARCOTICS

⚠ WARNING

Do not allow anyone under the influence of intoxicants and/or narcotics to work on or around industrial engines. Workers under the influence of intoxicants and/or narcotics are a hazard both to themselves and other employees and can cause severe personal injury or death to themselves or others.

PRESSURIZED FLUIDS/GAS/AIR

⚠ WARNING

Never use pressurized fluids/gas/air to clean clothing or body parts. Never use body parts to check for leaks or flow rates. Pressurized fluids/gas/air injected into the body can cause severe personal injury or death.

Observe all applicable local and federal regulations relating to pressurized fluid/gas/air.

PROTECTIVE GUARDS

⚠ WARNING

Provide guarding to protect persons or structures from rotating or heated parts. Contact with rotating or heated parts can result in severe personal injury or death.

It is the responsibility of the engine owner to specify and provide guarding. Refer to OSHA standards on “machine guarding” for details on safety rules and regulations concerning guarding techniques.

SPRINGS

⚠ WARNING

Always wear safety glasses when removing retaining (snap) rings. Verify the correct retaining ring pliers is used and the pliers is in good condition. If the retaining ring slips off the pliers when being installed or removed, it can be propelled with enough force to cause a serious eye injury. Disregarding this information could cause serious personal injury.

TOOLS

ELECTRICAL

⚠ WARNING

Do not install, set up, maintain or operate any electrical tools unless you are a technically qualified individual who is familiar with them. Electrical tools use electricity and if used improperly could cause severe personal injury or death.

HYDRAULIC

⚠ WARNING

Do not install, set up, maintain or operate any hydraulic tools unless you are a technically qualified individual who is familiar with them. Hydraulic tools use extremely high hydraulic pressure and if used improperly could cause severe personal injury or death.

⚠ CAUTION **Always follow recommended procedures when using hydraulic tensioning devices. Improper use of hydraulic tensioning tools can cause severe engine damage.**

PNEUMATIC

⚠ WARNING

Do not install, set up, maintain or operate any pneumatic tools unless you are a technically qualified individual who is familiar with them. Pneumatic tools use pressurized air and if used improperly could cause severe personal injury or death.

WEIGHT

⚠ WARNING

Always consider the weight of the item being lifted and use only properly rated lifting equipment and approved lifting methods. Failure to take adequate precautions can result in serious personal injury or death.

⚠ WARNING

Never walk or stand under an engine or component while it is suspended. Failure to adhere to this could result in severe personal injury or death.

WELDING

GENERAL

⚠ WARNING

Comply with the welder manufacturer's recommendations for procedures concerning proper use of the welder. Improper welder use can result in severe personal injury or death.

ON ENGINE

⚠ CAUTION **Ensure that the welder is properly grounded before attempting to weld on or near an engine. Ground welder as close to work area as possible. Failure to properly ground the welder could result in severe engine damage.**

⚠ CAUTION **Disconnect all engine harnesses and electronically controlled devices before welding with an electric arc welder on or near an engine. Failure to disconnect the harnesses and electronically controlled devices could result in severe engine damage.**

SECTION 1.10

RIGGING AND LIFTING ENGINES

RIGGING AND LIFTING ENGINE

⚠ WARNING

Exercise extreme care when moving the engine or its components. Never walk around or stand directly under an engine while it is suspended. Always consider the weight of the engine when selecting the hoisting chains and equipment. Be positive about the rated capacity of lifting equipment. Use only properly maintained lifting equipment with a lifting capacity which exceeds the known weight of the object to be lifted. Disregarding this information could result in severe personal injury or death.

Table 1.10-1 shows the approximate dry weight of the VGF inline engines.

Table 1.10-1. Engine Dry Weights

ITEM DESCRIPTION	F18	H24
Engine With Flywheel	5.500 lb. (2,500 kg)	7,200 lb. (3,272 kg)
Flywheel	342 lb. (155 kg)	342 lb. (155 kg)
Cylinder Head	80 lb. (36 kg)	80 lb. (36 kg)
Turbocharger	43 lb. (20 kg)	43 lb. (20 kg)
Intercooler Without Piping	243 lb. (110 kg)	243 lb. (110 kg)
Oil Pump	41 lb. (19 kg)	41 lb. (19 kg)

⚠ WARNING

Always lift the engine using the approved lifting eyes. VGF inline engines are equipped with two lifting eyes. Engine lifting eyes are meant to lift only the engine. They are not to be used for lifting of driven or auxiliary equipment that may be attached to the engine. Disregarding this information could result in severe personal injury or death.

To avoid personal injury or death, follow approved rigging procedures to ensure no undue strain on the lifting eyes, chains and cables when lifting the engine.

Attach the hook of the hoisting chain to the lifting eye. Bring the chain straight up and attach to a certified spreader bar that meets OSHA standards (see Figure 1.10-1 and Figure 1.10-2). Repeat the procedure for each lifting eye.

NOTE: *The lifting cable or chain must be with 15° of vertical.*

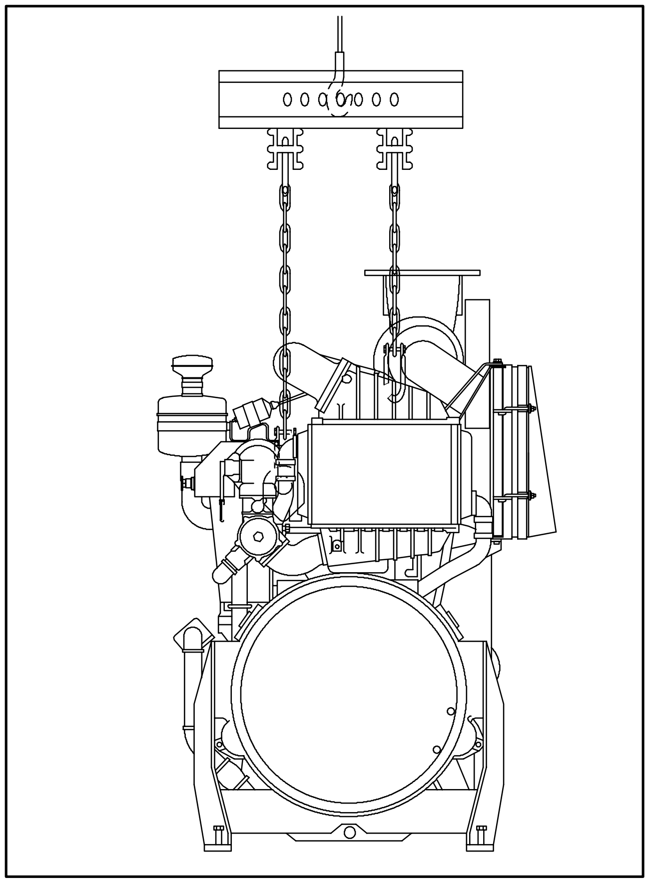


Figure 1.10-1. Correct Method Of Lifting Engine – Rear View

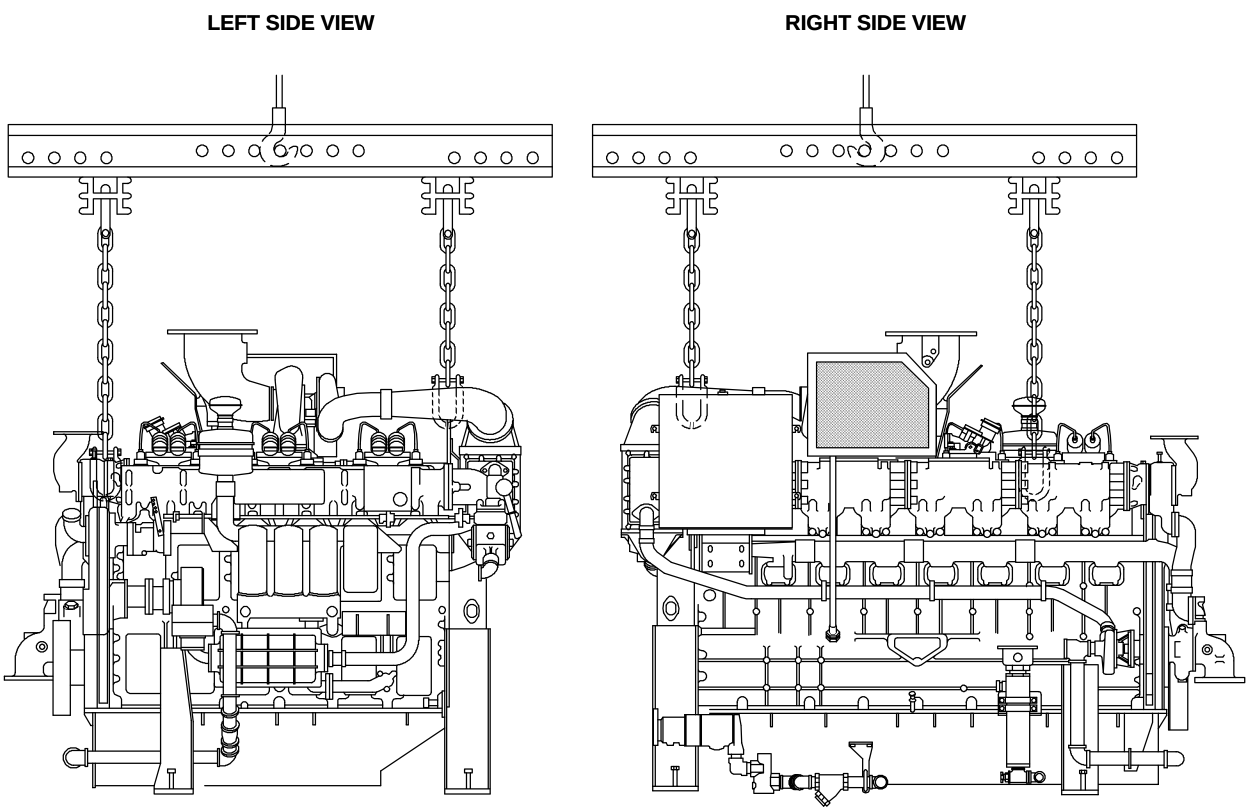


Figure 1.10-2. Correct Method Of Lifting Engine – Side Views

SECTION 1.15

GENERAL INFORMATION

INTRODUCTION TO VGF™ F18/H24 MODELS

Waukesha Engine, Dresser, Inc. manufactures two models of VGF inline engines: the F18 and H24.

The VGF F18 engine is a 6 cylinder, 4-cycle engine, and has a total cylinder displacement of 18 litres (1096 cubic in.). The F18 bore and stroke is 152 x 165 mm (5.98 x 6.5 in.), and piston speed is 9.9 meters per second (1950 feet per minute) at 1800 rpm.

The VGF H24 engine is a 8 cylinder, 4-cycle engine, and has a total cylinder displacement of 24 litres (1462 cu. in.). The H24 bore and stroke is 152 x 165 mm (5.98 x 6.5 in.), and piston speed is 9.9 meters per second (1950 feet per minute) at 1800 rpm.

Both the VGF F18 and H24 engines come in G, GL, GL LCR (Low Compression Ratio), GLD or GSID configurations. The GL and GLD models have a compression ratio of 11:1. The GL LCR model has a compression ratio of 8.7:1 and the G/GSID model has a compression ratio of 8.6:1.

The VGF F18/H24 G engine is a non turbocharged rich combustion (stoichiometric) engine that operates on natural gas for reduced emissions.

The VGF F18/H24 GL engine operates on natural gas and is designed to burn a lean air/fuel mixture for low fuel consumption and reduced emissions. GL engines are equipped with a turbocharger that “forces” high velocity ambient air through the intercooler, carburetor and intake manifold, before entering the combustion chamber.

The VGF F18/H24 GLD is also a lean burn combustion engine, except this engine uses a “draw-thru” fuel system. The turbocharger “draws” the air/fuel mixture from the carburetors to the turbocharger, then forces the mixture into the intercooler, intake manifold and finally into the combustion chamber. This system allows operation with a much lower fuel pressure than the GL series.

The VGF F18/H24 GSID is a rich combustion (stoichiometric) engine that uses a “draw-thru” fuel system. The turbocharger “draws” the air/fuel mixture from the carburetors to the turbocharger, then forces the mixture into the intercooler, intake manifold and finally into the combustion chamber. The GSID is typically operated at a setting just rich of stoichiometric (usually when operating with a three way catalyst to produce very low NO_x emissions).

MODEL PLATE (PREVIOUS ENGINES)

The model plate is located on the intake manifold (see Figure 1.15-1). This plate provides information on the engine model, size (bore x stroke), specification number, governed speed, serial number and date of manufacture (see Figure 1.15-1).

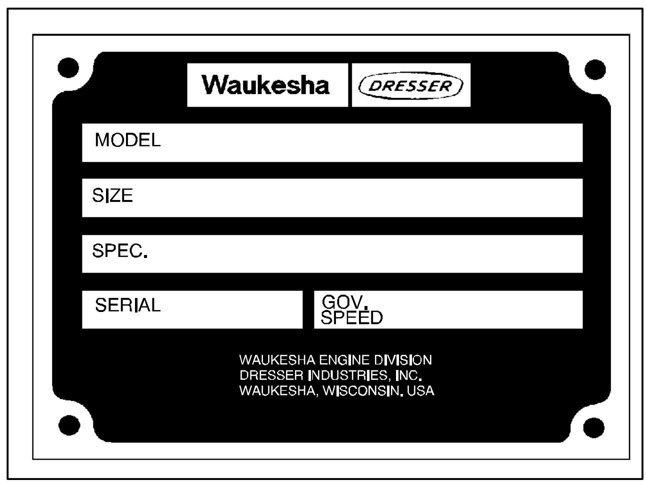


Figure 1.15-1. Previous Production Model Plate

SPECIFICATION PLATE (PREVIOUS ENGINES)

The specification plate is located on the breather system baffle box. This plate provides information on the engine compression ratio, timing, firing order, BMEP, duty (either continuous or intermittent) and valve clearance specifications (see Figure 1.15-2).

When requesting information about the engine or parts, it is important to know both the engine model number and serial number. If the nameplate is defaced or detached, the serial number is stamped on the right rear side surface of the crankcase.

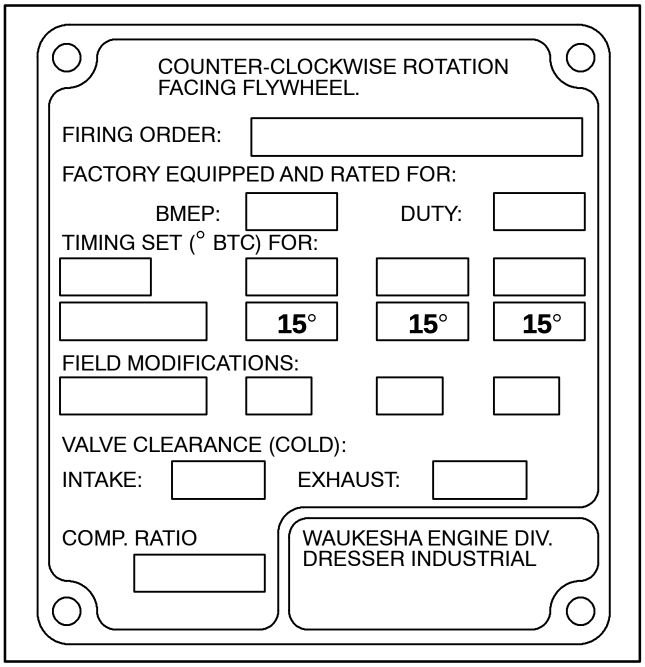


Figure 1.15-2. VGF Specification Plate

SERIAL NUMBERS AND ENGINE NAMEPLATE

Current production engines have the engine model, serial and specification numbers stamped on a single nameplate (see Figure 1.15-3).

The VGF engine nameplate provides the following information: model number, serial number, date inspected, special application approval number (power approval), valve clearance, compression ratio, firing order, governed speed, altitude limit at which an engine derate takes place, primary and secondary fuel ratings which show the fuel, minimum Waukesha Knock Index (WKI[R]), ignition timing, rated output in horsepower and kilowatts, and overload rating in horsepower and kilowatts (see Figure 1.15-4). This nameplate is located on the forward end of the intake manifold.

When requesting information, you will need to reference both the engine model and serial numbers. If the nameplate is defaced or detached, the serial number may be obtained directly off the crankcase. To locate it, look on the right side of the crankcase, just ahead of the flywheel housing (see Figure 1.15-5).

Figure 1.15-3. Engine Nameplate

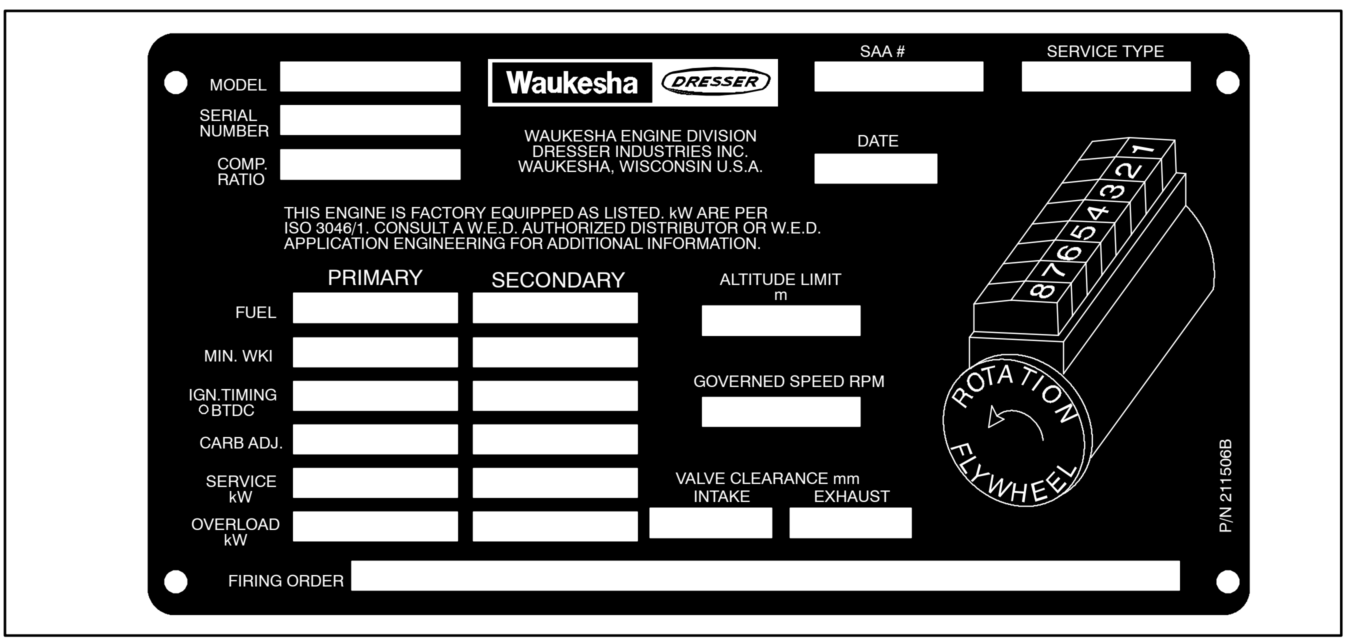


Figure 1.15-4. Current Nameplate Configuration

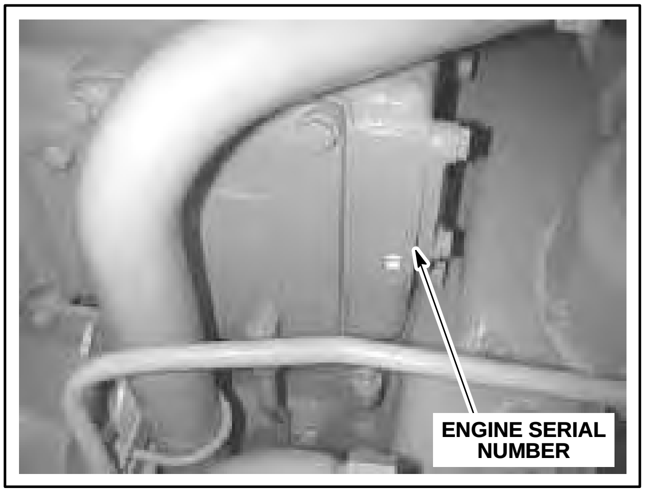


Figure 1.15-5. Engine Serial Number

ENGINE COMPONENT DESCRIPTION

CRANKCASE

The crankcase is made of a cast iron alloy with nodular iron main bearing caps. Main bearing caps are secured in place with two main bearing capscrews and two crossbolts per bearing. Upper and lower crankcase doors are provided to allow access to the camshaft, the crankshaft and connecting rods.

The lubrication system is a full pressure system with a gear type pump and three external full flow filter cannisters. An engine mounted cooler reduces the oil temperature.

CRANKSHAFT

Waukesha F18 and H24 engines rotate in the standard counterclockwise direction when facing the flywheel. The forged steel crankshaft is dynamically balanced and fully counterweighted and supported by seven main bearings in the F18. The H24 uses nine main bearings. A viscous vibration damper mounted on the front of the crankshaft reduces torsional stress.

CONNECTING RODS

The connecting rods are a drop forged alloy steel with a split serrated mating surface.

PISTONS

The pistons are made of an aluminum alloy, with a cast-in resist alloy top ring insert and a full floating piston pin. The pistons have a patented combustion bowl that allows the use of a lean air/fuel ratio mixture for fuel economy and reduced emissions. The piston and the crown are oil jet cooled and use three rings.

CYLINDER SLEEVES

The cylinder sleeves are replaceable, wet style, sealed with O-rings.

CAMSHAFT

Pivoted roller cam followers are used to transmit camshaft motion to the valves.

CYLINDER HEAD AND VALVES

This engine uses individual valve-in-head cylinder heads. Two Stellite® faced intake and two Stellite® faced exhaust valves with replaceable valve seats and guides are used in interchangeable cylinder heads.

NOTE: *Stellite® is a registered trademark of Stoody Deloro Stellite Inc.*

TURBOCHARGER

A high efficiency, radial flow turbocharger is mounted on top of the exhaust manifold on the engine. The turbocharger uses expanding exhaust gases to drive the compressor turbine and generate the required boost levels for the engine.

INTERCOOLER

A single box type intercooler is mounted at the rear of the engine. The intercooler on GL engines receives air from the turbocharger, cools the charge air and delivers the air to the carburetor. On GLD and GSID engines, the intercooler receives the air/fuel mixture from the carburetor, draws through the turbocharger, then cools the air/fuel charge for delivery to the intake manifold.

CARBURETOR

The naturally aspirated G model is equipped with a side draft carburetor. The GL model has push through carburetion and the GLD and GSID models have draw through carburetion. Gas regulators are different depending on application and are generally engine mounted.

The standard equipment air cleaner is an engine mounted, two stage, dry element air cleaner with a rain shield and service indicator.

INTAKE MANIFOLD

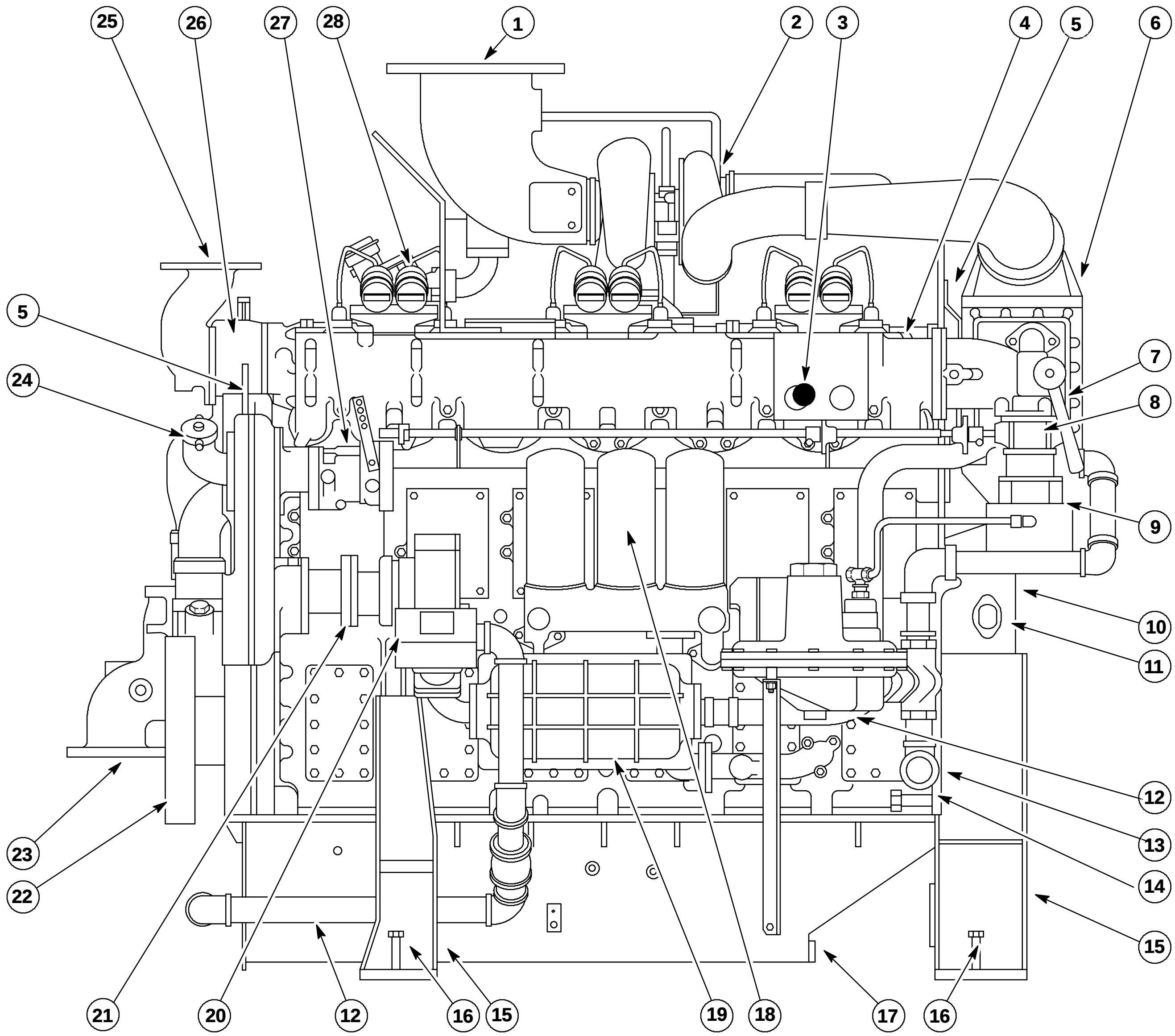
The air/fuel mixture passes through the intake manifold located on the left side of the engine. The individual ignition coils for each cylinder are mounted on the intake manifold.

EXHAUST MANIFOLD

The exhaust manifold is located on the right side of the engine and supplies the exhaust gases to drive the turbochargers. The manifold is jacket water cooled and sound damped with coolant that is supplied by water elbows from each cylinder head.

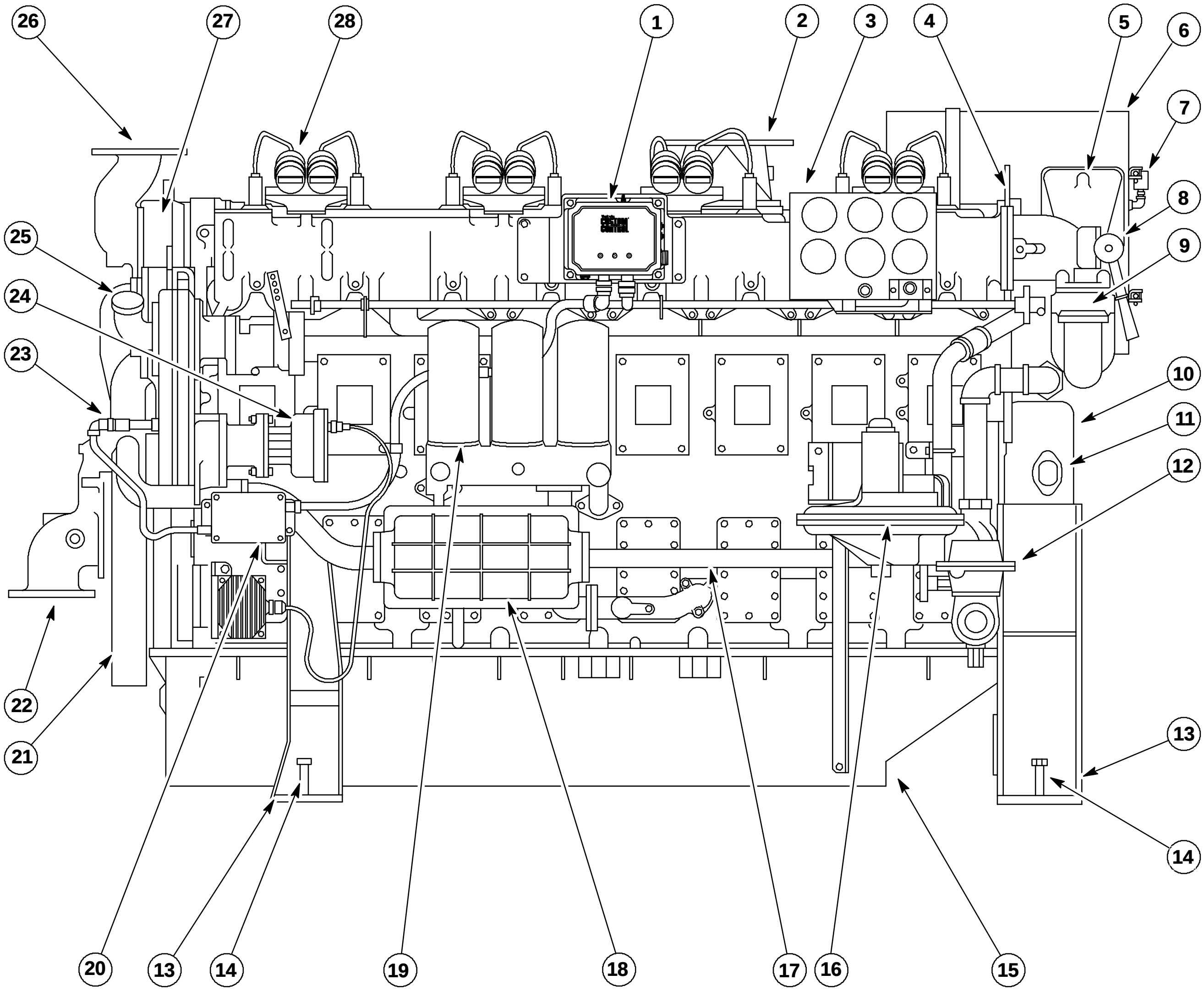
ENGINE IDENTIFICATION VIEWS

LEFT SIDE VIEW



1. Exhaust Outlet
2. Turbocharger
3. Control Panel
4. Intake Manifold
5. Lifting Eye
6. Intercooler
7. Hand Throttle
8. Butterfly Valve
9. Carburetor
10. Flywheel And Housing
11. Engine Timing Window
12. Auxiliary Water Piping
13. Fuel Inlet
14. Engine Barring Device
15. Engine Support
16. Jack Screw
17. Oil Drain
18. Oil Filters
19. Oil Cooler
20. Auxiliary Water Thermostat
21. Magneto
22. Vibration Damper
23. Jacket Water Inlet
24. Oil Fill
25. Jacket Water Outlet
26. Jacket Thermostat Housing
27. Governor
28. Ignition Coils

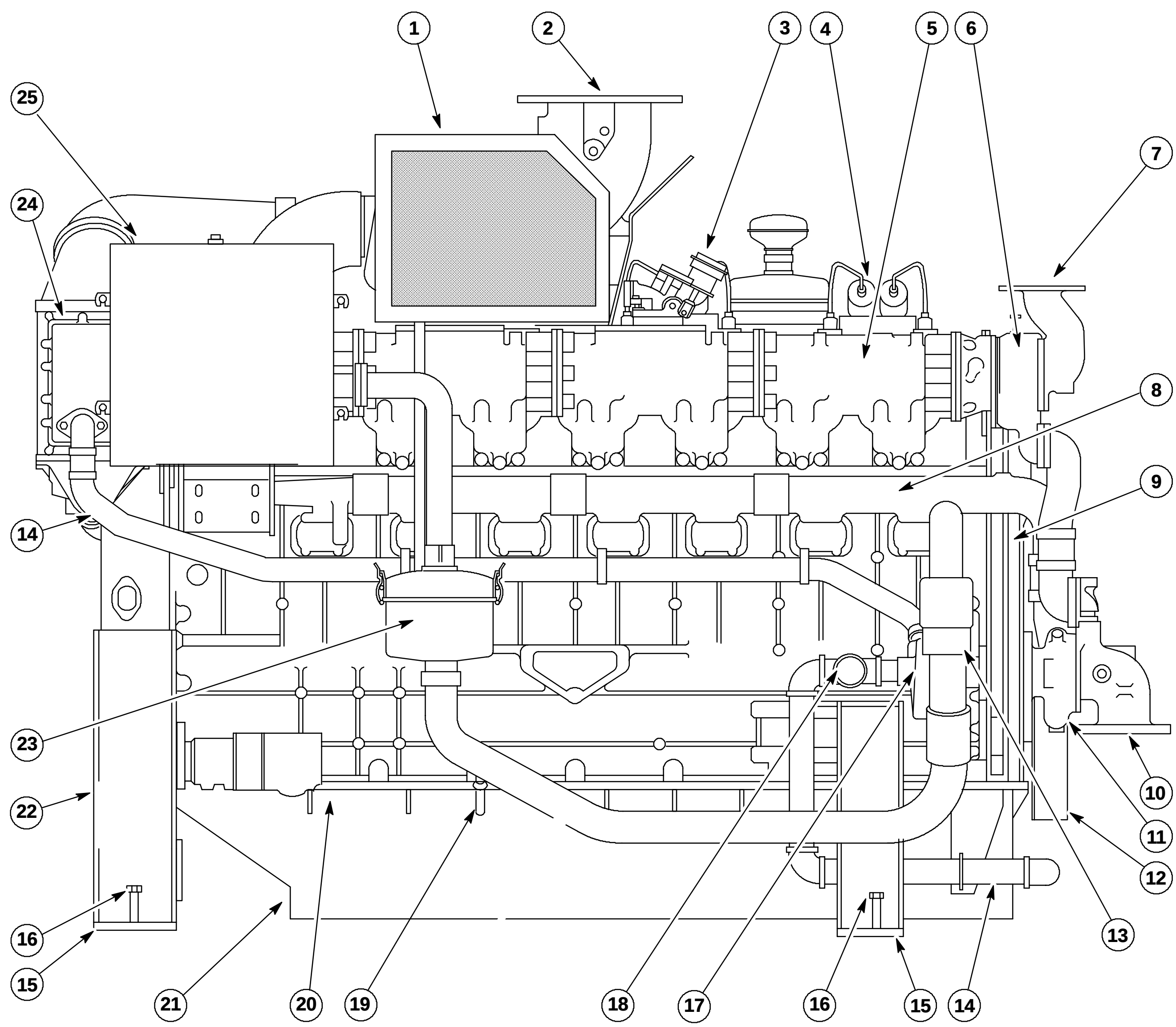
Figure 1.15-6. Left Side View – F18GL



1. CEC Ignition Module
2. Exhaust Outlet
3. Instrument Panel
4. Lifting Eye
5. Carburetor
6. Air Cleaner
7. Air Filter Restriction Indicator
8. Hand Throttle
9. Butterfly Valve
10. Flywheel And Housing
11. Engine Timing Window
12. Fuel Shutoff Valve
13. Engine Support
14. Jack Screw
15. Oil Drain
16. Fuel Pressure Regulator
17. Auxiliary Water Piping
18. Oil Cooler
19. Oil Filters
20. CEC Junction Box
21. Vibration Damper
22. Jacket Water Inlet
23. Hall-effect Sensor (CEC Ignition)
24. 24 Volt DC Generator (CEC Ignition)
25. Oil Fill
26. Jacket Water Outlet
27. Thermostat Housing
28. Ignition Coils

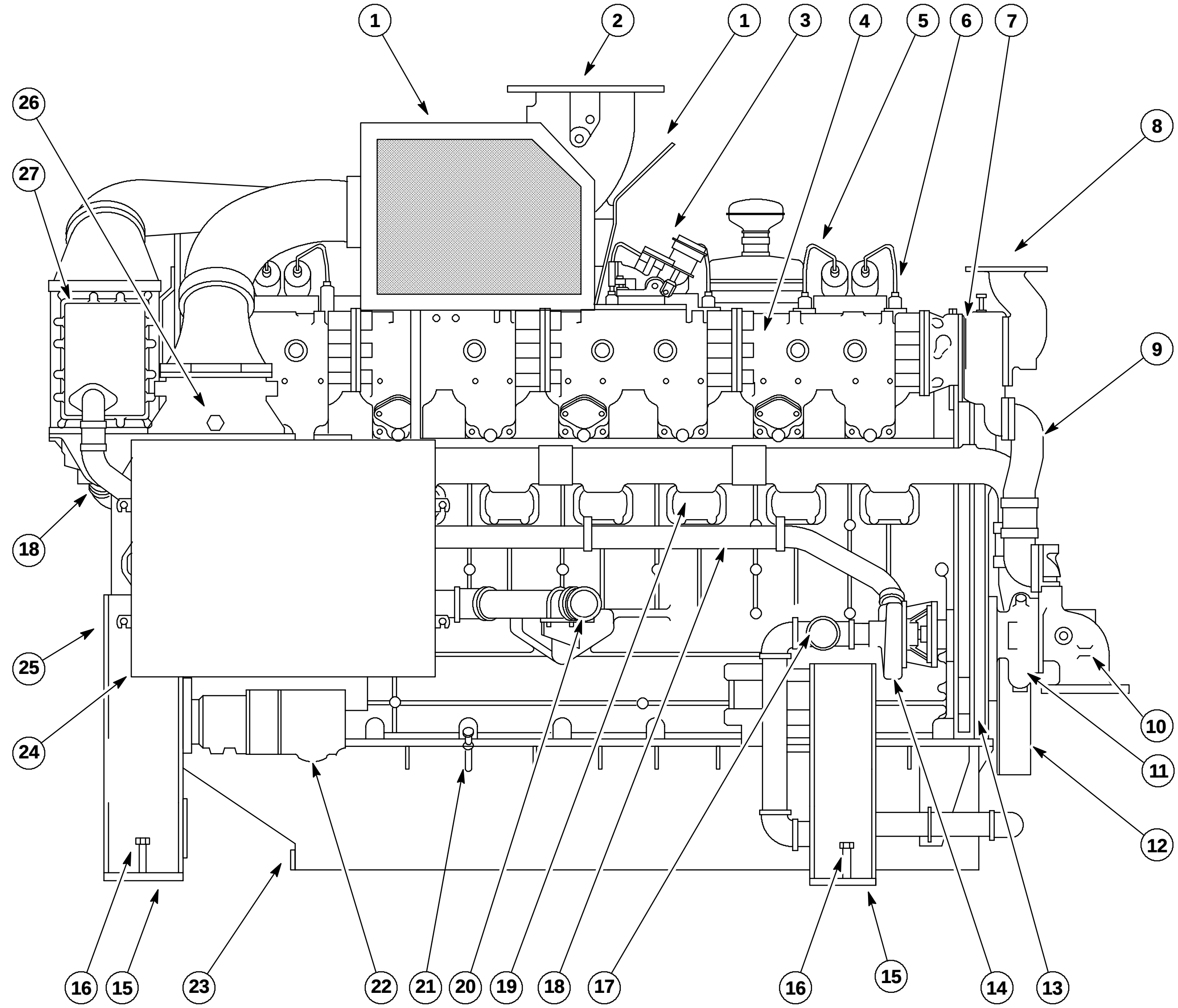
Figure 1.15-7. Left Side View – H24G

RIGHT SIDE VIEW



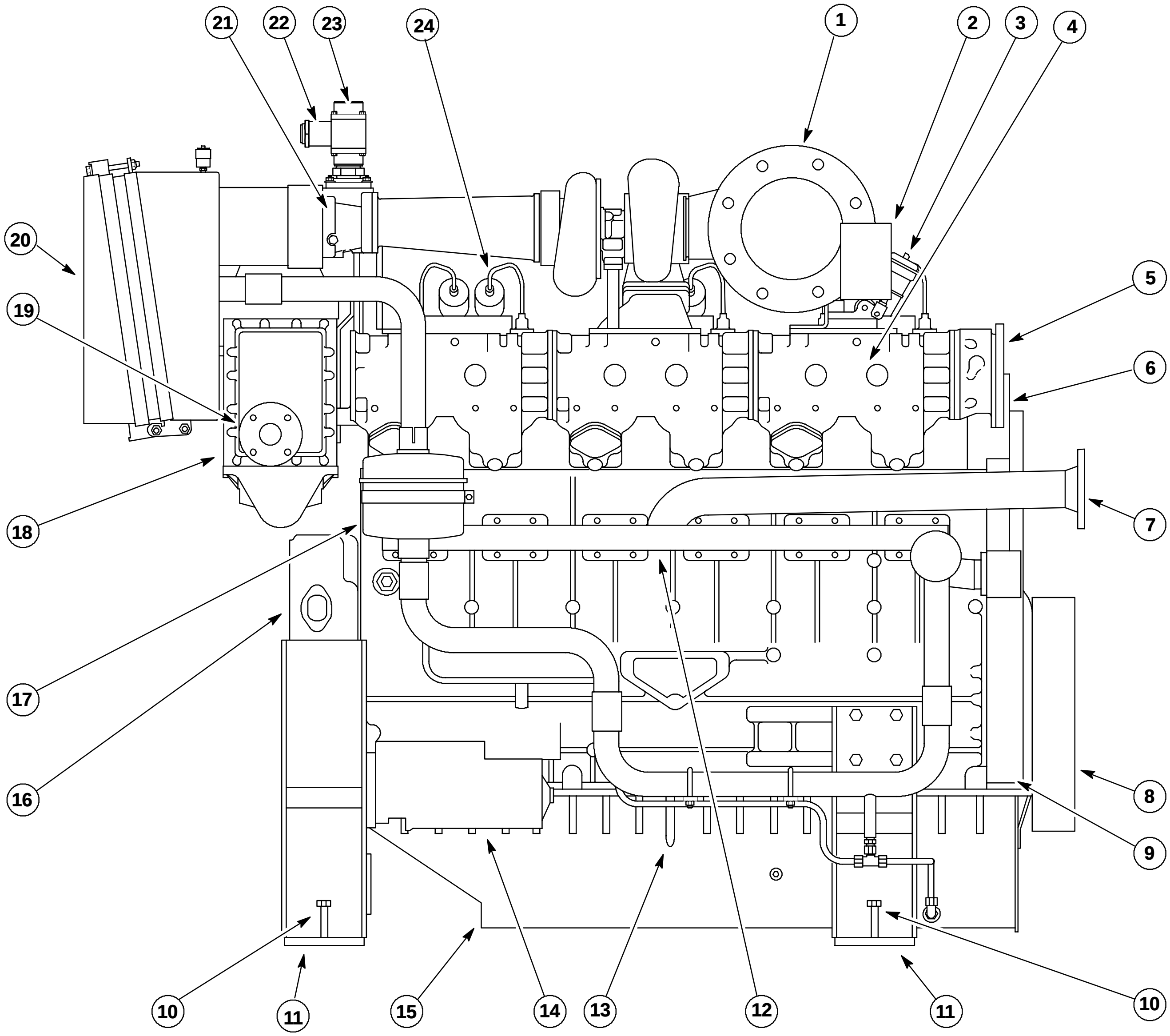
1. Heat Shield
2. Exhaust Outlet
3. Wastegate
4. Ignition Coils
5. Exhaust Manifold
6. Jacket Water Thermostat Housing
7. Jacket Water Outlet
8. Jacket Water Header
9. Gear Housing
10. Jacket Water Inlet
11. Jacket Water Pump
12. Vibration Damper
13. Breather Regulator
14. Auxiliary Water Piping
15. Engine Support
16. Jack Screw
17. Auxiliary Water Pump
18. Auxiliary Water Inlet
19. Oil Dipstick
20. Starter Motor Location
21. Oil Drain
22. Flywheel And Housing
23. Breather Oil Separator
24. Intercooler
25. Air Cleaner

Figure 1.15-8. Right Side View – H24GL



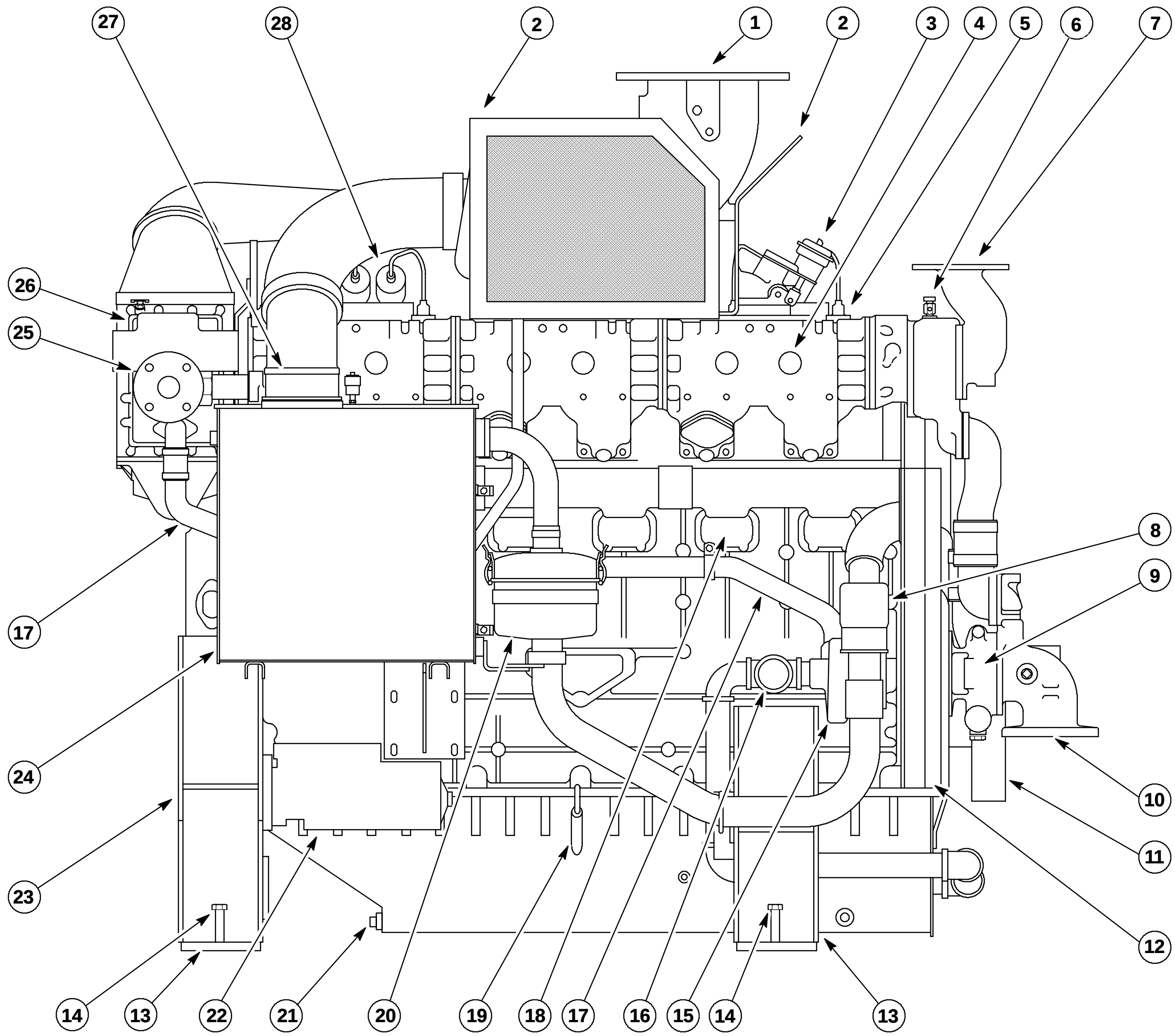
1. Heat Shield
2. Exhaust Outlet
3. Wastegate
4. Exhaust Manifold
5. Ignition Coils
6. Spark Plug Location
7. Jacket Water Thermostat Housing
8. Jacket Water Outlet
9. Jacket Water Bypass
10. Jacket Water Inlet
11. Jacket Water Pump
12. Vibration Damper
13. Gear Housing
14. Auxiliary Water Pump
15. Engine Support
16. Jack Screw
17. Auxiliary Water Inlet
18. Auxiliary Water Piping
19. Water Header
20. Fuel Inlet
21. Oil Dipstick
22. Starter Motor Location
23. Oil Drain
24. Air Cleaner
25. Flywheel And Housing
26. Carburetor Adjust
27. Intercooler

Figure 1.15-9. Right Side View – H24GLD, Impco Carburetor



1. Exhaust Outlet
2. Heat Shield
3. Wastegate
4. Exhaust Manifold
5. Jacket Water Outlet
6. Lifting Eye
7. Jacket Water Header Inlet
8. Vibration Damper
9. Gear Housing
10. Jack Screw
11. Engine Support
12. Jacket Water Header
13. Dip Stick
14. Starter Motor Location
15. Oil Drain
16. Flywheel and Housing
17. Breather Oil Separator
18. Intercooler
19. Auxiliary Water Inlet
20. Air Duct
21. Carburetor
22. Main Adjusting Screw
23. Fuel Inlet
24. Ignition Coils

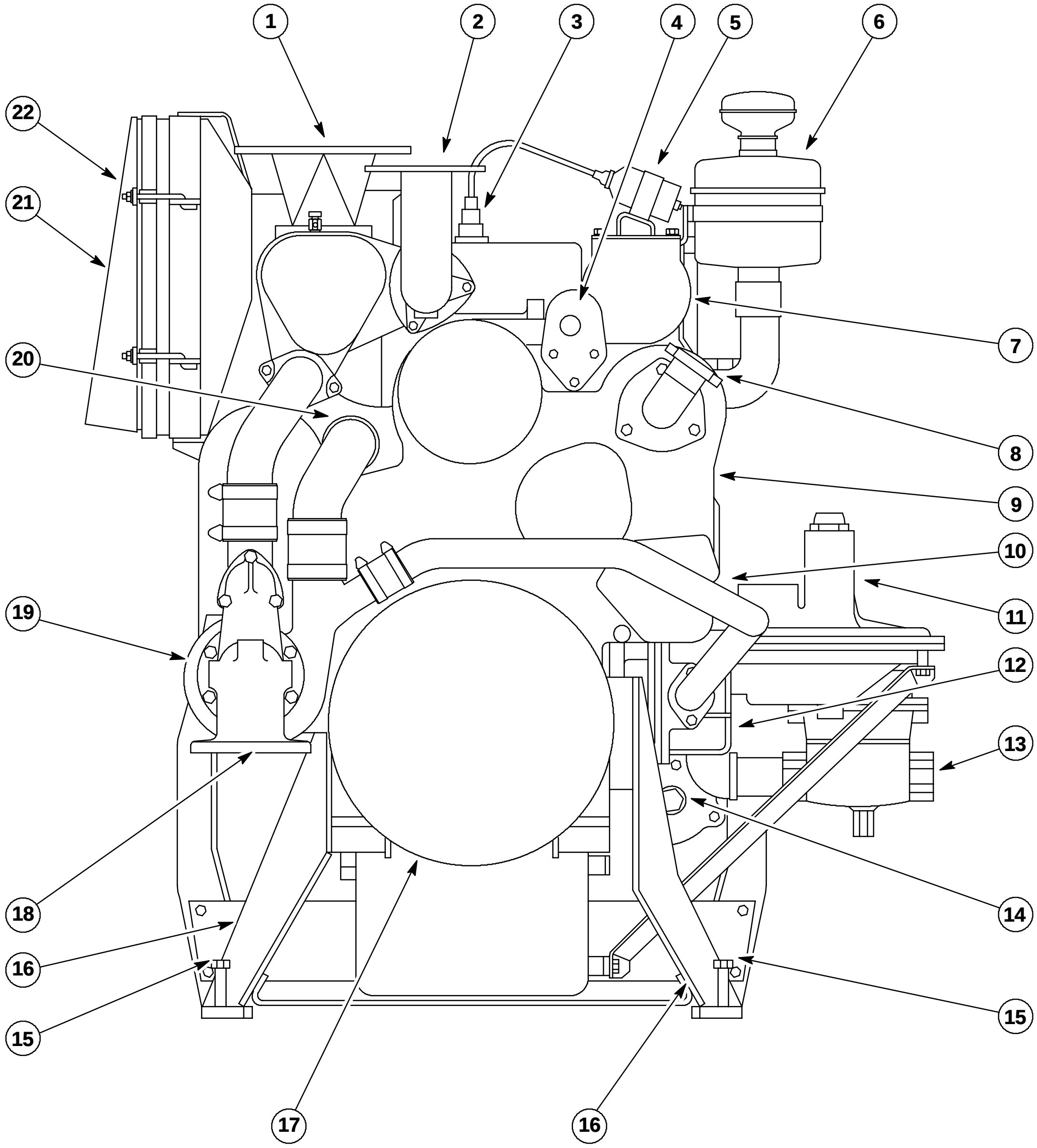
Figure 1.15-10. Right Side View – F18GLD, Deltec Carburetor And High Temperature Application



1. Exhaust Outlet
2. Heat Shield
3. Wastegate
4. Exhaust Manifold
5. Jacket Water Thermostat Housing
6. Thermostat Housing Air Bleed
7. Jacket Water Outlet
8. Breather Regulator
9. Jacket Water Pump
10. Jacket Water Inlet
11. Vibration Damper
12. Gear Housing
13. Engine Support
14. Jack Screw
15. Auxiliary Water Pump
16. Auxiliary Water Inlet
17. Auxiliary Water Piping
18. Water Header
19. Dip Stick
20. Breather Oil Separator
21. Oil Drain
22. Starter Location
23 Flywheel And Housing
24. Air Duct
25. Fuel Inlet
26. Intercooler
27. Carburetor
28. Ignition Coils

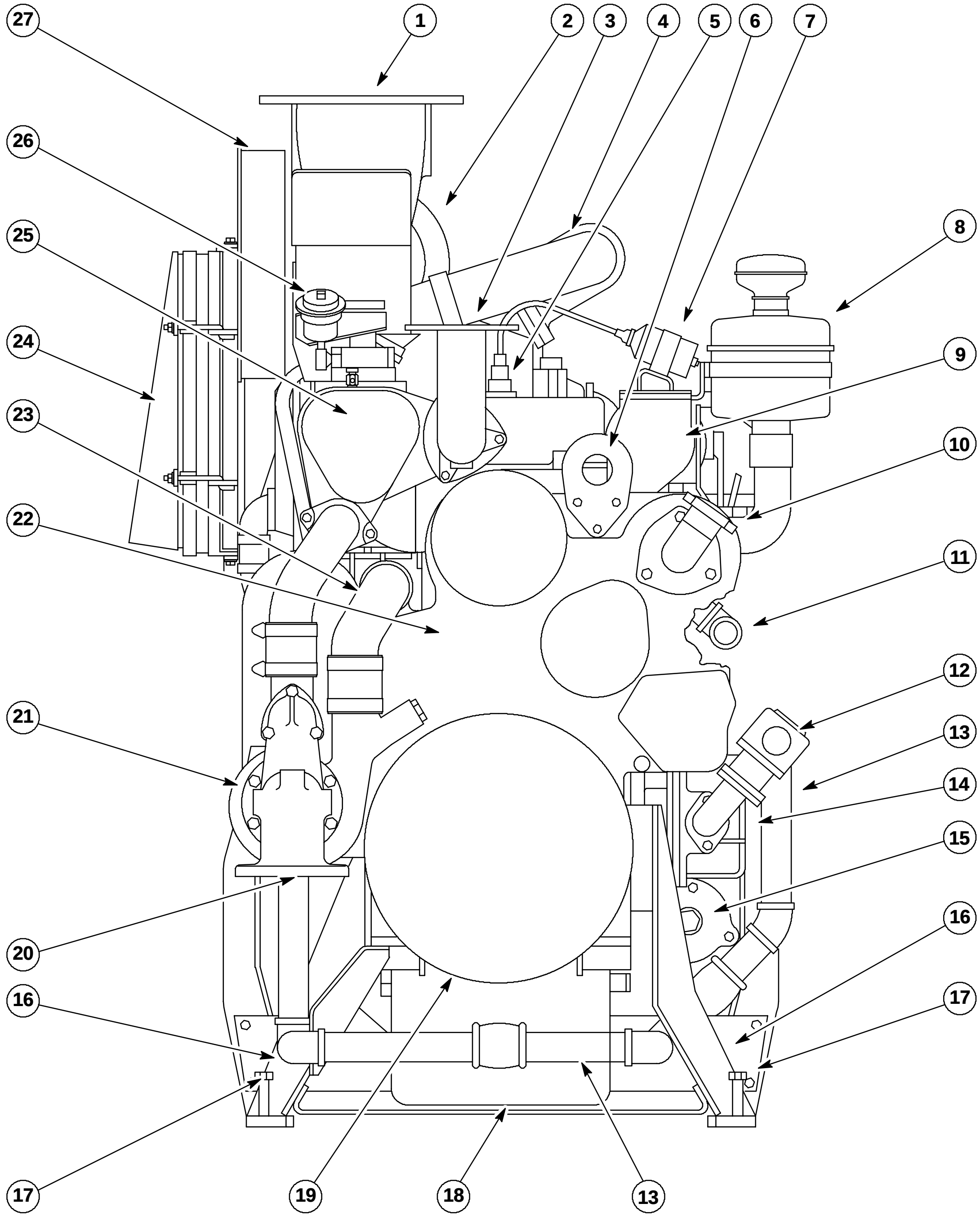
Figure 1.15-11. Right Side View – F18GSID

FRONT VIEW



1. Exhaust Outlet
2. Jacket Water Outlet
3. Spark Plug Location
4. Lifting Eye
5. Ignition Coils
6. Breather Oil Separator
7. Intake Manifold
8. Oil Fill
9. Gear Housing
10. Auxiliary Water Piping
11. Fuel Pressure Regulator
12. Oil Cooler
13. Fuel Shutoff Valve
14. Barring Device
15. Jack Screw
16. Engine Support
17. Vibration Damper
18. Jacket Water Inlet
19. Jacket Water Pump
20. Water Header
21. Jacket Water Thermostat Housing
22. Air Cleaner

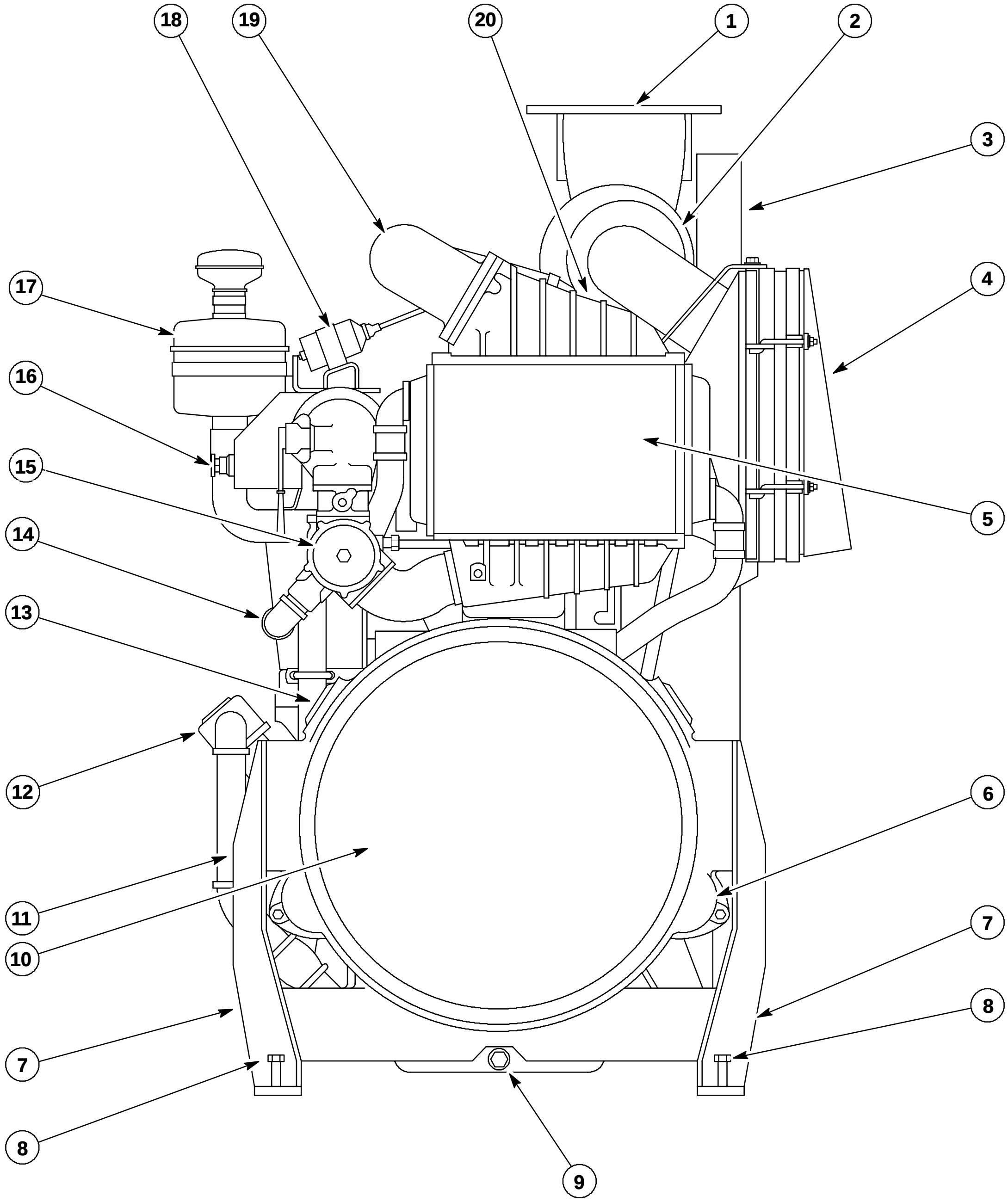
Figure 1.15-12. Front View – F18G/H24G



1. Exhaust Outlet
2. Turbocharger
3. Jacket Water Outlet
4. Turbocharger To Intercooler Air Connection
5. Spark Plug Location
6. Lifting Eye
7. Ignition Coils
8. Breather Oil Separator
9. Intake Manifold
10. Oil Fill
11. Fuel Inlet
12. Auxiliary Water Thermostat
13. Auxiliary Water Piping
14. Oil Cooler
15. Barring Device
16. Engine Support
17. Jack Screw
18. Oil Pan
19. Vibration Damper
20. Jacket Water Inlet
21. Jacket Water Pump
22. Gear Housing
23. Water Header
24. Air Cleaner
25. Jacket Water Thermostat Housing
26. Wastegate
27. Heat Shield

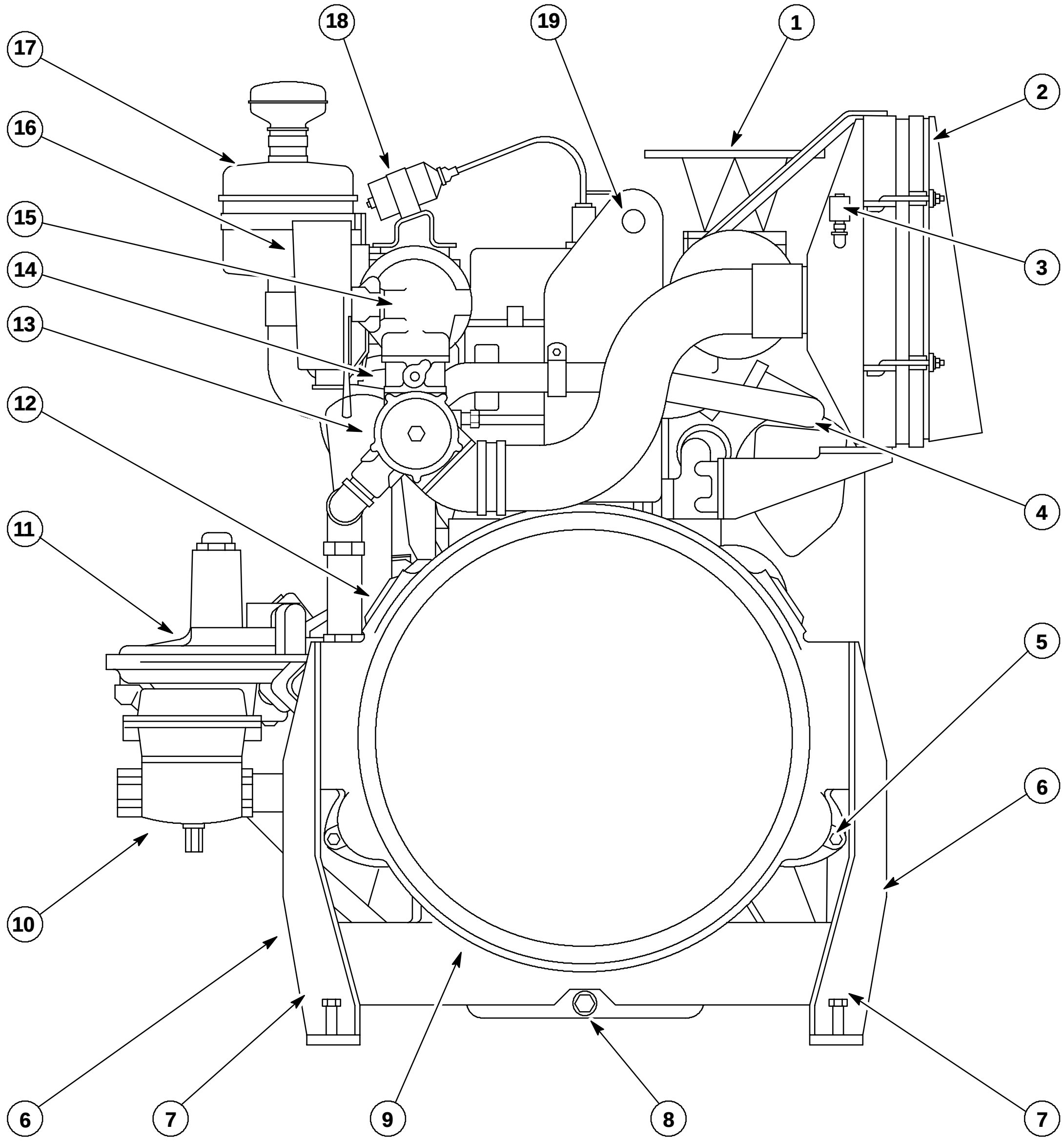
Figure 1.15-13. Front View – F18GL/H24GL

REAR VIEW



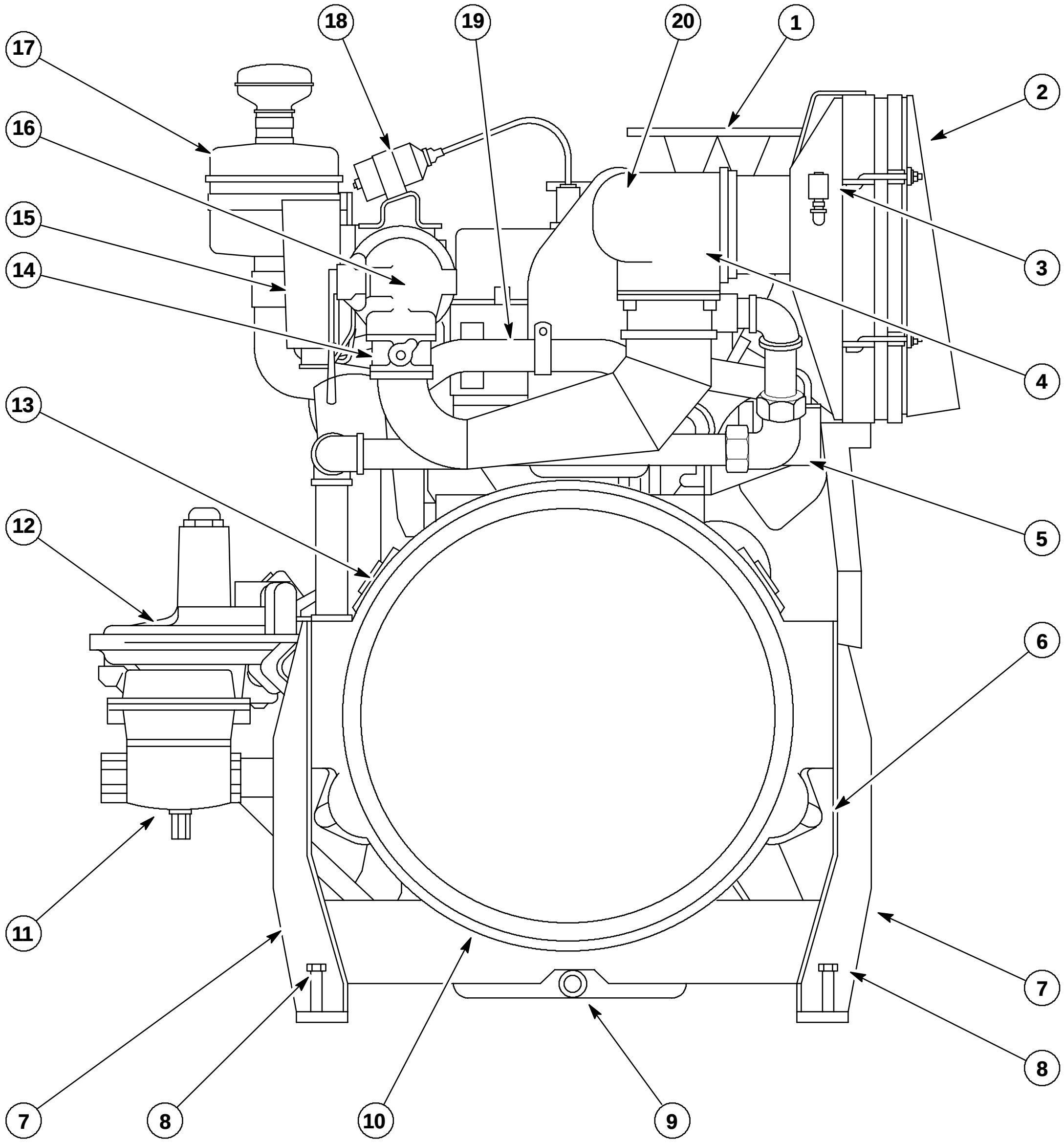
1. Exhaust Outlet
2. Turbocharger
3. Heat Shield
4. Air Cleaner
5. Intercooler
6. Starter Motor Location
7. Engine Support
8. Jack Screw
9. Oil Drain
10. Flywheel And Housing
11. Auxiliary Water Piping
12. Auxiliary Water Thermostat
13. Timing Window
14. Fuel Inlet
15. Carburetor
16. Instrument Panel
17. Breather Oil Separator
18. Ignition Coils
19. Intercooler Air Inlet
20. Lifting Eye

Figure 1.15-14. Rear View – F18GL/H24GL



1. Exhaust Outlet
2. Air Cleaner
3. Air Filter Restriction Indicator
4. Auxiliary Water Piping
5. Starter Motor Location
6. Engine Support
7. Jack Screw
8. Oil Drain
9. Flywheel And Housing
10. Fuel Shutoff Valve
11. Fuel Pressure Regulator
12. Timing Window
13. Carburetor
14. Butterfly Valve
15. Intake Manifold
16. Instrument Panel
17. Breather Oil Separator
18. Ignition Coils
19. Lifting Eye

Figure 1.15-15. Rear View – F18G



1. Exhaust Outlet
2. Air Cleaner Assembly
3. Air Filter Restriction Indicator
4. Carburetor
5. Fuel Piping
6. Starter Motor Location
7. Engine Support
8. Jack Screw
9. Oil Drain
10. Flywheel And Housing
11. Fuel Shutoff Valve
12. Fuel Pressure Regulator
13. Timing Window
14. Butterfly Valve
15. Instrument Panel
16. Intake Manifold
17. Breather Oil Separator
18. Ignition Coils
19. Auxiliary Water Piping
20. Lifting Eye

Figure 1.15-16. Rear View – F18G/H24G, Dual Fuel

INSTRUMENT PANEL GAUGES

Oil Pressure Switchgage: Monitors engine oil pressure at the main oil gallery (see Figure 1.15-17). This switchgage should be adjusted so that the switchgage contacts close when the engine oil pressure falls below a setpoint as specified in Section 6.05 *Engine Protection Systems,* Table 6.05–1.

Jacket Water Temperature Switchgage: Monitors engine jacket water temperature at the water outlet header (see Figure 1.15-17). This switchgage should be adjusted so that the switchgage contacts close when the engine jacket water temperature exceeds a setpoint as specified in Section 6.05 *Engine Protection Systems,* Table 6.05–1.

Intake Manifold Temperature Gauge: Monitors intake manifold charge temperature downstream of the intercooler (see Figure 1.15-17). Setpoint depends on application.

Electronic Tachometer: Displays engine crankshaft revolutions per minute (rpm) with a digital readout (see Figure 1.15-17).

Intake Manifold Vacuum/Pressure Gauge: Displays the approximate intake manifold pressure or intake manifold vacuum downstream of the throttle plate (see Figure 1.15-17.)

Lube Oil Temperature Switchgage: Monitors engine oil temperature at the oil filter housing (see Figure 1.15-17). This switchgage should be adjusted so that the switchgage contacts close when the engine oil temperature exceeds a setpoint as specified in Section 6.05 *Engine Protection Systems,* Table 6.05–15 .

NOTE: *Switchgages are not approved for, or supplied with, hazardous location (CSA approved) ignition equipped engines.*

Ammeter: Monitors current output of the belt driven alternator option (see Figure 1.15-17).

Magneto On/Off Switch: Is used as a normal or emergency shutdown switch. This switch will open the magneto ignition circuit (to ground) in the "OFF" position which blocks the current flow path; and closes the magneto ignition circuit to allow current flow from the magneto to the transformer coils in the "ON" position (see Figure 1.15-17).

Pushbutton Start Switch: Is used to complete the cranking circuit to the starter solenoid (electric starters) or to engage the starter valve (air/gas starters). See Figure 1.15-17.

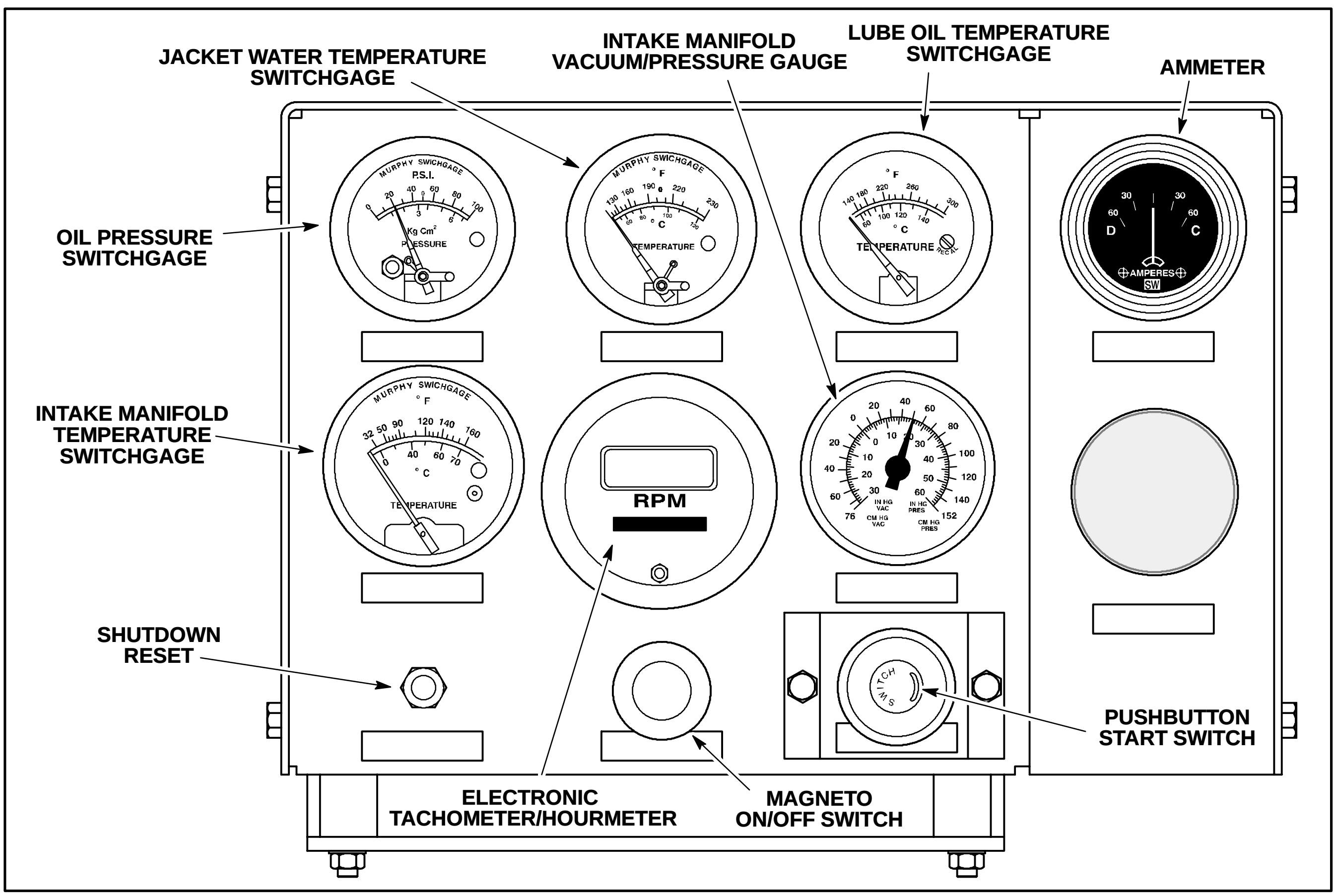


Figure 1.15-17. Instrument Panel

VGF F18/H24 SERVICE TOOLS LIST

You will need the following tools to perform the tasks indicated on the VGF F18 or H24 engines (see Table 1.15-1). In some instances, substitute items may be used, but only if specifically approved by Waukesha. To order these service tools, contact your local Waukesha Engine Distributor.

Table 1.15-1. Special Tools

TOOL P/N	TOOL DESCRIPTION
Group One	
472068	Spark Plug Tube Socket
472065	Spark Plug Tube Retaining Tool
475075	Spark Plug Extension Puller (CSA Ignition)
494421	Spark Plug Gapping Tool
475006	Spark Plug Gapping Tool (Use with P/N 494421)
475007	Oxygen Analyzer
494215	Compression Gauge
494217	Compression Tester Adapter
494258	Slack Tube Manometer
475072	Digital Manometer
494273	Torque Wrench (40 to 250 ft-lb)
494288	Dial Indicator Kit
494338	Induction Timing Light
494360	Emissions Accessory Kit
494227	Explosion Proof Timing Light (for CSA Ignition Systems)
474028	Spanner Set For GLD Main Adjusting Screw
472065	Spark Plug Tube Holding Tool
472074	Rocker Arm Cover Removal Tool (For Use With Flange Mounted CSA Ignition Coils)
Group Two	
472005	Valve Stem Seal Installer
472077	Valve Stem Seal Installer – used for P/N 304015C Blue Intake Seal and P/N 304015B Black Exhaust Seal
472008	Valve Guide Extractor
472009	Valve Guide Driver
472010	Valve Seat Extractor
472015	Rocker Arm Support/Manifold Wrench
472035	Valve Guide Pilot
472044	Valve Seat Grinding Wheel
494277	Valve Seat Grinder
472047	Valve Spring Compressor
475019	Torque Wrench (200 to 900 ft-lb)
494278	Dial Indicator
Group Three	
472002	Crankcase Spreader Tool
472007	Piston Removal Tool
472075	Piston Ring Expander
472076	Piston Ring Compressor
472012	Connecting Rod Bushing Press
472013	Cylinder Sleeve Removal Tool
472048	Front And Rear Crankshaft Seal Driver
472031	Water Pump Impeller Puller
472055	Camshaft Pilot Tool
472056	Camshaft Bushing Press
472057	Bearing Rollout Tool
472058	Guide Pin Kit
494245	Flexible Cylinder Hone
494262	Depth Gauge
494360	Emissions Accessory Kit

VGF Engine “G” Lead Test Pigtail Adapters

The early VGF series of engines did not include the “G” lead in the CEC ignition system. Special pigtail test adapters are available from Waukesha for use with oscilloscope testing. The pigtail adapter is installed between the wiring harness and the CEC Ignition Module. The wire that hangs out is the “G” lead and can be connected to the oscilloscope.

Table 1.15-2. Test Pigtail Adapters

TEST PIGTAIL – P/N	ENGINE MODEL
472059	F18 – 6 Cylinder
472060	H24 – 8 Cylinder

Model F18 And H24 Specifications

Table 1.15-3. Model F18 And H24G/GSID/GL/GLD Specifications

GENERAL SPECIFICATIONS		
Engine Model	**F18**	**H24**
Type	4-cycle overhead valve	4-cycle overhead valve
Aspiration, G	Naturally aspirated	Naturally aspirated
Aspiration, GL, GLD, GSID	Turbocharged, intercooled	Turbocharged, intercooled
Number of cylinders	Inline-6, 4-valves per cylinder	Inline-8, 4-valves per cylinder
Bore x stroke	5.98 x 6.5 in. (152 x 165 mm)	5.98 x 6.5 in. (152 x 165 mm)
Displacement	1096 cu. in. (18 litres)	1462 cu. in. (24 litres)
G, GL, GLD Compression ratio:	11:1	11:1
GL Low Compression ratio (LCR):	8.7:1	8.7:1
GSID Compression ratio:	8.6:1	8.6:1
Speed range, continuous and intermittent duty	1000 - 1800 rpm	1000 - 1800 rpm
Piston speed	32.5 ft/sec (9.91 m/sec) @ 1800 rpm	32.5 ft/sec (9.91 m/sec) @ 1800 rpm
Low idle	650 - 750 rpm	650 - 750 rpm
Bearings - Main		
Number	7	9
Diameter x width - in.	5.32 x 1.81 in. (135 x 46 mm)	5.32 x 1.81 in. (135 x 46 mm)
Total projected area/bearing	67.4 sq. in. (434.9 sq. cm)	86.7 sq. in. (559.1 sq. cm)
Bearings - Crankpin		
Diameter x width	4.53 x 1.81 in. (115 x 46.0 mm)	4.53 x 1.81 in. (115 x 46.0 mm)
Total projected area/bearing	49.2 sq. in. (317.4 sq. cm)	65.6 sq. in. (423.2 sq. cm)
Lubrication System		
Sump capacity, including filter and cooler	22 gallons (83.3 litres)	28 gallons (106 litres)
Main filter	15 micron at @ 90% efficiency	15 micron at @ 90% efficiency
Normal lube oil pressure: F18/H24G	70 ±6 psi (483 ±41 kPa)	70 ±6 psi (483 ±41 kPa)
Normal lube oil pressure: F18/H24GSID/GL/GLD at 185° F (85° C)	75 ±6 psi (517 ±41 kPa)	75 ±6 psi (517 ±41 kPa)
Normal lube oil pressure: F18/H24GSID/GL/GLD at 265° F (129° C)	70 ±6 psi (483 ±41 kPa)	70 ±6 psi (483 ±41 kPa)
Low oil pressure alarm	35 psi (241 kPa)	35 psi (241 kPa)
Low oil pressure shutdown setpoint	25 psi (173 kPa)	25 psi (173 kPa)
Prelube duration	30 seconds every 30 minutes	30 seconds every 30 minutes
Prelube pressure	5 psi (34.5 kPa)	5 psi (34.5 kPa)
Prelube flow	1.75 - 3.5 gpm (l/minute)	1.75 - 3.5 gpm (l/minute)
Postlube (after hot shutdown)	5 minutes	5 minutes
Normal oil header temperature	185° F (85° C)	185° F (85° C)
Crankcase Breather System		
Crankcase pressure - open system	zero to +3 in. (76 mm) H_2O	
Crankcase pressure - closed system	-3 in. (76 mm) to zero H_2O	
Air Induction System		
Maximum permissible restriction	15 in. (381mm) H_2O	15 in. (381mm) H_2O
Starting System		
Electric starting	24 volts DC	24 volts DC
Air pressure starting	150 psi (1034 kPa)	150 psi (1034 kPa)

(Continued)

GENERAL SPECIFICATIONS		
Engine Model	**F18**	**H24**
Cooling System		
Jacket water capacity, engine only	16 gallons (60 litres)	20 gallons (75 litres)
Auxiliary water capacity, engine only	6 gallons (23 litres)	6 gallons (23 litres)
Maximum inlet head, water pump	28 ft. (8.5 m)	28 ft. (8.5 m)
Minimum inlet head, water pump	See Engineering Standard Sheet S7424-1	See Engineering Standard Sheet S7424-1
Normal jacket water temperature range	174 – 195° F (79 – 97° C)	174 – 195° F (79 – 97° C)
Jacket water inlet flange, ANSI 125 lb.	3 in. (76.2 mm)	3 in. (76.2 mm)
Jacket water outlet flange, ANSI 125 lb. (size 80 per DIN 2576 mm)	3 in. (76.2 mm)	3 in. (76.2 mm)
Fuel System		
G – Natural gas pressure at regulator	5 – 10 psig (34 – 69 kPa)	5 – 10 psig (34 – 69 kPa)
GSID – Natural gas pressure at regulator	8 in. (203 mm) H_2O minimum	8 in. (203 mm) H_2O minimum
GL – Natural gas pressure at regulator	25 – 40 psig (172 – 276 kPa)	25 – 40 psig (172 – 276 kPa)
GLD – Natural gas pressure at regulator	20 in. (508 mm) H_2O minimum	20 in. (508 mm) H_2O minimum
G – Natural gas inlet pipe size	1.5 in. NPT (38.1 mm)	1.5.0 in. NPT (38.1 mm)
GSID – Natural gas inlet pipe size	1.5 in. NPT (38.1 mm)	1.5 in. NPT (38.1 mm)
GL – Natural gas inlet pipe size	1.25 in. NPT (31.8 mm)	1.25 in. NPT (31.8 mm)
GLD – Natural gas inlet pipe size	2.0 in. NPT (50.8 mm)	2.0 in. NPT (50.8 mm)
Exhaust System		
Maximum permissible back pressure	15 in. (381mm) H_2O	15 in. (381mm) H_2O
Exhaust outlet, pipe flange, ANSI 125 lb., G	6 in. (152.4 mm)	6 in. (152.4 mm)
Exhaust outlet, pipe flange, ANSI 125 lb., GSID, GL, GLD	8 in. (203 mm)	8 in. (203 mm)
Miscellaneous		
Heaviest engine part, cylinder block assembly	1150 lb. (522 kg)	1530 lb. (694 kg)
Heaviest engine part, top overhaul, cylinder head assembly	80 lb. (36 kg)	80 lb. (36 kg)
Recommended minimum spacing between engines	36 in. (914 mm)	36 in. (914 mm)
Recommended minimum overhead clearance	6 ft. (2 m)	6 ft. (2 m)
Weight, dry, approximate, G	5300 lb. (2400 kg)	7000 lb. (3180 kg)
Weight, dry, approximate, GL, GLD, GSID	5500 lb. (2500 kg)	7200 lb. (3270 kg)
Flywheel housing	SAE No. 0 (Same as SAE No. 0 except metric taps)	SAE No. 0 (Same as SAE No. 0 except metric taps)
Number of teeth on ring gear	150	150
Firing Order	1, 5, 3, 6, 2, 4	1, 4, 2, 6, 8, 5, 7, 3

TEMPERATURE AND PRESSURE TEST POINTS

Refer to Figure 1.15-18, Figure 1.15-19 and Figure 1.15-20 for location of temperature and pressure test points on all VGF engines.

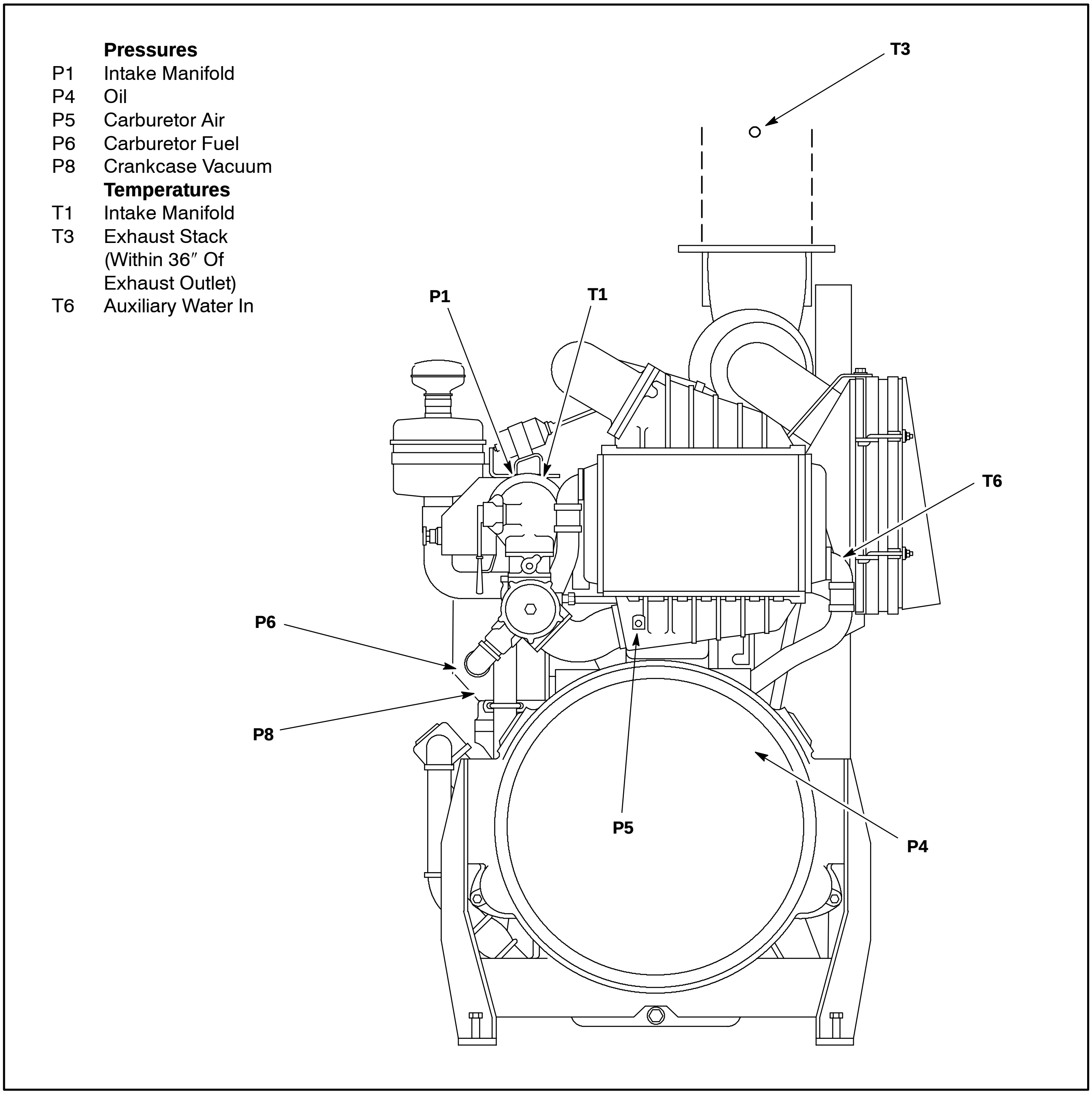
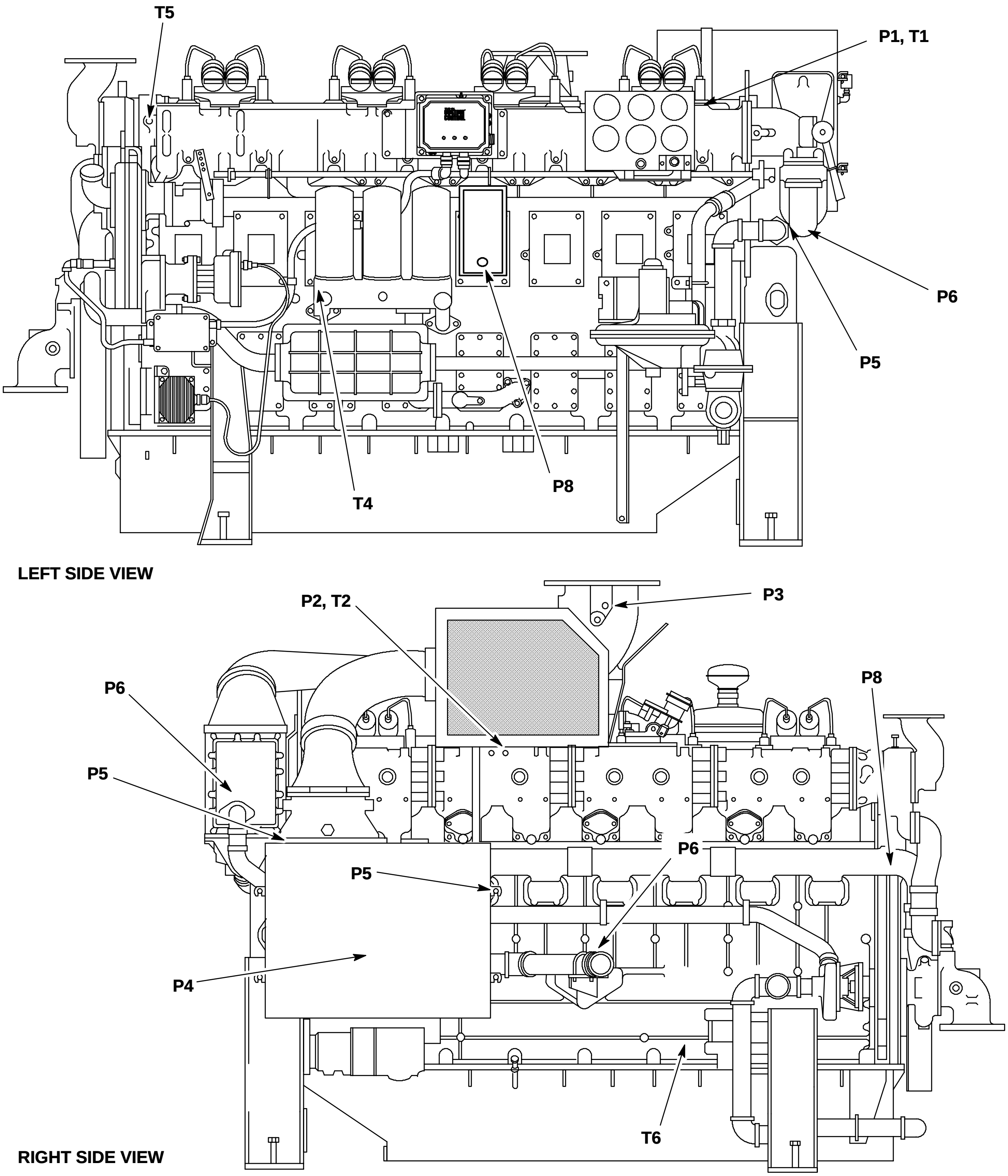


Figure 1.15-18. Rear View F18GL/H24GL, Impco



	Pressures		Temperatures
P1	Intake Manifold	T1	Intake Manifold
P2	Exhaust Manifold	T2	Exhaust Manifold
P3	Exhaust Back Pressure	T4	Oil
P4	Oil	T5	Jacket Water Outlet
P5	Carburetor Air	T6	Auxiliary Water Inlet
P6	Carburetor Fuel		
P8	Crankcase Vacuum		

Figure 1.15-19. Right And Left Side Views – F18GLD/H24GLD

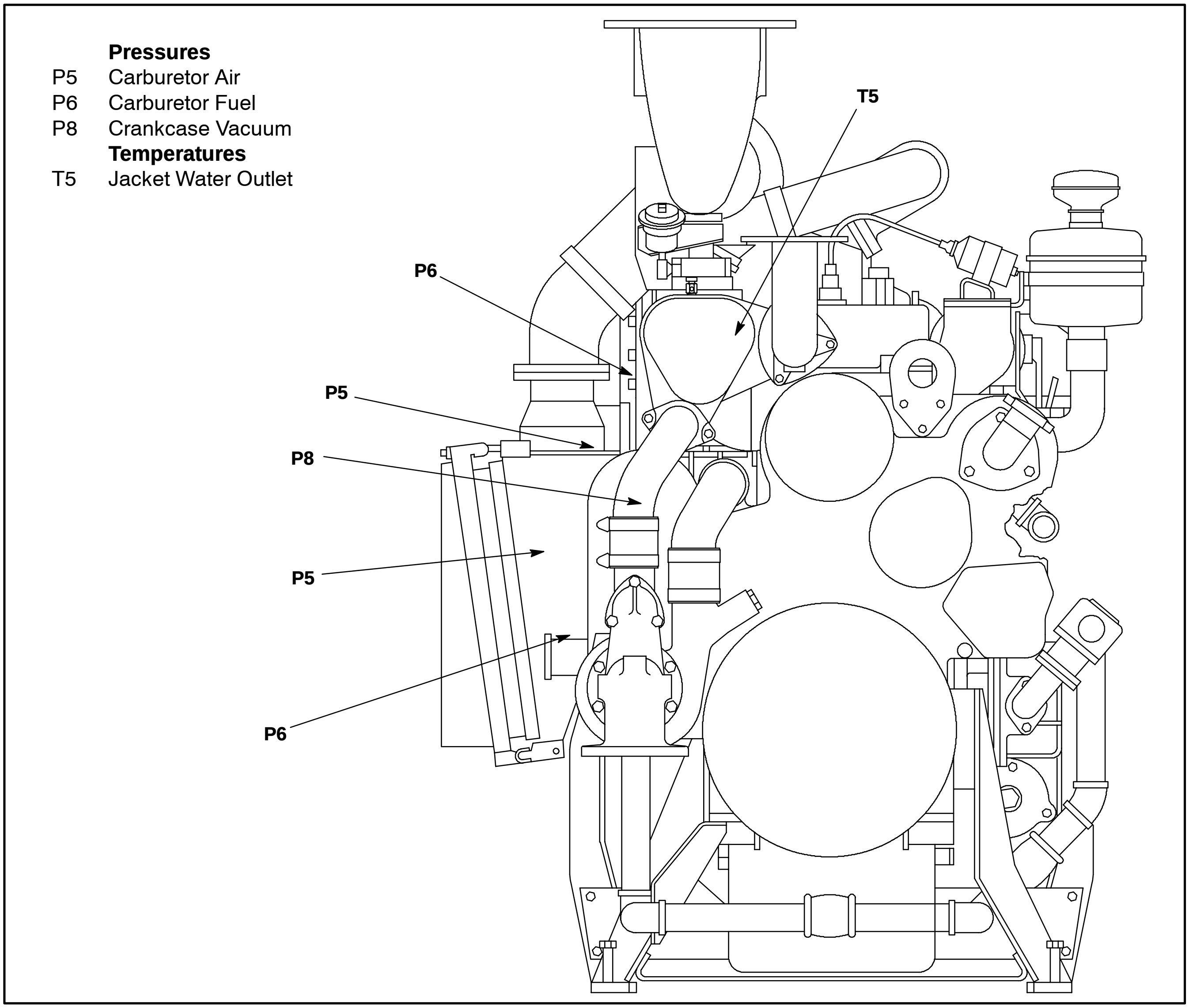


Figure 1.15-20. Front View F18GL/H24GL, Impco

TORQUE VALUES

Table 1.15-4 lists common hex head screw torque specifications for the F18/H24 engine. Additional torque values are listed in Table 1.15-5 through Table 1.15-7. All torque values assume dry hex head screws, unless other wise noted (*oil lubricated).

Table 1.15-4. F18/H24 Specific Engine Torques

ITEM	FOOT-LBS (ft-lb)	NEWTON-METERS (N·m)	APPLICATION INSTRUCTIONS
Auxiliary water pump adapter	19	26	Apply Loctite® 242, M10
Breather ejector exhaust inlet flange	32	43	Apply Anti-seize 3/8″ Hex Head Screw
Breather ejector pipe adapter flange screws	19	26	M10 x 40 mm
Butterfly valve housing to intake manifold	34	46	-
Camshaft thrust flange capscrews	37	50	Apply Loctite® 242, M10 x 30 mm
Camshaft driven gear capscrews	53	72	Apply Loctite® 242 (2 screws only- others are dry) M10 x 45 mm

(Continued)

ITEM	FOOT-LBS (ft-lb)	NEWTON-METERS (N·m)	APPLICATION INSTRUCTIONS
Cam door (rear)	37	50	Apply Loctite® 242 M10 x 25 mm
Carburetor to throttle body	15	20	Apply Anti-seize 5/16" Ferryhead Hex head screw
Gear Housing (inner hex head screws)	37	50	Apply Loctite® 242, M10 x 30 mm
Coil screws (CSA shielded ignition)	16 - 17	21.6 - 23.0	P/N 291102
Connecting rod capscrews	*310 ± 15	*420 ± 20	-
Connecting rod doors	37	50	Apply Loctite® 242, M10 x 20 mm
Cover plate P/N 305943 to gear cover	37	50	M10 x 35 mm
Cover plate P/N 304798B or 304798J to gear cover (ignition)	19	26	M8 x 20 mm
Cover plates to gear cover/housing	37	50	M10 x 30 mm M10 x 35 mm
Cylinder head nut	*116 *347	*157 *470	P/N 304020
Crankshaft counterweight bolts	205 - 215	278 - 292	P/N 304051
Damper driving flange	101	137	P/N 304888, M12 x 100, Grade 12.9
Exhaust manifold to cylinder head	53	72	M10 x 50 mm M10 x 150 mm
Exhaust bypass tube to wastegate flange	32	43	Apply Anti-seize, M10 x 30 mm
Exhaust bypass tube to exhaust outlet flange	27	36	Apply Anti-seize 3/8″ Hex Head Screw
Flywheel capscrews	*220 ± 5	*298 ± 7	P/N 304056B, M16 x 1.5", Grade 10.9
Flywheel housing to crankcase	158	214	P/N 290804, M16 x 55 mm Apply Loctite® 242
Front lifting eye	103	140	M14, Grade 10.9
Front mounting supports	158	214	M16 Hex Head Screw
Governor drive to gear cover	37	50	M10 x 35 mm
Head studs to crankcase	*72	*98	P/N 304000C P/N 304000F
Intermediate gear to hub	20	27	Apply Loctite® 242 P/N 291102, M8 x 20 mm
Intermediate gear hub to case	37	50	Apply Loctite® 242, M10 x 25 mm
Intake manifold hex head screws	37 65	50 88	Apply Loctite® 242 M10 x 40 mm M12 x 140 mm
Intake manifold cover plates	37	50	M10 x 30 mm
Intake elbow assembly to intake manifold	19	26	M8 x 25 mm
Jacket water pump	37	50	M10 Hex Nut, M10 Grade 10
Jacket water pump front impeller nut	109	148	P/N 304303B, Apply Loctite® 242
Jacket water pump drive gear (center) nut	144	196	P/N 305751
Jacket water pump rear nut	72	98	P/N 304437, Apply Loctite® 242
Knock sensor	35 - 40	47 - 54	-
Magneto drive to gear cover	37	50	M10 x 35 mm M10 x 85 mm
Magneto drive nut	75	100	P/N 293315, M20, Grade 8, Apply Loctite® 242
Magneto drive nut	75	100	P/N WS805066, M16, thin nut, Apply Loctite® 242
Main bearing cap bolt	*325 ± 15 *590 ± 15	*440 ± 20 *800 ± 20	P/N 304026

(Continued)

ITEM	FOOT-LBS (ft-lb)	NEWTON-METERS (N·m)	APPLICATION INSTRUCTIONS
Main bearing cap crossbolt	*37 ± 7 *92 ± 7	*50 ± 10 *125 ± 10	P/N 304818
Oil cooler/filter housing to crankcase	37	50	M10
Oil cooler/thermostatic valve flange connections	37	50	M10
Oil filler assembly to gear cover	19	26	M8 x 22 mm
Oil pump cover capscrews	35	46	P/N 290393, M10 x 25 mm
Oil pump to crankcase capscrews	65	88	Apply Loctite® 242 P/N 290724 M12 x 45 mm
Oil pan	37	50	Apply Loctite® 242 P/N 290679 M10 x 30 mm
Oil pump idler gear (to front main)	100	136	Apply Loctite® 242 P/N 350486 M14 x 90, Grade 10.9
Oil outlet tube P/N 305612B	37	50	M10
Outer gear cover capscrews	37	50	Apply Loctite® 242 P/N 350486, M14 x 90, Grade 10.9
Piston cooling jets	30	41	M14 Hollow Screw
Rear mounting supports	158	214	M16 Hex Head Screw
Rear oil seal	37	50	-
Rear lifting eye	64	87	M12 x 35 mm Grade 10.9
Rocker arm adjustment nuts	55	74	P/N 304045
Rocker arm support hex head screws	28	38	M10 x 35 mm M10 x 110 mm
Rocker cover nuts	29	39	P/N 290039, M10
Rocker arm doors	37	50	P/N 290039, M10
Spark plug P/N 60999Z	32 - 38	43 - 52	-
Spark plugs P/N 699919	29 - 39	39 - 49	-
Spark plugs (all others not specified)	40 - 45	54 - 61	-
Spark plug tube to cylinder head	150 - 160	203 - 216	Loctite® RC™ 620, Fel-Pro® ProLock
Thermostat housing to exhaust manifold	19	26	M10 x 30 mm M10 x 120 mm
Thermostat outlet connection (P/N 304870C) to thermostat	37	50	M10 x 35 mm M10 x 55 mm
Turbocharger adapter to exhaust manifold	46	62	Apply Anti-seize, M10 x 25 mm
Turbocharger V-band clamps (coupling)	9 - 11	12 - 15	-
Turbocharger to turbocharger adapter	46	62	Apply Anti-seize M10 x 40 mm Stainless Steel Grade 10.9
Turbocharger oil supply and drain flange screws	32	43	Apply Anti-seize, M10 x 25 mm
Vibration dampener and hub hex head screws	101	137	Apply Loctite® 271 M12 x 100 mm Grade 12.9
Wastegate mounting plate to exhaust manifold	46	62	Apply Anti-seize, M10
Wastegate to mounting plate	32	43	Apply Anti-seize, M10 x 30 mm
Water elbow	37	50	M10 x 35 mm
Water header hex head screws	19	26	M8
Water outlet flange P/N 304342C	37	50	M10
Water pump elbow P/N 304329A to jacket water pump	19	26	M8 x 22 mm
Water pump inlet connector P/N 304339	19	26	M8 x 65 mm
Water pump idler gear capscrews	53	72	Apply Loctite® 242

(Continued)

ITEM	FOOT-LBS (ft-lb)	NEWTON-METERS (N·m)	APPLICATION INSTRUCTIONS
Water pump cover screws 300061	19	26	Apply Loctite® 242
Water pump idler assembly to gear cover	37	50	Apply Loctite® 242

TORQUE VALUES

Table 1.15-5. Metric Standard Capscrew Torque Values (Untreated Black Finish)

COARSE THREAD CAPSCREWS (UNTREATED BLACK FINISH)								
ISO PROPERTY CLASS	5.6		8.8		10.9		12.9	
SIZE	TORQUE		TORQUE		TORQUE		TORQUE	
	N·m	in-lb	N·m	in-lb	N·m	in-lb	N·m	in-lb
M3	0.6	5	1.37	12	1.92	17	2.3	20
M4	1.37	12	3.1	27	4.4	39	10.4	92
M5	2.7	24	10.5	93	15	133	18	159
M6	4.6	41	10.5	93	15	133	10.4	92
M7	7.6	67	17.5	155	25	221	29	257
M8	11	97	26	230	36	319	43	380
M10	22	195	51	451	72	637	87	770
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
M12	39	28	89	65	125	92	150	110
M14	62	45	141	103	198	146	240	177
M16	95	70	215	158	305	224	365	269
M18	130	95	295	217	420	309	500	368
M20	184	135	420	309	590	435	710	523
M22	250	184	570	420	800	590	960	708
M24	315	232	725	534	1020	752	1220	899
M27	470	346	1070	789	1519	1113	1810	1334
M30	635	468	1450	1069	2050	1511	2450	1806
M33	865	637	1970	1452	2770	2042	3330	2455
M36	1111	819	2530	1865	3560	2625	4280	3156
M39	1440	1062	3290	2426	4620	3407	5550	4093

FINE THREAD CAPSCREWS (UNTREATED BLACK FINISH)						
ISO PROPERTY CLASS	8.8		10.9		12.9	
SIZE	TORQUE		TORQUE		TORQUE	
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
M8 x 1	27	19	38	28	45	33
M10 x 1.25	52	38	73	53	88	64
M12 x 1.25	95	70	135	99	160	118
M14 x 1.5	150	110	210	154	250	184
M16 x 1.5	225	165	315	232	380	280
M18 x 1.5	325	239	460	339	550	405
M20 x 1.5	460	339	640	472	770	567
M22 x 1.5	610	449	860	634	1050	774
M24 x 2	780	575	1100	811	1300	958

NOTE: *The conversion factors used in these tables are as follows: One N·m equals 0.7375 ft-lb and one ft-lb equals 1.355818 N·m.*

Table 1.15-6. Metric Standard Capscrew Torque Values (Electrically Zinc Plated)

COARSE THREAD CAPSCREWS (ELECTRICALLY ZINC PLATED)								
ISO PROPERTY CLASS	5.6		8.8		10.9		12.9	
SIZE	TORQUE		TORQUE		TORQUE		TORQUE	
	N·m	in-lb	N·m	in-lb	N·m	in-lb	N·m	in-lb
M3	0.56	5	1.28	11	1.8	16	2.15	19
M4	1.28	11	2.9	26	4.1	36	4.95	44
M5	2.5	22	5.75	51	8.1	72	9.7	86
M6	4.3	38	9.9	88	14	124	16.5	146
M7	7.1	63	16.5	146	23	203	27	239
M8	10.5	93	24	212	34	301	40	354
M10	21	186	48	425	67	593	81	717
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
M12	36	26	83	61	117	86	140	103
M14	58	42	132	97	185	136	220	162
M16	88	64	200	147	285	210	340	250
M18	121	89	275	202	390	287	470	346
M20	171	126	390	287	550	405	660	486
M22	230	169	530	390	745	549	890	656
M24	295	217	675	497	960	708	1140	840
M27	435	320	995	733	1400	1032	1680	1239
M30	590	435	1350	995	1900	1401	2280	1681
M33	800	590	1830	1349	2580	1902	3090	2278
M36	1030	759	2360	1740	3310	2441	3980	2935
M39	1340	988	3050	2249	4290	3163	5150	3798

FINE THREAD CAPSCREWS (ELECTRICALLY ZINC PLATED)						
ISO PROPERTY CLASS	8.8		10.9		12.9	
SIZE	TORQUE		TORQUE		TORQUE	
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
M8 x 1	25	18	35	25	42	30
M10 x 1.25	49	36	68	50	82	60
M12 x 1.25	88	64	125	92	150	110
M14 x 1.5	140	103	195	143	235	173
M16 x 1.5	210	154	295	217	350	258
M18 x 1.5	305	224	425	313	510	376
M20 x 1.5	425	313	600	442	720	531
M22 x 1.5	570	420	800	590	960	708
M24 x 2	720	531	1000	737	1200	885

Table 1.15-7. U.S. Standard Capscrew Torque Values

SAE GRADE NUMBER	Grade 1 or 2			Grade 5			Grade 8		
SIZE/ THREADS PER INCH	TORQUE in-lb (N·m)			TORQUE in-lb (N·m)			TORQUE in-lb (N·m)		
THREADS	DRY	OILED	PLATED	DRY	OILED	PLATED	DRY	OILED	PLATED
1/4 – 20	62 (7)	53 (6)	44 (5)	97 (11)	80 (9)	159 (18)	142 (16)	133 (15)	124 (14)
1/4 – 28	71 (8)	62 (7)	53 (6)	124 (14)	106 (12)	97 (11)	168 (19)	159 (18)	133 (15)
5/16 – 18	133 (15)	124 (14)	106 (12)	203 (23)	177 (20)	168 (19)	292 (33)	265 (30)	230 (26)
5/16 – 24	159 (18)	142 (16)	124 (14)	230 (26)	203 (23)	177 (20)	327 (37)	292 (33)	265 (30)
3/8 – 16	212 (24)	195 (22)	168 (19)	372 (42)	336 (38)	301 (34)	531 (60)	478 (54)	416 (47)
	ft-lb (N·m)			ft-lb (N·m)			ft-lb (N·m)		
3/8 – 24	20 (27)	18 (24)	16 (22)	35 (47)	32 (43)	28 (38)	49 (66)	44 (60)	39 (53)
7/16 – 14	28 (38)	25 (34)	22 (30)	49 (56)	44 (60)	39 (53)	70 (95)	63 (85)	56 (76)
7/16 – 20	30 (41)	27 (37)	24 (33)	55 (75)	50 (68)	44 (60)	78 (106)	70 (95)	62 (84)
1/2 – 13	39 (53)	35 (47)	31 (42)	75 (102)	68 (92)	60 (81)	105 (142)	95 (129)	84 (114)
1/2 – 20	41 (56)	37 (50)	33 (45)	85 (115)	77 (104)	68 (92)	120 (163)	108 (146)	96 (130)
9/16 – 12	51 (69)	46 (62)	41 (56)	110 (149)	99 (134)	88 (119)	155 (210)	140 (190)	124 (168)
9/16 – 18	55 (75)	50 (68)	44 (60)	120 (163)	108 (146)	96 (130)	170 (230)	153 (207)	136 (184)
5/8 – 11	83 (113)	75 (102)	66 (89)	150 (203)	135 (183)	120 (163)	210 (285)	189 (256)	168 (228)
5/8 – 18	95 (129)	86 (117)	76 (103)	170 (230)	153 (207)	136 (184)	240 (325)	216 (293)	192 (260)
3/4 – 10	105 (142)	95 (130)	84 (114)	270 (366)	243 (329)	216 (293)	375 (508)	338 (458)	300 (407)
3/4 – 16	115 (156)	104 (141)	92 (125)	295 (400)	266 (361)	236 (320)	420 (569)	378 (513)	336 (456)
7/8 – 9	160 (217)	144 (195)	128 (174)	429 (582)	386 (523)	343 465()	605 (820)	545 (739)	484 (656)
7/8 – 14	175 (237)	158 (214)	140 (190)	473 (461)	426 (578)	379 (514)	675 (915)	608 (824)	540 (732)
1.0 – 8	235 (319)	212 (287)	188 (255)	644 (873)	580 (786)	516 (700)	910 (1234)	819 (1110)	728 (987)
1.0 – 14	250 (339)	225 (305)	200 (271)	721 (978)	649 (880)	577 (782)	990 (1342)	891 (1208)	792 (1074)

NOTE: *Dry torque values are based on the use of clean, dry threads.*
Oiled torque values have been reduced by 10% when engine oil is used as a lubricant.
Plated torque values have been reduced by 20% for new plated capscrews.
Capscrews which are threaded into aluminum may require a torque reduction of 30% or more.
The conversion factor from ft-lb to in-lb is ft-lb x 12 equals in-lb.

ENGLISH/METRIC CONVERSIONS

Table 1.15-8. Metric Bolt Diameter To Hex Head Wrench Size Conversion Table

METRIC BOLT DIAMETER	METRIC STANDARD WRENCH SIZE	METRIC BOLT DIAMETER	METRIC STANDARD WRENCH SIZE
M3	6 mm	M18	27 mm
M4	7 mm	M20	30 mm
M5	8 mm	M22	32 mm
M6	10 mm	M24	36 mm
M7	11mm	M27	41 mm
M8	13 mm	M30	46 mm
M10	16 or 17 mm	M33	50 mm
M12	18 or 19 mm	M36	55 mm
M14	21 or 22 mm	M39	60 mm
M16	24 mm	M42	65 mm

Table 1.15-9. English To Metric Formula Conversion Table

CONVERSION	FORMULA	EXAMPLE
Inches to Millimeters	Inches and any fraction in decimal equivalent multiplied by 25.4 equals millimeters.	2-5/8 in. = 2.625 x 25.4 = 66.7 mm
Cubic Inches to Litres	Cubic inches multiplied by 0.01639 equals litres.	9388 cu. in. = 9388 x 0.01639 = 153.9 L
Ounces to Grams	Ounces multiplied by 28.35 equals grams.	21 oz. = 21 x 28.35 = 595 g
Pounds to Kilograms	Pounds multiplied by 0.4536 equals kilograms.	22,550 lbs. = 22,550 x 0.4536 = 10,229 kg
Inch Pounds to Newton-meters	Inch pounds multiplied by 0.113 equals Newton-meters.	360 in-lb = 360 x 0.113 = 40.7 N·m
Foot Pounds to Newton-meters	Foot pounds multiplied by 1.3558 equals Newton-meters.	145 ft-lb = 145 x 1.3558 = 197 N·m
Pounds per Square Inch to Kilograms per Square Centimeter	Pounds per square inch multiplied by 0.0703 equals kilograms per square centimeter.	45 psi = 45 x 0.0703 = 3.2 kg/cm^2
Pounds per Square Inch to Kilopascals	Pounds per square inch multiplied by 6.8947 equals kilopascals.	45 psi = 45 x 6.8947 = 310 kPa
Fluid Ounces to Cubic Centimeters	Fluid ounces multiplied by 29.57 equals cubic centimeters.	8 oz. = 8 x 29.57 = 237 cc
Gallons to Litres	Gallons multiplied by 3.7853 equals litres.	148 gal. = 148 x 3.7853 = 560 L
Degrees Fahrenheit to Degrees Centigrade	Degrees Fahrenheit minus 32 divided by 1.8 equals degrees Centigrade.	212° F - 32 ÷ 1.8 = 100° C

Table 1.15-10. Metric To English Formula Conversion Table

CONVERSION	FORMULA	EXAMPLE
Millimeters to Inches	Millimeters multiplied by 0.03937 equals inches.	67 mm = 67 x 0.03937 = 2.6 in.
Litres to Cubic Inches	Litres multiplied by 61.02 equals cubic inches.	153.8 L = 153.8 x 61.02 = 9385 cu. in.
Grams to Ounces	Grams multiplied by 0.03527 equals ounces.	595 g = 595 x 0.03527 = 21.0 oz.
Kilograms to Pounds	Kilograms multiplied by 2.205 equals pounds.	10,228 kg = 10,228 x 2.205 = 22,553 lbs.
Newton-meters to Inch Pounds	Newton-meters multiplied by 8.85 equals inch pounds.	40.7 N·m = 40.7 x 8.85 = 360 in-lb
Newton-meters to Foot Pounds	Newton-meters multiplied by 0.7375 equals foot pounds.	197 N·m = 197 x 0.7375 = 145 ft-lb
Bar to Pounds per Square Inch	Bar multiplied by 14.5 equals pounds per square inch.	685 Bar = 685 x 14.5 = 9933 psi
Kilograms per Square Centimeter to Pounds per Square Inch (psi)	Kilograms per square centimeter multiplied by 14.22 equals pounds per square inch.	3.2 kg/cm^2 = 3.2 x 14.22 = 46 psi
Kilopascals to Pounds per Square Inch (psi)	Kilopascals multiplied by 0.145 equals pounds per square inch.	310 kPa = 310 x 0.145 = 45.0 psi
Cubic Centimeters to Fluid Ounces	Cubic centimeters multiplied by 0.0338 equals fluid ounces.	236 cc = 236 x 0.0338 = 7.98 oz.
Litres to Gallons	Litres multiplied by 0.264 equals gallons.	560 L = 560 x 0.264 = 148 gal.
Degrees Centigrade to Degrees Fahrenheit	Degrees Centigrade multiplied by 1.8 plus 32 equals Degrees Fahrenheit.	100° C = 100 x 1.8 + 32 = 212° F

INDEX OF SEALANTS, ADHESIVES, AND LUBRICANTS

The following is a list of sealants, adhesives and lubricants (see Table 1.15-11) required to perform the tasks in this manual. Where possible, brand names are included with the task. When they are not, this index may be used to match the general description to a specific product or its equivalent (ie. pipe sealant = Perma Lok® Heavy Duty Pipe Sealant with Teflon or its equivalent). Waukesha does not endorse one brand over another. In all cases, equivalent products may be substituted for the brand name listed. All part numbers listed are the manufacturer's numbers.

Table 1.15-11. Sealants, Adhesives, and Lubricants

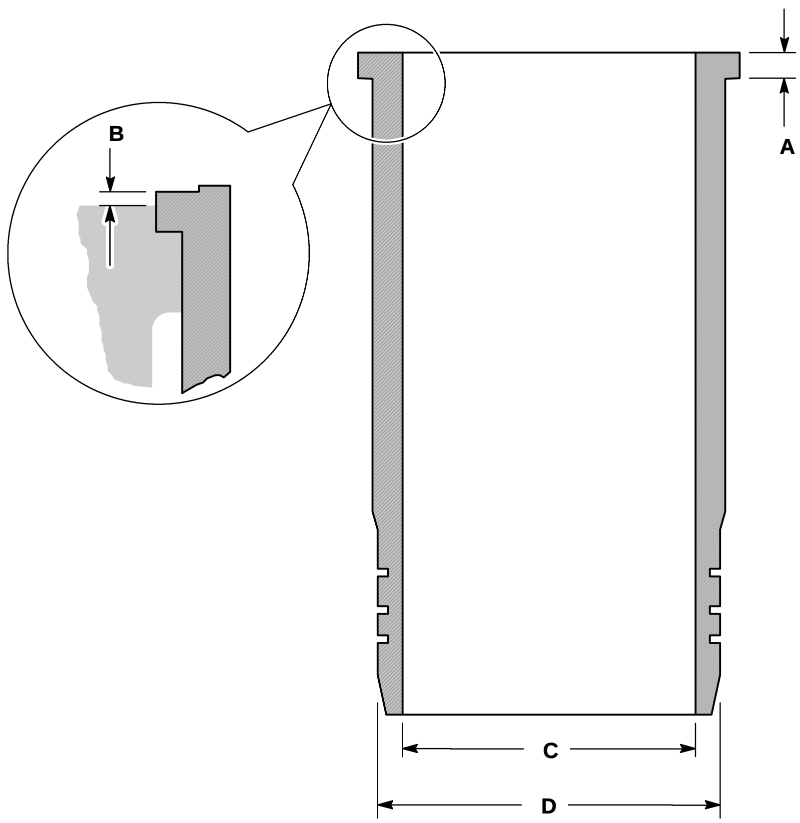
NAME USED IN TEXT	BRAND NAME/DESCRIPTION
High Temperature Anti-seize compound	FEL-PRO® C5-A®, P/N 51005 or Loctite® Anti-Seize 767/ Copper based anti-seize compound
Anti-Seize	Bostik Never Seez® Anti-Seize and Lubricating Compound/Nickle based anti-seize compound
Black Silicone	G.E. Silmate® Silicone Rubber
Bluing Agent	Magnaflux® Products: Penetrant (SKL-HF/S) Developer (SKD-NF-ZP-9B) Cleaner/Remover (SKC-NF/ZC-7B)
Bluing Paste	Permatex® Non Drying Prussian Blue (mfg. by Loctite® Corporation)
Ceramic bonded high temperature solid film lubricant	Lube-Lok® 1000 or equivalent
Cleaning Solvent/Mineral Spirits	Amisol® Solvent (mfg. by Standard Oil)
Dielectric Silicone Grease	Dow Corning DC-200, G.E. G-624, GC Electronics 25
Engine Oil	See Lubricating Oil
Epoxy Sealant	Scotch Weld® No. 270 B/A Black Epoxy Potting Compound/Adhesive, P/N's. A and B (3M ID No. 62-3266-7430-6 (PA)
Gasket Adhesive	Scotch Grip® 847 Rubber and Gasket Adhesive (mfg. by 3M), 3M ID No. 62-0847-7530-3
Heavy Lube Oil	Vactra® 80W90 Gear Oil (mfg. by Mobil)
Liquid Soap	Dove® Dishwashing Liquid
Lithium Grease	See Molycote t Paste G
Locquic® Primer "T"	Item No. 74756 (mfg. by Loctite® Corporation)
Loctite® 242	Loctite® Item No. 24241/a blue colored removable thread locking compound
Loctite® 271	Loctite® Item No. 27141/a red colored thread locking compound
Loctite® Compound 40	Loctite® Item No. 64041/High Temperature Retaining Compound 40
Loctite® Hydraulic Sealant	Loctite® Item No. 56941
Loctite® RC t /609	Loctite® Item No. 60931
Loctite® 620	Loctite® Item No. 620-40/High Temperature Retaining Compound
Lubricating Oil/Engine Oil	New oil of the type used in the crankcase
Magnaflux®	See Bluing Agent
Metal Assembly Spray	Dow Corning Lubricant G-n
Molycote® Paste G	Dow Corning Molycote t Paste G or CITGO Lithoplex® Grease NLGI No. 2 Product Code 55-340/ a molybdenum-based grease
O-ring Lubricant	Parker Super O-Lube t /dry silicone lubricant
Permatex® No. 3D Aviation Form-A-Gasket® Sealant Liquid	Loctite® Item No. 3D
Permatex® No. 2 Form-A-Gasket® Sealant	Loctite® Item No. 2C
Permatex High Tack Spray-A-Gasket®	Loctite® Item No. 99MA
Pipe Sealant	Perma Lok® Heavy Duty Pipe Sealant with Teflon, Item No. LH050
Stellite®	Stellite® is a registered trademark of Stoody Deloro Stellite, Inc.
WD-40®	WD-40® is a registered trademark of the WD-40 Company.

SECTION 1.20

SPECIFICATIONS

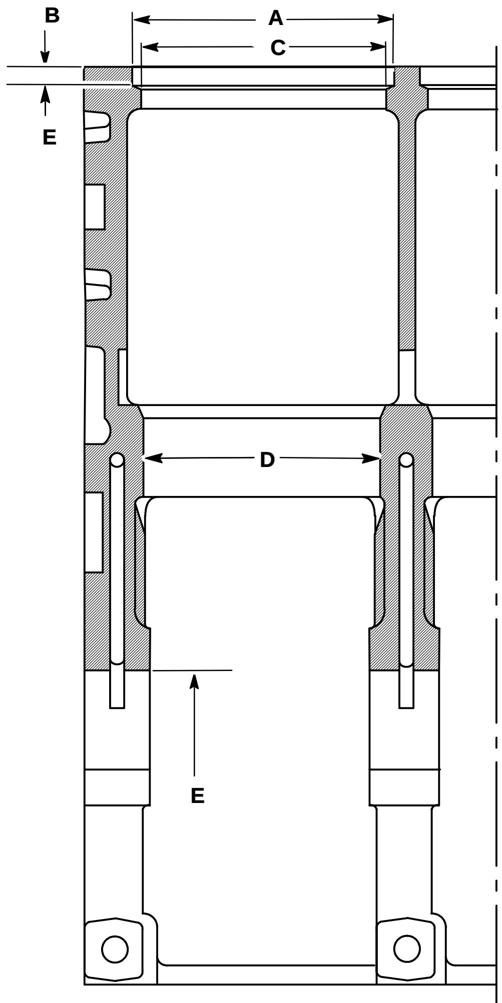
SPECIFICATIONS

Table 1.20-1. Cylinder Liner



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Flange height	0.550 (13.97)	0.5512 (14.001)	0.552 (14.021)
(B) Liner protrusion above crankcase	0.000 (0.000)	0.0027 (0.069)	0.0047 (0.119)
(C) Liner ID	5.991 (152.171)	5.984 (151.993)	5.985 (152.019)
(D) Liner OD (lower seal area)	6.768 (171.907)	6.769 (171.932)	6.770 (171.957)
Liner out of round limit	0.003 (0.076)	0.000 (0.000)	0.001 (0.025)
Liner bore maximum taper	0.005 per inch of piston travel	–	–
Liner seal area to crankcase clearance	0.007 (0.178)	0.002 (0.043)	0.005 (0.127)

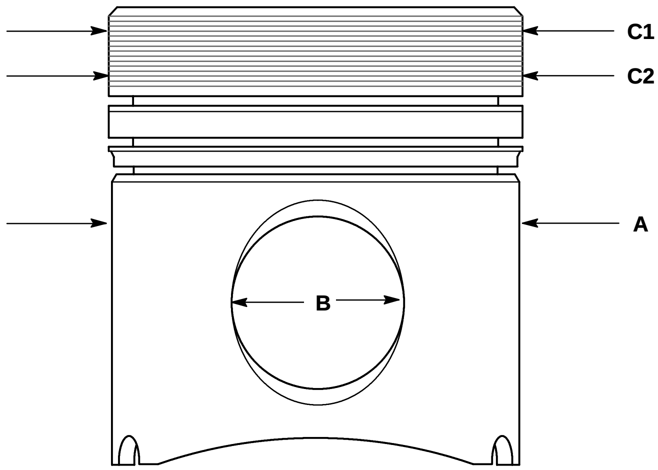
Table 1.20-2. Crankcase



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Liner counterbore diameter	7.4547 (189.350)	7.4508 (189.250)	7.4547 (189.350)
(B) Liner counterbore depth	0.5502 (13.975)	0.5512 (14.000)	0.5530 (14.046)
(C) Crankcase upper bore	6.9110 (175.540)	6.9094 (175.500)	6.9110 (175.540)
(D) Crankcase lower bore	6.7743 (172.067)	6.7717 (172.000)	6.7732 (172.040)
(E) Crankcase main bearing journal bore	5.5530 (141.046)	5.5512 (141.000)	5.5522 (141.026)

NOTE: *The camshaft bushings are to be assembled with the split line toward the top.*
NOTE: *The #1 camshaft bushing is a special thrust bushing.*

Table 1.20-3. Piston



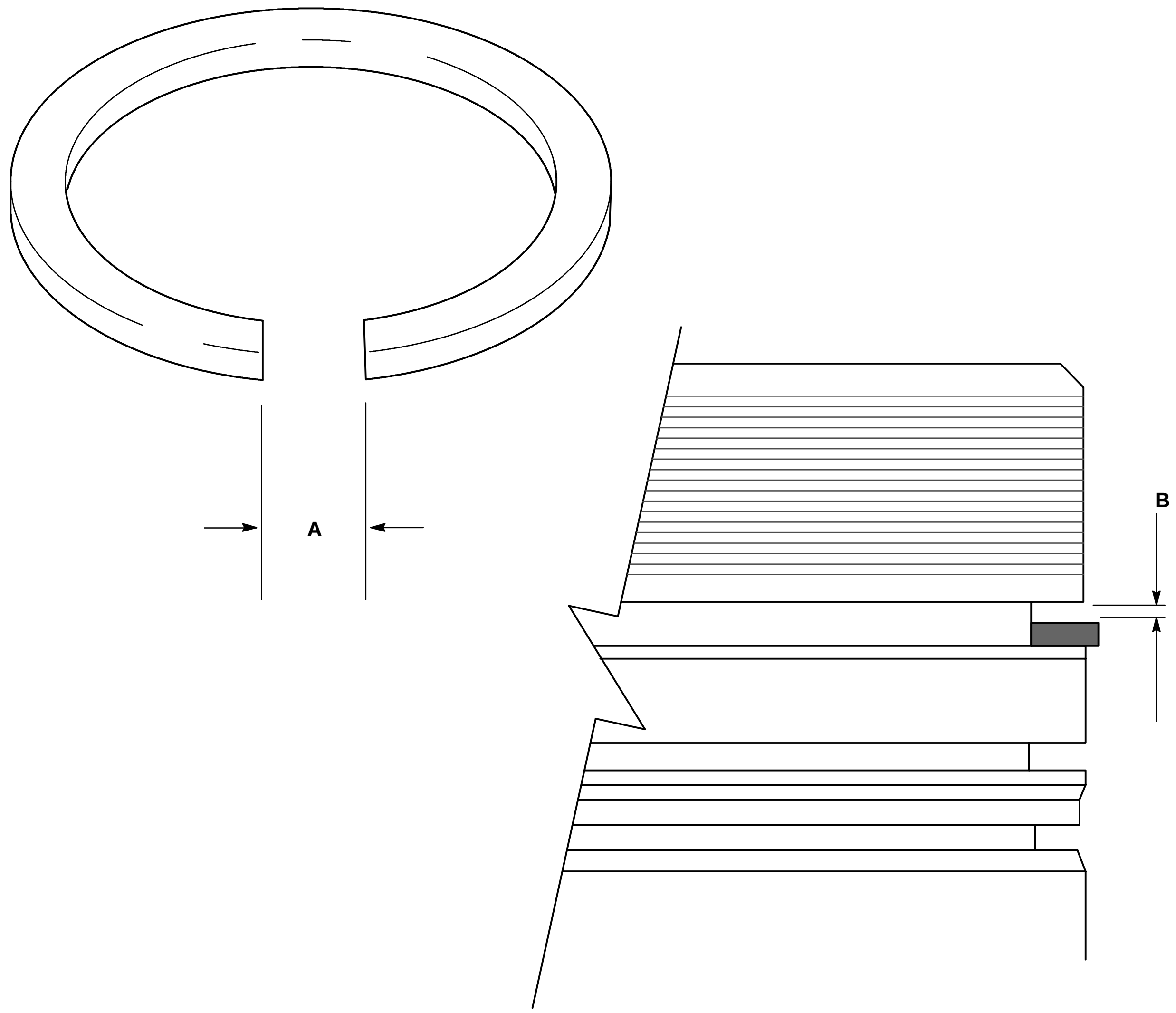
Piston Material: Cast aluminum alloy (skirt is treated with “Graffal 20”, a gray phosphate lubricant for break-in).			
Piston Type: Cam ground			
Pistons are remove from: Top of the crankcase.			
Permissible piston weight: 3704 to 3781 grams (131 to 133 oz.)			
GL/GLD Compression ratio: 11:1 (GL LCR Compression ratio 8.7:1)			
G/GSID Compression ratio: 8.6:1			
	WEAR LIMIT in. (mm)	**NEW MINIMUM in. (mm)**	**NEW MAXIMUM in. (mm)**
(A) 90° from pin hole (top)	5.9710 (151.663)	5.9740 (151.739)	5.9748 (151.761)
(B) Piston pin bore	2.5608 (65.044)	2.5593 (65.005)	2.5595 (65.012)
(C1) Piston head land diameter	5.943 (150.95)	5.947 (151.05)	5.948 (151.09)
(C2) Piston head land diameter	5.956 (151.28)	5.958 (151.33)	5.963 (151.46)

NOTE: *Current production engine pistons are marked “INTAKE” to face the intake (outside) of the crankcase.*

Table 1.20-4. Piston Pin

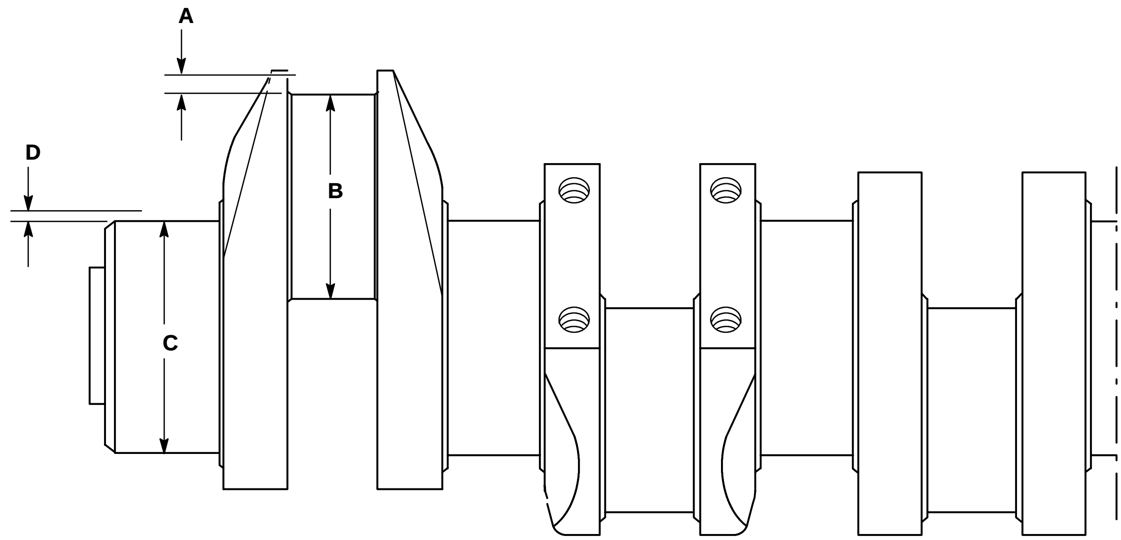
	WEAR LIMIT in. (mm)	**NEW MINIMUM in. (mm)**	**NEW MAXIMUM in. (mm)**
(A) Piston pin diameter	2.5577 (64.966)	2.5587 (64.992)	2.559 (65.000)
Piston pin to connecting rod bore clearance	0.0031 (0.08)	0.0014 (0.0254)	0.0023 (0.058)

Table 1.20-5. Piston Rings



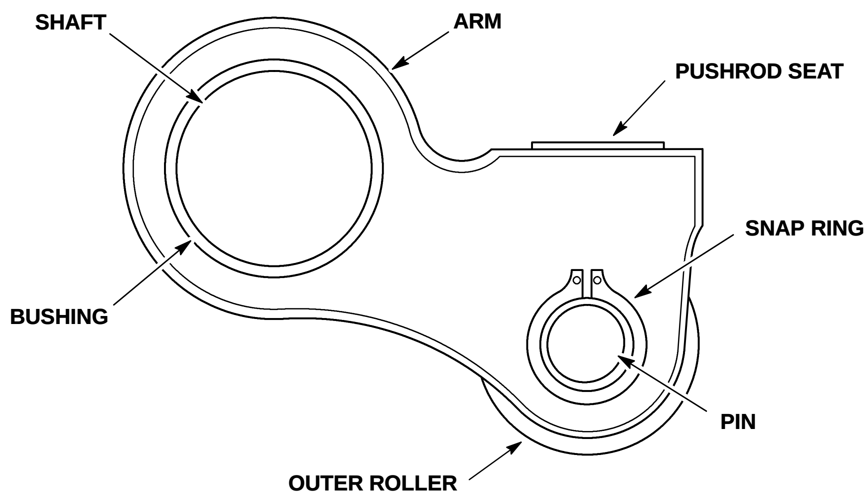
Top ring: Barrel-faced chrome plated, compression (top is marked "TOP").			
Second ring: Tapered face compression (top marked with a dot for "TOP" or "UP").			
Third ring: Conformable grooved oil ring with expander.			
	WEAR LIMIT in. (mm)	**NEW MINIMUM in. (mm)**	**NEW MAXIMUM in. (mm)**
(A) Ring gap			
Top	0.0598 (1.52)	0.0197 (0.50)	0.030 (0.762)
2nd	0.063 (1.60)	0.0236 (0.60)	0.033 (0.838)
3rd	0.061 (1.55)	0.0197 (0.50)	0.031 (0.787)
(B) Side clearance (piston ring to ring groove)			
Top	0.0059 (0.15)	0.0020 (0.050)	0.0033 (0.085)
2nd	0.0039 (0.10)	0.0020 (0.050)	0.0033 (0.085)
3rd	0.0059 (0.15)	0.0012 (0.030)	0.0024 (0.060)

Table 1.20-6. Crankshaft



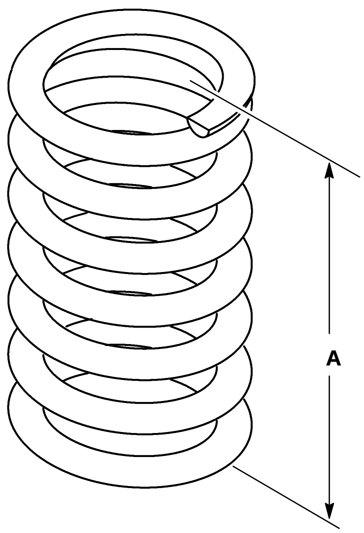
	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
Crankshaft endplay	0.0300 (0.762)	0.0138 (0.350)	0.0250 (0.636)
Thrust ring thickness (standard)	0.1328 (3.373)	0.1378 (3.500)	0.1409 (3.580)
(A) Connecting rod bearing running clearance	0.0110 (0.279)	0.0033 (0.083)	0.0069 (0.176)
(B) Connecting rod bearing journal diameter	4.5240 (114.910)	4.5269 (114.983)	4.5282 (115.017)
1st repair - 0.020″ Bearings	4.5040 (114.402)	4.5069 (114.475)	4.5082 (114.508)
Connecting rod bearing journal maximum undersize diameter	4.4870 (113.969) Do not grind beyond this limit.		
(C) Main bearing journal diameter	5.3114 (134.909)	5.3134 (134.960)	5.3150 (135.000)
1st repair-0.020″ bearings	5.2914 (134.402)	5.2934 (134.452)	5.2950 (134.493)
(D) Main bearing running clearance	0.011 (0.279)	0.0039 (0.100)	0.0078 (0.199)
Main bearing journal maximum undersize diameter	5.274 (133.959) Do not grind beyond this limit.		
Main bearing journal maximum out-of-round	0.0021 (0.0533)		
Main bearing journal maximum taper	0.001 (0.025)		
Connecting rod journal maximum out-of-round	0.0018 (0.0457)		
Connecting rod journal maximum taper	0.001 (0.025)		
Thermal growth (crankshaft expansion from 70° F (21° C) to normal operating temperature, measured from the base of the engine supports).	0.007 (0.18)		

Table 1.20-7. Camshaft Followers



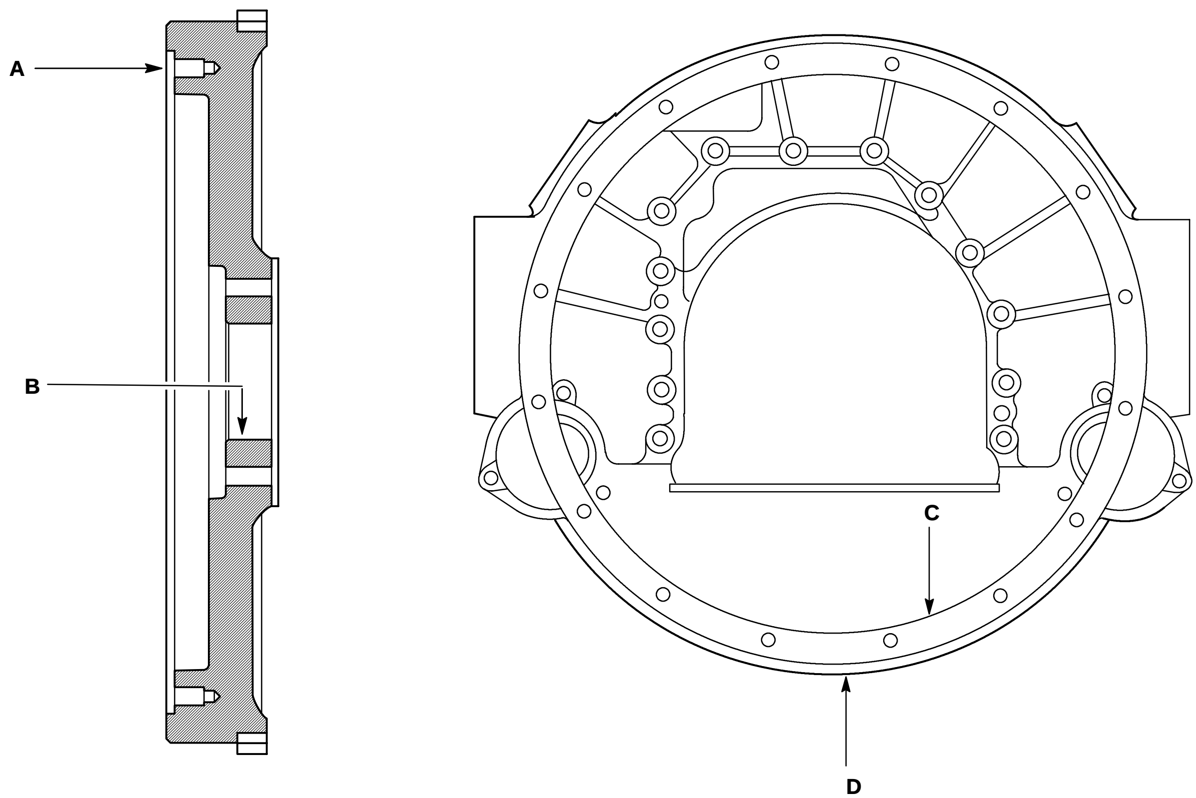
	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
Bushing ID	1.263 (32.08)	1.2602 (32.01)	1.261 (32.03)
Shaft OD	1.2579 (31.95)	1.2595 (31.991)	1.2597 (31.996)
Pin OD	0.6276 (15.94)	0.6287 (15.97)	0.6291 (15.98)
Follower Bushing ID (Not Shown)	0.635 (16.13)	0.6319 (16.05)	0.6337 (16.07)
Follower Bushing OD (Not Shown)	0.9028 (22.93)	0.9039 (22.96)	0.9047 (22.98)
Roller ID	0.9102 (23.12)	0.9079 (23.06)	0.9091 (23.09)
Roller OD	1.3362 (33.94)	1.337 (33.96)	1.3386 (34.00)

Table 1.20-8. Valve Spring Clearances



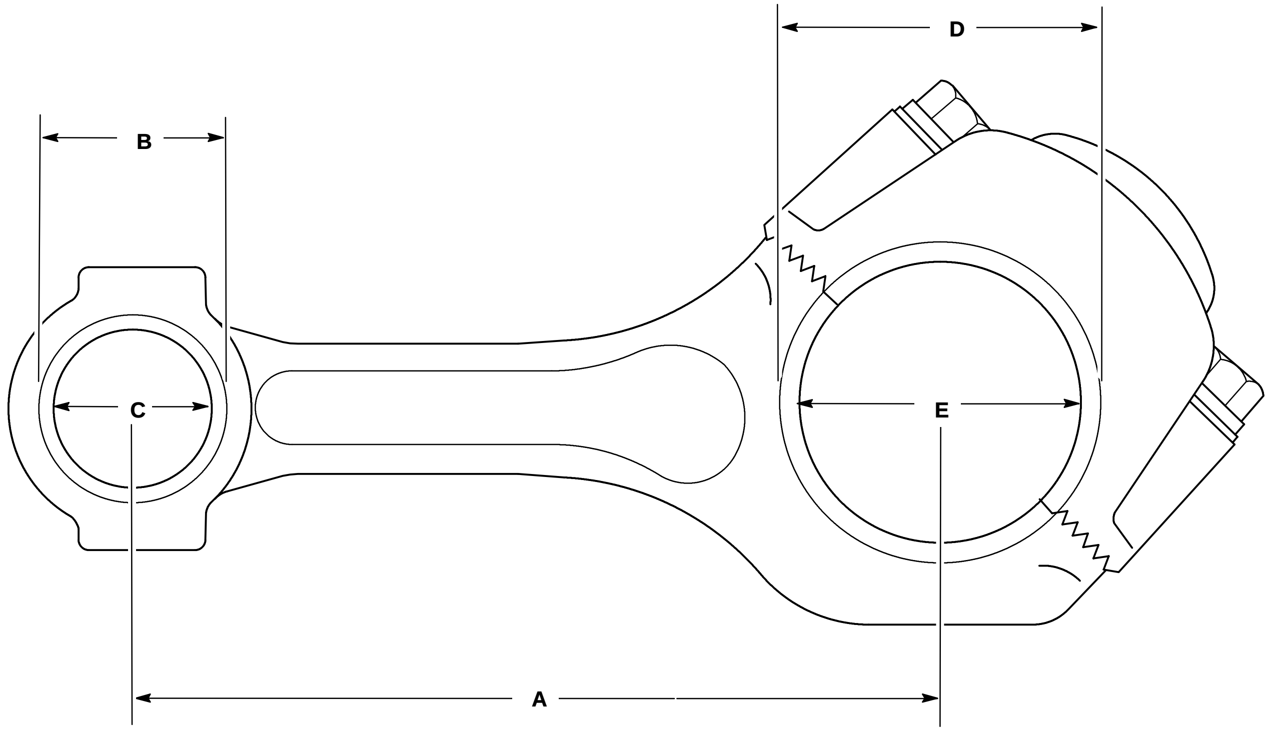
	OUTER (A)	INNER (B)
Wire diameter	0.177 in. (4.5 mm)	0.133 in. (3.4 mm)
Number of coils	7	8
Load at specified length (valve closed)	41.8 – 48.1 lb. @ 2.118 in. (19 – 21.8 kg @ 53.8 mm)	18.5 – 21.6 lb @ 1.921 in. (8.4 – 9.8 kg @ 48.8 mm)
Load at specified length (valve open)	90.4 – 99.3 lb @ 1.539 in. (41 – 45 kg @ 39.1 mm)	53.8 – 62.2 lb @ 1.3425 in (24.4 – 28.2 kg @ 34.1 mm)
Intake and exhaust valve spring free length	**NEW MINIMUM**	**NEW MAXIMUM**
Outer (A)	2.592 in. (65.836 mm)	2.753 in. (69.926 mm)
Inner (B)	2.204 in. (55.982 mm)	2.340 in. (59.436 mm)

Table 1.20-9. Flywheel And Housing



	MAXIMUM in. (mm)
(A) Face run out on flywheel	0.013 (0.330)
(B) Pilot bore run-out	0.005 (0.127)
(C) Housing bore run-out	0.010 (0.254)
(D) Housing face run-out	0.010 (0.254)

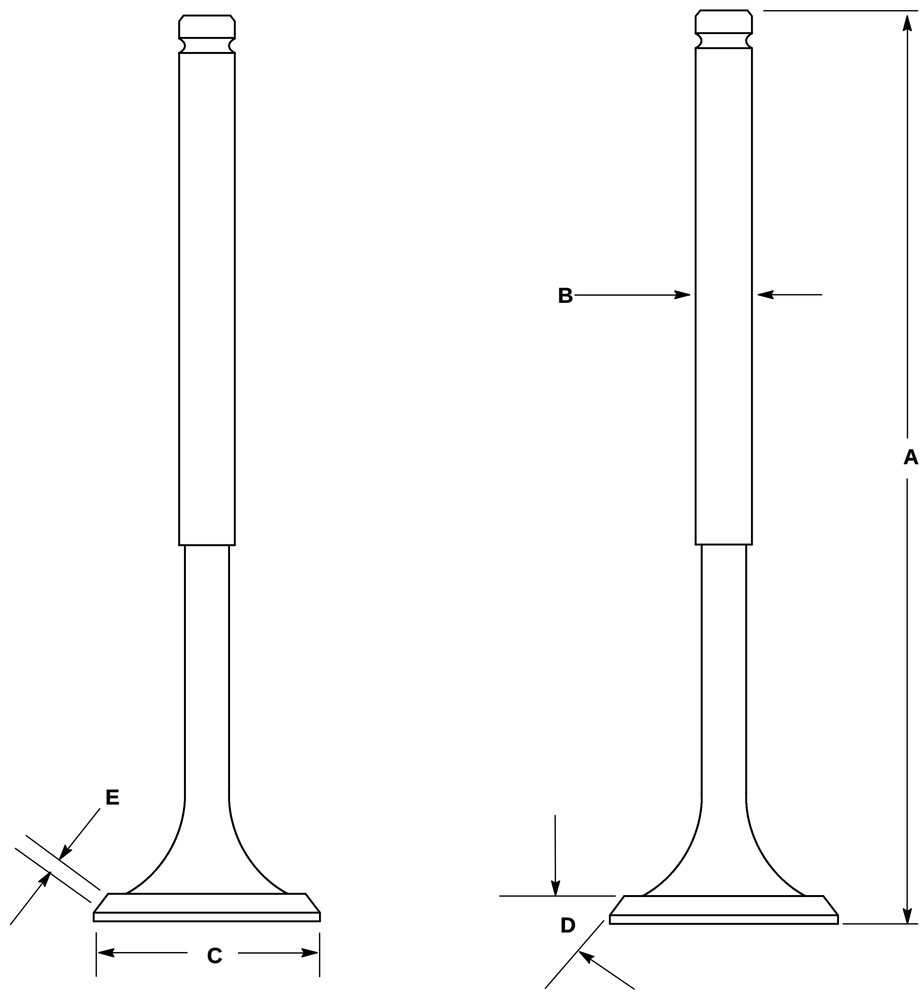
Table 1.20-10. Connecting Rod, Bushing And Bearing



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
Rod material - Heat treated steel forging			
Permissible variation 21.16 ± 0.10 lb. (9600 ± 45 grams)			
(A) Rod Length, center to center	12.204 (309.981)	12.204 (309.981)	12.2047 (310.0)
(B) Rod small end finish size	2.758 (70.053)	2.756 (70.002)	2.7567 (70.028)
(C) Bushing bore diameter	2.5625 (65.087)	2.560 (65.024)	2.561 (65.049)
Bushing press fit in rod (interference fit between the rod and bushing)	0.002 (0.050)	0.003 (0.076)	0.005 (0.127)
Bushing OD		2.759 (70.084)	2.761 (70.129)
Pin clearance in bushing	0.0043 (0.109)	0.0014 (0.035)	0.0027 (0.068)
(D) Rod large end finish size *	4.766 (121.056)	4.7638 (121.000)	4.7648 (121.025)
Rod large end width		2.0772 (52.760)	2.0795 (52.820)
Rod side clearance *		0.0142 (0.360)	0.025 (0.635)
(E) Rod bearing inside diameter	4.535 (115.189)	4.5315 (115.100)	4.5338 (115.159)
Bearing running clearance (theoretical)	0.011 (0.279)	0.003 (0.076)	0.007 (0.178)
Connecting rod maximum twist	With bushing 0.005 (0.127), without bushing 0.010 (0.254)		

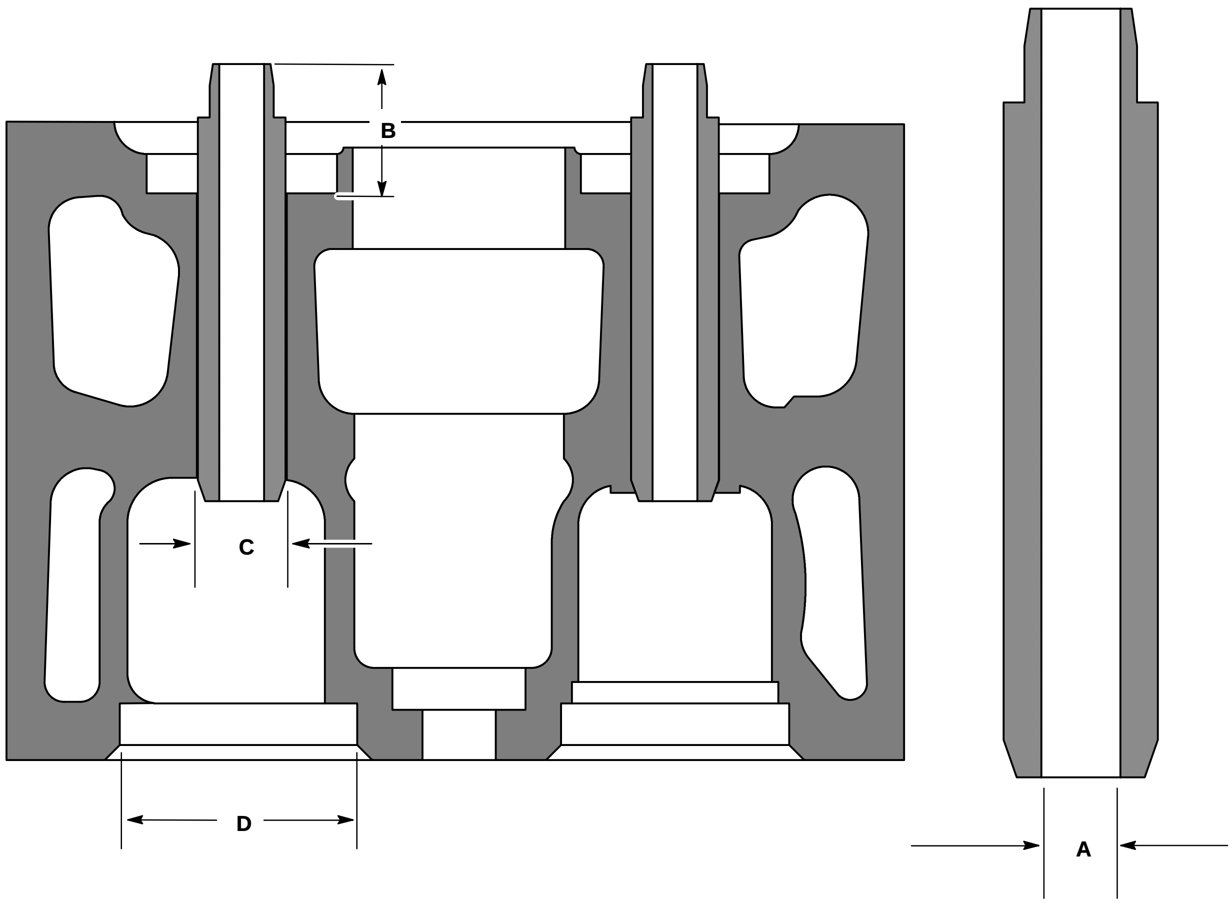
NOTE: ** Check with the bolts installed and torqued to 310 ±15 ft-lb (420 ± 20 N·m).*

Table 1.20-11. Valve Clearances



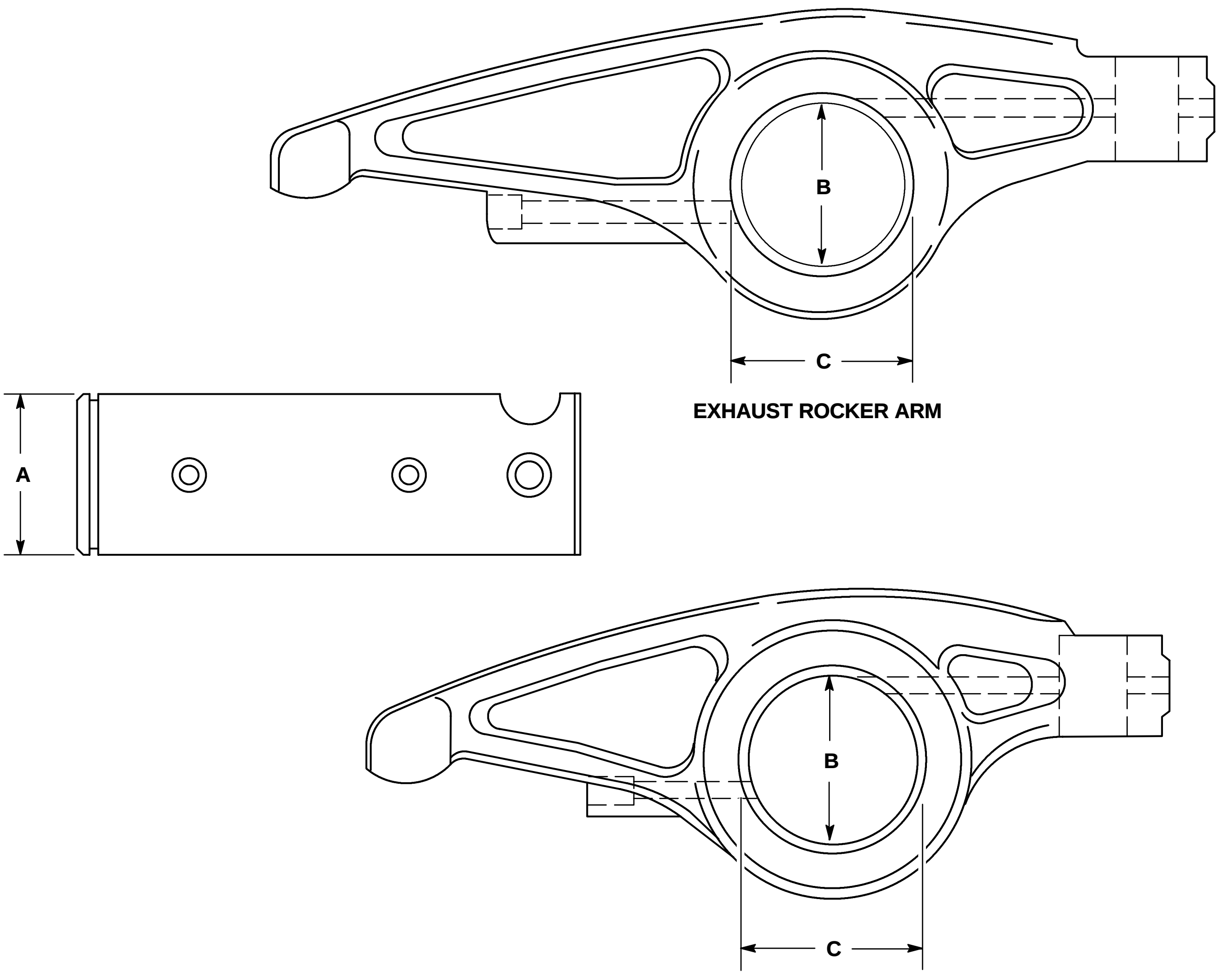
	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Valve length			
Intake	7.597 (192.963)	7.607 (193.22)	7.629 (193.78)
Exhaust	7.597 (192.963)	7.607 (193.22)	7.629 (193.78)
(B) Valve stem diameter			
Intake	0.429 (10.910)	0.430 (10.936)	0.431 (10.954)
Exhaust	0.429 (10.910)	0.430 (10.936)	0.431 (10.954)
(C) Valve head diameter			
Intake	2.043 (51.90)	2.043 (51.90)	2.051 (52.10)
Exhaust	2.043 (51.90)	2.043 (51.90)	2.051 (52.10)
(D) Valve face angle			
Intake	1/2°	19° 15′	19° 45′
Exhaust	1/2°	19° 15′	19° 45′
(E) Valve face width			
Intake	0.175 (4.45)	0.175 (4.45)	0.249 (6.33)
Exhaust	0.175 (4.45)	0.175 (4.45)	0.249 (6.33)
Valve heads below cylinder head deck	0.108 (2.74)	0.041 (1.04)	0.059 (1.50)

Table 1.20-12. Cylinder Head Clearances



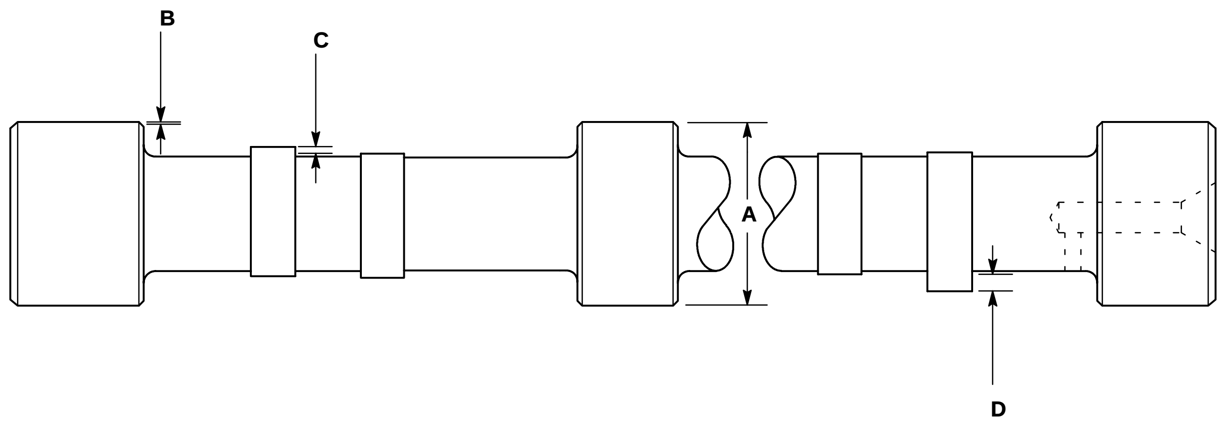
	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Valve guide ID			
Intake	0.4365 (11.087)	0.4343 (11.023)	0.4346 (11.040)
Exhaust	0.4365 (11.087)	0.4343 (11.023)	0.4346 (11.040)
Valve Guide ID to stem OD Clearance			
Intake	0.0003 (0.0076)	0.003 (0.076)	0.004 (0.104)
Exhaust	0.0003 (0.0076)	0.003 (0.076)	0.004 (0.104)
(B) Valve guide protrusion above head counterbore			
Intake		1.092 (27.737)	1.112 (28.245)
Exhaust		1.092 (27.737)	1.112 (28.245)
(C) Valve guide counterbore in head			
Intake	0.7879 (20.013)	0.7874 (20.000)	0.7879 (20.013)
Exhaust	0.7879 (20.013)	0.7874 (20.000)	0.7879 (20.013)
(D) Valve seat counterbore inside diameter			
Intake	2.167 (55.042)	2.1654 (55.000)	2.1665 (55.0300)
Exhaust	2.167 (55.042)	2.1654 (55.000)	2.1665 (55.0300)

Table 1.20-13. Rocker Arm Assemblies



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Rocker arm shaft OD	1.2579 (31.950)	1.2589 (31.976)	1.2595 (31.991)
(B) Rocker arm bushing ID (ream to ID)	1.262 (32.055)	1.260 (32.009)	1.261 (32.034)
(C) Rocker arm bore ID			
Intake	1.418 (36.039)	1.417 (36.000)	1.418 (36.039)
Exhaust	1.418 (36.039)	1.417 (36.000)	1.418 (36.039)
Clearance of rocker arm bushing to shaft:	0.004 (0.101)	0.0007 (0.018)	0.002 (0.059)

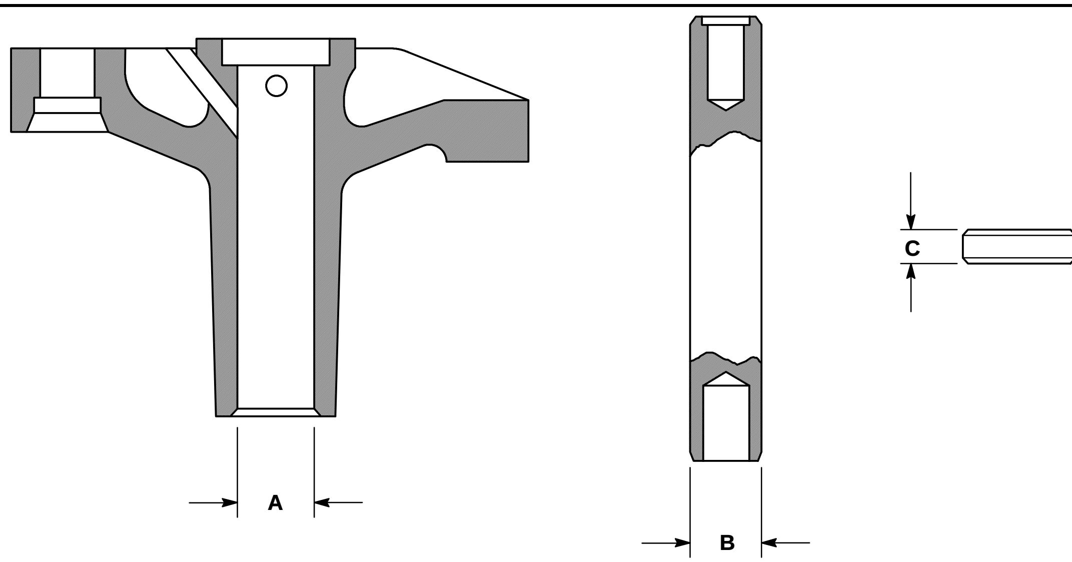
Table 1.20-14. Camshaft



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Camshaft bearing journal diameter	2.6723 (67.8764)	2.6736 (67.9094)	2.675 (67.940)
(B) Camshaft bearing journal running clearance	0.008 (0.203)	0.002 (0.051)	0.005 (0.127)
Camshaft endplay	0.011 (0.279)	0.004 (0.101)	0.006 (0.152)
Endplay adjustment-increase or decease shim pack (Shims are available in .004, .006, .008, .020 in. [0.1, 0.15, 0.12, 0.5 mm].)			
Cam lobe lift			
(C) Intake	0.412 (10.465)	0.417 (10.592)	
(D) Exhaust	0.411 (10.439)	0.416 (10.570)	

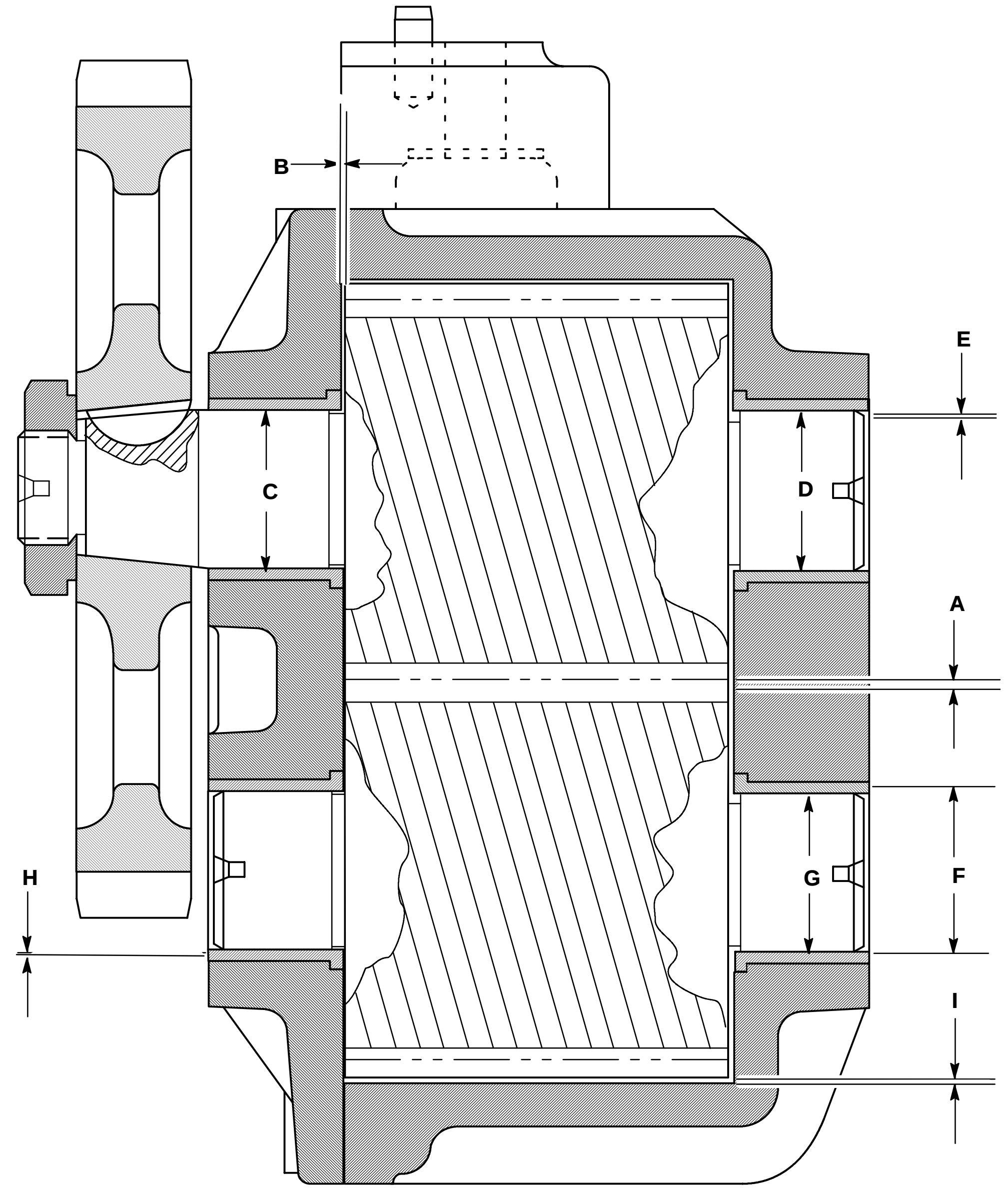
NOTE: *Camshaft coupling should never be loose (8 cylinder engines).*

Table 1.20-15. Cross Bar And Guide



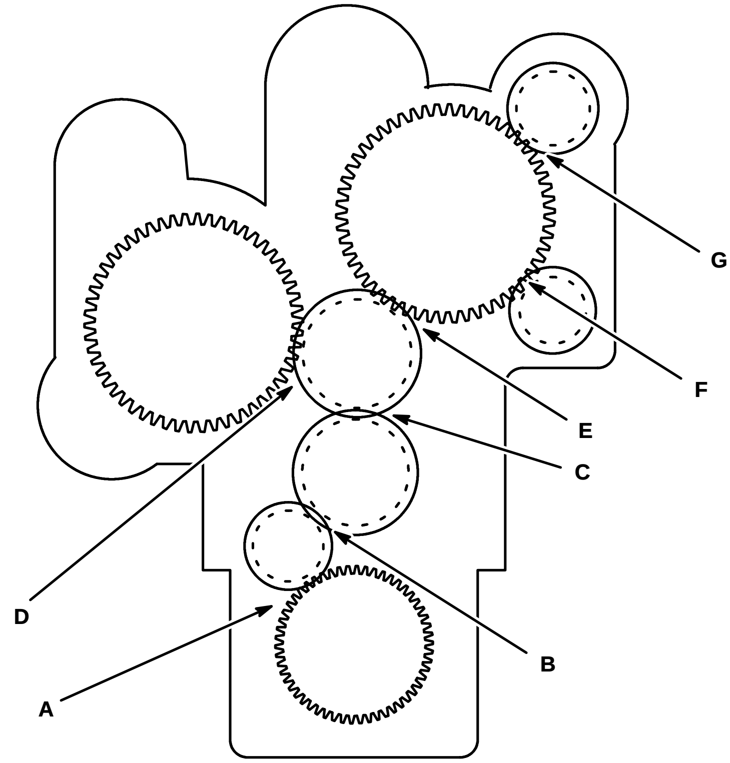
	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Cross bar ID	0.555 (14.097)	0.5531 (14.050)	0.5542 (14.077)
(B) Guide OD	0.551 (13.995)	0.5525 (14.033)	0.5529 (14.044)
Clearance of cross bar to guide	0.0037 (0.094)	0.0002 (0.005)	0.0017 (0.043)
(C) Seat Thickness	0.157 (3.99)	0.1579 (4.01)	0.1587 (4.03)

Table 1.20-16. Oil Pump



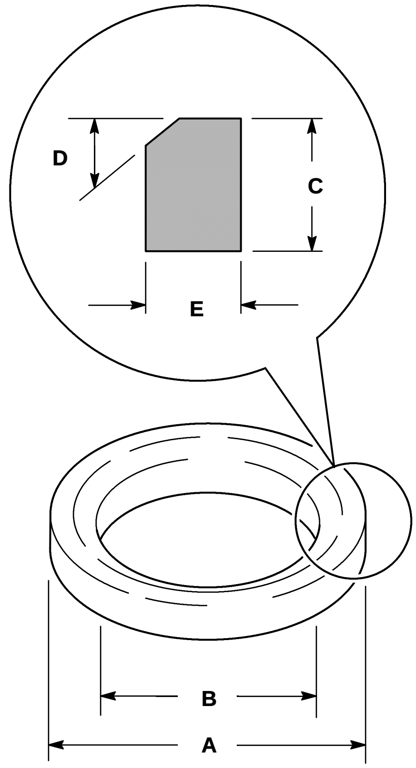
	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Oil pump pressure gear backlash	0.012 (0.304)	0.0055 (0.139)	0.008 (0.203)
(B) Pressure gear to cover endplay	0.012 (0.304)	0.0055 (0.139)	0.008 (0.203)
(C) Drive shaft bushing ID	1.1839 (30.071)	1.1810 (29.997)	1.1819 (30.020)
(D) Drive shaft OD	1.1785 (29.933)	1.1794 (29.957)	1.1803 (29.979)
(E) Drive shaft running clearance	0.005 (0.127)	0.001 (0.025)	0.002 (0.051)
(F) Idler gear bushing ID	1.1839 (30.0710)	1.1810 (29.997)	1.1819 (30.0202)
(G) Idler gear shaft OD	1.1785 (29.933)	1.1794 (29.956)	1.1803 (29.979)
(H) Idler gear shaft running clearance	0.005 (0.127)	0.001 (0.025)	0.0024 (0.062)
(I) Radial clearance between pumping gear teeth and pump chamber wall	0.015 (0.381)	0.005 (0.127)	0.012 (0.305)

Table 1.20-17. Front Gear Train Backlash



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Oil Pump Intermediate (Idler) To Oil Pump Gear	0.010 (0.254)	0.006 (0.15)	0.013 (0.33)
(B) Oil Pump Intermediate (Idler) To Crankshaft Gear	0.010 (0.254)	0.006 (0.15)	0.014 (0.35)
(C) Crankshaft Gear To Crankshaft Intermediate (Idler)	0.011 (0.279)	0.008 (0.20)	0.012 (0.30)
(D) Crankshaft Intermediate (Idler) To Jacket Water Pump Gear	0.011 (0.279)	0.004 (0.11)	0.016 (0.40)
(E) Crankshaft Intermediate (Idler) To Camshaft Gear	0.011 (0.279)	0.007 (0.17)	0.012 (0.30)
(F) Camshaft Gear To Magneto Gear	0.011 (0.279)	0.004 (0.11)	0.013 (0.33)
(G) Camshaft Gear To Governor Gear	0.011 (0.279)	0.004 (0.11)	0.013 (0.33)

Table 1.20-18. Valve Seat Clearances



	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Valve seat insert OD		
Intake	2.169 (55.102)	2.170 (55.118)
Exhaust	2.169 (55.102)	2.170 (55.118)
(B) Valve seat insert ID		
Intake	1.740 (44.20)	1.764 (44.80)
Exhaust	1.740 (44.20)	1.764 (44.80)
(C) P/N 304010K Valve seat insert height		
Intake	0.335 (8.50)	0.339 (8.61)
Exhaust	0.335 (8.50)	0.339 (8.61)
P/N 304010L Valve seat insert height		
Intake	0.325 (8.25)	0.329 (8.35)
Exhaust	0.325 (8.25)	0.329 (8.35)
(D) Valve seat insert face angle		
Intake	19° 30′	19° 30′
Exhaust	19° 30′	19° 30′
(E) Valve seat insert seat width		
Intake	0.205 (5.207)	0.45 (11.43)
Exhaust	0.205 (5.207)	0.45 (11.43)

NOTE: *Valve seat selection depends on the cylinder head gasket installed on crankcase.*

SECTION 2.00

CYLINDER HEAD REMOVAL

Table 2.00-1. Special Tools For Cylinder Head

TOOL P/N	TOOL DESCRIPTION
472015	Rocker Arm Support/Manifold Wrench
472065	Spark Plug Tube Retaining Tool

CYLINDER HEAD REMOVAL

NOTE: *Individual cylinder heads can be removed without removing the intake or exhaust manifolds.*

⚠ WARNING

Always shut off the fuel supply and clear the engine supply lines and piping of accumulated gas prior to performing maintenance on the engine. Disregarding this information could result in severe personal injury or death.

1. Shut off fuel source.

2. Drain all coolant from engine.

3. Disconnect exhaust thermocouple leads located next to cylinder head, if applicable (see Figure 2.00-1).

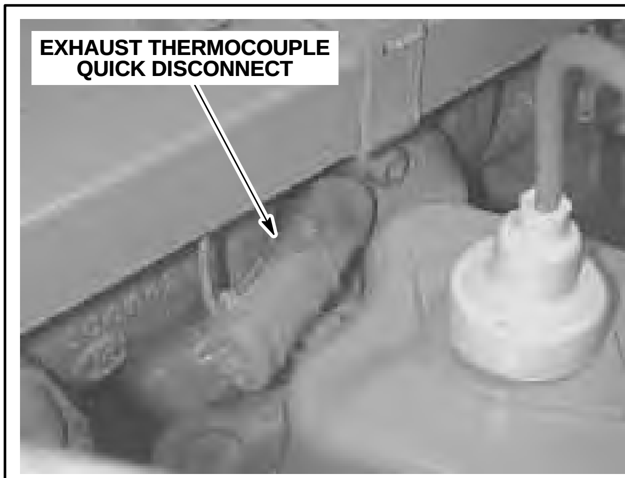


Figure 2.00-1. Exhaust Thermocouple

4. Remove thermocouple conduit, if applicable (see Figure 2.00-2).

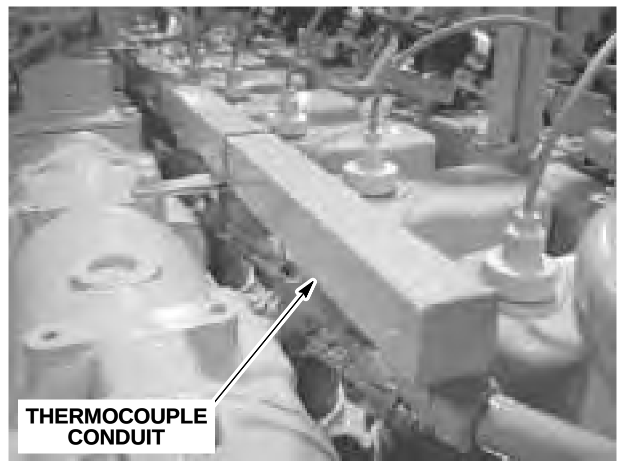


Figure 2.00-2. Exhaust Thermocouple Conduit

NOTE: *Remove the turbocharger discharge elbow only if it interferes with the removal of a cylinder head (see Steps 5 and 6).*

5. Loosen hose clamp on turbocharger discharge elbow (see Figure 2.00-3).

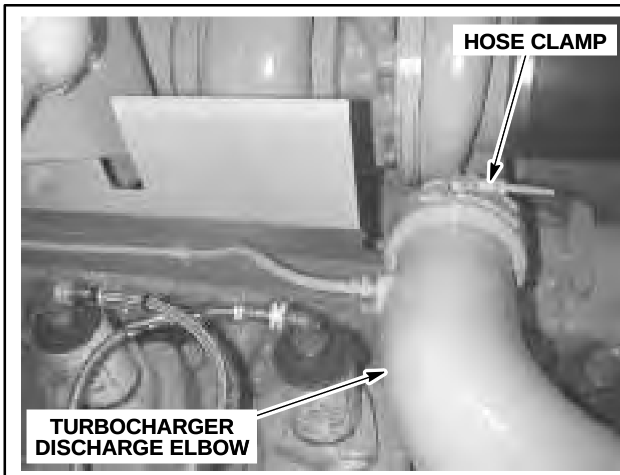


Figure 2.00-3. Turbocharger Discharge Elbow

6. Remove M12 x 35 mm hex head screws and remove turbocharger discharge elbow (see Figure 2.00-4).

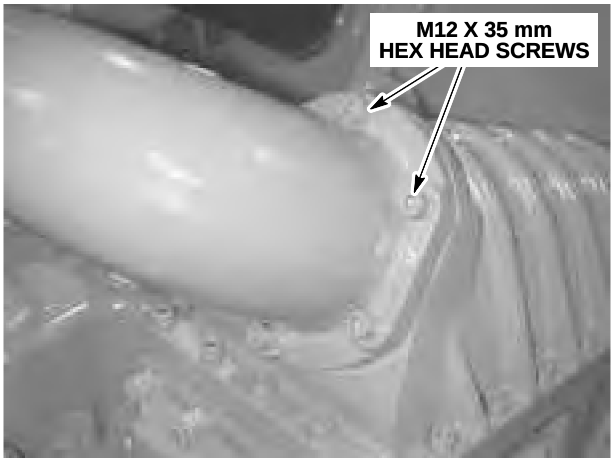


Figure 2.00-4. Turbocharger Discharge Elbow

7. Remove turbocharger heat shield if required (see Figure 2.00-5).

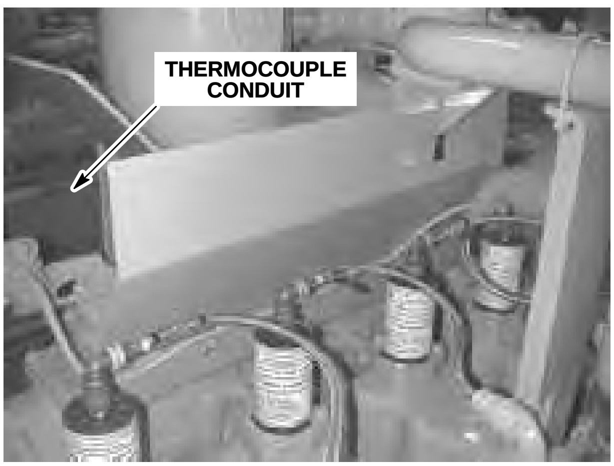


Figure 2.00-5. Heat Shield

8. **Non CSA—**Remove high tension lead and spark plug cover tube from cylinder head (see Figure 2.00-6).

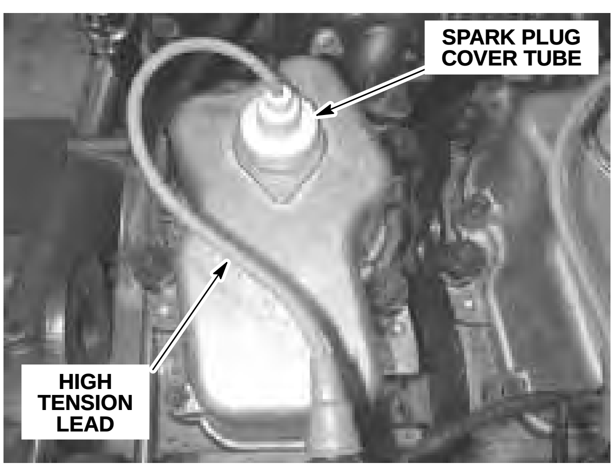


Figure 2.00-6. High Tension Coil Lead

9. **Non CSA—**Remove spark plug. Use Tool P/N 472065 to hold spark plug tube while removing spark plug (see Figure 2.00-7).

Figure 2.00-7. Spark Plug Tube Tool – P/N 472065

10. **Non CSA—**Remove four M10 hex nuts and flat washers and lift rocker arm cover from cylinder head (see Figure 2.00-8).

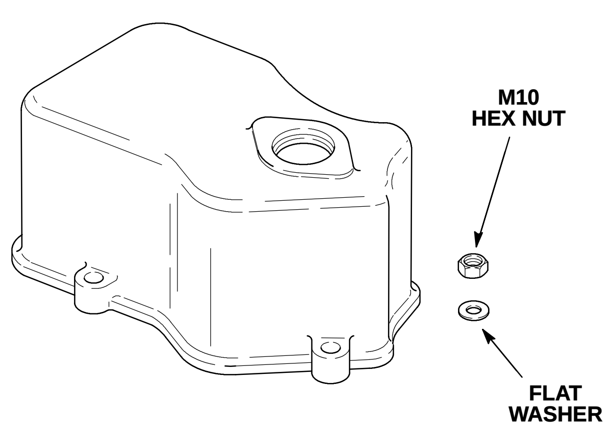


Figure 2.00-8. Rocker Arm Cover – Standard

CAUTION **Always remove the coil and spark plug extension first, then remove the rocker cover. Do not use the CSA flange mounted ignition coil as a handle when lifting the rocker cover. The CSA coil can be damaged if it is used to lift the rocker cover.**

11. **CSA—**Disconnect high tension lead from flange mounted coil (see Figure 2.00-9).

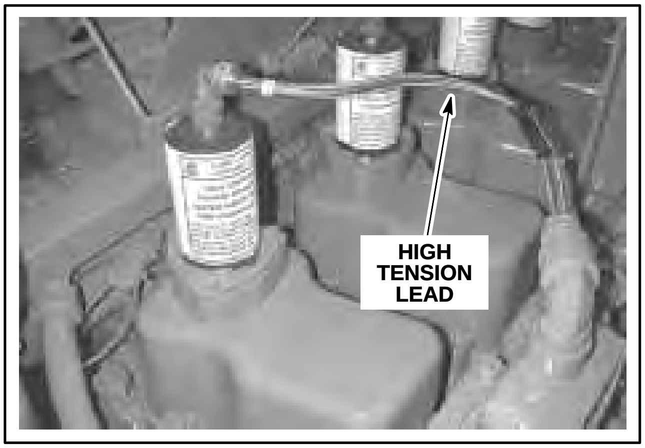


Figure 2.00-9. CSA High Tension Lead

12. **CSA—**Remove M8 x 20 mm hex head screws from flange mounted ignition coil (see Figure 2.00-10).

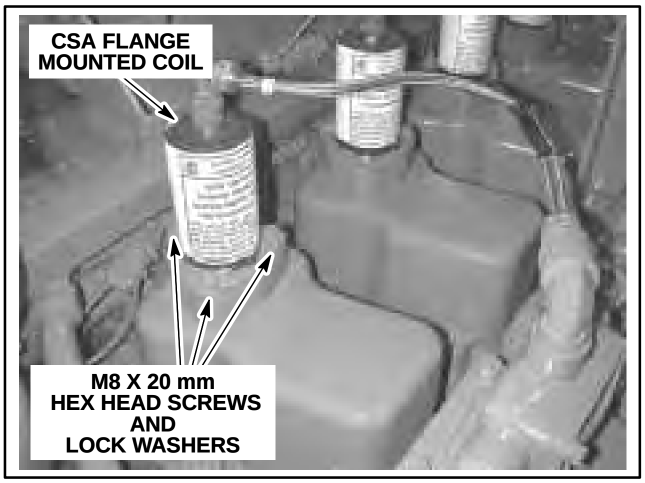


Figure 2.00-10. CSA Flange Mounted Coil

13. **CSA—**Remove coil and spark plug extension from rocker arm cover.

14. **CSA—**Remove spark plug. Use Tool P/N 472065 to hold spark plug tube (see Figure 2.00-11).

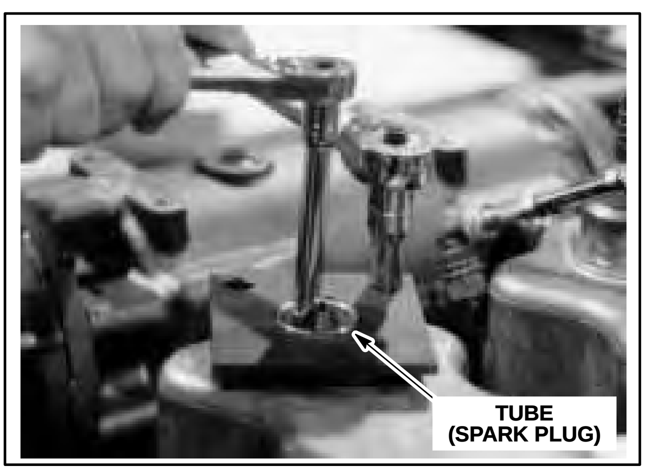


Figure 2.00-11. Spark Plug Tube Tool – P/N 472065

15. **CSA—**Remove four hex nuts and lock washers from rocker arm cover (see Figure 2.00-12).

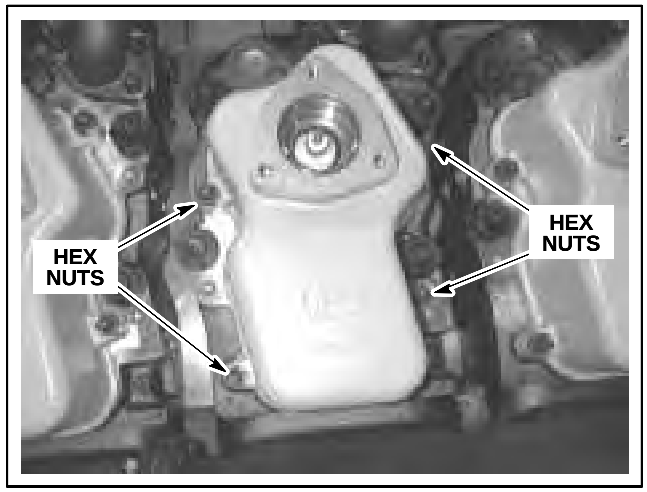


Figure 2.00-12. CSA Rocker Arm Cover

NOTE: *Engines that are equipped with flange mounted shielded ignition coils (CSA) have very tight clearances between the rocker arm cover and the recess tube. To prevent damage to the ignition coil or rocker arm cover, use the rocker arm cover removal tool (P/N 472074) during disassembly.*

16. **CSA—**Install disc on top of rocker arm cover and secure with M8 hex head screws (see Figure 2.00-13).

17. **CSA—**Turn puller screw clockwise. Continue turning screw until rocker arm cover is clear of recess tube (see Figure 2.00-13).

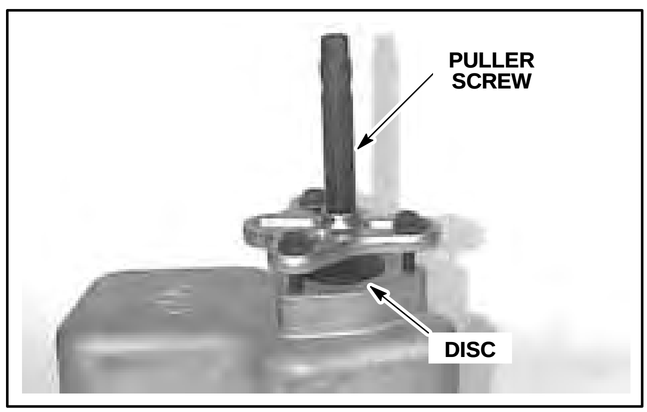


Figure 2.00-13. Rocker Arm Cover Removal Tool

18. **CSA—**Remove rocker arm cover from cylinder head.

19. Remove M10 x 110 mm hex head screws from rocker arm stand (see Figure 2.00-14).

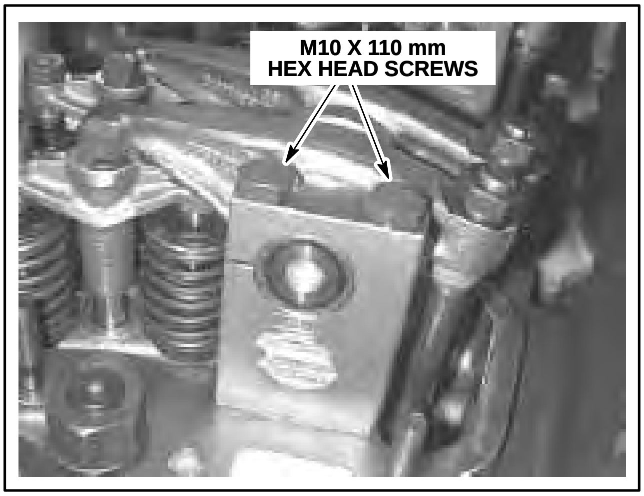


Figure 2.00-14. Rocker Arm Support Installation

20. Remove M10 x 35 mm hex head screws from rocker arm stand (see Figure 2.00-16). Use rocker arm support wrench P/N 472015 (see Figure 2.00-15). Remove rocker arm stand.

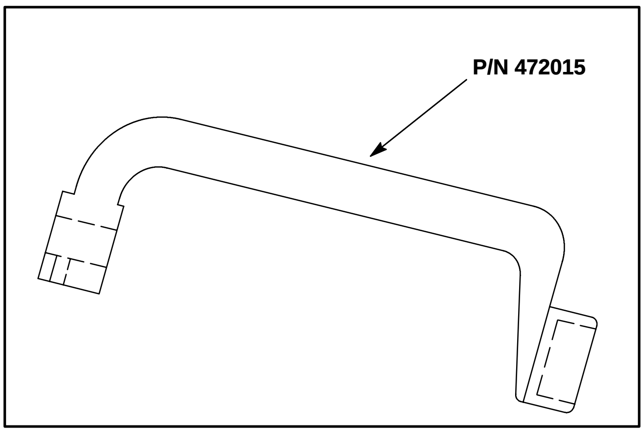


Figure 2.00-15. Rocker Arm Support Wrench

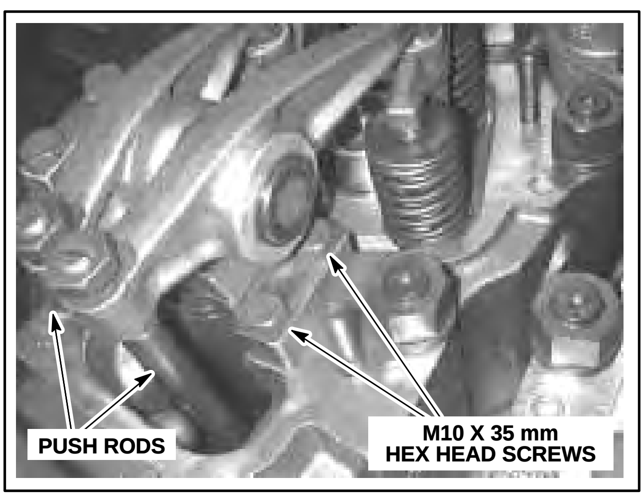


Figure 2.00-16. Rocker Arm Support Installation

21. Remove push rods. Record location.

22. Remove cross bar seats and cross bars from cylinder head (see Figure 2.00-17).

23. Remove rocker arm cover recess tube.

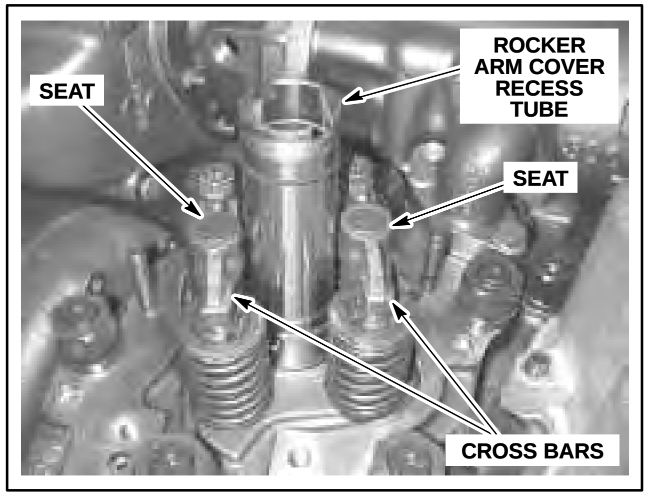


Figure 2.00-17. Cross Bar Installation

NOTE: *Do not remove the intake manifold or exhaust manifold if only one cylinder head is going to be removed. For instructions on removing the entire intake or exhaust manifold see Section 5.15* Air Induction System, *"Intake Manifold Removal" and Section 5.35* Exhaust System, *"Exhaust Manifold Removal."*

24. Remove M12 x 140 mm and M10 x 40 mm hex head screws from intake manifold (only for cylinder heads being removed) (see Figure 2.00-18).

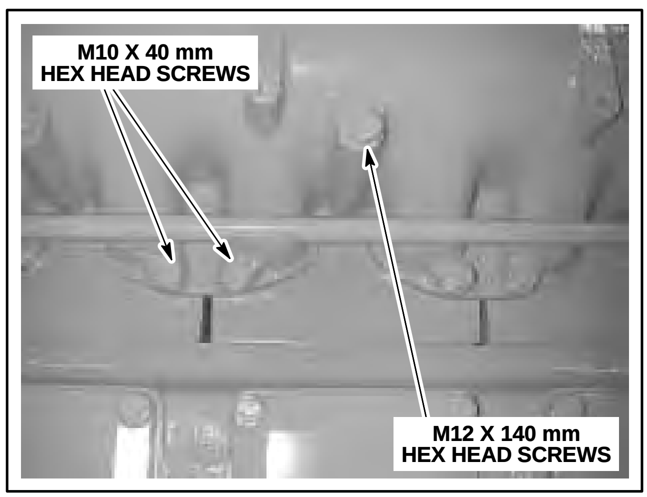


Figure 2.00-18. Intake Manifold

25. Remove governor regulating shaft if it interferes with cylinder head removal (see Figure 2.00-19).

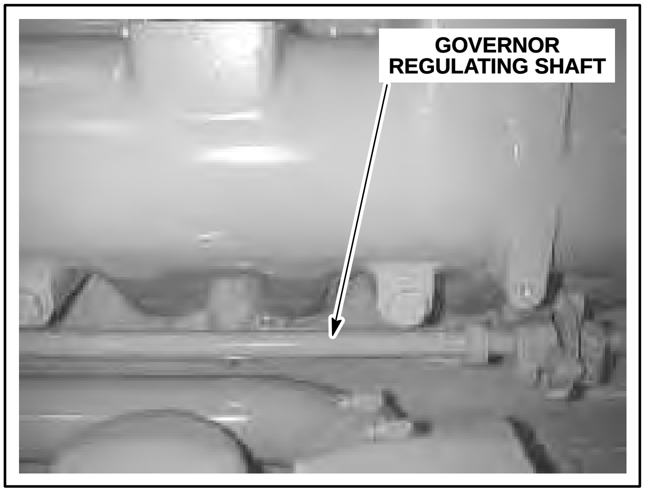


Figure 2.00-19. Intake Manifold

26. Loosen all remaining intake manifold hex head screws on entire cylinder bank, regardless of number of cylinder heads being removed (see Figure 2.00-20).

27. Remove M12 x 150 mm and M12 x 50 mm hex head screws from exhaust manifold (only for cylinder heads being removed) (see Figure 2.00-20).

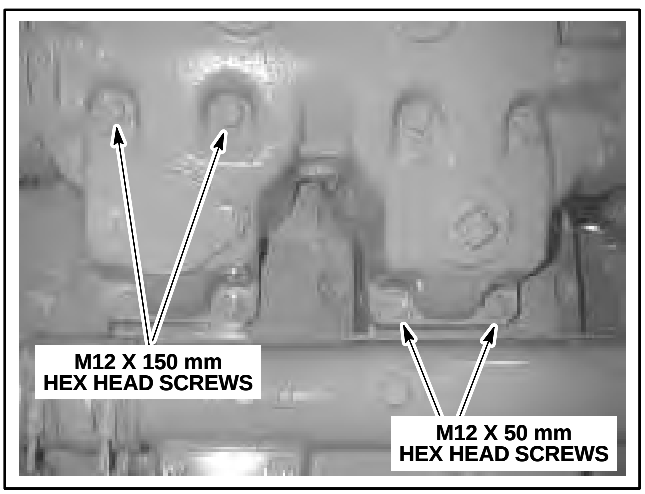


Figure 2.00-20. Exhaust Manifold

28. **CSA—**If required remove U-bolts from intake manifold to provide additional clearance between CSA conduit and cylinder head (see Figure 2.00-21).

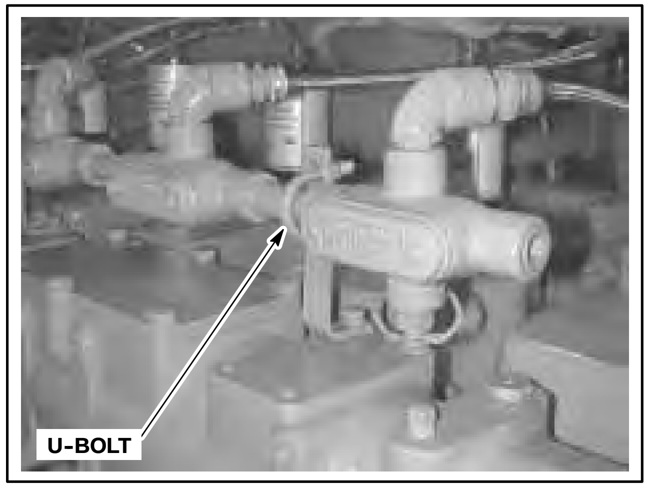


Figure 2.00-21. CSA Conduit

29. Remove vortox separator bracket if it interferes with cylinder head removal (see Figure 2.00-22).

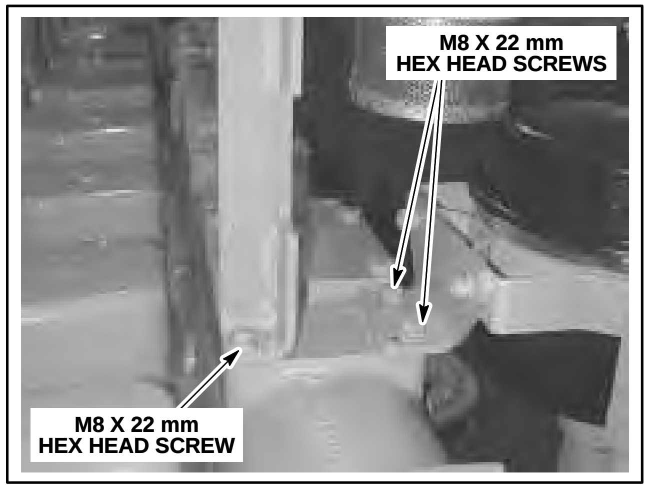


Figure 2.00-22. Vortox Separator Bracket

30. **Current Engines—**Remove four M10 x 35 mm socket head screws and remove water elbow (see Figure 2.00-23).

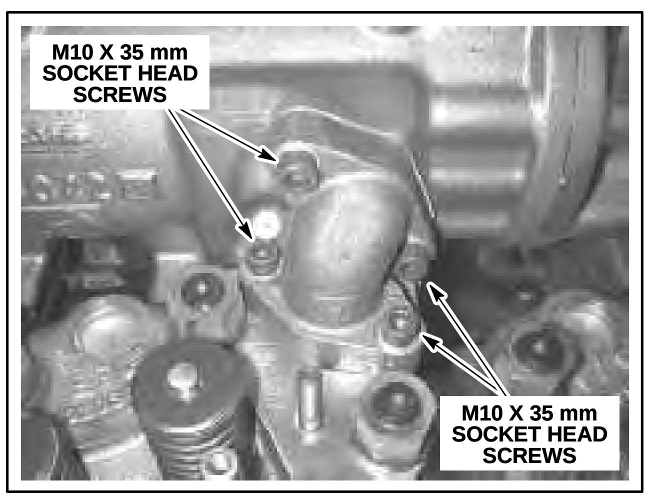


Figure 2.00-23. Current—Water Elbow Assembly

31. **Previous Engines—**Remove four M10 x 35 mm hex head screws and remove water elbow (see Figure 2.00-24).

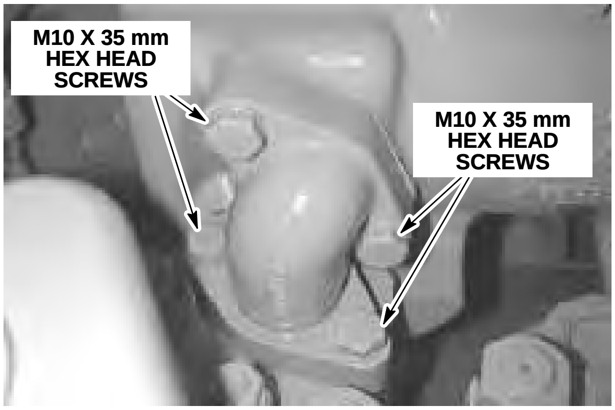


Figure 2.00-24. Previous—Water Elbow Assembly

32. Loosen exhaust manifold hex head screws on cylinder head next to one being removed.

33. Secure lifting device to rocker arm cover studs (see Figure 2.00-25).

Figure 2.00-25. Rocker Arm Cover Studs

34. Remove cylinder head nuts (six) and washers (see Figure 2.00-26).

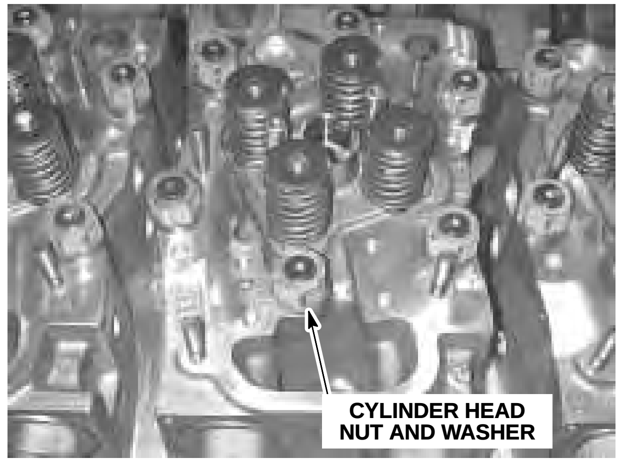


Figure 2.00-26. Cylinder Head

35. Remove lifting eye support bracket from last cylinder head (see Figure 2.00-27).

Figure 2.00-27. Lifting Eye

⚠ WARNING

VGF cylinder heads weigh 80 lb. (36 kg) each. Never walk or stand under an engine or component while it is suspended. Use only properly maintained lifting equipment that has a lifting capacity greater than the known weight of the object to be lifted. Disregarding this information could result in severe personal injury or death.

⚠ CAUTION **Raise the cylinder head at an angle that closely approximates the angle of the crankcase to avoid damage to the deck surface or the parallel pins. Disregarding this information could result in product damage.**

36. Lift cylinder head off crankcase head studs at an angle that closely approximates the angle of the crankcase. Cylinder heads weigh 80 lb. (36 kg) each. Lift only with properly rated lifting device.

CAUTION **Position the cylinder heads on a wooden board or pallet. Place each head on its side to avoid damage to the gasket surface. Disregarding this information could result in product damage.**

37. Remove head gasket. Early model head gaskets contain an oil bushing and O-ring (see Figure 2.00-28 and Figure 2.00-29).

38. Remove exhaust gasket and any other foreign material from crankcase deck.

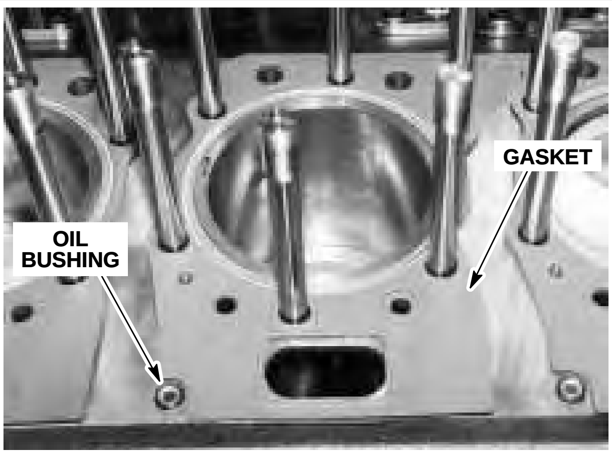


Figure 2.00-28. Cylinder Head Gasket - P/N 300000B

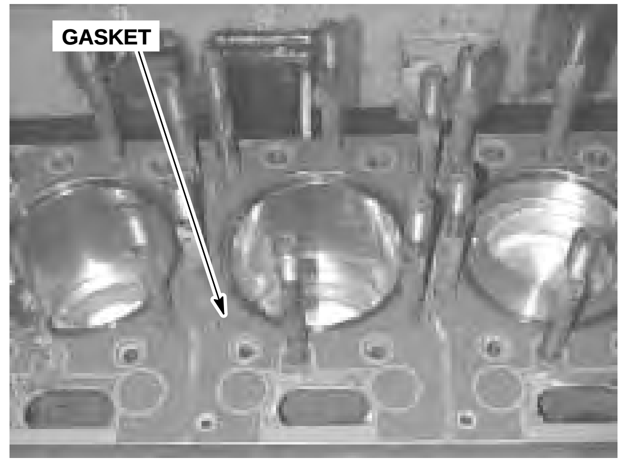


Figure 2.00-29. Cylinder Head Gasket - P/N 300000D

39. Remove and discard O-rings from cylinder head (see Figure 2.00-30).

Figure 2.00-30. Intake Manifold O-Rings

SECTION 2.05

CRANKCASE COMPONENT REMOVAL

Table 2.05-1. Special Tools For Crankcase

TOOL P/N	TOOL DESCRIPTION
472007	Piston Removal Tool
472013	Cylinder Liner Installation/Removal Tool
742055	Camshaft Pilot Tool
472002	Crankcase Spreader Tool

PISTON COOLING JET REMOVAL

The piston cooling jets are located in the crankcase and direct cooling oil to the pistons. The piston cooling jets are installed after the piston and liner to prevent possible damage to the jet. Remove the piston cooling jets to prevent damage during piston and sleeve removal. The jets may be reached by removing the connecting rod inspection doors.

NOTE: *Record the cylinder number the cooling jet was positioned at so that it can be reinstalled in its original location.*

1. Remove M10 x 20 mm hex head screws and remove connecting rod inspection cover (see Figure 2.05-1).

Figure 2.05-1. Connecting Rod Inspection Cover

2. Remove M8 socket head screw and M14 hollow screw (see Figure 2.05-2). Remove piston cooling jet.

NOTE: *Engine may contain a copper washer that is installed with the M14 hollow screw. If the piston cooling jet contains a copper washer make sure it is installed during assembly.*

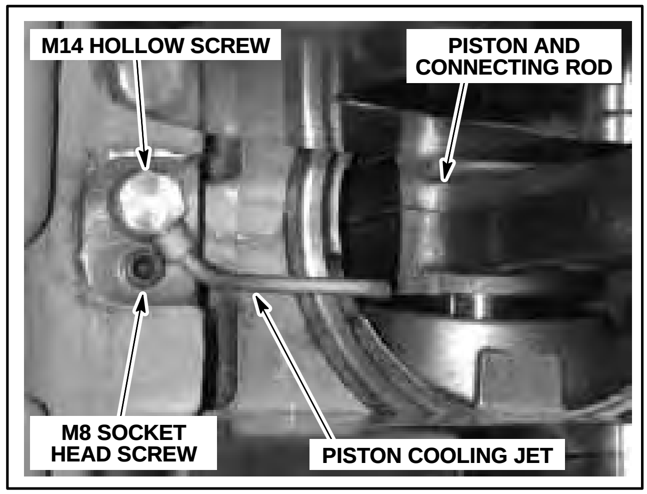


Figure 2.05-2. Piston Cooling Jet

NOTE: *See Section 5.30* Lubrication System *"Piston Cooling Jets" for information on previous versions of cooling jets.*

3. Inspect piston cooling jet for cracks or damage.

PISTON REMOVAL

NOTE: *This procedure assumes the cylinder heads have already been removed from the crankcase. See Section 2.00* Cylinder Head Removal *for instructions on removing the cylinder heads.*

NOTE: *Drain all engine oil before proceeding. Engine coolant should already be drained.*

1. Remove M10 x 20 mm hex head screws and remove connecting rod inspection cover (see Figure 2.05-1).

2. Remove piston cooling jet, if applicable.

3. Bar engine over until connecting rod cap has rotated into a position that allows access to connecting rod bolts (see Figure 2.05-3).

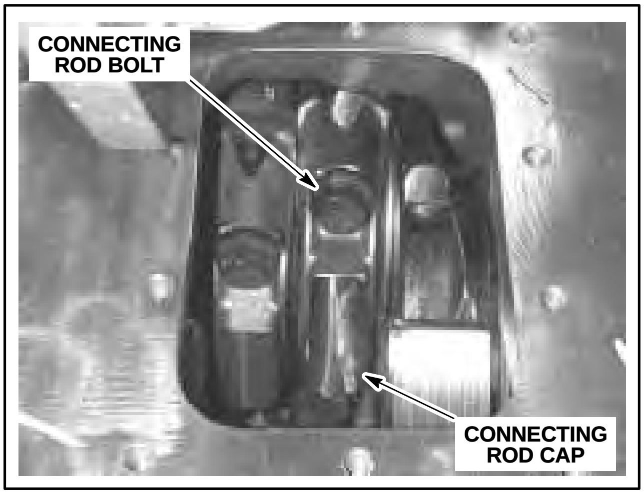


Figure 2.05-3. Connecting Rod Access

CAUTION Connecting rods and caps are matched sets. Do not intermix the connecting rods and caps. Additionally, bearing halves, if removed from the connecting rods should not be intermixed. Disregarding this information could result in product damage.

4. Remove connecting rod bolts and connecting rod cap. Bearings must remain with their mated connecting rod and cap (see Figure 2.05-4). "Tag" bearings (if removed) with connecting rod number for ease of assembly.

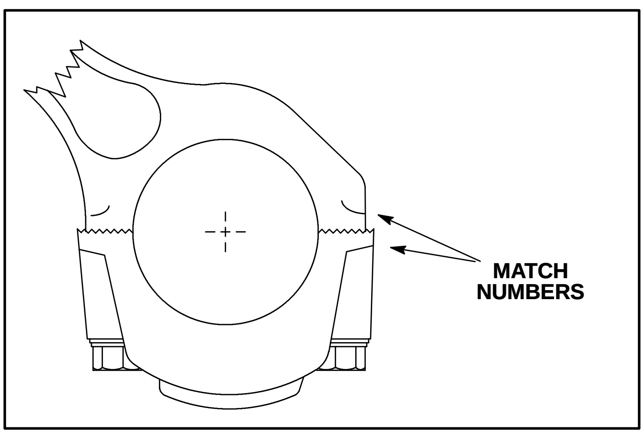


Figure 2.05-4. Match Cap And Rod Numbers

NOTE: *Bar the engine over to move each piston to its lowest point of travel to ensure removal of the entire carbon ridge and to avoid nicking or scratching the piston with the carbon scraper.*

5. Remove cylinder liner carbon ridge. Use a suitable carbon scraper (see Figure 2.05-5).

CAUTION Avoid scraping too deep into the cylinder liner bore when removing the carbon ridge. Cutting too deep into the cylinder liner bore could damage the ring travel zone. Disregarding this information could result in product damage.

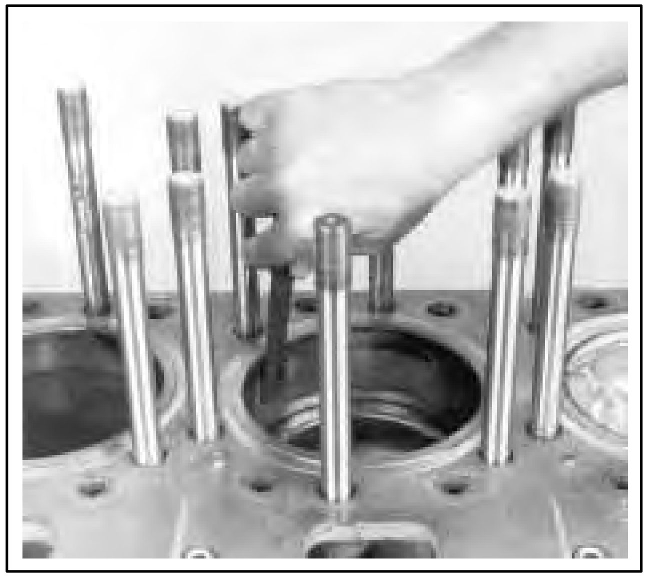


Figure 2.05-5. Carbon Removal

6. Install piston removal/installation tool P/N 472007 (see Figure 2.05-6).

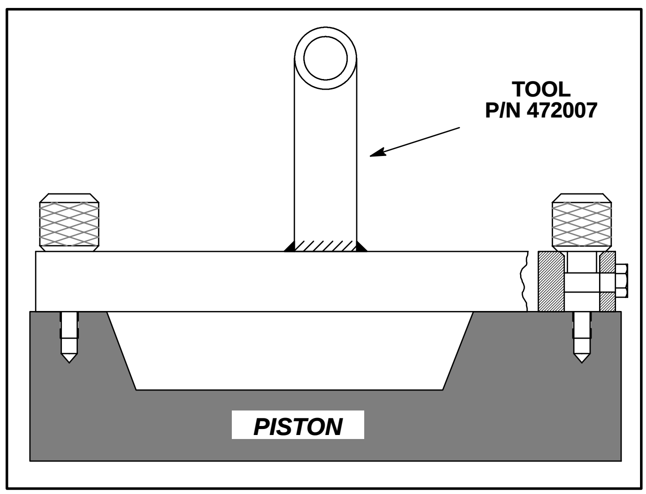


Figure 2.05-6. Piston Removal/Installation Tool

CAUTION Do not allow the connecting rod to make contact with the cylinder liner or crankshaft. Wrap shop rags around the end of the connecting rod to prevent the rod end from scratching the cylinder liner or crankshaft. Disregarding this information could result in product damage.

7. Carefully remove piston and rod assembly (see Figure 2.05-7).

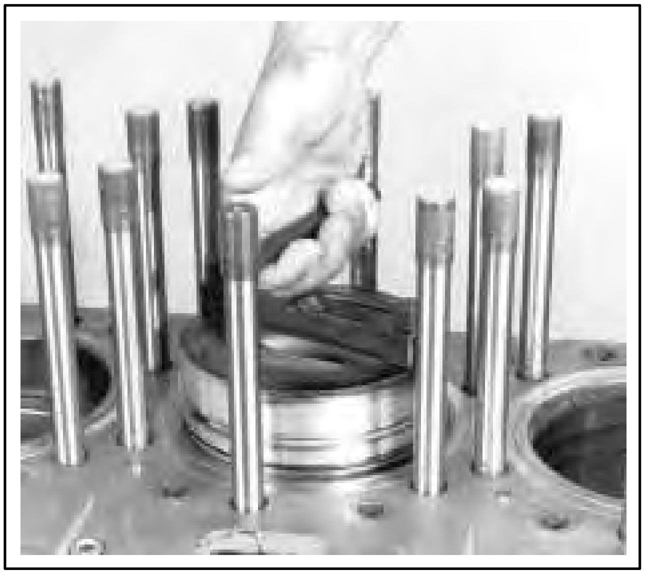


Figure 2.05-7. Piston Removal

8. Place rod cap on connecting rod and secure with connecting rod bolt. Verify rod cap and connecting rod are a matched set.

⚠ CAUTION Do not bar the crankshaft over while rod caps are removed. Completely remove the piston and connecting rod assembly before barring over the engine. Disregarding this information could result in product damage.

9. Remove remaining pistons.

CYLINDER LINER REMOVAL

1. Install hex nuts on four cylinder head studs.

2. Install cylinder liner removal tool (P/N 472013) into cylinder liner (see Figure 2.05-8 and Figure 2.05-9).

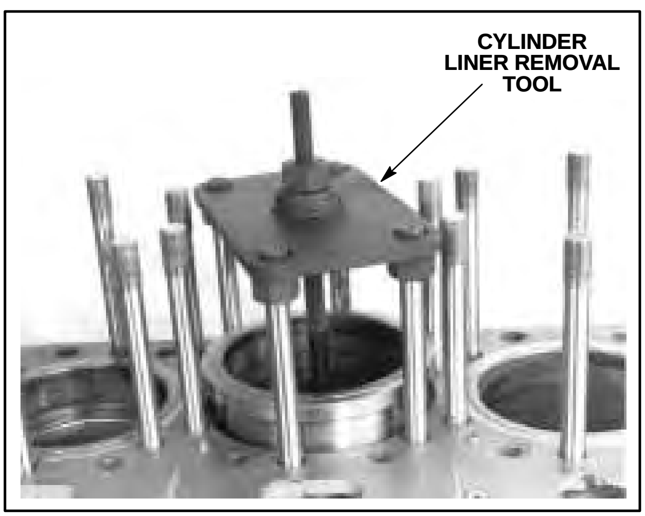


Figure 2.05-8. Cylinder Sleeve Removal

3. Tighten center nut until liner is pulled from crankcase (see Figure 2.05-9).

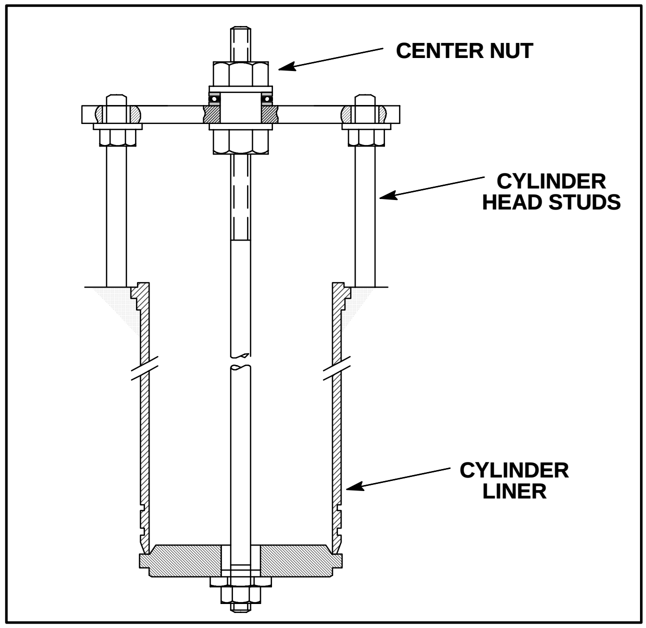


Figure 2.05-9. Sleeve Removal Tool

4. Pull tool and cylinder liner “up” to cylinder head nuts. Remove cylinder head nuts.

5. Remove tool with cylinder liner from crankcase.

PARALLEL PIN REMOVAL

Parallel pins are located in the upper right and lower left of each cylinder (see Figure 2.05-10). These pins position the head gasket and cylinder head in the proper location on the crankcase.

1. Thread an M5 hex head screw into parallel pin center (Figure 2.05-10). Pull pin out (by M5 hex head screw) using a slide hammer or puller.

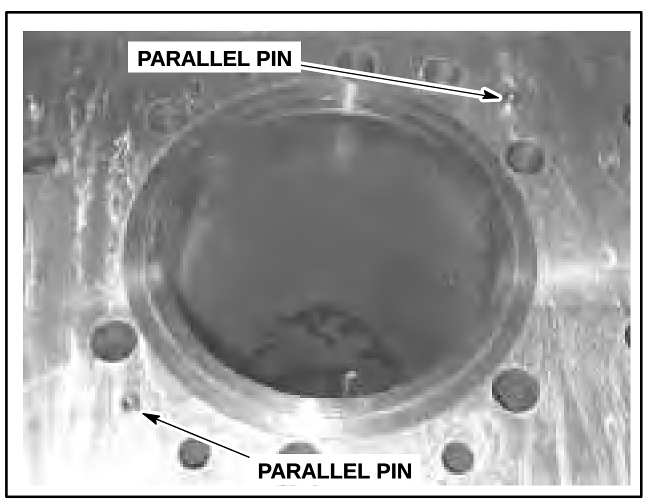


Figure 2.05-10. Parallel Pins

FRONT GEAR HOUSING REMOVAL

1. Remove breather system connection from right side gear housing, if equipped (see Figure 2.05-11).

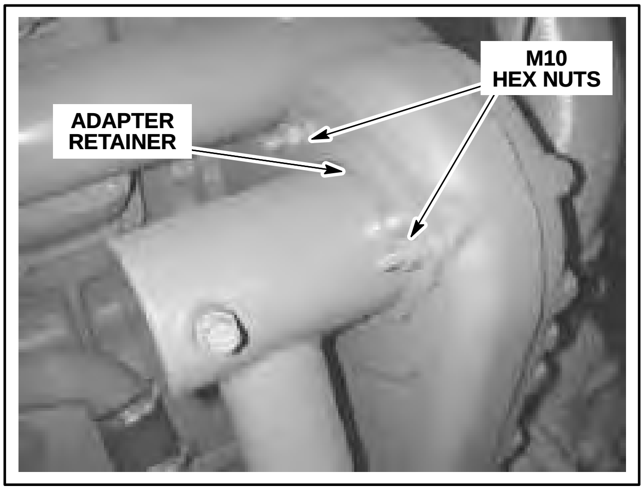


Figure 2.05-11. Upper Oil Separator Inlet Tube

2. Disconnect and remove auxiliary and jacket water pumps from gear housing (see Figure 2.05-12). Remove front section of water manifold that feeds water into block. See Section 5.25 *Cooling System* for complete cooling system information.

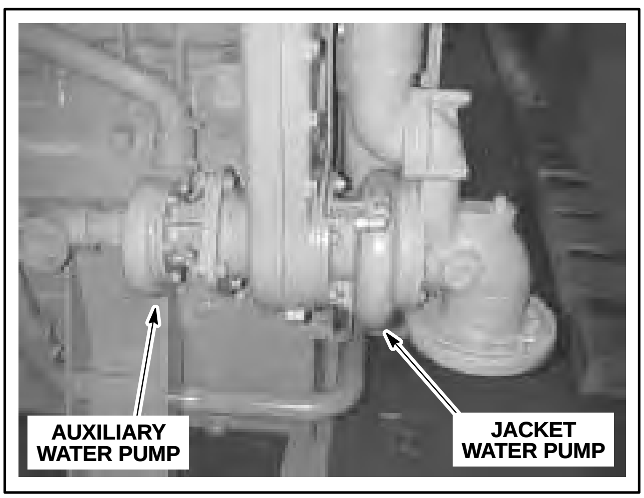


Figure 2.05-12. Auxiliary And Jacket Water Pumps

3. Remove water pump idler oil supply tube from back side of gear housing (see Figure 2.05-13).

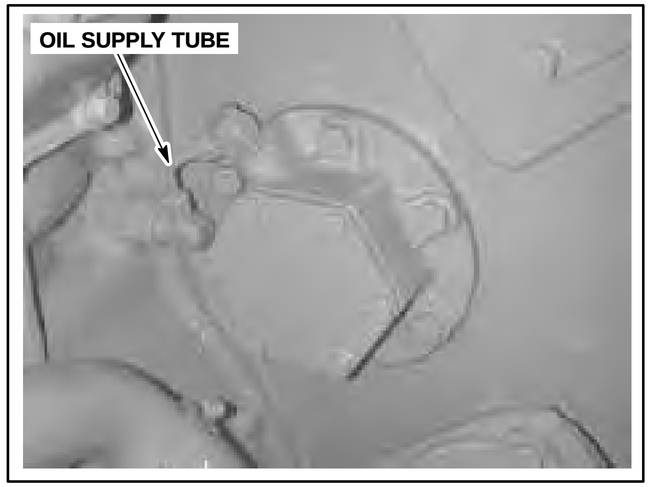


Figure 2.05-13. Water Pump Idler Oil Supply

4. Remove governor and drive from rear of gear housing (see Figure 2.05-14). See Section 5.00 *Engine Speed Governing System* for complete information.

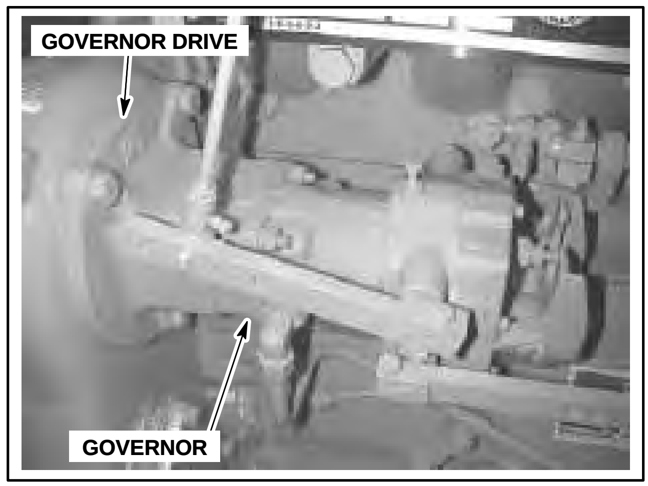


Figure 2.05-14. PSG Governor

5. Remove magneto and magneto drive from rear of gear housing (see Figure 2.05-15). See Section 5.10 *Ignition System – CEC/Magneto* for information.

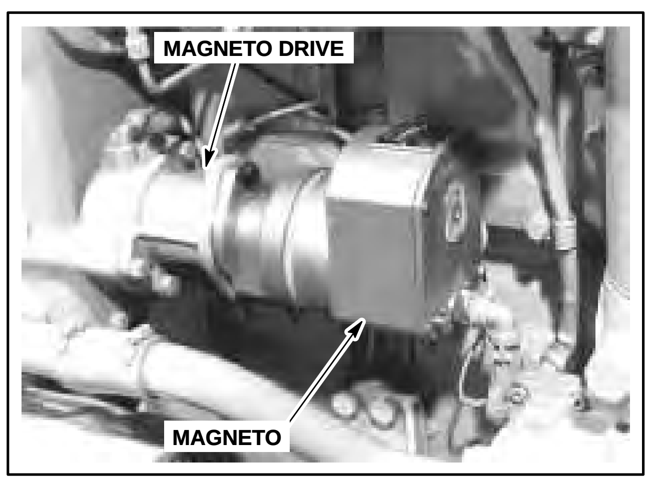


Figure 2.05-15. Magneto

6. Remove Hall-effect pickup (if equipped with CEC ignition) from front of gear housing (see Figure 2.05-16). See Section 5.10 *Ignition System - CEC/Magneto* for complete information.

Figure 2.05-16. Hall-effect Pickup Location

7. Remove hex head screws and spacers that hold vibration damper guard to front gear housing (see Figure 2.05-17).

Figure 2.05-17. Vibration Damper Guard

⚠ WARNING

The six cylinder vibration damper weighs 70 lb. (32 kg) and the eight cylinder vibration damper weighs 149 lb. (68 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

8. Remove one upper M12 socket screw and install M12 guide pin (see Figure 2.05-18).

Figure 2.05-18. Vibration Damper

9. Remove remaining M12 socket screws. Install suitable lifting device and remove vibration damper.

10. Remove M12 socket screws and damper driving flange from front of crankshaft (Figure 2.05-19).

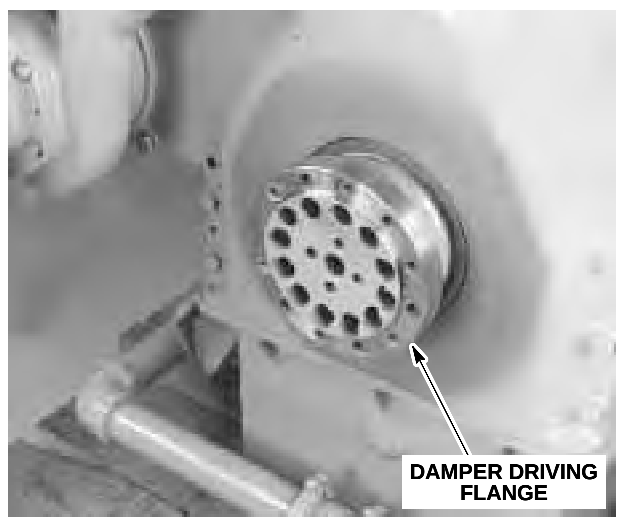


Figure 2.05-19. Damper Driving Flange

Crankshaft Front Seal Replacement

1. Use a rolling pry bar to pull seal out of gear cover (see Figure 2.05-20).

Figure 2.05-20. Crankcase Seal Removal

2. Use driver (P/N 472048) to drive seal into front gear cover (see Figure 2.05-21).

Figure 2.05-21. Front Crankshaft Seal Installation

NOTE: *The gear cover can be removed without removing the oil pan and damaging the oil pan gasket. Use a puller with an M8 capscrew to remove the threaded M12 x 70 mm dowel pins (see Figure 2.05-22).*

3. Remove M10 hex head screws that secure cover to gear housing. Remove M10 socket head screws that attach base of cover to oil pan.

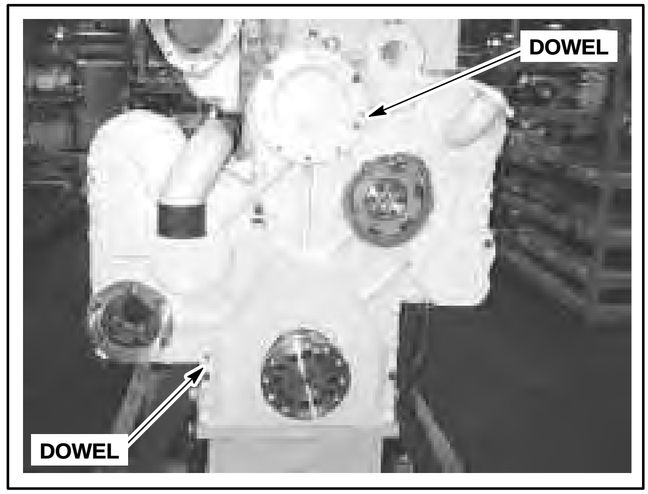


Figure 2.05-22. Front Gear Cover Dowel Locations

⚠ WARNING

The front gear cover weighs 106 lb. (48 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

4. Install lifting eyes into front gear cover. Secure lifting device to front cover (see Figure 2.05-23).

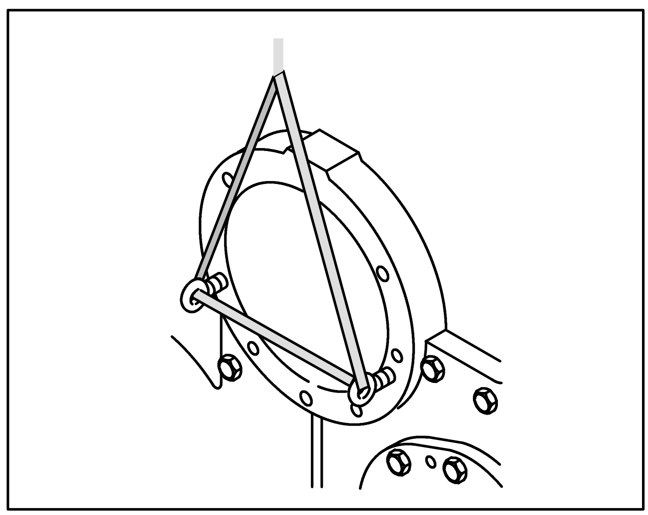


Figure 2.05-23. Lifting The Gear Housing

5. Remove camshaft, intermediate gear and water pump idler gears from gear housing (see Figure 2.05-24).

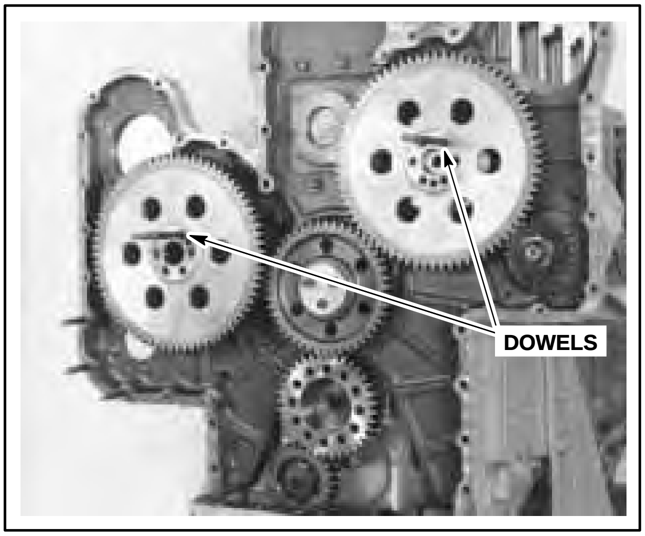


Figure 2.05-24. Camshaft And Idler Gear Removal

⚠ WARNING

The front gear housing weighs 98 lb. (44 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

6. Remove thrust flange from camshaft area of gear housing (see Figure 2.05-25).

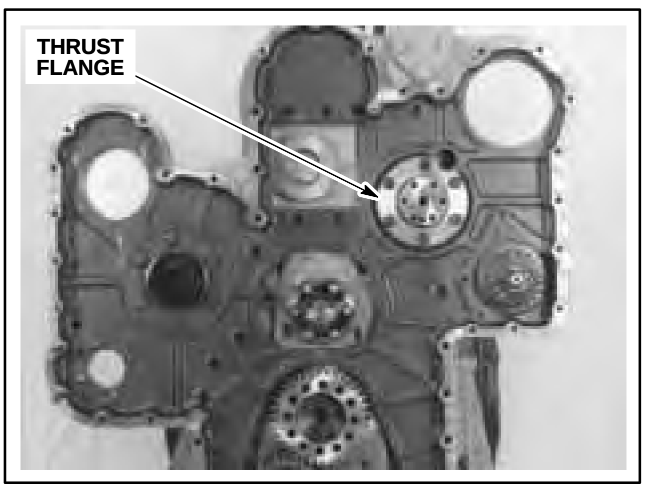


Figure 2.05-25. Camshaft Thrust Flange

NOTE: *The camshaft may be removed from the crankcase without removing the gear housing.*

7. Attach a lifting device to gear housing. Remove M10 hex head screws that attach gear housing to crankcase (see Figure 2.05-26).

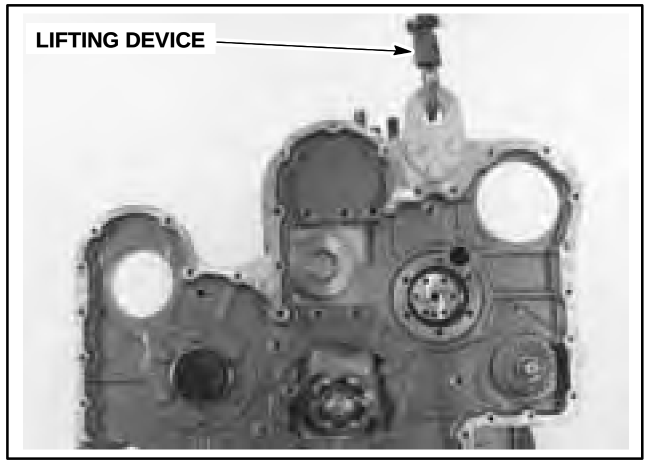


Figure 2.05-26. Front Gear Housing

8. Remove front crankshaft gear (see Figure 2.05-27).

Figure 2.05-27. Crankshaft Gear Removal

9. Remove oil pump idler gear from front bearing cap (see Figure 2.05-28).

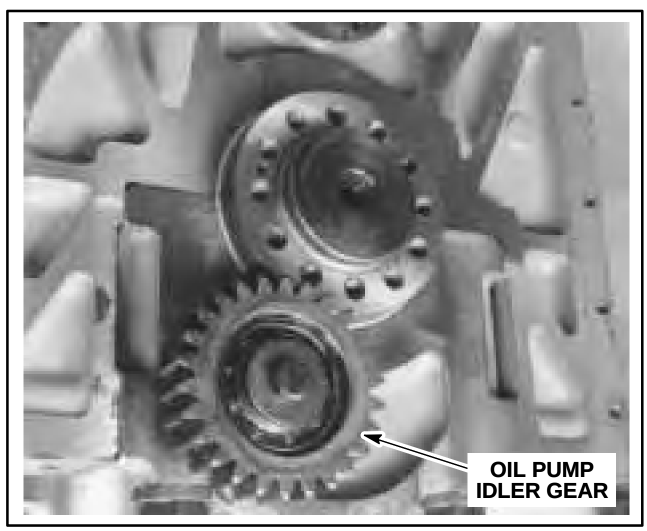


Figure 2.05-28. Oil Pump Idler Gear

ENGINE SUPPORTS REMOVAL

⚠ WARNING

With the prior components removed the six cylinder crankcase assembly weighs approximately 2,500 lb. (1,130 kg) and the eight cylinder crankcase weighs 3,300 lb. (1,500 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

1. Support crankcase with suitable equipment. Remove rear engine supports and brace from flywheel housing (see Figure 2.05-29).

Figure 2.05-29. Rear Engine Support

2. Remove front engine supports from both sides of crankcase (see Figure 2.05-30).

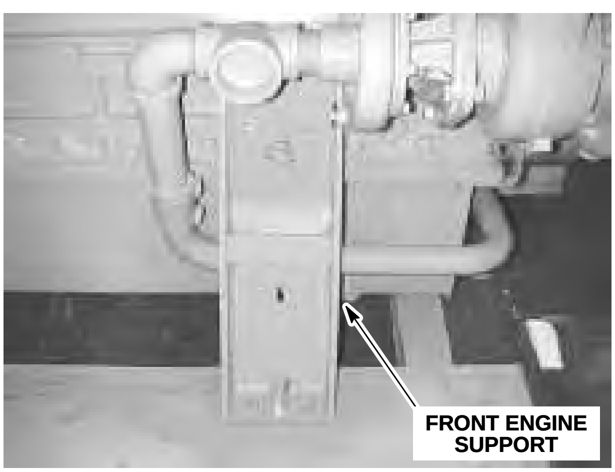


Figure 2.05-30. Front Engine Support

FLYWHEEL AND FLYWHEEL HOUSING REMOVAL

1. Disconnect and remove starter from flywheel housing (see Figure 2.05-31). See Section 5.45 *Starting System* in this manual for complete information.

Figure 2.05-31. Electric Starter

2. Remove barring device from flywheel housing (see Figure 2.05-32).

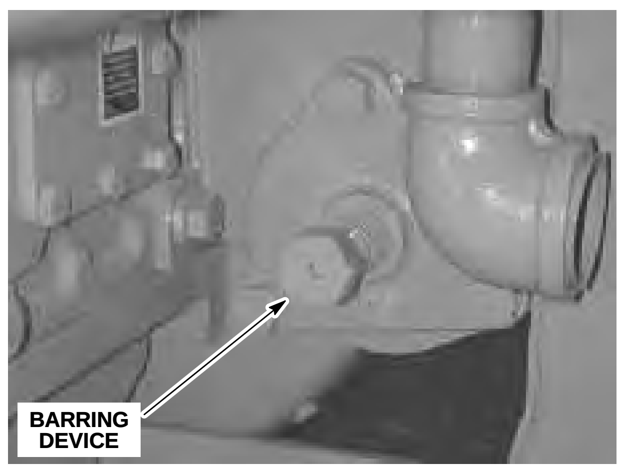


Figure 2.05-32. Barring Device

3. Remove two flywheel capscrews and install alignment dowels. Install a lifting device onto flywheel (see Figure 2.05-33). Remove remaining hex head screws.

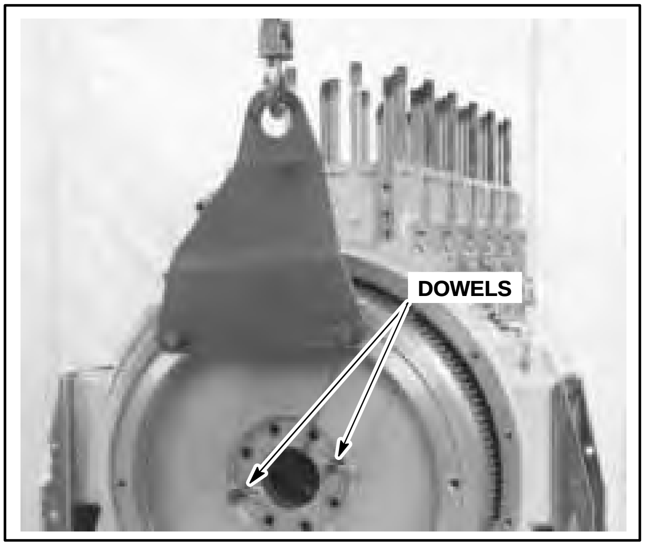


Figure 2.05-33. Flywheel Removal

⚠ WARNING

The flywheel weighs 240 lb. (109 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

4. Remove flywheel and dowels from engine.

⚠ WARNING

The flywheel housing weighs 190 lb. (86 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

5. Install a lifting sling through timing holes in flywheel housing (see Figure 2.05-34). Remove two hex head screws from crankcase and install alignment dowels.

6. Remove flywheel housing by sliding it off dowels.

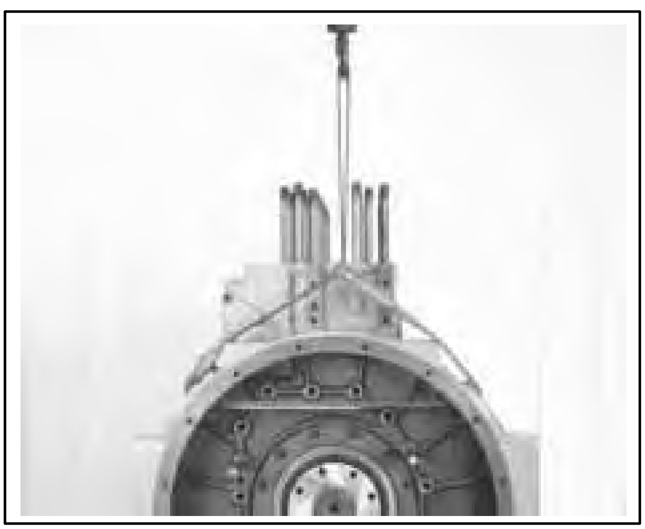


Figure 2.05-34. Flywheel Housing Removal

Crankshaft Rear Seal Replacement

The crankshaft rear seal carrier can be removed without removing the flywheel housing.

1. Use a puller and M10 hex head screws to remove two alignment dowels. Remove rear seal carrier hex head screws from back of crankcase. Remove oil pan hex head screws from carrier (see Figure 2.05-35).

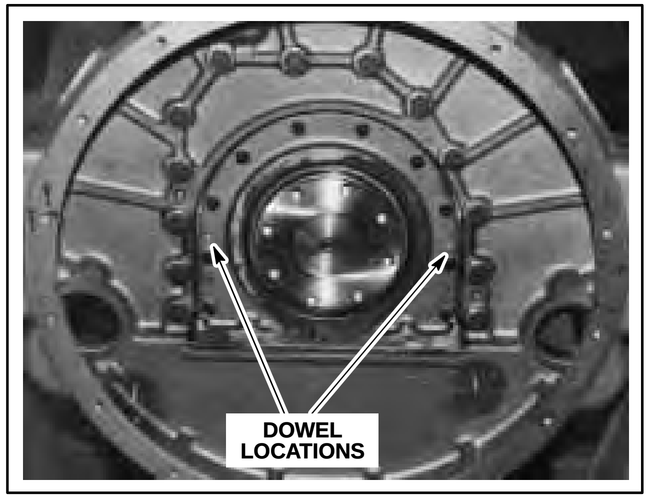


Figure 2.05-35. Rear Seal Carrier

2. Use M10 jackscrew locations to remove seal carrier from crankcase (see Figure 2.05-36).

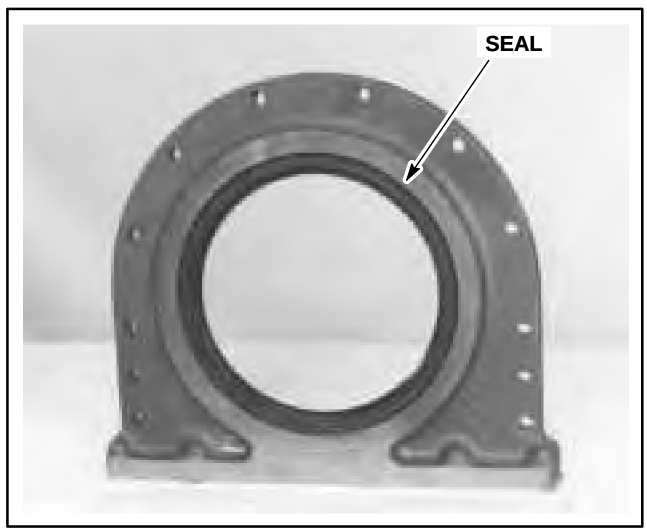


Figure 2.05-36. Rear Crankshaft Seal Carrier

3. Remove gasket from crankcase.

4. Use driver (P/N 472048) and drive seal into rear seal carrier.

5. Install alignment dowels in back of crankcase. Install new gasket and seal carrier onto rear of crankcase (over alignment dowels) (see Figure 2.05-37).

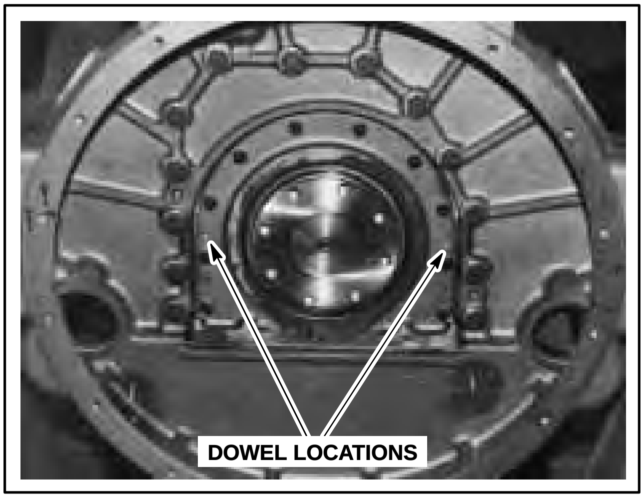


Figure 2.05-37. Rear Seal Carrier Installation

CAMSHAFT AND FOLLOWERS REMOVAL

NOTE: *The camshaft may be removed without removing the pivot shafts and cam followers by making an auxiliary rocker shaft arm holder tool (see Figure 2.05-38).*

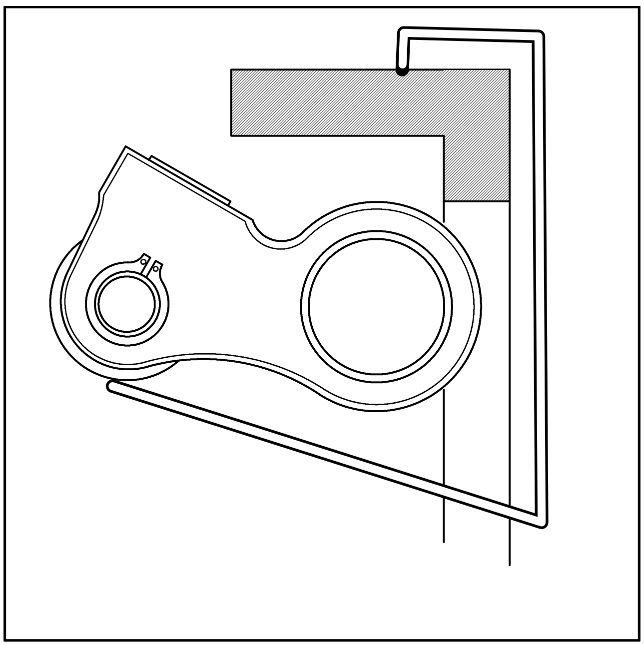


Figure 2.05-38. Cam Follower Holding Tool

CAM FOLLOWERS REMOVAL

NOTE: *The front gear housing does not have to be removed to remove the camshaft followers and shafts. Remove the Hall-effect sensor cover and CEC timing disc. Bar the engine over until the cam gear hole aligns with follower shaft (see Figure 2.05-39).*

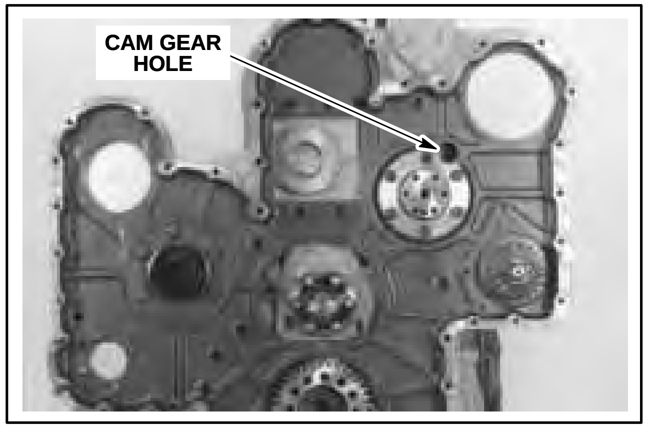


Figure 2.05-39. Camshaft Thrust Flange

1. Remove oil filters and baffle box from crankcase (see Figure 2.05-40).

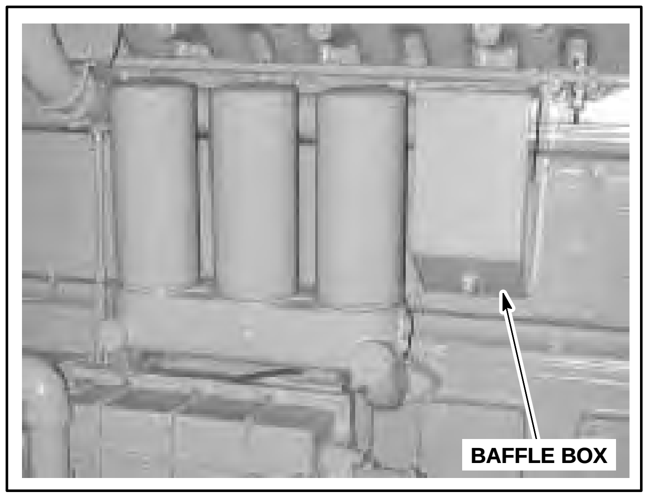


Figure 2.05-40. Lube Oil Filters

2. Remove fuel regulator support bracket from last two camshaft access doors (see Figure 2.05-41).

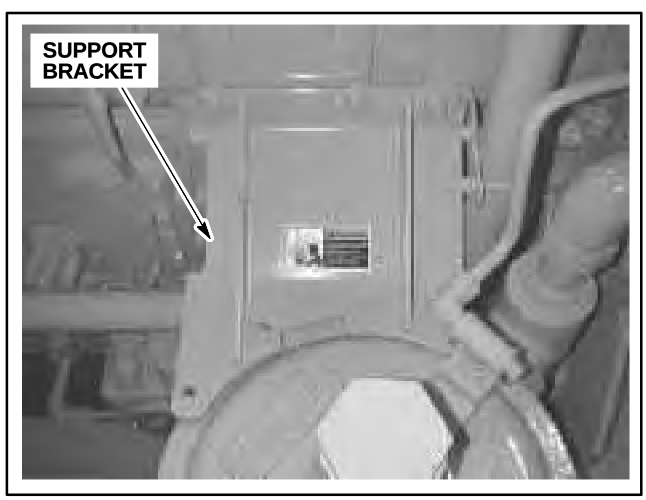


Figure 2.05-41. Regulator Support Bracket

3. Remove all camshaft access doors from crankcase (see Figure 2.05-42).

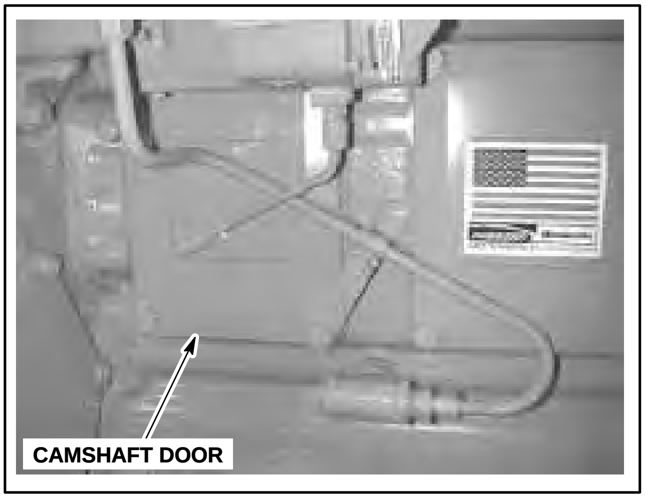


Figure 2.05-42. Camshaft Access Doors

NOTE: *The front gear cover has to be removed to remove the camshaft driving gear and camshaft.*

4. Remove thrust flange from front gear housing (see Figure 2.05-43).

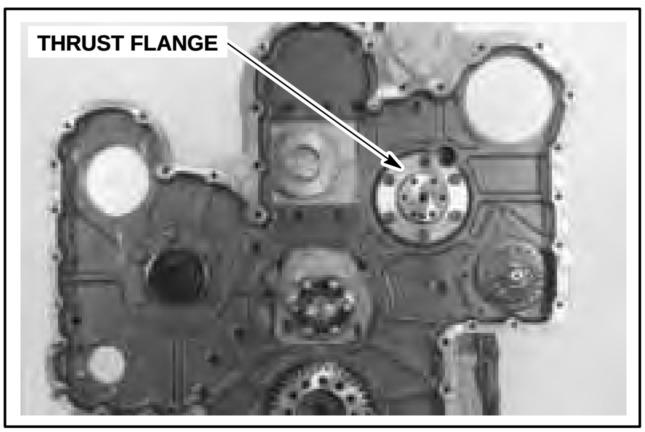


Figure 2.05-43. Camshaft Thrust Flange

5. Remove cam cover from rear of crankcase (see Figure 2.05-44).

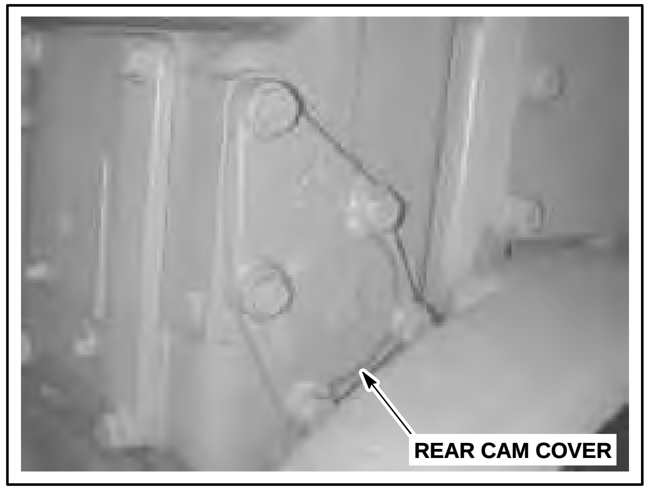


Figure 2.05-44. Rear Camshaft Cover

6. Remove hex nuts and socket head set screw (5 mm) that secure each rocker arm shaft (see Figure 2.05-45). Each shaft is held by two set screws.

Figure 2.05-45. Follower Shaft Retaining Screws

7. Insert a hex wrench into center of rocker arm shaft, rotate and remove front half of shaft while reaching into camshaft access hole and removing camshaft followers (see Figure 2.05-46 and Figure 2.05-47).

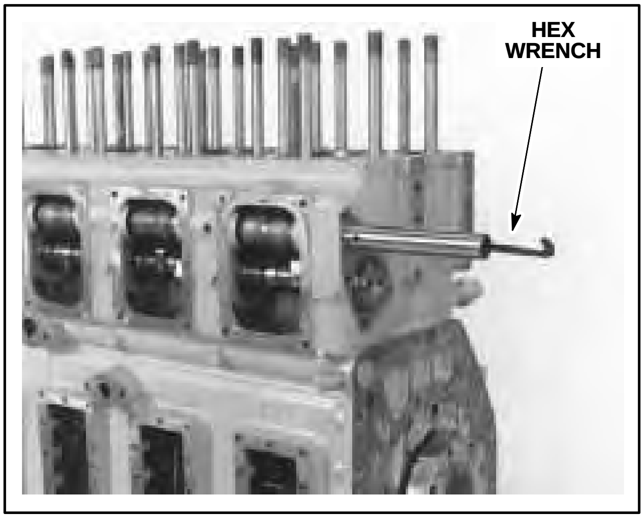


Figure 2.05-46. Rocker Arm Shaft Removal

8. Remove cam followers while pulling shaft out of crankcase (see Figure 2.05-47). Mark location of follower for assembly.

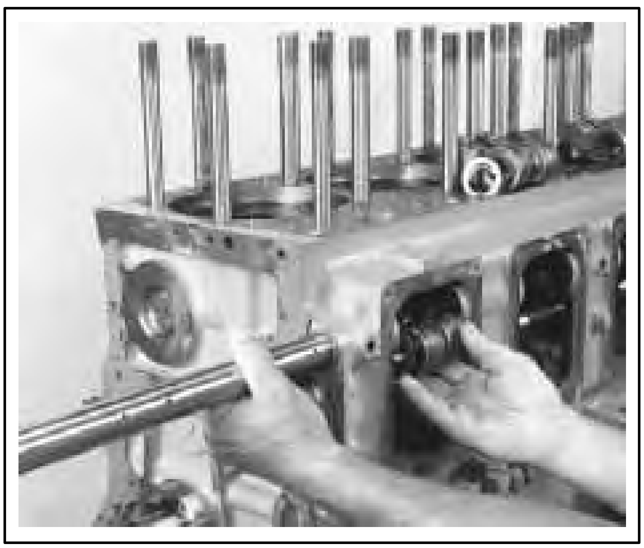


Figure 2.05-47. Camshaft Follower Removal

⚠ CAUTION **Care must be taken during camshaft removal to avoid damaging the camshaft lobes and camshaft bushings.**

⚠ WARNING

The six cylinder camshaft weighs 49 lb. (22 kg). The eight cylinder camshaft weighs 67 lb. (31 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

9. Thread camshaft removal/installation pilot tool, P/N 472024, into rear of camshaft (see Figure 2.05-48 and Figure 2.05-49).

NOTE: *Tool P/N 472024 can be used only if the flywheel housing has been removed.*

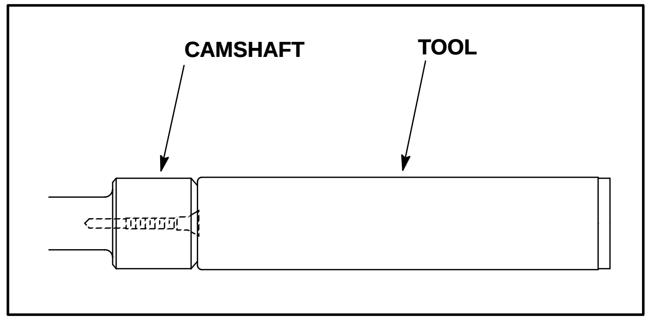


Figure 2.05-48. Camshaft Pilot Tool

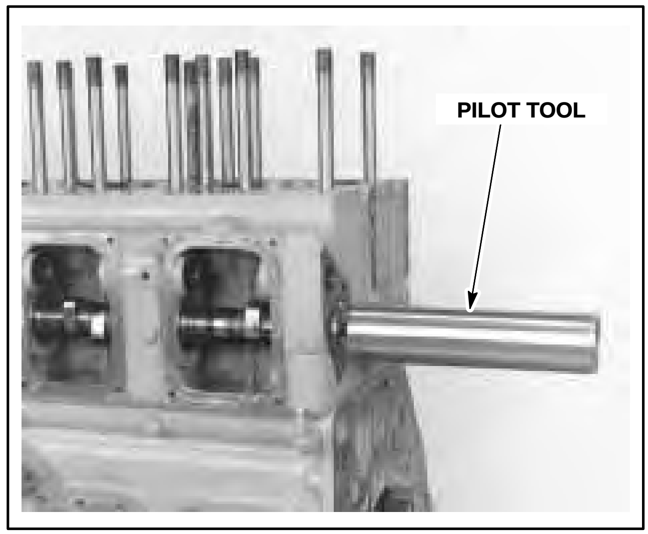


Figure 2.05-49. Camshaft Removal

OIL PAN REMOVAL

The oil pan can be removed from the crankcase assembly without removing the front gear and flywheel housings.

NOTE: *Oil pan removal requires a minimum of 29 in. (734 mm) clearance.*

1. Disconnect oil level regulator vent tube from regulator and cam cover (see Figure 2.05-50 and Figure 2.05-51). Disconnect crankcase ventilation system's left side oil separator oil drain tube.

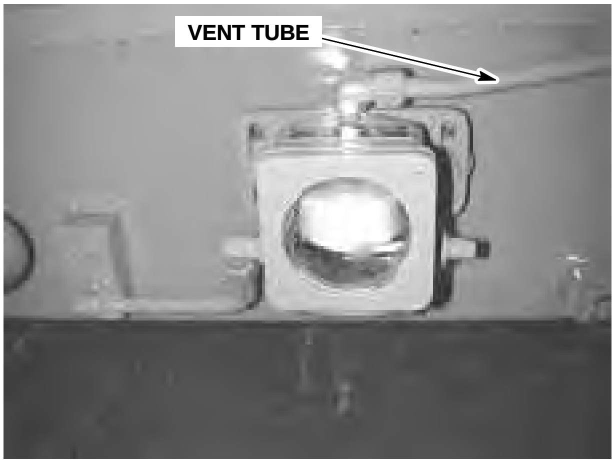


Figure 2.05-50. Lube Oil Leveler

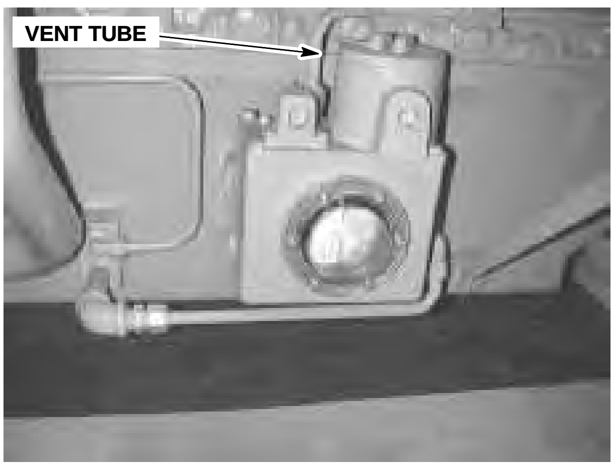


Figure 2.05-51. Lube Oil Leveler

2. Remove breather system oil separator and drain on right side of engine (see Figure 2.05-52).

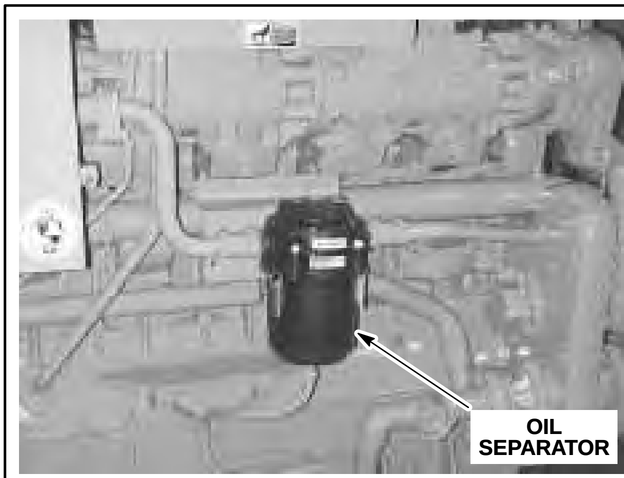


Figure 2.05-52. Breather System

3. Remove fuel regulator support bracket from oil pan (see Figure 2.05-53).

Figure 2.05-53. Fuel Regulator Support Bracket

4. Mark location and remove air/gas starter piping support bracket from oil pan (see Figure 2.05-54).

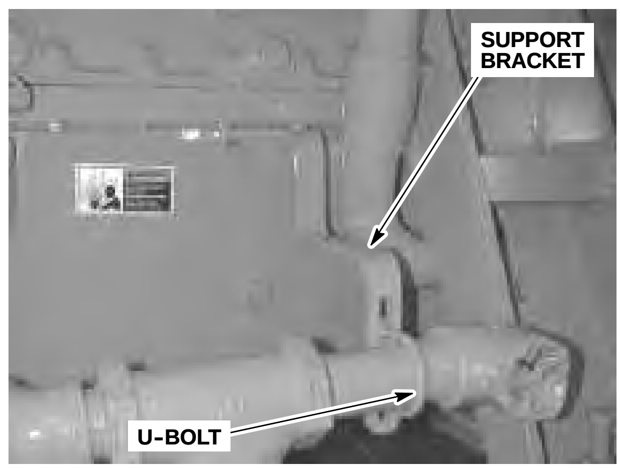


Figure 2.05-54. Air/Gas Starter Motor Connections

⚠ WARNING

The six cylinder oil pan weighs approximately 147 lb. (67 kg) and the eight cylinder oil pan weighs 187 lb. (85 kg). Use a suitable lifting device and exercise caution during removal or installation to avoid severe personal injury or death.

5. Remove oil pan from crankcase. A minimum clearance of 29 in. (734 mm) is required (see Figure 2.05-55). Make sure oil pump and piping is not damaged during pan removal.

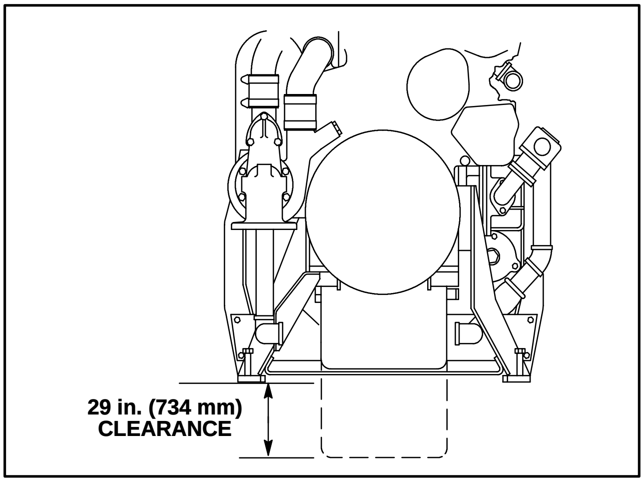


Figure 2.05-55. Oil Pan Removal Clearance

6. After oil pan is clear of crankcase, oil pump and plumbing may be removed (see Figure 2.05-56). See Section 5.30 *Lubrication System* in this manual for complete information.

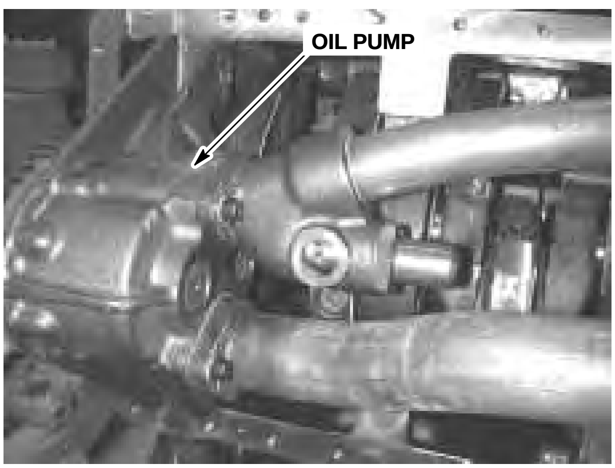


Figure 2.05-56. Oil Pump

MAIN BEARING CAP REMOVAL

***NOTE:** One main bearing cap may be removed and replaced without disturbing the others. If one main bearing cap is to be installed, complete the applicable steps for tightening either dual dowel pin caps or single dowel pin caps. See "Crankshaft Removal" in this section for complete instructions on removing main bearing caps.*

CRANKSHAFT REMOVAL

1. Set crankcase upside down in a suitable location.

2. Remove main bearing cap crossbolts from sides of crankcase. Make sure that bearing caps are marked and matched to crankcase location.

⚠ CAUTION Do not spread the crankcase more than 0.006 in. (0.15 mm). Use a dial indicator to measure the spread of the crankcase sides. Disregarding this information could result in product damage.

3. Install crankcase spreader tool P/N 472002 (see Figure 2.05-57) between bearing caps #1 and #2. Adjust tool and spread crankcase. Remove bearing caps.

4. Move spreader tool between caps #3 and #4. Remove and repeat sequence for rest of main bearing caps (see Figure 2.05-57).

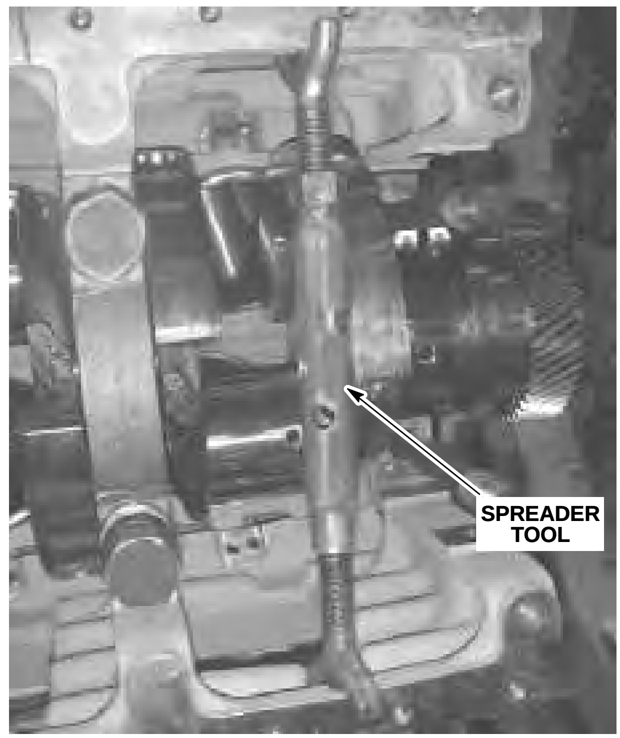


Figure 2.05-57. Crankcase Spreader Tool

5. Center main bearing cap also contains a thrust washer on either side of bearing cap. Thrust washer can be identified by a tab in bearing cap (see Figure 2.05-58).

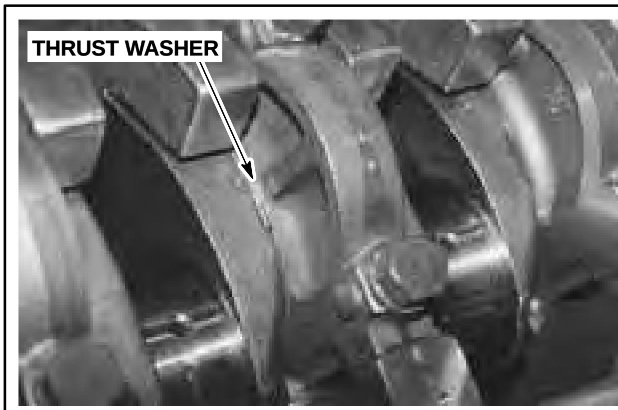


Figure 2.05-58. Main Bearing Cap Thrust Washer

6. Left side #5 and #6 crossbolts have special washers and O-rings (see Figure 2.05-59). These crossbolts pass through oil passages and must be reinstalled in their original locations.

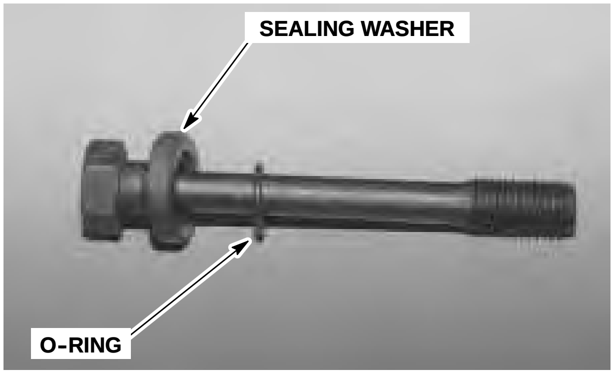


Figure 2.05-59. Bearing Cap CrossBolt

⚠ WARNING

The six cylinder crankshaft weighs 800 lb. (362 kg). The eight cylinder crankshaft weighs 1100 lb. (500 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

7. Attach suitable lifting device around connecting rod journals of crankshaft and lift crankshaft from crankcase (see Figure 2.05-60).

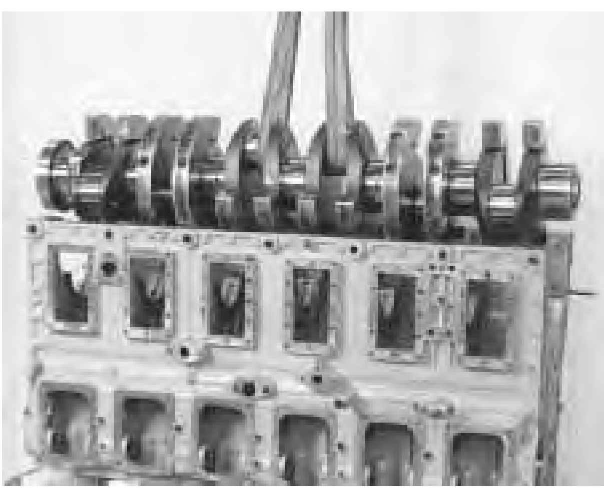


Figure 2.05-60. Crankshaft Removal

CRANKCASE PLUGS

Two O-ring sealed oil gallery plugs are located on the front and rear of the crankcase. Remove the plugs to clean the crankcase oil galleries.

1. Use a puller with an M8 capscrew to remove smaller plugs from crankcase (see Figure 2.05-61). Remove and discard O-rings on plug.

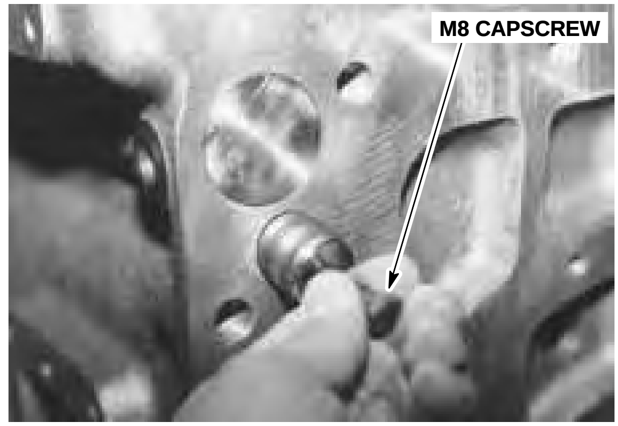


Figure 2.05-61. Oil Gallery Plug

2. Insert Allen wrench through closest port and push larger plugs out of crankcase (see Figure 2.05-62). Remove and discard O-ring on plug.

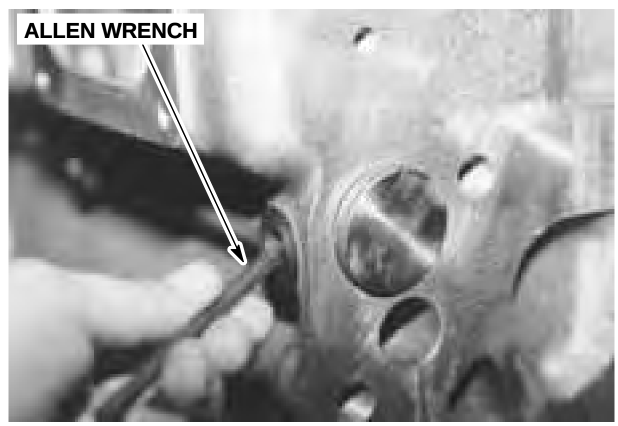


Figure 2.05-62. Oil Gallery Plug

3. Remove both dowel pins from crankcase using a puller and M8 hex head screw (see Figure 2.05-63).

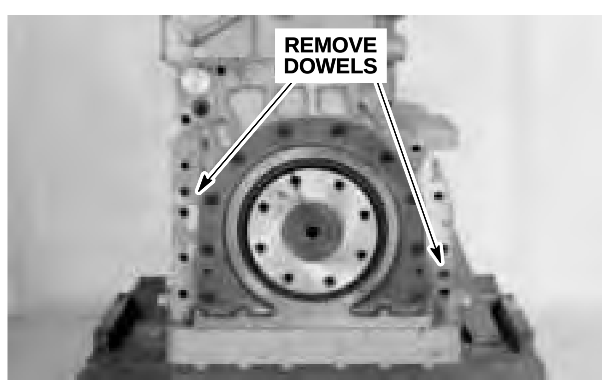


Figure 2.05-63. Crankcase Rear Dowels

SECTION 3.00

CYLINDER HEAD DISASSEMBLY AND OVERHAUL

Table 3.00-1. Special Tools For Cylinder Head

TOOL P/N	TOOL DESCRIPTION
472068	Spark Plug Tube Socket
494273	Torque Wrench (40 to 250 ft-lb)
472005	Valve Stem Seal Installer
472077	Valve Stem Seal Installer – used for P/N 304015C Blue Intake Seal and P/N 304015B Black Exhaust Seal
472008	Valve Guide Extractor
472009	Valve Guide Driver
472010	Valve Seat Extractor
472015	Rocker Arm Support/Manifold Wrench
472035	Valve Guide Pilot
494014	20 Degree Valve Seat Grinding Stone
494277	Valve Seat Grinder
472047	Valve Spring Compressor
475019	Torque Wrench (200 to 900 ft-lb)
494278	Dial Indicator

CYLINDER HEAD DISASSEMBLY

ROCKER ARM REMOVAL

1. Remove M10 x 110 mm hex head screws from rocker arm assembly (see Figure 3.00-1).

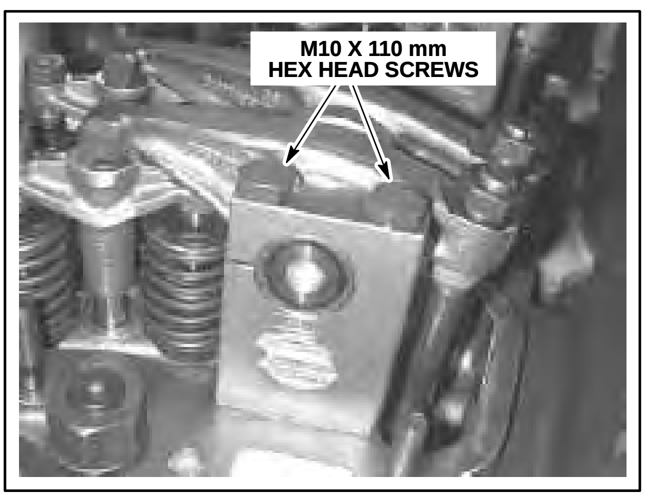


Figure 3.00-1. Rocker Arm Support

2. Use rocker arm support wrench (P/N 472015) and remove M10 x 35 mm hex head screws. Remove rocker arm stand from cylinder head (see Figure 3.00-2 and Figure 3.00-3).

NOTE: *Rocker arm components must be installed in their original locations. Mark or tag the rocker arm components to ensure installation in original locations.*

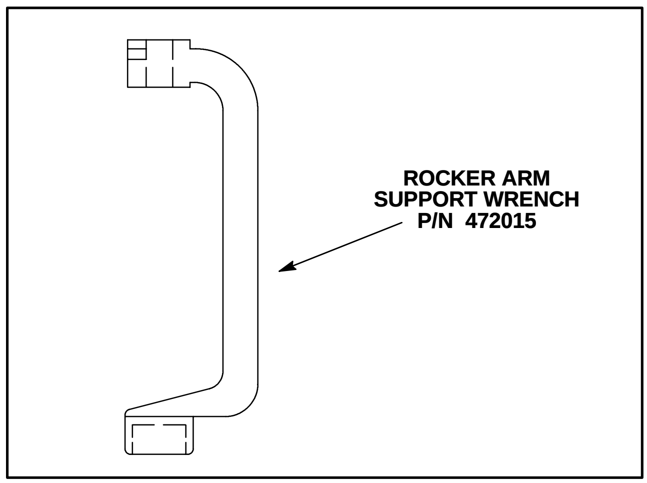


Figure 3.00-2. Rocker Arm Support Wrench

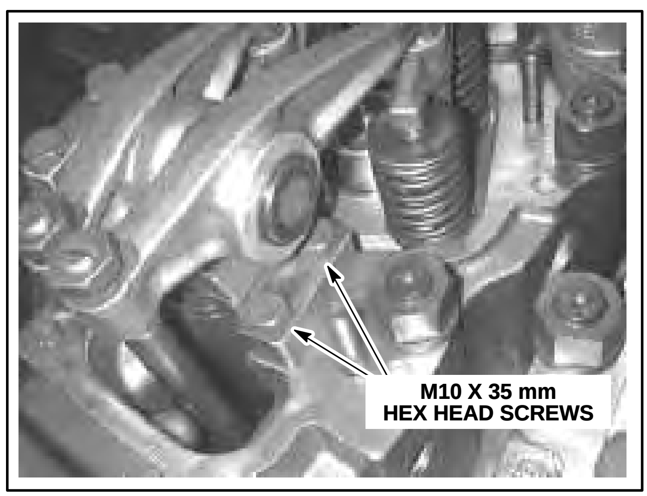


Figure 3.00-3. Rocker Arm Support

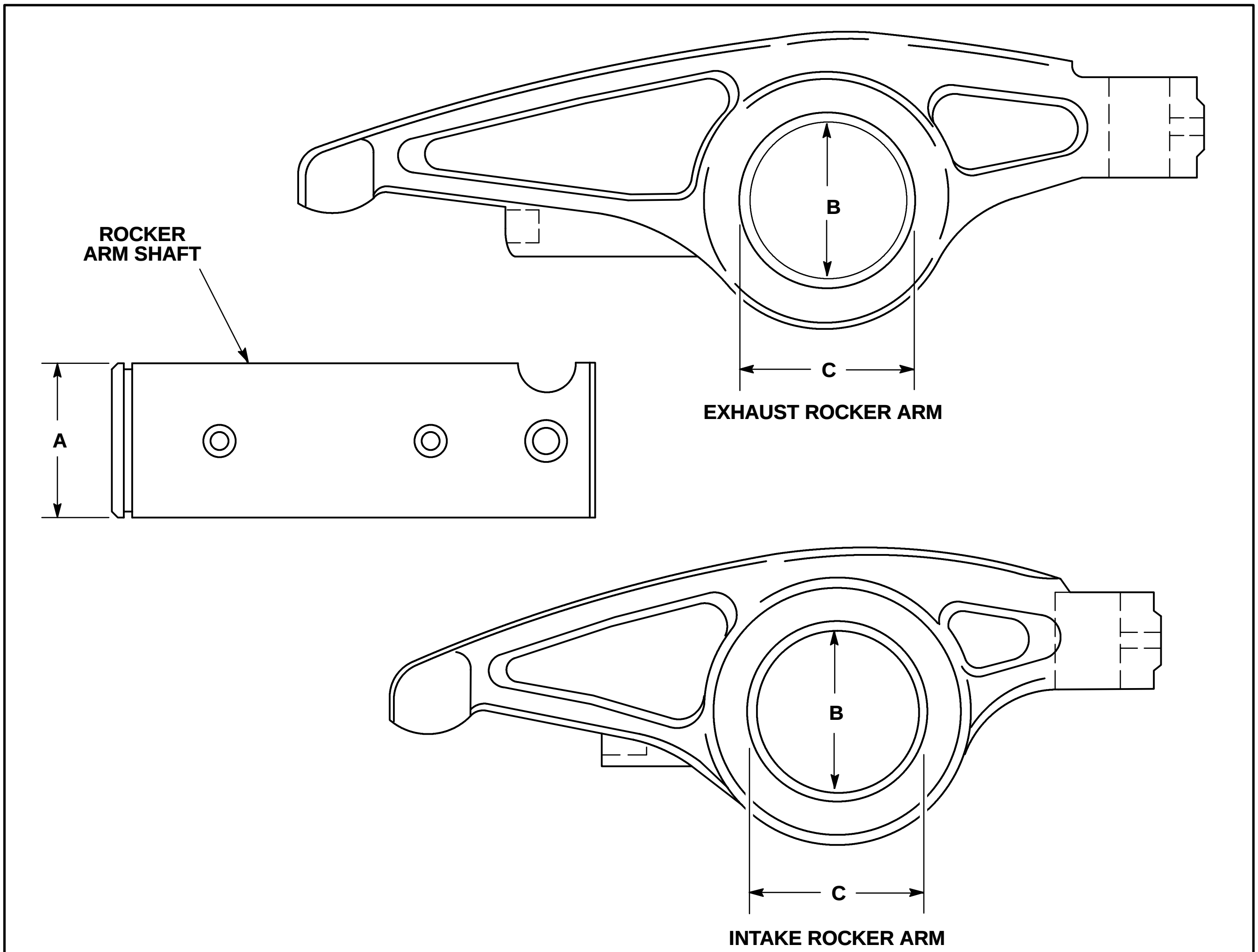


Figure 3.00-4. Intake and Exhaust Rocker Arms

Table 3.00-2. Rocker Arm Assemblies

	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Rocker arm shaft OD	1.2579 (31.950)	1.2589 (31.976)	1.2595 (31.991)
(B) Rocker arm bearing ID (ream to ID)	1.262 (32.055)	1.260 (32.009)	1.261 (32.034)
(C) Rocker arm bore ID			
Intake	1.418 (36.017)	1.417 (36.000)	1.418 (36.017)
Exhaust	1.418 (36.017)	1.417 (36.000)	1.418 (36.017)
Clearance of rocker arm bearing to shaft:	0.004 (0.101)	0.0007 (0.018)	0.002 (0.051)

ROCKER ARM INSPECTION

Poor lubrication to the rocker arms can cause rocker arm tip wear. Worn rocker arm tips can cause unnatural valve motions and difficulty in setting valve lash with a feeler gage.

1. Inspect rocker arm tips for wear. If rocker arm tip has any damage replace it.

2. All rocker arm oil tubes and oil passages must be free of obstructions. The ball socket must rotate freely in the rocker arm.

3. Inspect rocker arm bearings for wear. Measure bearing ID and rocker arm shaft OD (see Figure 3.00-4 and Table 3.00-2). Replace bearing if it exceeds specifications.

4. Measure rocker arm bore ID. Replace rocker arm if measurement exceeds specification.

CROSS BAR INSPECTION

NOTE: *Cross bars must be installed in their original positions. Mark or label the cross bars to prevent them from being installed in the wrong location.*

1. Remove cross bars from cylinder head (see Figure 3.00-5).

NOTE: *Seats may be loose and fall from the cross bars. Do not lose seats when removing the cross bars.*

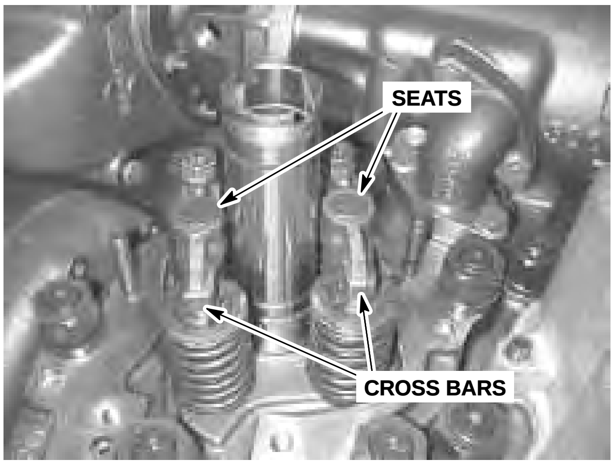


Figure 3.00-5. Cross Bars And Seats

2. Remove seat and inspect cross bar for wear or damage (see Figure 3.00-6).

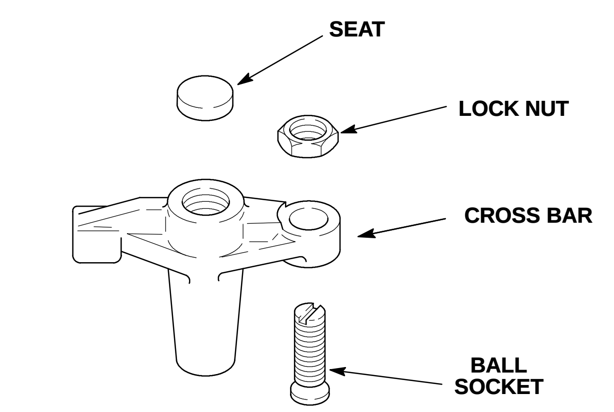


Figure 3.00-6. Cross Bar Assembly

3. Oil passages in cross bar must be free of any obstructions. Ball socket must rotate freely in cross bar.

4. Measure and record internal diameter (ID) of cross bar at three different locations (see Figure 3.00-7). Replace cross bar if it exceeds specifications (see Table 3.00-3).

Table 3.00-3. Cross Bar ID Specifications

WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
0.555 (14.097)	0.5531 (14.050)	0.5542 (14.077)

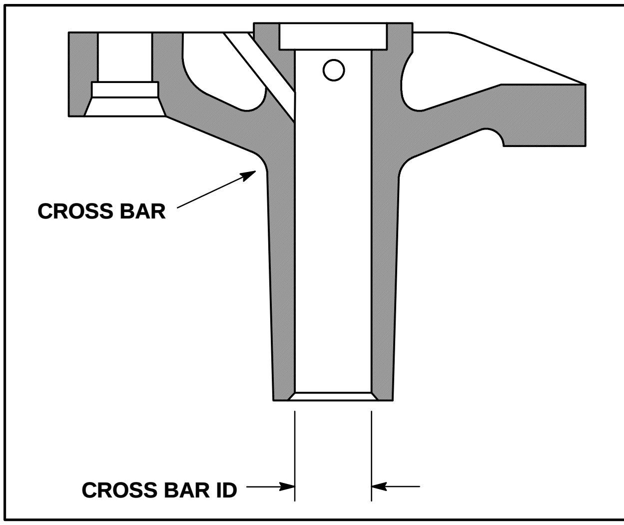


Figure 3.00-7. Cross Bar Measurement

5. Measure and record outside diameter (OD) of cross bar guide (located in cylinder head) at three different locations (see Figure 3.00-8). Replace cross bar guide if OD exceeds specifications (see Table 3.00-4).

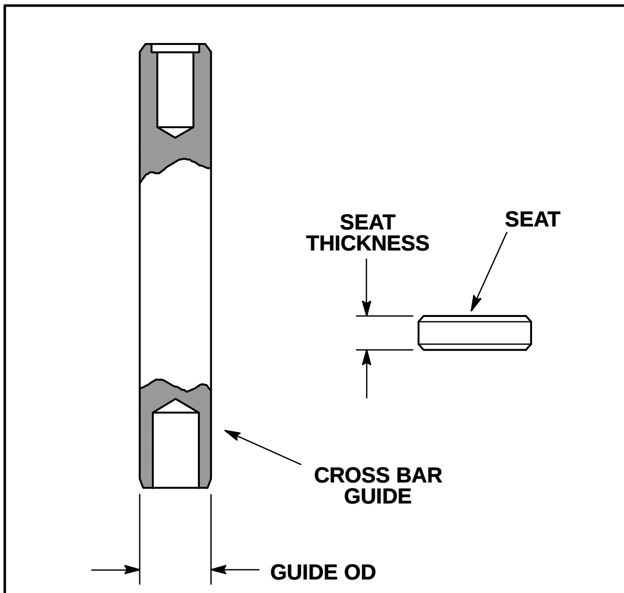


Figure 3.00-8. Cross Bar Guide And Seat

Table 3.00-4. Cross Bar Guide OD

WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
0.551 (13.995)	0.5525 (14.033)	0.5529 (14.044)

6. Compare recorded cross bar guide OD to cross bar ID. If difference exceeds specification, replace parts as needed (see Table 3.00-5).

Table 3.00-5. Cross Bar To Guide Clearance

WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
0.0037 (0.094)	0.0002 (0.005)	0.0017 (0.043)

7. Measure cross bar seat thickness (see Figure 3.00-6 and Figure 3.00-8). Replace cross bar seat if it exceeds specifications (see Table 3.00-6).

Table 3.00-6. Cross Bar Seat Specifications

WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
0.157 (3.99)	0.1579 (4.01)	0.1587 (4.03)

ROCKER ARM ASSEMBLY

NOTE: *Both the exhaust rocker arm and intake rocker arm use the same assembly procedure.*

1. Press spring pins into exhaust rocker arm and intake rocker arm. Spring pin end should be free and clear of any obstruction (see Figure 3.00-9).

NOTE: *After new bearings are installed they must be bored out to the correct internal diameter (ID). See Table 3.00-2 for specifications.*

2. Press new bearings into rocker arms. Make sure that the oil holes in bearing and rocker arm align (see Figure 3.00-9).

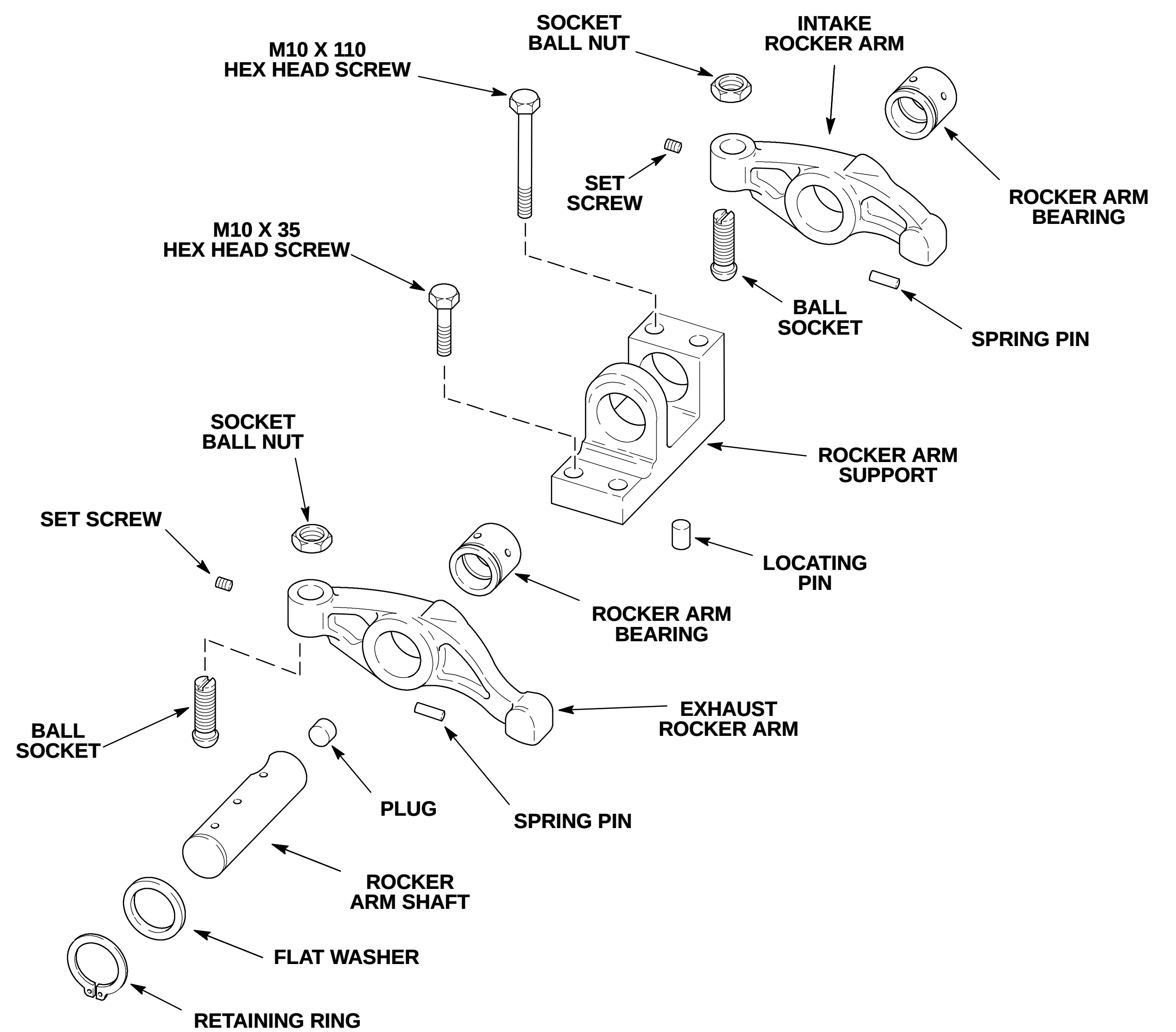


Figure 3.00-9. Rocker Arm Assembly

NOTE: *The set screw does not lock the ball socket to the rocker arm. The set screw is used for blocking the end of the rocker arm oil passage.*

3. Apply Loctite® 272 to set screw and install in rocker arm.

4. Install ball socket and lock nut into rocker arms. Do not fully tighten.

ROCKER ARM SUPPORT ASSEMBLY

1. Press locating pin into bottom of rocker arm support (see Figure 3.00-9).

2. Install plug into rocker arm shaft.

⚠ WARNING

Always wear safety glasses when removing retaining (snap) rings. Verify the correct retaining ring pliers is used and it is in good condition. If the retaining ring slips off the pliers when being installed or removed, it can be propelled with enough force to cause a serious eye injury. Disregarding this information could result in severe personal injury.

3. Install flat washer and retaining ring onto end of rocker arm shaft.

NOTE: *The two M10 x 35 mm hex head screws, that secure the rocker arm support to the cylinder head, must be inserted into the support before installing the rocker arms.*

4. Insert two M10 x 35 mm hex head screws into rocker arm support (see Figure 3.00-9). Do not install rocker arm support onto cylinder head at this time.

5. Apply clean engine oil to rocker arm shaft and rocker arm.

6. Align intake and exhaust rocker arms with rocker arm support (see Figure 3.00-10).

NOTE: *The end of the rocker arm shaft is notched to provide clearance for the M10 x 110 mm hex head screw. While the rocker arm shaft is being installed, gently rotate it to align the "notch" with the hex head screw hole.*

7. Push rocker arm shaft through rocker arms and into support. Insert two M10 x 110 mm hex head screws (see Figure 3.00-10).

NOTE: *See Section 4.05* Cylinder Head Installation *to install the rocker arm support onto the cylinder head. The rocker arm support assembly covers one of the cylinder head nuts and is installed only after the head is secured to the crankcase.*

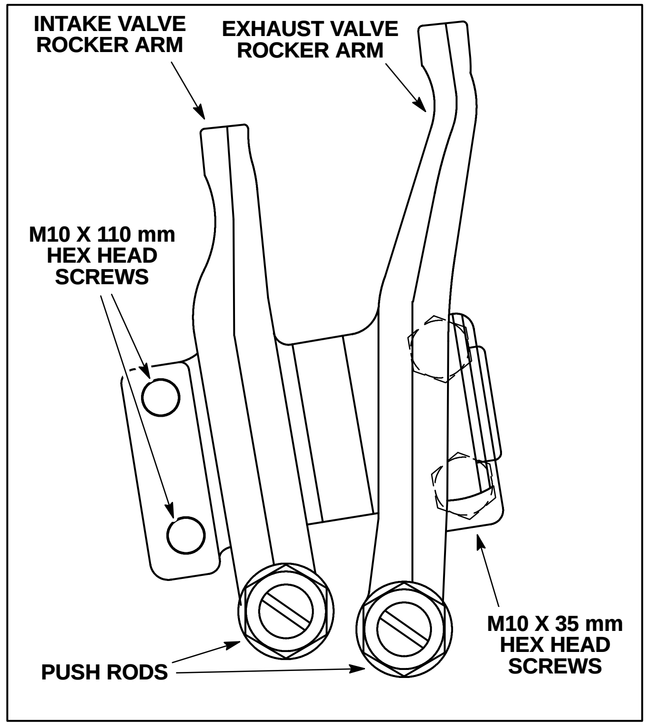


Figure 3.00-10. Rocker Arm Support

SPARK PLUG TUBE AND CROSS BAR GUIDE REMOVAL

1. Remove spark plug tube with spanner wrench (P/N 472068). Remove steel washer if installed (see Figure 3.00-11).

Figure 3.00-11. Spark Plug Tube

2. Remove cross bar guides (see Figure 3.00-11). Guide tops contain M8 threads. Install M8 bolt into guide and remove guide with slide hammer.

CYLINDER HEAD INSPECTION

NOTE: *Use Magnaflux ™ to inspect the cylinder heads for cracks whenever they are removed from the engine. Contact a local machine shop to have the heads Magnaflux ™ inspected.*

1. Clean gasket surface and remove any foreign material from cylinder head (see Figure 3.00-12).

Figure 3.00-12. Cylinder Head Face

2. Place straight edge along cylinder head face. Measure gap between straight edge and cylinder head face (see Figure 3.00-13).

3. Cylinder head must be resurfaced if gap exceeds 0.003 in. (0.76 mm). Do not remove more than 0.020 in. (0.508 mm) of material.

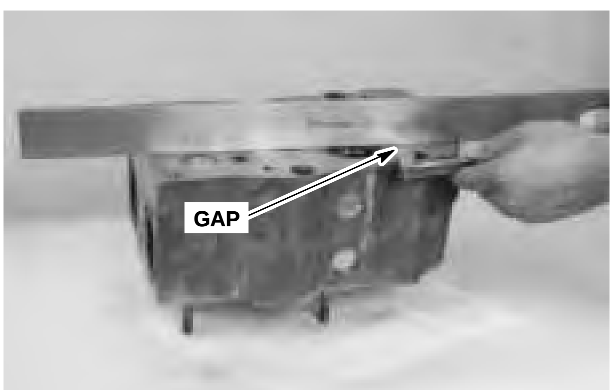


Figure 3.00-13. Measure Head For Warpage

4. Measure distance between cylinder head face and valve face (valve recession) (see Figure 3.00-14).

5. Inspect valve face and valve seat for wear. Replace valve, or valve and seat if recession is greater than 0.113 in. (3.00 mm). See “Valve Condemning” in this chapter.

Figure 3.00-14. Measure Valve Recession

6. Remove water jet from cylinder head face. Install tap in water jet. Tap should cut threads into walls of water jet. Pull tap and water jet from cylinder head.

NOTE: *The tap may be unscrewed from the water jet and a larger diameter bolt installed. Pull the bolt and water jet from the cylinder head.*

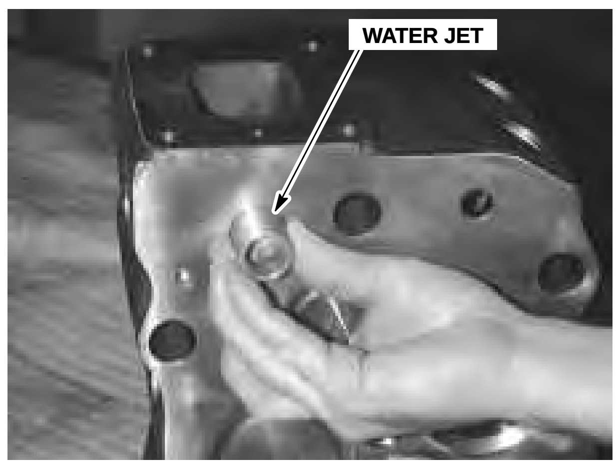


Figure 3.00-15. Remove Water Jet

INTAKE AND EXHAUST VALVES

INTAKE AND EXHAUST VALVE REMOVAL

⚠ WARNING

Use caution when removing or installing the valve springs. They are under tension and can eject from the cylinder head during the removal process. Use the valve spring compressor (P/N 472047) for this procedure. Wear safety goggles. Failure to take adequate precautions can result in severe personal injury.

1. Compress valve springs and remove valve split locks (keepers).

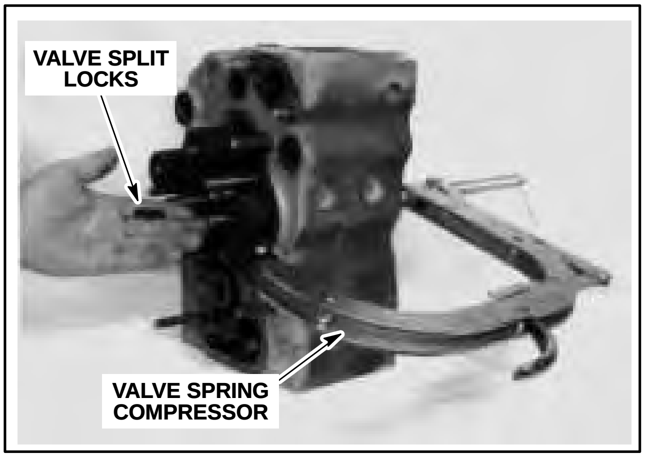


Figure 3.00-16. Valve Split Locks

NOTE: *Valve components must be installed in their original positions. Mark or label the locations of the valve components to prevent them from being installed in the wrong location.*

2. Remove valve spring retainer and valve springs (see Figure 3.00-17).

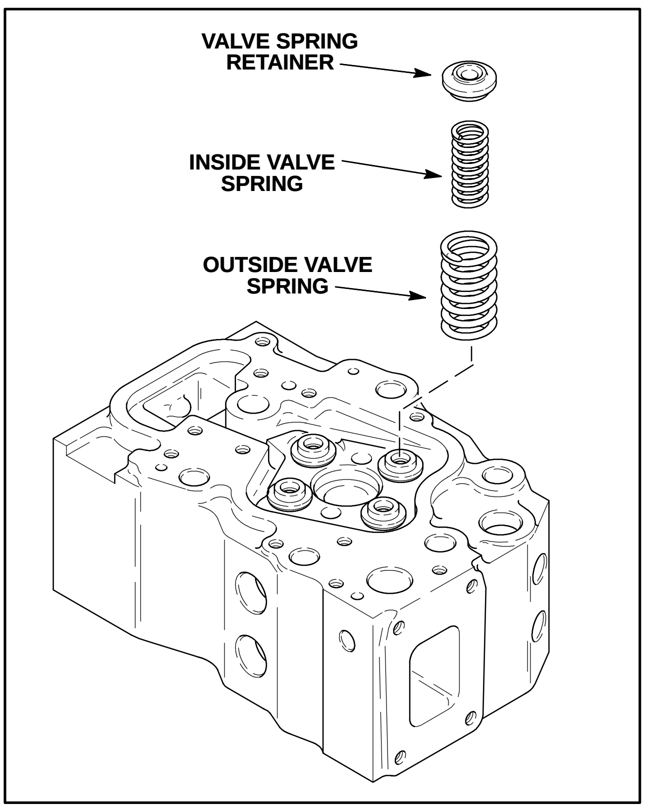


Figure 3.00-17. Remove Valve Springs

3. Remove valve and valve stem seal from cylinder head (see Figure 3.00-18).

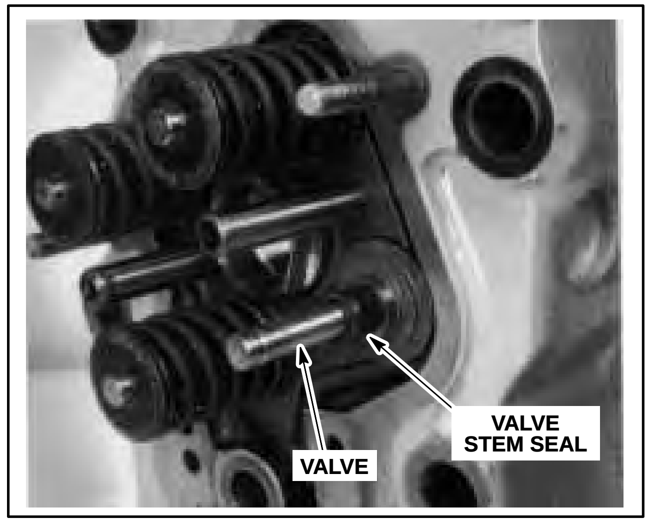


Figure 3.00-18. Valve Removal

4. Remove valve spring seat (see Figure 3.00-19).

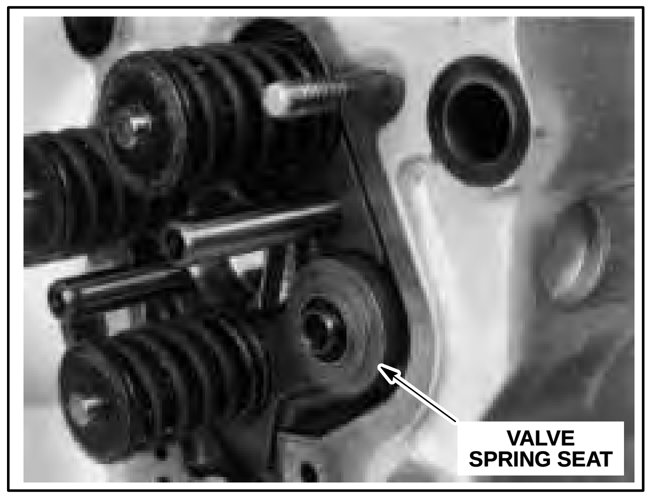


Figure 3.00-19. Valve Seat

5. Repeat Steps 1 through 4 for each valve.

VALVE SEAT INSERT AND VALVE GUIDE REMOVAL

1. Remove valve seats with valve seat removal tool (P/N 472010) (see Figure 3.00-20).

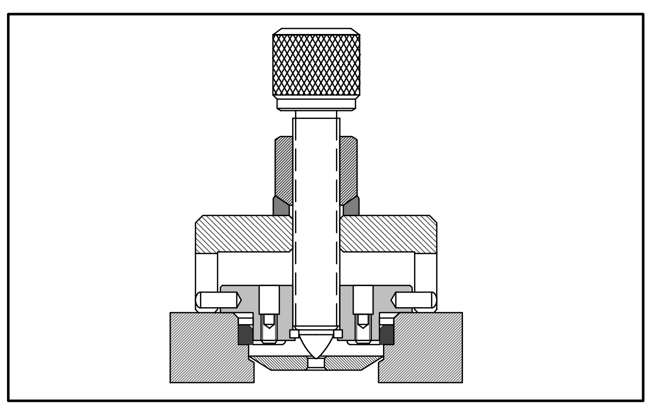


Figure 3.00-20. Valve Seat Removal Tool

NOTE: *Valve guides can only be removed by pressing them from the bottom of the cylinder head. Place cylinder head in hydraulic press upside down to press guides out.*

2. Press valve guides from cylinder head. Use valve guide removal tool (P/N 472008) (see Figure 3.00-21).

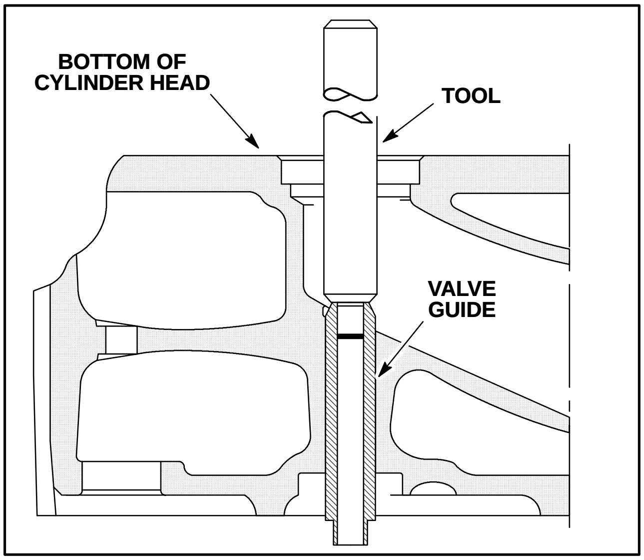


Figure 3.00-21. Valve Guide Removal Tool

EXHAUST/INTAKE VALVE FAILURE ANALYSIS

VALVE INSPECTION

Inspect the valves for the following conditions:

- Valve stem wear
- Recessed valve face
- Valve face pitting
- Heavy carbon and varnish deposits on the valve stem, rust, or pitting on the valve stem
- Burned valve face
- Worn retainer groove

VALVES

The major causes of valve failures include:

- Deposits on the valves
- Distortion of the valve seat
- Improper valve clearance
- Scuffing of the valve stem
- Deposits on the valve guide
- Erosion
- Heat fatigue
- Breaks
- Wear

Deposits on the valves can be a result of too high a valve stem temperature for the type of oil that is being used or the use of high ash oil. See *Lube Oil Recommendations-Service Bulletin 12-1880Y (or latest revision)*.

These deposits can reduce the effectiveness of the heat transfer to the cylinder head and result in valve failure. Additional factors which can cause deposit related valve failures include:

- Valve seats that have been ground too wide will reduce the seating pressure and reduce the valves' ability to crush deposits when closing.

Distortion of the valve seat can lead to burned valves and is usually caused by:

- Failure of the cooling system.
- Loose valve seats which reduce or stop the transfer of heat between the valve seat insert and the cylinder head.
- Warped sealing surfaces on the head or crankcase which can distort the valve seats when the head is torqued. Improper tightening, excess fastener torque, and using the wrong torque sequence can also distort the valve seats.

Improper valve clearance can cause the valve to be held off its seat and the resulting blow-by will burn the valve face. Causes of improper valve clearance include:

- Valve clearance not set to the proper specification.
- Valve clearance not reset after engine break-in and cylinder head retorque.

Scuffing of the valve stem can be the result of a lack of lubrication, too much or too little stem to guide clearance, or as a damaged finished surface on the valve stem of valve guide.

Deposits on the guide can cause lacquering of the stem or guide and cause the valve to be held open.

Erosion of the valve stem under the valve head can result in valve breakage. Causes of valve erosion include:

- High H_2S levels
- Faulty combustion
- Excessive valve temperatures
- Improper air/fuel mixture ratios which overheat and erode the valves (rich burn engines) due to slow burn rate.

Heat fatigue (overheating) can cause valve head cracking and breakage. Causes of heat fatigue include:

- Worn valve guides
- Distorted valve seats
- Improper air/fuel ratios

Breaks are generally two different types:

- Fatigue breaks are the gradual breakdown of the valve due to high heat and pressure.
- Impact breaks are the mechanical breakage of the valve caused by seating the valve with too much force.

Wear on the valve stem and guide can cause valve face burning. Worn valve guides lead to valve failures:

- Worn valve guides lead to out of round seating, which allows leakage and the resulting valve face burning.
- Excessive valve stem to guide clearance allows too much oil to run down the stem, which causes excessive deposits and results in the valve sticking.

Causes of worn valve guides include:

- Worn rocker arms which cause excessive side thrust on the valve stem.
- Poor lubrication which results in scoring.
- Carbon deposits on the valve stem will wear the valve guide into a bell-mouthed shape.

VALVE REPAIR

VALVE CLEANING

⚠ WARNING

Always wear face mask protection when operating a power driven wire brush. Disregarding this information could result in severe personal injury or death.

Remove the valves from the cylinder head. Clean the valves with a power driven wire brush, being careful not to scratch the valve stem.

VALVE CONDEMNING

1. Replace both valve and seat if valve recession exceeds 0.118 in. (3.00 mm).

NOTE: *See Table 3.00-7 and Table 3.00-8 for complete valve and cylinder head dimensions.*

2. If valve recession is acceptable, but valve requires replacement or reconditioning, valve seats must be reground. Grind valve seats to a 20° angle.

NOTE: *The valve face or stem may be ground in an attempt to resurface or remanufacture a worn valve. If the resurfaced valve exceeds the specifications listed, then it must be replaced (Figure 3.00-22 and Table 3.00-7).*

VALVE STEM RESURFACING

1. Measure valve at three different locations along stem (see Table 3.00-7). If stem diameter is less than 0.429 in. (10.896 mm), replace valve.

2. Check valve stem runout with a dial indicator after resurfacing. Replace valve if stem runout is greater than 0.002 in. (0.050 mm).

VALVE RESURFACING

NOTE: *Replace both valve and seat if valve recession exceeds 0.118 in. (3.00 mm).*

1. Use the diamond tool to dress the grinding wheel.

2. Grind valves to correct 20° angle, width and contact pattern.

3. Take only light cuts from valve face surface.

NOTE: *Always move the stone away from the valve when finished. Moving the valve away from the stone while in contact will leave a groove in the surface of the valve.*

4. Continue to make light cuts until all surface imperfections are removed and runout is within specifications.

5. Valves must be replaced if more than 0.020 in. (0.5 mm) of material is removed from valve face angle during resurfacing. The minimum thickness for both intake and exhaust valves is 0.075 in. (1.90 mm) (see Figure 3.00-22).

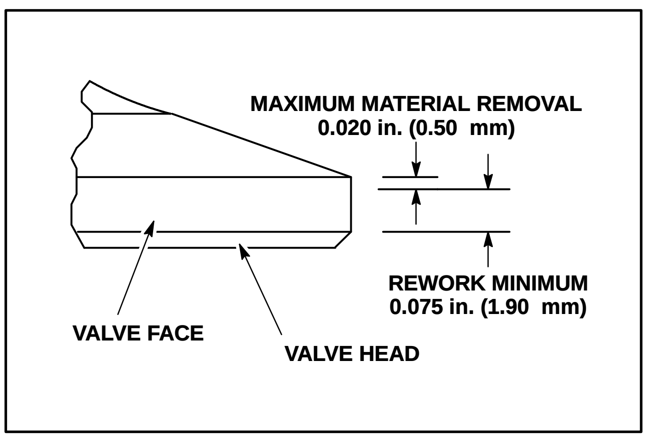
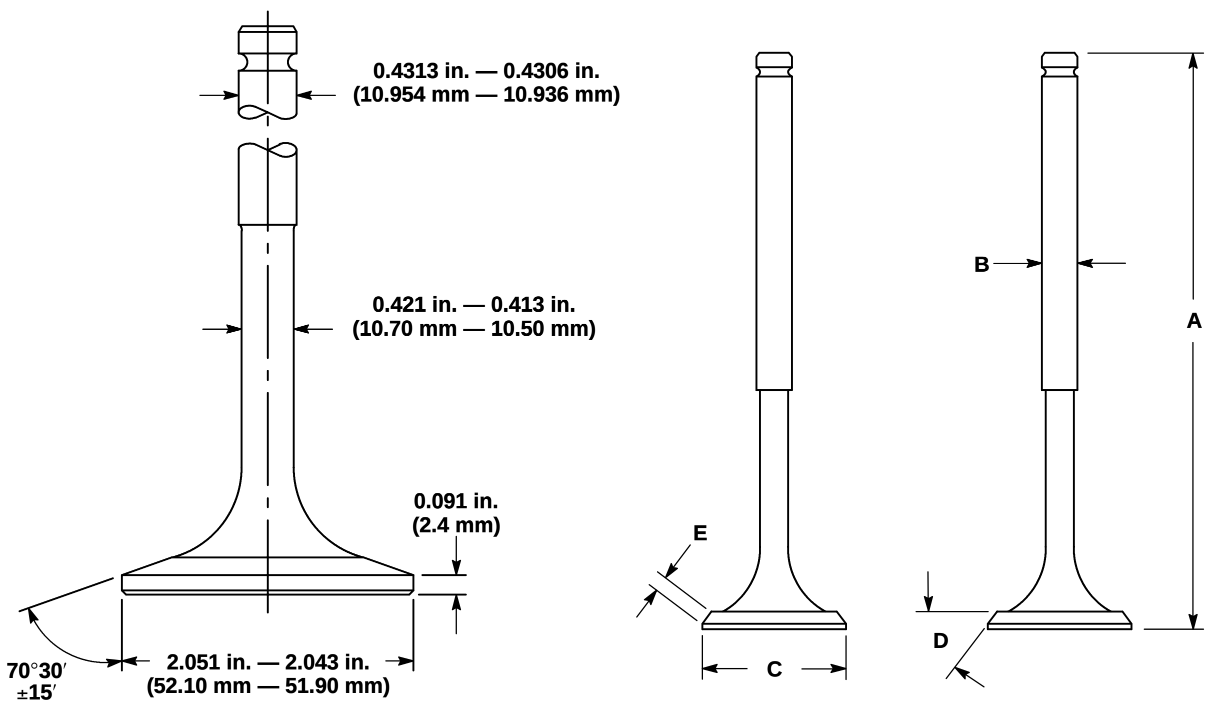


Figure 3.00-22. Valve Rework Dimensions

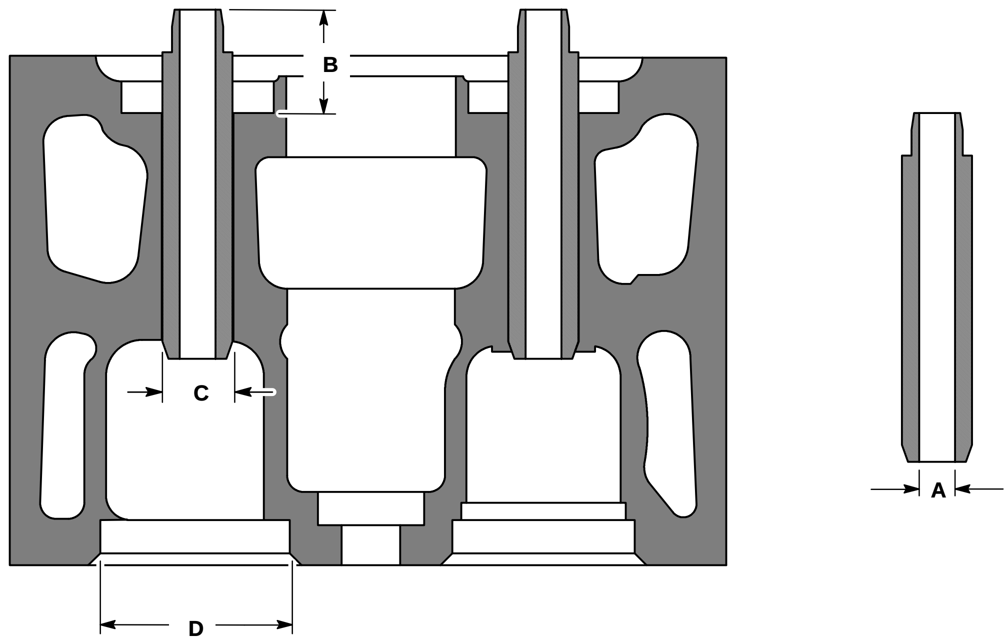
6. Check valve face runout after resurfacing. Valve must be replaced if runout is greater than 0.002 in. (0.050 mm).

Table 3.00-7. Valve Clearances



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Valve length			
Intake	7.597 (192.963)	7.607 (193.22)	7.629 (193.78)
Exhaust	7.597 (192.963)	7.607 (193.22)	7.629 (193.78)
(B) Valve stem diameter			
Intake	0.429 (10.897)	0.430 (10.922)	0.431 (10.947)
Exhaust	0.429 (10.897)	0.430 (10.922)	0.431 (10.947)
(C) Valve head diameter			
Intake	2.043 (51.89)	2.043 (51.89)	2.051 (52.10)
Exhaust	2.043 (51.89)	2.043 (51.89)	2.051 (52.10)
(D) Valve face angle			
Intake	1/2°	19° 15′	19° 45′
Exhaust	1/2°	19° 15′	19° 45′
(E) Valve face width			
Intake	0.175 (4.44)	0.175 (4.44)	0.249 (6.32)
Exhaust	0.175 (4.44)	0.175 (4.44)	0.249 (6.32)
Valve heads below cylinder head deck	0.108 (2.74)	0.041 (1.04)	0.059 (1.50)

Table 3.00-8. Valve Guide Clearances



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Valve Guide ID			
Intake	0.4365 (11.087)	0.434 (11.023)	0.435 (11.049)
Exhaust	0.4365 (11.087)	0.434 (11.023)	0.435 (11.049)
Valve Guide ID to Stem OD Clearance			
Intake	0.0003 (0.0076)	0.003 (0.076)	0.004 (0.102)
Exhaust	0.0003 (0.0076)	0.003 (0.076)	0.004 (0.102)
(B) Valve guide protrusion above head counterbore			
Intake		1.092 (27.737)	1.112 (28.245)
Exhaust		1.092 (27.737)	1.112 (28.245)
(C) Valve guide counterbore in head			
Intake	0.7879 (20.013)	0.7874 (20.000)	0.7879 (20.013)
Exhaust	0.7879 (20.013)	0.7874 (20.000)	0.7879 (20.013)
(D) Valve seat counterbore inside diameter			
Intake	2.167 (55.042)	2.1654 (55.000)	2.1665 (55.0300)
Exhaust	2.167 (55.042)	2.1654 (55.000)	2.1665 (55.0300)

VALVE GUIDE INSTALLATION

NOTE: *The valve guides must be installed before installing the valve seats. The valve seat installation tool uses the valve guide to center itself.*

Select the correct valve guide for your engine application (see applicable VGF Parts Catalog). Install valve guides from top of cylinder head. Use valve guide installation tool P/N 472009.

1. Apply a small amount of grease onto valve guide.

2. Press valve guide into cylinder head. Valve guide tool will “bottom out” at spring seat area (see Figure 3.00-23). Valve guide length is equal for all four valves.

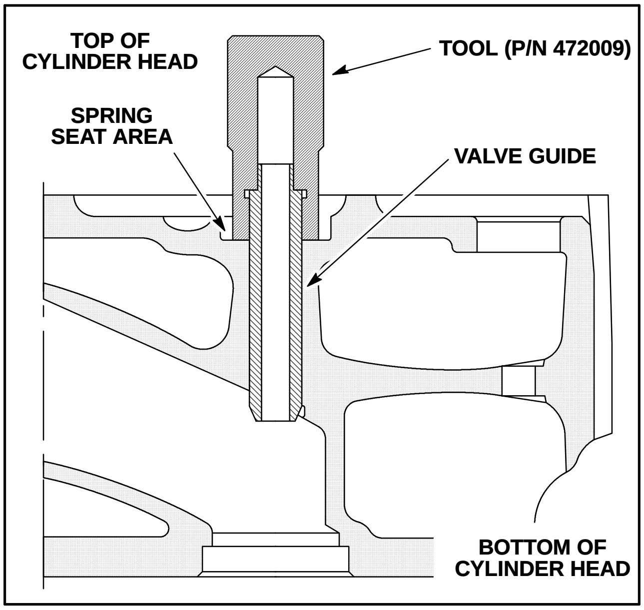


Figure 3.00-23. Valve Guide Installation

VALVE SEAT INSTALLATION

NOTE: *Read the complete instructions on installing valve seats before attempting the procedure.*

NOTE: *The valve guides must be installed before installing the valve seats. The valve seat installation tool uses the valve guide to center itself.*

1. Clean cylinder head valve seat bore.

NOTE: *High temperature head gasket (P/N 300000D) is thinner than previous gaskets. Because of this, the valve seat insert must also be thinner in order to provide the proper valve-to-piston clearance. If high temperature head gasket (P/N 300000D) is used, then valve seat insert (P/N 304010L) must be installed or grind down valve seat insert (P/N 304010K). All VGF engines built in the United States after August 15, 1997 use the P/N 300000D gasket.*

NOTE: *If using cylinder head gasket P/N 300000B, either valve seat insert (P/N 304010K or P/N 304010L) is acceptable without modification.*

2. Install valve seat. If using high temperature head gasket (P/N 300000D) and valve seat (P/N 304010K), be prepared to grind valve seat to obtain proper valve recession.

NOTE: *The valve seats must be chilled in either liquid nitrogen or a solution of dry ice and denatured alcohol. The outside diameter of the valve seats will shrink when they are chilled. This chilling process allows the valve seat to fit into the cylinder valve bore. As the valve seat warms to room temperature, it expands and produces an extremely tight fit with its mated cylinder bore.*

⚠ DANGER

Comply with the liquid nitrogen/Dry Ice manufacturer's recommendations for proper use and handling of liquid nitrogen/Dry Ice. Improper handling or use of liquid nitrogen/Dry Ice *will* result in severe personal injury or death.

⚠ WARNING

Liquid nitrogen -196° F (-126° C) and dry ice -78° F (-61° C) are extremely cold and will cause severe burns if they come into contact with human skin. To prevent burns to the skin, wear protective equipment when working with liquid nitrogen or dry ice. Disregarding this information could result in severe personal injury or death.

To cool valve seats with liquid nitrogen:

- Attach a thin wire with a hook on one end to each of the four valve seats. The wire must be long enough to extend out of the container and allow easy removal without placing your hand into the container. Lower the valve seats into a container of liquid nitrogen. Make sure that there is enough liquid nitrogen in the container to completely cover all the valve seats.

To cool valve seats with Dry Ice and denatured alcohol:

- Attach a thin wire with a hook on one end to each of the four valve seats and place them in a container of dry ice covered with denatured alcohol. The wire must be long enough to extend out of the container and allow easy removal without placing your hand into the container. The wire is used to remove the valve seats from the dry ice.

NOTE: *The amount of time needed to chill the valve seats depends on the freezing agent that is used. If liquid nitrogen is used, the valve seat will be sufficiently chilled after the liquid nitrogen stops boiling, usually about 5 minutes. If a solution of dry ice and denatured alcohol is used, the valve seat will be sufficiently chilled if it remains in the solution for at least 20 minutes.*

3. Use "hooked" wire to remove valve seat from chilling agent.

4. Quickly remove valve seat (**do not** use bare hands) from wire and place it onto valve seat installation tool P/N 472004.

5. Quickly insert installation tool and seat into cylinder head valve bore. Drive valve seat into bore until it has bottomed (see Figure 3.00-24).

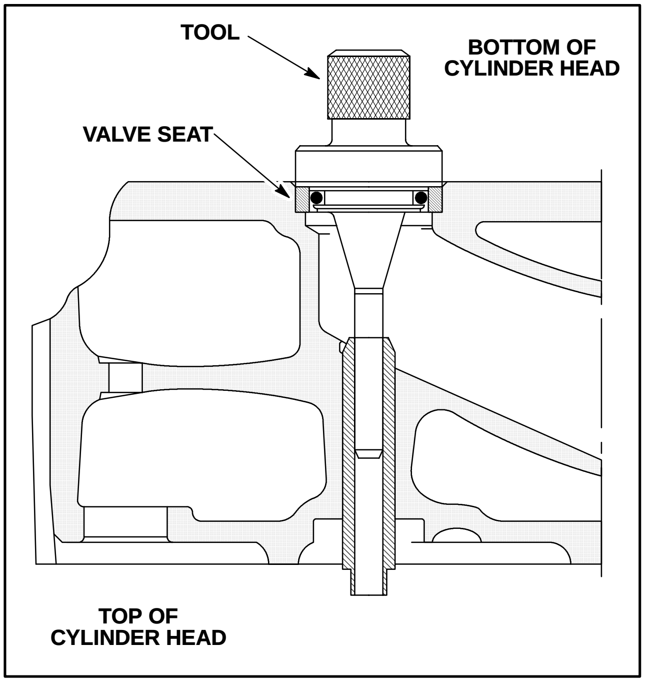


Figure 3.00-24. Valve Seat Installation Tool – P/N 472004

6. Install remaining valve seats.

7. Measure and record valve recession. Insert valve into cylinder head. Measure distance from cylinder head face to valve face (see Figure 3.00-25 and Figure 3.00-26).

Figure 3.00-25. Measure Valve Recession

8. If using high temperature cylinder head gasket (P/N 300000D), a valve recession of 0.059 – 0.079 in. (1.5 – 2.0 mm) is required (see Figure 3.00-26).

9. If using cylinder head gasket (P/N 300000B), valve recession must not exceed 0.118 in. (3.00 mm).

10. Grind valve seats as required.

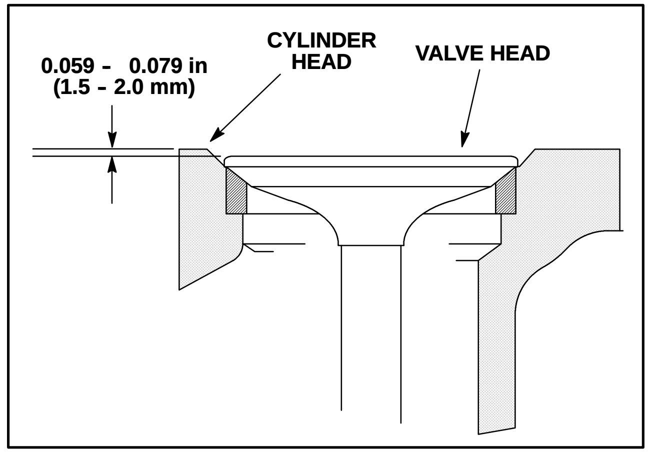


Figure 3.00-26. Valve Recession

VALVE SEAT GRINDING

NOTE: *See Figure 3.00-28 and Table 3.00-10 for complete valve seat specifications.*

NOTE: *Use of the Hall–Toledo EDP Valve Seat Grinder (P/N 494277) is the only factory approved service method of grinding valve seats (an eccentric grinder, diamond dresser, stand and necessary wrenches are included).*

⚠ CAUTION Machining accuracy depends upon the fit of the pilot mandrel. The pilot mandrel should fit snugly in the guide and in the hub of the grinder stone. Be sure that the upper end of the mandrel does not wobble during the grinding procedure. Upper end movement will produce a seat that is not ground true, causing damage to equipment.

NOTE: *The pilot mandrel allows each valve seat to be ground concentric with the valve guide. The pilot mandrels (P/N 472035) supplied by Waukesha Engine are made only for use with the Hall–Toledo EDP Valve Seat Grinder.*

1. Install handle on pilot mandrel. Insert mandrel (0.564 in.) into intake or exhaust valve guide. Turn round knob until mandrel is snug (see Figure 3.00-27).

2. Remove handle from pilot mandrel. Slide on dial indicator that reads 0.001 in. (0.0254 mm) (P/N 494278) (see Figure 3.00-27).

3. Measure valve seat concentricity to determine amount of valve seat grinding required.

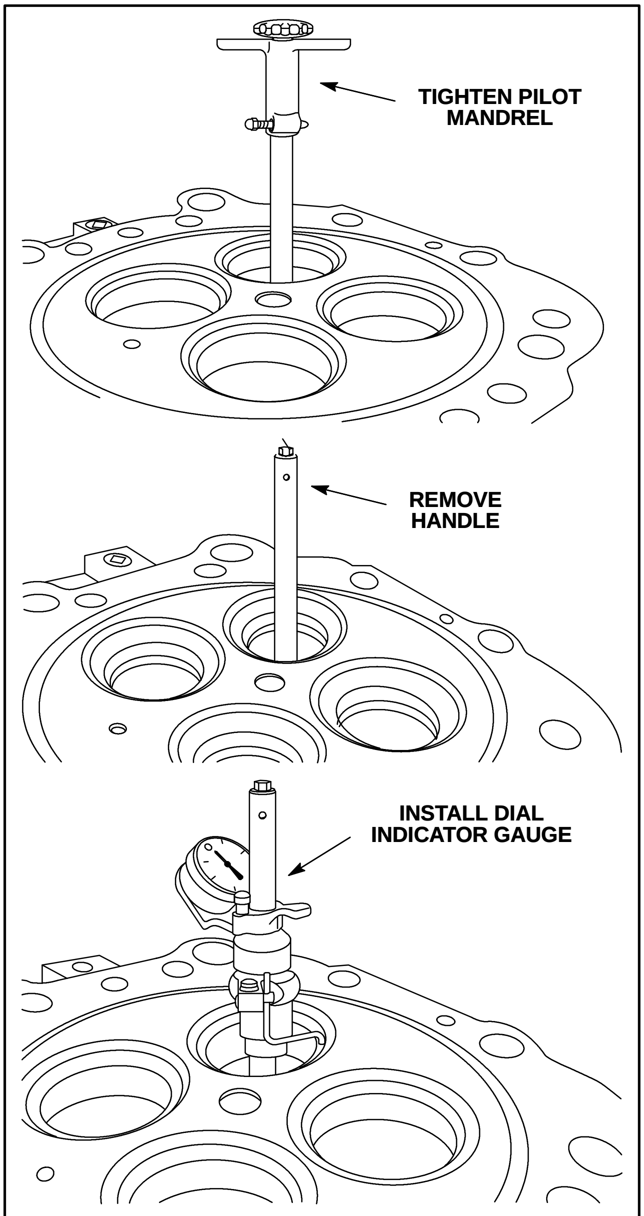


Figure 3.00-27. Measure Valve Seat Concentricity

⚠ CAUTION **Do not grind the valve seats too long and do not apply too much pressure to the grinding stone. Disregarding this information could result in product damage.**

⚠ CAUTION **Always dress the stone before grinding. The stone should be dressed to the proper angle after each seat is ground. Failure to dress the stone could cause damage to the equipment.**

4. Refer to Table 3.00-9 to select proper degree angle grinding stone. Rough grind valve seat insert until a total indicated runout of not more than 0.002 in. (0.0508 mm) or ± 0.001 in. (0.025 mm) is obtained.

Table 3.00-9. Valve Seat Insert Grinding Stones

TYPE STONE	ANGLE	TOOL P/N
Seat Angle	20 Degrees	494014

NOTE: *Install a fine grit stone or dress the stone with fine compound to perform the final grinding.*

5. Finish grind valve seat until it becomes highly polished and has a total indicated runout of less than 0.001 in. (0.025 mm).

6. Repeat grinding procedure as necessary.

⚠ WARNING

Compressed air can pierce the skin and cause severe personal injury or death. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris.

⚠ WARNING

Always use approved cleaning solvents in a well ventilated area. Contact with skin could result in severe personal injury or death.

7. Use compressed air to blow away all loose dust. Wipe down valve seat and seat insert surfaces with a non-volatile cleaning solution or solvent and dry with a clean cloth.

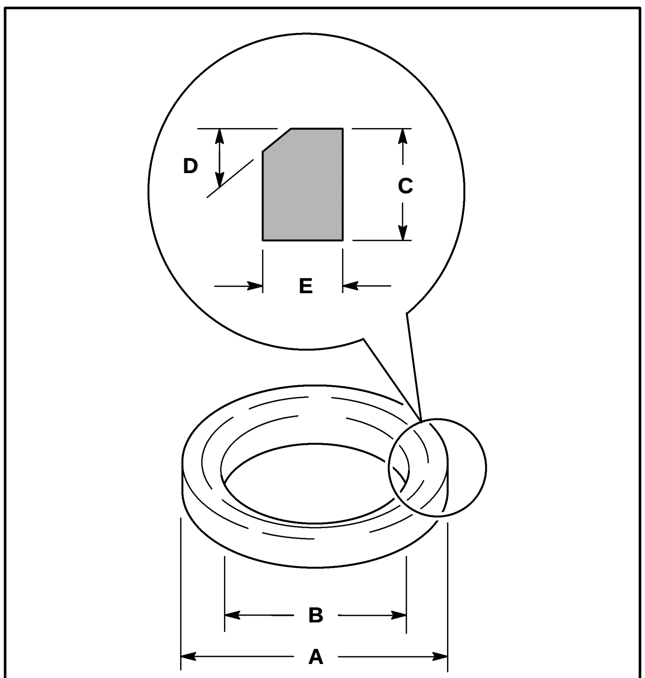


Figure 3.00-28. Valve Seat Dimensions

Table 3.00-10. Valve Seat Clearances

	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Valve seat insert OD		
Intake	2.169 (55.102)	2.170 (55.121)
Exhaust	2.169 (55.102)	2.170 (55.121)
(B) Valve seat insert ID		
Intake	1.740 (44.20)	1.764 (44.80)
Exhaust	1.740 (44.20)	1.764 (44.80)
(C) P/N 304010K Valve seat insert height		
Intake	0.335 (8.50)	0.339 (8.60)
Exhaust	0.335 (8.50)	0.339 (8.60)
P/N 304010L Valve seat insert height		
Intake	0.325 (8.25)	0.329 (8.35)
Exhaust	0.325 (8.25)	0.329 (8.35)
(D) Valve seat insert face angle		
Intake	19° 30′	19° 30′
Exhaust	19° 30′	19° 30′
(E) Valve seat insert seat width		
Intake	0.205 (5.207)	0.215 (5.461)
Exhaust	0.205 (5.207)	0.215 (5.461)

NOTE: *Valve seat selection depends on the cylinder head gasket installed on crankcase.*

VALVE SEAT LAPPING

1. Apply a fine grinding compound sparingly around entire valve edge (face) (see Figure 3.00-22).

NOTE: *Lap the valves in the location in which they will be installed.*

2. Install a light lifting spring over valve stem.

3. Apply lubricating oil into valve guide bore and slide valve into cylinder head. Spring should hold valve off seat.

4. Press down until valve is seated. Rotate valve a 1/4 turn, first in one direction, then in the other. Do this three or four times.

5. Release pressure on valve stem, spring should lift valve straight off its seat. Turn valve about 10 to 15 degrees clockwise and repeat grinding procedure. Continue until valve has been rotated a complete 360 degrees and all grinding compound has been rubbed off valve seat.

6. Remove valve and spring from cylinder head. Clean valve and valve seat insert of any lapping compound.

⚠ CAUTION **Ensure that all lapping compound is completely removed from the valve and valve seat. Failure to completely clean all lapping compound from the valve and valve seat could cause damage to equipment.**

7. Carefully inspect mating surfaces. A properly lapped valve will show a gray, frosty surface. If properly lapped, lapped surface width will equal valve seat width (see Table 3.00-10).

8. Repeat lapping procedure if necessary. Regrind valve seat insert if results are not acceptable.

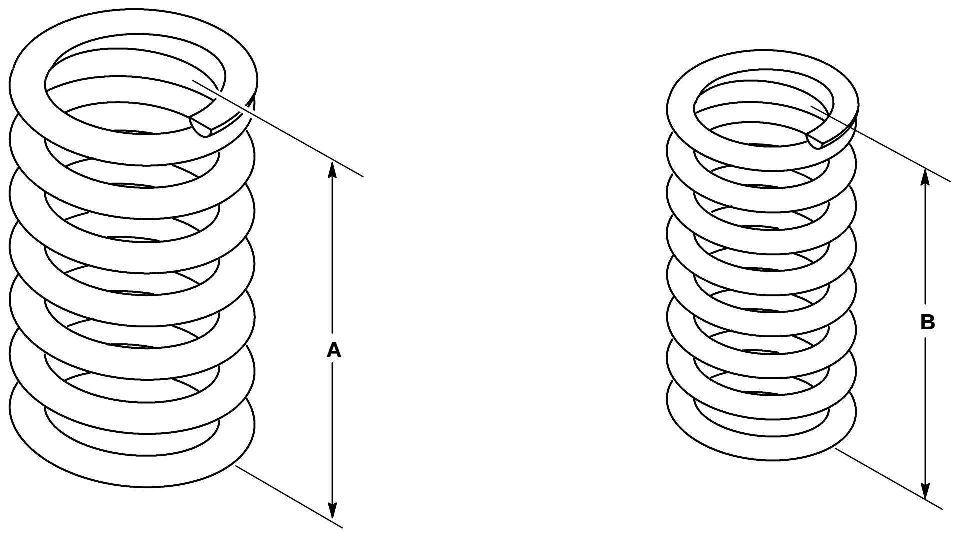
9. Apply Permatex® Prussian blue dye sparingly around entire circumference of valve seat surface.

NOTE: *The blue dye will be removed where the valve and seat make contact (contact pattern).*

NOTE: *If the valve contact pattern is not correctly centered on the valve face or does not show around the entire valve seat, **grind the seat**, not the valve.*

10. Install valve in cylinder head. Gently push down on valve stem until valve face just contacts valve seat. Do not rotate or turn valve. Carefully pull valve straight out of head.

Table 3.00-11. Valve Spring Clearances



	OUTER (A)	INNER (B)
Wire diameter	0.177 in. (4.5 mm)	0.133 in. (3.4 mm)
Number of coils	7	8
Load at specified length (valve closed)	41.8 - 48.1 lb. @ 2.118 in. (19 - 21.8 kg @ 53.8 mm)	18.5 - 21.6 lb @ 1.921 in. (8.4 - 9.8 kg @ 48.8 mm)
Load at specified length (valve open)	90.4 - 99.3 lb @ 1.539 in. (41 - 45 kg @ 39.1 mm)	53.8 - 62.2 lb @ 1.3425 in (24.4 - 28.2 kg @ 34.1 mm)
Intake and exhaust valve spring free length	**NEW MINIMUM**	**NEW MAXIMUM**
Outer (A)	2.592 in. (65.836 mm)	2.753 in. (69.926 mm)
Inner (B)	2.204 in. (55.981 mm)	2.340 in. (59.436 mm)

VALVE SPRINGS

NOTE: *Always test or replace valve springs during cylinder head overhauls.*

1. Clean valve springs, seats and retainers with a suitable solvent.

2. Examine valve springs, seats, and retainers for rust pitting and cracks. Replace pitted or cracked springs.

3. Measure spring free length. Measure load at specified length (use spring scale). Replace springs that do not meet specifications.

VALVE SPLIT LOCKS (KEEPERS)

NOTE: *Always use new split locks with new valves.*

1. Clean valve split locks with a suitable solvent.

2. Inspect inside and outside for wear. Excessive wear can allow the valve spring retainer to slide off.

NOTE: *Wear on the outside of the split locks can be caused by overspeeding the engine or the engine being assembled out of time.*

CYLINDER HEAD ASSEMBLY

SET SCREW REPLACEMENT

P/N 300302A and earlier cylinder heads are equipped with set screw plugs at two locations in the sides of the heads. These plugs block oil passages drilled in the cylinder head during manufacturing.

1. Install set screws (if removed). Apply Perma-Lok® LH050 or LH150.

CUP PLUG INSTALLATION

1. Install cup plugs (if removed). Apply Permatex® Form-a-Gasket® HD3 to cup plugs.

EXPANDER PLUG REPLACEMENT

NOTE: *P/N 300302B cylinder heads are equipped with expander plugs in two locations. These plugs block oil passages drilled in the cylinder head during manufacturing. The expander plug is made of a sleeve and a ball. The ball is driven into the sleeve, causing the sleeve to expand and grip the wall of the drilled hole (see Figure 3.00-29).*

1. Drill expander plug out with a carbide tipped drill. Sleeve must be completely removed. Use a “pick” to remove any remaining pieces.

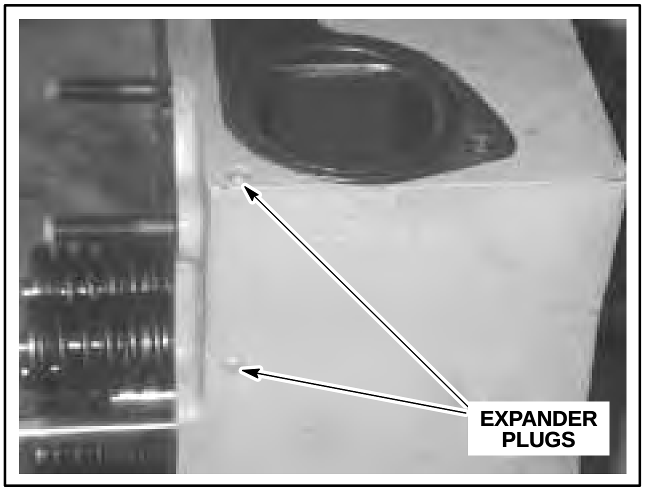


Figure 3.00-29. Expander Plug Location

NOTE: *Expander plugs are available in two sizes; one for use in the standard size hole and a 1 mm oversized plug for use in service situations. Production expander plug (P/N 306024) uses a 7 mm hole. Service expander plug (P/N 306024A) uses a 8 mm hole.*

2. Drill out expander hole using a 8 mm drill. Do not drill deeper than original expander hole.

NOTE: *If needed, polish out all marks in expander hole. Surface must be smooth in order for sleeve to seal properly.*

3. Place service expander plug (P/N 306024A) into hole.

4. Drive expander ball into sleeve. Top edge of sleeve must be below cylinder head surface. Expander plug must be driven below top of sleeve.

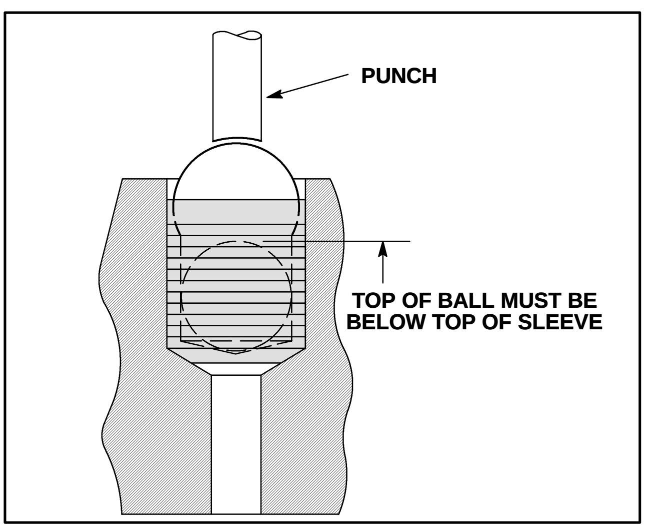


Figure 3.00-30. Expander Plug Installation

WATER JET INSTALLATION

1. Apply Loctite® 271 to outside edge of water jet. Install water jet with opening facing exhaust valves. Water jet opening should be positioned slightly (11°) off center.

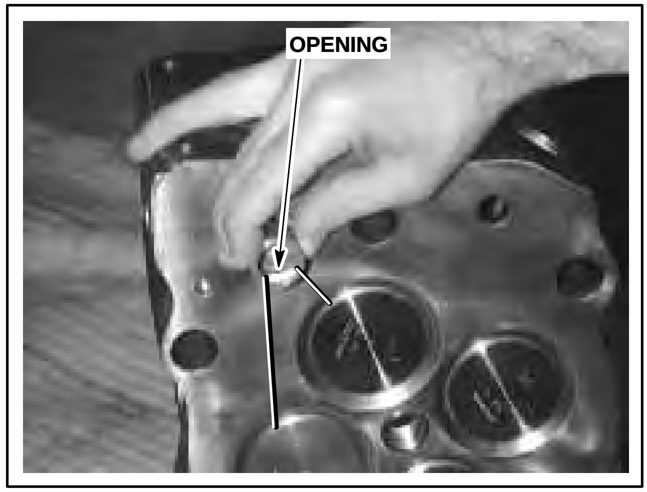


Figure 3.00-31. Water Jet Installation

CROSS BAR GUIDES

1. Press cross bar guides into cylinder head until they “bottom out” in bore.

SPARK PLUG HOLDER INSTALLATION

NOTE: *Spark plug holder P/N 305003J is used for cylinder head P/N 300302C. This plug holder uses two O-rings (P/N 305882) on the top and a seal washer on the bottom (see Figure 3.00-32 and Figure 3.00-33).*

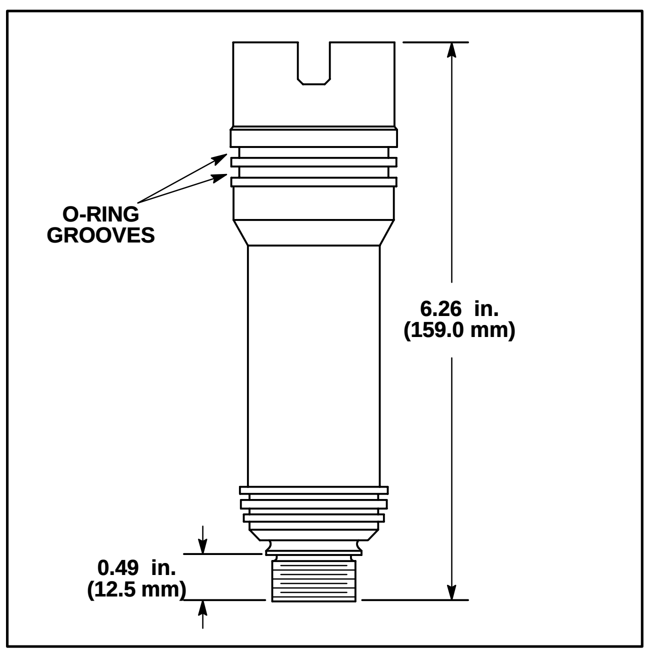


Figure 3.00-32. Spark Plug Holder P/N 305003J

2. Lubricate O-rings with Parker Super O-Lube™.

3. Place seal washer onto bottom of spark plug tube (see Figure 3.00-33). Apply Loctite® RC™ 620, Fel-Pro® ProLock, or equivalent to plug holder threads.

NOTE: *Spark plug holder P/N 305003K (GLD/2) does not use a seal washer.*

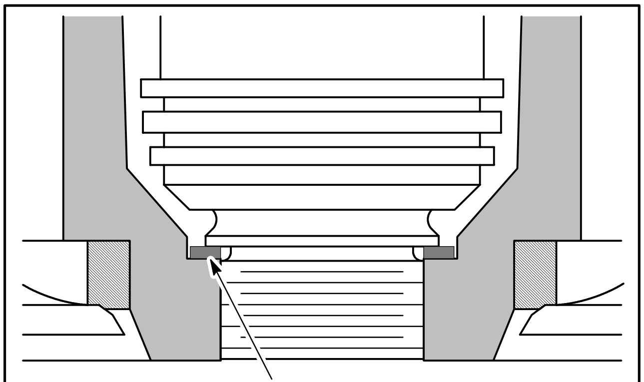


Figure 3.00-33. Spark Plug Holder Seal Washer

4. Install spark plug holder in cylinder head. Tighten holder to 150 – 160 ft-lb (203 – 216 N·m) with spark plug holder tool (P/N 472068).

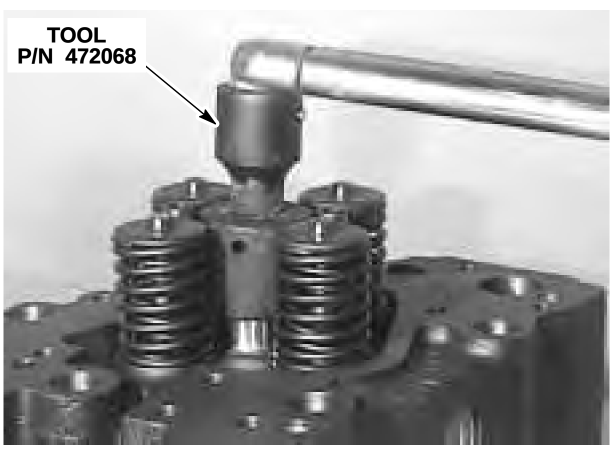


Figure 3.00-34. Spark Plug Holder Tool

VALVE INSTALLATION (ALL CURRENT ENGINES EXCEPT F18/H24G'S)

NOTE: *Always reinstall the valve components in their original locations.*

Cylinder head assembly P/N AE300302C is required for VGF F18/H24GL Low Compression Ratio (LCR) and High Compression Ratios (HCR) engines.

P/N AE300302C includes valve spring retainer, P/N 304014A. Valve spring retainer (P/N 304014A) has a groove and 4 holes in the top surface to allow more oil to reach the valve stem (see Figure 3.00-35).

Oil on the valve stem is controlled by new "barbed" seals. Different seals are used on the intake and exhaust valves. The valve seals are color coded for easy identification:
P/N 304015C, Blue, Intake Valve Stem Seal
P/N 304015B, Black, Exhaust Valve Stem Seal

⚠ WARNING

Failure to use Tool P/N 472077 will result in damage to the valve seals (P/N 304015C or P/N 304015B) making them ineffective. Improper installation of these valve seals could result in severe engine damage.

A new valve guide, P/N 300009C, is required when using the new valve stem seals. This guide features a barbed end to hold the seal in place.

Valve P/N 300036K is used for both intake and exhaust valve locations. This valve has a polished chrome stem to reduce valve stem seal wear.

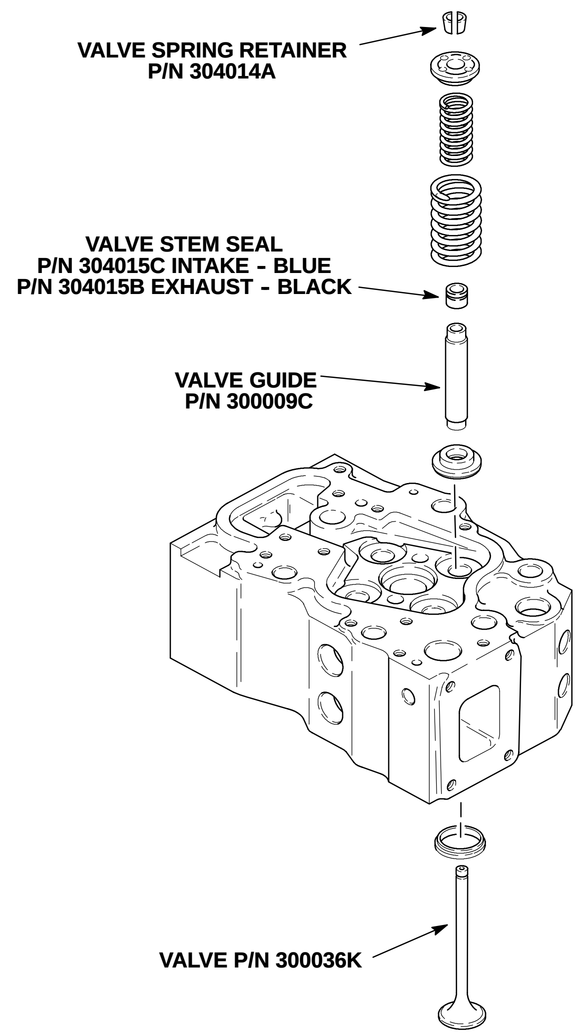


Figure 3.00-35. P/N AE300302C Cylinder Head

1. Lightly lubricate valve stems with molybdenum grease (Citgo Lithoplex® #2 grease or the equivalent). Insert valves into cylinder head.

NOTE: *Use tool P/N 472077 to install Blue Intake Valve Stem Seal (P/N 304015C) and Black Exhaust Valve Stem Seal P/N 304015B.*

2. Place valve stem seal onto valve stem. Press seal down using valve guide tool P/N 472005 or P/N 472077 (see Figure 3.00-36).

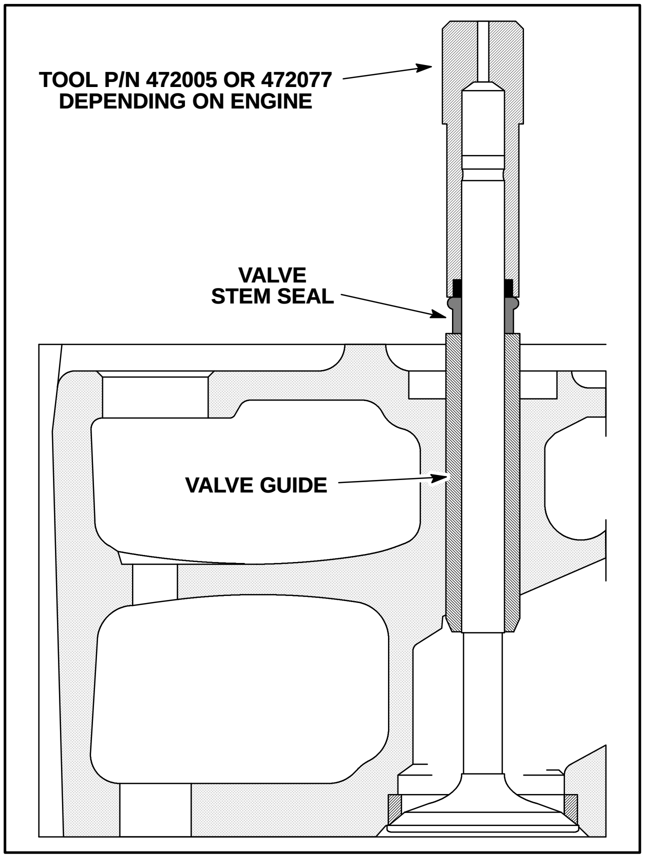


Figure 3.00-36. Valve Stem Seal Installation Tool

3. Install spring seat onto cylinder head (see Figure 3.00-37).

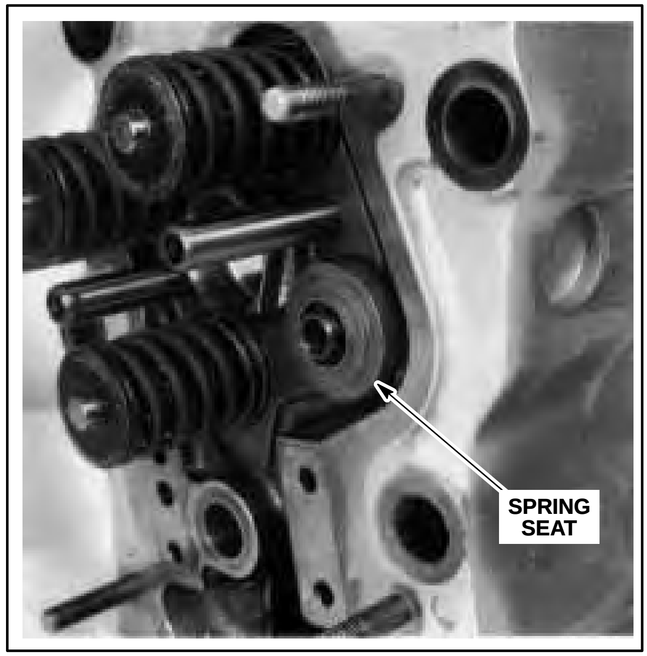


Figure 3.00-37. Valve Seat

4. Install inner and outer valve springs. Place valve spring retainer on top of springs (see Figure 3.00-38).

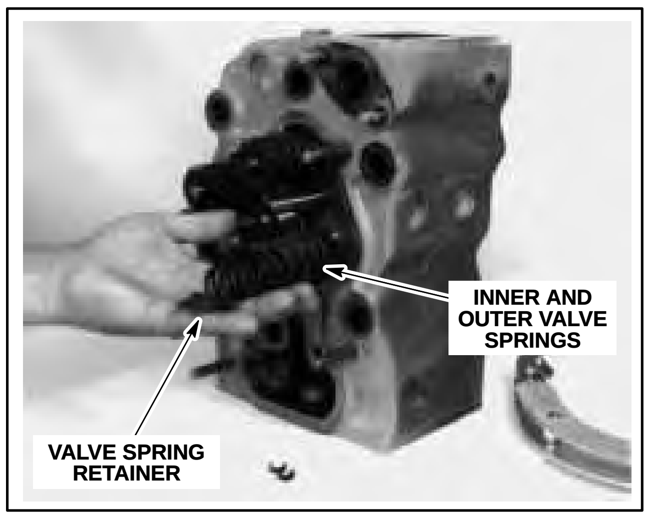


Figure 3.00-38. Install Valve Springs

⚠ WARNING

Use caution when removing or installing the valve springs. They are under tension and can eject from the cylinder head during the removal process. Use the valve spring compressor (P/N 472047) for this procedure. Wear safety goggles. Failure to take adequate precautions can result in severe personal injury.

5. Compress valve springs and retainer with valve spring compressor (P/N 472047) (see Figure 3.00-39).

Figure 3.00-39. Valve Spring Compressor

6. While valve springs are compressed, carefully insert two valve split locks (see Figure 3.00-40).

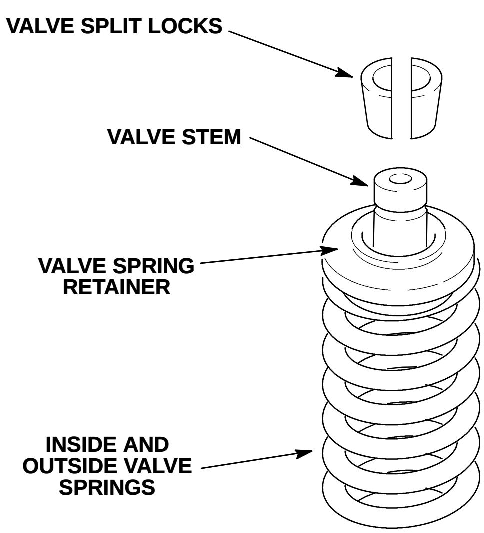


Figure 3.00-40. Valve Springs

7. Remove spring compressor. Gently tap valve stem with a soft hammer to check if split locks are seated.

8. Repeat Steps 1 through 7 for remaining valves.

CROSS BAR INSTALLATION

NOTE: *The cross bars and seats are installed only after the cylinder head is installed and secured with hex nuts.*

1. Install cross bars and seats (see Figure 3.00-41).

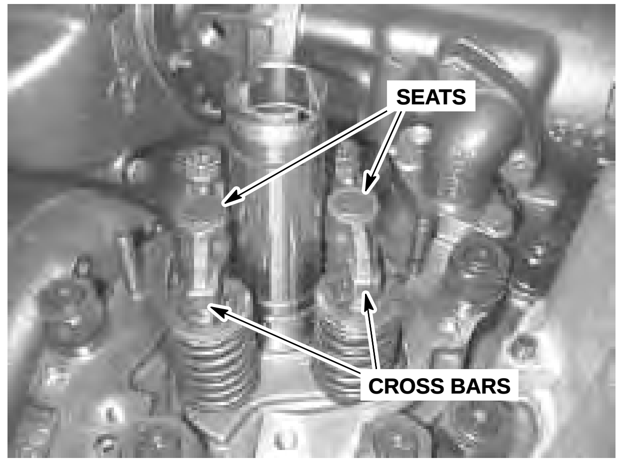


Figure 3.00-41. Cross Bars And Seats

STUD INSTALLATION

1. Apply Loctite® 242 to rocker cover stud threads. Install rocker cover studs into cylinder head (see Figure 3.00-42).

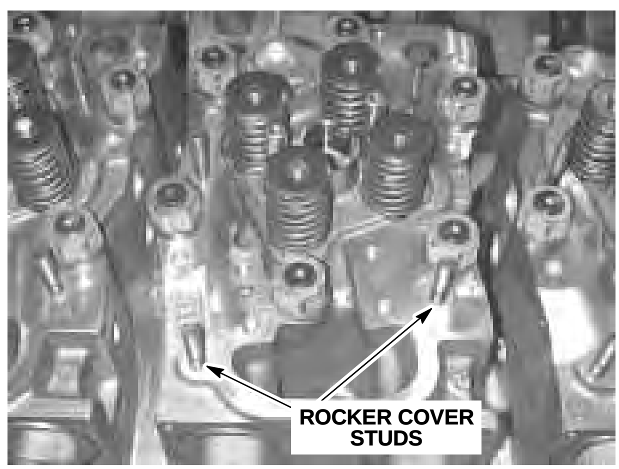


Figure 3.00-42. Rocker Cover Head Studs

SECTION 3.05

CRANKCASE DISASSEMBLY AND OVERHAUL

Table 3.05-1. Crankcase Tools

TOOL P/N	TOOL DESCRIPTION
472002	Crankcase Spreader Tool
494278	Dial Indicator
472013	Cylinder Liner Installation/Removal Tool
499967	Piston Ring Compressor
472007	Piston Installation Tool
472055	Camshaft Pilot Installation Tool
472012	Connecting Rod Bushing Press
472056	Camshaft Bushing Press
472058	Guide Pin Kit

CRANKCASE CLEANING AND INSPECTION

NOTE: *The crankshaft should already be removed from the crankcase. Refer to Chapter 2.05* Crankcase Component Removal *"Crankshaft Removal" for additional information.*

CRANKCASE DESCRIPTION

The crankcase is made of cast iron. Crankshaft main bearing saddles are machined in the crankcase "webs." Oil passages are drilled in the crankcase and route lube oil to the main bearings. Excess lube oil collects in the oil pan and is then pumped back through the crankcase.

Each main bearing cap is secured to the crankcase with two vertical bolts and two horizontal crossbolts. The two horizontal crossbolts, one from each side, provide exact positioning between the crankcase and each bearing cap. This provides the necessary support for the lower part of the crankcase.

Routine access to the crankcase is through inspection openings located on the left hand side of the engine block. A single camshaft is located on the left hand side of the crankcase. The bottom of the crankcase is enclosed by the oil pan.

⚠ WARNING

Be sure you have read and understood the safety and warning information in Section 1.05 *Safety* and Section 1.10 *Rigging And Lifting Engines*, before proceeding. Failure to take adequate precautions when servicing this product can result in severe personal injury or death.

⚠ WARNING

Never walk or stand under an engine or component while it is suspended. Use properly rated lifting equipment and approved lifting methods. Failure to take adequate precautions can result in severe personal injury or death.

⚠ WARNING

The six cylinder crankcase weighs 1384 lb. (628 kg) and the eight cylinder crankcase weighs 1845 lb. (837 kg) completely stripped of other components. If ANY components are still attached, the crankcase will be heavier by the amount of the component's weight. Make sure that the crankcase is properly supported and that properly rated lifting equipment and rigging are used. Failure to take adequate precautions can result in severe personal injury or death.

CRANKCASE CLEANING

Crankcases should be cleaned by "hot tanking," however, alternative methods may be used. Lime and scale deposits must be removed. A caustic solution such as Oaklite 32 will break down lime deposits into solution. Steam cleaning will only break down oil deposits and not lime deposits.

Precision machined surfaces must be clean in order to get accurate measurements. All cylinder liner bores must be cleaned down to bare metal for proper cylinder liner sealing.

CRANKCASE INSPECTION

The crankcase should be thoroughly checked for cracks. Special attention should be paid to the area between the cylinders. Cracks may be detected by using a dye penetrant. The lower cylinder liner seal area in the cylinder block must be checked. Crankcase tolerances are listed in Table 3.05-11. Discard the crankcase if any cracks are found.

CRANKSHAFT CLEANING, INSPECTION AND REPAIR

CRANKSHAFT CLEANING

⚠ CAUTION Never remove the crankshaft counterweights from the crankshaft. The crankshaft is balanced at the factory with the counterweights attached. The counterweight mounting holes are oversize, and it is impossible to attach the weights back in the original positions. Disregarding this information will result in product damage and/or personal injury.

Once the crankshaft is removed from the engine it should be thoroughly cleaned. All VGF crankshafts have internal oil passages.

These openings are plugged with set screws to prevent loss of engine oil pressure. Prior to hot tank cleaning, these set screws should be removed from the crankshaft.

Always remove the set screws from the crankshaft for proper cleaning of the oil passages. If the set screws are not removed, they will make flushing of the oil passages difficult and will prevent inspection of the oil passages for debris.

Cleaning solution can easily be trapped in these passages and bearing failure can result upon engine startup. Insert a high pressure air line into the passageways and blow out any remaining cleaning solution. Verify all cleaning solution is thoroughly removed from the oil passageways.

1. Remove set screws from crankshaft (see Figure 3.05-1).

2. Flush cleaning solution through oil passages. Run a wire brush through all oil passages to loosen deposits.

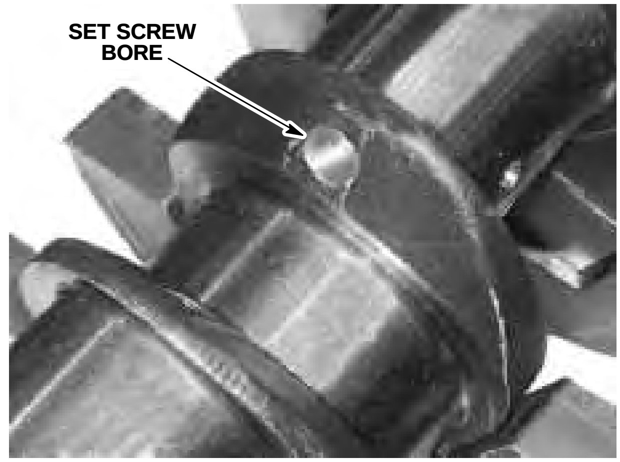


Figure 3.05-1. Crankshaft Set Screws

⚠ WARNING

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

3. Dry crankshaft with compressed air after it is removed from hot tank. Insert a stiff, clean wire through all oil passages to verify they are clear of any obstructions.

4. Coat crankshaft with a thin coat of oil to prevent surface oxidation.

⚠ CAUTION Make sure set screws are installed in the oil passages of the crankshaft. An engine operating without crankshaft set screws installed will have bearing failure and piston/sleeve damage due to low oil pressure. Disregarding this information will result in product damage and/or personal injury.

5. Apply Loctite® 242 to set screw threads. Tighten set screws until three threads show below crankshaft surface (see Figure 3.05-1). Peen set screws into place (see note below).

NOTE: *Wedge a pointed punch between the set screw and crankshaft threads. Strike the punch to bend the crankshaft threads and lock the set screw in place. Remove any metal chips. Repeat for remaining set screws.*

6. Carefully examine entire crankshaft and verify all oil passages have set screws installed.

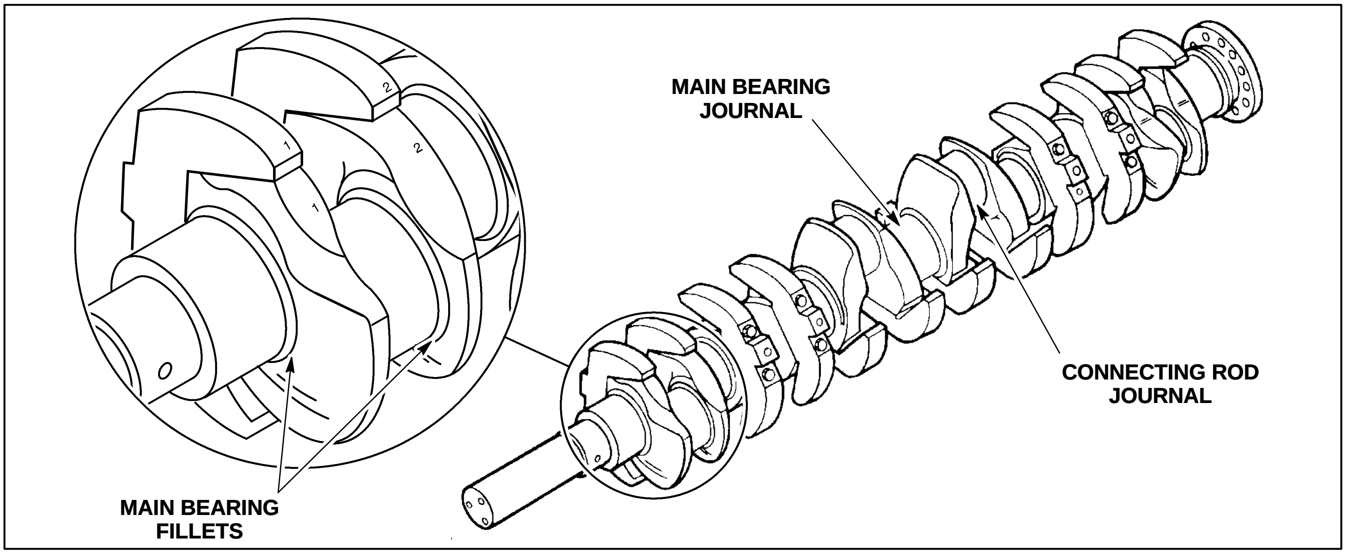


Figure 3.05-2. 12 Cylinder Crankshaft

CRANKSHAFT INSPECTION AND MEASUREMENT

The crankshaft should be checked with Magnaflux® for cracks. Small surface cracks (a few thousandths of an inch deep) in the journals can be ground out. The crankshaft must be checked with Magnaflux® again to verify the removal of all surface cracks. Never use a crankshaft that has known cracks in it.

Crankshafts which require grinding (turning) should be sent to a machine shop or crankshaft repair facility.

1. Inspect and check with Magnaflux® main bearing journals, connecting rod journals and bearing fillets (see Figure 3.05-2). These areas are most likely to develop cracks.

2. Measure and record main bearing journal outside diameter (OD) and connecting rod journal OD. Compare recorded measurements to specifications listed in Table 3.05-13. Measurements are used in crankshaft grinding.

3. Measure and inspect end play thrust surface. If it is in poor condition, the surface must be reground. Compare recorded measurements to specifications listed in Table 3.05-13.

4. Inspect the thrust washer thrust surface. If the thrust surface is in poor condition, the washer must be replaced. Compare recorded measurements to specifications listed in Table 3.05-13.

NOTE: *The crankshaft may have some deflection under its own weight when supported between centers. Deflection usually follows a symmetrical pattern.*

5. Inspect the crankshaft for straightness. The shaft must be inspected for straightness before it can be ground.

CRANKSHAFT REPAIR

NOTE: *Repairs to the crankshaft journals should only be performed by a firm specializing in such work. Contact your distributor or Waukesha Engine's Service Operations Department for the latest information regarding this process.*

Crankshaft Polishing

If the crankshaft journal surface is uneven, but the specifications are still within limits, the journal should be polished. Do not polish the journal by "hand." Polishing the crankshaft, where critical tolerances are involved, requires great skill and specialized equipment. Waukesha Engine recommends contacting a company which specializes in polishing such highly machined surfaces.

Crankshaft Grinding

⚠ CAUTION If there is any doubt as to the condition of a chromed crankshaft, or verification of a possible crack under the chrome plate, the chrome plating must be ground off and the shaft inspected. Disregarding this information could result in product damage and/or personal injury.

NOTE: *The crankshaft journals must be stress relieved (shot-peened) prior to grinding.*

There are two options when machining the crankshaft:

- **Option 1 –** If standard size bearings are to be used:

1. Chrome plate crankshaft journals. Do not chrome plate fillet surfaces. Crankshaft chrome plating should have a hardness of 50 Rockwell "C."

2. Grind crankshaft journals to new maximum OD as specified in Table 3.05-13. There should be approximately 0.060 in. (1.524 mm) of chrome plate remaining. Crankshaft main and rod journals should be finished to a "12 RMS" finish.

- **Option 2 –** If undersized bearings (0.020 in.) are used:

1. Grind crankshaft journals so they are 0.020 in. (0.51 mm) less than new maximum OD (see Table 3.05-13).

2. Install appropriate undersized bearings. Crankshaft main and rod journals should be finished to a "12 RMS" finish.

CAUTION **After a crankshaft is rebuilt and before it is installed into the engine, check and verify that all tolerances are correct. Disregarding this information could result in product damage and/or personal injury.**

Crankshaft Grinding

When crankshafts are balanced, they must be balanced with counterweights attached. If required, always remove metal from the counterweights.

Precision balancing of crankshafts can increase bearing life 25 to 100 percent.

Static balancing (shaft is placed on knife edges and will come to rest with the heaviest part of the shaft on the bottom) is not adequate.

Maximum allowable unbalance in static and dynamic mode is 4.3 ounce inches (312 grams centimeter).

The shaft must be spin balanced. Spin balancers are able to locate kinetic and dynamic unbalance. This type of unbalance creates forces that cause the shaft to rock and twist on an axis perpendicular to the axis of rotation. Rotating the crankshaft is the only method capable of identifying this type of balance problem.

Crankshaft Counterweights

WARNING

Tighten counterweight hex head screws to the proper torque. Improperly tightened hex head screws can cause the counterweights to become loose, resulting in catastrophic engine damage and possible severe personal injury or death.

To prevent loose counterweights, verify counterweight hex head screws are tightened to 210 ft-lb ±5 (285 N·m ±7). Check counterweight hex head screw torque whenever the following conditions exist:

- Crankshaft has been removed from engine
- 30 to 60 days after initial startup (rebuilt or new)
- Once a year

1. Retighten each counterweight capscrew to 210 ft-lb ± 5 (285 N·m ± 7).

2. Any hex head screw not meeting torque specifications must be inspected (includes washer).

3. Check hex head screw for nicks, cracks, galled or stretched threads and/or other damage. Check washer for nicks and abrasive wear. Replace counterweight hex head screw (P/N 304051) and/or hardened washer (P/N 304052B) if any defects are found.

Crankshaft Counterweight Installation

CAUTION **Never remove the crankshaft counterweights from the crankshaft. The crankshaft is balanced at the factory with the counterweights attached. The counterweight mounting holes are oversized, and it is impossible to attach the weights back in their original positions. Disregarding this information could result in product damage and/or personal injury.**

If counterweights are removed, use the following procedure:

1. Place counterweight on crankshaft flat with part number facing main bearing journal.

2. Verify locating dowel pins are in position for each counterweight.

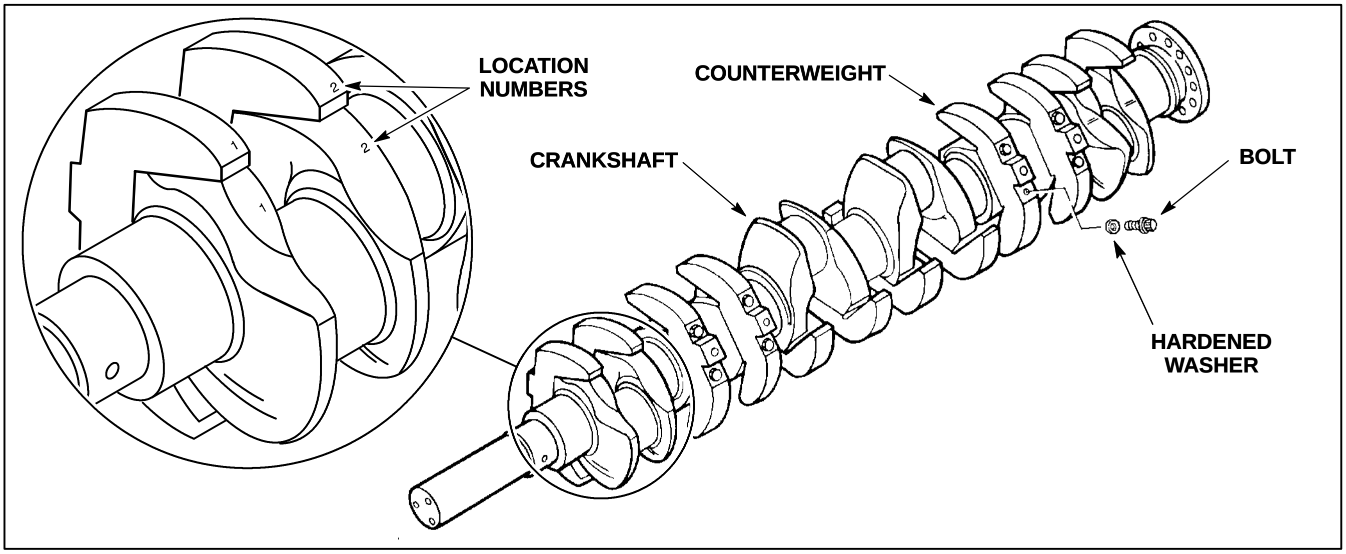


Figure 3.05-3. Crankshaft

3. Verify counterweight and crankshaft cheek are stamped with identical location numbers (see Figure 3.05-3).

⚠ WARNING

Installing the counterweights in the wrong location will cause the crankshaft to be unbalanced. Operating an engine with an unbalanced crankshaft could result in catastrophic engine damage and possible severe personal injury or death.

4. Verify counterweight side is flush with or slightly set back from crankshaft wall on main bearing side. Counterweight may overlap wall slightly on rod bearing side.

NOTE: *Overlapping the wall on the main bearing side will interfere with installation of the main bearing cap.*

5. Lubricate the first few threads of counterweight bolt, underside of bolt head and one side of hardened washer with engine oil.

6. Slide hardened washer on bolt with lubricated side facing bolt head.

7. Secure counterweight to crankshaft with bolts. Tighten bolts to 210 ft-lb ±5 (285 N·m ±7).

CAMSHAFT

CAMSHAFT CLEANING AND INSPECTION

⚠ CAUTION **Replace all camshaft follower assemblies when a new camshaft is installed. Wear patterns on used followers could result in early failure of a new camshaft.**

NOTE: *If any of the camshaft drive gears exceed the gear lash tolerances, they MUST be replaced.*

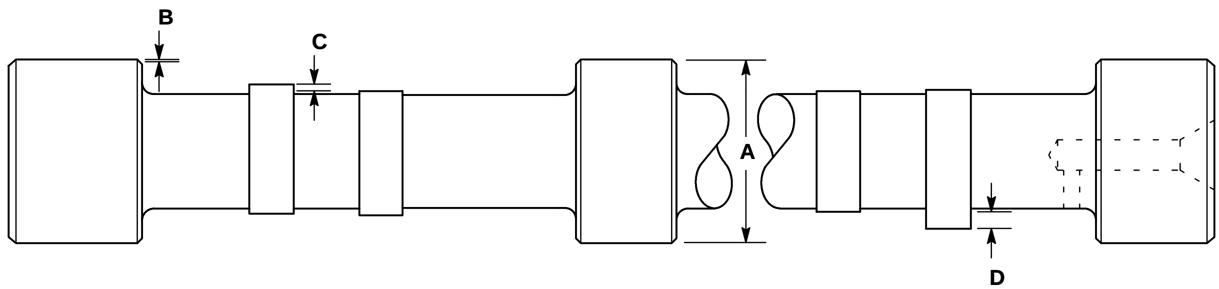
NOTE: *The camshaft bearings should be replaced at engine overhaul.*

Normally the camshaft needs no special maintenance, other than regular inspections of its bearings, journals, and cam lobes when other routine maintenance is performed (see Table 3.05-2).

Since camshafts rotate at 1/2 engine speed and are liberally lubricated, camshaft bearing surfaces are usually found in good condition. If after inspection, the camshaft or its journals are not in satisfactory condition, it will be necessary to chrome plate the camshaft and grind it back to size.

⚠ CAUTION **Keep all chrome from fillet areas. Camshaft journals should be polished after the camshaft is ground back to standard size. Disregarding this information could result in product damage.**

Table 3.05-2. Camshaft



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Camshaft bearing journal diameter	2.6723 (67.8764)	2.6736 (67.9094)	2.675 (67.940)
(B) Camshaft bearing journal running clearance	0.008 (0.203)	0.002 (0.051)	0.005 (0.127)
Camshaft endplay	0.011 (0.279)	0.004 (0.101)	0.006 (0.152)
Endplay adjustment-increase or decease shim pack (Shims are available in .004, .006, .008, .020 in. [0.1, 0.15, 0.12, 0.5 mm].)			
Cam lobe lift			
(C) Intake	0.412 (10.465)	0.417 (10.592)	
(D) Exhaust	0.411 (10.439)	0.416 (10.570)	

NOTE: *Camshaft coupling must never be loose (8 cylinder engines).*

1. Inspect camshaft lobes and bearing journals for excessive wear (see Figure 3.05-4).

NOTE: *A slight wear pattern is normal. Camshaft lobes will show a wear pattern as wide as the follower roller. The camshaft must be reconditioned or replaced if the cam lobes show any sign of wear from the followers. These light wear patterns may be polished using a lathe.*

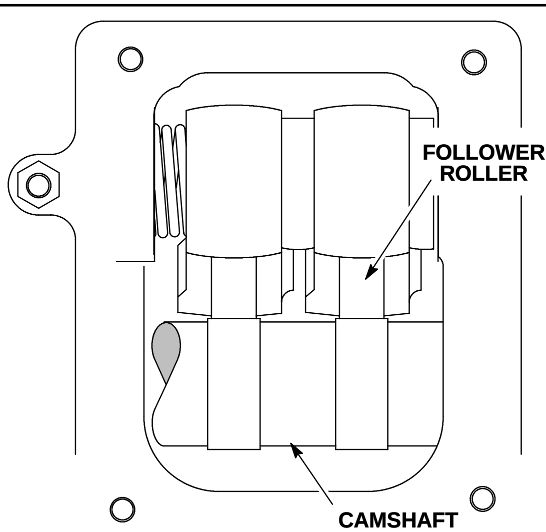


Figure 3.05-4. Inspect Cam Followers

2. Polish camshaft lobes using a lathe.

3. Inspect camshaft for heavily pitted areas. Replace camshafts that have pitting that cannot be polished out.

4. Inspect camshaft followers.

5. Check camshaft for straightness. Support end bearing journals of camshaft on blocks. Rotate camshaft and check for straightness with a dial indicator. Camshaft must be straight within 0.001 in. (0.0254 mm).

6. Check camshaft bearing journal running clearance (this check should be repeated after polishing, before assembly).

NOTE: *Oil flows through the camshaft bushings and into the camshaft. The camshaft itself directs oil flow to lubricate the cam followers and to drilled passages to the cylinder heads. Remove the plugs from both ends of the camshaft and thoroughly clean the internal passage of sludge.*

7. Flush cleaning solution through oil passages. Loosen deposits in oil passages with a stiff wire brush.

⚠ WARNING

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

8. Dry camshaft using compressed air. Verify oil passages are clear of any obstruction (use a stiff wire brush).

9. Lightly coat camshaft with oil to prevent surface oxidation.

CAMSHAFT FOLLOWERS

CAMSHAFT FOLLOWER CLEANING AND INSPECTION

⚠ WARNING

Cleaning solvents may be toxic or flammable. Keep away from heat or flame. Read the manufacturer's warnings on the container. Always use approved cleaning solvents in a well ventilated area. Contact with skin could result in severe personal injury or death.

⚠ CAUTION **Replacement (new) camshaft followers are shipped from the factory coated with a light rust preventative. Never immerse new camshaft followers in any type of cleaning solvent. This would not only remove the outer rust preventative coating, but would also remove the lubricant from the camshaft follower bushing and pin, which could result in failure of the component.**

1. Clean camshaft followers of any varnish or buildup.

2. Inspect cam follower roller for smooth rotation (ensure that roller is properly lubricated). Check roller for tight or loose spots.

3. Inspect outside diameter (OD) of roller for scuffing or chips (see Figure 3.05-5).

4. Disassemble cam follower and measure components for wear (see Table 3.05-3, Figure 3.05-5 and Figure 3.05-6). Replace worn components.

NOTE: *Never install "used" retaining rings. If the retaining rings are removed from the camshaft followers, replace them with new ones.*

⚠ WARNING

Always wear safety glasses when removing retaining (snap) rings. Verify the correct retaining ring pliers is used and it is in good condition. If the retaining ring slips off the pliers when being installed or removed, it can be propelled with enough force to cause a serious eye injury. Disregarding this information could result in severe personal injury.

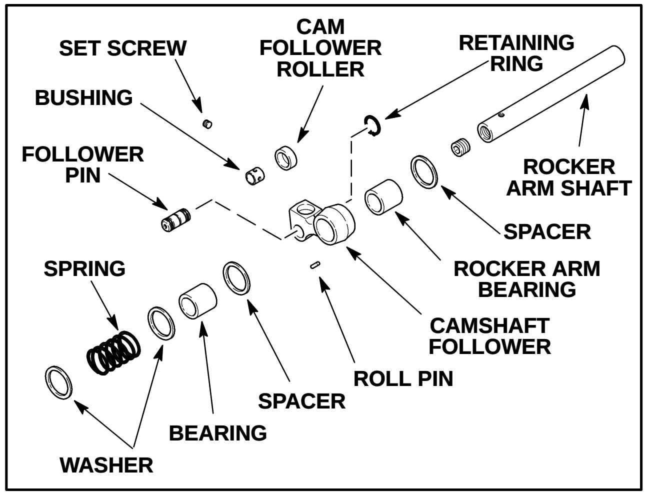


Figure 3.05-5. Camshaft Follower Disassembly

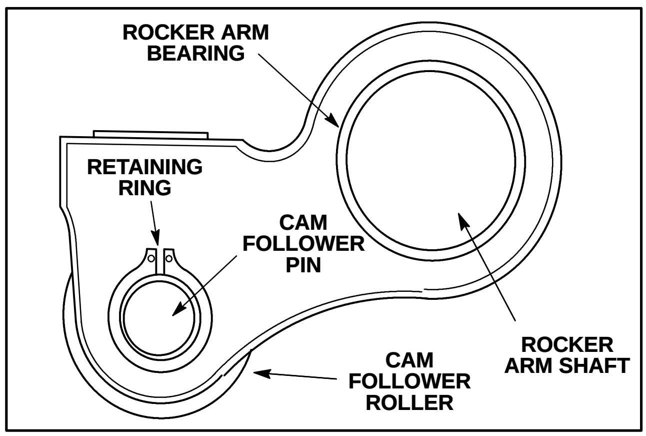


Figure 3.05-6. Camshaft Follower

⚠ CAUTION **Never install cam followers "dry." Always lubricate the cam followers with S.A.E. 20 or 30 weight oil prior to installation. Disregarding this information could result in product damage and/or personal injury.**

5. Lubricate both new and used followers in S.A.E. 20 or 30 weight oil prior to installation. Always store cam followers in S.A.E. 20 or 30 weight oil.

Table 3.05-3. Camshaft Follower Tolerances

SPECIFICATION	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
Rocker Arm Bushing ID	1.263 (32.08)	1.2602 (32.01)	1.261 (32.03)
Rocker Arm Shaft OD	1.2579 (31.95)	1.2595 (31.991)	1.2597 (31.996)
Camshaft Follower Pin OD	0.6276 (15.94)	0.6287 (15.97)	0.6291 (15.98)
Camshaft Follower Bushing ID (see Figure 3.05-5)	0.635 (16.13)	0.6319 (16.05)	0.6327 (16.07)
Camshaft Follower Bushing OD (see Figure 3.05-5)	0.9028 (22.93)	0.9039 (22.96)	0.9047 (22.98)
Camshaft Follower Roller ID	0.9102 (23.12)	0.9079 (23.06)	0.9091 (23.09)
Camshaft Follower Roller OD	1.3362 (33.94)	1.337 (33.96)	1.3386 (34.00)

PISTON

PISTON DISASSEMBLY

WARNING

Always wear safety glasses when removing piston pin retaining rings. Verify the correct retaining ring pliers is used and it is in good condition. If the retaining ring slips off the pliers when being installed or removed, it can be propelled with enough force to cause a serious eye injury. Disregarding this information could result in severe personal injury.

NOTE: *The piston pins are full floating and are not press fit. Due to manufacturing tolerances some pins may fit slightly tighter than others.*

1. Remove pin retaining rings. Slide out pin and remove connecting rod (see Figure 3.05-7).

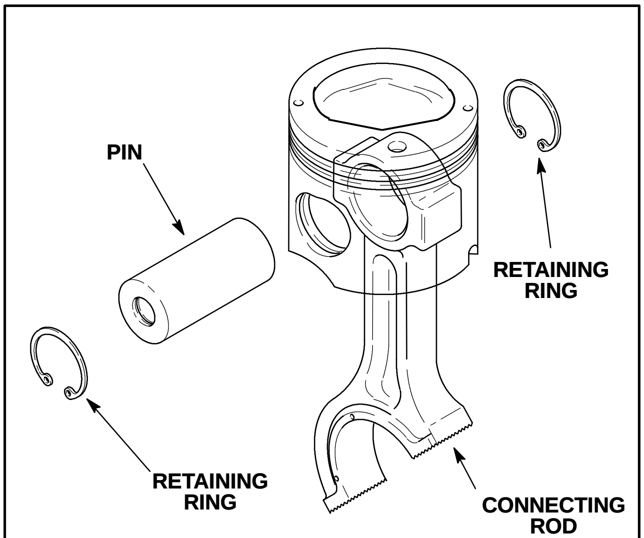


Figure 3.05-7. Piston Pin

CAUTION **Do not install used (more than 50 hours running time) piston rings. Previously used rings will not seat or wear properly, resulting in decreased oil control and compression.**

2. Use piston ring expander pliers P/N 472075 to remove first and second compression rings from piston (see Figure 3.05-8). Discard piston rings.

3. Remove oil control ring from piston.

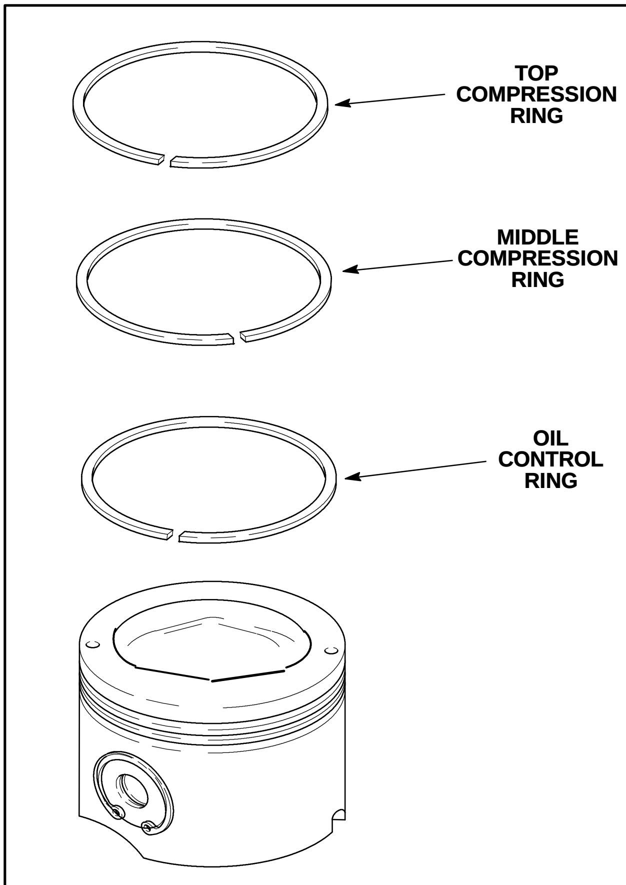


Figure 3.05-8. Piston Ring Removal

PISTON CLEANING AND INSPECTION

⚠ CAUTION Do not sand blast or glass bead pistons. Sand and glass bead blasting removes the tin plating and rounds off the ring lands. Disregarding this information could result in product damage.

⚠ CAUTION Do not place pistons in any type of caustic hot bath. Caustic solutions will dissolve aluminum and the tin plating may blister or warp if heated to temperatures above 212° F (100° C).

⚠ WARNING

Use only non-flammable cleaning solvents. Do not use gasoline. Disregarding this information could result in severe personal injury or death.

New Pistons

NOTE: *New pistons are coated with an anti-corrosive film used for storage protection. Before installing new pistons into the engine remove this protective film.*

1. Use a non-flammable cleaning solvent and a soft bristle brush to remove protective film.

⚠ WARNING

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

2. Dry pistons with compressed air, coat with clean engine oil and assemble into engine immediately.

Used Pistons

NOTE: *To remove carbon deposits, immerse the pistons in a concentrated solution of a liquid cleaner (i.e. Mr. Clean®) heated to 122° F (50° C) for a minimum of 24 hours. Stubborn deposits can be removed by using a hard brass brush. The cleaning solution or detergent used must **not** damage aluminum. Maintain the temperature of the cleaning solution below 212° F (100° C).*

1. Remove carbon deposits by washing pistons in cleaning solution or detergent.

⚠ CAUTION Exercise care to avoid scratching the sides of the piston ring grooves. Disregarding this information could result in product damage.

2. Use a ring groove cleaner to remove carbon deposits from piston ring grooves.

3. Clean oil drain notches located in oil control ring groove (see Figure 3.05-9). **Do not** use a wire brush.

NOTE: *Pistons with superficial wear marks, minor scratching or mild scoring may continue to be used.*

4. Inspect pistons for excessive damage. Discard pistons with cracked, broken or bent ring lands. Check piston skirt for cracks, gouges, deep scratches or heavy scoring (displaced metal formed into patches or crowns). Check piston pin bore for any cracks (see Figure 3.05-9).

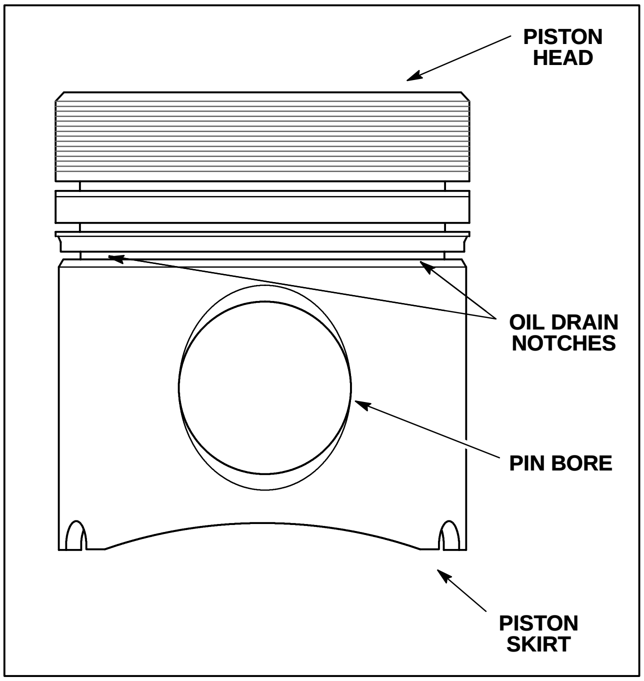
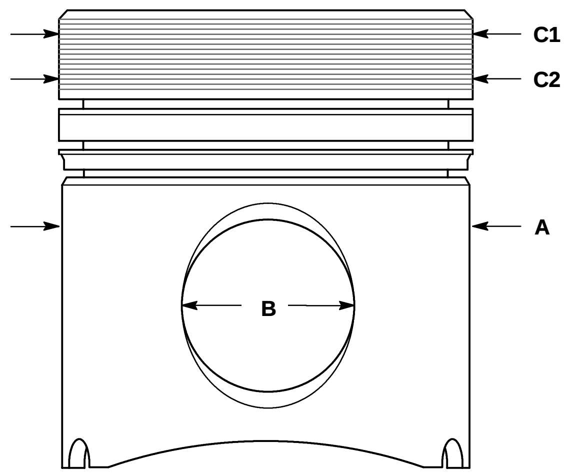


Figure 3.05-9. Piston Oil Drain Holes

5. Check piston heads for evidence of burning, etching, melting and valve contact. If imprints can be seen, the engine has been assembled out of time (see Section 1.20 *Specifications* for rear gear train timing marks).

6. Feel around edge of piston skirt for dings, nicks, or burrs. Lightly file edge of piston skirt to remove any defects.

Table 3.05-4. Piston Tolerances



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) 90° from pin hole (top)	5.9710 (151.663)	5.9740 (151.739)	5.9748 (151.761)
(B) Piston pin bore	2.5608 (65.044)	2.5593 (65.006)	2.5595 (65.012)
(C1) Piston head land diameter	5.9429 (150.95)	5.9469 (151.05)	5.9484 (151.09)
(C2) Piston head land diameter	5.9559 (151.28)	5.9579 (151.33)	5.963 (151.46)

⚠ WARNING

Never operate an engine with a cracked piston. Operating an engine with a cracked piston could result in severe engine damage and possible severe personal injury or death.

NOTE: *One of the most important areas to dye check pistons for cracks is around the top of piston pin bore.*

7. Use Magnaflux® Dye Penetrant Test Kit (P/N 494283) to test piston for surface cracks. Test around pin bores, ring lands and oil drain holes.

8. Polish pistons and pin bores with fine grit crocus cloth to remove minor scuff marks and scratches.

9. Replace cracked and/or damaged pistons. If piston shows no cracks or excessive damage, continue inspection.

⚠ CAUTION **Waukesha assumes absolutely no liability for any damage that may occur from engine parts that exceed the published wear limit. Reuse of engine parts that do not meet the new part specifications are the sole responsibility of the user. Under no circumstances is the reuse of any part exceeding the published wear limits justified.**

⚠ CAUTION **Use the published wear limits with discretion. Although Waukesha recognizes that many used parts are suitable for continued service, there is almost always a corresponding reduction in performance. Carefully consider the following items before reusing any particular part: (a.) The number of mating parts being reused. (b.) The extent of the repair relative to the expected service life prior to the next major overhaul. (c.) The engine application, such as horsepower requirement, maintenance intervals and type of installation. (d.) The problems that may occur through reuse.**

10. Measure piston diameter “A” 90 degrees from piston pin bore (see A in Table 3.05-4). Discard piston if diameter exceeds limits.

11. Measure inside diameter (ID) of piston pin bore at four locations (see B in Table 3.05-4). Discard piston if ID exceeds limits.

NOTE: *Worn ring grooves result in high oil consumption and blow-by of exhaust gases. Blow-by of exhaust gases contaminates the engine oil with acids and leaves sludge in the crankcase.*

12. Insert edge of new ring into piston ring groove (see Figure 3.05-10).

13. Insert feeler gauge between ring upper surface and ring land. Measure and record ring groove side clearance.

14. Measure and record ring groove side clearance at several locations around piston circumference.

15. Replace pistons that exceed limits (see Table 3.05-5).

16. Cover pistons with clean plastic sheet to protect from dust and dirt.

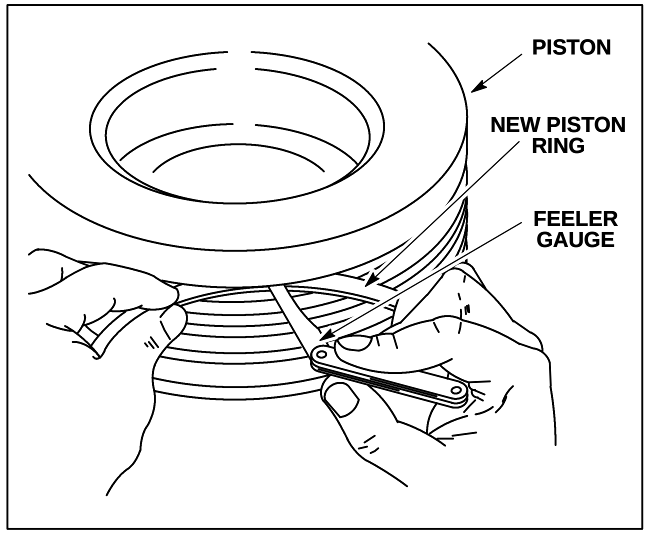
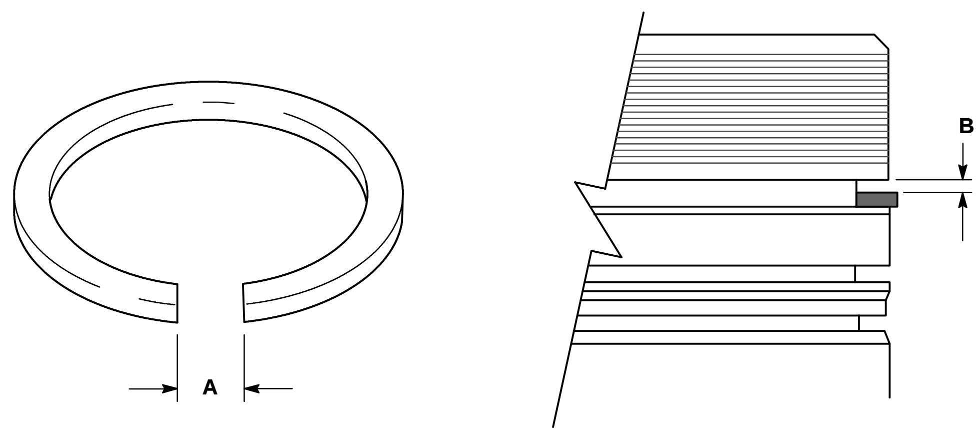


Figure 3.05-10. Check Piston Ring Groove Clearance

Table 3.05-5. Piston Ring Dimensions



Top ring: Barrel-faced chrome plated, compression (top is marked “TOP”).			
Second ring: Tapered face compression (top marked with a dot for “TOP” or “UP”).			
Third ring: Conformable grooved oil ring with expander.			
	WEAR LIMIT in. (mm)	**NEW MINIMUM in. (mm)**	**NEW MAXIMUM in. (mm)**
(A) Ring gap			
Top	0.0598 (1.52)	0.0197 (0.50)	0.030 (0.762)
2nd	0.063 (1.60)	0.0236 (0.60)	0.033 (0.838)
3rd	0.061 (1.55)	0.0197 (0.50)	0.031 (0.787)
(B) Side clearance (piston ring to ring groove)			
Top	0.0059 (0.15)	0.0020 (0.050)	0.0033 (0.084)
2nd	0.0039 (0.10)	0.0020 (0.050)	0.0033 (0.084)
3rd	0.0059 (0.15)	0.0012 (0.030)	0.0020 (0.050)

Table 3.05-6. Piston Pin

SPECIFICATION	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Piston pin diameter	2.5577 (64.966)	2.5587 (64.991)	2.5591 (65.001)
Piston pin to connecting rod bore clearance	0.0031 (0.08)	0.0014 (0.0356)	0.0023 (0.058)

PISTON RING INSPECTION

Perform the following checks before installing the piston rings. See Section 4 *Crankcase Component Assembly* for piston ring installation procedures.

⚠ CAUTION Do not install used (more than 50 hours running time) piston rings. Previously used rings will not seat or wear properly. Installing used rings will result in decreased oil control and compression.

1. Insert new ring into cylinder sleeve. Install piston upside down into cylinder liner. Push ring with piston to lower end of cylinder bore. Measure ring gap with feeler gauge. Discard piston ring if gap exceeds limits listed in Table 3.05-5.

⚠ CAUTION Insufficient ring gap may cause the ends to abut at engine operating temperatures, resulting in ring breakage, sleeve scuffing and/or piston seizure. Disregarding this information could result in product damage and/or personal injury.

⚠ CAUTION Excessive ring gap results in high oil consumption and blow-by of exhaust gases. Blow-by of exhaust gases contaminates the engine oil supply with acids and leaves sludge in the crankcase. Disregarding this information could result in product damage and/or personal injury.

PISTON PIN CLEANING AND INSPECTION

1. Wash piston pins in a non-caustic cleaning solution or solvent.

⚠ WARNING

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

2. Dry piston pins with compressed air.

NOTE: *Always replace the pin when a new piston is installed.*

3. Visually inspect pin for etching, scoring, damage or excessive wear. Any surface wear or defect that may be felt is cause for replacement.

4. Measure outside diameter (OD) of piston pin where pin bore and rod bushings make contact. See Table 3.05-6 and Figure 3.05-11 for piston pin specifications. Discard pin if it exceeds limits.

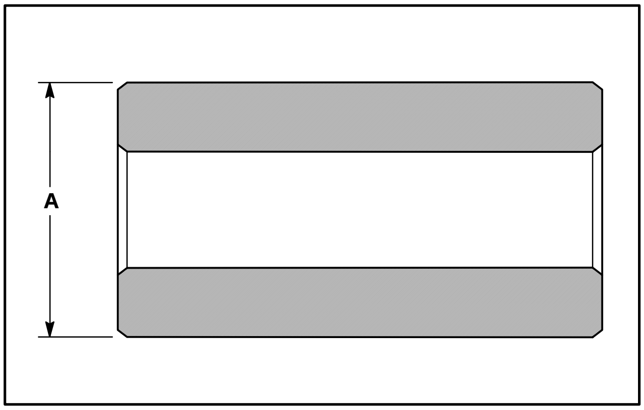


Figure 3.05-11. Piston Pin

5. Polish piston pins with fine grit crocus cloth to remove minor scuff marks and scratches.

6. Out-of-round conditions can be corrected by turning with a lathe.

7. Cover piston pins with clean plastic sheet to protect from dust and dirt.

CONNECTING ROD

CONNECTING ROD INSPECTION

⚠ CAUTION Lack of attention to the integrity of the connecting rod bearing bores during an overhaul may result in a rod bearing failure. Careful attention must be given to all aspects of the rod and bolts.

1. Clean connecting rod mating surfaces between rod and cap with non-caustic solution.

NOTE: *Current connecting rod bolts (P/N 304055B) should be replaced during major overhaul or if excessive overspeed, over tightening, or hydraulic lock are suspected. Previous connecting rod bolts may only be retightened three times before replacement.*

2. Clean oil hole located at top of rod. Clean all bolts thoroughly. Replace bolts if damaged.

NOTE: *Do not re-tap the connecting rods or chase the bolt threads. The connecting rod and bolts are tapped with a "rolled" thread and cannot be duplicated.*

3. Inspect all connecting rod bolts for nicks or damage. When lubricated with SAE 30 weight oil, bolts must screw into rod face by hand. If bolt will not screw in by hand, clean thread and try a new bolt. If a new bolt does not screw in freely, the rod must be discarded.

4. Install connecting rod cap and secure with connecting rod bolts and washers (see Figure 3.05-12.). Lubricate bolt threads and washer faces with clean engine oil and tighten to 310 ±15 ft-lb (420 ± 20 N·m).

5. Measure and record the three inside diameters at points “A,” “B,” and “C” as shown in Figure 3.05-12.

- If the difference between points “A” and “C” exceeds 0.002 in. (0.05 mm), rod is unusable (use Table 3.05-7 for calculations).

Table 3.05-7. Connecting Rod, Bushing And Bearing

MEASURE FOR MISMATCH	
Diameter “A” equals	___
Diameter “C” equals	___
Difference of “A”–“C” equals	___

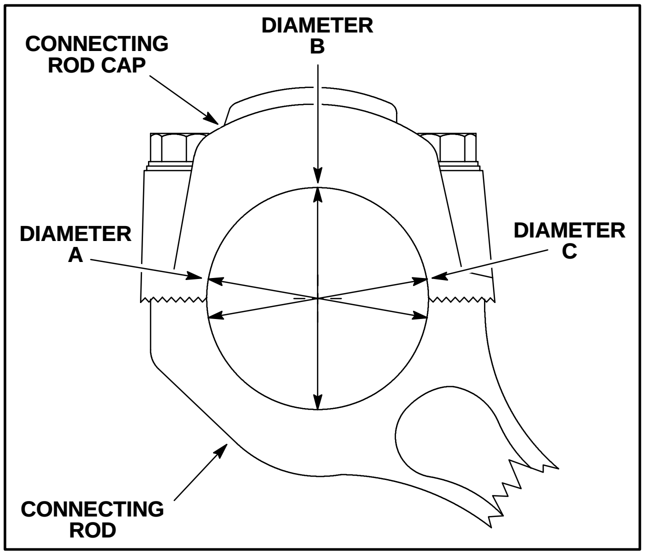


Figure 3.05-12. Connecting Rod

- If the difference between point “B” and the average of “A” and “C” (A + C divided by 2) exceeds 0.002 in. (0.05 mm), rod is unusable (use Table 3.05-8 for calculations).

Table 3.05-8. Connecting Rod, Bushing And Bearing

MEASURE FOR OUT OF ROUND	
Diameter “A” equals	___
Diameter “C” equals	___
The sum of “A”+“C” equals	___
The sum of “A”+“C” divided by 2 equals	___
Diameter “B” equals	___
Difference equals	___

6. Measure inside diameter (ID) of connecting rod piston pin bore (see Figure 3.05-13). Replace bushing if ID exceeds limits (see Table 3.05-9).

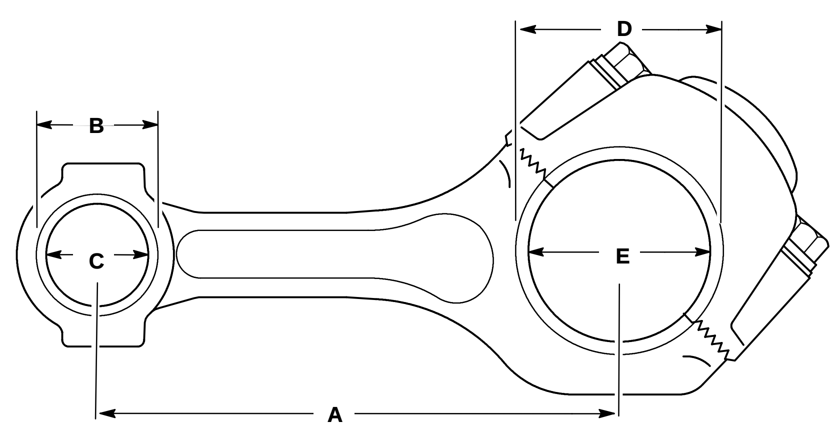


Figure 3.05-13. Connecting Rod, Bushing And Bearing

Table 3.05-9. Connecting Rod, Bushing And Bearing

	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
Rod material-Heat treated steel forging			
Permissible variation 21.16 ± 0.10 lb. (9600 ± 45 grams)			
(A) Rod length, center to center	12.204 (309.981)	12.204 (309.981)	12.2047 (310.00)
(B) Rod small end finish size	2.758 (70.053)	2.756 (70.002)	2.757 (70.028)
(C) Bushing bore diameter (piston pin)	2.5625 (65.087)	2.5604 (65.035)	2.5614 (65.060)
Bushing press fit in rod (interference fit between the rod and bushing)	0.002 (0.050)	0.0026 (0.065)	0.0051 (0.129)
Bushing OD		2.7592 (70.084)	2.761 (70.129)
Pin clearance in bushing	0.0043 (0.109)	0.0014 (0.035)	0.0027 (0.068)
(D) Rod large end finish size*	4.766 (121.056)	4.7638 (121.000)	4.7648 (121.025)
Rod large end width		2.0772 (52.760)	2.0795 (52.820)
Rod side clearance*		0.0142 (0.360)	0.0252 (0.640)
(E) Rod bearing inside diameter	4.535 (115.189)	4.5315 (115.100)	4.5338 (115.159)
Bearing running clearance (theoretical)	0.011 (0.279)	0.0034 (0.087)	0.0066 (0.168)
Connecting rod maximum twist	with bushing 0.005 (0.127), without bushing 0.010 (0.254)		

NOTE: * Check with the bolts installed and tightened to 310 ±15 ft-lb (420 ± 20 N·m).

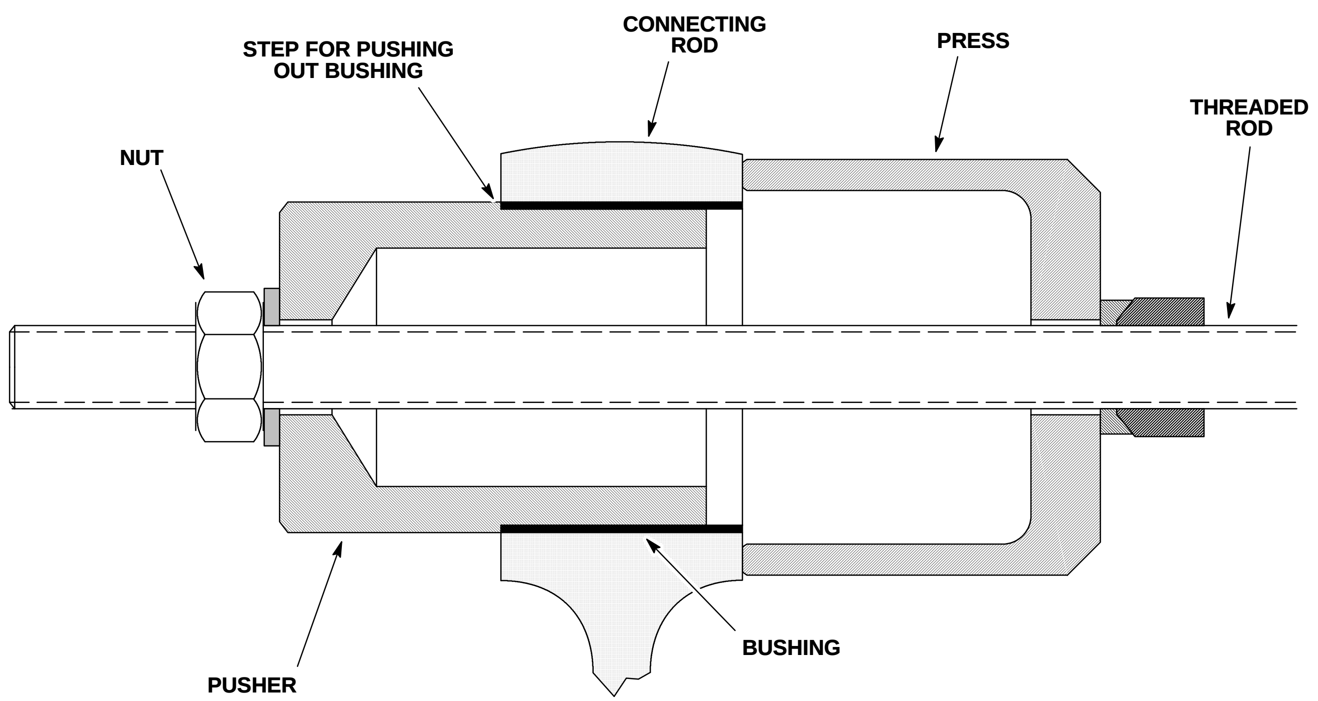


Figure 3.05-14. Connecting Rod Bushing Press Removal

CONNECTING ROD BUSHING REMOVAL

1. Secure rod end in vice (see Figure 3.05-15). Make sure “soft jaws” are installed to prevent rod damage.

Figure 3.05-15. Connecting Rod Bushing Press

2. Remove piston pin bushing from connecting rod with tool P/N 472012 (see Figure 3.05-14).

CONNECTING ROD ASSEMBLY

1. Secure rod end in vice. Make sure “soft jaws” are installed to prevent rod from damage.

NOTE: *The piston pin bushing inside diameter is unfinished and must be sized to match the piston pin being used with each connecting rod. When installing the bushing, the oil hole must be in alignment with the connecting rod oil hole (see Figure 3.05-16).*

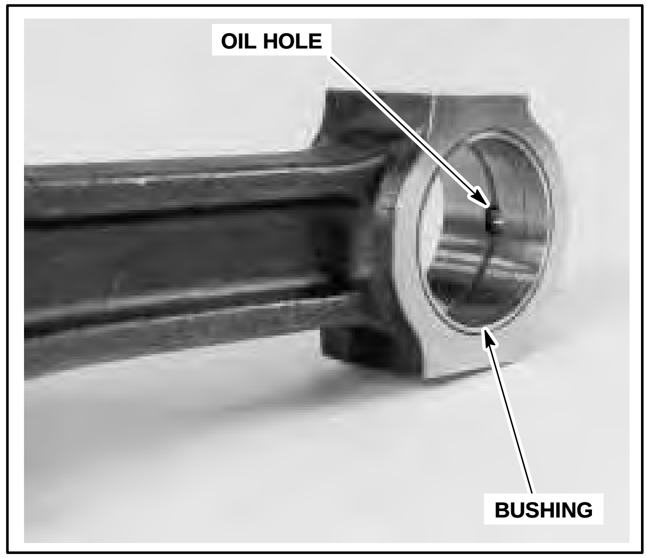


Figure 3.05-16. Connecting Rod Small End

2. Use tool P/N 472012 to install piston pin bushings (see Figure 3.05-17).

3. Bore pin bushing to correct size (see note below).

NOTE: *The pin bushing center must be located 12.204 – 12.205 in. (309.9 – 310.0 mm) from the center of the crankshaft bore (large end of rod), after machining. It is acceptable for the pin bushing wear surface (thickness) to be unequal between top and bottom. The center to center rod length must be maintained (see Table 3.05-9).*

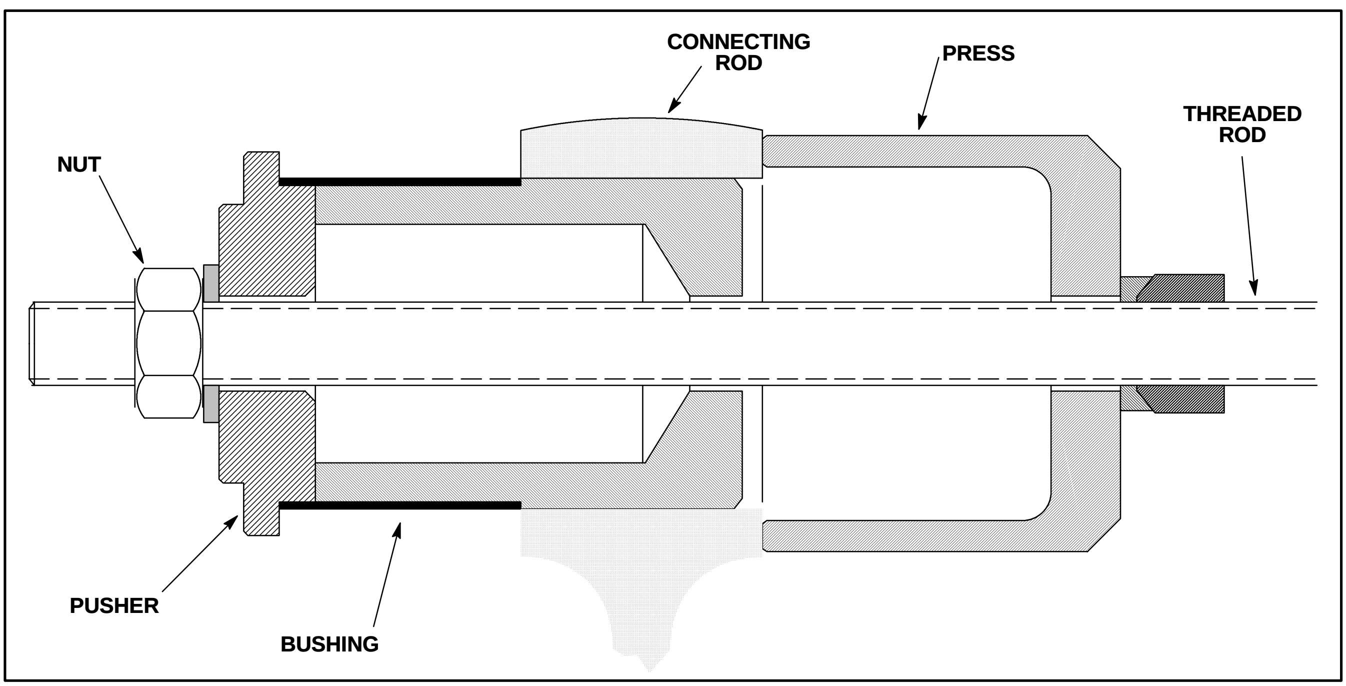


Figure 3.05-17. Connecting Rod Bushing Press Installation

4. Turn the connecting rod upside down and clamp in a vise.

5. Install new bearing inserts. **Do not** touch bearing surfaces.

⚠ CAUTION Connecting rod bolts can be tightened and loosened three times before they must be replaced. Disregarding this information could result in product damage and/or personal injury.

6. Install connecting rod cap and secure with connecting rod bolts and washers (see Figure 3.05-12). Lubricate bolt threads and washer faces with clean engine oil and tighten to 66 ft-lb (90 N·m).

7. Measure and record connecting rod bearing bore ID. Compare recorded measurements with specifications listed in Table 3.05-9.

8. If measurement exceeds limitations, connecting rod must be resized or replaced.

9. To determine connecting rod bearing running clearance, subtract connecting rod bore ID (bearing installed) from crankshaft connecting rod journal OD.

NOTE: *Bearing running clearance is 0.003 in. (0.076 mm) minimum to 0.007 in. (0.178 mm) maximum.*

CYLINDER LINER INSPECTION

CYLINDER LINER DEGLAZING

NOTE: *Deglazing removes wear patterns, minor scuff marks and scratches without enlarging the liner bore diameter. Use a flexible ball-type deglazing tool (see Figure 3.05-18), (8-1/2 in. bore – P/N 494236; 9-3/8 in. bore – P/N 494234). The bristle tip or finishing stone arrangement (180 to 250 grit) is able to produce a 60 degree cross hatch pattern (see Figure 3.05-19). The angular cross hatch pattern ensures an even flow of oil onto the cylinder walls and promotes longer liner, piston and ring life.*

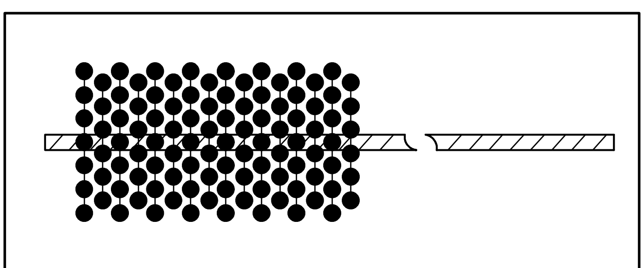


Figure 3.05-18. Flexible Hone

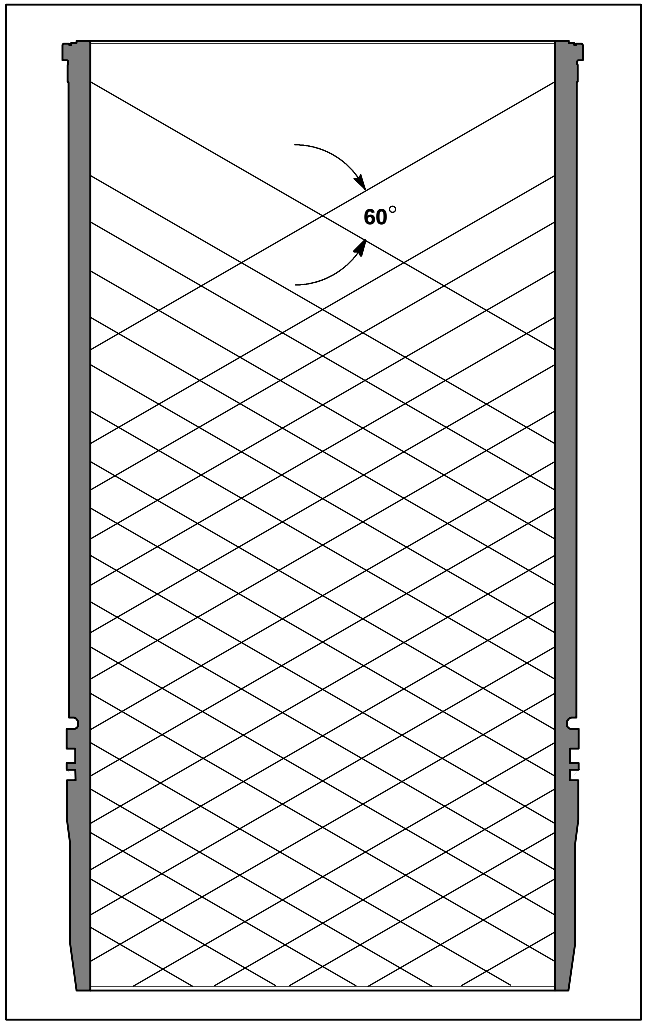


Figure 3.05-19. Cylinder Sleeve Deglazing Cross Hatch Pattern

1. Apply clean engine oil to cylinder liner.

⚠ CAUTION A uni-directional honing pattern does not provide optimum lubrication and may result in severe piston scuffing.

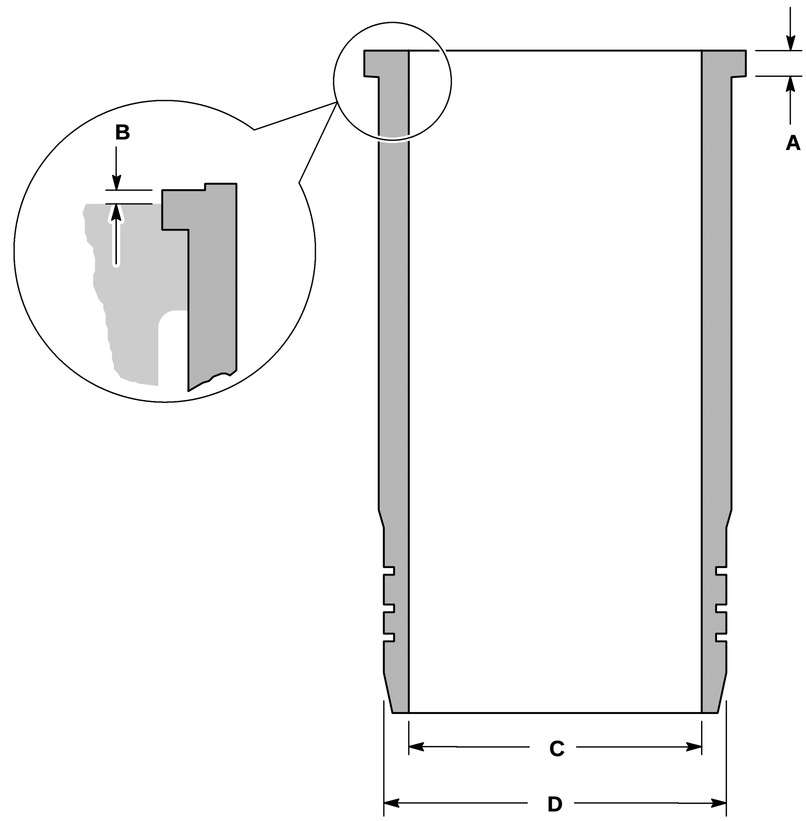
2. Install deglazing tool in slow-speed drill.

NOTE: *To obtain the desired cross hatch pattern adjust the speed of the drill and the up and down motion.*

3. Stop to examine liner bore and/or take measurements (see Table 3.05-10). A precise cross hatch pattern in piston travel area is very important.

4. Move deglazing tool up and down entire length of liner bore for 10 to 12 complete repetitions.

Table 3.05-10. Cylinder Liner Dimensions



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Flange height	0.550 (13.97)	0.551 (14.001)	0.552 (14.021)
(B) Liner protrusion above crankcase	0.000 (0.00)	0.0027 (0.069)	0.0047 (0.119)
(C) Liner ID	5.991 (152.171)	5.984 (151.993)	5.985 (152.019)
(D) Liner OD (lower seal area)	6.768 (171.907)	6.769 (171.932)	6.770 (171.958)
Liner out of round limit	0.003 (0.076)	0.000 (0.00)	0.001 (0.025)
Liner bore maximum taper	0.003 (0.076)	–	–
Liner seal area to crankcase clearance	0.007 (0.177)	0.002 (0.043)	0.005 (0.127)

NOTE: *Make the transition between the naturally worn surface and the area cut with the ridge reamer as smooth as possible.*

CAUTION Failure to remove all abrasive particles may result in premature sleeve, piston and ring wear, and possible engine failure.

5. Wash cylinder liner bore with liquid dishwashing soap and warm water to remove all abrasive particles and residual grit. Continue cleaning until a clean cloth shows no evidence of dirt or debris.

WARNING

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

6. Rinse liner with hot water and dry with compressed air.

7. Apply clean engine oil to inside of liner.

8. Cover cylinder liners with a clean plastic sheet to protect them from dust and dirt.

LOWER CYLINDER LINER BORE

Cavitation and erosion can affect the lower cylinder liner area (see Figure 3.05-20) and prevent the cylinder liner rings from sealing. This area must be in good condition. If grooves or pockmarks have affected the area, or fretting (angular patterning) can be seen or felt, the bore must be machined and restored to standard size (requires the installation of an "oversized" cylinder ring). This operation should only be performed by service shops that have experience in this type of repair.

⚠ CAUTION Do not resurface the lower liner area. If material is removed from the lower liner area, the cylinder liner will be loose when installed. Disregarding this information could result in product damage.

The cylinder liner counterbore depth must be checked (see Table 3.05-11). The correct depth will allow the liner O-rings to seat properly.

Cylinder liner side play cannot be tolerated. Any lateral motion, no matter how slight, will cause the cylinder liner to crack and separate at the top flange. The top flange will remain in place due to the cylinder head/flange mounting.

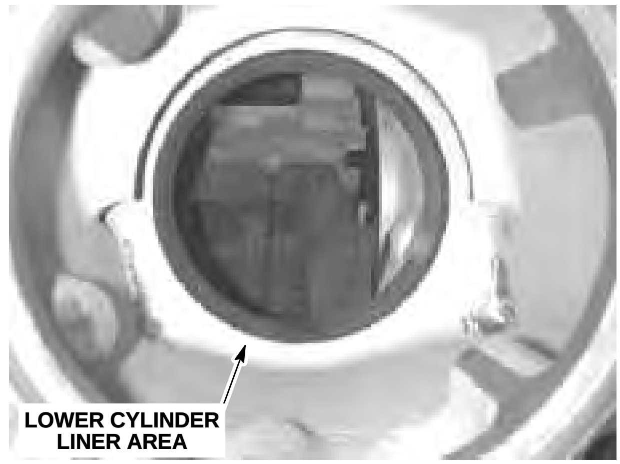
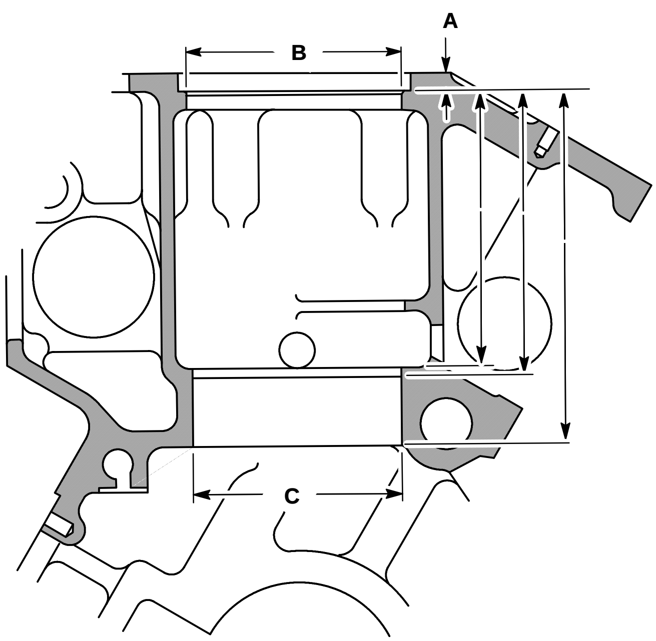


Figure 3.05-20. Lower Cylinder Liner

Table 3.05-11. Crankcase Dimensions



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
(A) Liner counterbore depth	0.5502 (13.975)	0.5512 (14.000)	0.5530 (14.045)
(B) Crankcase upper bore	6.9110 (175.540)	6.9094 (175.500)	6.9110 (175.540)
(C) Crankcase lower bore	6.7743 (172.066)	6.7717 (172.000)	6.7732 (172.040)

FLYWHEEL

RING GEAR REMOVAL

⚠ WARNING

Always wear protective equipment when installing or removing components with an interference fit. Installation or removal of interference components may cause flying debris. Failure to use protective equipment may result in severe personal injury or death.

⚠ CAUTION **Do not try to pry or tap the ring gear from the flywheel. The shrink fit holds the ring gear with sufficient bond that damage to the gear will result if these methods are used.**

1. Cut into ring gear with hack saw (see Figure 3.05-21). **Do not** cut into flywheel.

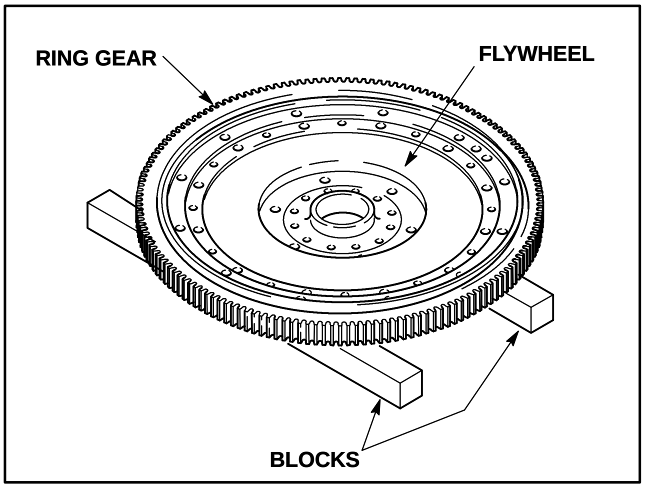


Figure 3.05-21. Flywheel Ring Gear

2. Insert cold chisel into cut and gently tap until ring gear splits and separates from flywheel.

3. Clean outer circumference of flywheel. Remove burrs or raised spots that would prevent new ring gear from seating properly.

RING GEAR INSTALLATION

1. Position flywheel on flat surface.

NOTE: *If the shop oven is not large enough, a torch may be used to heat the ring gear. If the torch is used, make sure to heat the ring gear evenly to prevent the ring gear from binding during installation.*

⚠ WARNING

Always wear protective equipment when installing or removing components with an interference fit. Installation or removal of interference components may cause flying debris. Failure to use protective equipment may result in severe personal injury or death.

⚠ WARNING

Heated components can cause severe burns. Do not handle heated parts with bare hands. Failure to use protective equipment may result in severe personal injury or death.

2. Heat ring gear to approximately 300 - 350° F (149 -177° C).

3. Install ring gear onto flywheel before it cools.

4. Check flywheel balance. Balance must be within 150 gm/0.39 in. (1 cm). Any metal removed must be removed from the outer rim.

TIMING TAPE INSTALLATION

1. Remove old timing tapes.

2. Remove any oil, grease and dirt from flywheel that would prevent proper adhesion of a new timing tape.

3. Align “TDC” mark on timing tape with “TDC 1RB-6R” (12 cylinder engines) or “TDC 1RB-8R” (16 cylinder engines) stamped on flywheel. Timing tape should be readable when facing flywheel from rear.

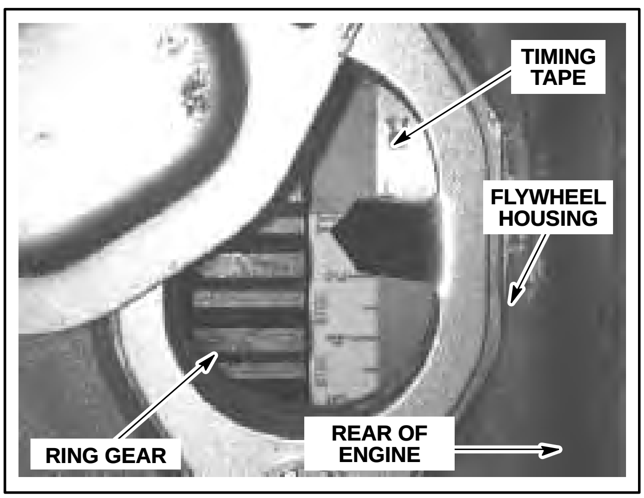


Figure 3.05-22. Timing Tape Installation

4. Peel adhesive backing off timing tape.

5. Place top of tape (inside edge) directly behind letter "T" in "TDC" on rim of flywheel. Use machined lines for reference. Tightly press timing tape into place.

CHECKING CRANKCASE TOLERANCES

Main Bearing Bore Inspection

The main bearing bore must be checked for wear and/or distortion, including out-of-round, taper, surface condition, and bore size.

Normally main bearing bores are found in alignment. Misalignment could occur if the engine had not been properly installed.

If bearing bores are not worn or damaged, or if all damaged caps have been replaced, the bore may be considered properly aligned if a standard size crankshaft can be rotated freely with the main bearings installed and lubricated, and with the bearing caps tightened to the proper torque.

Replacement bearing caps are furnished semi-finished. They must be installed in the correct location, tightened to the proper torque, and then "align-bored."

Main Bearing Cleaning

1. Clean all oil passages. Make sure all "sludge" is removed.

⚠ WARNING

Compressed air can pierce the skin and cause severe injury. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris. Disregarding this information could result in severe personal injury or death.

2. Use compressed air to dry bearing caps and oil passages.

NOTE: *Main bearing caps must be installed in their proper positions and tightened to the proper torque (in the proper sequence) before making any of these checks.*

Main Bearing Bore Inspection

After the crankshaft main bearing caps are installed (without the crankshaft), different bearing cap measurements are recorded and compared with "known" values. The difference in values determines the condition of the main bearings and caps.

The main bearing caps are stamped with #1 through #6 for six cylinder engines and #1 through #8 for eight cylinder engines. The number stamped on the bearing cap must match the number stamped on the bearing saddle.

NOTE: *Late model crankcases use two dowel pins to align the bearing caps. Early model crankcases use one dowel pin to align the bearing cap. The tightening procedures are different for single and dual dowel pin crankcases. Use the correct tightening procedure for each crankcase.*

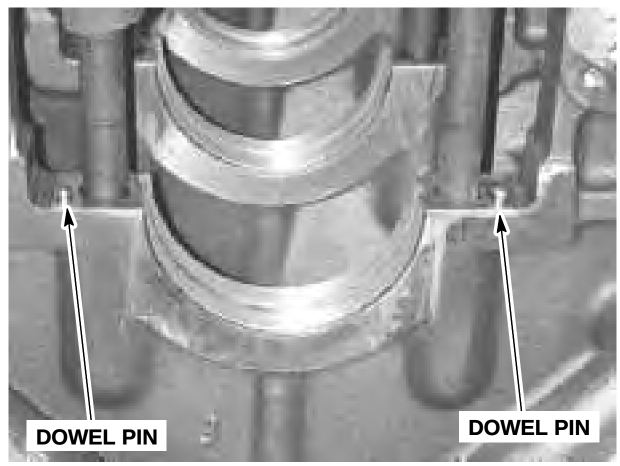


Figure 3.05-23. Dual Dowel Pin Crankcase

NOTE: *The crankcase spreader tool is optional for late model crankcases (dual dowel pins). For these crankcases, in some instances, it may make installation of the main bearing caps easier.*

⚠ CAUTION **Do not spread the crankcase more than 0.006 in. (0.15 mm). Use a dial indicator to measure the spread of the crankcase sides. Disregarding this information could result in product damage.**

1. Install crankcase spreader tool (P/N 472002) along side bearing cap #1 or #5 depending on engine model. Spread crankcase sides. Do not exceed 0.006 in. (0.15 mm).

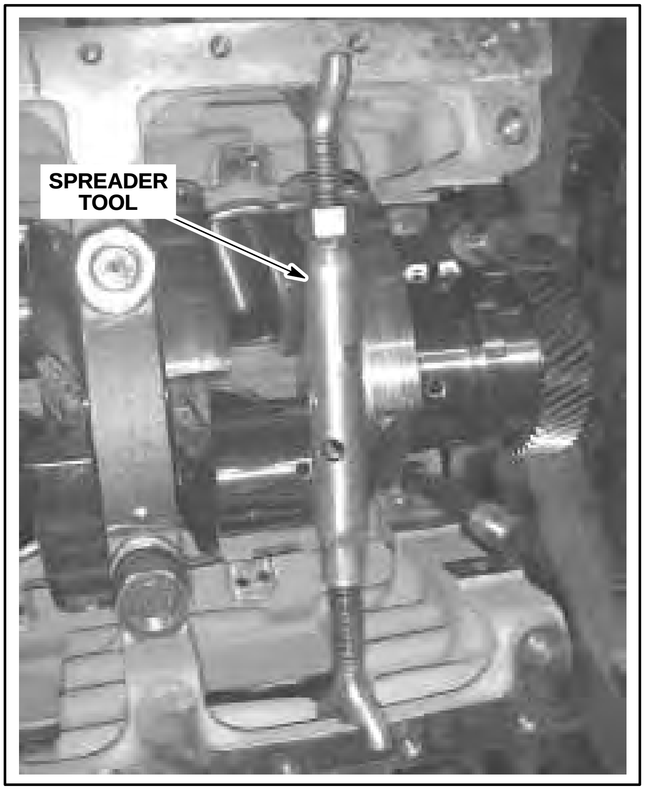


Figure 3.05-24. Crankshaft Spreader Tool

MAIN BEARING CAP INSTALLATION (CRANKSHAFT REMOVED)

The main bearing caps are stamped with #1 through #6 for six cylinder engines and #1 through #8 for eight cylinder engines. The number stamped on the bearing cap must match the number stamped on the bearing saddle.

NOTE: *All torques stated assume bolt threads are coated with clean engine oil. Do not use any lubricant containing molybdenum disulfide.*

SINGLE DOWEL MAIN BEARING CAPS

1. Apply clean engine oil to all bolt threads.

2. Install all main bearing caps and secure with bolts, tighten only enough to seat firmly (see Figure 4.00-9). Make sure bearing cap number matches saddle number. Slot and dowel hole in bearing cap should align with dowels in crankcase.

NOTE: *Left side #5 and #6 main bearing cap crossbolts use special washers and O-rings to seal properly. These crossbolts run through oil passages (see Figure 3.05-25). The differences are visible from the bottom of crankcase.*

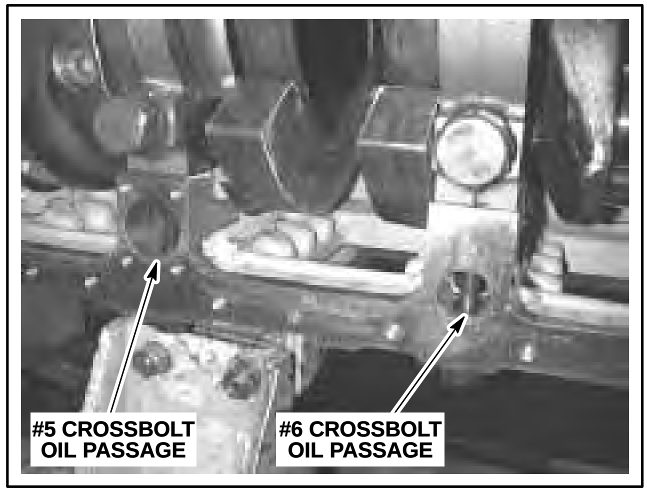


Figure 3.05-25. Crossbolt Oil Passage

3. Install and partially tighten two crossbolts adjacent to spreader on right hand side (dowel side of bearing cap only). Tighten to 37 ± 7 ft-lb (50 ± 10 N·m). Move spreader to new location and repeat until all right crossbolts are installed. Remove spreader.

4. Tighten all right side crossbolts (begin with #1) to 92 ± 7 ft-lb (125 ± 10 N·m).

5. Starting with #1 main bearing, install all left side crossbolts and tighten to 37 ± 7 ft-lb (50 ± 10 N·m).

6. Starting with #1 main bearing, tighten all left side crossbolts to 92 ± 7 ft-lb (125 ± 10 N·m).

7. Starting with #1 main bearing, tighten all main bearing bolts to 325 ± 15 ft-lb (440 ± 20 N·m). Tighten right bolt first, then left bolt for all remaining main bearing caps.

8. Starting with #1 main bearing, tighten all main bearing bolts to 590 ± 15 ft-lb (800 ± 20 N·m). Tighten right bolt first, then left bolt for all remaining main bearing caps.

DUAL DOWEL MAIN BEARING CAPS

1. Install main bearing caps (see Figure 3.05-26). Make sure bearing cap number matches saddle number. Dowel holes in bearing caps should align with dowels in crankcase.

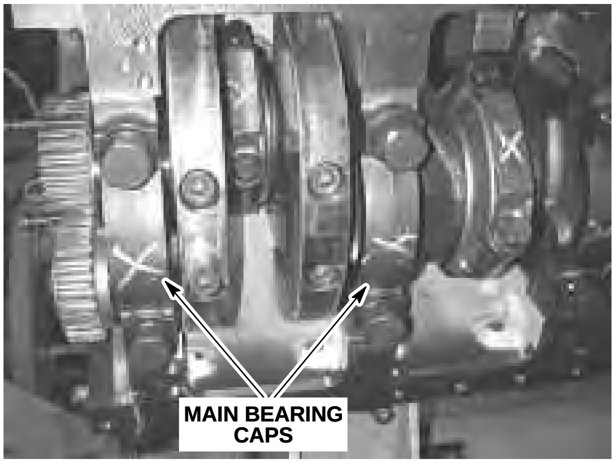


Figure 3.05-26. Main Bearing Cap Installation

2. Apply clean engine oil to all bolt threads.

3. Starting with #1 main bearing, install main bearing cap bolts and tighten to 74 ft-lb (100 N·m).

4. Remove spreader if installed.

5. Starting with #1 main bearing, install all right crossbolts and tighten to 37 ± 7 ft-lb (50 ± 10 N·m).

6. Tighten all main bearing cap bolts to 147 ft-lb (200 N·m) (begin with #1). Tighten right hand side first.

7. Tighten all right side crossbolts (begin with #1) to 92 ± 7 ft-lb (125 ± 10 N·m).

NOTE: *Left side #5 and #6 main bearing cap crossbolts require special washers and O-rings to seal properly. These crossbolts run through oil passages (see Figure 3.05-27). The differences are visible from the bottom of crankcase.*

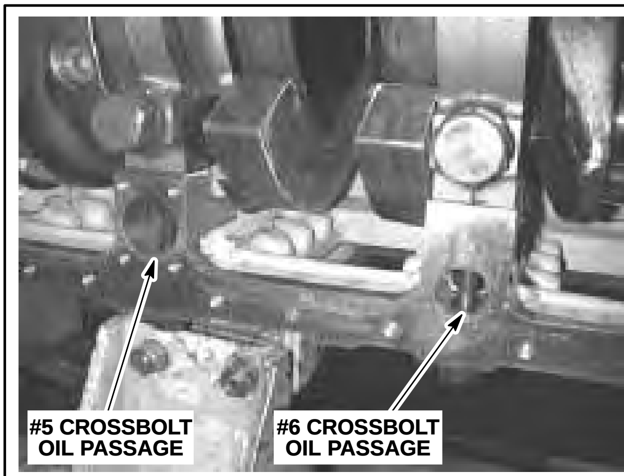


Figure 3.05-27. Crossbolt Oil Passage

8. Install all left side crossbolts (begin with #1) and tighten to 37 ± 7 ft-lb (50 ± 10 N·m).

9. Starting with #1 main bearing, tighten all left side crossbolts to 92 ± 7 ft-lb (125 ± 10 N·m).

10. Starting with #1 main bearing, tighten all main bearing bolts to 325 ± 15 ft-lb (440 ± 20 N·m). Tighten right bolt first, then left bolt for all remaining main bearing caps.

11. Starting with #1 main bearing, tighten all main bearing bolts to 590 ± 15 ft-lb (800 ± 20 N·m). Tighten right bolt first, then left bolt for all remaining main bearing caps.

Main Bearing Bore Measurements

1. Measure and record main bearing bore inside diameter (ID) at four different locations. Use an inside micrometer (see Figure 3.05-28).

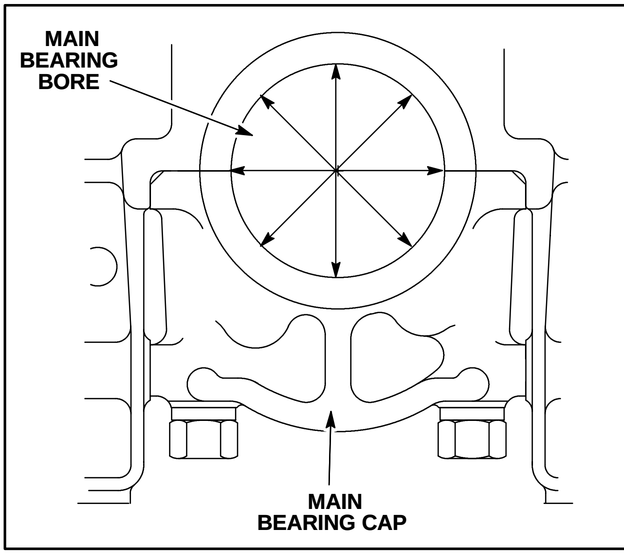


Figure 3.05-28. Measure Main Bearing Bores

NOTE: *Bearings caps that exceed these tolerances are unusable and must be replaced.*

NOTE: *If the crankcase main bearing bore requires re-boring for alignment, install bearing caps without the bearings and tighten nuts to 130 ± 7 ft-lb (175 ± 10 N·m). Torques for crossbolts remain the same (as stated in installation procedures).*

2. Compare recorded measurements to specifications listed below:

- Maximum out-of-round measurement of 0.001 in. (0.0254 mm) is allowed if horizontal dimension exceeds vertical dimension.

- Maximum taper in any bearing bore is 0.0005 in. (0.0127 mm).
- Bore diameter should not exceed 6.574 – 6.575 in. (167.00 – 167.005 mm).

3. Inspect bearing cap surfaces. Bearing cap surfaces must be flat, free from burrs and nicks, and must match evenly when tightened. Main bearing bore finish should be 80 micro–inches.

Main Bearing Running Clearance

NOTE: *One main bearing cap may be removed and replaced without disturbing the others. If one main bearing cap is to be installed, complete the applicable steps for tightening either dual dowel pin caps or single dowel pin caps.*

CAUTION **When used properly, Plastigage™ is an acceptable method of measuring bearing running clearance. If the bearing clearance is greater than the capability of the Plastigage™ being used, inaccurate measurements will be obtained. Inaccurate measurements may cause bearing and/or crankshaft failure.**

1. Measure and record main bearing crankshaft journal outside diameter (OD) at four different locations. Record both minimum and maximum diameters. Use an outside micrometer (see Figure 3.05-29).

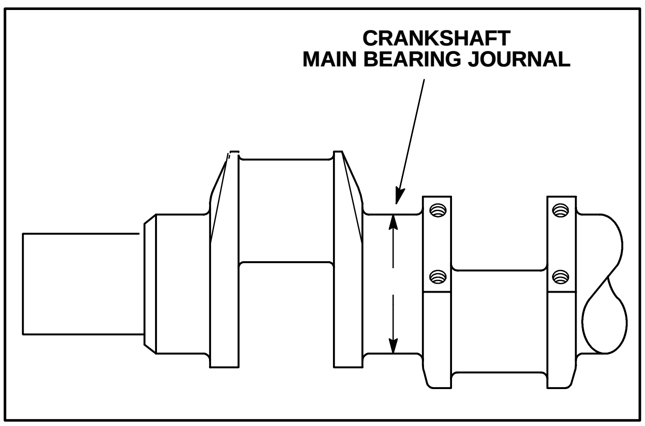


Figure 3.05-29. Crankshaft Main Bearing Journal

2. Compare measured main bearing journal diameters with main bearing journal diameters listed in Table 3.05-13. If actual measurements exceed these specifications, then effected crankshaft journal must be ground undersized (if able) or replaced.

3. Insert recorded minimum/maximum bearing ID and minimum/maximum journal OD (for each mated bearing and journal pair) into bearing thickness formulas (see Figure 3.05-31). Record calculated minimum/maximum bearing thickness.

4. Measure and record bearing crown thickness at both top and bottom bearing halves (see Figure 3.05-30). Use a micrometer with a ball adapter (for measuring spherical surfaces).

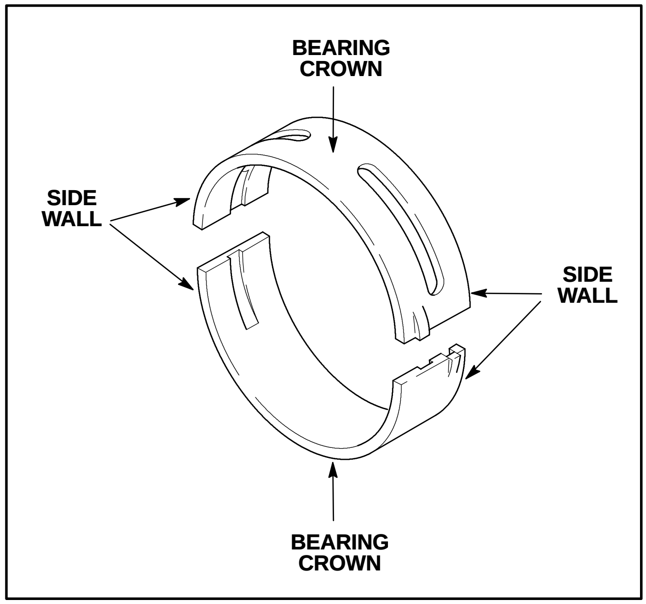


Figure 3.05-30. Main Bearing Running Clearance

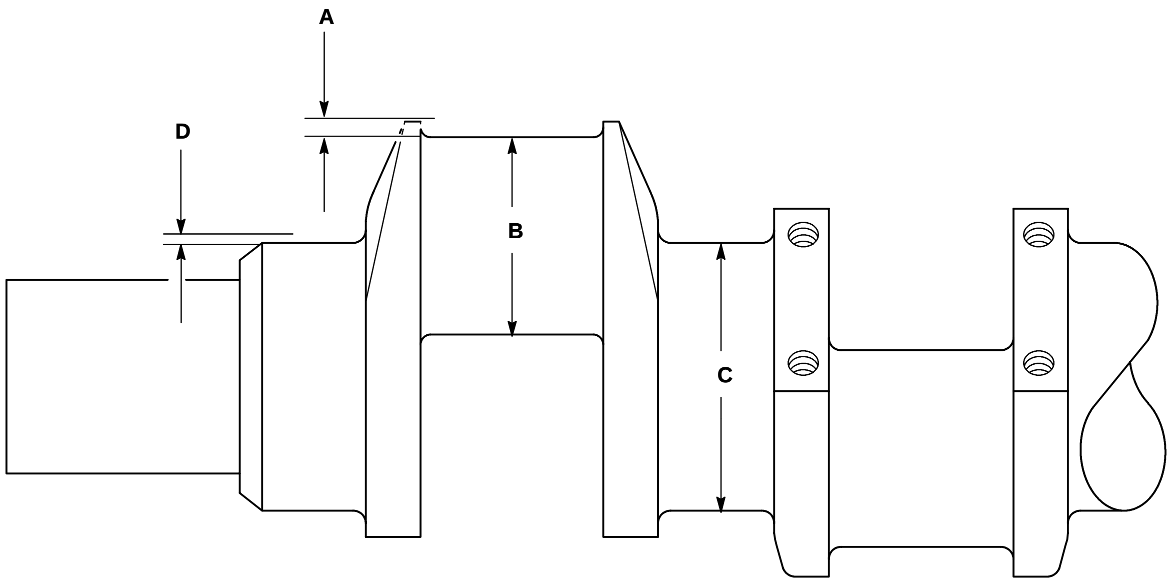
5. Measured bearing crown thickness must be within limits or bearing is unusable (see Table 3.05-12). Bearing side wall thickness (measured at four locations) must be 0.0000 – 0.0007 in. (0.0000 – 0.0178 mm) less than bearing crown thickness or bearing is unusable (see Figure 3.05-30).

Table 3.05-12. Main Bearings

TOOL P/N	TOOL DESCRIPTION	WALL THICKNESS AT BEARING CROWN
A300225F	Standard	0.1155 – 0.1161 in. (2.933 – 2.950 mm)
A300225	(0.020 in.) Oversized	0.1255 – 0.1262 in. (3.188 – 3.205 mm)

6. Compare minimum/maximum bearing thickness to actual measured thickness. Actual measured thickness must fall within calculated minimum/maximum thickness or bearing is unusable.

Table 3.05-13. Crankshaft Specifications



	WEAR LIMIT in. (mm)	NEW MINIMUM in. (mm)	NEW MAXIMUM in. (mm)
Crankshaft endplay	0.0300 (0.762)	0.0138 (0.350)	0.0250 (0.635)
Thrust ring thickness (standard)	0.1328 (3.373)	0.1378 (3.500)	0.1409 (3.580)
(A) Connecting rod bearing running clearance	0.0110 (0.279)	0.0033 (0.083)	0.0069 (0.175)
(B) Connecting rod bearing journal diameter	4.5240 (114.910)	4.5269 (114.983)	4.5282 (115.016)
1st repair - 0.020″ Bearings	4.5040 (114.402)	4.5069 (114.475)	4.5082 (114.508)
Connecting rod bearing journal maximum undersize diameter	4.4870 (113.969)	***NOTE:*** *Do not grind beyond this limit.*	
(C) Main bearing journal diameter	5.3114 (134.909)	5.3134 (134.960)	5.3150 (135.001)
1st repair-0.020″ bearings	5.2914 (134.402)	5.2934 (134.452)	5.2950 (134.493)
(D) Main bearing running clearance	0.011 (0.279)	0.0039 (0.099)	0.0078 (0.199)
Main bearing journal maximum undersize diameter	5.274 (133.959)	***NOTE:*** *Do not grind beyond this limit.*	
Main bearing journal maximum out-of-round	0.0021 (0.0533)		
Main bearing journal maximum taper	0.0021 (0.0533)		
Connecting rod journal maximum out-of-round	0.0018 (0.0457)		
Connecting rod journal maximum taper	0.0018 (0.0457)		
Thermal growth (crankshaft expansion from 70° F (21° C) to normal operating temperature, measured from the base of the engine supports).	0.007 (0.18)		

$$Min.\ bearing\ thickness = \frac{(Min.\ bore\ ID) - (Max.\ journal\ OD) - (Max.\ running/oil\ clearance)}{2}$$

$$Max.\ bearing\ thickness = \frac{(Max.\ bore\ ID) - (Min.\ journal\ OD) - (Min.\ running/oil\ clearance)}{2}$$

Figure 3.05-31. Bearing Thickness Formula

CAMSHAFT BUSHING REMOVAL

1. Remove three M6 x 16 mm socket head screws from front camshaft bushing (flanged).

2. Install camshaft bushing press (P/N 472756). Flanged bushing is pressed out from inside of crankcase. Remove front flanged bushing with press (see Figure 3.05-33).

3. Remove remaining camshaft bushings (non-flanged) with camshaft bushing press (see Figure 3.05-34).

CAMSHAFT BEARING BORE INSPECTION

1. Measure and record camshaft bearing bore inside diameter (ID) at four different locations. Use an inside micrometer (see Figure 3.05-32).

2. Compare recorded measurements to specifications:

- Flanged thrust bushing bore ID should be 4.0945 – 4.0965 in. (104.000 – 104.051 mm).
- Camshaft bushing bore (non-flanged) ID should be 3.8583 – 3.8601 in. (98.000 – 98.047 mm).

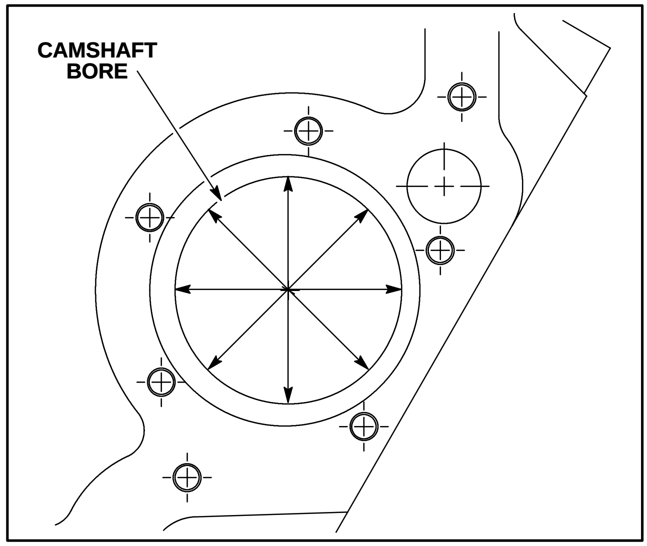


Figure 3.05-32. Measure Camshaft Bearing Bores

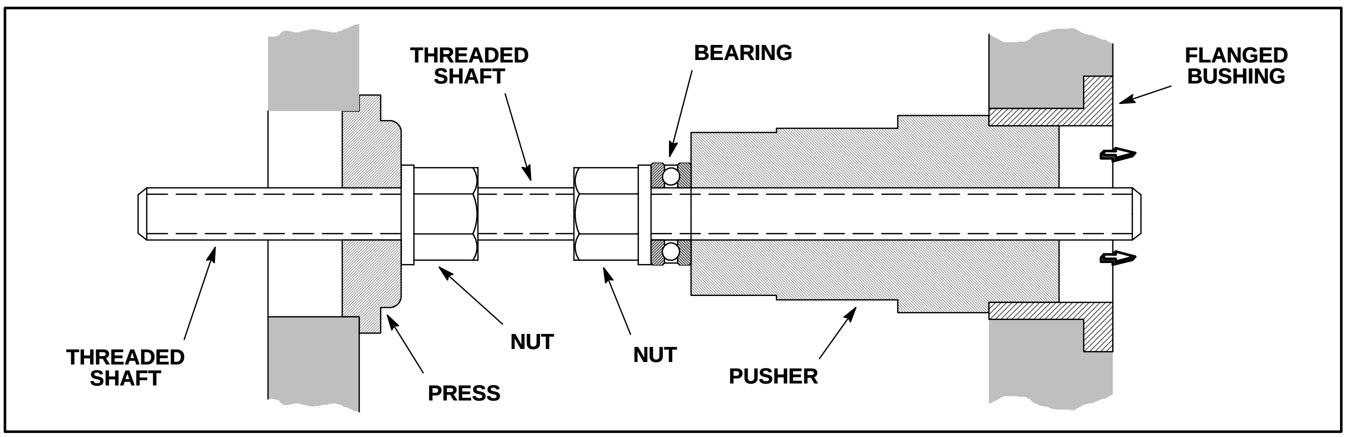


Figure 3.05-33. Cam Thrust Bushing Removal

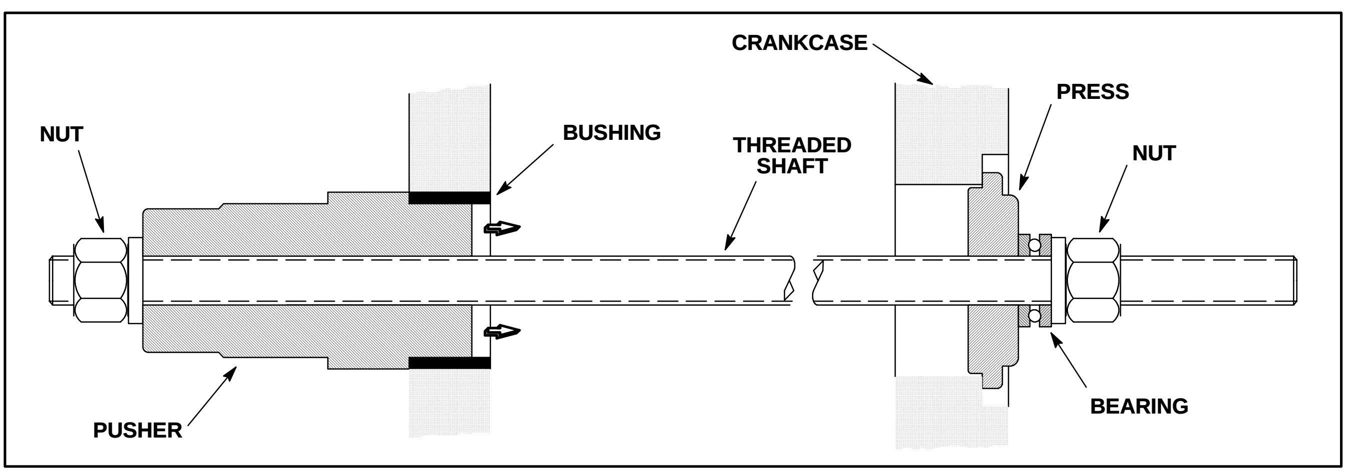


Figure 3.05-34. Camshaft Bushing Press

SECTION 4.00

CRANKCASE COMPONENT ASSEMBLY

Table 4.00-1. Special Tools

TOOL P/N	TOOL DESCRIPTION
472002	Crankcase Spreader Tool
494278	Dial Indicator
472013	Liner Installation Tool
499967	Piston Ring Compressor
472007	Piston Installation Tool
472055	Camshaft Pilot Installation Tool
472012	Connecting Rod Bushing Press
472056	Camshaft Bushing Press
472058	Guide Pin Kit

CRANKCASE ASSEMBLY

⚠ WARNING

The six cylinder crankcase weighs 1384 lb. (628 kg) and the eight cylinder crankcase weighs 1845 lb. (837 kg) completely stripped of other components. If any components are still attached, the crankcase will be heavier by the amount of the component's weight. Lift only with properly rated lifting device and rigging to avoid severe personal injury or death.

⚠ WARNING

Lift the engine using the approved lifting eyes. Never lift the engine with driven or auxiliary equipment still attached. Use approved spreader and rigging procedures. Disregarding this information could result in severe personal injury or death.

⚠ WARNING

Assemble the engine in a rollover stand to provide maximum safety. The crankshaft is installed with the engine upside down. Rotating the engine block using chains and lifting devices is extremely dangerous and not recommended. Disregarding this information could result in severe personal injury or death.

CRANKCASE DOWEL PIN INSTALLATION

1. Install bearing cap dowel pins in bearing saddle (see Figure 4.00-1).

NOTE: *Current engines use two dowel pins per saddle (located on opposite sides) (see Figure 4.00-1 and Figure 4.00-2). Previous engines use one pin per saddle.*

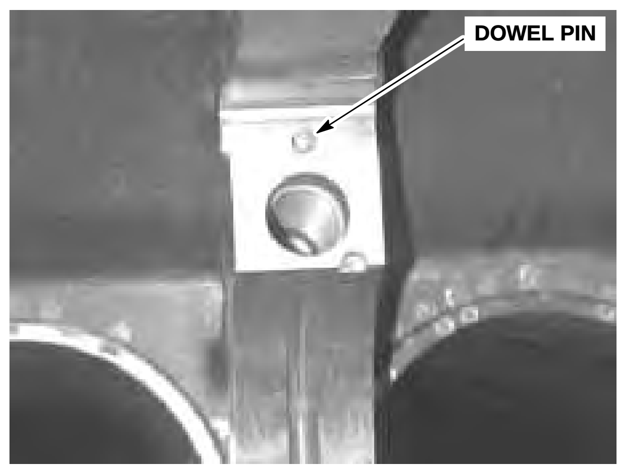


Figure 4.00-1. Crankcase Dowel Pin

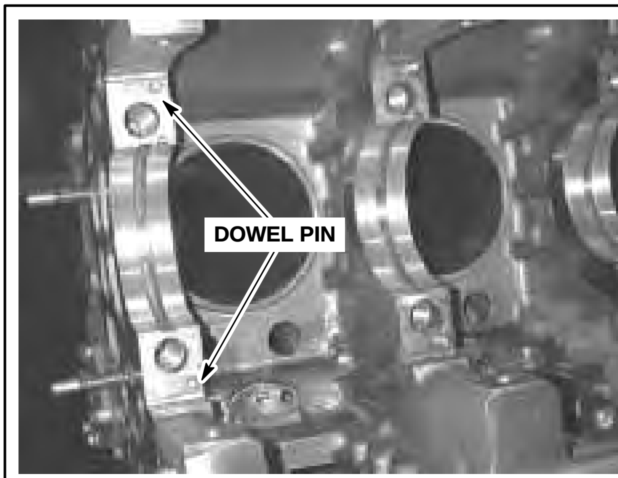


Figure 4.00-2. Dual Dowel Pin Crankcase

CRANKSHAFT ASSEMBLY

NOTE: *Only under extreme circumstances should counterweights be removed. Counterweights are "hand lapped" to fit their specific location. Installing counterweights in the wrong position will lead to crankshaft failure. If for some reason counterweights have been removed, see Section 3.05,* Crankcase Disassembly And Overall, *"Crankshaft Counterweight Installation."*

1. Verify counterweight hex head screws are tightened to 210 ± 5 ft-lb (285 N·m ± 7) (see Figure 4.00-3).

2. If hex head screw does not meet specified torque, inspect for damage (this includes washer).

3. Check hex head screw for nicks, cracks, galled or stretched threads and/or other damage. Replace if damaged.

4. Check washer for nicks and abrasive wear. Replace if damaged.

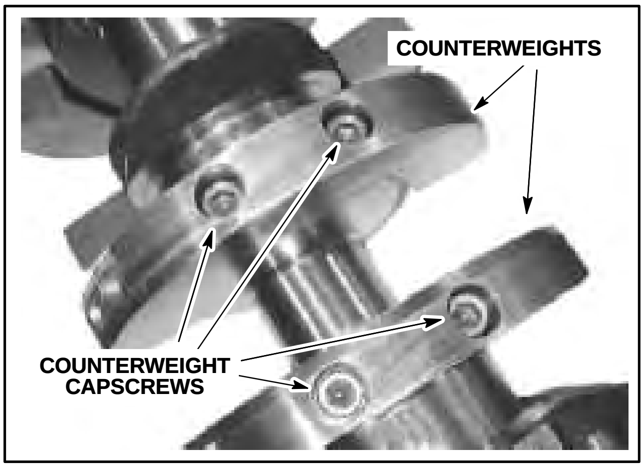


Figure 4.00-3. Crankshaft Counterweights

5. Make sure oil passages in crankshaft are clean. Apply Loctite® 242 to the crankshaft plugs and install plugs in the crankshaft (see Figure 4.00-4).

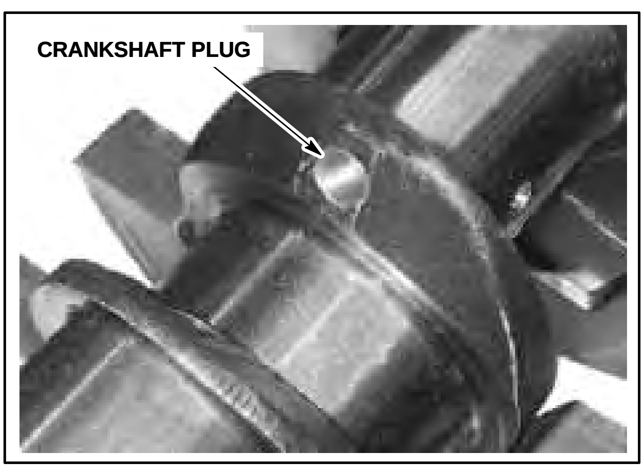


Figure 4.00-4. Crankshaft Plugs

CRANKSHAFT INSTALLATION

⚠ WARNING

The six cylinder crankshaft weighs 800 lb. (362 kg). The eight cylinder crankshaft weighs 1100 lb. (498 kg). Lift only with properly rated lifting device and rigging to avoid severe personal injury or death.

NOTE: *Coat your hands with clean engine oil before installing bearings to prevent skin acids from etching the bearing surface.*

1. Install upper main bearing inserts in crankcase. Lubricate inside bearing surface (crankshaft side) with clean engine oil (see Figure 4.00-5).

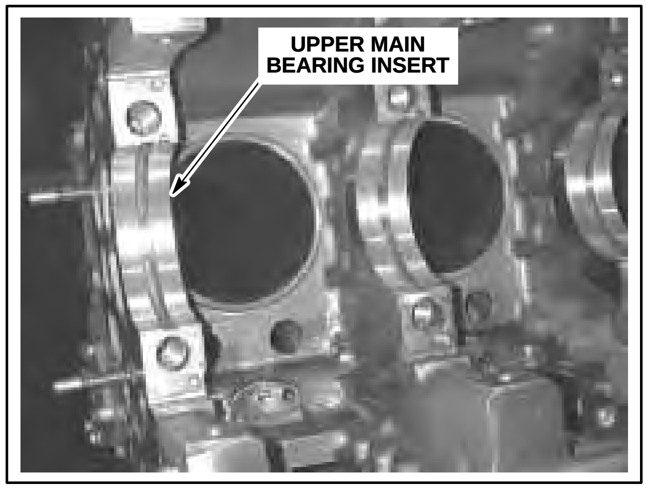


Figure 4.00-5. Upper Main Bearing

2. Attach suitable lifting sling around connecting rod journals and lower crankshaft into crankcase (see Figure 4.00-6).

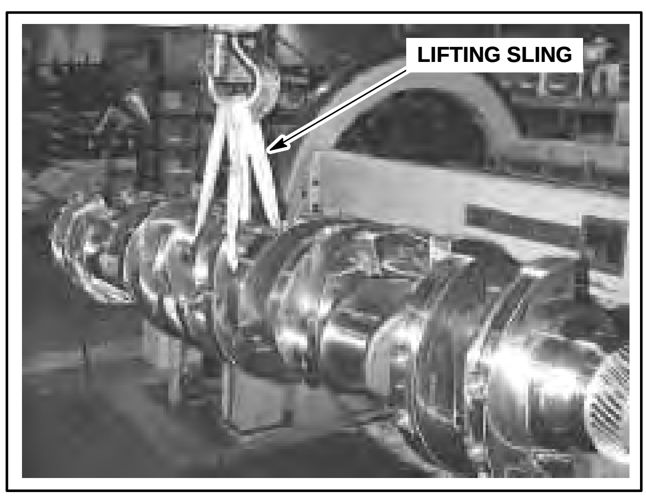


Figure 4.00-6. Crankshaft Rigging

MAIN BEARING CAP INSTALLATION

The main bearing caps are stamped with #1 through #6 for six cylinder engines and #1 through #8 for eight cylinder engines. The number stamped on the bearing cap must match the number stamped on the bearing saddle.

NOTE: *One main bearing cap may be removed and replaced without disturbing the others. If one main bearing cap is to be installed, complete the applicable steps for tightening either dual dowel pin caps or single dowel pin caps.*

NOTE: *Current crankcases use two dowel pins to align the bearing caps (see Figure 4.00-7). Previous crankcases use one dowel pin to align the bearing cap. The tightening procedures are different for single and dual dowel pin crankcases. Use the correct tightening procedures for each crankcase.*

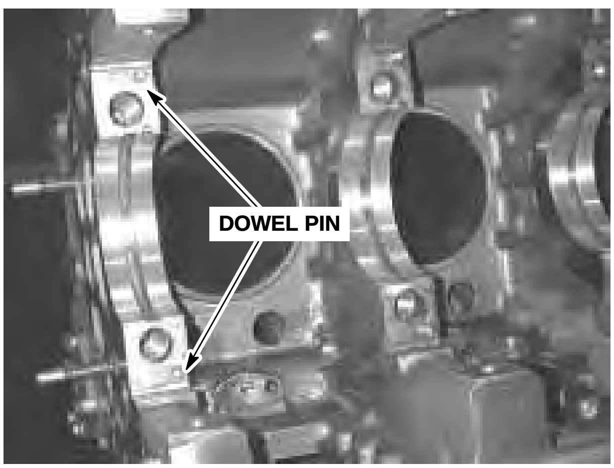


Figure 4.00-7. Dual Dowel Pin Crankcase

NOTE: *Use of the crankcase spreader tool may be required when installing main bearing caps on dual dowel pin crankcases.*

⚠ CAUTION **DO NOT spread the crankcase more than 0.006 in. (0.15 mm). Use a dial indicator to measure the spread of the crankcase sides. Disregarding this information could result in product damage.**

1. Install crankcase spreader tool (P/N 472002). Start with bearing cap #1. Spread crankcase sides. Do not exceed 0.006 in. (0.15 mm).

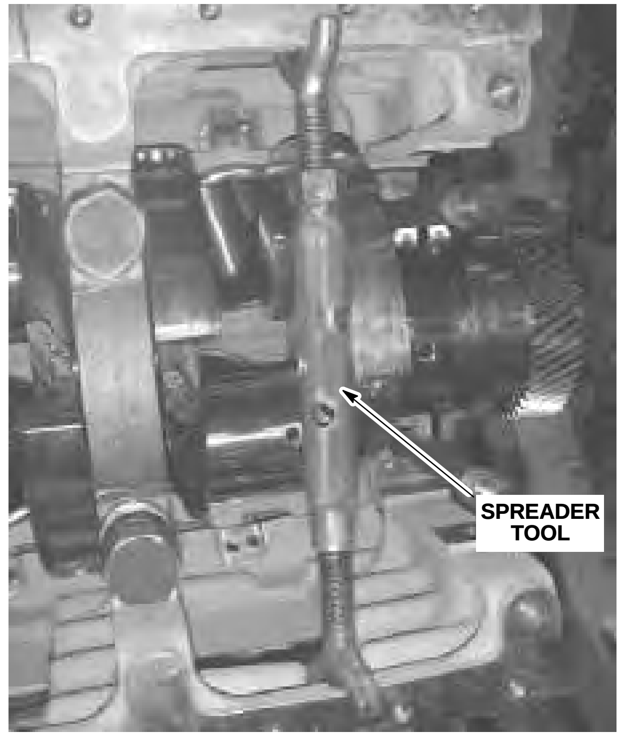


Figure 4.00-8. Crankcase Spreader Tool

NOTE: *All torques stated assume bolt threads are coated with clean engine oil. Do not use any lubricant containing molybdenum disulfide.*

SINGLE DOWEL MAIN BEARING CAPS

1. Apply clean engine oil to all bolt threads.

2. Install all main bearing caps and secure with bolts, tighten only enough to seat firmly (see Figure 4.00-9). Make sure bearing cap number matches saddle number. Slot and dowel hole in bearing cap should align with dowels in crankcase.

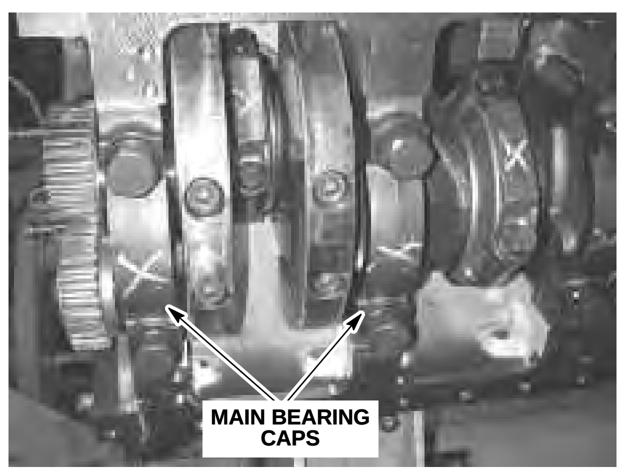


Figure 4.00-9. Main Bearing Cap Installation

3. Install upper and lower thrust washers on both sides of #4 (six cylinder) or #5 (eight cylinder) main bearing cap (see Figure 4.00-10).

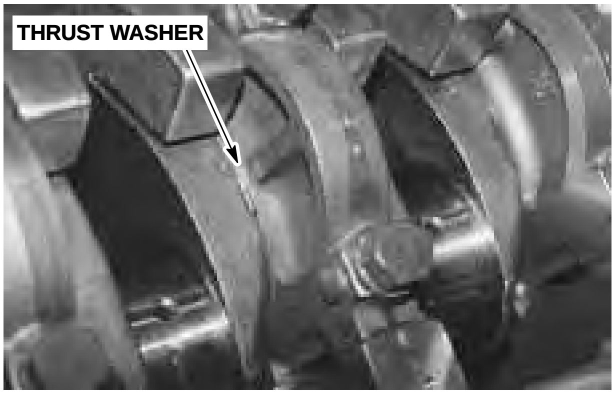


Figure 4.00-10. Main Bearing Cap Thrust Washer

NOTE: *Left side #5 and #6 main bearing cap crossbolts require special washers and O-rings to seal properly. These crossbolts run through oil passages (see Figure 4.00-11). The differences are visible from the bottom of crankcase.*

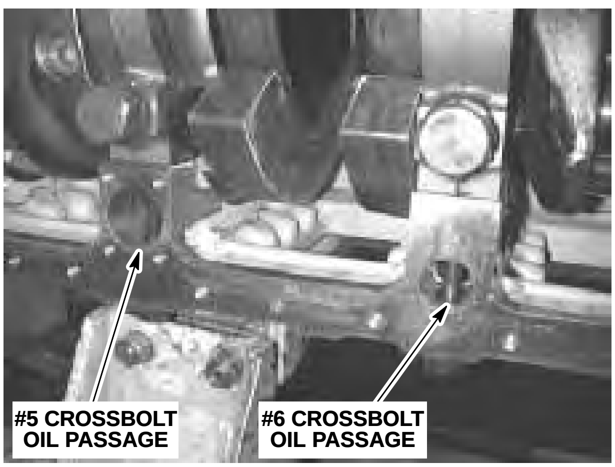


Figure 4.00-11. Crossbolt Oil Passage

4. Install and partially tighten two crossbolts adjacent to spreader on right hand side (dowel side of bearing cap only). Tighten to 37 ± 7 ft-lb (50 ± 10 N·m). Move spreader to new location and repeat until all right crossbolts are installed. Remove spreader.

5. Tighten all right side crossbolts (begin with #1) to 92 ± 7 ft-lb (125 ± 10 N·m).

6. Starting with #1 main bearing, install all left side crossbolts and tighten to 37 ± 7 ft-lb (50 ± 10 N·m).

7. Starting with #1 main bearing, tighten all left side crossbolts to 92 ± 7 ft-lb (125 ± 10 N·m).

8. Starting with #1 main bearing, tighten main bearing bolts to 325 ± 15 ft-lb (440 ± 20 N·m). Tighten right bolt first, then left bolt for all remaining main bearing caps.

9. Starting with #1 main bearing, tighten main bearing bolts to 590 ± 15 ft-lb (800 ± 20 N·m). Tighten right bolt first, then left bolt for all remaining main bearing caps.

10. Install front gear to crankshaft. Align offset hole in gear with offset hole in crankshaft. Gear must bottom on shoulder of shaft (see Figure 4.00-12).

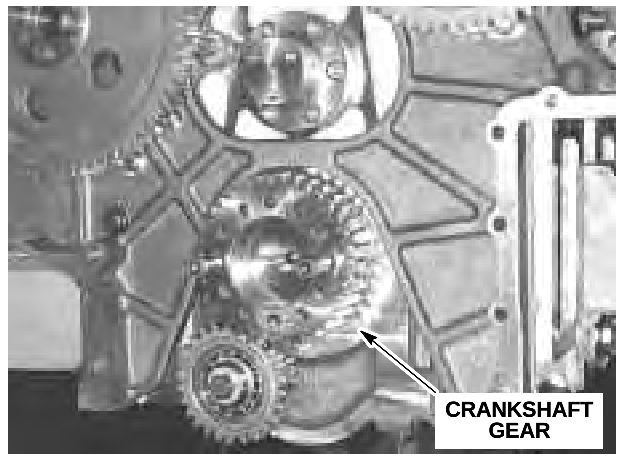


Figure 4.00-12. Crankshaft Gear Installation

DUAL DOWEL MAIN BEARING CAPS

1. Lubricate crankshaft surface of bearings with clean engine oil.

2. Install main bearing caps (see Figure 4.00-13). Make sure bearing cap number matches saddle number. Dowel holes in bearing caps should align with dowels in crankcase.

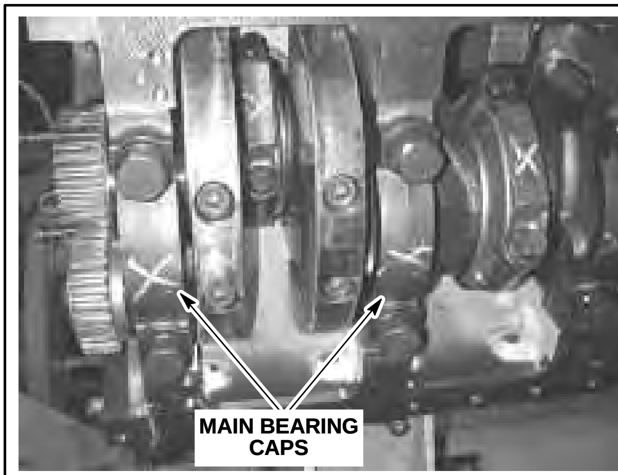


Figure 4.00-13. Main Bearing Cap Installation

3. Install upper and lower thrust washers on both sides of #4 (six cylinder) or #5 (eight cylinder) main bearing cap (see Figure 4.00-14).

Figure 4.00-14. Main Bearing Cap Thrust Washer

4. Starting with #1 main bearing, install all main bearing cap bolts and tighten to 74 ft-lb (100 N·m).

5. Remove spreader if installed.

6. Install all right crossbolts and tighten to 37 ± 7 ft-lb (50 ± 10 N·m) (begin with #1 main bearing).

7. Tighten all main bearing cap bolts to 147 ft-lb (200 N·m) (begin with #1). Tighten right hand side first.

8. Tighten all right side crossbolts (begin with #1) to 92 ± 7 ft-lb (125 ± 10 N·m).

9. Install all left side crossbolts (begin with #1) and tighten to 37 ± 7 ft-lb (50 ± 10 N·m).

NOTE: *Left side #5 and #6 main bearing cap crossbolts require special washers and O-rings to seal properly (see Figure 4.00-15). These crossbolts run through oil passages (see Figure 4.00-16). The differences are visible from the bottom of crankcase.*

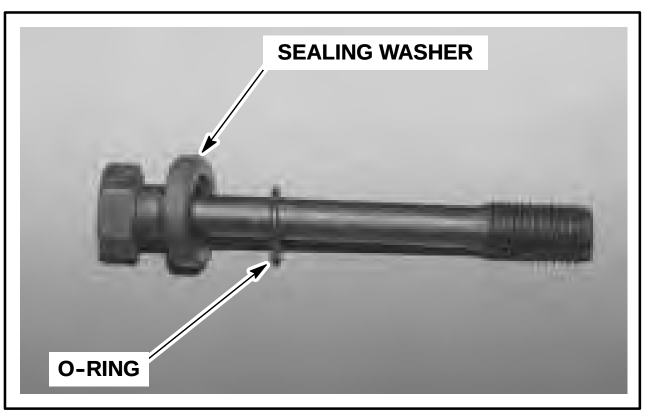


Figure 4.00-15. Bearing Cap CrossBolt

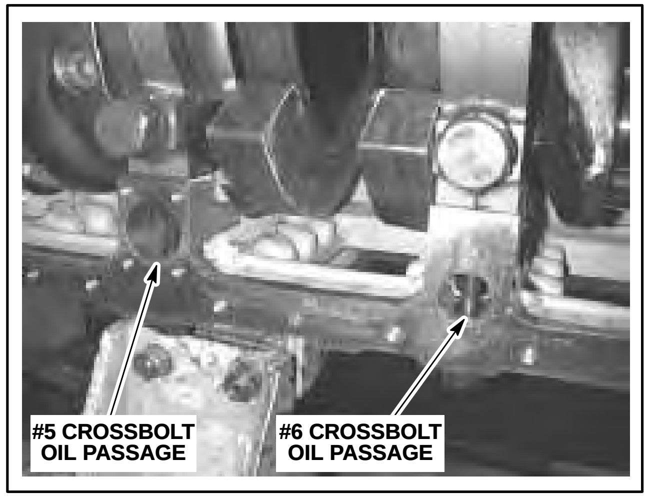


Figure 4.00-16. Crossbolt Oil Passage

10. Starting with #1 main bearing, tighten all left side crossbolts to 92 ± 7 ft-lb (125 ± 10 N·m).

11. Tighten main bearing bolts to 325 ± 15 ft-lb (440 ± 20 N·m) (begin with #1 main bearing). Tighten right bolt first, then left bolt for all remaining main bearing caps.

12. Tighten main bearing bolts to 590 ± 15 ft-lb (800 ± 20 N·m) (begin with #1 main bearing). Tighten right bolt first, then left bolt for all remaining main bearing caps.

13. Install front gear to crankshaft. Align offset hole in gear with offset hole in crankshaft. Gear must bottom on shoulder of shaft (see Figure 4.00-17).

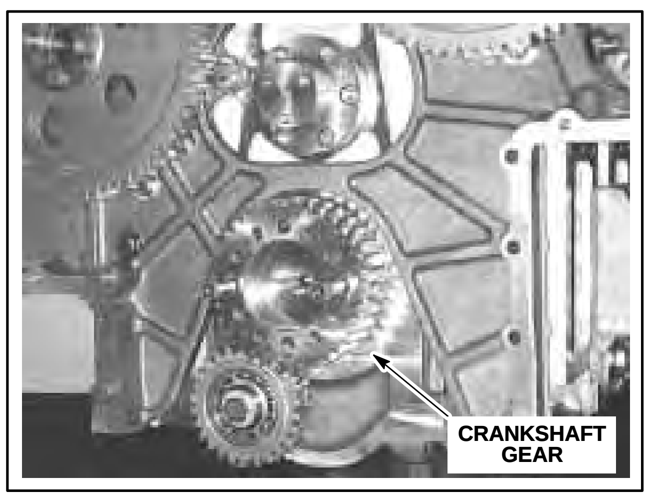


Figure 4.00-17. Crankshaft Gear Installation

CYLINDER LINER INSTALLATION

1. Install O-ring seals into cylinder liner grooves. Make sure O-ring seals are in correct order (square cut seal goes on first) (see Figure 4.00-18).

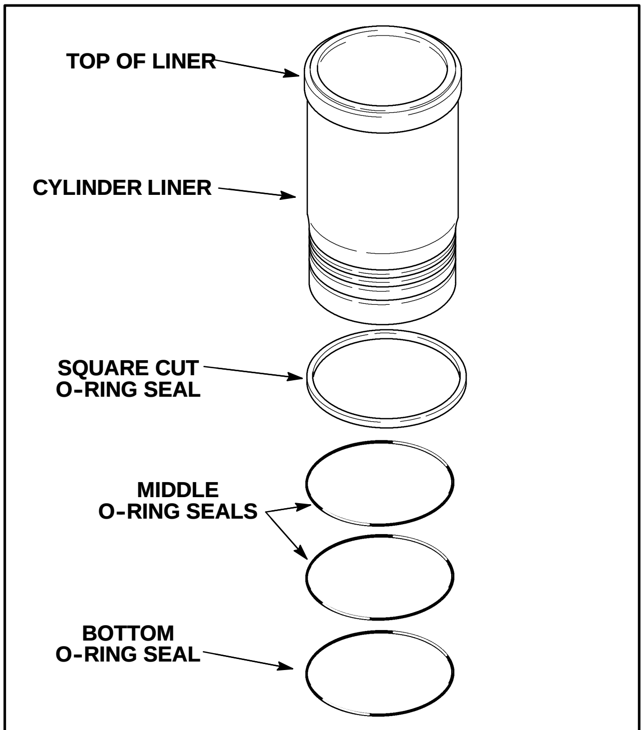


Figure 4.00-18. Cylinder liner Assembly

2. Lubricate O-rings with Parker Super-O-Lube™ before installing liner in crankcase. O-ring seals must not be twisted.

3. Install Tool P/N 472013 onto crankcase as shown in Figure 4.00-19. Tighten center nut to press cylinder liner into crankcase bore.

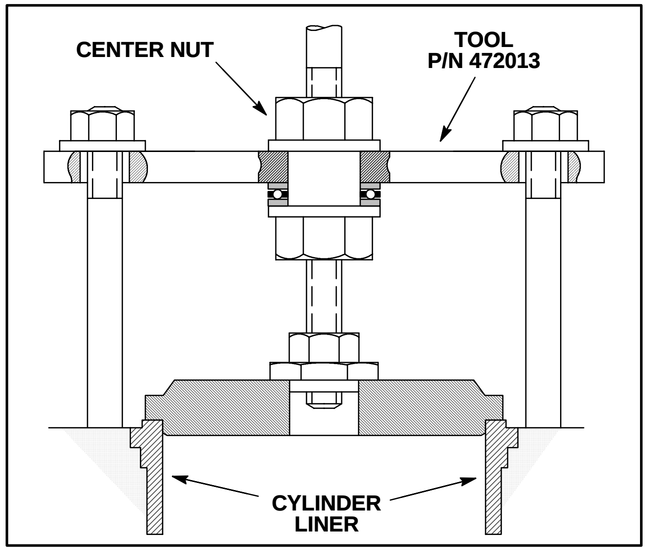


Figure 4.00-19. Cylinder Liner Installation Tool

NOTE: *If an O-ring seal gets forced out of its groove during cylinder liner installation, it will actually push the cylinder liner out-of-round. Checking cylinder liner roundness after crankcase installation is necessary to ensure the liner seals are properly installed in their grooves.*

4. Measure cylinder liner width (with dial bore gauge) in at least five locations inside of liner. Record measurements.

5. Determine if an out-of-round condition exists. If one measurement differs from published or actual liner internal diameter (ID) by 0.003 in. (0.076 mm) (see Table 3.05-10), then an out of round condition exists.

6. If cylinder liner is out of round, then remove liner and replace O-ring seal if damaged.

7. Verify O-ring seals are in liner grooves. Reinstall liner and recheck cylinder bore.

8. Repeat above procedure for remaining cylinders.

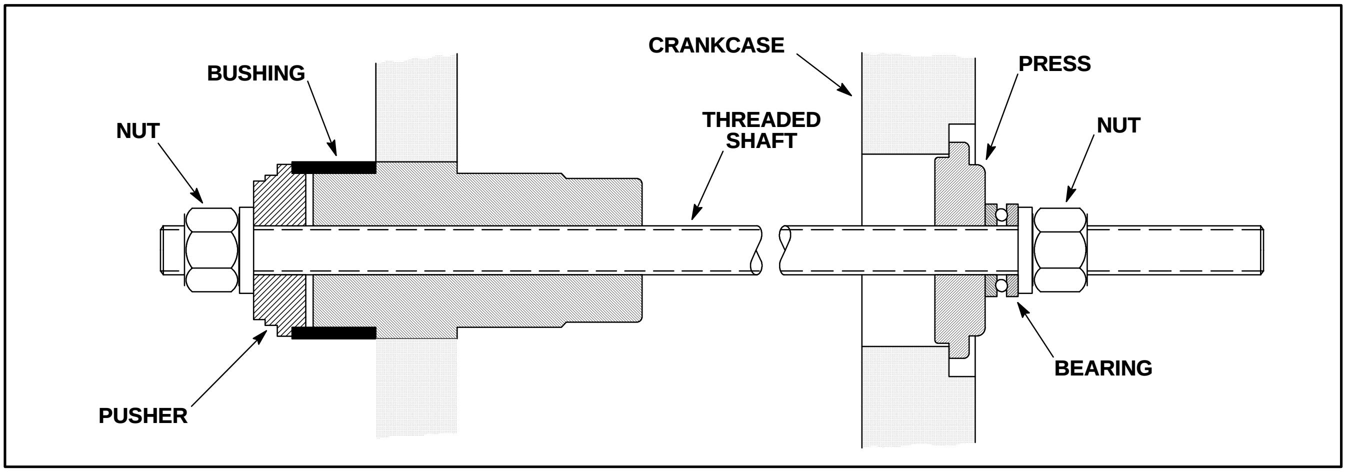


Figure 4.00-20. Camshaft Bushing Press Installation

CAMSHAFT BUSHINGS INSTALLATION

CAUTION Make sure that both right rear and left front camshaft double bushings are installed. Omitting either bushing in these locations will cause a loss of lubricating oil to the turbochargers and the auxiliary water pump. Oil starvation results in rapid bearing failure and possible damage to the cam journal.

1. Install camshaft bushing press P/N 472056 (see Figure 4.00-20).

2. Install camshaft bushings starting from the rear and work forward. Oil holes in bushings must align with oil supply holes in crankcase.

3. Hex head capscrews hold bearing shells in crankcase (see Figure 4.00-21). Do not install screws that are too long or the screws will contact with the camshaft.

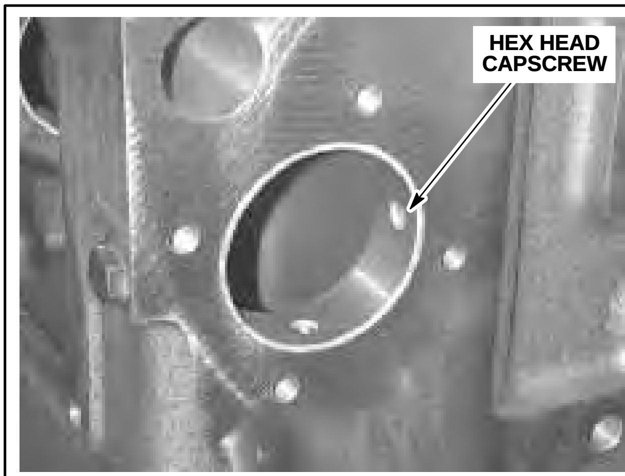


Figure 4.00-21. Cam Bearing Installation

4. The front camshaft bushing is also a thrust bearing. Hold the bushing in the crankcase with three M6 x 16 socket head capscrews (see Figure 4.00-22).

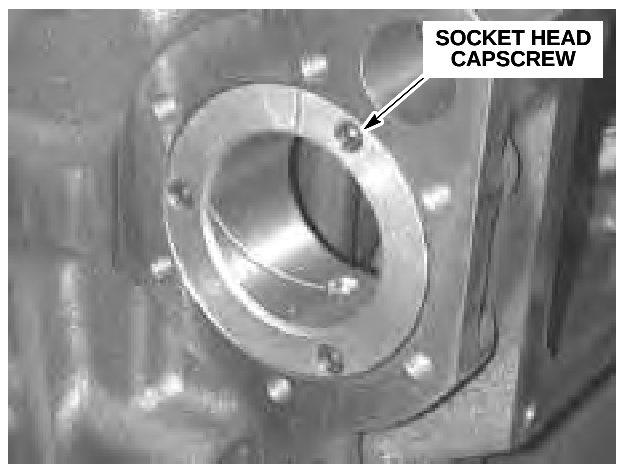


Figure 4.00-22. Front Camshaft Bushing

CYLINDER HEAD STUD INSTALLATION

NOTE: *Do not install head studs dry. Do not use lubricant containing molybdenum or Loctite® on the stud threads. Lubricate studs with clean engine oil.*

1. Install cylinder head studs in crankcase (use a collet type stud driver). Tighten studs to 72 ft-lb (98 N·m) (see Figure 4.00-23).

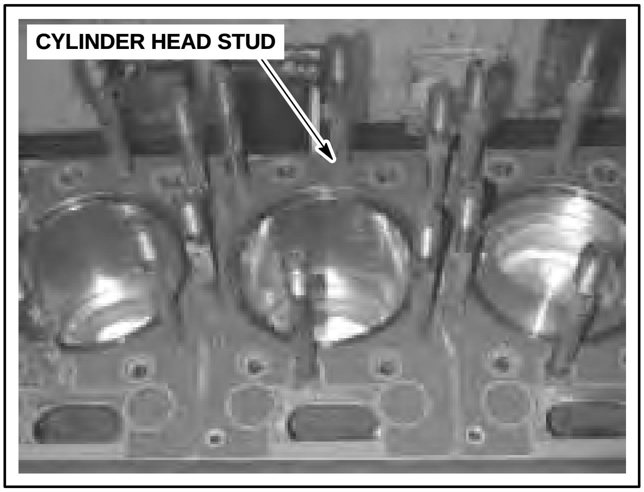


Figure 4.00-23. Cylinder Head Stud Installation

PARALLEL PIN INSTALLATION

1. Install two parallel pins per cylinder (upper right and lower left). Gently tap pins in place (see Figure 4.00-24).

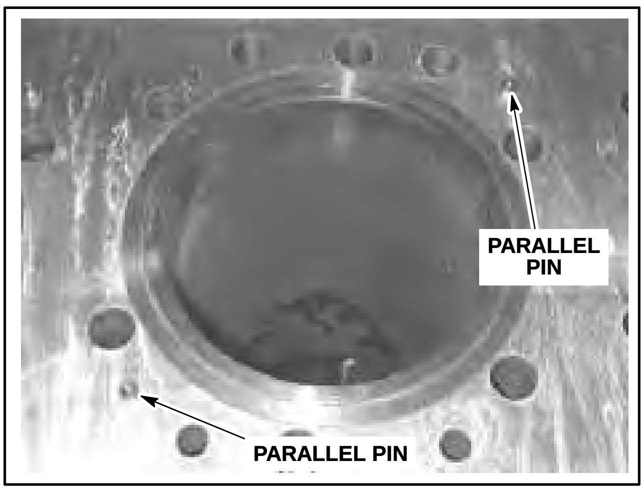


Figure 4.00-24. Crankcase Parallel Pin

PISTON AND CONNECTING ROD INSTALLATION

1. Assemble connecting rod bushing press (P/N 472012), connecting rod and bushing as depicted (see Figure 4.00-25 and Figure 4.00-26).

NOTE: *The oil supply hole in the bushing must be aligned with the oil supply hole in the connecting rod.*

2. Tighten nut on press until bushing is fully seated in connecting rod (see Figure 4.00-26).

NOTE: *The piston pin bushing inside diameter is unfinished and must be sized to match the piston pin being used with each connecting rod.*

NOTE: *The pin bushing center must be located 12.204 – 12.2047 in (309.981 – 310.0 mm) from the center of the crankshaft bore (large end of rod), after machining. It is acceptable for the pin bushing wear surface (thickness) to be unequal between top and bottom. The center to center rod length must be maintained (see Table 3.05-9, located in Section 3.05).*

WARNING

Always wear safety glasses when removing piston pin retaining rings. Verify the correct retaining ring pliers is used and it is in good condition. If the retaining ring slips off the pliers when being installed or removed, it can be propelled with enough force to cause a serious eye injury. Disregarding this information could result in severe personal injury.

3. Install one retaining ring in piston (see Figure 4.00-25).

4. Place connecting rod inside of piston. Align “INTAKE” mark on piston with open end of connecting rod (see Figure 4.00-25).

NOTE: *The piston pins are full floating and are not a press fit. Due to manufacturing tolerances some piston pins may fit slightly tighter than others.*

5. Insert piston pin through piston and connecting rod. Secure piston pin with remaining retaining ring.

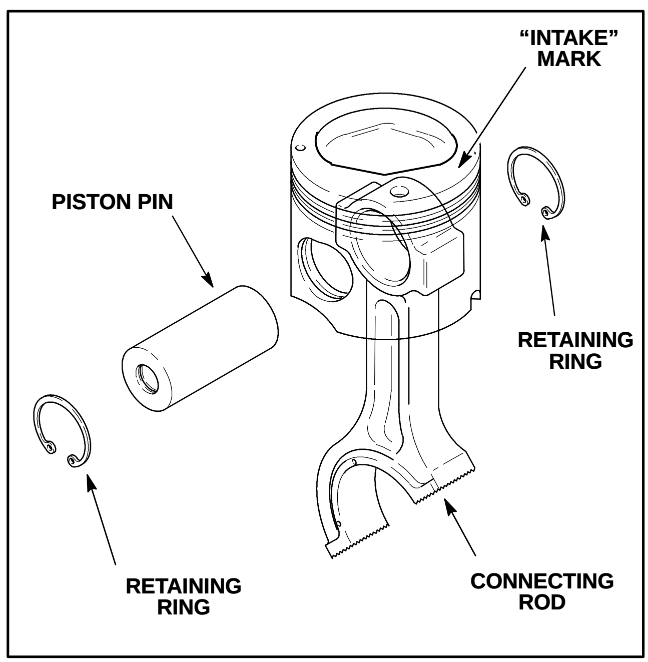


Figure 4.00-25. Piston – Connecting Rod

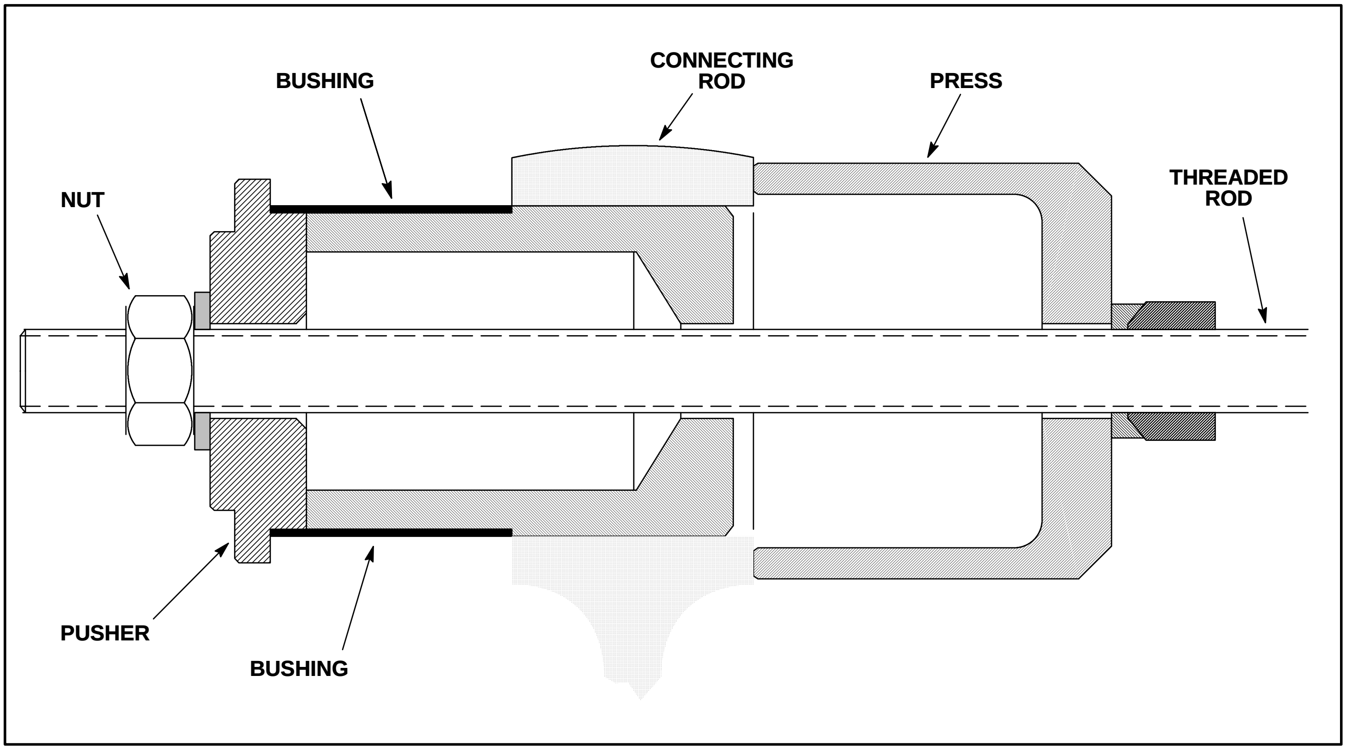


Figure 4.00-26. Connecting Rod Bushing Press

PISTON RING INSTALLATION

CAUTION Use the proper piston ring spreader (Tool P/N 472075) to prevent excessive ring twist and expansion. Over expansion may cause the ring to crack opposite the ring gap. Defective or distorted rings result in blow-by of exhaust gases, increased oil consumption and lower service life on components. Disregarding this information could result in product damage and/or personal injury.

CAUTION Do not install used (more than 50 hours running time) piston rings. Previously used rings will not seat or wear properly. Installing used rings will result in decreased oil control and compression.

Proper piston ring installation is critical in achieving long bottom end overhaul life. Use ring expander tool P/N 472075 to install the rings on the piston.

1. Lightly coat pistons and rings with clean engine oil.

2. Install oil control ring (P/N 300705).

3. Install protruding “end” of expander spring wire into oil control ring opening. This will prevent the expander spring from “floating” (see Figure 4.00-28).

4. Slide Teflon “tube” directly behind the ring end gap (see Figure 4.00-29).

5. Install middle compression ring using ring expander tool P/N 472075 (see Figure 4.00-27). Middle compression ring must be installed with label “TOP” visible.

NOTE: *GSID and GL LCR engines use middle compression ring P/N 300605A. G, GL and GLD engines use middle compression ring P/N 300605.*

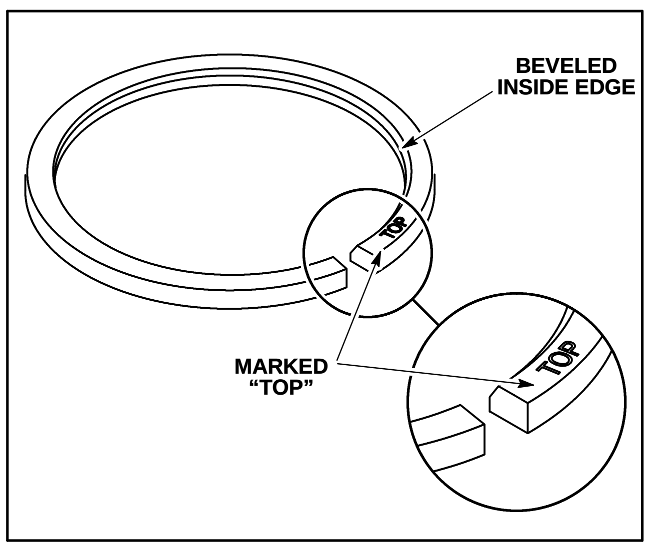


Figure 4.00-27. Middle Compression Rings

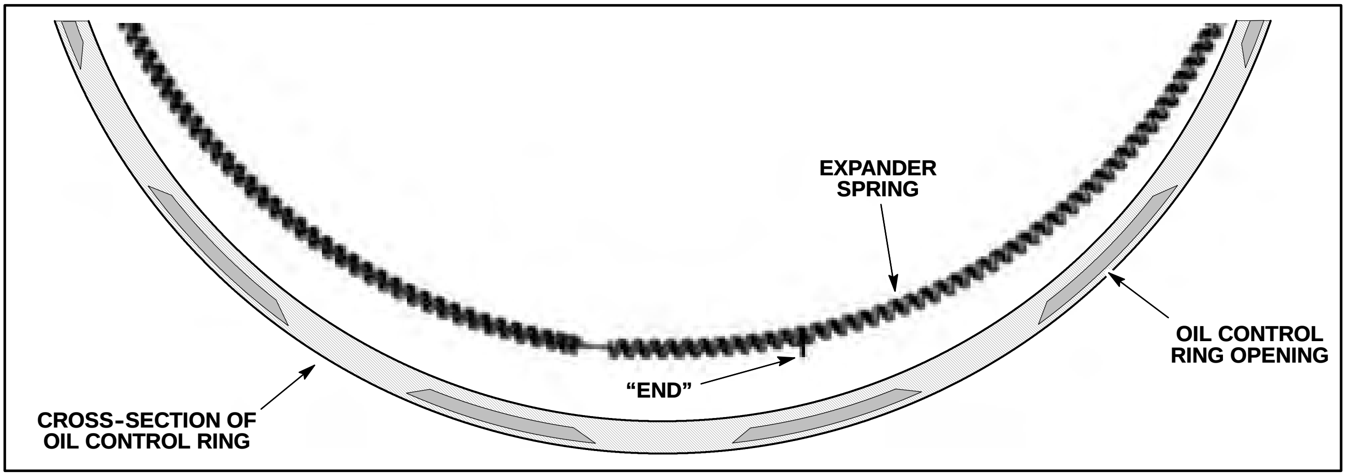


Figure 4.00-28. Oil Control Ring Expander Spring

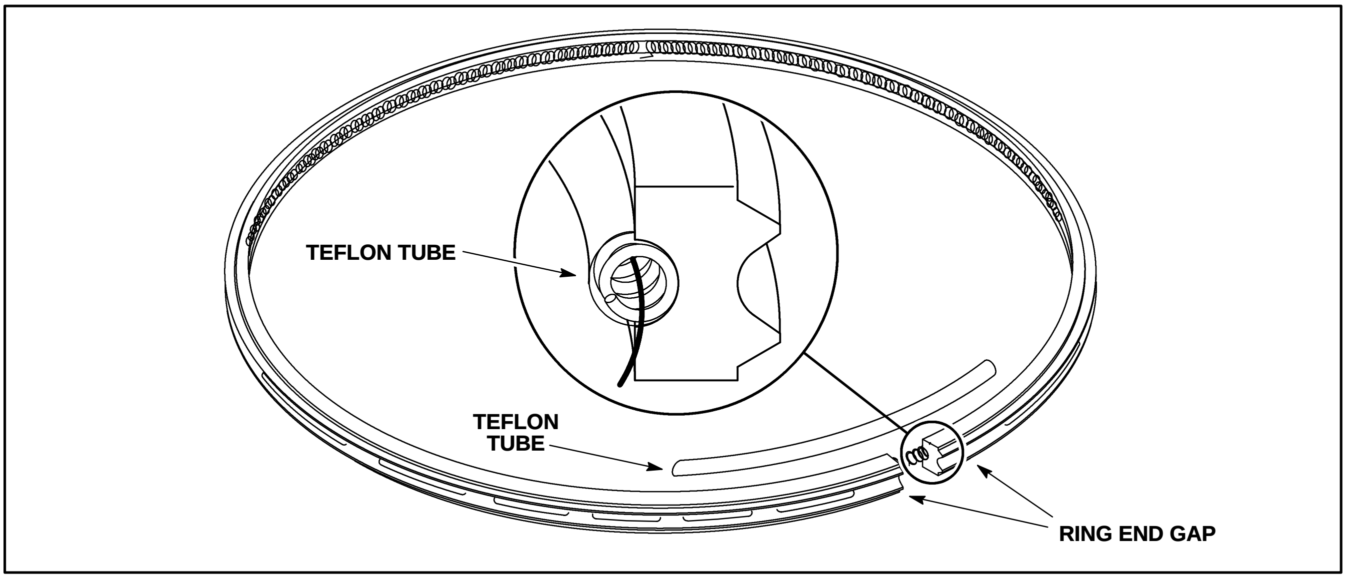


Figure 4.00-29. Oil Control Ring Teflon Tube

6. Install top compression ring (P/N 300805) using ring expander tool P/N 472075 (see Figure 4.00-30). Top compression ring must be installed with label "TOP" visible and beveled edge on inside.

7. Stagger ring gaps 120° from each other (see Figure 4.00-30).

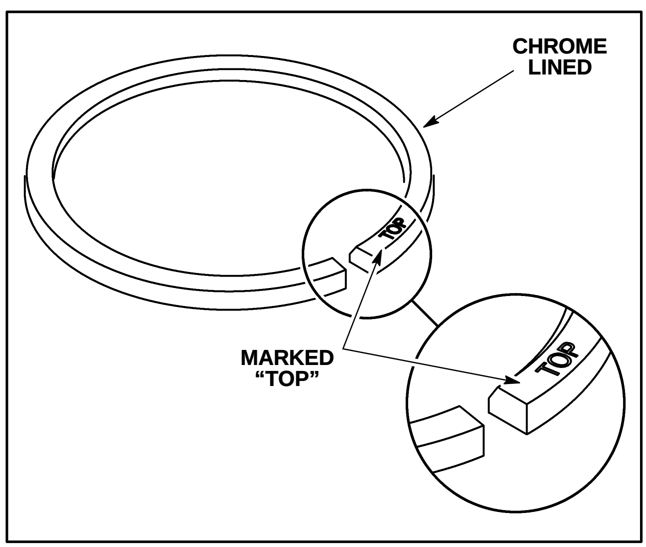


Figure 4.00-30. Middle Compression Rings

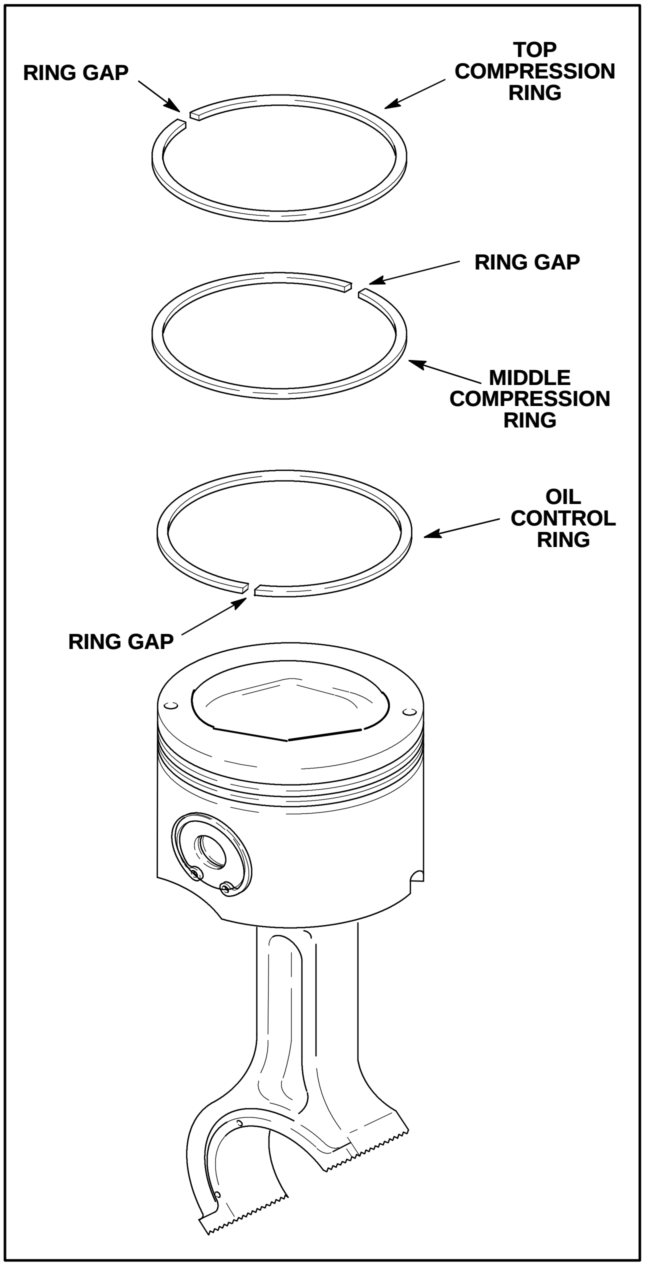


Figure 4.00-31. Piston Ring Installation

NOTE: *Apply a light coat of clean engine oil to the connecting rod bearing and crankshaft journal.*

NOTE: *Install upper connecting rod bearing prior to installing piston assembly.*

8. Install piston installation tool P/N 472007 onto top of piston (see Figure 4.00-32).

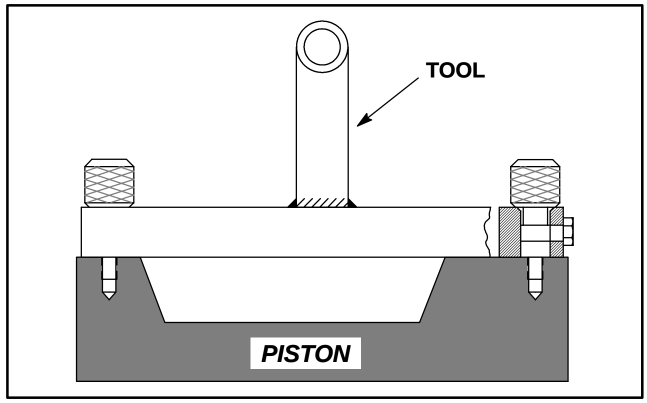


Figure 4.00-32. Piston Installation Tool

9. Install piston ring compressor P/N 472076 around piston and compress rings (see Figure 4.00-33).

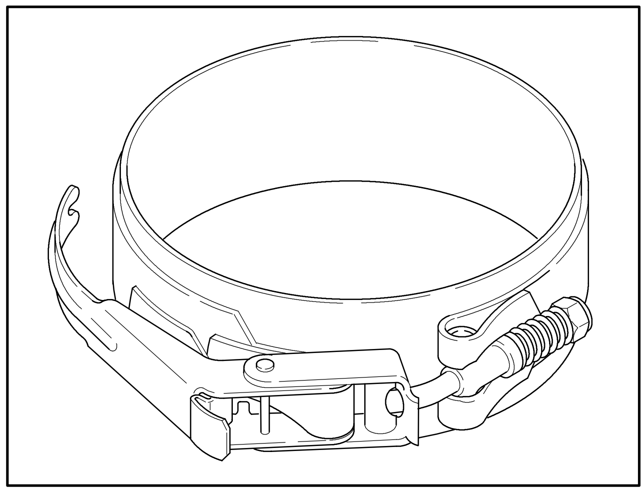


Figure 4.00-33. Piston Ring Compressor P/N 472076

NOTE: *Cover the end of the connecting rod with a shop rag or cloth to prevent scoring the cylinder liner when installing the pistons (see Figure 4.00-34).*

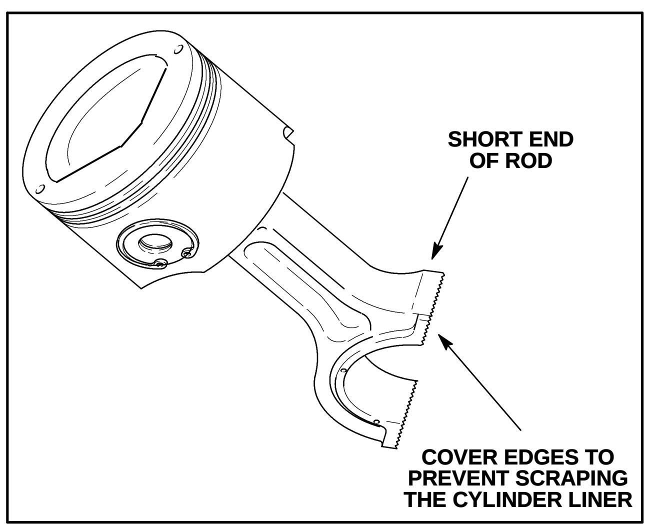


Figure 4.00-34. Rod End

NOTE: *The piston is marked with the word* "INTAKE" *which is installed closest to the outside edge of the crankcase (see Figure 4.00-35).*

10. Install piston with short end of connecting rod closest to outside edge of crankcase (see Figure 4.00-35). Piston "intake" mark should also be closest to outside edge of crankcase.

Figure 4.00-35. Piston Installation

11. Install lower bearing insert into connecting rod cap.

NOTE: *Current connecting rod bolts (P/N 304055B) should be replaced during major overhaul or if excessive overspeed, over tightening, or hydraulic lock are suspected. Previous connecting rod bolts may only be retightened three times before replacement.*

12. Lubricate connecting rod bolt threads and head where it contacts rod cap with clean engine oil. Install connecting rod bolts and tighten to 310 ± 15 ft-lb (420 ± 20 N·m) (see Figure 4.00-36).

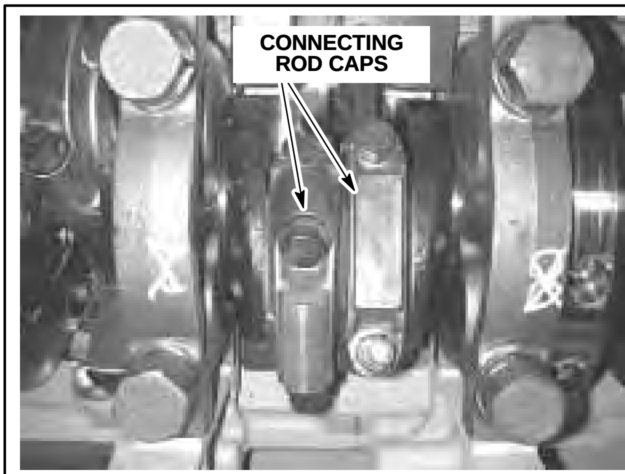


Figure 4.00-36. Connecting Rod Cap

13. Assemble and install remaining pistons.

CONNECTING ROD INSTALLATION (WITHOUT REMOVING OIL PAN)

Installing the connecting rod capscrews through the crankcase (without removing the oil pan) requires the offset adapter P/N 472001 (see Figure 4.00-37). Improper use of the adapter can cause incorrect torque values to be applied to the connecting rod bolts during installation. See "Offset Torque Wrench Adapter" in this section for proper use of the adapter.

OFFSET TORQUE WRENCH ADAPTER

The removal and installation of the connecting rod cap screws through the crankcase on inline VGF engines requires the use of the offset adapter P/N 472001 (see Figure 4.00-37).

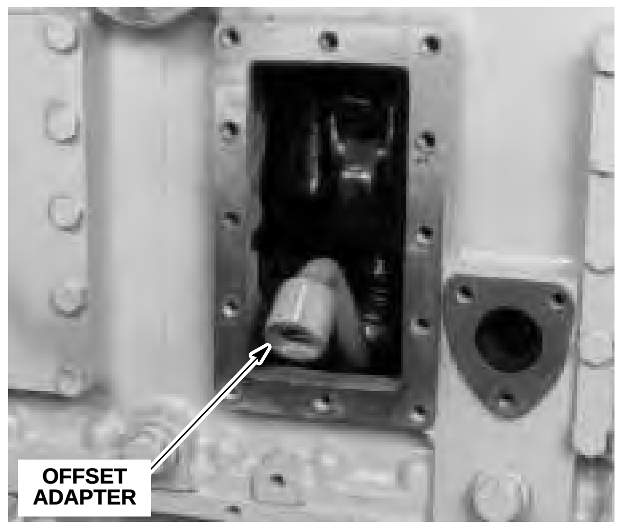


Figure 4.00-37. Offset Adapter On Connecting Rod

The offset adapter is available from the Waukesha Engine Product Training Center.

USING THE ADAPTER CORRECTLY

Torque wrenches are constructed so that the position of the applied load can be varied on the frame or handle of the wrench. Offset adapters or extensions will not work correctly with torque wrenches without applying correction factors.

The adapter P/N 472001 has an offset of 4.25 in. (108 mm) (see Figure 4.00-38). Improper use of the adapter can cause incorrect torque values to be applied to the connecting rod bolts during installation.

The following calculations or formulas apply to either adaptors or extensions having the axis of their work engaging member intersecting the extended center line of the torque wrench frame.

The same principles apply to other offset equipment, such as crows foot wrenches.

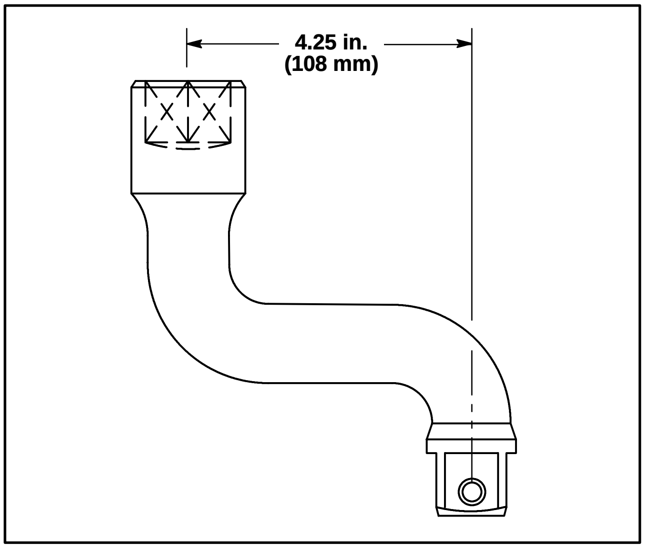


Figure 4.00-38. Offset Adapter Dimension

NOTE: *In the following examples shown the torque wrench lever length is 24 inches long. Each torque wrench has its own lever length which must be used when calculating the formulas.*

The letters represent the following values when calculating the formulas.

T_a = Torque exerted at the end of the adapter
T_W = Wrench scale reading
L = Lever Length of the wrench
A = Length of adapter

NOTE: *L and A must use similar units of measure (both in inches, millimeters, feet, etc.).*

In the following examples the torque value (T_a) is 326 ft-lb, the torque wrench length (L) (for this example only) is 24 inches, and the effective length of the adapter (A) is 4.25 inches.

To keep all the units common, convert the torque to in-lb (or the inch dimensions to feet).

$$310\ ft - lb \times 12 = 3720\ in - lb$$

EXAMPLE 1

The adapter is installed inline with the torque wrench. The full effective length of the adapter, 4.25 inches, is added to the length of the torque wrench (see Figure 4.00-39).

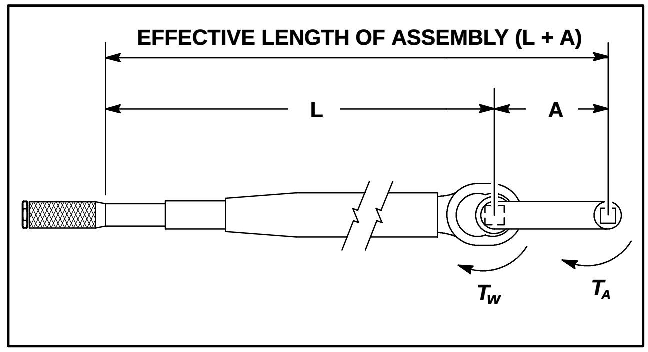


Figure 4.00-39. Adapter Installed Inline With Wrench

Torque Wrench Scale Reading (T_w) =

$$T_w = \frac{T_a \times L}{(L + A)}$$

$$T_w = \frac{3720\ in - lb \times 24\ in.}{(24\ in. + 4.25\ in.)}$$

$$T_w = 3160.354\ in - lb\ scale\ reading.$$

Divide the inch pound reading by 12 to convert to foot pounds:

$$3160.359\ in - lb \div 12 = 263.36\ ft - lb$$

The adjusted torque wrench scale reading is 263.36 ft-lb.

EXAMPLE 2

This is the recommended configuration with the adapter installed 90° to the torque wrench (see Figure 4.00-40).

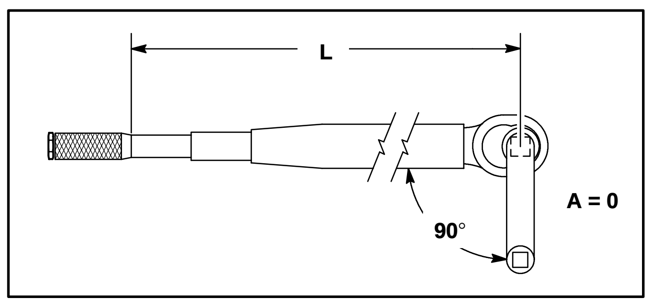


Figure 4.00-40. Adapter Install 90° To Wrench

Torque Wrench Scale Reading (T_w) =

$$T_w = \frac{T_a \times L}{(L + A)}$$

$$T_w = \frac{3720\ in - lb \times 24\ in.}{(24\ in. + 0\ in.)}$$

$$T_w = 3720\ in - lb\ scale\ reading.$$

Divide the inch pound reading by 12 to convert to foot pounds:

$$3720\ in - lb \div 12 = 310\ ft - lb$$

The adjusted torque wrench scale reading is 310 ft-lb.

Because *A = 0* in this configuration, the adapter has no effect on the torque wrench reading.

EXAMPLE 3

The adapter is installed at an angle with the torque wrench. Measure the effective length of the adapter *(A)* (see Figure 4.00-41).

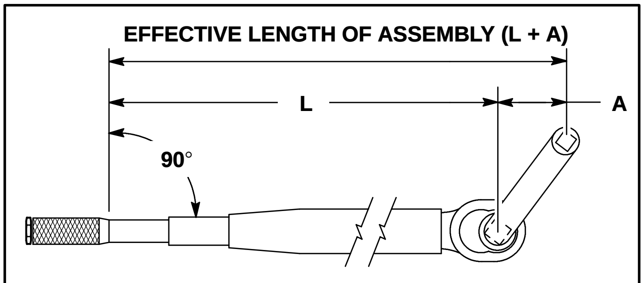


Figure 4.00-41. Adapter Installed At Angle To Wrench

NOTE: *For this example A = 2.5 inches.*

Torque Wrench Scale Reading (T_w) =

$$T_w = \frac{T_a \times L}{(L + A)}$$

$$T_w = \frac{3720 \ in - lb \times 24 \ in.}{(24 \ in. + 2.5 \ in.)}$$

$$T_w = 3369.057 \ in - lb \ scale \ reading.$$

Divide the inch pound reading by 12 to convert to foot pounds:

$$3369.057 \ in - lb \div 12 = 280.8 \ ft - lb$$

The adjusted torque wrench scale reading is 280.8 ft-lb.

PISTON COOLING JETS

NOTE: *For information on previous models of piston cooling jets see Section 5.30* Lubrication System.

INSTALLATION

The piston cooling jets are located in the crankcase and direct cooling oil to the pistons. The piston cooling jets are installed after the piston and liner to prevent possible damage to the jet. The jets may be reached by removing the connecting rod inspection doors.

1. Install piston cooling jets into original crankcase location. Install M14 hollow screw and copper washer, if applicable.

NOTE: *Engine may contain a copper washer that is installed with the M14 hollow screw.*

2. Install M8 socket head screw (M8 screw is used as a stop). Turn M14 hollow screw until piston jet makes contact with socket head screw (see Figure 4.00-42). Previous versions use two M8 socket head screws.

3. Tighten M14 hollow screw to 30 ft-lb (41 N·m).

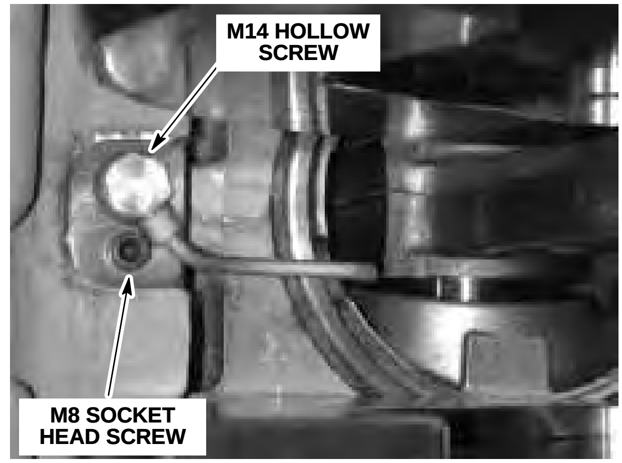


Figure 4.00-42. Piston Cooling Jet

4. Repeat procedure for remaining cylinders.

CLEARANCE CHECK

NOTE: *Carefully bar the engine over by hand and check the clearance between the piston cooling jet tubes and the connecting rods (see Figure 4.00-43).*

1. Measure clearance between piston cooling tube and connecting rod. Minimum clearance is 0.040 in. (1 mm) (see Figure 4.00-43). If the piston cooling jet tube has to be bent more than 0.12 in. (3 mm), replace the jet.

2. If clearance between piston cooling jet tube and connecting rod is less than 0.040 in. (1 mm), gently bend piston cooling jet tube away from point of contact.

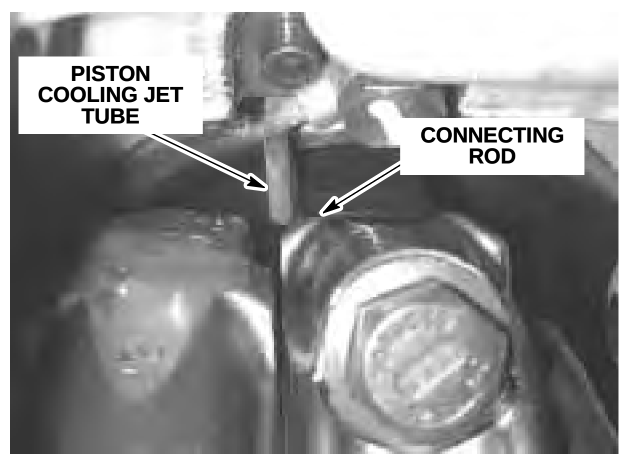


Figure 4.00-43. Piston Cooling Jet Clearance

OIL GALLEY PLUGS AND LOCATING DOWELS

INSTALLATION

Two O-ring sealed oil gallery plugs are located on the front and rear of the crankcase.

1. The smaller plug uses two O-rings for sealing (see Figure 4.00-44). Lubricate O-rings with Parker Super-O-Lube™ before installing in crankcase.

NOTE: *Make sure that the "tapped hole" in the oil gallery plug faces out. The "tapped hole" is used to remove the plug during engine disassembly.*

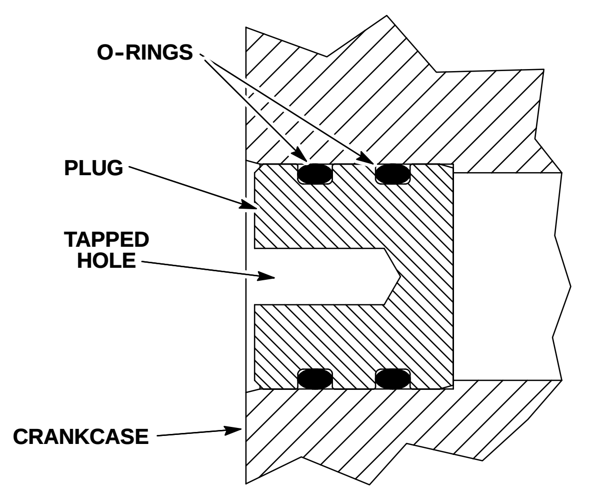


Figure 4.00-44. Oil Galley Plug Detail

2. Press oil gallery plugs into crankcase until they bottom out in bore. Make sure tapped hole faces out (see Figure 4.00-45 and Figure 4.00-46).

Figure 4.00-45. Oil Gallery Plug Installation

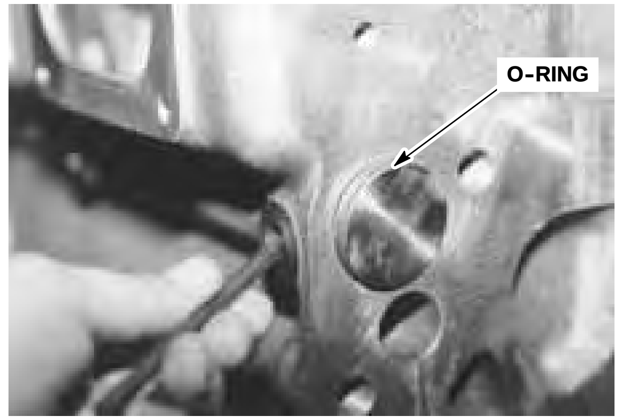


Figure 4.00-46. Oil Gallery Plug Installation

3. Apply pipe sealant and install M10 socket head screw in top, rear surface of crankcase (see Figure 4.00-47).

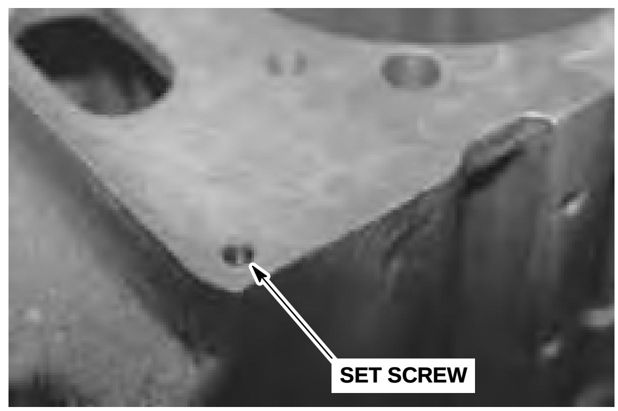


Figure 4.00-47. Crankcase Set Screw Installation

4. Install M14 plugs and washers in oil gallery ports (see Figure 4.00-48).

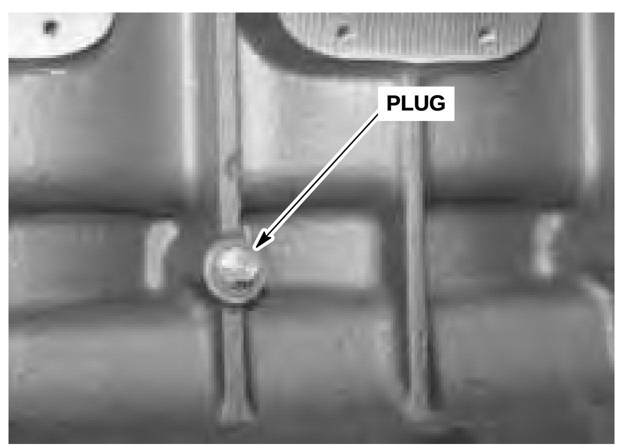


Figure 4.00-48. Oil Gallery Plug

5. Install pipe adapter with copper sealing washer in crankcase for magneto and governor oil supply (see Figure 4.00-49).

NOTE: *If the engine is equipped without a gear housing mounted governor and magneto drives (a combination of 4024 rear mounted governor and CEC Ignition Module), install an M18 plug and copper sealing washer.*

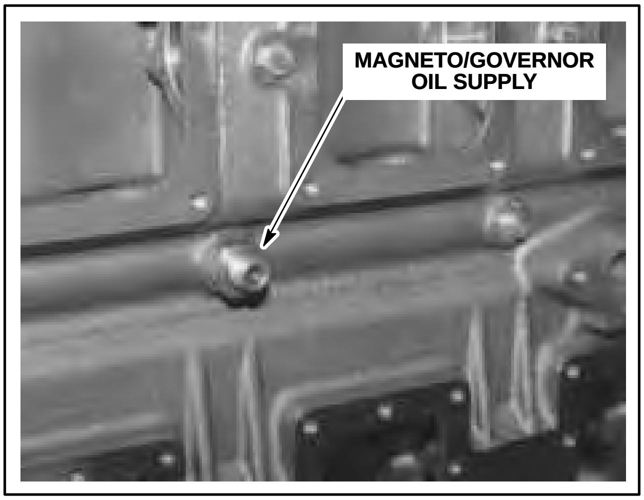


Figure 4.00-49. Pipe Adapter Installation

6. Apply Loctite® 242 to threads of stud adapter and install in center port location on left side of crankcase (see Figure 4.00-50). Install M10 studs in adapter and matching hole.

7. Apply pipe thread sealant and install turbocharger oil drain adapter in crankcase. Install a plug in adapter for use on naturally aspirated engines (G series) (see Figure 4.00-51).

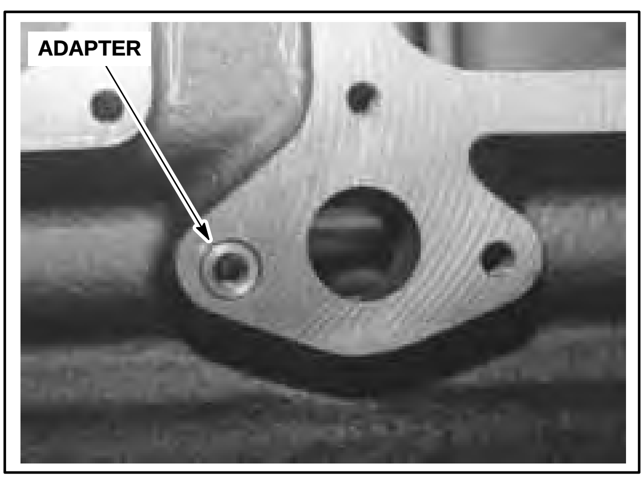


Figure 4.00-50. Stud Adapter

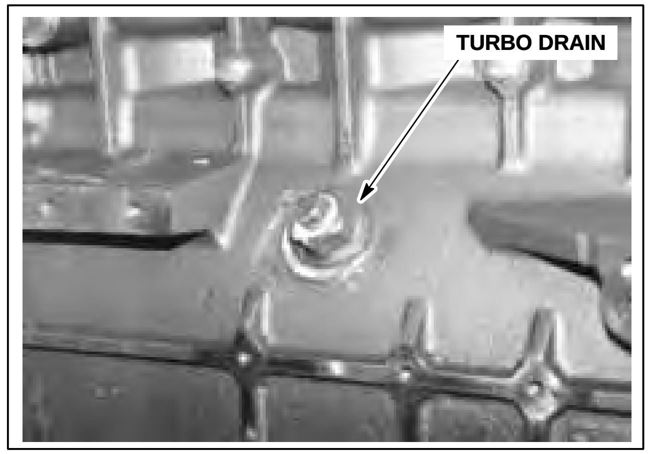


Figure 4.00-51. Turbo Oil Drain Plugged – G Models

8. Engine prelube system uses an adapter and pipe union installed in crankcase. Union location is in front of oil filter base (see Figure 4.00-52).

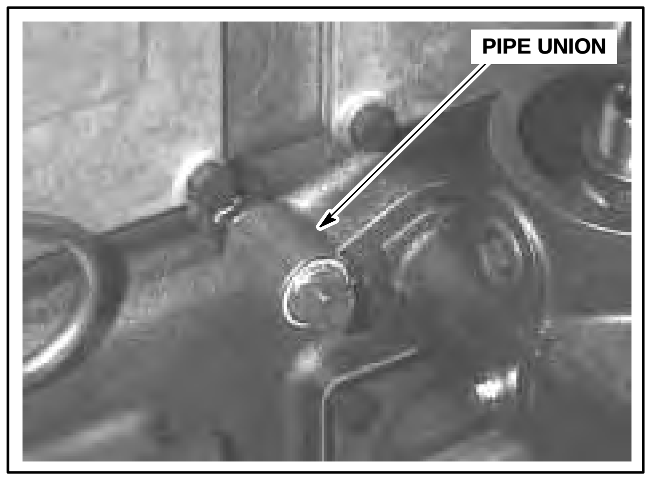


Figure 4.00-52. Prelube Connection

REAR LIFTING EYE

1. Install lifting eye and secure to crankcase with hex head screws (see Figure 4.00-53).

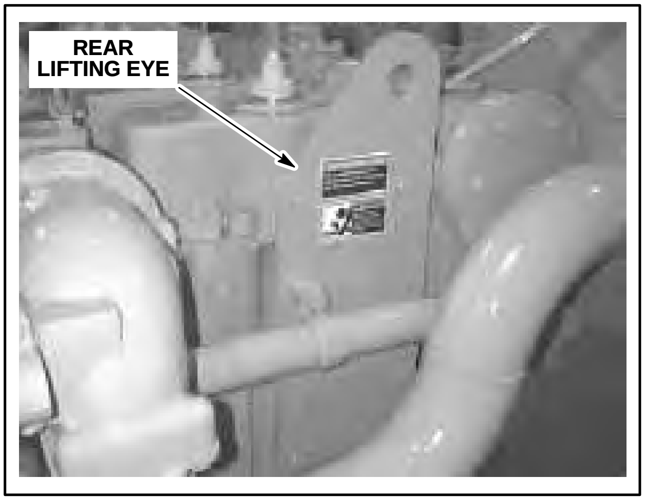


Figure 4.00-53. Rear Lifting Eye F18/H24GSID/GL/GLD

2. Locate brace under head nuts (see Figure 4.00-54). Brace replaces washers on cylinder head stud. Tighten cylinder head nuts to 116 ft-lb (157 N·m), then 347 ft-lb (470 N·m). Tighten lifting eye hex head screws to 64 ft-lb (87 N·m).

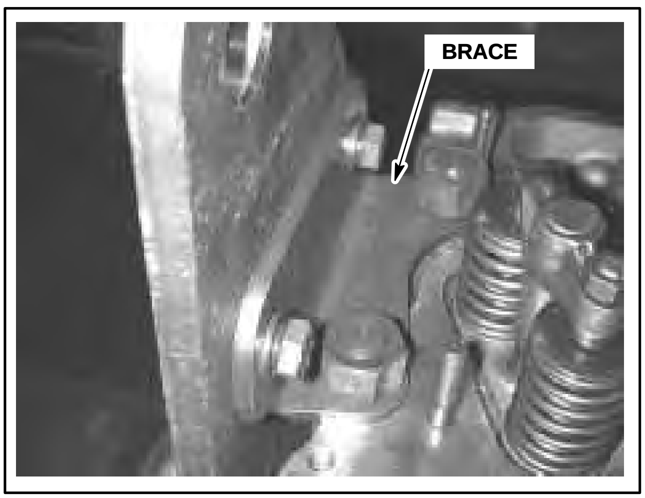


Figure 4.00-54. Rear Lifting Eye Brace

WATER PUMP IDLER HOUSING

The water pump idler uses a plain bushing lubricated by engine oil, mounted in the front gear housing.

1. Press bushing into idler housing (see Figure 4.00-57). Bushing must be installed below edge of housing.

2. Lubricate hub with engine oil and install in idler housing. Secure hub with M8 x 18 mm hex head screws.

3. Install gasket and outer cover on idler housing. Install six M8 x 18 mm hex head screws.

FRONT GEAR HOUSING INSTALLATION

WATER PUMP IDLER

1. Apply pipe thread sealant and install reducing bushing and tube fitting onto right front crankcase (see Figure 4.00-55).

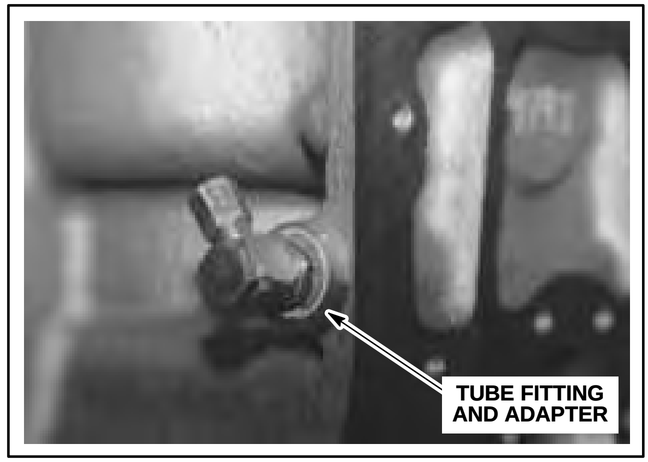


Figure 4.00-55. Idler Gear Oil Supply

2. Install new O–ring onto water pump idler housing. Install assembly onto housing. Make sure oil inlet port is installed in “11 o’clock” position on gear housing (see Figure 4.00-56).

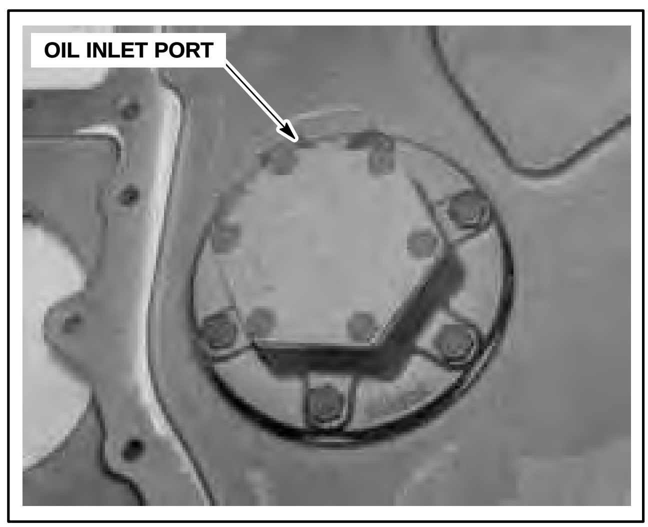


Figure 4.00-56. Water Pump Idler Assembly

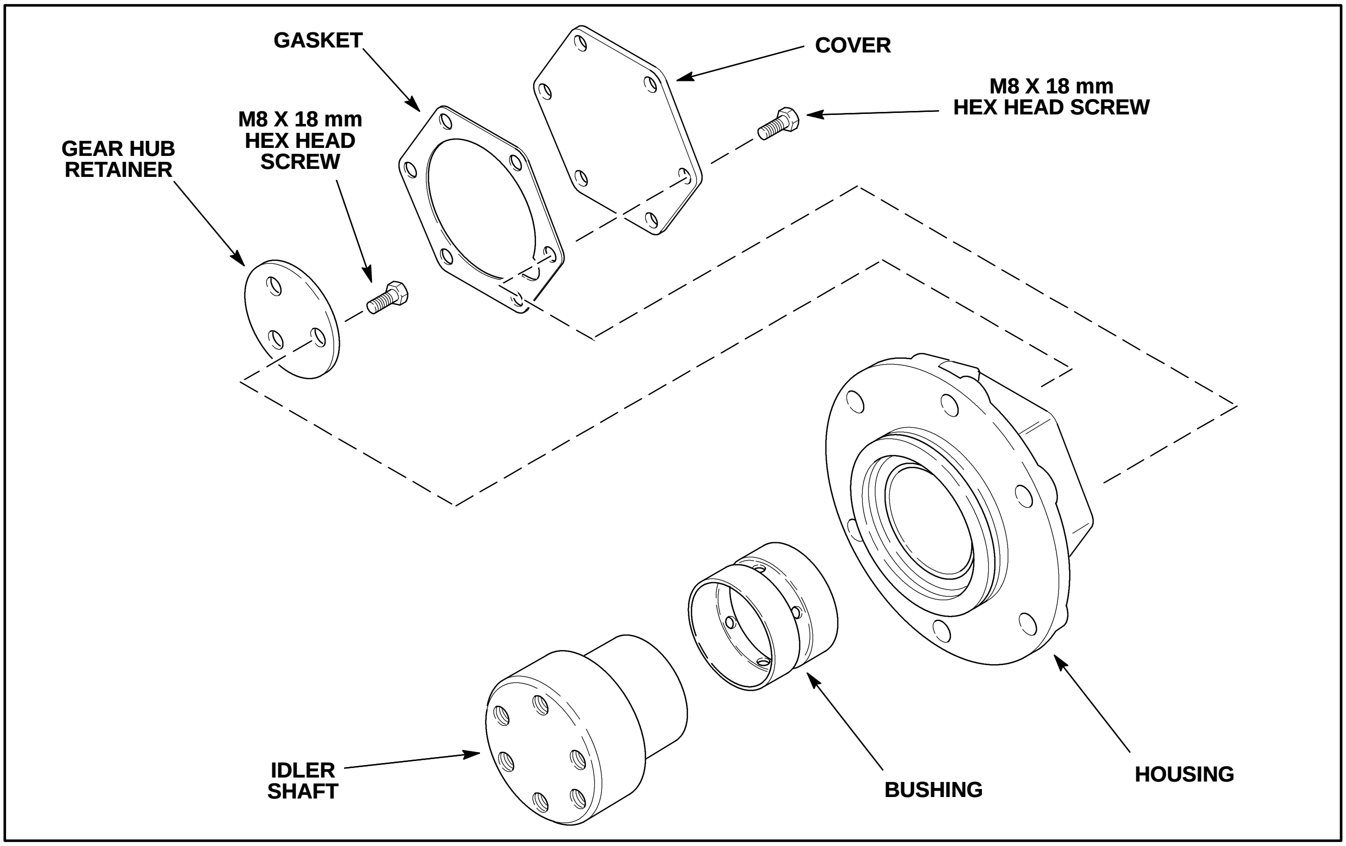


Figure 4.00-57. Water Pump Idler Housing

FRONT LIFTING EYE INSTALLATION

1. Install front lifting eye on gear housing (see Figure 4.00-58). Install M14 body fit bolt through lower lifting eye hole and into gear housing. Install spacer, lock washer and hex nut on back of gear housing. Install two M14 capscrews and lock washers through lifting eye and into gear housing. Tighten all fasteners to 103 ft-lb (140 N·m).

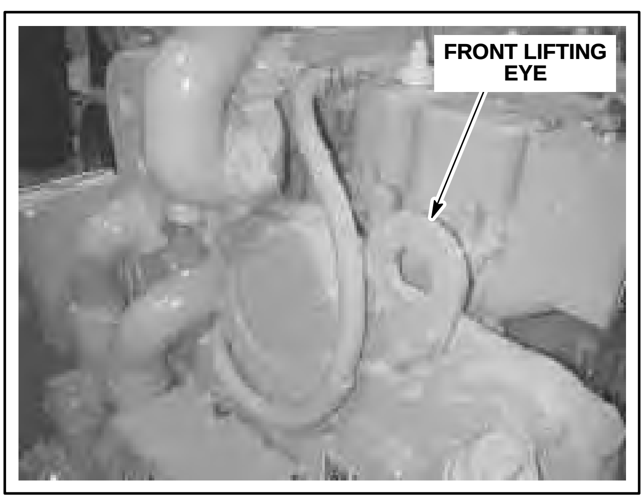


Figure 4.00-58. Front Lifting Eye

GEAR HOUSING

NOTE: *The camshaft and cam followers and shafts may be installed in the crankcase before installation of front gear housing.*

1. Install guide pins in front of crankcase (see Figure 4.00-59).

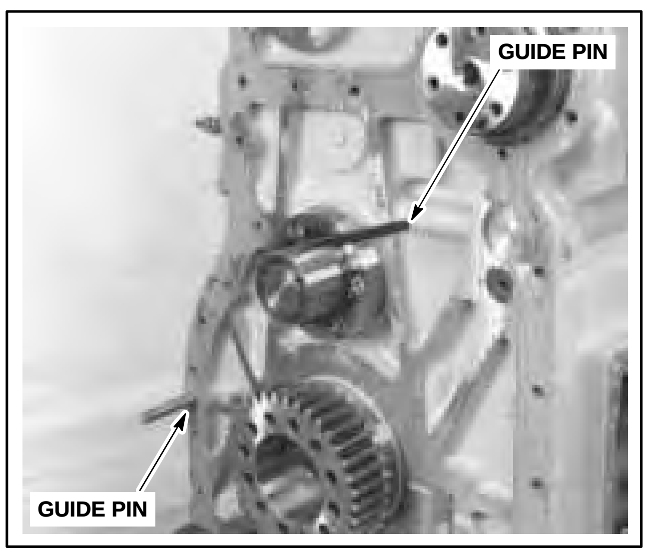


Figure 4.00-59. Gear Housing Guide Pins

2. Run a bead of GE Silmate® RTV1473 gasket eliminator around the sealing surface of the crankcase (see Figure 4.00-60).

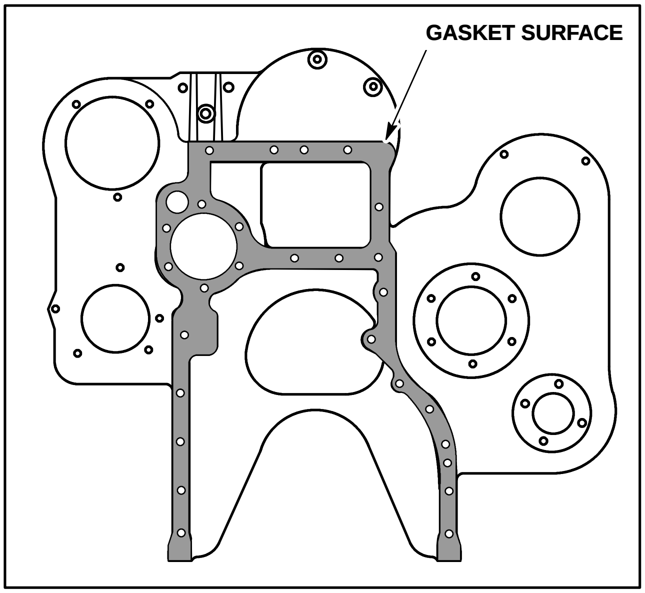


Figure 4.00-60. Gear Housing Gasket Surface

⚠ WARNING

The front gear housing weighs 97 lb. (44 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

NOTE: *If the gear housing is not bolted tightly to the crankcase while the RTV cures there will be improper clearances and incorrect tolerances for the gear train, camshaft and driven equipment.*

3. Use lifting eye to lift gear housing into place on locating dowel pins (see Figure 4.00-61).

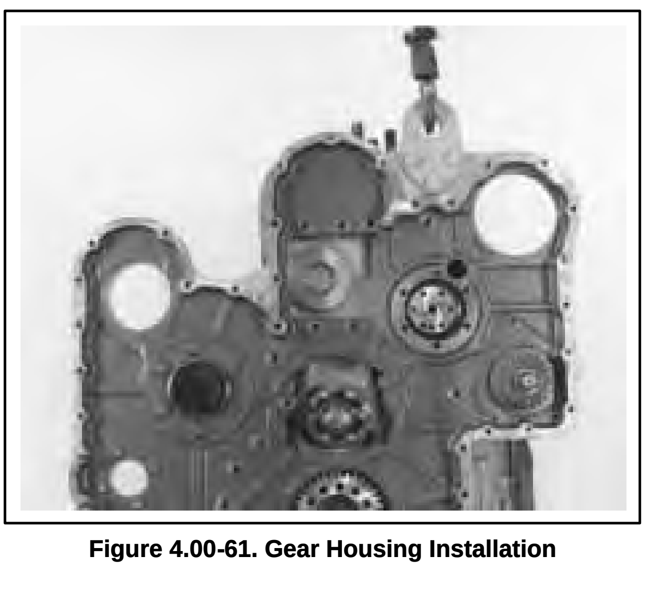


Figure 4.00-61. Gear Housing Installation

4. Install 12 hex head screws and tighten to 29 ft-lb (39 N·m).

5. Install oil supply tube between crankcase and water pump idler (see Figure 4.00-62).

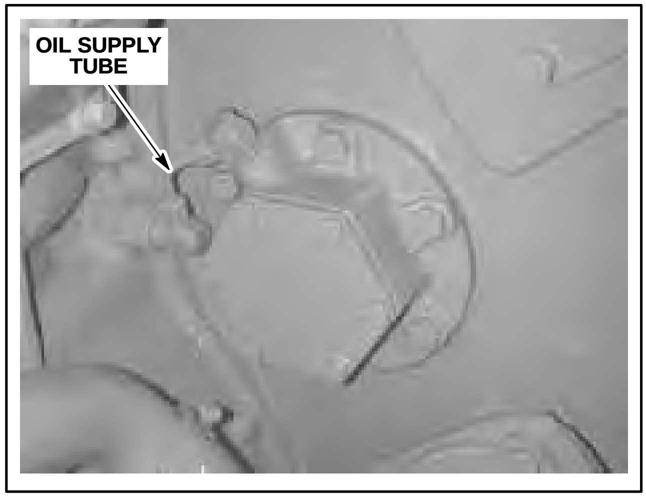


Figure 4.00-62. Oil Supply Tube

6. Apply Perma-Lok® LH050 to threads of two M10 x 90 mm studs. Install studs in gear housing. Installed height of the studs must be 80 mm (see Figure 4.00-63).

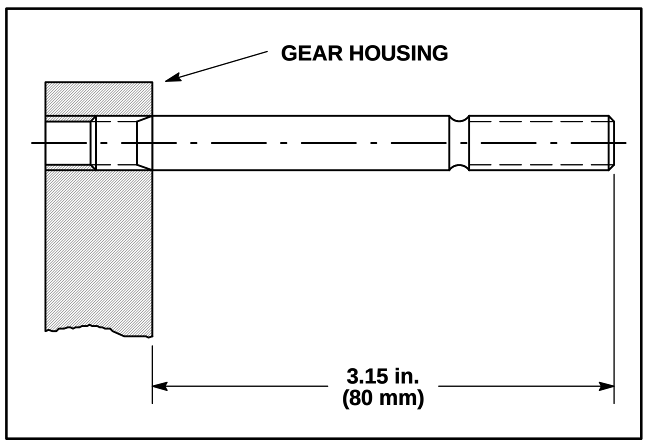


Figure 4.00-63. Magneto Drive Studs Installation

7. Different sized studs are used depending on the ignition system. Engines that are not equipped with a magneto drive require shorter studs for the drive cover (see Figure 4.00-64).

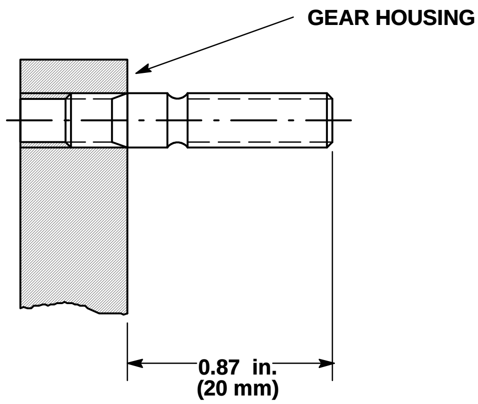


Figure 4.00-64. CEC Cover Studs Installation

CAMSHAFT INSTALLATION

⚠ WARNING

Make sure that all RTV sealant is removed from the camshaft area. Any material that is left in the cam bore will cause errors in setting camshaft endplay.

1. Remove any excess RTV from gear housing camshaft and cam follower shaft bores (see Figure 4.00-65).

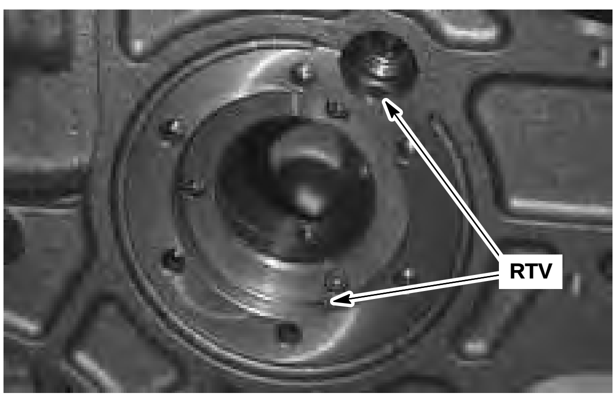


Figure 4.00-65. Remove Excess RTV In Bore

2. Install camshaft pilot installation tool P/N 472055, on front of camshaft.

NOTE: *Lubricate the camshaft lobes and journal surfaces with a Molycote t lubricant.*

3. Slide camshaft into crankcase from rear of engine (see Figure 4.00-66).

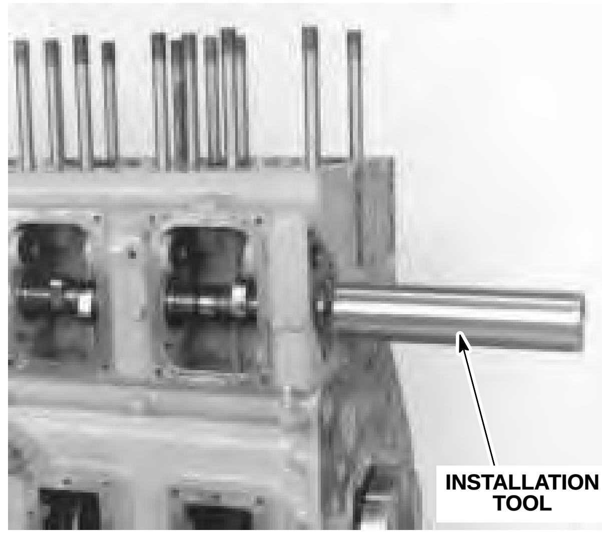


Figure 4.00-66. Camshaft Installation

4. Remove installation tool from camshaft.

5. Install camshaft thrust flange and any shims that were removed. Align notch in flange with hole in gear housing (see Figure 4.00-67).

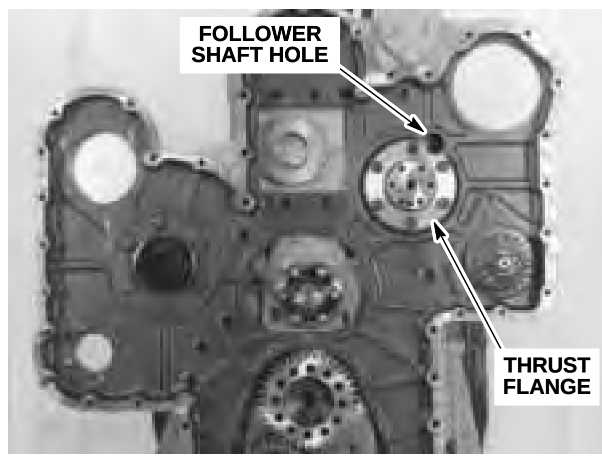


Figure 4.00-67. Camshaft Thrust Bushing Installation

6. Use a dial indicator to measure camshaft end play. Use shims to adjust endplay to 0.004 – 0.006 in. (0.101 – 0.152 mm). Apply Loctite 242® and tighten hex head screws to 37 ft-lb (50 N·m).

SECTION 4.05

CYLINDER HEAD INSTALLATION

CYLINDER HEAD INSTALLATION

NOTE: *See Section 4.10* Valve Adjustment *in this manual for valve lash adjustment procedure.*

STUD INSTALLATION

Table 4.05-1. Special Tools For Cylinder Head

TOOL P/N	TOOL DESCRIPTION
472015	Rocker Arm Support/Manifold Wrench

1. Lubricate cylinder head studs (threads) with clean engine oil.

NOTE: *Do not install head studs dry. Do not use lubricant containing molybdenum or Loctite® on the stud threads. Lubricate cylinder head studs (threads) with clean engine oil.*

2. Install cylinder head studs into crankcase. Use collet type stud driver. Tighten studs to 72 ft-lb (98 N·m) (see Figure 4.05-1).

NOTE: *Cylinder Head Gasket P/N 300000D is used for high temperature applications (see Figure 4.05-1).*

CAUTION When using cylinder head gasket P/N 300000D, the installed height of the valve in the cylinder head must be 0.059 – 0.079 in. (1.5 – 2.0 mm). Install P/N 304010L valve seat, or grind P/N 304010K valve seat to obtain said clearance. Disregarding this information could result in product damage.

NOTE: *Cylinder heads for GL/GLD engines (P/N AD300302C) and GSID engines (P/N CD300302C) have valve seat insert P/N 304010L installed for use with P/N 300000D cylinder head gasket.*

NOTE: *Cylinder Head Gasket P/N 300000B requires the installation of a new O-ring (P/N 304721) and oil supply tube (P/N 304349). Gasket P/N 300000B is not intended for high temperature applications (see Figure 4.05-2).*

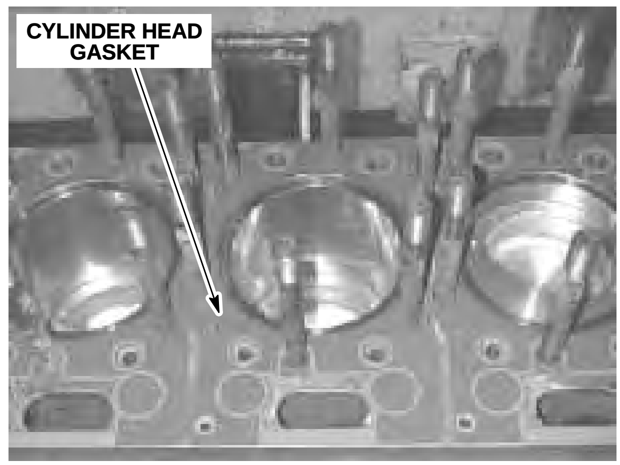


Figure 4.05-1. Cylinder Head Gasket – P/N 300000D

Figure 4.05-2. Cylinder Head Gasket – P/N 300000B

3. Install cylinder head gaskets.

WARNING

The cylinder head weighs 80 lb. (36 kg). Lift only with properly rated lifting device and rigging to avoid severe personal injury or death.

4. Install cylinder head using suitable lifting device (see Figure 4.05-3).

Figure 4.05-3. Cylinder Head Installation

NOTE: *To aid in aligning the heads and improving manifold sealing when replacing a bank of heads, loosely install the heads to the crankcase and install either the intake or exhaust manifold to the heads. Then tighten the head nuts to final torque.*

NOTE: *Do not install head nuts dry. Do not use Molycoat™ lubricant or Loctite® on the cylinder head nuts. Lubricate cylinder head nuts with clean engine oil.*

5. Secure cylinder head with washers and nuts (see Figure 4.05-4). Secure rear lifting eye brace to rear cylinder head using washers and nuts (see Figure 4.05-5).

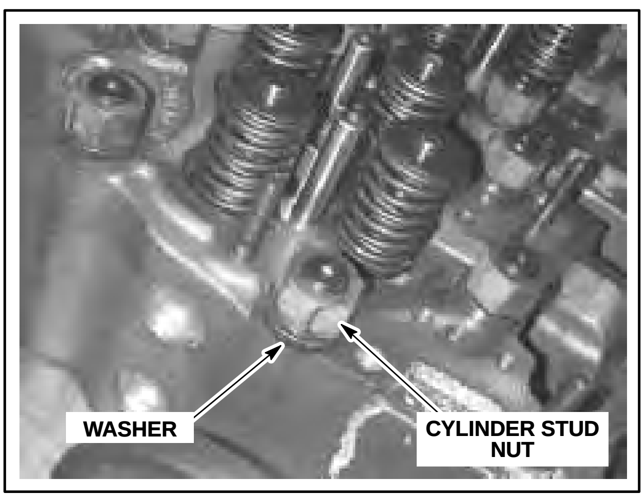


Figure 4.05-4. Cylinder Head Installation

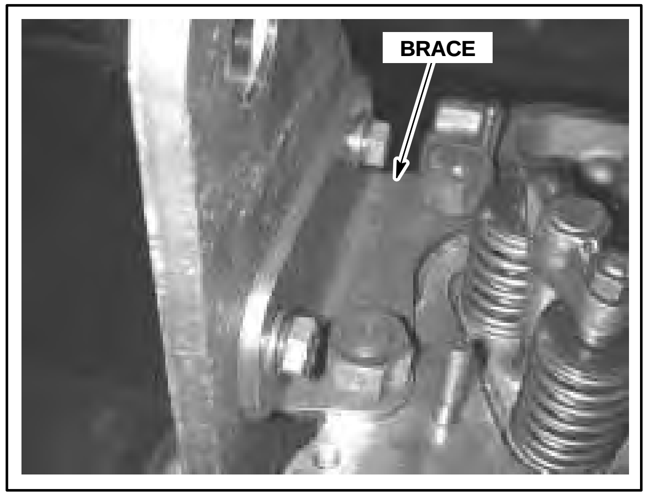


Figure 4.05-5. Rear Lifting Eye Brace

NOTE: *Cylinder head nuts are tightened in three steps. Use the proper tightening sequence (see Figure 4.05-6).*

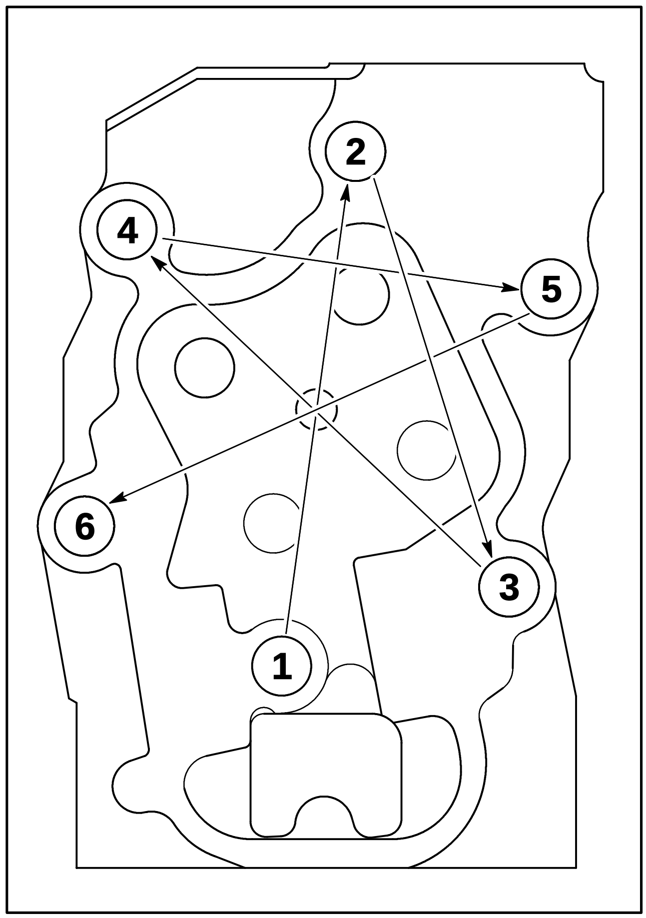


Figure 4.05-6. Cylinder Head Bolt Tightening Sequence – Top View

6. Tighten cylinder head nuts to 116 ft-lb (157 N·m). Use proper tightening sequence.

7. Tighten cylinder head nuts to 231 ft-lb (314 N·m). Use proper tightening sequence.

8. Tighten cylinder head nuts to 347 ft-lb (470 N·m). Use proper tightening sequence.

NOTE: *The spark plug holder must be installed prior to the installation of the cross bar and rocker arm assemblies.*

9. Install spark plug holder and washer (if applicable). Make sure new O-rings are installed (see Figure 4.05-7).

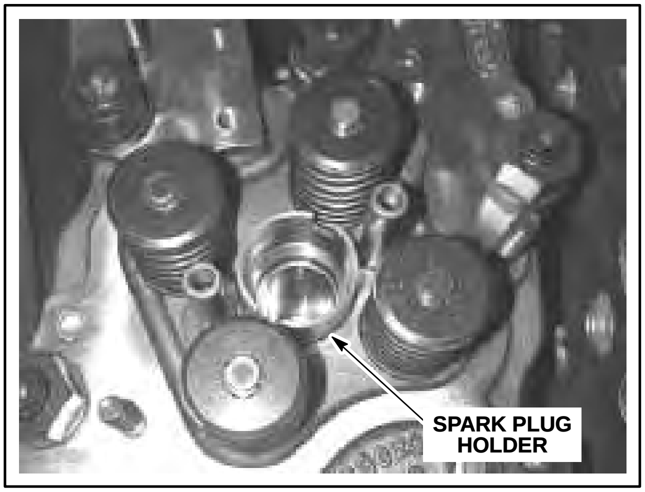


Figure 4.05-7. Spark Plug Holder

10. Install new intake manifold O-rings into cylinder head. Each cylinder head uses two O-rings (see Figure 4.05-8).

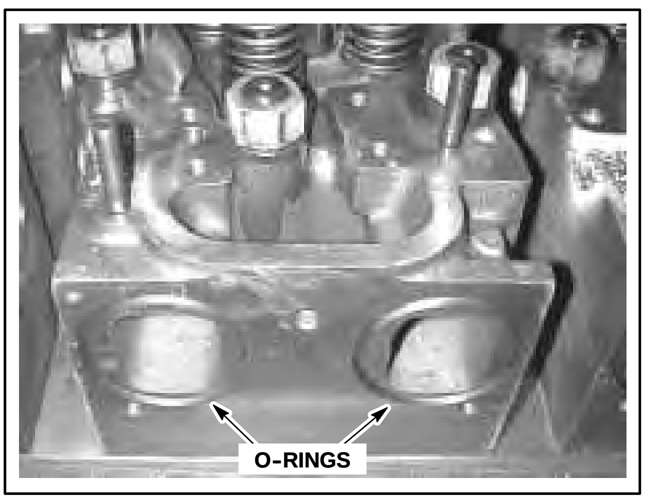


Figure 4.05-8. Cylinder Head O-Rings

11. Install seat, adjusting screw and adjusting nut onto cross bar (see Figure 4.05-9).

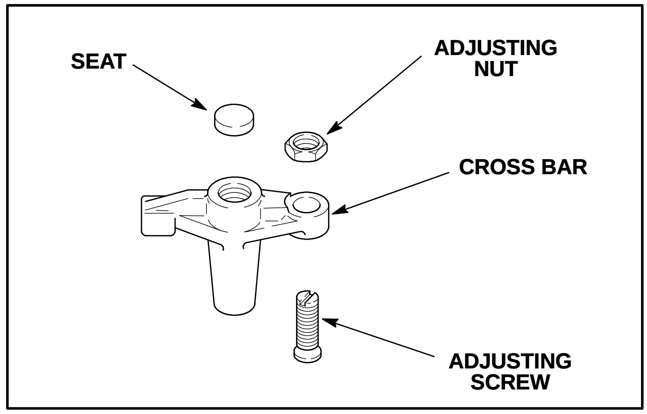


Figure 4.05-9. Cross Bar Assembly

12. Install cross bar assemblies onto cylinder heads (see Figure 4.05-10). Cross bar assembly (adjusting nut side) is positioned closest to exhaust manifold.

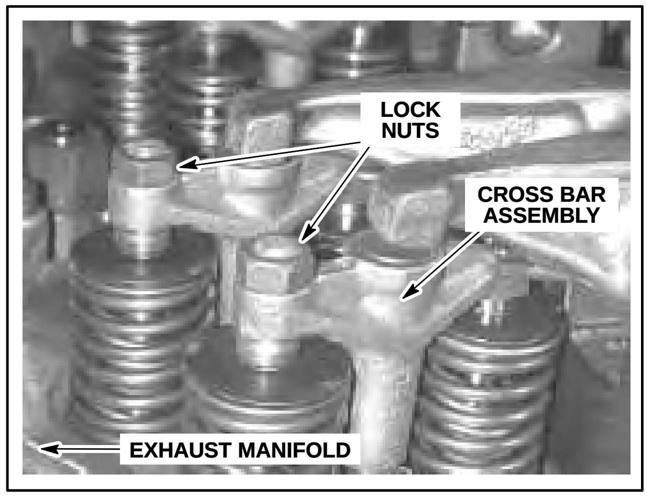


Figure 4.05-10. Cross Bar Installation

13. Install pushrods into original locations in cylinder heads (see Figure 4.05-11).

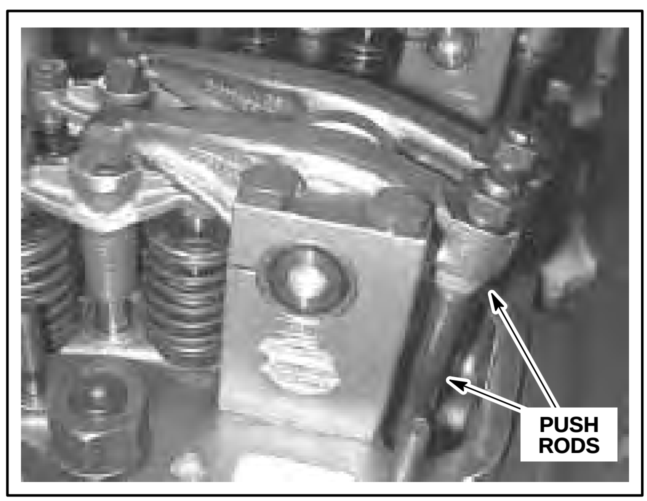


Figure 4.05-11. Pushrod Installation

NOTE: *See Section 3.00* Cylinder Head Disassembly And Overhaul *for detailed instructions on assembling and inspecting the rocker arms.*

14. Assemble rocker arm components (see Figure 4.05-12).

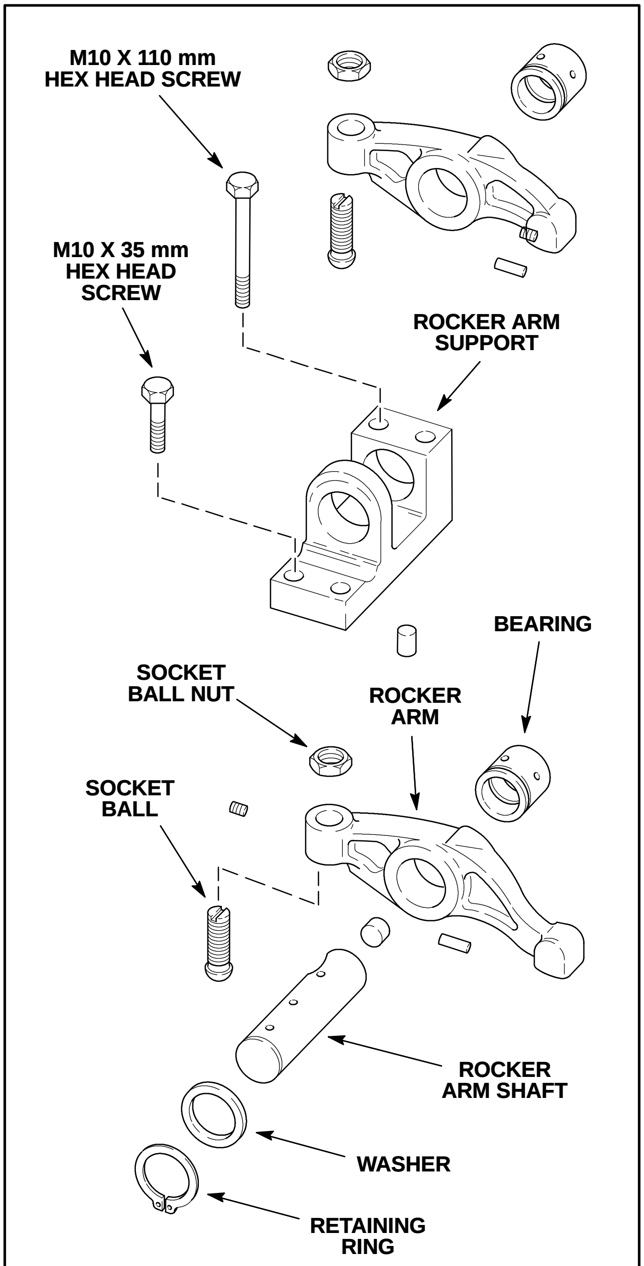


Figure 4.05-12. Rocker Arm Components

15. Install rocker arm assemblies over push rods (see Figure 4.05-13).

16. Secure rocker arm assemblies to cylinder head with M10 x 110 mm hex head screws and M10 x 35 mm hex head screws (see Figure 4.05-13 and Figure 4.05-14).

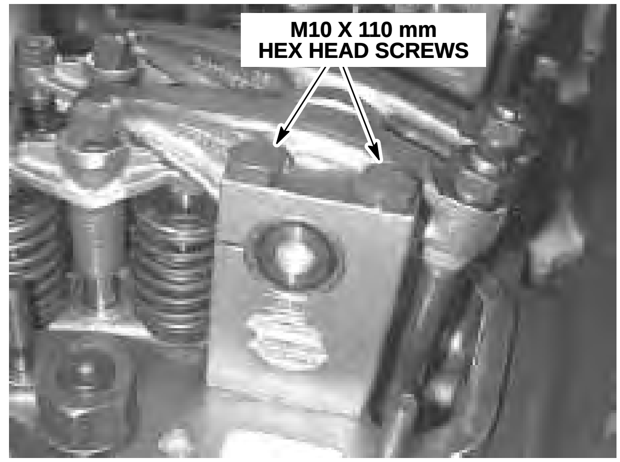


Figure 4.05-13. Rocker Arm Support Installation

Figure 4.05-14. Rocker Arm Support Installation

⚠ CAUTION The rocker arm assembly hex head screws must be tightened to the required torque. Loose rocker arm assemblies result in scuffed pushrod and rocker arm tips and can result in valve failures. Disregarding this information could result in product damage.

17. Tighten rocker arm hex head screws to 28 ft-lb (38 N·m). Use tool P/N 472015 to tighten rocker arm support M10 x 35 mm hex head screws (see Figure 4.05-15).

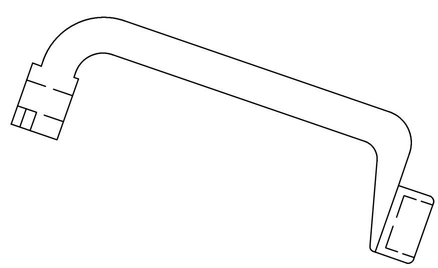


Figure 4.05-15. Rocker Arm Support Wrench

EXHAUST MANIFOLD INSTALLATION

See Section 5.35 *Exhaust System* for complete exhaust manifold and system installation.

1. Install M10 guide studs in the exhaust side of the cylinder heads. Locate the exhaust manifold gaskets on the guide studs (see Figure 4.05-16).

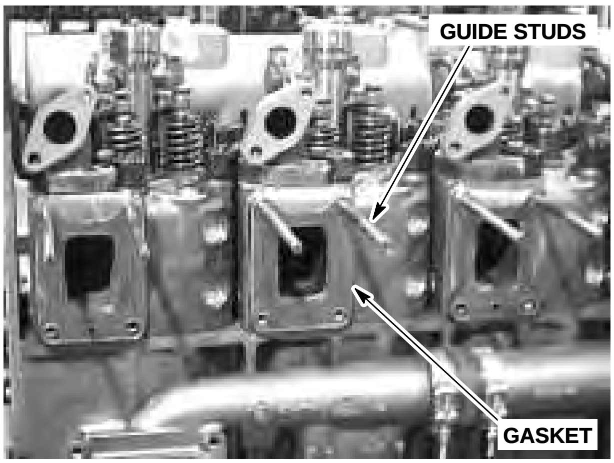


Figure 4.05-16. Cylinder Head Exhaust Ports

NOTE: *The gasket must be installed with the coolant drain hole in the lower position (see Figure 4.05-17).*

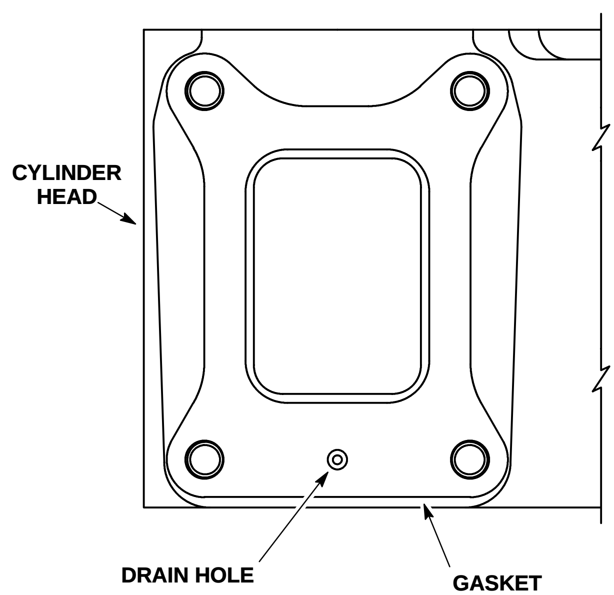


Figure 4.05-17. VGF Exhaust Manifold Drain Hole

⚠ WARNING

The six cylinder exhaust manifold weighs 269 lb. (122 kg). The eight cylinder exhaust manifold weighs 343 lb. (155 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

2. Use a suitable lifting device to lift the exhaust manifold to the cylinder heads. Install the manifold capscrews into the cylinder head. Use a long extension with a swivel to reach from the bolt head from the other side of the engine.

3. Tighten exhaust manifold M10 hex head screws to 53 ft-lb (72 N·m) (see Figure 4.05-18).

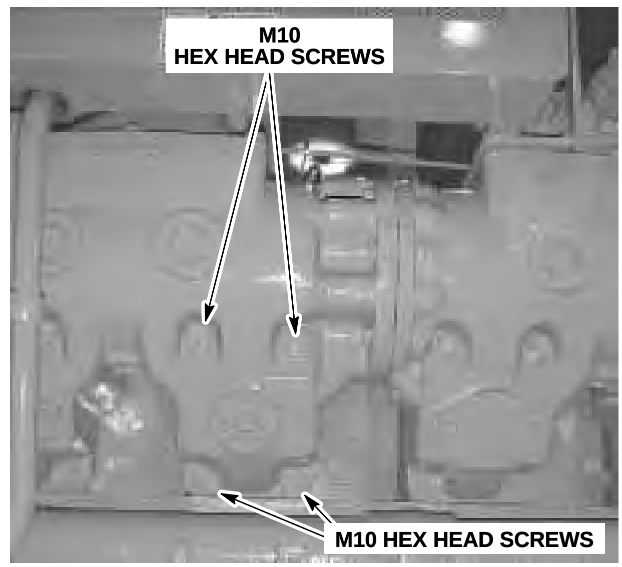


Figure 4.05-18. F18GL Exhaust Manifold

NOTE: *Previous production water elbows were secured with M10 x 35 mm hex head screws and lock washers. Tighten to 37 ft-lb (50 N·m) regardless of fastener used.*

4. **Current Engines—**Install water elbow between cylinder head and exhaust manifold. Make sure gaskets are installed on both ends of water elbow. Secure with M10 x 35 mm socket head screws and tighten to 37 ft-lb (50 N·m) (see Figure 4.05-19).

NOTE: *Tighten socket head screws in an "X" pattern to prevent water leaks (see numbered pattern in Figure 4.05-19).*

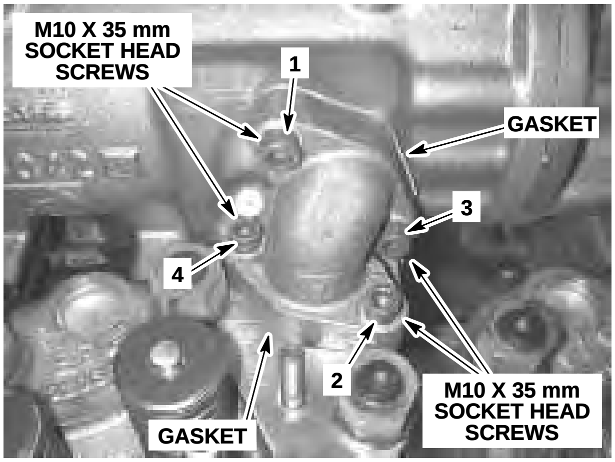


Figure 4.05-19. Water Elbow Assembly

5. **Previous Engines—**Install water elbow and secure with four M10 x 35 mm hex head screws and tighten to 37 ft-lb (50 N·m) (see Figure 4.05-20).

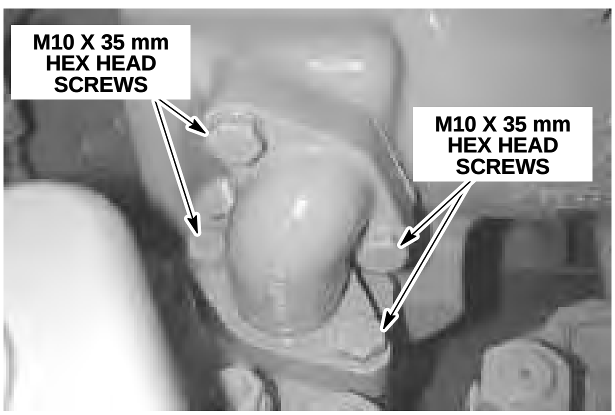


Figure 4.05-20. Previous—Water Elbow Assembly

INTAKE MANIFOLD INSTALLATION

1. Install new O-rings on cylinder head intake ports (see Figure 4.05-21).

Figure 4.05-21. Cylinder Head O-Rings

⚠ WARNING

The six cylinder intake manifold and elbow assembly weighs 51 lb. (23 kg). The eight cylinder intake manifold and elbow assembly weighs 65 lb. (30 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

2. Attach suitable lifting brackets to intake manifold (see Figure 4.05-22). Use lifting device to support manifold while installing intake manifold fasteners. Two different size fasteners are used to attach manifold to head.

NOTE: *The butterfly valve can be installed on the engine separately or attached to the intake manifold.*

Figure 4.05-22. Intake Manifold Installation

3. Secure intake manifold with M12 x 140 mm and M10 x 40 mm hex head screws. Apply Loctite® 242 onto threads.

4. Tighten M12 hex head screws to 65 ft-lb (88 N·m). Tighten M10 hex head screws to 37 ft-lb (50 N·m).

NOTE: *See Section 5.15* Air Induction System *"Intake Manifold Installation" for additional information.*

ROCKER ARM COVER INSTALLATION

1. Install new O-rings on rocker arm cover recess tube (see Figure 4.05-23).

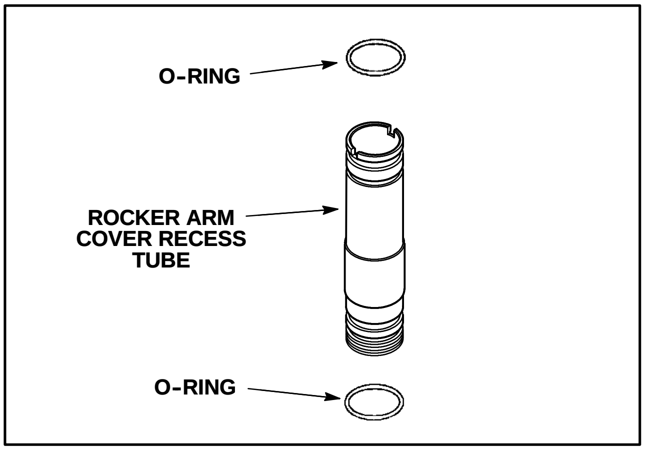


Figure 4.05-23. Rocker Arm Cover Recess Tube

NOTE: *Engines that are to be equipped with flange mounted shielded ignition coils (CSA) require a different rocker arm cover recess tube.*

2. Install rocker arm cover recess tube into spark plug holder (already installed in cylinder head) (see Figure 4.05-24).

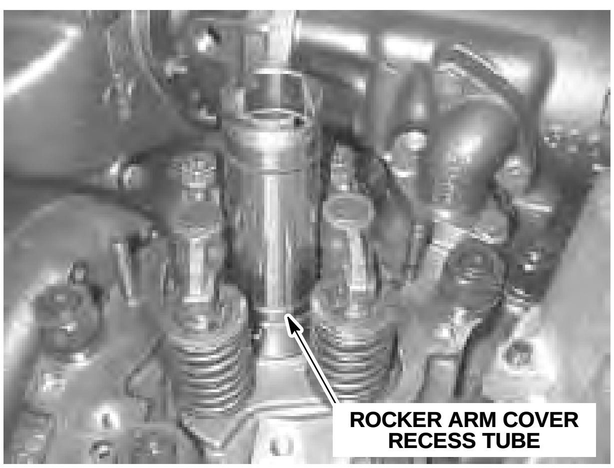


Figure 4.05-24. Rocker Arm Cover Recess Tube

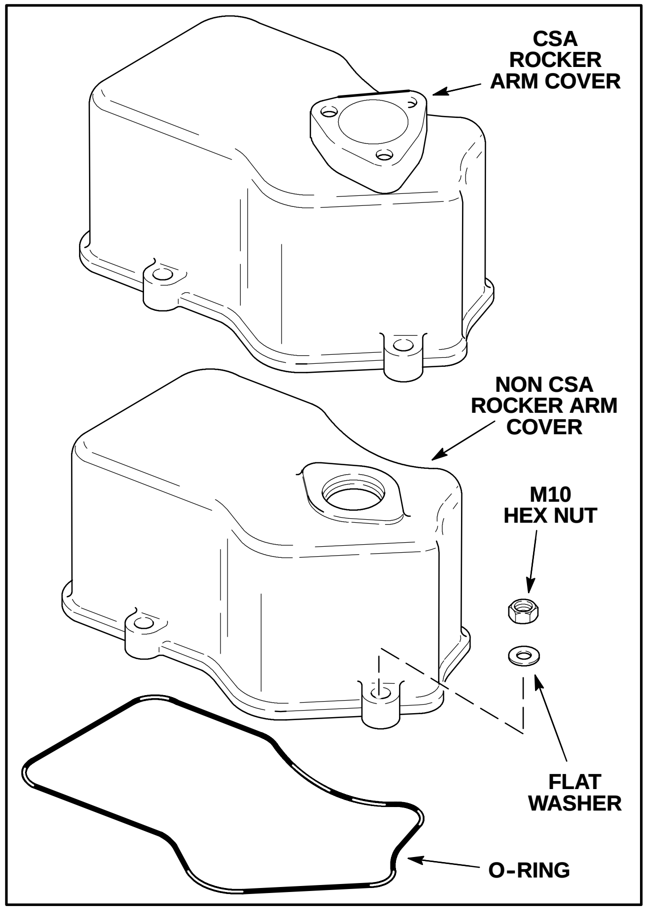


Figure 4.05-25. Rocker Cover Installation

NOTE: *Engines that are to be equipped with flange mounted shielded ignition coils require a different rocker cover (see Figure 4.05-25).*

3. Install O-ring gasket in rocker arm cover. Apply gasket adhesive to O-ring (to secure in place during installation).

4. Install rocker arm cover and secure with M10 hex nuts (Grade 10) and washers (see Figure 4.05-26). Tighten to 29 ft-lb (39 N·m).

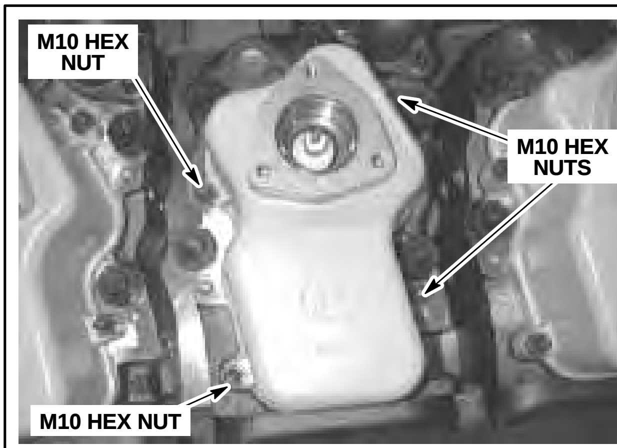


Figure 4.05-26. CSA Valve Cover

NOTE: *Spark plugs should be installed in the cylinder heads. See Section 5.10,* Ignition System – CEC/Magneto *"Spark Plugs" for complete spark plug installation instructions.*

5. **CSA—**Install spark plug extension tube.

6. Install ignition system coils and harness onto intake manifold (see Figure 4.05-27) See Section 5.10 *Ignition System – CEC/Magneto* for complete ignition system installation information.

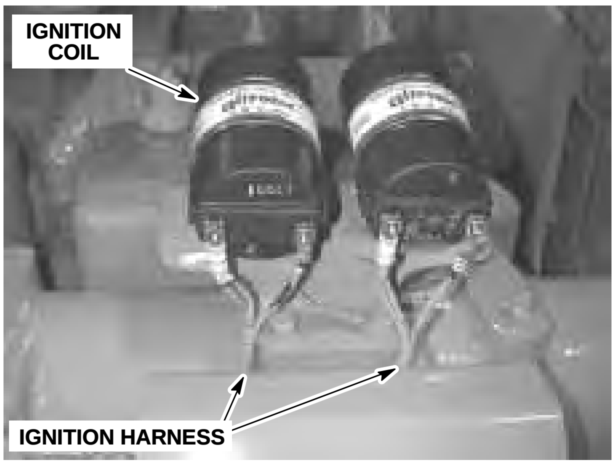


Figure 4.05-27. Ignition Coil (Non CSA)

⚠ CAUTION Ignition coils that are improperly grounded can cause misfiring. Make sure CSA coils are installed with three M8 x 20 mm hex head screws that are properly tightened. Disregarding this information could result in product damage and/or personal injury.

NOTE: *When installing flange mounted CSA coils, position them on the rocker arm cover so the key way on the cannon plug will align with the ignition lead, without excessive twisting of the lead.*

7. **CSA—**Install flange mounted coil (use new O–ring) and secure with M8 x 20 mm hex head screws and washers. Tighten hex head screws to 16 – 17 ft-lb (21.6 – 23.0 N·m) (oiled threads) (see Figure 4.05-28).

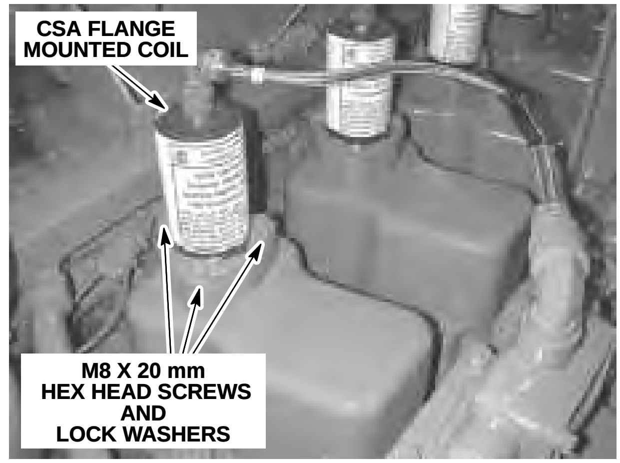


Figure 4.05-28. CSA Flange Mounted Coil

8. **CSA—**Connect high tension lead to flange mounted coil (see Figure 4.05-29).

Figure 4.05-29. CSA High Tension Coil Lead

9. **Non CSA—**Install high tension lead and spark plug cover tube onto spark plug (see Figure 4.05-30).

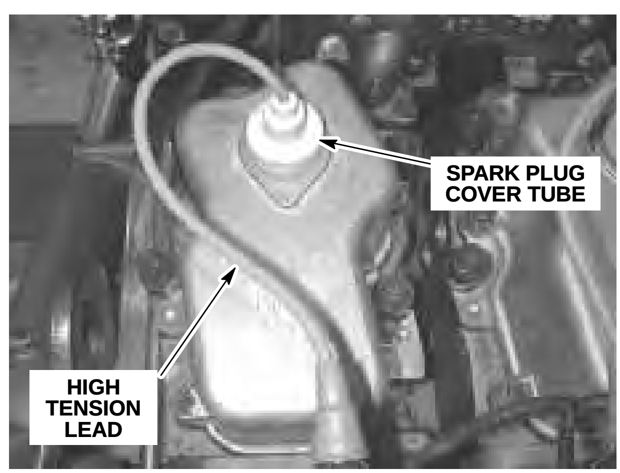


Figure 4.05-30. High Tension Coil Lead

SECTION 4.10

VALVE ADJUSTMENT

ROCKER ARM COVER REMOVAL

STANDARD COIL

1. Remove high tension lead and spark plug cover tube from cylinder head (see Figure 4.10-1).

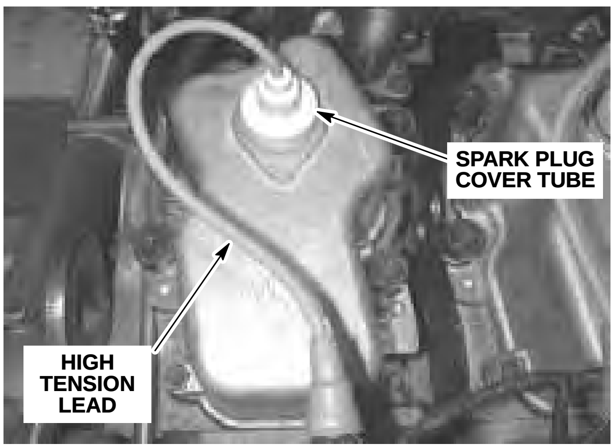


Figure 4.10-1. High Tension Coil Lead

2. Remove four M10 hex nuts and flat washers and lift rocker arm cover from cylinder head (see Figure 4.10-2).

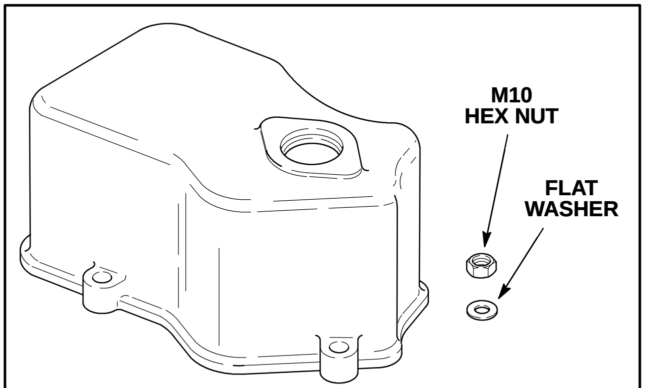


Figure 4.10-2. Rocker Arm Cover – Standard

FLANGE MOUNTED COIL—CSA

On engines equipped with flange mounted shielded ignition coils the clearance between the rocker arm cover and the access tube is extremely small. Tool P/N 472074 is used for cover removal. The tool consists of a puller assembly and a disc. The disc is sized to fit on top of the spark plug access tube (see Figure 4.10-3).

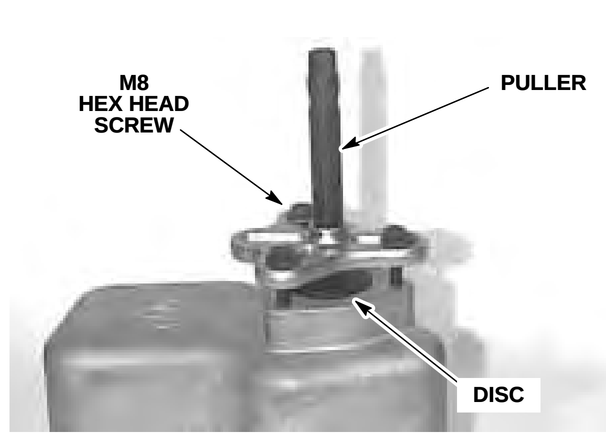


Figure 4.10-3. Rocker Cover Removal Tool P/N 472074

1. Disconnect high tension lead from coil (see Figure 4.10-4).

Figure 4.10-4. CSA High Tension Coil Lead

⚠ CAUTION Always remove the coil and spark plug extension first, then remove the rocker cover. Do not use the CSA flange mounted ignition coil as a handle when lifting the rocker cover. The CSA coil can be damaged if it is used to lift the rocker cover.

2. Remove M8 x 20 mm hex head screws from flange mounted ignition coil (see Figure 4.10-5).

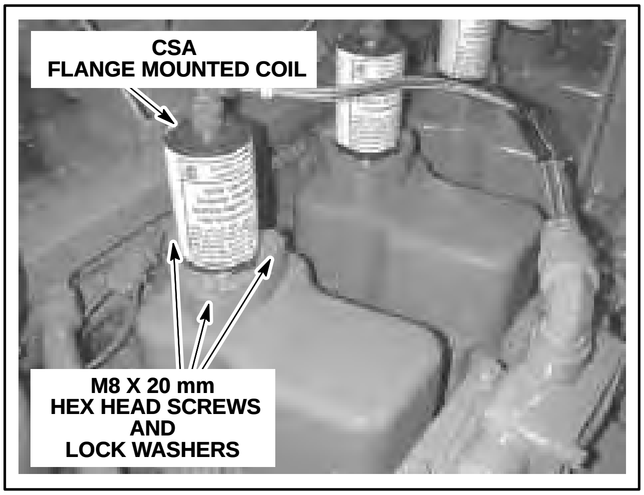


Figure 4.10-5. CSA Flange Mounted Coil

3. Remove coil and spark plug extension from rocker arm cover.

4. Remove four hex nuts and lock washers from rocker arm cover (see Figure 4.10-6).

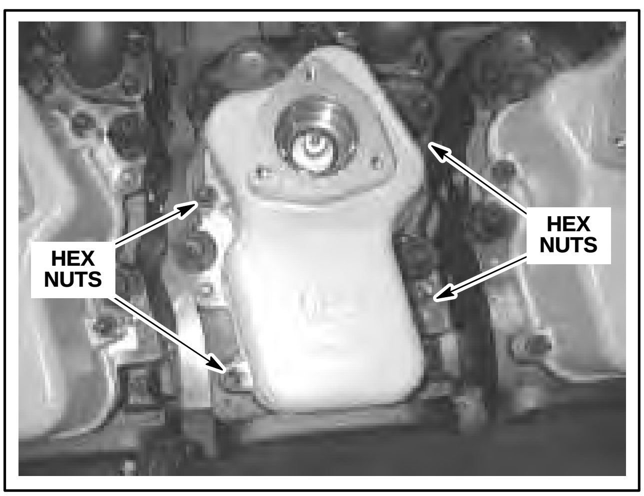


Figure 4.10-6. CSA Rocker Arm Cover

5. Install disc on top of rocker arm cover and secure with M8 hex head screws (see Figure 4.10-7).

6. Turn puller screw clockwise. Continue turning screw until rocker arm cover is clear of recess tube.

7. Remove rocker arm cover.

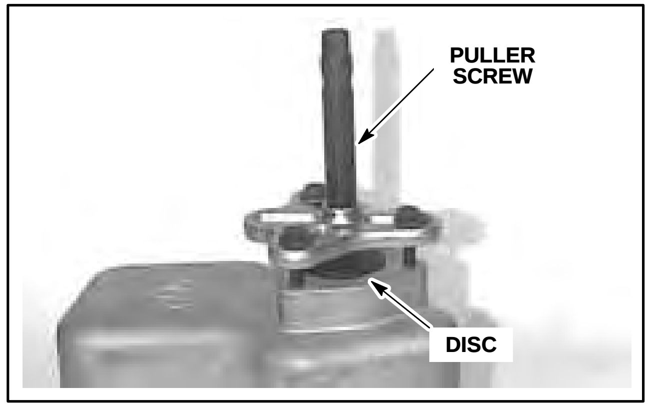


Figure 4.10-7. Rocker Arm Cover Removal Tool

VALVE ADJUSTMENT

NOTE: *Top Dead Center (TDC) is marked on the flywheel and can be observed through the timing hole on the left side of the flywheel housing. The compression stroke can be determined by checking the rocker arms on that cylinder for looseness (all four valves closed).*

1. Use barring device to rotate engine until #1 cylinder is at Top Dead Center (TDC) during compression stroke.

2. Loosen cylinder #1 rocker arm adjusting screws (see Figure 4.10-8).

3. Push down on fixed side of cross bar. Hold down and turn cross bar adjusting screw clockwise until contact with valve stem is made (see Figure 4.10-8).

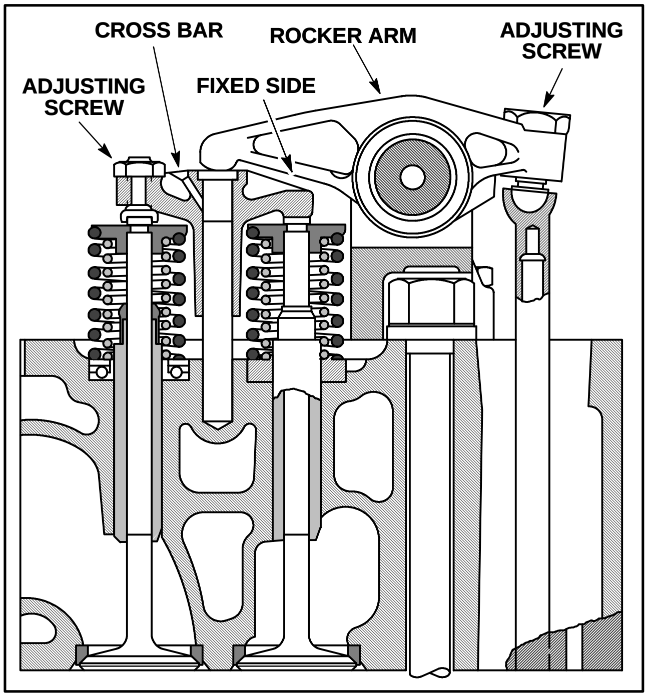


Figure 4.10-8. Rocker Arm Adjusting Screws

4. Verify cross bar is making contact with both valves (at same time).

5. Tighten cross bar adjustment lock nut while keeping adjusting screw from turning. Support cross bar to maintain contact with both valves while tightening lock nut.

6. Insert feeler gauge between cross bar and rocker arm (see Figure 4.10-9). Make sure correct size feeler gauge is used (see Table 4.10-1).

Table 4.10-1. Valve Clearance – Cold

VALVES	CLEARANCES
Intake Valves (Cold)	0.008 in. (0.20 mm)
Exhaust Valves (Cold)	0.026 in. (0.66 mm)

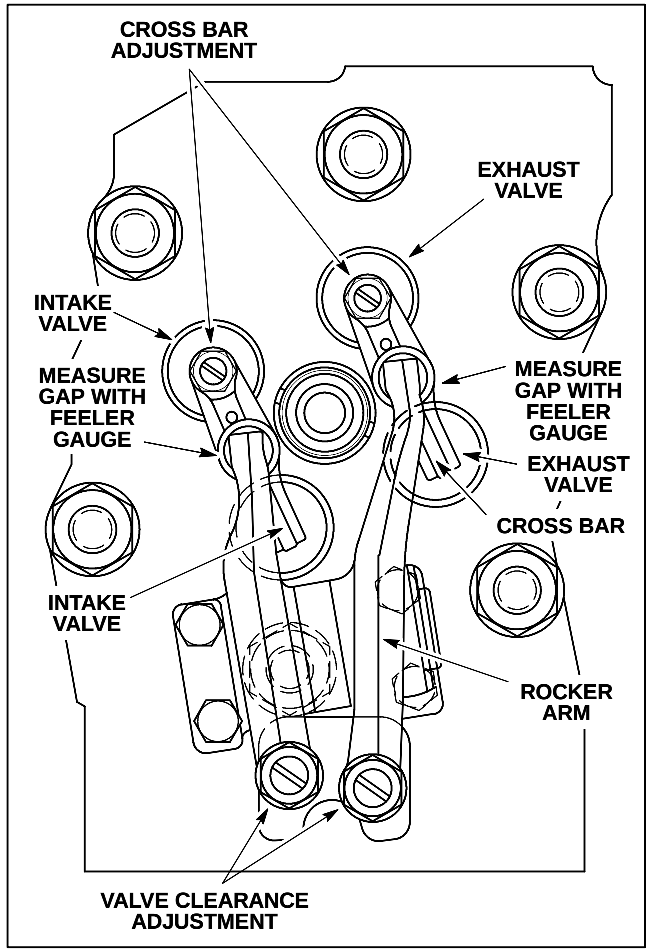


Figure 4.10-9. Rocker Arm Adjustments

7. Turn valve clearance adjustment screw until it contacts push rod socket. Feeler gauge should be snug between cross bar and rocker arm (see Figure 4.10-9).

8. Tighten lock nut. Do not allow valve clearance adjustment screw to move.

9. Repeat procedure for remaining valves on cylinder #1.

NOTE: *The valve adjustment order by cylinder is:*
Six Cylinder – 1 5 3 6 2 4
Eight Cylinder – 1 4 2 6 8 5 7 3

10. Repeat adjustment procedure for all other cylinders. Make sure the correct adjustment order is followed.

ROCKER ARM COVER INSTALLATION

1. Install O-ring gasket in rocker arm cover. Apply gasket adhesive to O-ring (to secure in place during installation).

2. Install rocker arm cover and secure with M10 hex nuts (Grade 10) and washers (see Figure 4.10-10). Tighten to 29 ft-lb (39 N·m).

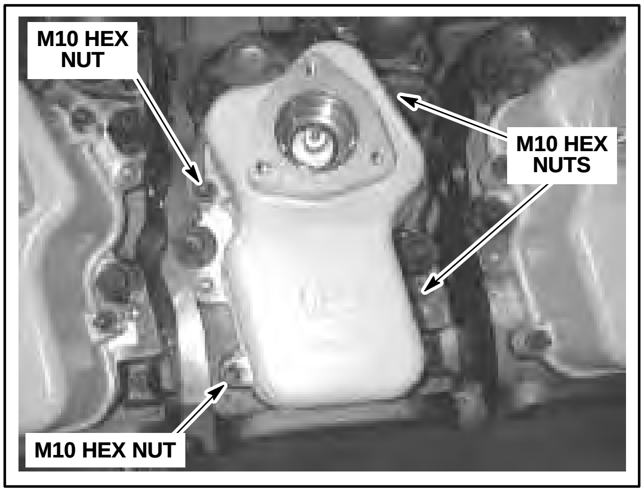


Figure 4.10-10. CSA Valve Cover

⚠ CAUTION Ignition coils that are improperly grounded can cause misfiring. Make sure CSA coils are installed with three M8 x 20 mm hex head screws that are properly tightened. Disregarding this information could result in product damage and/or personal injury.

NOTE: *When installing flange mounted CSA coils, position them on the rocker arm cover so the key way on the cannon plug will align with the ignition lead, without excessive twisting of the lead.*

3. **CSA—**Install flange mounted coil (use new O-ring) and secure with M8 x 20 mm hex head screws and washers. Tighten hex head screws to 16 - 17 ft-lb (21.6 - 23.0 N·m) (oiled threads) (see Figure 4.10-11).

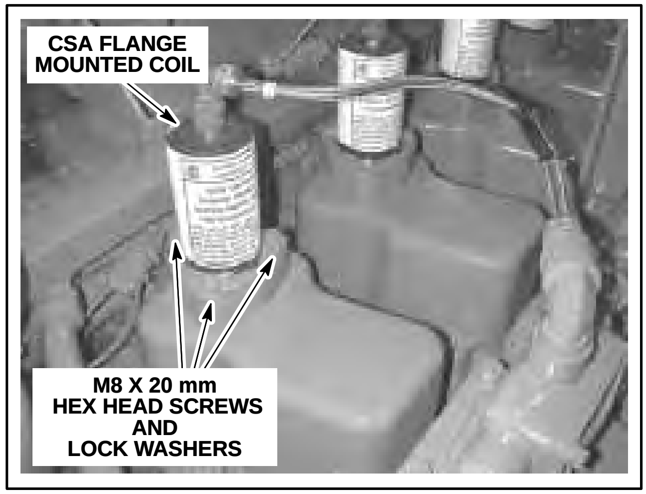


Figure 4.10-11. CSA Flange Mounted Coil

4. **CSA—**Connect high tension lead to flange mounted coil (see Figure 4.10-12).

Figure 4.10-12. CSA High Tension Coil Lead

5. **Non CSA—**Install high tension lead and spark plug cover tube onto spark plug (see Figure 4.10-13).

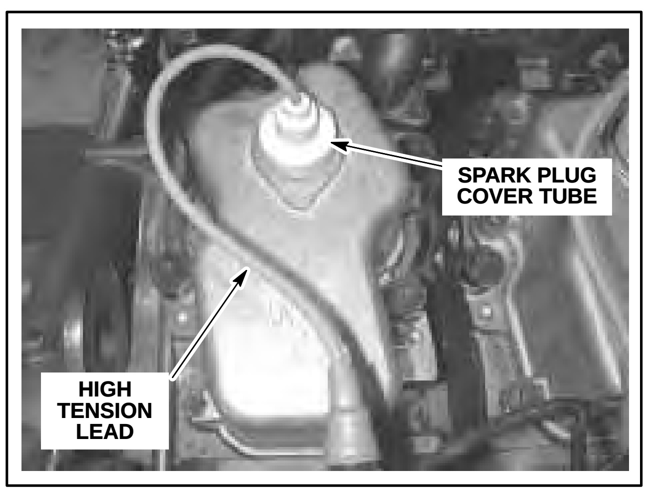


Figure 4.10-13. High Tension Coil Lead

SECTION 5.00

ENGINE SPEED GOVERNING SYSTEM

SPEED GOVERNING SYSTEM COMPONENTS

The engine speed control system consists of the following engine mounted components:

- Governor
- Governor drive (If equipped)
- Governor actuator (If equipped)
- Governor linkage and regulator shafts
- Magnetic pickup unit (Required with EG3P and 4024 governors)

GOVERNOR

The governor controls the engine rpm by controlling the amount of air/fuel supplied to the engine. The governor speed control can be isochronous, which means that the governor will maintain a constant engine rpm regardless of load (within the capacity of the engine). The governor speed control can also operate in a droop mode which means that the governor will allow the engine to slow down slightly under load. This allows for more stable governor operation.

The governor drive is located on the back of the front gear housing. EG3P and PSG governors mount on the governor drive and turn the throttle shaft which is connected to the throttle butterfly valve. The 4024 electric governor is mounted on top of the intake manifold and linked directly to the throttle butterfly valve.

The engine may also be equipped with one of the following governors:

- 4024 EPG governor (electrically powered governor) (see Figure 5.00-1).
- EG3P electro-hydraulic governor actuator (see Figure 5.00-2), uses the following control boxes:
  - •• 2301 Droop speed control
  - •• 2301A Isochronous load sharing control
- PSG governor (engine driven hydraulic speed governor) (see Figure 5.00-3).

Figure 5.00-1. 4024 EPG Governor

Figure 5.00-2. EG3P Governor Actuator

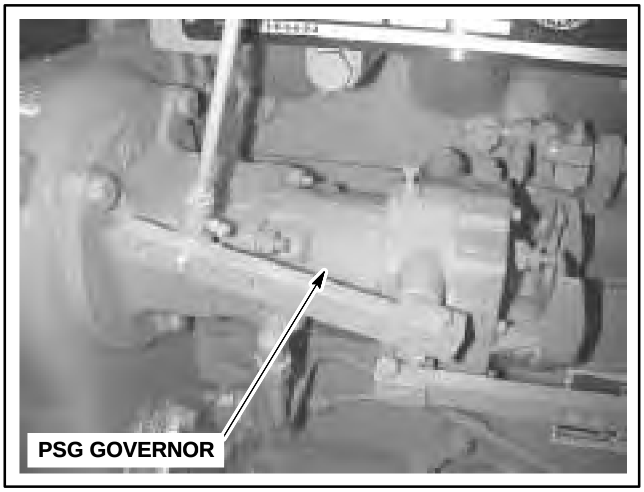


Figure 5.00-3. PSG Governor

GOVERNING LINKAGE

PSG and EG3P governor action is transmitted from the governor terminal shaft, through a rod assembly attached to a shaft assembly to the throttle butterfly (see Figure 5.00-4).

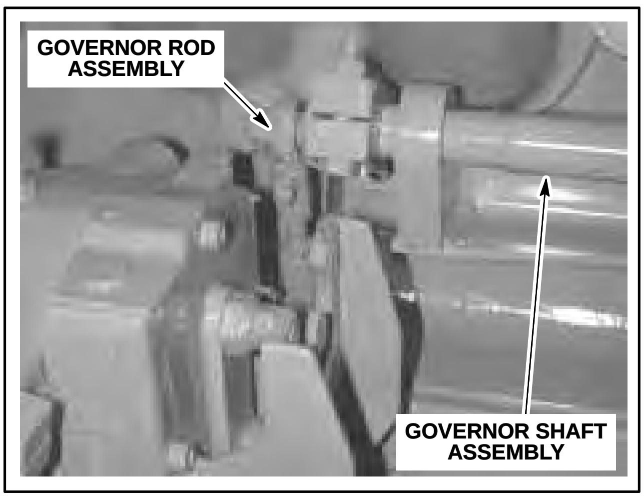


Figure 5.00-4. Governor Rod

The 4024 governor actuator rod attaches directly to the throttle butterfly shaft (see Figure 5.00-5).

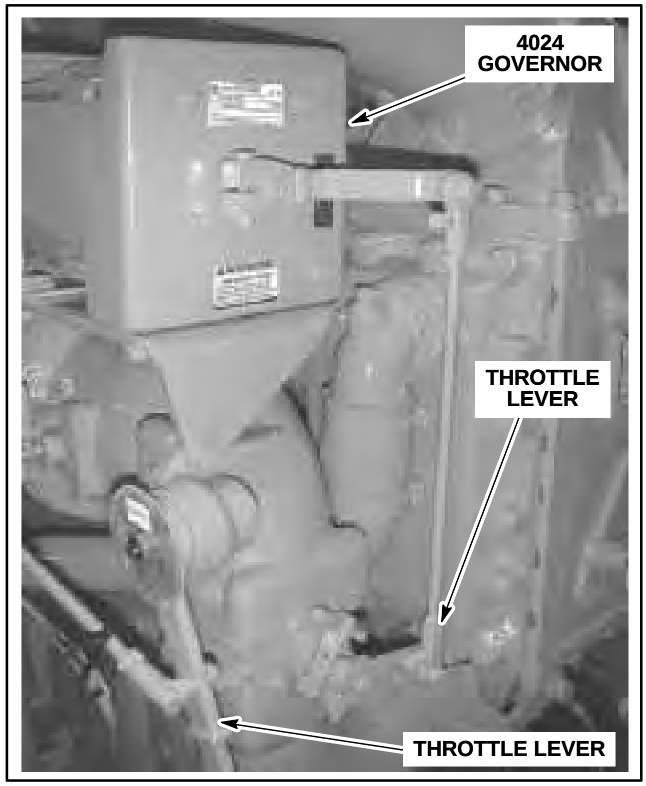


Figure 5.00-5. 4024 Governor And Linkage

PSG And EG3P Governor Rod Assembly

1. The PSG and EG3P governor lever is installed with a splined bushing installed on the governor shaft (see Figure 5.00-6).

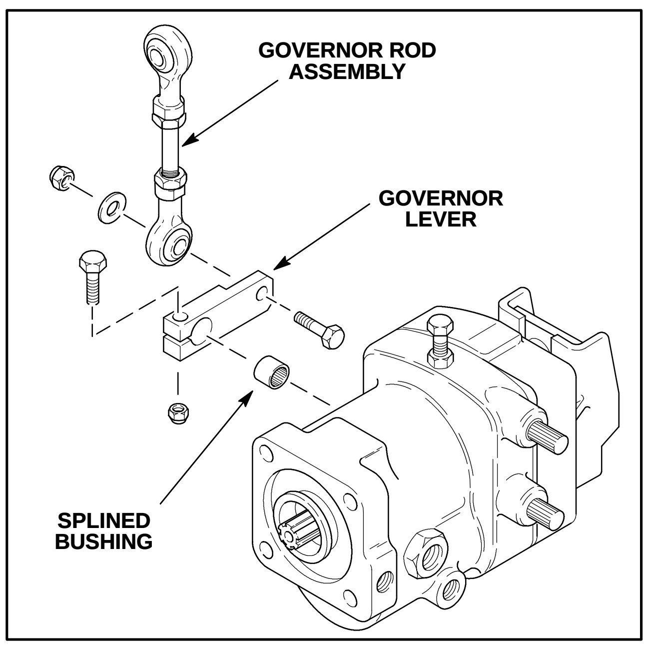


Figure 5.00-6. Governor Rod And Lever Installation

2. The PSG and EG3P governor rod length must be 3.52 in. (89.5 mm) between the rod eyes (see Figure 5.00-7).

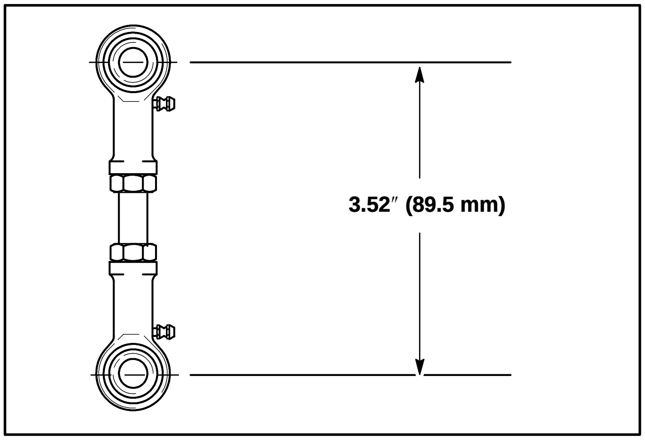


Figure 5.00-7. PSG And EG3P Governor Rod Length

3. See “Governor Linkage Adjustment” in this section for final governor adjustments.

4024 Governor Rod Assembly

1. The 4024 governor actuator is mounted on a bracket attached to the intake manifold elbow (see Figure 5.00-8).

2. The governor rod is attached to the throttle lever that is attached to the butterfly valve (see Figure 5.00-8).

Figure 5.00-8. 4024 Governor And Linkage

3. The governor rod length must be set to 11.6 in. (294 mm) between the rod eyes (see Figure 5.00-9).

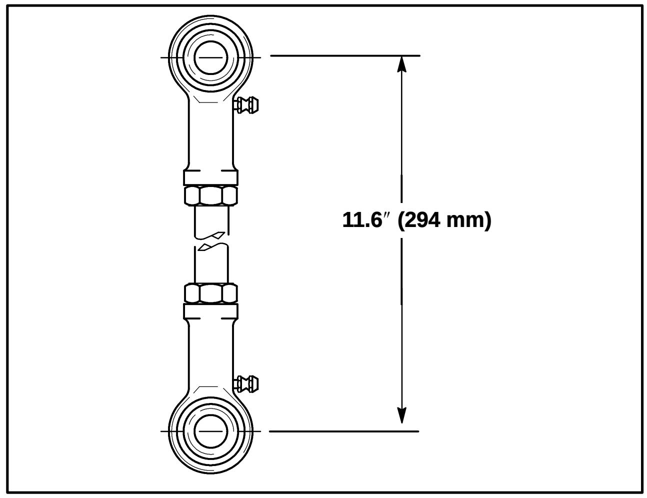


Figure 5.00-9. 4024 Governor Rod Length

4. See “Governor Linkage Adjustment” in this section for final governor adjustments.

AIR ACTUATOR

The engine may also be equipped with an air actuator (see Figure 5.00-10).

Figure 5.00-10. Governor Air Actuator

Operation (with air actuator)

A signal from a pneumatic supply pressurizes the governor speed setting mechanism. The speed is determined by the amount of air pressure that is supplied to the actuator. Typical pneumatic pressure range is 3 to 15 psi (20.7 to 103.4 kPa). Governors operating at these pressures will control the engine speed between 1000 and 1800 rpm.

AIR ACTUATOR ADJUSTMENT

The air actuator mounting has changed because of design and detail changes. The adjustment procedure remains the same with either style of actuator mounting.

1. Remove rod connecting air actuator arm to governor lever (see Figure 5.00-11).

2. Adjust governor low speed stop screw for desired low idle speed.

3. Adjust high speed stop screw on governor for high idle that will produce rated load at rated speed.

4. Reduce supply air pressure to air actuator to less than minimum rated pressure. Arm should be fully retracted.

5. Install and adjust governor rod until governor lever is at low speed idle stop.

6. Remove rod from air actuator arm.

7. Apply 5 psi (0.03 mPa) air pressure above maximum rated pressure so that air actuator arm is fully extended.

8. Pull on governor rod so that governor lever is brought to full speed position.

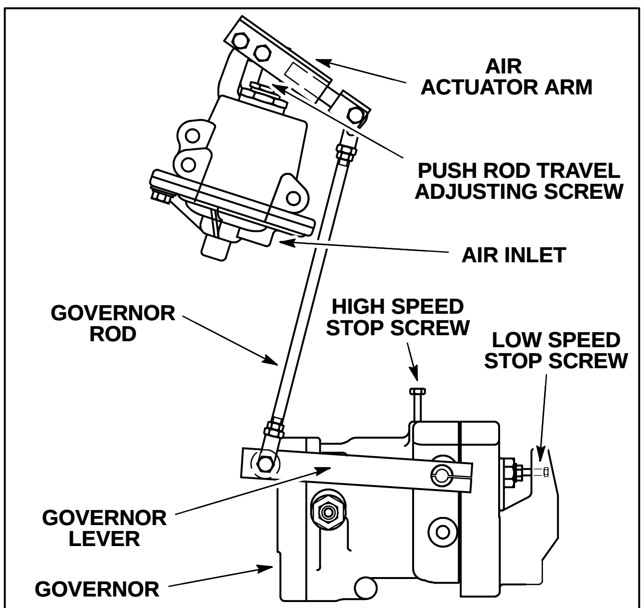


Figure 5.00-11. Air Actuator

9. Back off governor low speed stop screw. Air pressure to air actuator should be less than minimum rated pressure. If low speed idle is incorrect, adjust governor rod to correct length. Turn governor low speed stop screw to just barely touch and lock into position.

10. Back off governor high speed stop screw and apply 5 psi (0.03 mPa) air pressure above maximum rating of air actuator. If high idle speed is incorrect, adjust push rod travel adjusting screw as required and lock into position.

GOVERNOR LINKAGE ADJUSTMENT

WARNING

Before making any adjustment to an operating governor on an engine, check that you have hand throttle control over the engine speed. Failure to take adequate precautions can result in severe personal injury or death.

PSG GOVERNING SYSTEM

NOTE: *Normally, the only requirement for putting a newly overhauled PSG governor into service is adjusting the compensation needle valve to obtain maximum stability, while still maintaining good response (see Figure 5.00-19). The maximum speed may also need to be adjusted. All other operating adjustments are made during factory testing according to engine manufacturer's specifications and should not require further adjustment.*

1. The universal spider on the regulating shaft must be 3.07 in. (78 mm) from the rear support bracket. Adjust as necessary.

2. Install the governor lever at angle "C", 26°, with governor terminal shaft at the "No Fuel" position and torque governor lever capscrew to 75 – 80 in-lb (8.6 N·m) (see Figure 5.00-12).

3. Install regulating shaft lever at angle "D" 3°, and Distance "B" with the throttle butterfly valve in the "No Fuel" or closed position.

4. Install the governor rod to the governor lever.

5. With the governor lever at the "No Fuel" position and butterfly held closed, adjust the threaded rod assembly so that a capscrew will pass through the rod ends and the hole in the regulating shaft lever.

6. Recheck the adjustments to ensure that the throttle butterfly travels from fully open to fully closed.

7. Check all the fasteners on the rod and levers for tightness. Governor rod thread must be engaged into the rod ends a minimum of six threads.

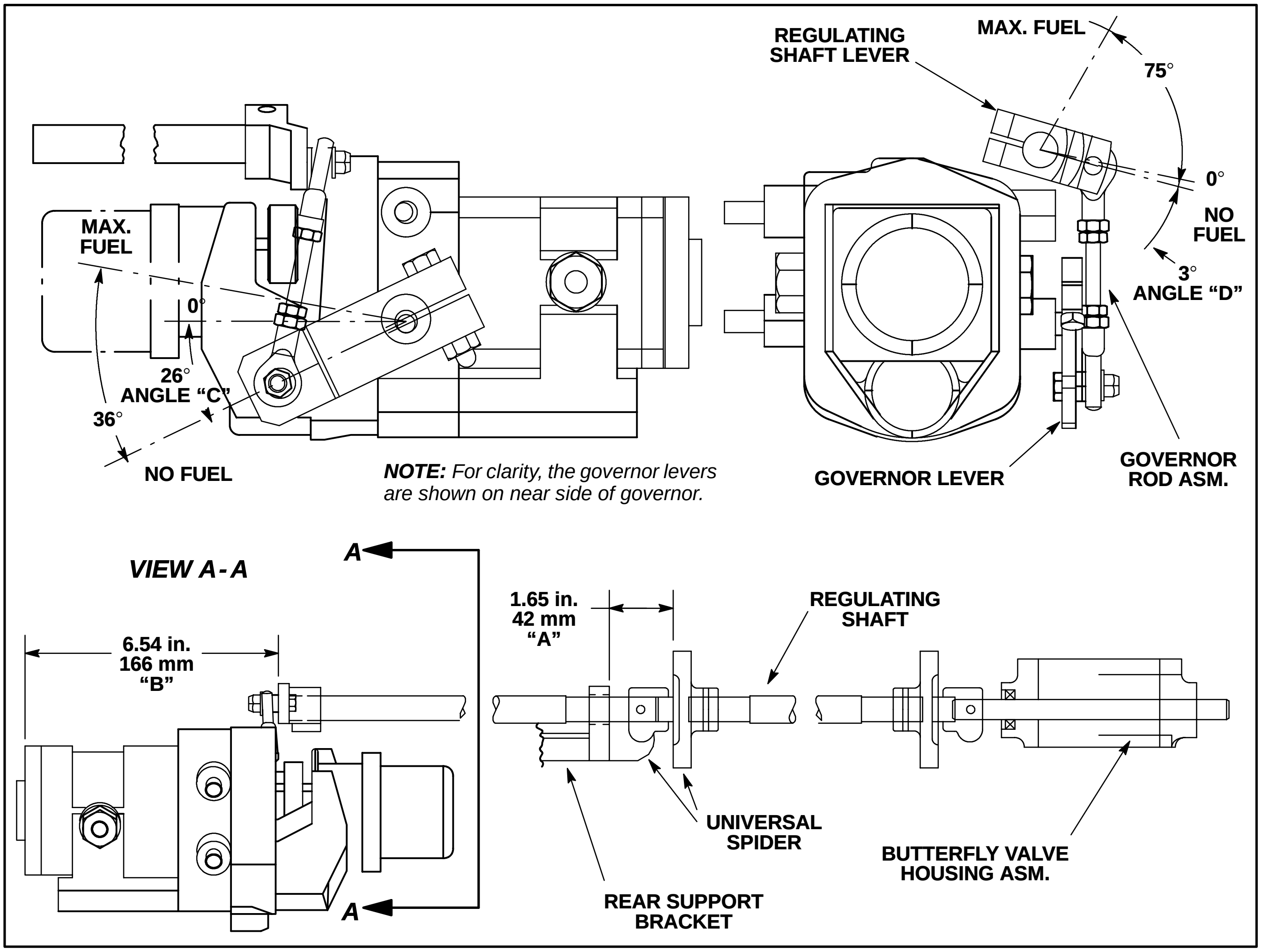


Figure 5.00-12. PSG Governor Linkage Adjustment

EG3P GOVERNING SYSTEM

⚠ WARNING

Before making any adjustment to an operating governor on an engine, check that you have hand throttle control over the engine speed. Failure to take adequate precautions can result in severe personal injury or death.

NOTE: *Normally, the only requirement for putting a newly overhauled governor into service is adjusting the compensation needle valve to obtain maximum stability, while still maintaining good throttle response (see Figure 5.00-19). The maximum speed may also need to be adjusted. All other operating adjustments are made during factory testing according to engine manufacturer's specifications and should not require further adjustment.*

1. Distance from universal spider to rear support bracket must be 3.07 in. (78 mm). Adjust as necessary.

2. Install governor lever at angle "C", 57°, with governor terminal shaft at "No Fuel" position and tighten governor lever capscrew to 75 – 80 in-lb (8.5 – 9.0 N·m) (see Figure 5.00-13).

3. Install regulating shaft lever at angle "D", 5°, and Distance "B", 182 mm, with throttle butterfly valve in "No Fuel" or closed position.

4. Install governor rod to governor lever.

5. With governor lever at "No Fuel" position and butterfly held closed, adjust threaded rod assembly so that a capscrew will pass through rod ends and hole in regulating shaft lever.

6. Recheck adjustments to ensure that throttle butterfly travels from fully open to fully closed.

7. Check all fasteners on rod and levers for tightness. Governor rod thread must be engaged into rod ends a minimum of six threads.

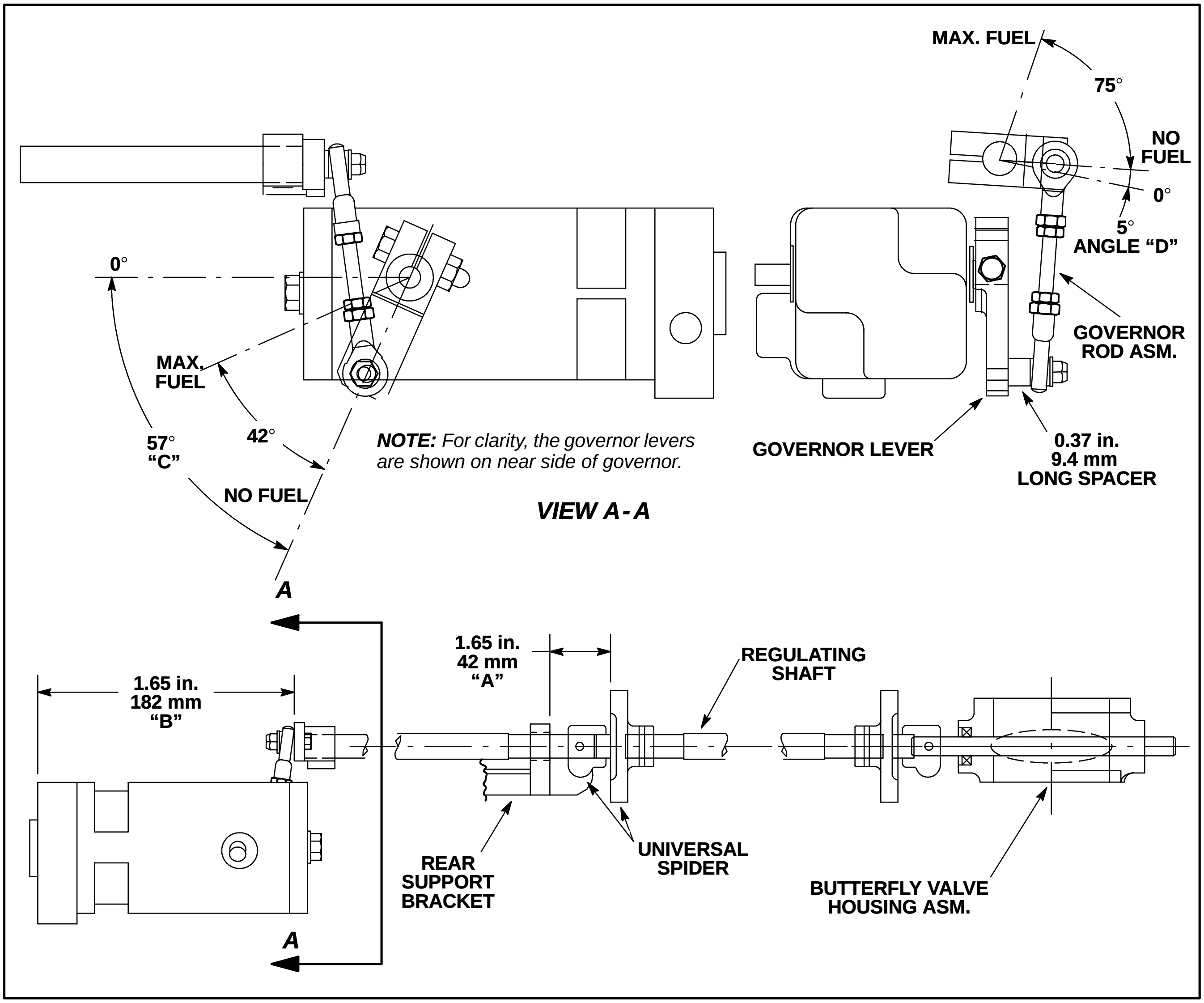


Figure 5.00-13. EG3P Governor Linkage Adjustment

4024 EPG GOVERNING SYSTEM

⚠ WARNING

Before making any adjustment to an operating governor on an engine, check that you have hand throttle control over the engine speed. Failure to take adequate precautions can result in severe personal injury or death.

1. Adjust butterfly stop screw to keep butterfly valve from sticking in full closed position.

2. Install governor lever at angle "A" with governor terminal shaft at "No Fuel" position and tighten governor lever capscrew to 75 – 80 in-lb (8.5 – 9.0 N·m) (see Figure 5.00-14).

3. Position throttle shaft lever at angle "B" with butterfly in closed position. Install governor rod to governor.

4. With governor terminal shaft in "No Fuel" position and butterfly valve held closed, adjust governor rod so that a capscrew will pass through rod ends and hole in butterfly lever at R50.8 and R76.2. Tighten butterfly lever capscrew to 75 – 80 in-lb (8.5 – 9.0 N·m).

5. Turn governor rod 1/4 turn clockwise, as viewed from above. This will lengthen rod assembly and preloads governor lever. Tighten rod lock nuts.

6. Check all fasteners on rod and levers for tightness. Governor rod thread must be engaged into rod ends a minimum of six threads.

NOTE: *R50.8 and R76.2 are the actual dimensions in millimeters from the shaft hole centerline to the center of the desired hole.*

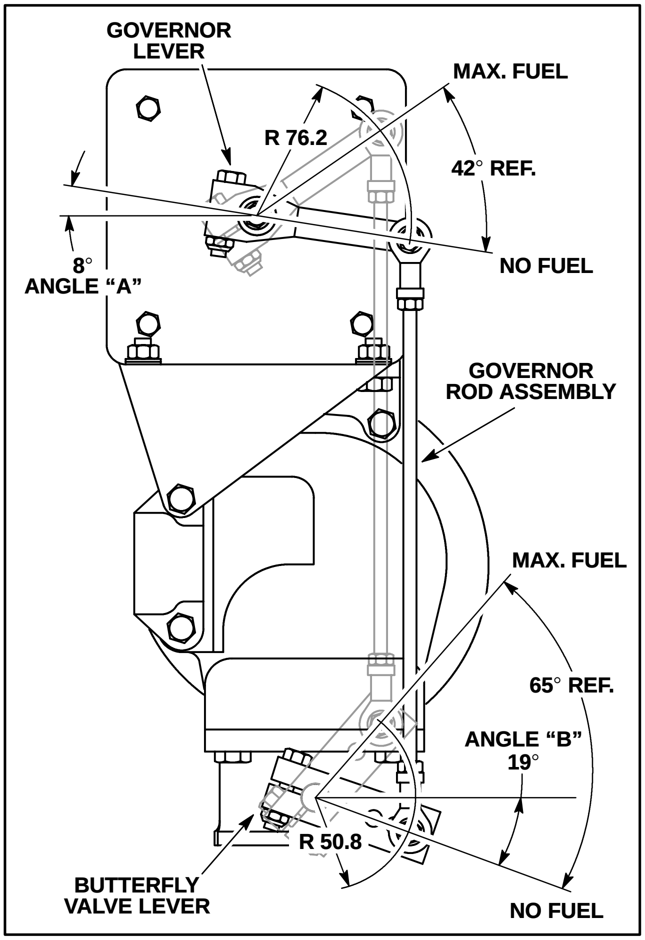


Figure 5.00-14. 4024 Governor Linkage Adjustment

MAGNETIC SPEED SENSOR INSTALLATION AND GAP ADJUSTMENT

The magnetic speed sensor reads engine speed from the flywheel teeth for use with 4024 and EG3P governors.

NOTE: *Do not adjust the speed sensor gap when the engine is running or damage to the sensor will occur.*

NOTE: *Air actuators may require venting to remove air for proper throttle control.*

⚠ CAUTION **Do not remove the governor lever from the governor terminal shaft. If the governor lever must be removed, carefully mark its position on the terminal shaft. Installing the governor lever in the wrong position on the terminal shaft may lead to an overspeed condition resulting in catastrophic engine damage. Disregarding this information could result in product damage and/or personal injury.**

⚠ WARNING

Before making any adjustment to an operating governor on an engine, check that you have hand throttle control over the engine speed. Failure to take adequate precautions can result in severe personal injury or death.

⚠ CAUTION **Both the governor lever and butterfly valves must open and close at the same time. The distance the governor linkage travels must not be limited by the butterfly valve striking the housing. This imposes unnecessary loads on the linkage. Disregarding this information could result in product damage.**

1. Locate magnetic pickup mounting holes positioned above timing covers on either side of upper flywheel housing or on lower flywheel housing. Remove hex head plug, if applicable.

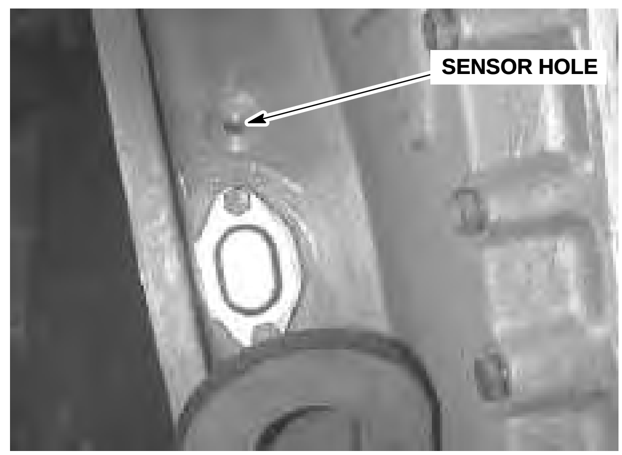


Figure 5.00-15. Governor Speed Sensor Hole

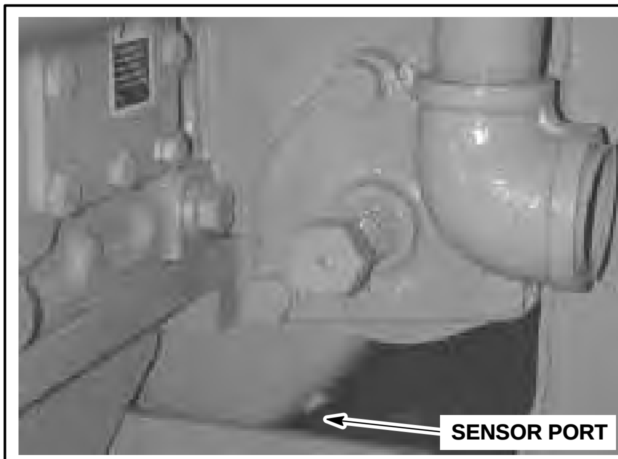


Figure 5.00-16. Alternate Speed Sensor Location

2. Rotate flywheel until one tooth is centered in sensor hole (see Figure 5.00-17).

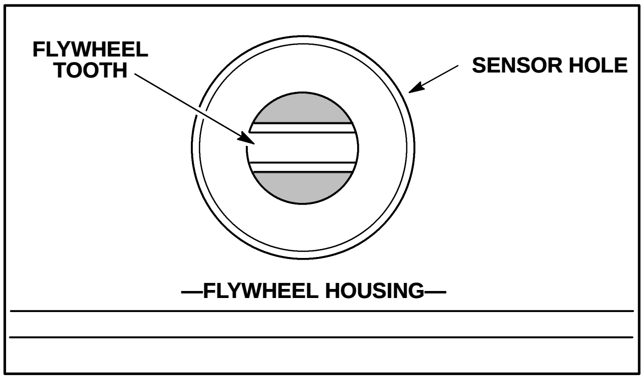


Figure 5.00-17. Ring Gear Tooth Alignment

CAUTION Always follow recommended procedures for magnetic pickup sensor installation. If the top of the flywheel tooth is able to make contact with the sensor "pole face" (bottom), then rotation of the flywheel will damage the pickup sensor.

3. Thread sensor (magnetic pickup) into flywheel housing hole until "pole face" makes contact with flywheel tooth, **then back sensor out 1/4 turn** (see Figure 5.00-18).

NOTE: *The above procedure will ensure the required gap, 0.012 in. – 0.020 in. (0.3 mm – 0.5 mm), is maintained. A feeler gauge can only be used if the driven equipment is removed.*

4. **With engine driven equipment removed** – measure gap between pole face and ring gear tooth with feeler gauge. Gap must be 0.012 in. – 0.020 in. (0.3 mm – 0.5mm), readjust if necessary (see Figure 5.00-18).

5. Tighten jam nut (7/8 inch hex) against flywheel housing. **Do not allow sensor to turn while tightening jam nut.**

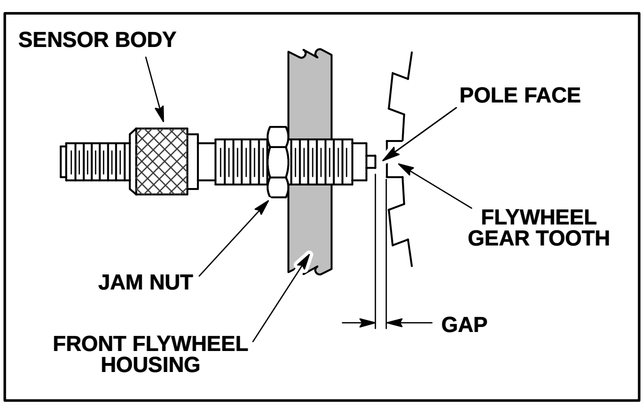


Figure 5.00-18. Magnetic Pickup Sensor

GOVERNOR SYSTEM MAINTENANCE

Lubricate the governor control rod ends through their grease fittings. The governor drive is lubricated by engine oil and does not require external lubrication. Check the oil lines and fittings for any leaks or cracks and make repairs.

COMPENSATION NEEDLE VALVE ADJUSTMENT – PSG ONLY

The compensation needle valve is an adjustable part of the engine speed control system. The setting of this valve affects the governor stability. It is set according to the individual characteristics of the engine.

1. With engine at IDLE speed, open compensation needle valve several turns until engine begins to hunt (see Figure 5.00-19). In some cases, manually disturbing the governor linkage is needed to cause the governor to move through its full stroke. Allow this hunting to occur for several minutes to remove any air trapped in the hydraulic circuits.

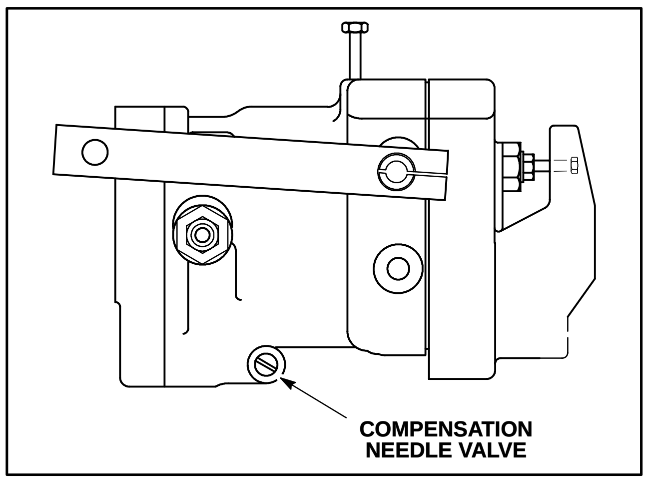


Figure 5.00-19. Valve Adjustment (PSG)

2. Slowly close compensation needle valve until speed hunting is eliminated. Keep needle valve open as far as possible to prevent any sluggishness in governor response. The needle valve setting will vary from 1/16 of a turn to 2 turns open. Never close it tight or governor will not operate properly.

3. Check governor stability by manually disturbing governor speed setting. Compensation adjustment is satisfactory when governor returns to speed with only a slight overshoot or undershoot. Once needle valve adjustment is correct do not change it.

NOTE: *Air actuators may require venting to remove air for proper throttle control.*

GOVERNOR DRIVE

GOVERNOR DRIVE REMOVAL

1. Disconnect governor rod assembly from shaft assembly (see Figure 5.00-20).

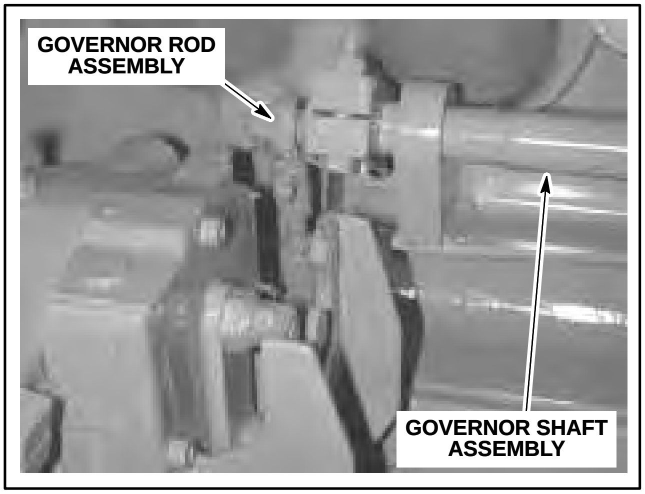


Figure 5.00-20. Governor Rod

2. Remove oil supply and drain tubes from governor (see Figure 5.00-21).

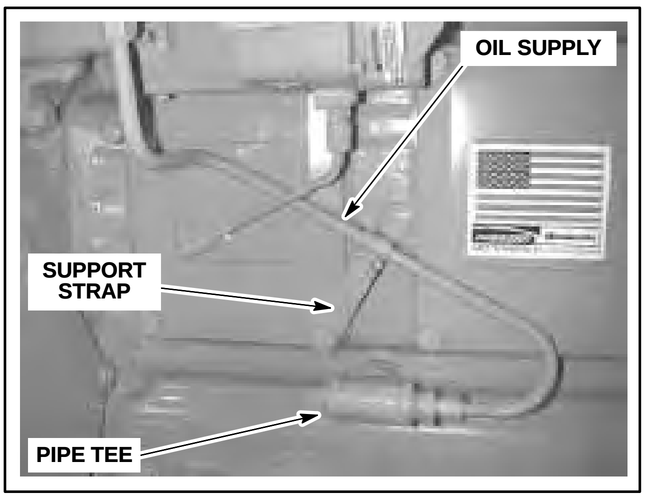


Figure 5.00-21. Governor Oil Drain Tube

3. Remove governor and coupling from governor drive.

4. Remove three capscrews, washers and drive from front gear housing (see Figure 5.00-22).

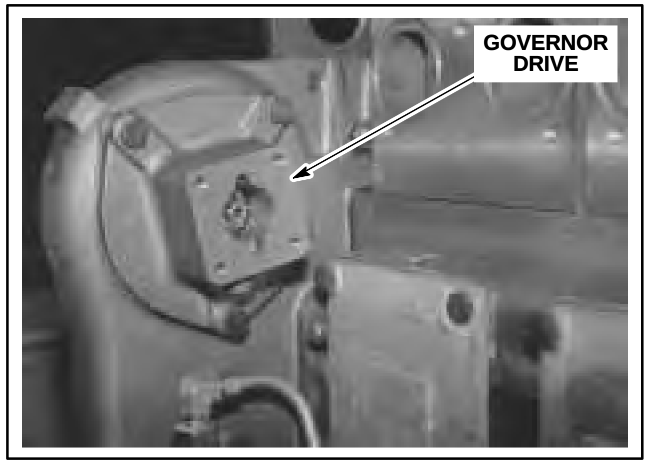


Figure 5.00-22. Governor Drive

5. Remove any gasket material from gear housing.

6. Inspect governor drive gear for signs of tooth damage or wear (see Figure 5.00-23).

Figure 5.00-23. Governor Drive Location

GOVERNOR DRIVE DISASSEMBLY

1. Remove spacer block and gasket from governor drive (see Figure 5.00-24).

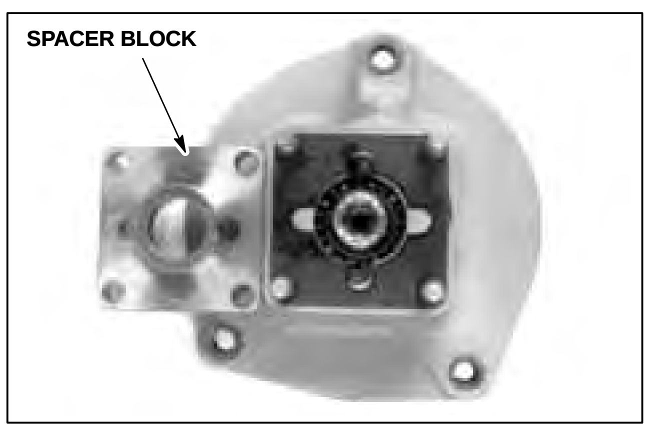


Figure 5.00-24. Governor Drive

⚠ WARNING

Always wear safety glasses when removing retaining (snap) rings. Verify the correct retaining ring pliers is used and the pliers is in good condition. If the retaining ring slips off the pliers when being installed or removed, it can be propelled with enough force to cause a serious eye injury. Disregarding this information could cause serious personal injury.

2. Remove shaft coupling and snap ring (see Figure 5.00-25).

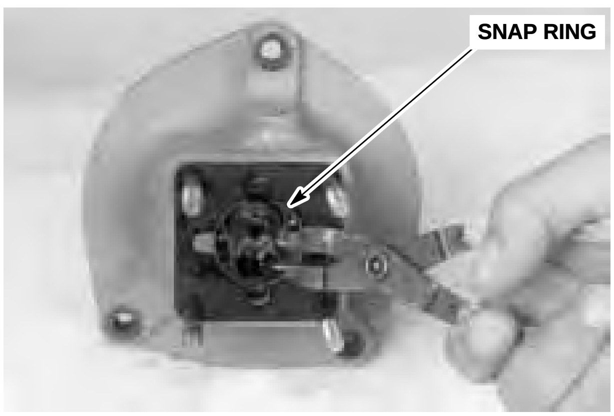


Figure 5.00-25. Governor Drive Disassembly

3. Press shaft and gear assembly from housing.

4. Remove bearing retaining ring (see Figure 5.00-26).

Figure 5.00-26. Governor Drive Disassembly

5. Press bearings from housing.

6. Inspect shaft bearings for signs of roughness during rotation.

7. Inspect shaft gear and coupling for any visible signs of damage (see Figure 5.00-27).

Figure 5.00-27. Governor Drive Gear, Shaft And Coupling

GOVERNOR DRIVE ASSEMBLY

⚠ WARNING

Always wear safety glasses when removing retaining (snap) rings. Verify the correct retaining ring pliers is used and the pliers is in good condition. If the retaining ring slips off the pliers when being installed or removed, it can be propelled with enough force to cause a serious eye injury. Disregarding this information could cause serious personal injury.

1. Press bearings and spacer into housing. To prevent bearing damage, press only on outer race of bearing (see Figure 5.00-28 and Figure 5.00-31). Install bearing retaining ring in housing.

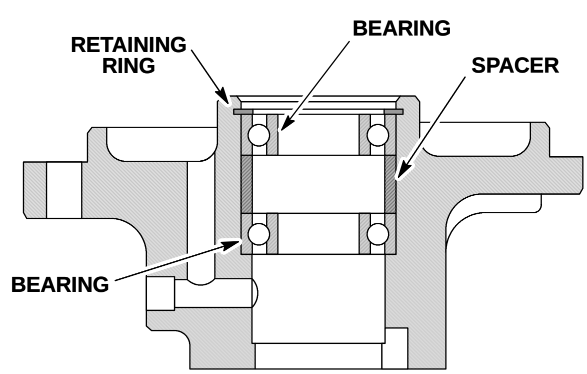


Figure 5.00-28. Governor Drive Bearings

2. Press shaft assembly in housing (see Figure 5.00-31).

3. Install retaining ring and shaft coupling (see Figure 5.00-29).

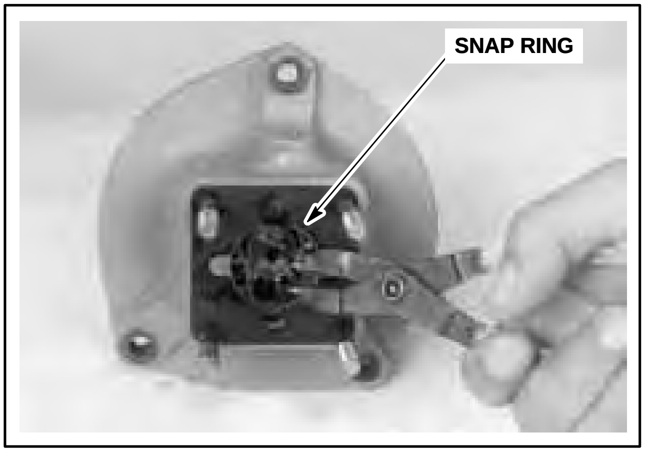


Figure 5.00-29. Governor Drive Disassembly

4. Install new gasket and spacer block on housing. Spacer is installed with holes lined up in vertical position (see Figure 5.00-30).

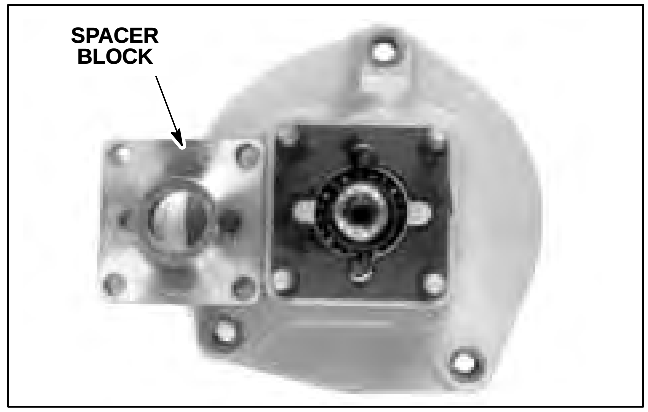


Figure 5.00-30. Governor Drive

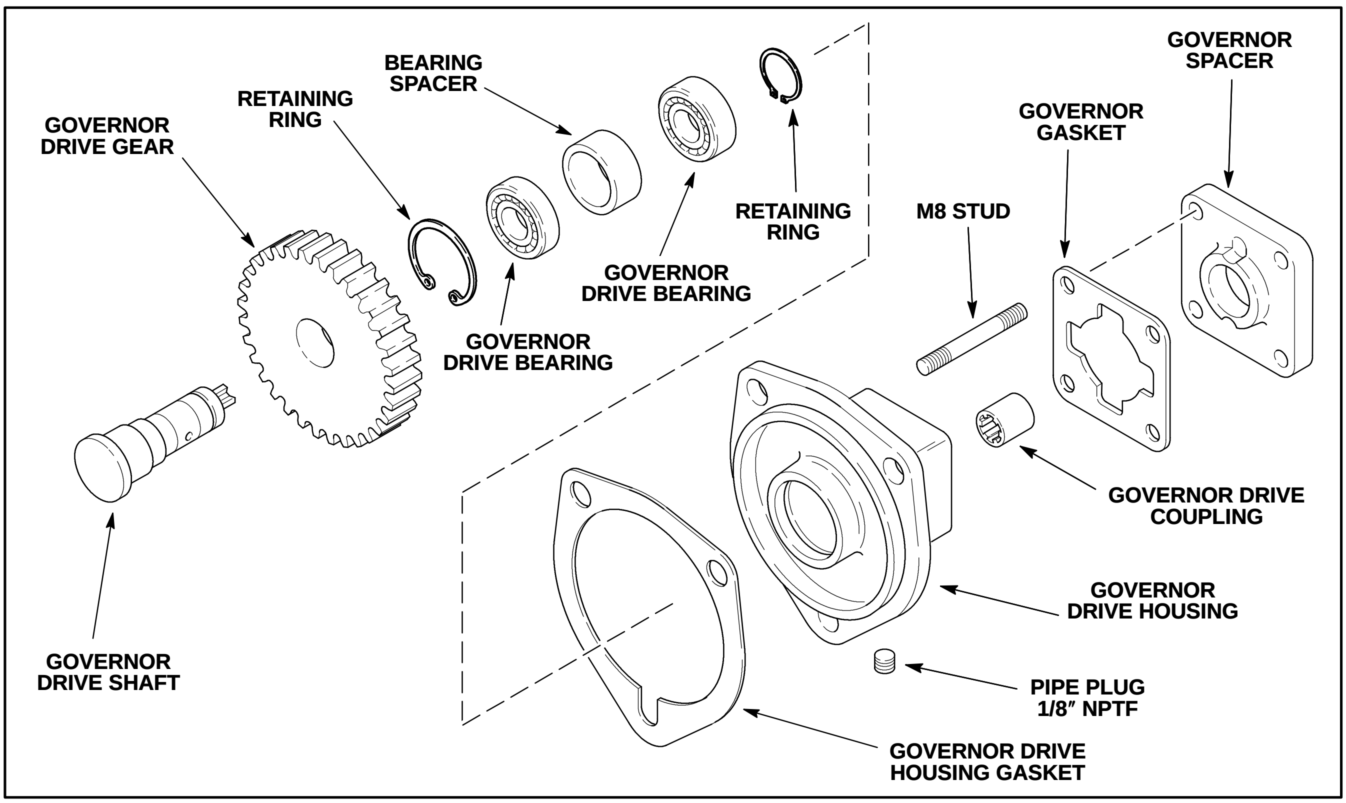


Figure 5.00-31. Governor Drive Assembly

GOVERNOR DRIVE INSTALLATION

1. Inspect camshaft gear teeth for damage. Clean governor drive mounting surface of gear housing (see Figure 5.00-32).

Figure 5.00-32. Governor Drive Location

2. Secure governor drive to gear cover with M10 x 35 mm hex head screws (use new gasket) (see Figure 5.00-33). Install copper sealing washer gasket on lower hex head screw. Tighten hex head screws to 37 ft-lb (50 N·m).

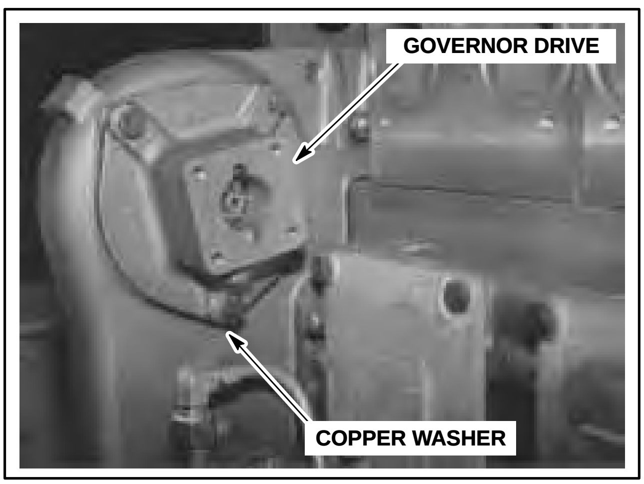


Figure 5.00-33. Governor Drive Installation

GOVERNOR INSTALLATION

4024 ACTUATOR

1. Install 4024 actuator onto bracket with 3/8 in. –16 hex head screws. Secure bracket to intake manifold elbow with M8 hex head screws (see Figure 5.00-34).

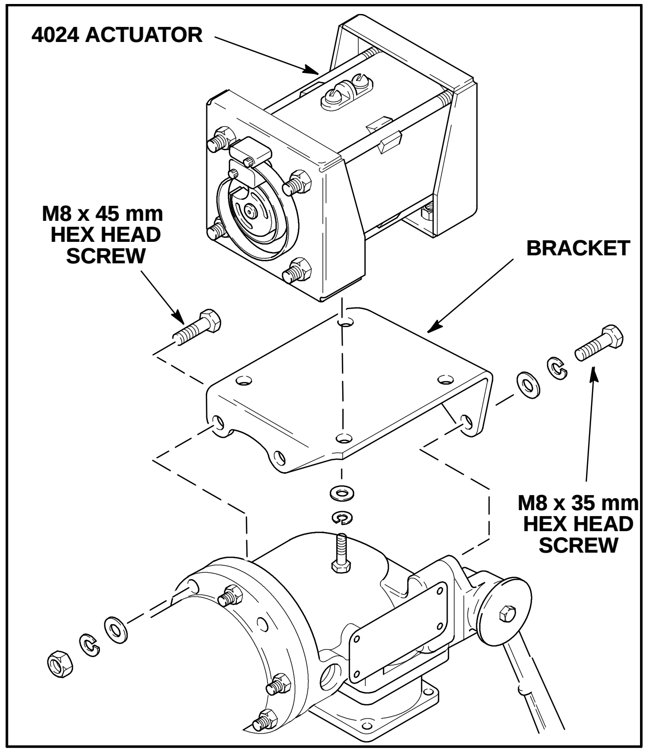


Figure 5.00-34. 4024 Actuator Mounting

2. Attach governor rod to governor shaft with splined bushing (see Figure 5.00-35).

3. Attach governor rod to butterfly valve (see Figure 5.00-35).

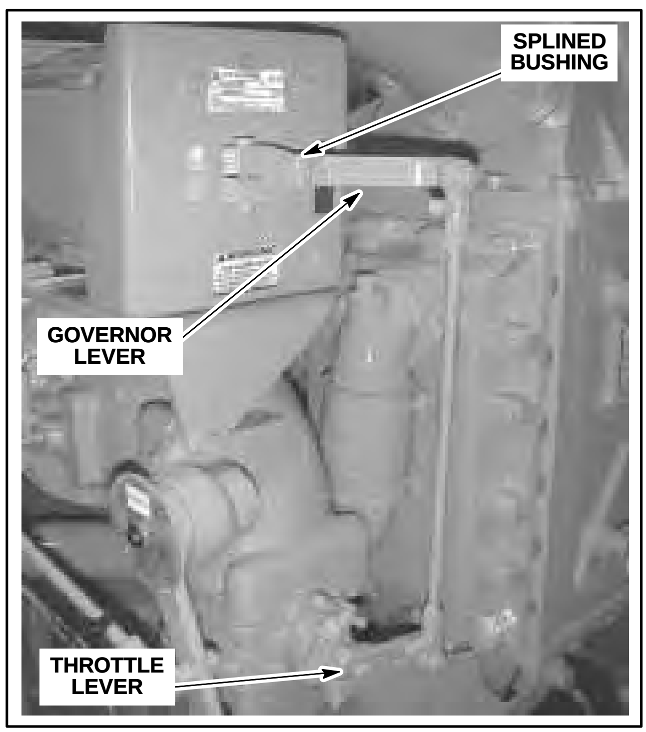


Figure 5.00-35. 4024 Governor And Linkage

4. See “Governor Linkage Adjustment” in this section for final governor adjustments.

SG, PSG AND EG3P ACTUATORS

⚠ CAUTION Ensure that the oil hole on the bottom of the governor is not blocked by the gasket when installing EG3P governors. Disregarding this information could result in product damage and/or personal injury.

NOTE: *The larger 13/32 in. (0.4062 mm) diameter cut out oil hole is positioned over the oil drain on the EG3P governor (see Figure 5.00-36 and Figure 5.00-37).*

1. Install gasket onto governor drive spacer, ensure gasket does not block oil hole on bottom of governor (see Figure 5.00-36 and Figure 5.00-37).

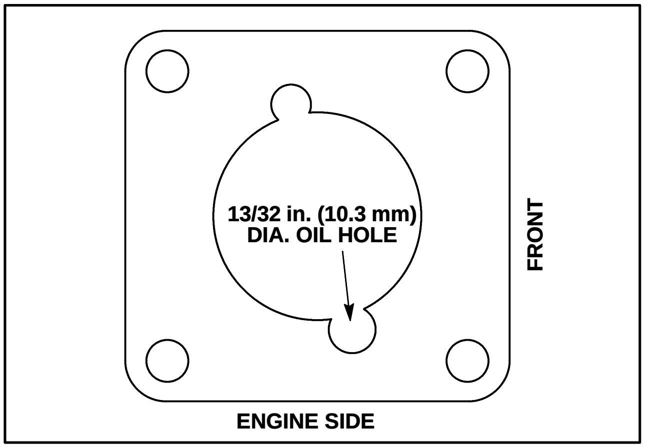


Figure 5.00-36. EG3P Gasket

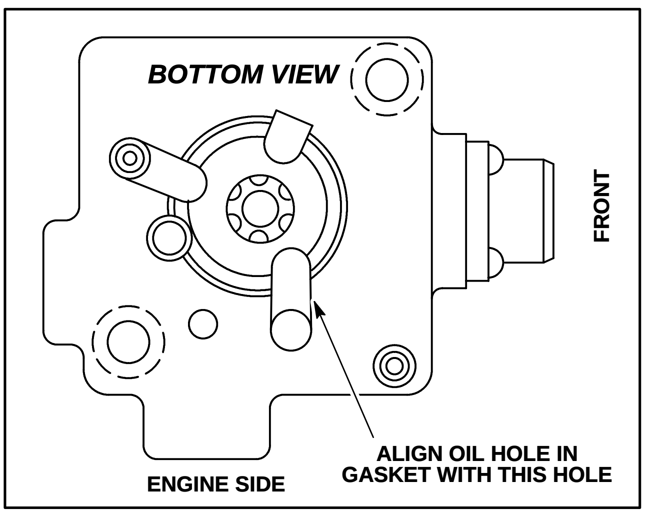


Figure 5.00-37. EG3P Governor – Bottom View

NOTE: *Governor side of the gasket is critical when used with the EG3P governor (see Figure 5.00-38).*

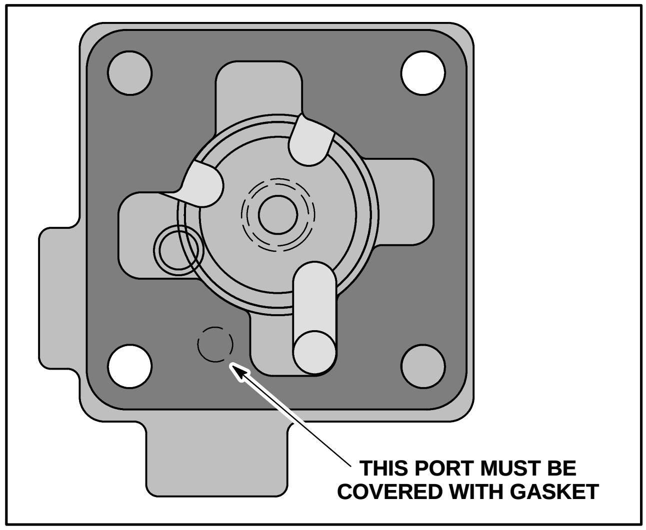


Figure 5.00-38. Gasket Located On EG3P Governor Base

2. Verify bottom shaft of governor is engaged with splined connector. Secure governor to governor drive with lock washers and nuts.

3. Apply Perma Lok® Heavy Duty Pipe Sealant with Teflon to threads of fittings and connect oil lines from drive housing to governor.

GOVERNOR OIL PIPING

The lube oil supply hole is located between the first and second camshaft inspection doors (see Figure 5.00-39).

1. Remove crankcase plug and install copper washer, pipe adapter and tee. If unit is not magneto drive equipped, install plug in front side of tee.

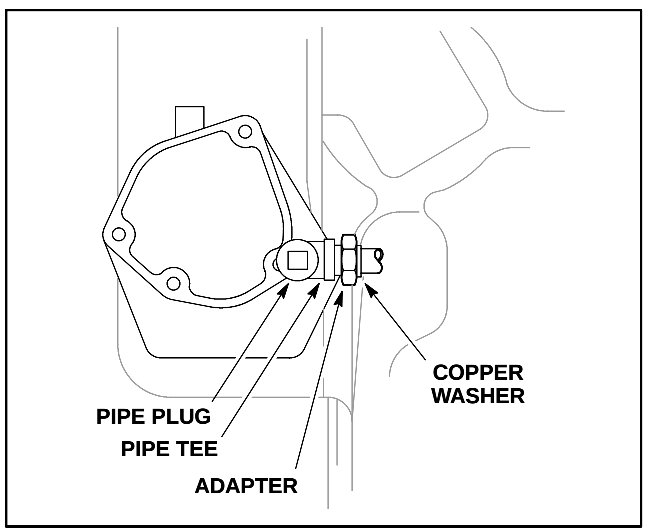


Figure 5.00-39. Magneto Drive Oil Supply Adapters

2. Camshaft cover P/N 304700F is required to provide governor and magneto drive clearance. Drain hole is added for use with EG3P, PSG and SG governor actuators (see Figure 5.00-41).

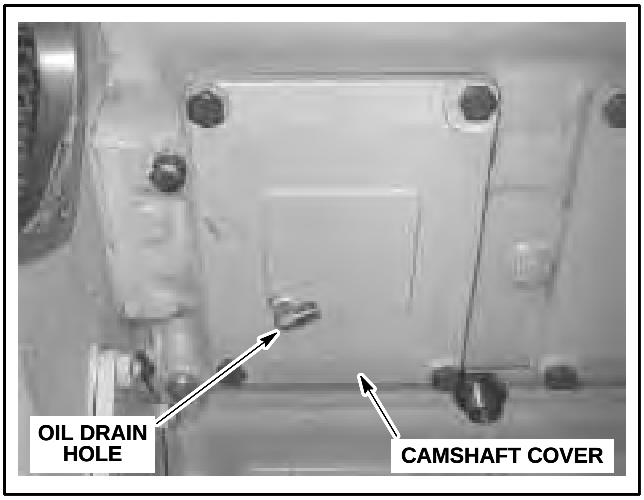


Figure 5.00-40. Camshaft Cover – P/N 304700F

3. Each model governor has its own unique oil supply and drain tubes. Install oil supply tube and pipe adapter into tee. Support supply tube with strap and clip from lower camshaft cover (see Figure 5.00-41). Secure support strap with M10 x 35 mm hex head screw.

4. Install drain tube between EG3P or PSG governor drain and front camshaft cover (see Figure 5.00-41).

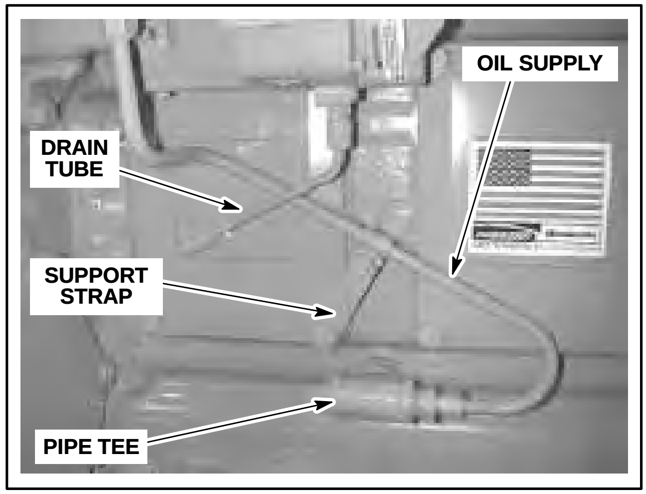


Figure 5.00-41. Governor Oil Drain Tube

GOVERNOR LINKAGE

PSG and EG3P governors require the use of the following linkage (see Figure 5.00-42).

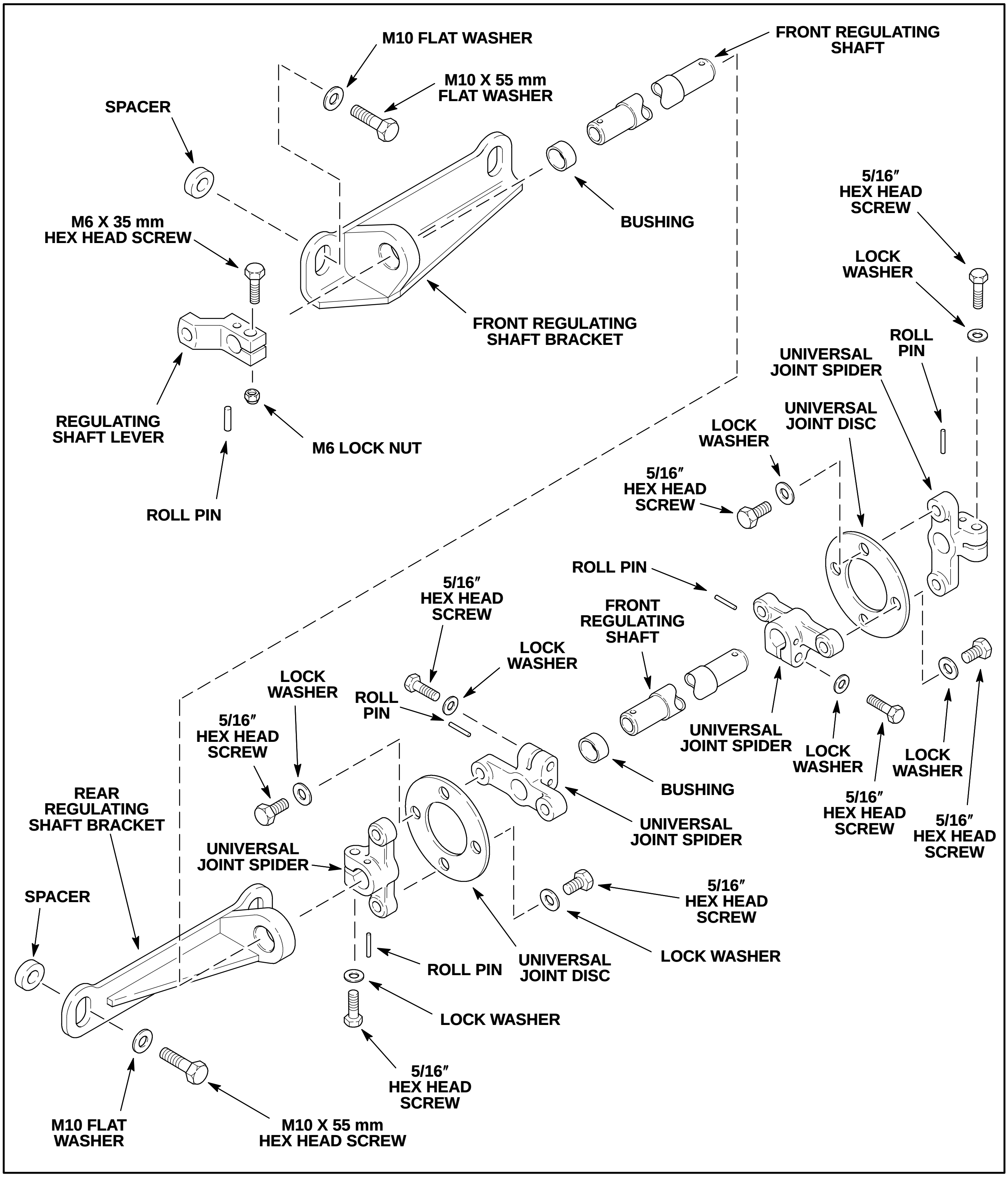


Figure 5.00-42. Governor Linkage

GOVERNOR LINKAGE INSTALLATION

The PSG and EG3P governors use a shaft along the crankcase to the butterfly valve to control the valve. The governor regulator shaft runs along the intake manifold to the butterfly valve (see Figure 5.00-43).

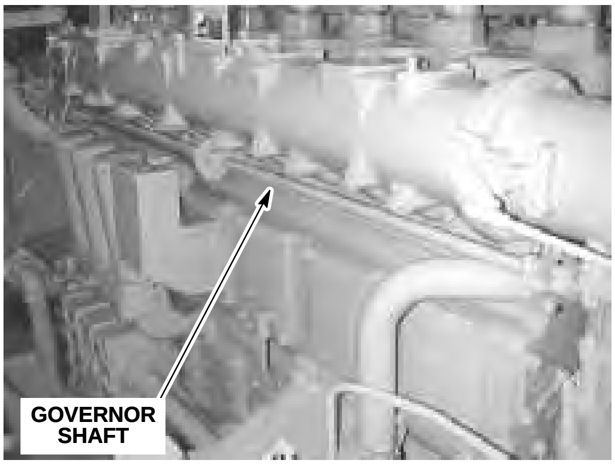


Figure 5.00-43. Governor Regulator Shaft

1. Install support brackets onto intake manifold and secure with M10 x 55 mm hex screws and spacers (see Figure 5.00-44 and Figure 5.00-45). Tighten M10 hex head screws to 37 ft-lb (50 N·m). Tighten M12 hex head screws to 65 ft-lb (88 N·m).

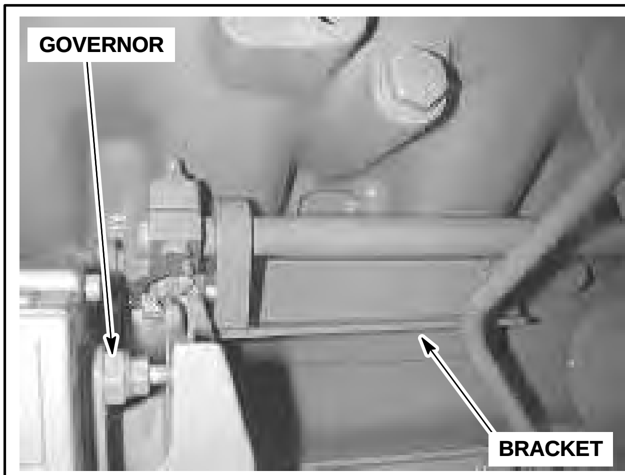


Figure 5.00-44. Support Bracket

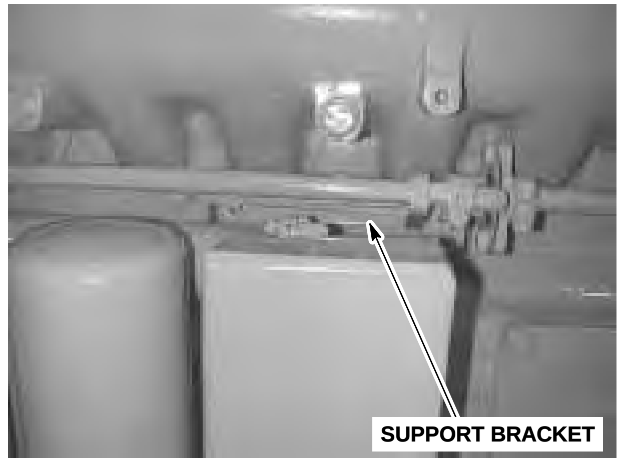


Figure 5.00-45. Governor Shaft Support Bracket

2. Press bushings into each bracket.

3. Install front regulator shaft in brackets.

4. Rear regulator shaft assemblies have different dimensions depending on engine model:
   10.98 in. ± 0.03 (279 ± 0.8 mm) – six cylinder
   27.12 in. ± 0.03 (689 ± 0.8 mm) – eight cylinder
The measurement is the distance between the universal joint discs (see Figure 5.00-46).

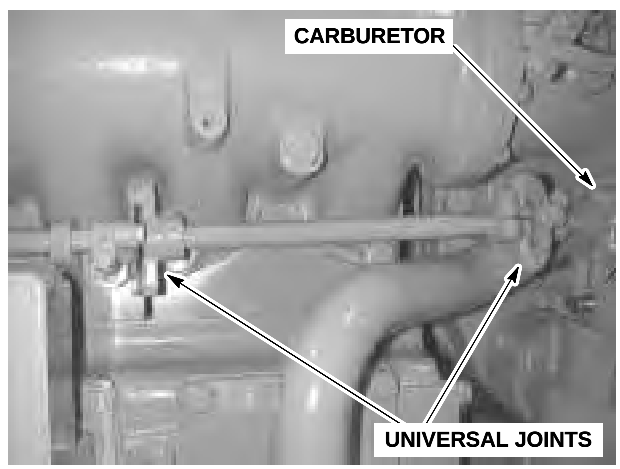


Figure 5.00-46. Universal Joints

5. Install rear regulator shaft between front regulator shaft and throttle valve.

QUICK START OIL SUPPLY

An optional governor oil supply is available for EG3P and PSG governors in quick start applications. The oil reservoir provides instant throttle response upon crank initiation.

A filter element is used as an oil reservoir (see Figure 5.00-47).

Replace the filter element every 6 months.

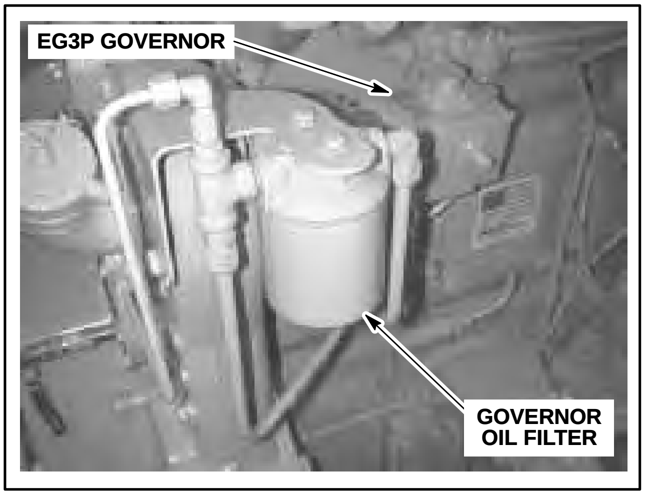


Figure 5.00-47. Quick Start Oil Supply

Both systems use a vent tube that connects to the oil filler assembly on the front of the gear housing (see Figure 5.00-48).

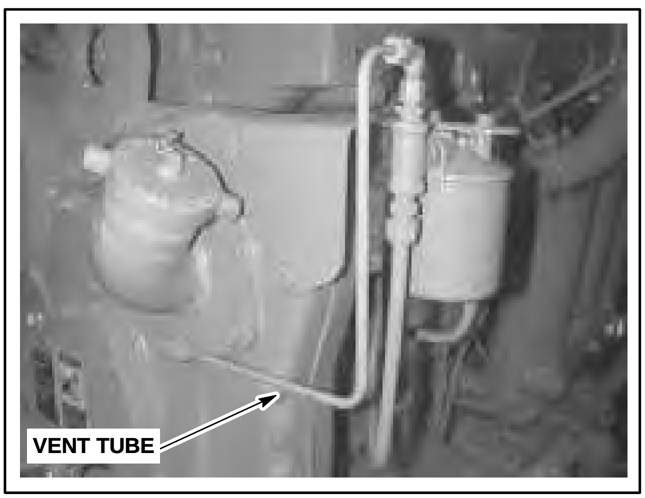


Figure 5.00-48. Oil Fill Location

OIL SUPPLY INSTALLATION

NOTE: *Apply pipe thread sealant to all connections.*

1. Install pipe tee and pipe nipple into filter head (see Figure 5.00-49). Install reducer bushing into upper part of tee. Install tube adapters in tee. Install filter base to support bracket.

2. Install support filter support bracket onto front of gear housing.

3. Install oil supply tubing from crankcase tee to filter base.

4. Install vent tube between pipe tee and oil fill assembly.

5. Each model governor has its own unique oil supply and drain tubes. Install oil supply tube and pipe adapter into tee.

AIR ACTUATOR INSTALLATION

1. Install mounting bracket on left front intake manifold (Figure 5.00-50). Secure with four M10 x 40 mm hex head screws.

2. Secure actuator onto mounting bracket with two M10 x 25 mm hex head screws.

3. Install threaded rod between actuator and governor lever. Governor lever should already be installed.

4. Install control rod between actuator yoke and governor lever.

5. See “Air Actuator Adjustment” in this section for complete adjustment information.

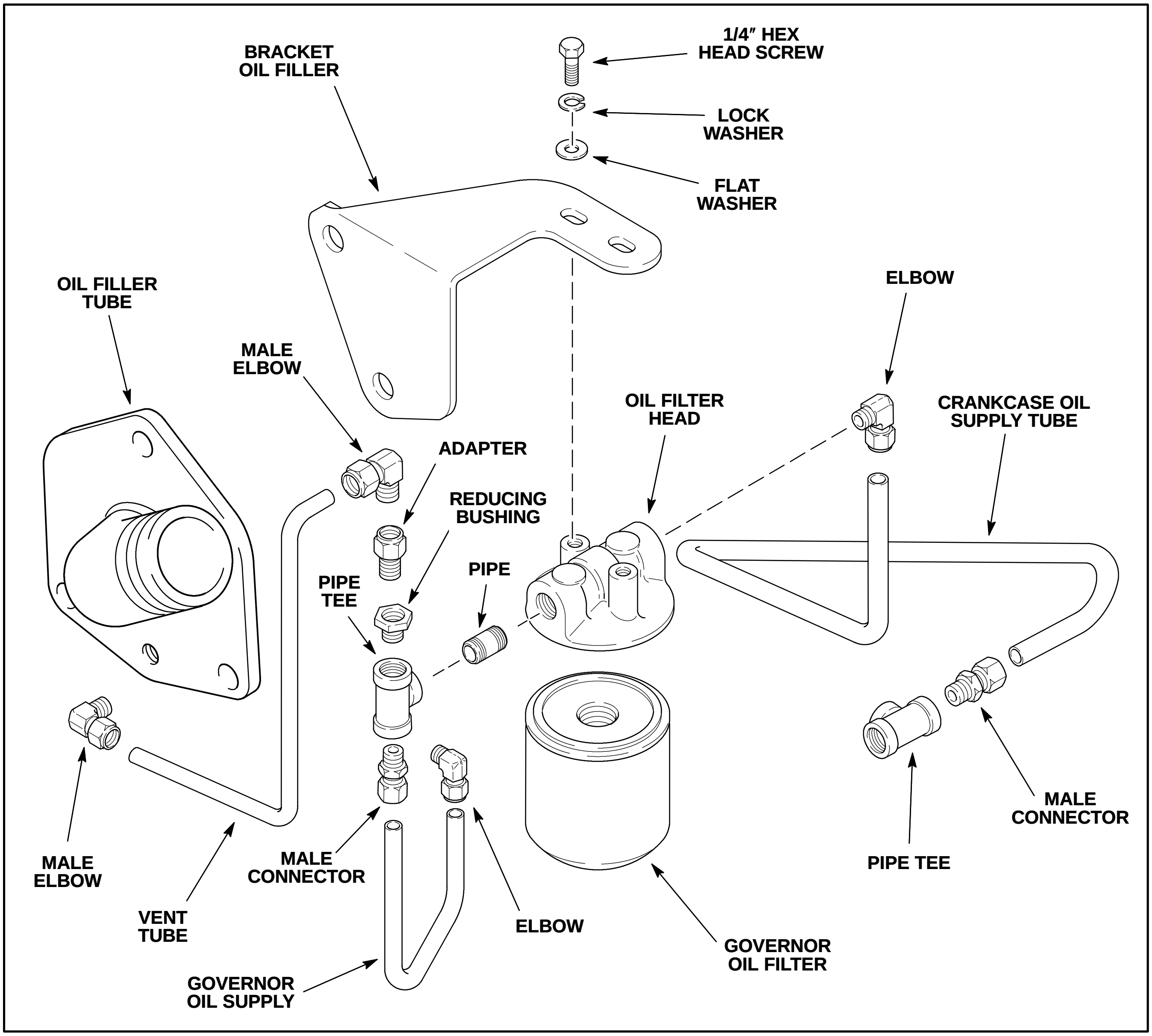


Figure 5.00-49. Governor Quick Start Oil Supply

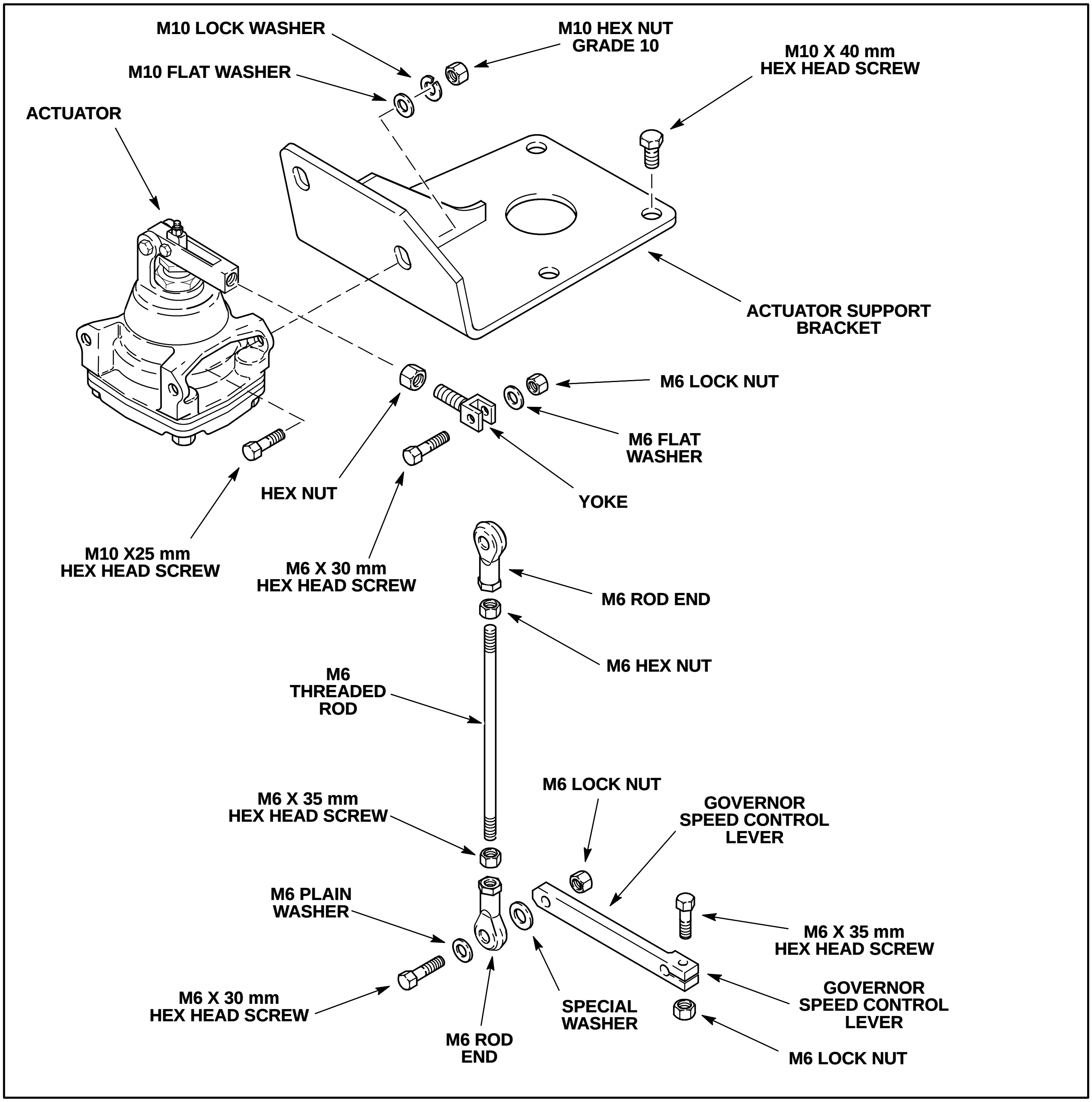


Figure 5.00-50. Air Actuator Installation

GOVERNOR THROTTLE INSTALLATION

1. Install mounting bracket on left front intake manifold (Figure 5.00-51). Secure with two 3/8 in. – 16 x 1 in. hex head screws and 3/8 in. lock washers.

2. Install throttle lever bracket onto mounting bracket. Secure with M8 x 40 mm hex head screw, lock washer and flat washer (see Figure 5.00-52).

3. Install throttle lever and instruction plate. Secure with 3/8 in. – 16 x 2 in. – 1/4, throttle control spring and 3/8 in. – 16 hex nut.

4. Install and adjust rod between throttle lever and governor lever.

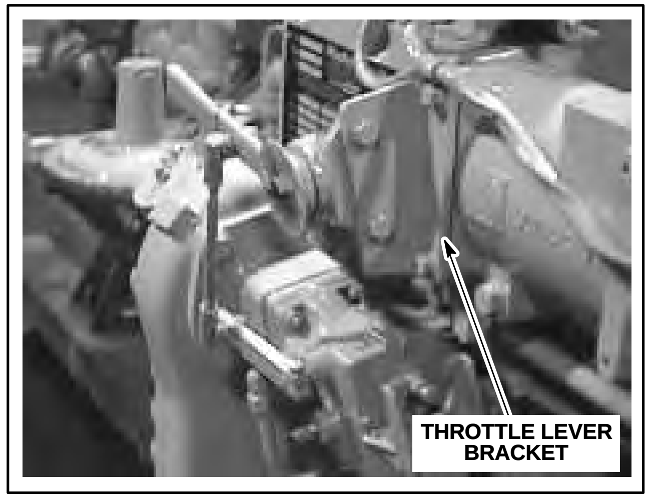


Figure 5.00-51. Governor Throttle Control

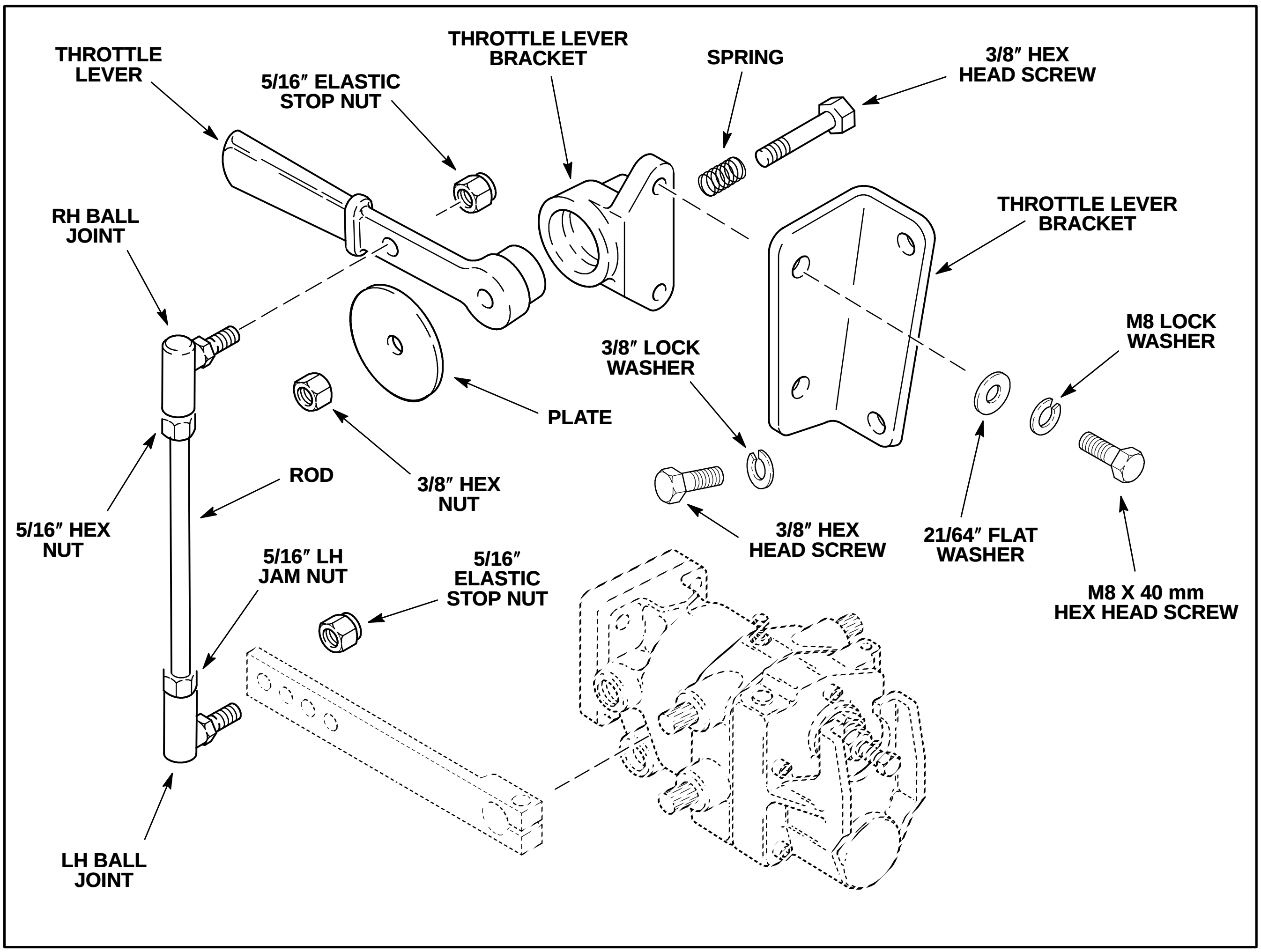


Figure 5.00-52. Governor Throttle Control

SECTION 5.05

FUEL SYSTEM

FUEL SYSTEM COMPONENTS

COMPONENT DESCRIPTION

The engine fuel system consists of the following engine mounted components:

- Carburetors
- Throttle valves
- Fuel pressure regulator and balance line(s)
- Fuel shutoff valve

CARBURETOR

The carburetor uses an air valve to meter the fuel gas proportionally to the air flow. A regulator controls the fuel gas supply pressure to the carburetor. A pressure range of 3 ± 1 in. (77.1 ± 25 mm) water column is typical for the F18/H24GL operating on 900 Btu LHV natural gas. A pressure range of 3 ± 0.5 in. (76.2 ± 12 mm) water column is typical for the F18/H24GLD operating on 900 Btu LHV natural gas.

The Impco carburetors consist of a main body with a venturi and a diaphragm operated gas metering valve (see Figure 5.05-1, Figure 5.05-2, Figure 5.05-3 and Figure 5.05-4). The amount of air passing into the engine is measured by an air-flow measuring valve which rises proportionally to the air volume passing through the carburetor. The gas metering valve is attached to the air measuring valve which opens the gas valve proportionally to the air volume. This controls the air/fuel ratio throughout the engine speed and load range.

Figure 5.05-1. Impco 200 Carburetor

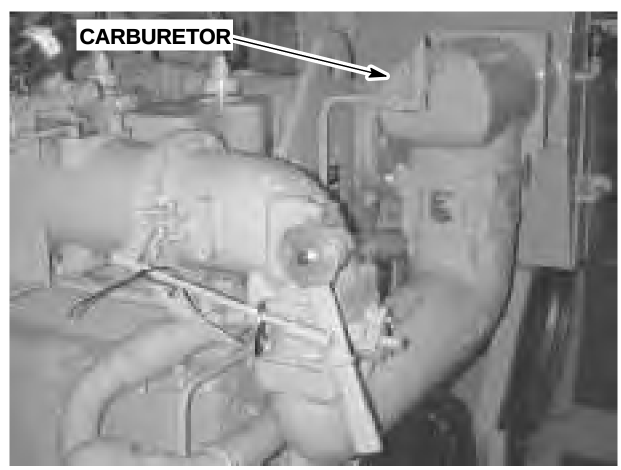


Figure 5.05-2. H24G Impco 600 Carburetor

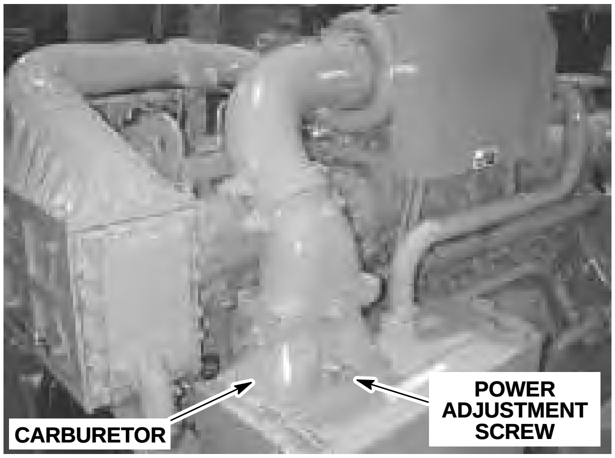


Figure 5.05-3. F18/H24 GLD IMPCO 600D Carburetor

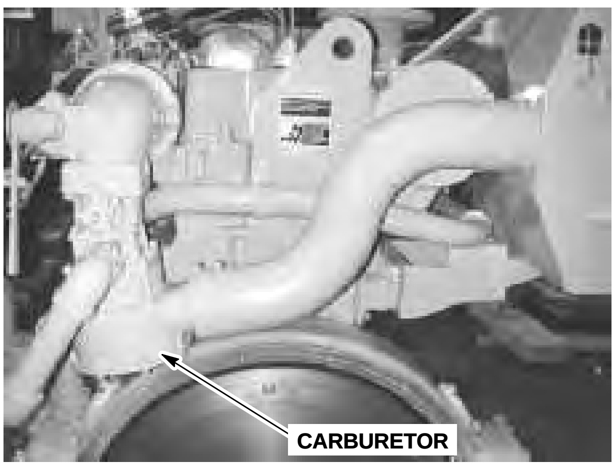


Figure 5.05-4. Impco 400 Carburetor

Deltec carburetors contain no moving parts. The main adjustment screw (MAS) controls the fuel gas to the carburetor. The carburetor consists of a main body with a perforated venturi insert that allows fuel gas to be drawn into the air stream. The size and number of the holes controls the air/fuel mixture.

GLD Deltec carburetors have low inlet restriction for improved performance. The carburetor's flat tracking provides desirable performance and low emissions and allows lean operation with low octane fuels (see Figure 5.15-8 and Figure 5.05-6).

⚠ WARNING

The Deltec carburetion system must have a positive gas shutoff valve that opens upon cranking and closes whenever engine rotation stops. The Deltec carburetor will not stop the flow of gas into the engine. Disregarding this information could result in severe personal injury or death.

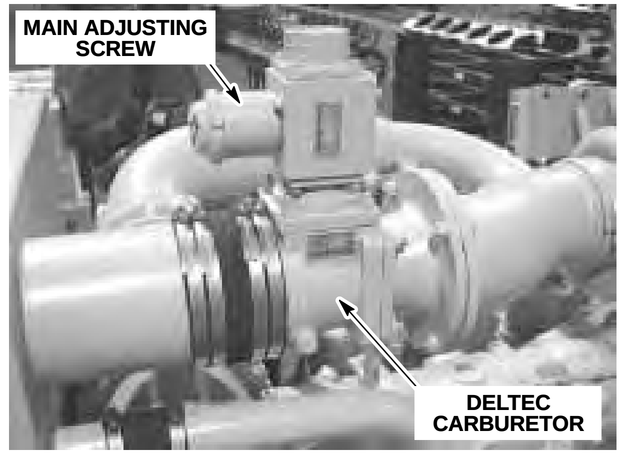


Figure 5.05-5. F18/H24 GLD Deltec Fuel System

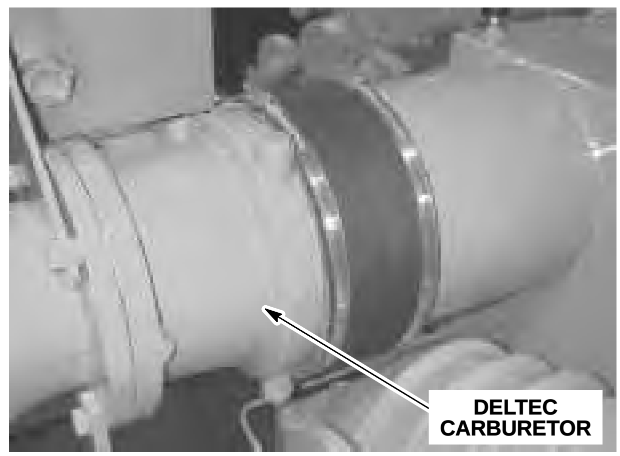


Figure 5.05-6. F18/H24 GLD Deltec Fuel System

FUEL PRESSURE REGULATOR – GL (IF EQUIPPED)

The GL engine has an S211 or Y692 cast iron regulator which reduces the supply line pressure (25 – 50 psi) to a carburetor inlet pressure above turbocharger boost pressure (see Figure 5.05-7). From this regulator, the fuel gas is directed to the carburetor.

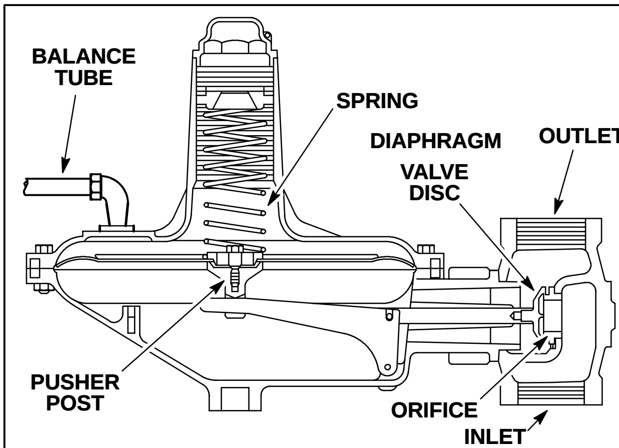


Figure 5.05-7. Fuel Pressure Regulator – S211 Shown

FUEL SHUTOFF VALVE (IF EQUIPPED)

The fuel solenoid shutoff valve is located at the gas fuel inlet to the regulator valve (see Figure 5.05-8). This valve is electrically actuated by a safety switch powered by the magneto. An electrical signal causes the gas valve to close off the fuel supply for normal and emergency shutdowns. The latching valve should be turned 1/4 turn clockwise to latch the valve open for starting. The manual lever can be rotated clockwise to manually close the valve for shutdown.

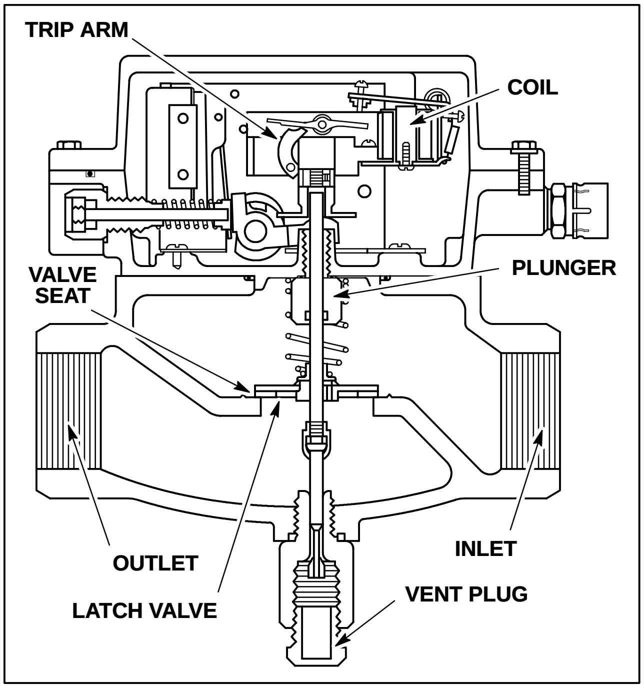


Figure 5.05-8. Shutoff Valve

Rotate the manual lever counterclockwise to open the latch valve for starting. This causes the plunger to lift away from the valve seat and latches the trip arm. When the safety switch actuates, a circuit is completed through the coil, causing a magnetic action which releases the trip arm. Spring tension forces the plunger down on the valve seat, sealing off fuel gas flow. Gas pressure on top of the plunger helps to assure a positive seal. Once the valve has operated, it must be manually reset before restarting the engine.

CARBURETOR REMOVAL

⚠ WARNING

Ensure that the fuel source is completely shut off prior to working on fuel system components. Clear the engine supply lines and piping of accumulated gas before performing any maintenance work on the fuel system or severe personal injury or death could result.

CARBURETOR REMOVAL – IMPCO 200

Current production standard and low compression ratio F18/H24GL engines use the Impco 400 carburetor.

1. Remove hose clamps from air cleaner tube to carburetor (see Figure 5.05-9). Disconnect carburetor from intercooler connection.

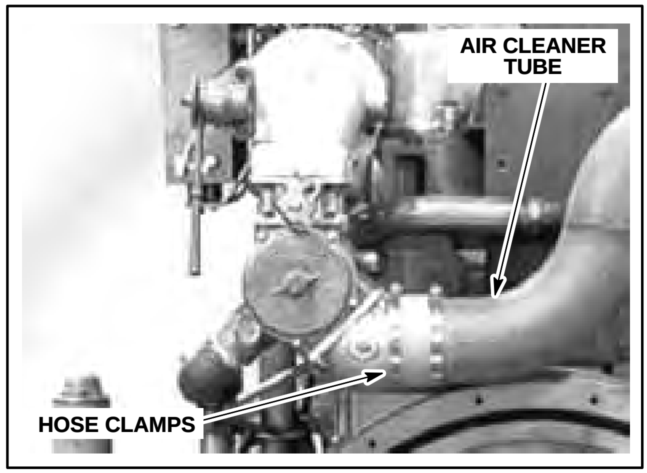


Figure 5.05-9. F18G Carburetor

2. Disconnect fuel supply pipe at Dresser elbow (see Figure 5.05-10). Remove piping with carburetor.

Figure 5.05-10. Impco 200 Fuel Piping

3. Disconnect pressure regulator balance tube from carburetor air inlet (see Figure 5.05-11).

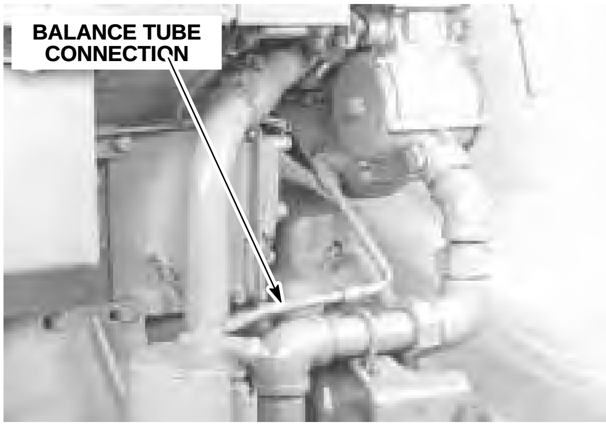


Figure 5.05-11. Impco 200 Balance Tube

4. Disconnect governor shaft from EG3P and PSG governor actuators at throttle valve universal joint (see Figure 5.05-12).

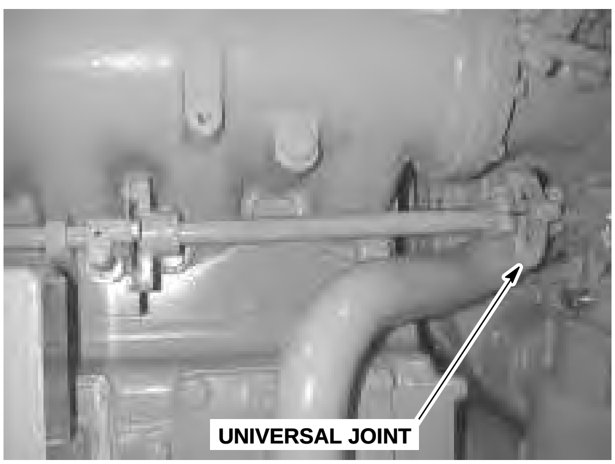


Figure 5.05-12. Butterfly Valve

NOTE: *The 4024 governor actuator linkage is mounted on the intake manifold elbow. The linkage is mounted directly on the butterfly valve.*

5. Remove linkage from butterfly valve (see Figure 5.05-13).

6. Remove butterfly valve housing to intake manifold elbow hex head screws (see Figure 5.05-14).

Figure 5.05-13. 4024 Actuator Linkage

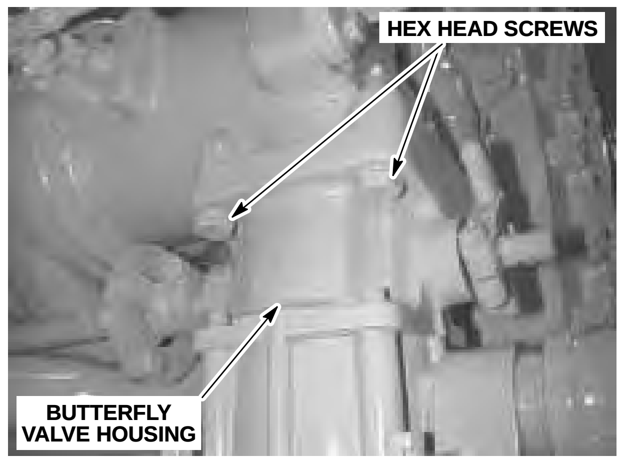


Figure 5.05-14. Butterfly Valve

CARBURETOR DISASSEMBLY – IMPCO 200

1. Remove five capscrews securing cover to carburetor body (see Figure 5.05-15).

2. Remove cover and gasket.

3. Remove air valve spring.

4. Remove four screws securing backup plate to valve assembly. Remove backup plate, diaphragm and ring.

5. Remove air/gas valve assembly.

6. Remove idle air bleed screw, spring and seal. Discard seal if a replacement part is available.

NOTE: *If additional service is required on the Impco 200D carburetor, contact an authorized Impco repair center for complete service information.*

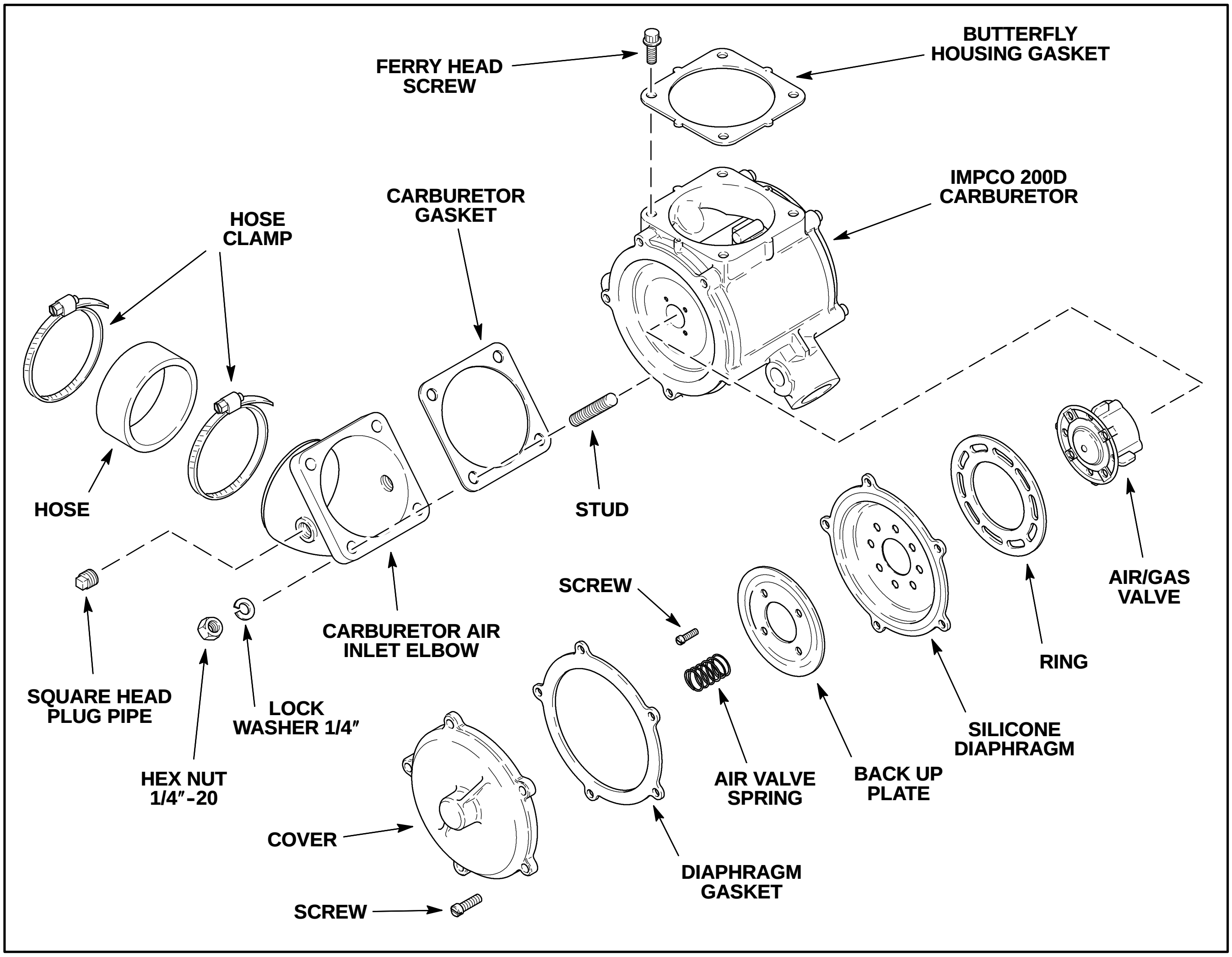


Figure 5.05-15. Carburetor - Impco 200

CARBURETOR CLEANING AND INSPECTION

⚠ WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners or other highly volatile fluids for cleaning.

1. Clean all metal parts in an approved cleaning solvent.

2. Brush inside of tubes and fittings to remove deposits.

3. Dry parts with moisture-free compressed air.

4. Inspect diaphragm for tears, cracks or other damage. Replace diaphragm if damaged.

NOTE: *If damage to the diaphragm is present it may be advisable to replace the complete air gas valve and the diaphragm to be sure proper sealing is maintained.*

5. Inspect spring for corrosion or distortion. Replace spring if damaged.

6. Inspect all threaded parts for damaged or stripped threads. If damage is present, replace parts as necessary.

7. Inspect gas valve for damage of any kind. If damaged, replace parts as necessary.

8. Check all mounting surfaces to be sure gasket material has been removed.

CARBURETOR ASSEMBLY – IMPCO 200

NOTE: *If the idle adjustment screw was removed in Step 6 of "Carburetor Cleaning and Inspection", install a new seal on the screw and install the screw into the carburetor body.*

1. Assemble valve assembly, ring, new diaphragm and backup plate. Install four capscrews to secure parts together (see Figure 5.05-16).

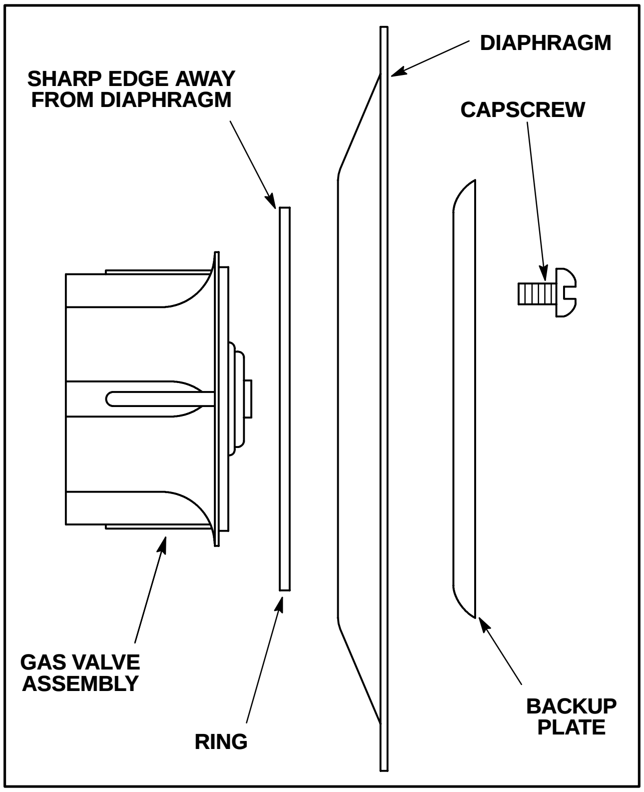


Figure 5.05-16. Proper Gas Valve Assembly

2. Install assembled components into carburetor body.

3. Install air valve spring.

4. Install new gasket on carburetor body and install cover. Secure cover to body using five capscrews.

5. Turn on gas supply and check for leakage in system. If leakage is found, turn off gas supply and repair before putting into service.

CARBURETOR REMOVAL – IMPCO 400

⚠ WARNING

Ensure that the fuel source is completely shut off prior to working on fuel system components. Clear the engine supply lines and piping of accumulated gas before performing any maintenance work on the fuel system or severe injury or death could result.

Current production standard and low compression ratio F18/H24GL engines use the Impco 400 carburetor.

NOTE: *Waukesha VGF fuel systems include a Dresser elbow that connects the fuel line (see Figure 5.05-17). See "Dresser Elbow Service" at the end of this section for complete information.*

1. Disconnect fuel supply pipe at Dresser Elbow (see Figure 5.05-17). Remove piping with carburetor.

2. Remove fuel regulator balance tube from carburetor body (see Figure 5.05-17).

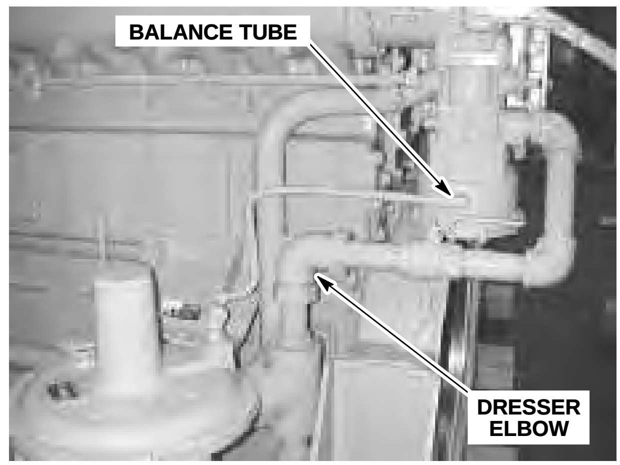


Figure 5.05-17. Balance Line

3. Disconnect governor shaft from throttle valve at universal joint (see Figure 5.05-18).

Figure 5.05-18. Governor Linkage

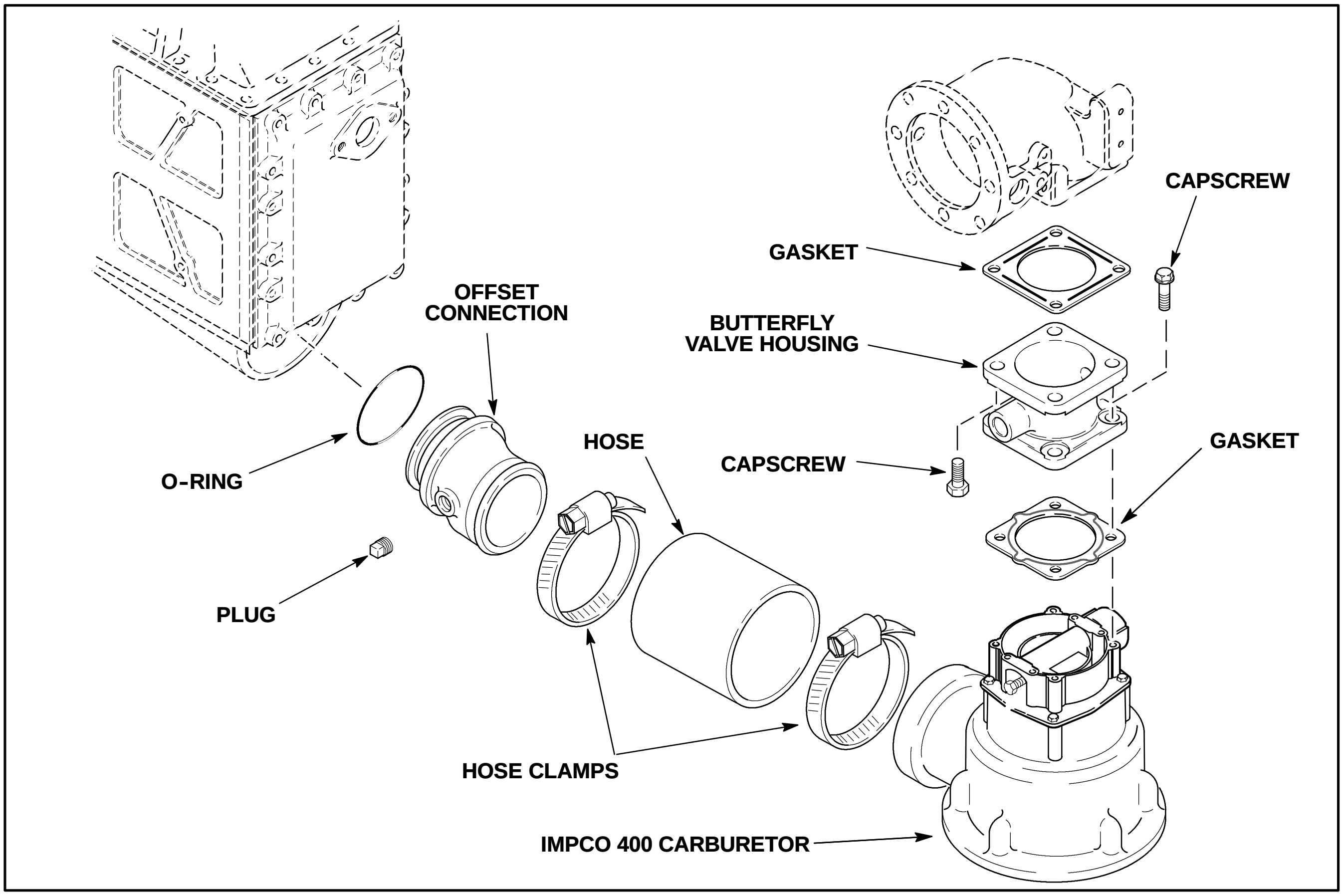


Figure 5.05-19. GL Impco 400 Carburetor

4. Remove hose clamps from carburetor to intercooler air connection (see Figure 5.05-20).

5. Remove butterfly valve housing to intake manifold elbow hex head screws (see Figure 5.05-14).

Figure 5.05-20. Intercooler To Carburetor Connection

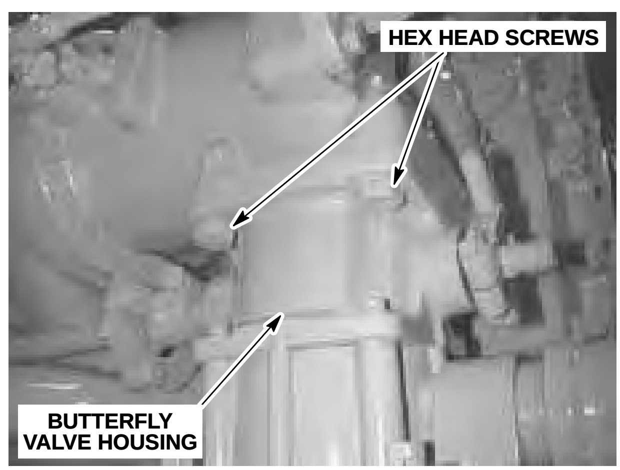


Figure 5.05-21. Butterfly Valve Housing

CARBURETOR INSTALLATION – IMPCO 400

Current production standard and low compression ratio F18/H24GL engines use the Impco 400 carburetor.

A new fuel cone is available for Impco 400 VF carburetors installed on F18GL and H24GL Low Compression Ratio (LCR) engines. The new fuel cone contains a larger idle band that improves starting capability. The new fuel cone is standard equipment on all LCR engines (equipped with Impco 400 VF carburetors) built after August 28, 2001.

Install the new fuel cone (P/N 305960) to improve the starting capability on F18GL and H24GL LCR engines (see Figure 5.05-22).

NOTE: *The minimum engine cranking speed during engine start (using the new fuel cone) is 140 rpm.*

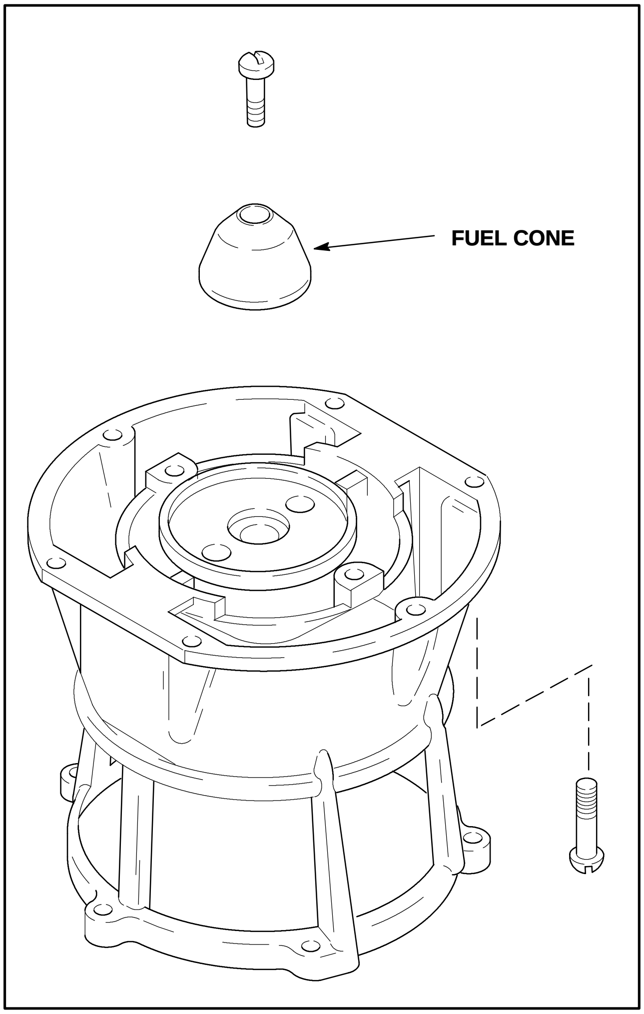


Figure 5.05-22. Impco 400 VF Carburetor

1. Install new O-ring onto intercooler offset air connection (see Figure 5.05-23).

Figure 5.05-23. Offset Connection

2. Secure carburetor to intercooler using hose and clamps (see Figure 5.05-19 and Figure 5.05-25).

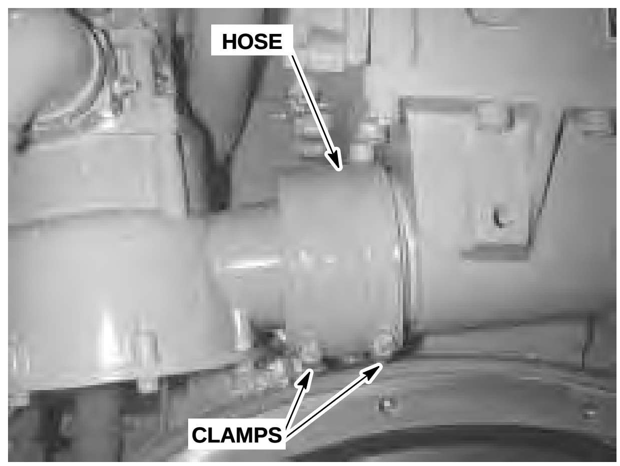


Figure 5.05-24. Intercooler To Carburetor Connection

3. Secure butterfly valve housing to intake manifold with M10 x 25 mm hex head screws. Tighten screws to 34 ft-lb (46 N·m) (see Figure 5.05-25).

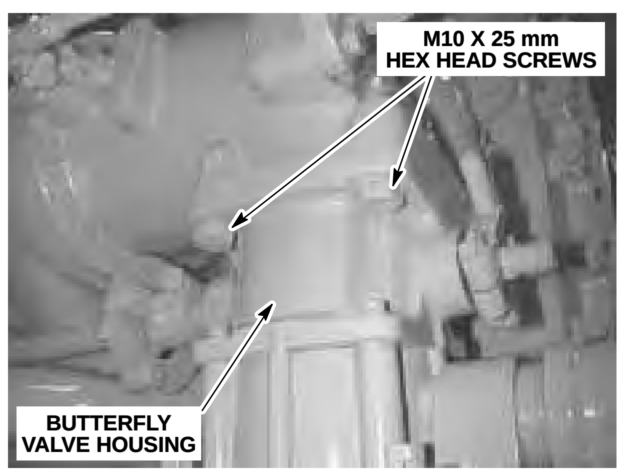


Figure 5.05-25. Butterfly Valve Housing

4. Install governor shaft for EG3P and PSG governor actuators at throttle valve (see Figure 5.05-26).

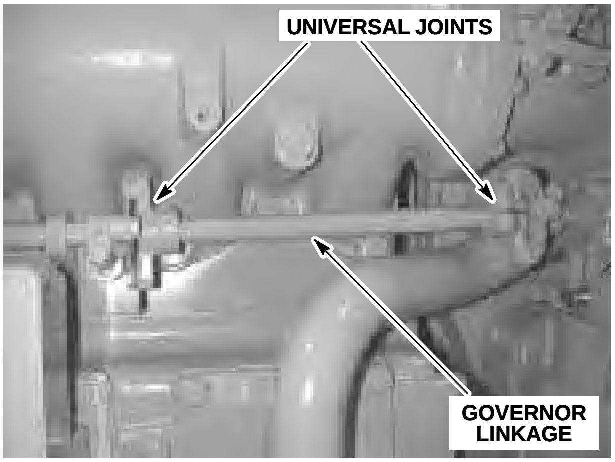


Figure 5.05-26. Governor Linkage

NOTE: *The 4024 governor actuator linkage is mounted on the intake manifold elbow. The linkage is mounted directly on the throttle valve.*

5. Install linkage onto throttle valve (see Figure 5.05-27).

Figure 5.05-27. 4024 Actuator Linkage

NOTE: *Waukesha VGF fuel systems include a Dresser elbow coupling that easily connects the fuel lines (see Figure 5.05-28). See "Dresser Elbow Service" at the end of this section for complete information.*

6. Install fuel regulator balance tube on carburetor body (see Figure 5.05-28).

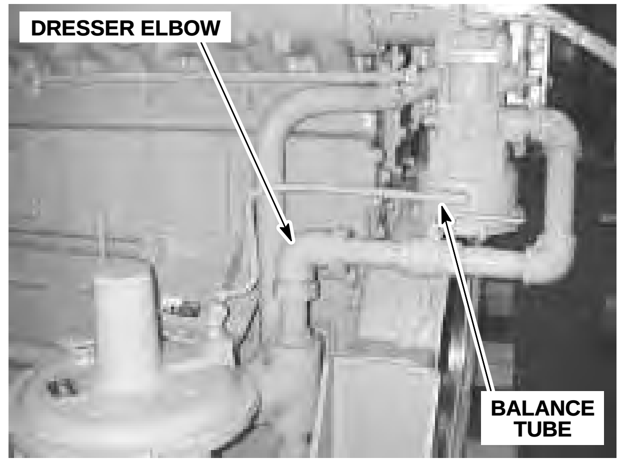


Figure 5.05-28. Balance Line

CARBURETOR REMOVAL – IMPCO 600

⚠ WARNING

Ensure that the fuel source is completely shut off prior to working on fuel system components. Clear the engine supply lines and piping of accumulated gas before performing any maintenance work on the fuel system or severe injury or death could result.

The H24G and F18/H24G dual fuel engines use an Impco 600 carburetor mounted on the air duct.

1. Disconnect fuel supply pipe at Dresser coupling (see Figure 5.05-29). Remove piping with carburetor.

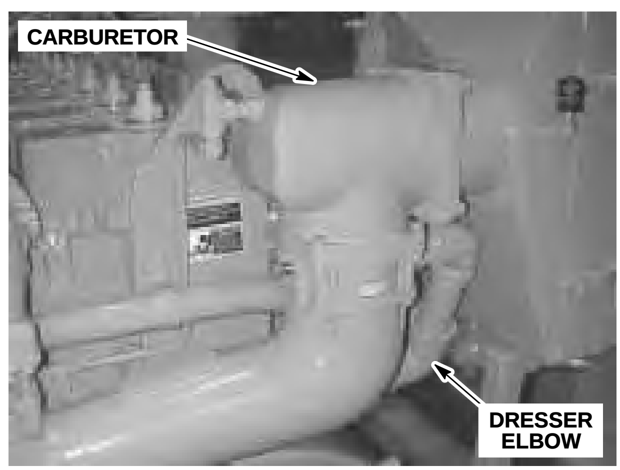


Figure 5.05-29. F18/H24G IMPCO Carburetor

2. Disconnect pressure regulator balance tube from carburetor air bonnet (see Figure 5.05-30).

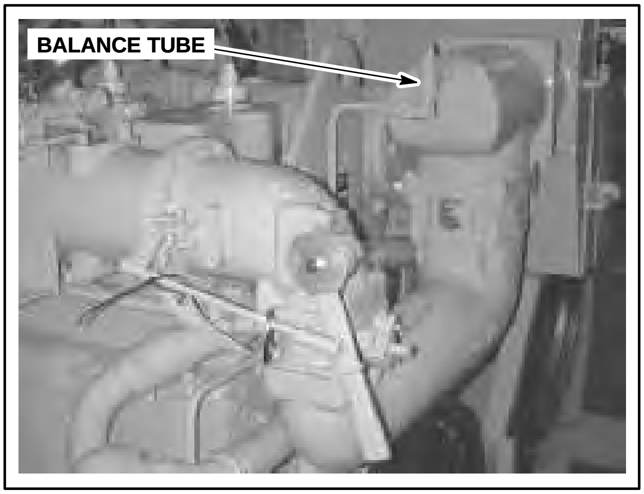


Figure 5.05-30. H24G Impco 600 Carburetor

3. Remove carburetor fasteners from air duct (see Figure 5.05-31). Air duct can remain in place on engine.

4. Remove carburetor fasteners from air inlet elbow. Remove carburetor from engine.

CARBURETOR INSTALLATION – IMPCO 600

1. Position new gasket on upper flange of carburetor assembly (see Figure 5.05-31).

2. Install carburetor gasket and carburetor elbow to air horn. Secure with hex head screws and lock washers.

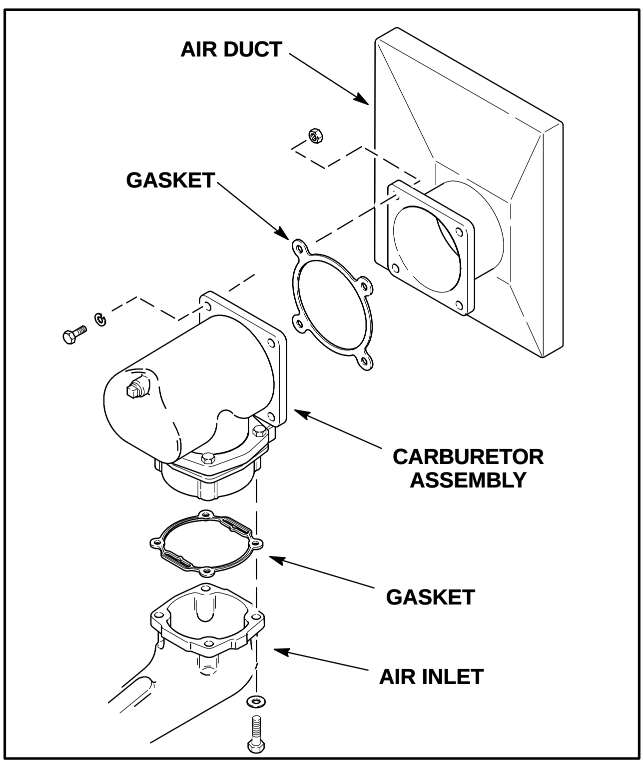


Figure 5.05-31. H24G Impco 600 Carburetor

3. Connect balance line to carburetor and air horn (see Figure 5.05-32). Use pipe sealant on all connections.

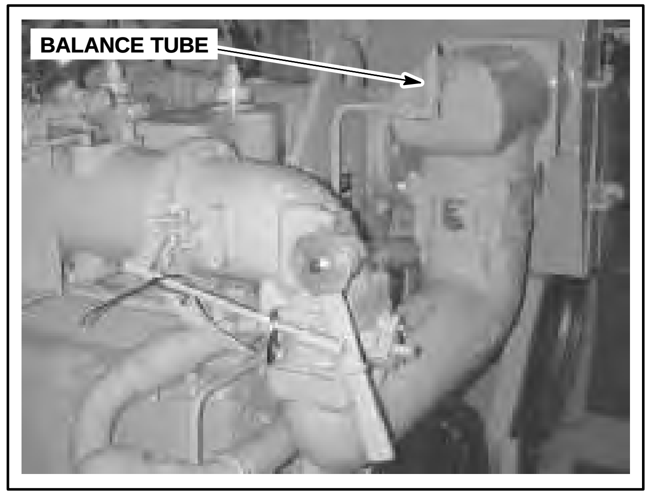


Figure 5.05-32. H24G Impco 600 Carburetor

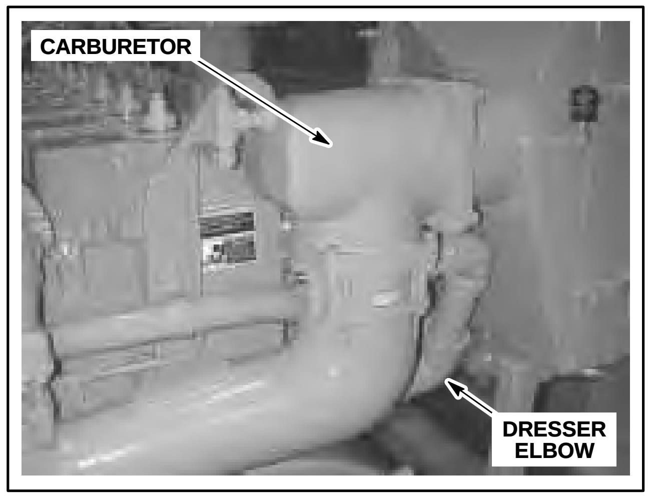


Figure 5.05-33. F18/H24G IMPCO Carburetor

CARBURETOR REMOVAL – IMPCO 600 GSID

⚠ WARNING

Ensure that the fuel source is completely shut off prior to working on fuel system components. Clear the engine supply lines and piping of accumulated gas before performing any maintenance work on the fuel system or severe injury or death could result.

The F18/H24GSID engines use an Impco 600 VFI carburetor mounted on the air duct.

NOTE: *The air valves and diaphragms for Impco GSID carburetors are accessible without removing the carburetor assembly from the engine.*

1. Disconnect fuel supply pipe at Dresser elbow (see Figure 5.05-34). Remove piping with carburetor.

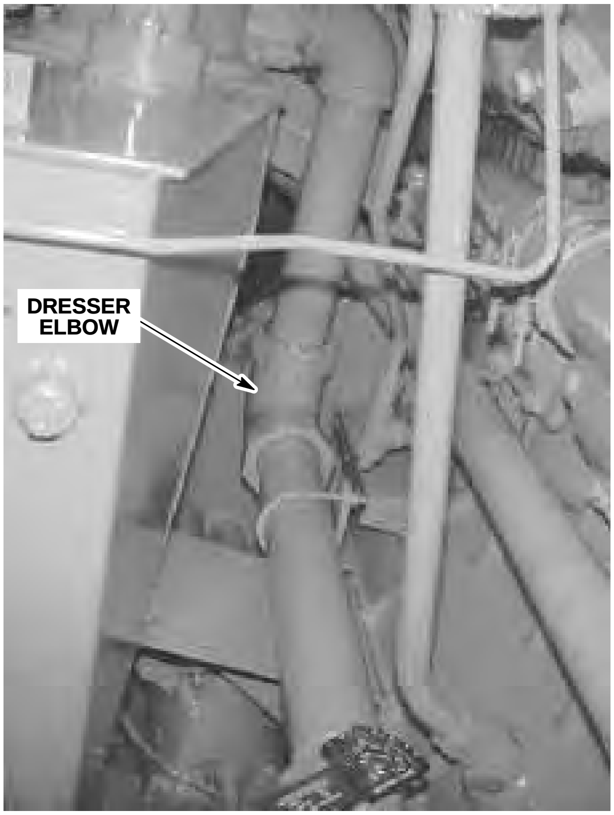


Figure 5.05-34. Impco GLD Fuel Piping

2. Remove turbocharger inlet elbow and adapter from carburetor (see Figure 5.05-35).

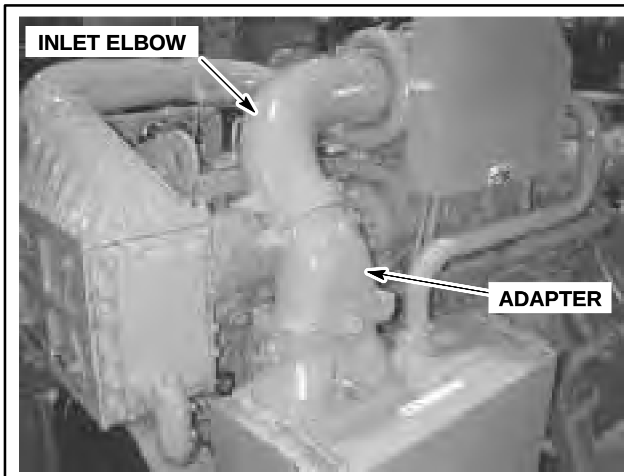


Figure 5.05-35. F18/H24 GLD IMPCO 600D Carburetor

3. Remove four capscrews from air duct and remove carburetor (see Figure 5.05-36). Remove carburetor from air duct.

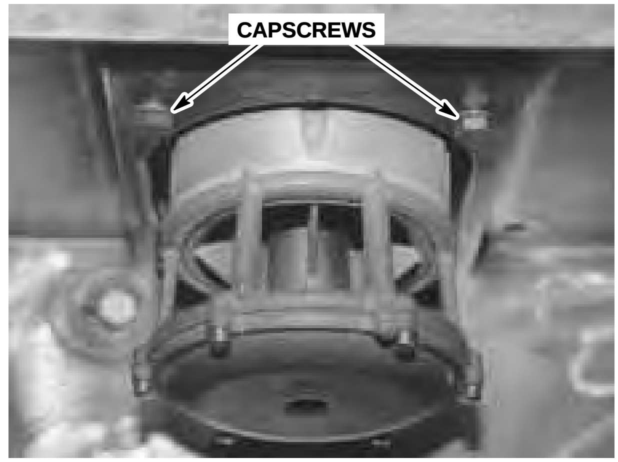


Figure 5.05-36. Carburetor – GSID

CARBURETOR REMOVAL – GLD IMPCO 600D

⚠ WARNING

Ensure that the fuel source is completely shut off prior to working on fuel system components. Clear the engine supply lines and piping of accumulated gas before performing any maintenance work on the fuel system or severe injury or death could result.

The F18/H24GLD engines use an Impco 600D VFI carburetor mounted on the air duct.

NOTE: *The air valves and diaphragms for Impco GLD carburetors are accessible without removing the carburetor assembly from the engine (see Figure 5.05-37).*

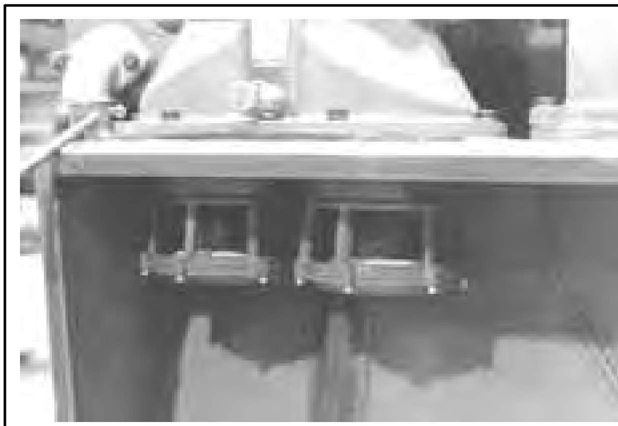


Figure 5.05-37. Impco GLD Carburetor

1. Disconnect fuel inlet by removing four capscrews that secure flange to carburetor body (see Figure 5.05-38).

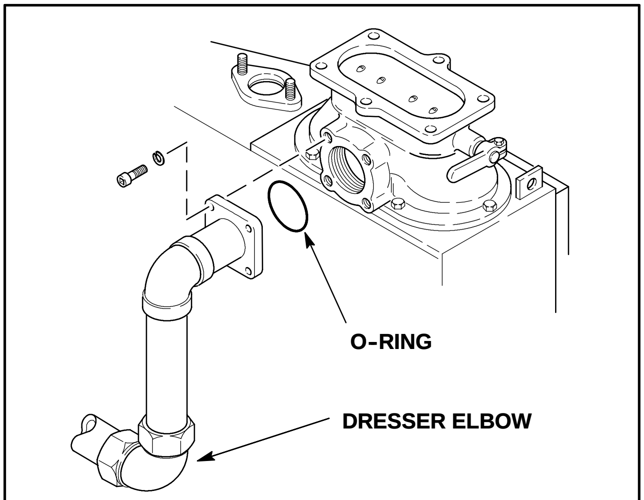


Figure 5.05-38. Carburetor Fuel Connection

2. Fuel pipe connects to Dresser elbow (see Figure 5.05-39). Fuel inlet may be disconnected at this point. Remove piping with carburetor.

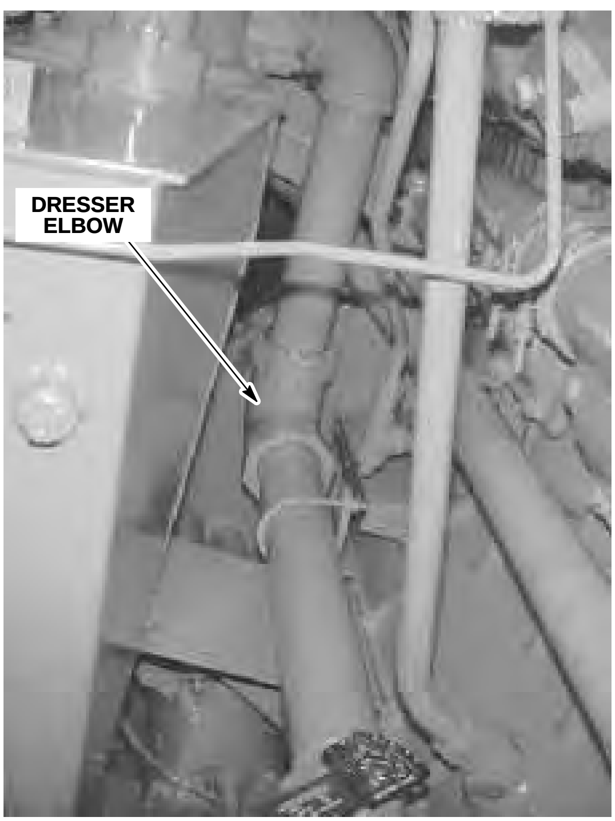


Figure 5.05-39. Impco GLD Fuel Piping

3. Remove straps that hold carburetor adapter to turbocharger air inlet. Remove six M12 x 30 mm hex head screws that hold carburetor adapter to carburetor body (see Figure 5.05-40).

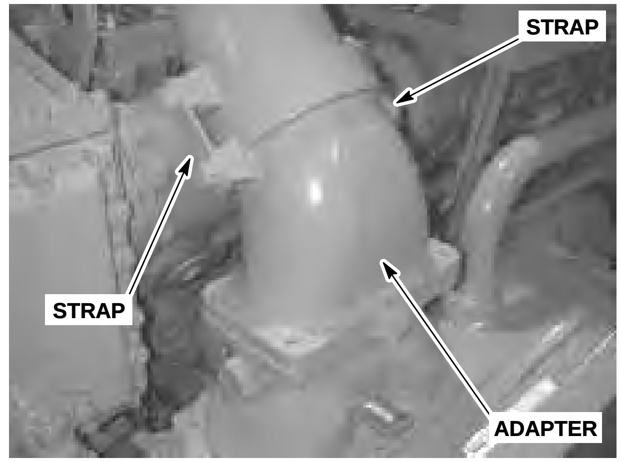


Figure 5.05-40. Impco 600D Carburetor

4. Remove six 3/8 in. hex head screws that secure carburetor body to air duct (see Figure 5.05-41). Remove carburetor from air duct.

Figure 5.05-41. F18/H24GLD Impco 600D Carburetor

CARBURETOR INSTALLATION – IMPCO GLD

1. Install carburetor body on to air duct (use new gasket). Secure with 3/8 in. hex head screws (see Figure 5.05-41).

2. Install adapter to carburetor body (use new gasket). Secure with six M12 x 30 mm hex head screws (see Figure 5.05-42).

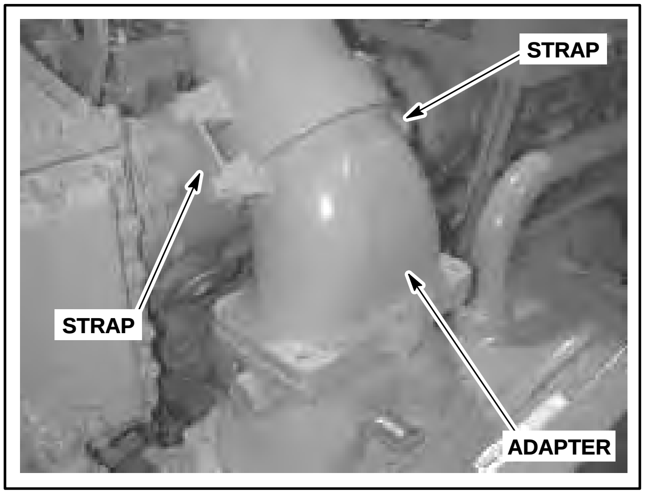


Figure 5.05-42. Impco 600D Carburetor

3. Install new O-ring onto adapter (see Figure 5.05-43). Install turbo air inlet to carburetor air connection. Secure with retainers and clamp.

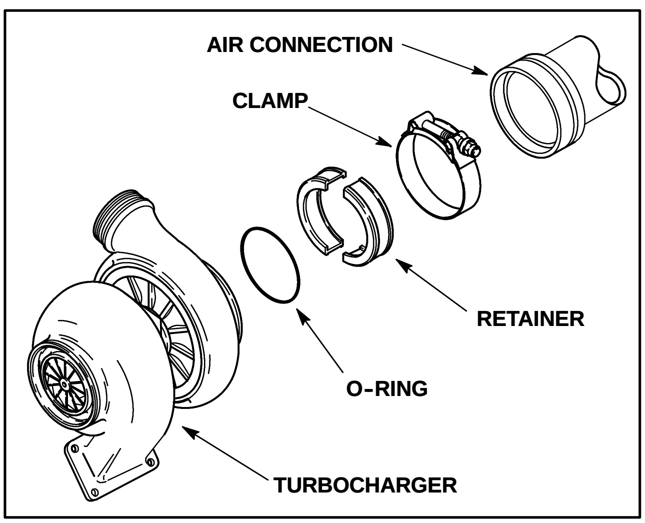


Figure 5.05-43. GLD/GSID Turbo Air Inlet Connection

4. Install new O-ring and attach fuel inlet pipe to back of carburetor body (see Figure 5.05-44). Connect fuel inlet piping to site connections.

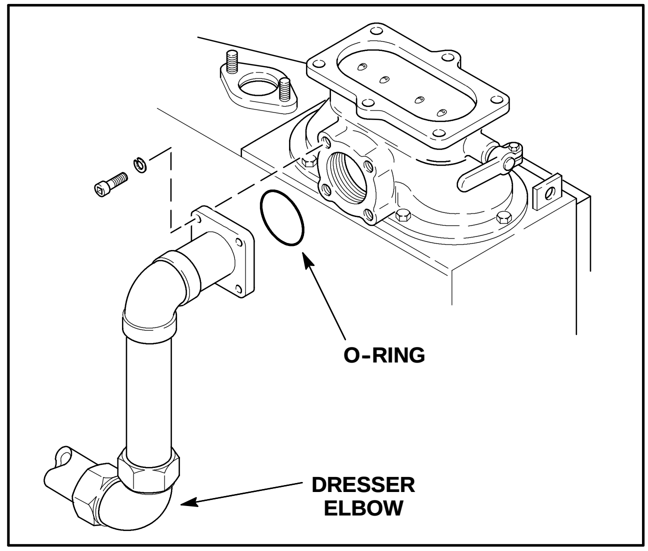


Figure 5.05-44. Carburetor Fuel Connection

CARBURETOR DISASSEMBLY

CARBURETOR DISASSEMBLY – IMPCO 400

NOTE: *The Impco 400 (Figure 5.05-45) and 600 (Figure 5.05-46) parts are similar in appearance and service procedures, but do not interchange. Use parts specific for the carburetor model for service.*

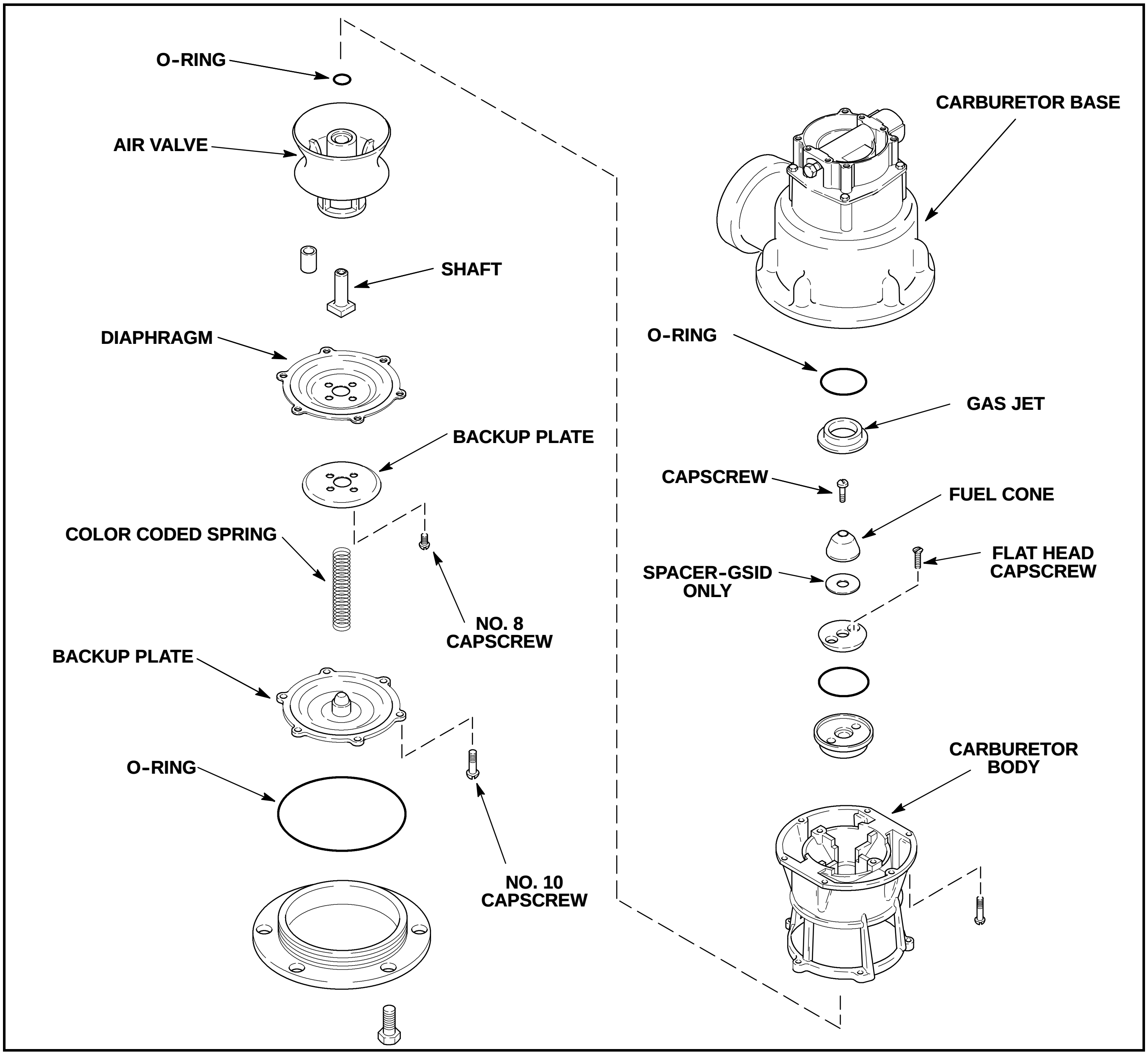


Figure 5.05-45. Typical Impco 400 Carburetor

CARBURETOR DISASSEMBLY – IMPCO 600

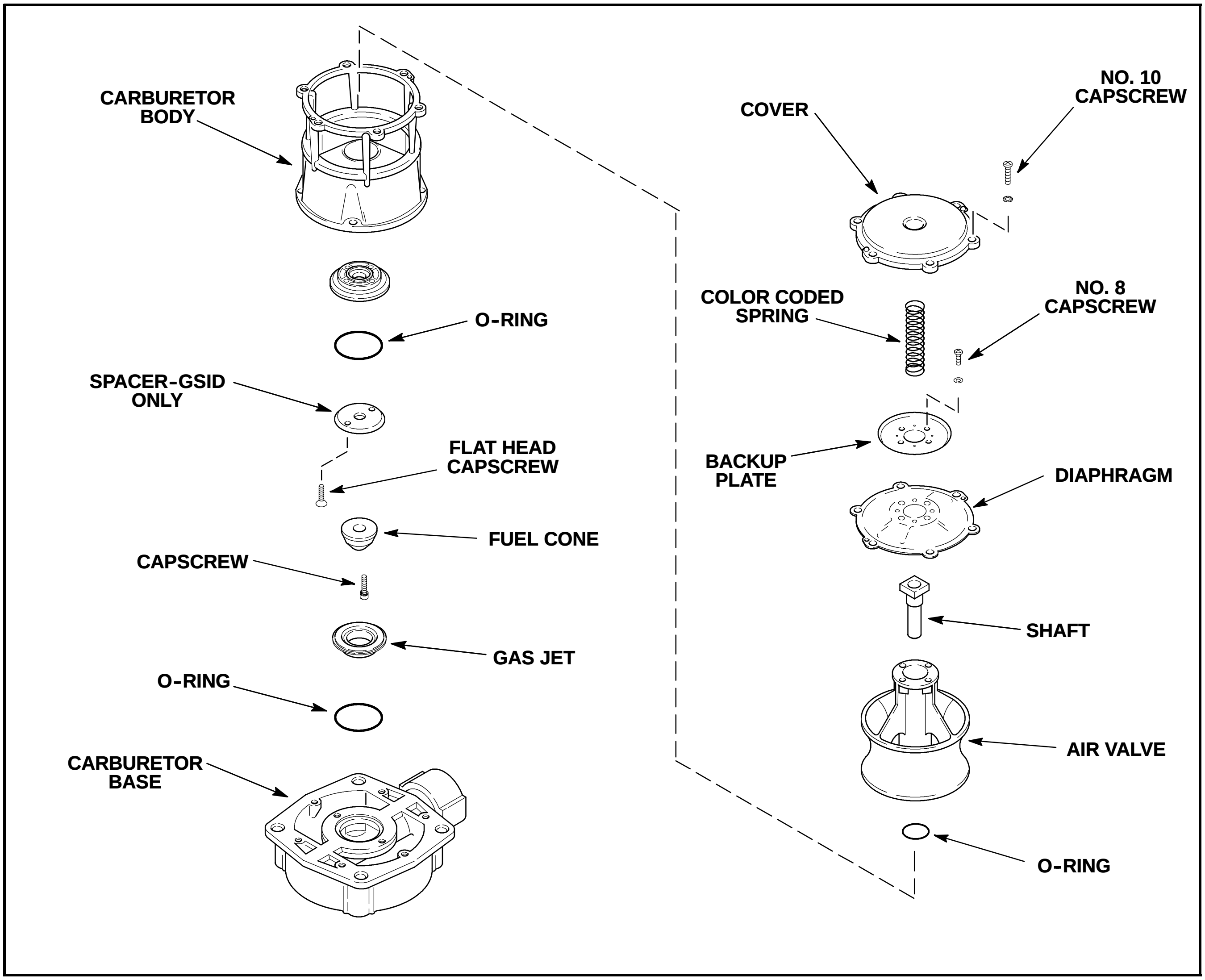


Figure 5.05-46. Typical Impco 600 Carburetor

SECTION 5.10

IGNITION SYSTEM – CEC/MAGNETO

IGNITION SYSTEM COMPONENTS

The ignition system consists of the following components:

- CEC Ignition Module
- Hall-effect pickup (CEC)
- Magneto
- Primary wiring harness
- Ignition coil
- Shielded ignition coil (CSA)
- Ignition switch
- Junction box
- Secondary wiring

IGNITION SYSTEM COMPONENT DESCRIPTION

IGNITION MODULE – CEC IGNITION

The CEC Ignition Module uses a Hall-effect pickup, a magnetic switching device to read the reference magnet disc installed on the camshaft gear. This method of timing determines the exact position of the crankshaft. The microcircuit-based, digital CEC Ignition Module interprets the pickup's impulses to set the optimum ignition timing. The Ignition Module then directs a precisely timed voltage to the appropriate coil.

Refer to the *Custom Engine Control Ignition Module Manual Form 6272* for information on the installation, operation and maintenance of the CEC Ignition Module.

Refer to *Custom Engine Control Ignition Module Installation, Operation and Maintenance Manual Form 6253* for information on previous production Ignition Module (not equipped with LEDs).

IGNITION MODULE – LEDS

The current production IM is equipped with three diagnostic LEDs located on the front of the module.

The three LEDs are labeled "Power," "Pickup," and "Application" (see Figure 5.10-1). These LEDs give the operator a visual confirmation on (1) incoming power, (2) Hall-effect pickup signal, and (3) proper application settings.

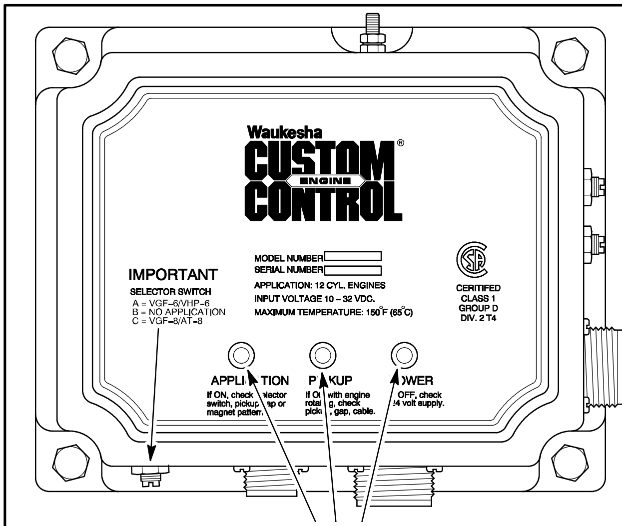


Figure 5.10-1. Ignition Module Diagnostic LEDs

The following LED indications are normal :

Normal operation (engine running)

- "Power" LED – ON
- "Pickup" LED – OFF
- "Application" LED – OFF

Power applied to Ignition Module (engine not running)

- "Power" LED – ON
- "Pickup" LED – ON
- "Application" LED – OFF

CEC IGNITION FUSES

CEC Ignition Modules do not require fuses for safe and effective operation. If fuses are required for some reason, note the following:

1. Install fuse as close to power source as possible (see Figure 5.10-105 for CEC Ignition Module voltages).

2. Install fuse prior to junction box connection.

3. Do not install fuse inside of a Waukesha Engine junction box or CEC Ignition Module.

4. Always follow local electrical codes.

Current production engines have the Ignition Module located below the Junction Box. The Ignition Module bracket is mounted on the intake manifold (see Figure 5.10-2).

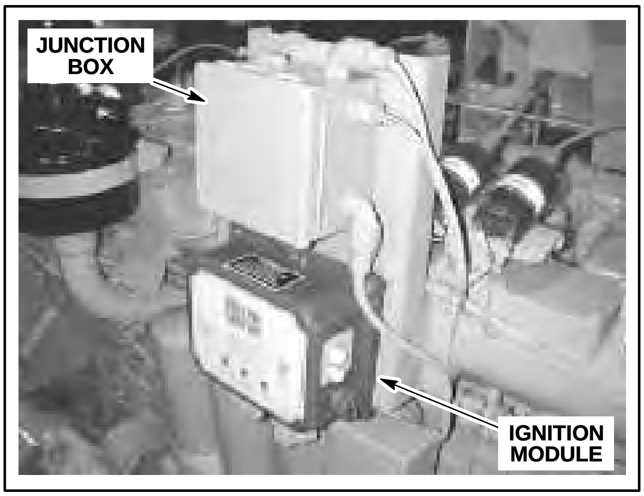


Figure 5.10-2. Current Ignition Module

Previous engines use an angled mounting bracket that located the Ignition Module above the Junction Box (see Figure 5.10-3).

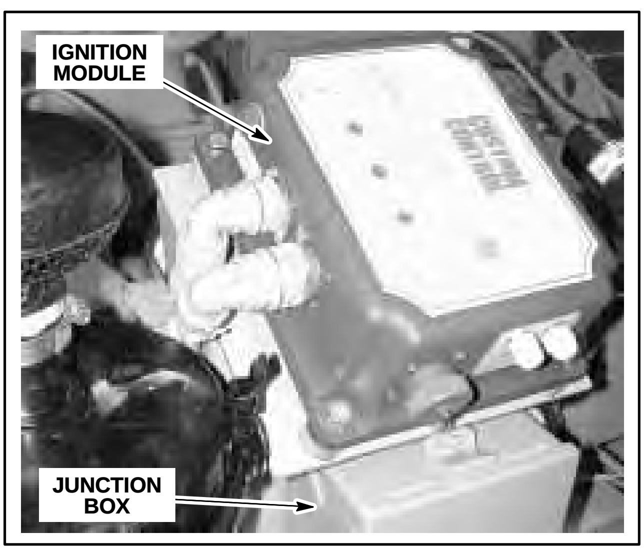


Figure 5.10-3. Previous Ignition Module

MAGNETIC TIMING DISC

The magnetic timing disc is located under a cover in the front gear housing, attached to the cam gear (see Figure 5.10-4). Trigger magnets for the Hall-effect sensor are permanently mounted on the disc.

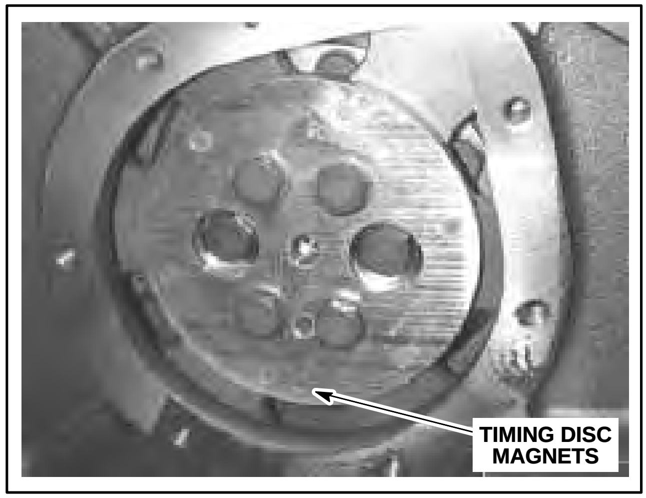


Figure 5.10-4. CEC Timing Disc

HALL-EFFECT PICKUP - CEC IGNITION

The Hall-effect pickup is located on the front gear cover. The pickup senses each magnet as it passes and trips the logic circuit of the CEC module to fire (see Figure 5.10-5).

Figure 5.10-5. Hall-effect Pickup Location

MAGNETO

The magneto is located on the engine's left side front gear housing (see Figure 5.10-6).

Figure 5.10-6. F18/H24 Magneto

The magneto uses solid state electronic components. Self-generated alternating current is rectified to direct current and stored within a capacitor. Silicon controlled rectifiers (SCR's) function as switches to release the stored energy to the ignition coils. A trigger coil arrangement produces the voltage needed to turn on the SCR.

WIRING HARNESS

A flexible wiring harness is used to connect the magneto and CEC Ignition Module to the ignition coils. The wiring harness uses solderless connectors on the coil terminals and a multiple pin connector at the Ignition Module and magneto connections.

HIGH TENSION LEADS

The standard high tension leads route the ignition secondary current from the ignition coils to the spark plugs.

SPARK PLUGS

The spark plugs are housed within the cylinder head and ignite the air/fuel mixture in the combustion chamber. Spark plug life will depend on the engine operating conditions.

MAGNETO

The magneto is the standard ignition system magneto.

As the magneto rotates, it generates alternating current (AC) that is converted (rectified) into direct current (DC). The DC energy is then stored in a capacitor. Silicon controlled rectifiers (SCR's) function as switches and release the stored energy to the ignition coils. A trigger coil arrangement produces the voltage needed to turn the SCR on.

HALL-EFFECT PICKUP

The Hall-effect pickup is the standard CEC ignition pickup.

TIMING DISC

The timing disc is the standard CEC ignition system timing disc.

SHIELDED SPARK PLUG

Previous production shielded ignitions required a special threaded spark plug to allow installation of the integral coil. Current flange mounted coils do not require a special spark plug.

IGNITION COILS

The ignition coils produce a high energy, long duration spark, which provides consistent cylinder firing. These coils are located either on mounting brackets on top of the intake manifolds (see Figure 5.10-7) or directly on top of the rocker arm cover (CSA) (see Figure 5.10-8).

Figure 5.10-7. Standard Ignition Coil

⚠ CAUTION **Do not use the CSA ignition coil as a handle to lift the rocker cover. The coil can be damaged. Always remove the coil and spark plug extension before removing the rocker cover.**

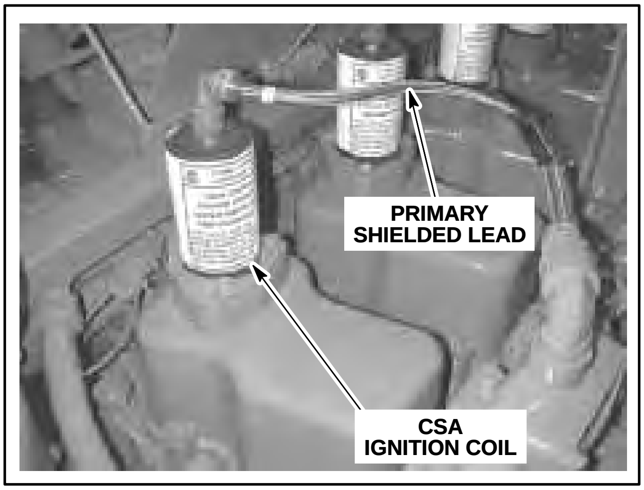


Figure 5.10-8. CSA Flange Mounted Ignition Coil

NOTE: *To ensure long coil life, a heat shield is required for the turbocharger and exhaust outlet (see Figure 5.10-9 and Figure 5.10-10).*

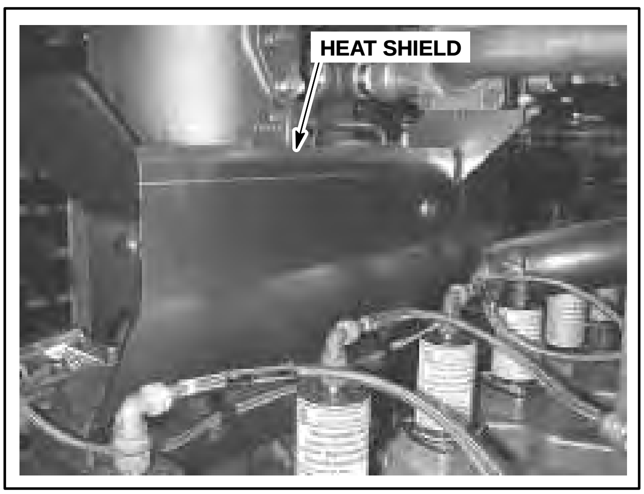


Figure 5.10-9. CSA Ignition Coil Heat Shield

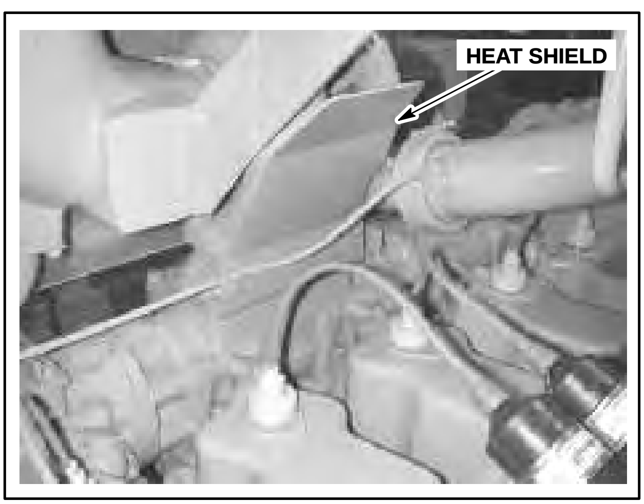


Figure 5.10-10. Standard Ignition Coil Heat Shield

HIGH TENSION WIRES

The standard high tension leads or primary shielded lead (CSA) route the ignition secondary current from the ignition coils to the spark plugs (see Figure 5.10-8).

SPARK PLUGS

The spark plugs are located within the cylinder head and ignite the air/fuel mixture in the combustion chamber. Spark plug life will depend on the engine operating conditions.

PRIMARY WIRING

The wiring that connects the Ignition Module or magneto to the junction boxes is housed within ridged and flexible conduits. Junction boxes are used at each cylinder to provide the connections to the ignition coils (see Figure 5.10-11). The primary wiring that connects the junction boxes to the coils is housed within a steel braided wire jacket.

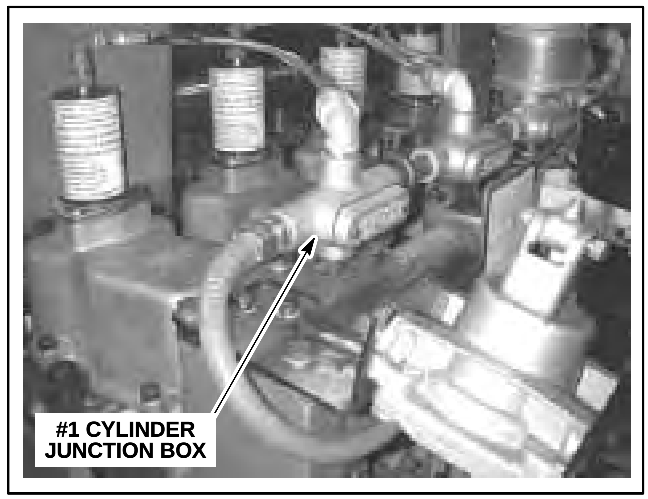


Figure 5.10-11. Shielded Ignition System

IGNITION SWITCH

This explosion-proof switch is mounted above the Ignition Module junction box. This switch is used for both normal and emergency shutdowns (see Figure 5.10-12).

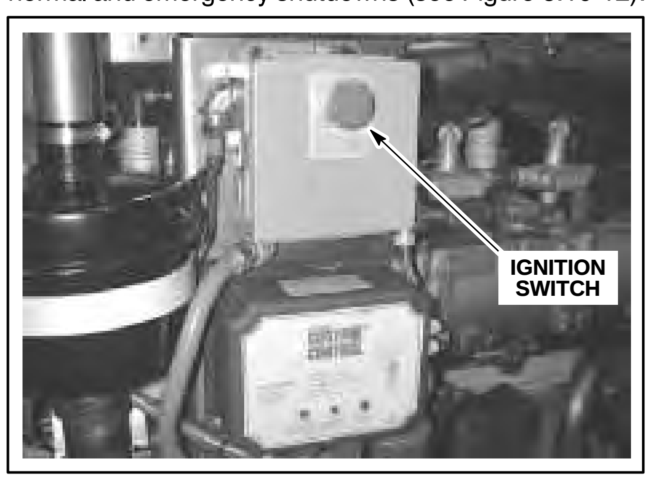


Figure 5.10-12. CSA Stop Switch

CURRENT PRODUCTION TIMING LIGHT HOOKUP

1. **Shielded Ignition—**Remove cover of #1 cylinder shielded ignition box. (see Figure 5.10-13).

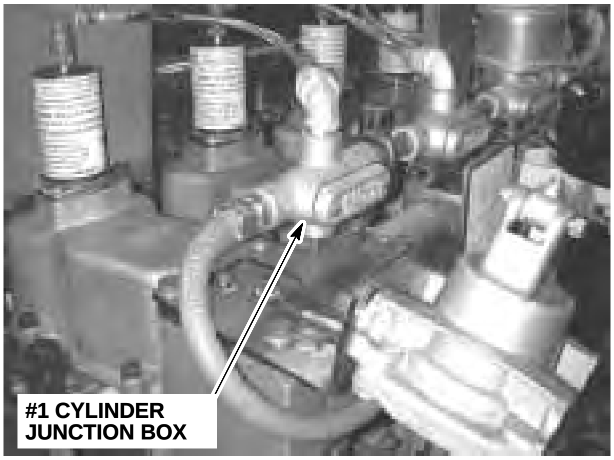


Figure 5.10-13. Shielded Ignition System

2. **Shielded Ignition—**Install an inductive timing light around wire labeled “A” (see Figure 5.10-14).

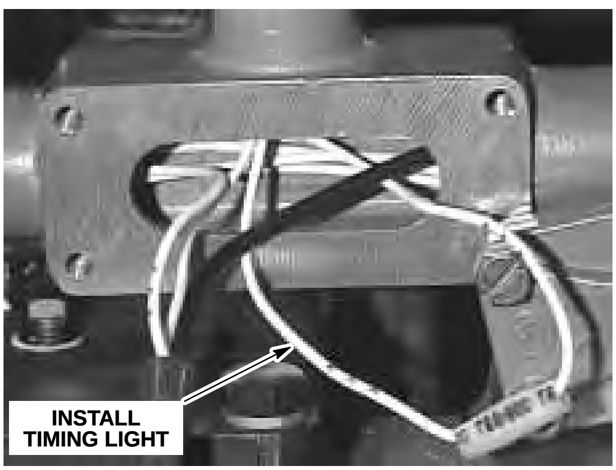


Figure 5.10-14. #1 Cylinder Junction Box

3. Check engine timing at flywheel using a timing light (see Figure 5.10-15). See “CEC Ignition Timing Adjustment” in this section for specific engine timing.

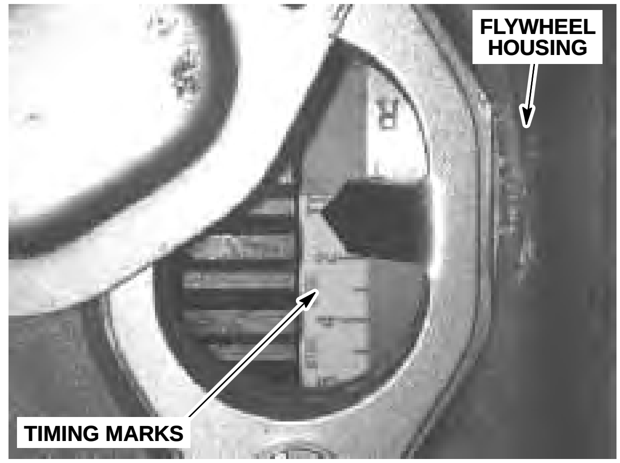


Figure 5.10-15. Timing Marks

PREVIOUS TIMING LIGHT HOOKUP (CEC IGNITION MODULE)

The hookup for the explosion proof timing light (P/N 494227) is located on the flywheel end of the ignition conduit (see Figure 5.10-16).

Figure 5.10-16. Shielded Ignition Timing Light Hookup

PREVIOUS TIMING LIGHT HOOKUP (MAGNETO)

The hookup for the explosion proof timing light (P/N 494227) is located on the bottom of the explosion-proof ignition switch (see Figure 5.10-17).

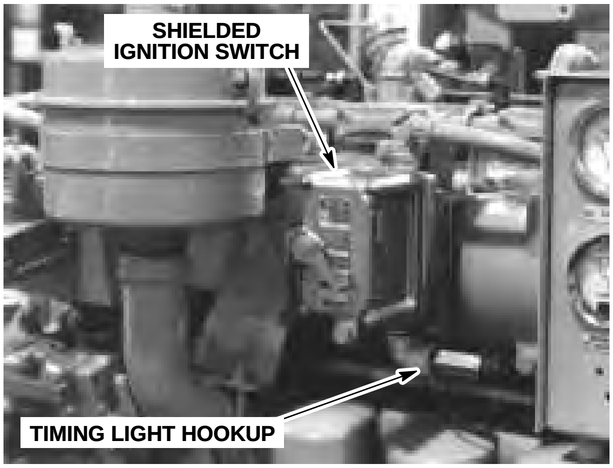


Figure 5.10-17. Shielded Ignition Switch

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

IGNITION SYSTEM MAINTENANCE

Spark plugs, boots, connectors, and coils must be properly maintained to preserve electrical integrity.

Whenever service is required on the ignition system, the boot and the O-ring should be inspected for damage and replaced if damage is observed.

1. Clean ignition coil contacts at every spark plug change. If a defective coil is suspected, test by replacing ignition coil with one that is known to be good or see "Ignition Coil Testing" in this section.

2. Inspect magneto drive coupling for wear or damage. Replace coupling every 4000 hours or when wear is observed.

NOTE: *To help seal out moisture and prevent corrosion, use a dielectric silicone grease on the high tension connectors between the coils and the spark plug connectors.*

Some acceptable dielectric greases are:

- Du Pont Krytox® GPL-206
- G.E. G-624
- GC Electronics 25

3. Inspect the wiring harness and connectors for moisture, corrosion, cracks, or dirt that can cause a short to ground.

⚠ CAUTION **Use Krytox® GPL-206 (P/N 489341) grease or equivalent between the boot ID and the spark plug insulator. This grease will assist in releasing the boot (P/N 740011) from the plug. Boot damage will occur if the boot is not greased. Damaged boots will allow flashover and shorten spark plug life.**

NOTE: *Krytox® GPL-206 (P/N 489341) is a higher temperature fluorinated grease manufactured by Miller-Stephenson Chemical Co., Inc. For technical information on Krytox® GPL-206 call: 1-800-992-2424 (8-4 Eastern Time) or in Canada 1-800-323-4621 (8-4 Eastern Time).*

⚠ CAUTION **The current spark plug connectors include the connector, an O-ring and a high temperature boot. Damage to the boot and the O-ring occurs due to the extreme heat in the spark plug well. Waukesha Service Operations recommends replacement of the boot and O-ring every six months to prevent damage to the components and/or possible personal injury.**

The spark plug extension consists of a silicone O-ring, a red high temperature silicone rubber boot and a white extension. Inspect the boot for damage and replace if necessary. The boot (P/N 740011) should be replaced every six months. The extension contact and spring should work freely and be cleaned of all corrosion. Inspect the extension O-ring for cracking or other damage. The O-ring (P/N 296178) should be replaced every six months.

SPARK PLUGS

SPARK PLUG REMOVAL – STANDARD IGNITION

CAUTION Do not pull on the spark plug cables to remove the spark plug cover tubes. Pulling on the cable may loosen or detach the terminal connection within the cover tube. Grasp the spark plug cover tube firmly and pull it out of the rocker arm cover. Disregarding this information could result in product damage and/or personal injury.

1. Remove spark plug cover tube (Figure 5.10-18). Do not pull on cable.

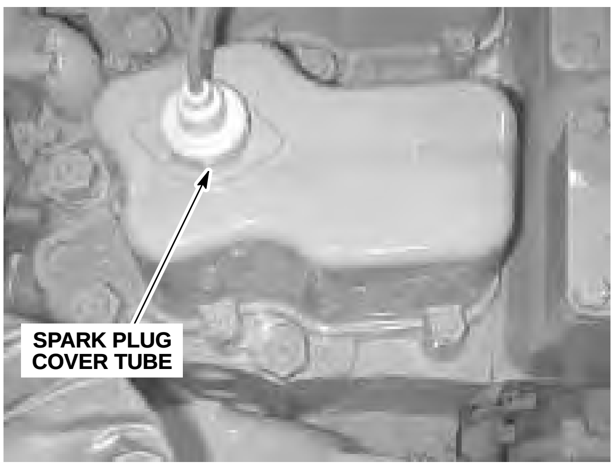


Figure 5.10-18. Rocker Arm Cover

2. Remove spark plug. Use spark plug tube retaining tool (P/N 472065) to prevent spark plug tube from turning (Figure 5.10-19).

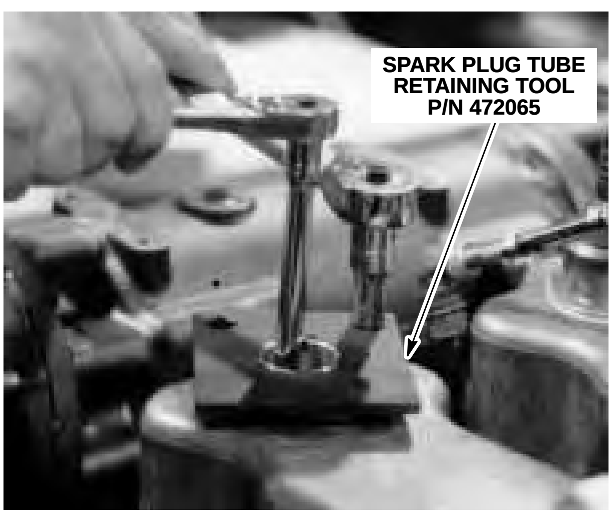


Figure 5.10-19. Spark Plug Tube Retaining Tool

SPARK PLUG REMOVAL – CSA FLANGED IGNITION COIL

CAUTION Do not use the ignition coil as a handle to lift the rocker cover. The coil can be damaged. Always remove the coil and spark plug extension before removing the rocker cover.

1. Disconnect primary shielded lead from ignition coil (see Figure 5.10-20).

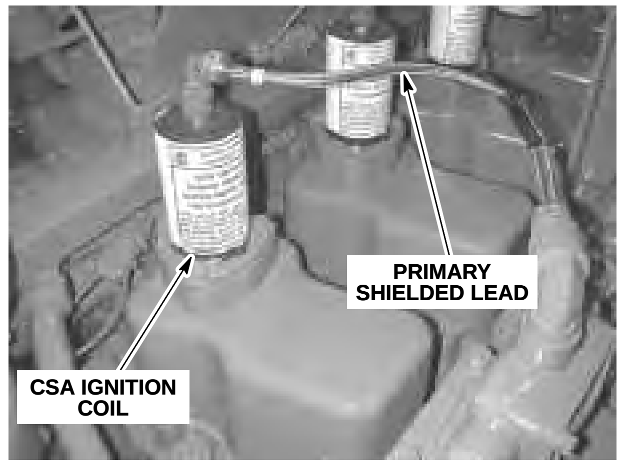


Figure 5.10-20. CSA Ignition Coil

2. Remove three M8 x 20 mm capscrews and lock washers from coil flange. Use hand pressure to lift coil from rocker arm cover.

3. Remove spark plug extension with spark plug extension puller (P/N 475075) (see Figure 5.10-22).

4. Remove spark plug. Use spark plug tube retaining tool (P/N 472065) to prevent spark plug tube from turning (see Figure 5.10-21).

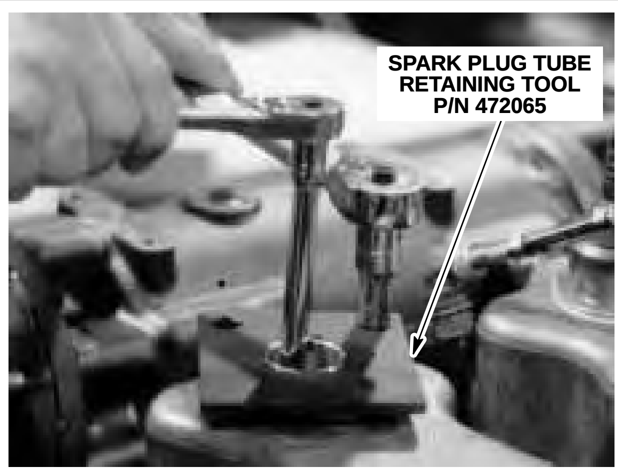


Figure 5.10-21. Spark Plug Tube Retaining Tool

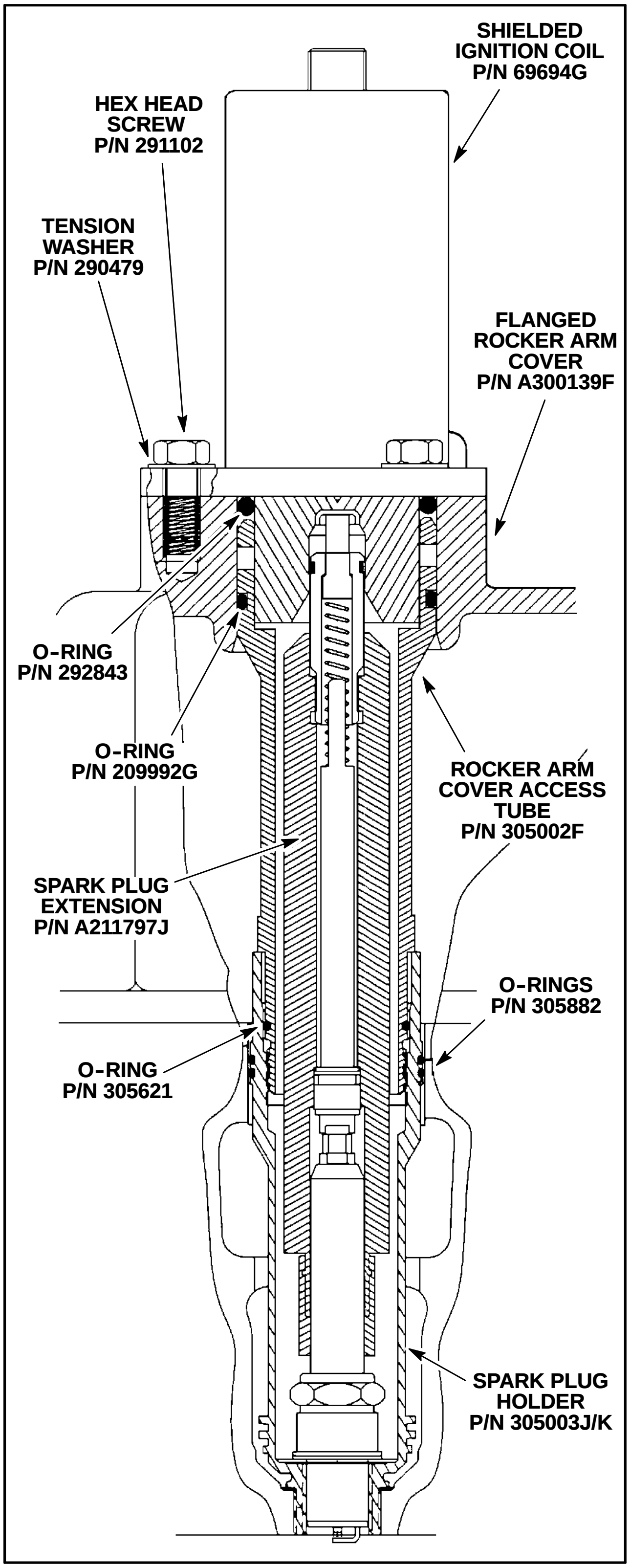


Figure 5.10-22. CSA Ignition Assembly

SPARK PLUG INSTALLATION – CSA COIL

NOTE: *See Table 5.10-1 and Table 5.10-3 "Spark Plug Specifications" in this section for part numbers, torque and correct gap of spark plug.*

1. Install spark plug and tighten to appropriate torque. Replace spark plug gaskets every time a spark plug (except P/N 69919) is reinstalled.

2. Install O-rings (apply Parker Super O-Lube™) onto rocker arm cover access tube (see Figure 5.10-23). Install access tube into spark plug holder.

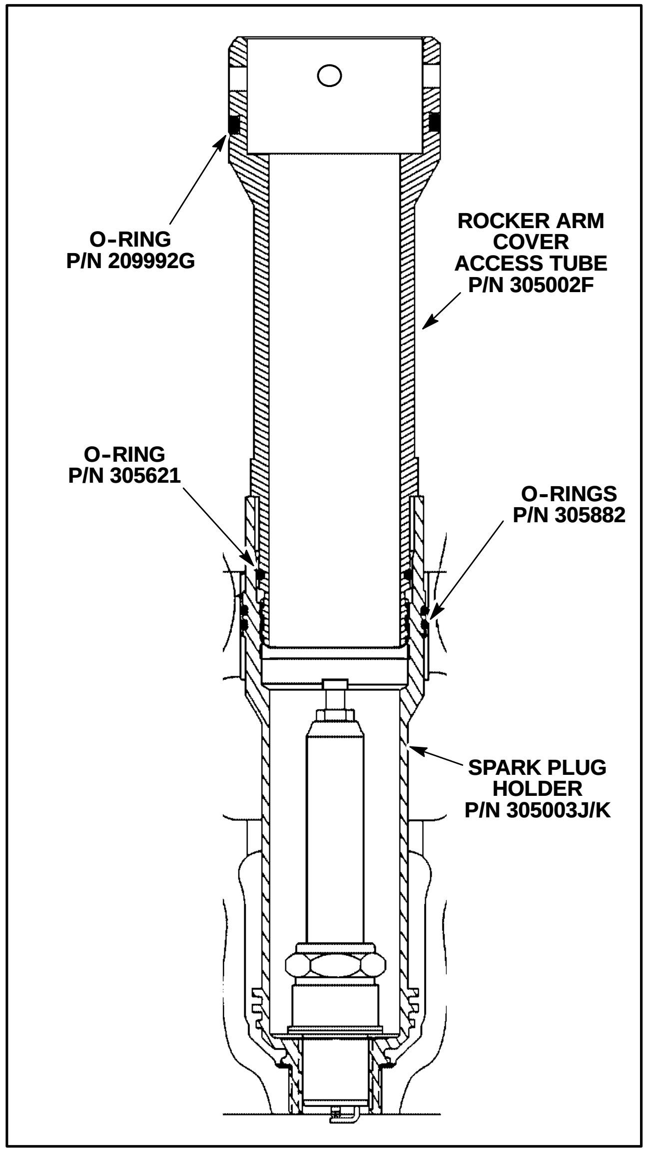


Figure 5.10-23. Shielded Ignition Assembly

3. Apply a high performance fluorinated grease such as Krytox® GPL-206 (P/N 489341) or equivalent to inside surface of boot and extension (see Figure 5.10-24).

⚠ CAUTION Use Krytox® GPL-206 grease (P/N 489341) or equivalent between the boot ID and the spark plug insulator. This grease will assist in releasing the boot from the plug. Boot damage will occur if the boot is not greased. Damaged boots will allow flashover and will shorten spark plug life.

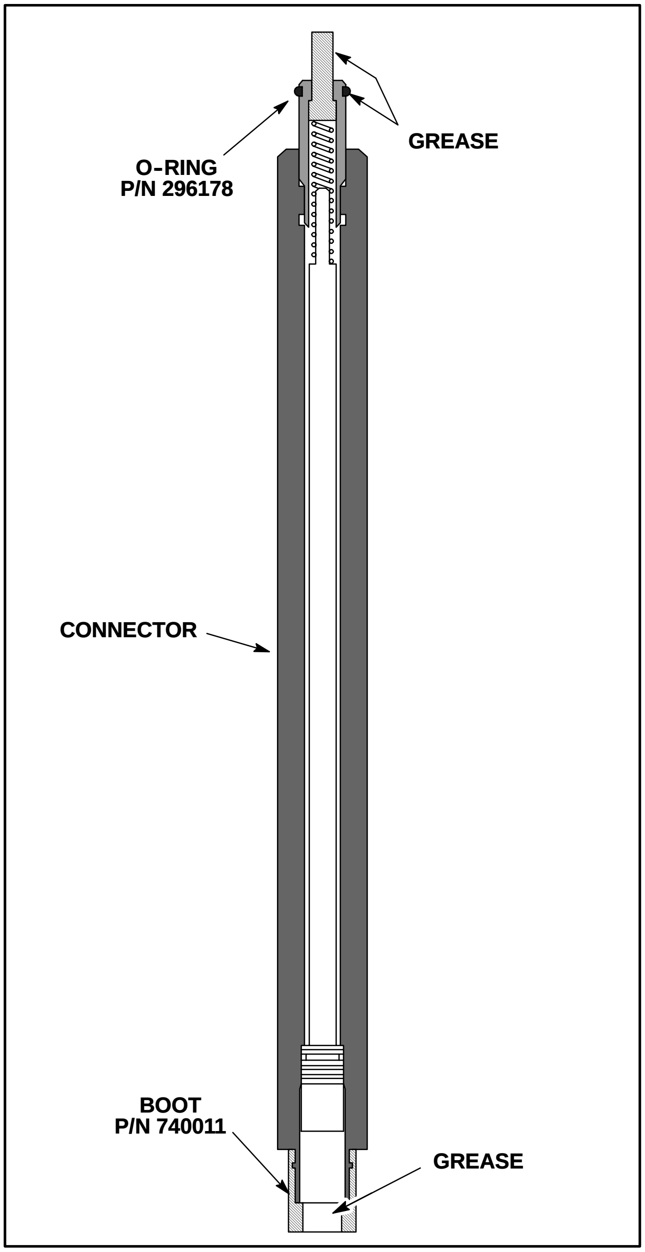


Figure 5.10-24. Spark Plug Extension

4. Install extension onto spark plug.

NOTE: *Make sure the key way on the coil connector aligns with the primary shielded lead cannon plug, without excessive twisting of the lead.*

5. Install flange mounted CSA coil and O-ring (see Figure 5.10-25).

⚠ CAUTION Ignition coils that are improperly grounded can cause misfiring. Make sure CSA coils are installed using three M8 x 20 mm hex head screws that are properly tightened. Disregarding this information could result in product damage and/or personal injury.

6. Secure coil with three M8 x 20 hex head screws and tension washers (see Figure 5.10-25). Tighten hex head screws to 16 - 17 ft-lb (21.6 - 23.0 N·m).

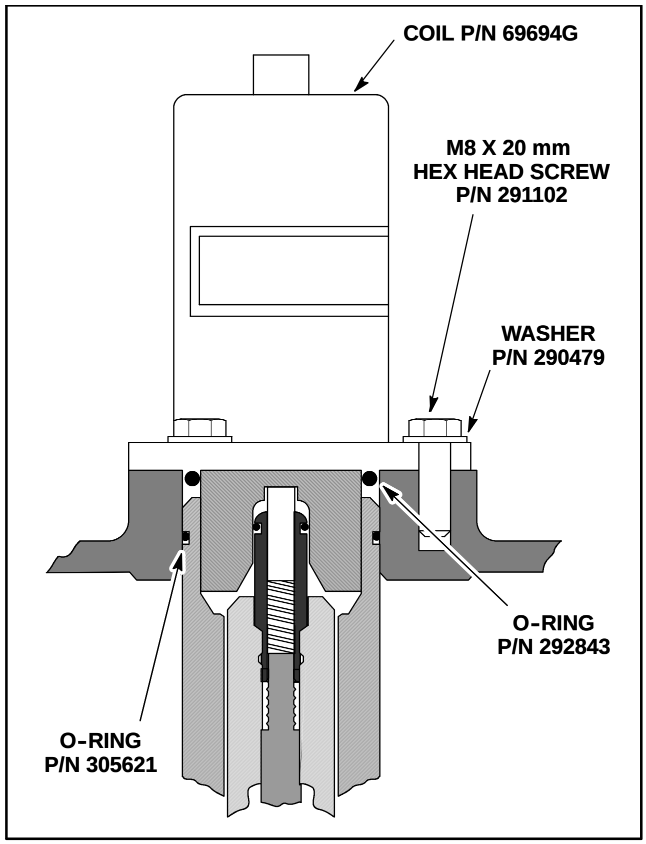


Figure 5.10-25. Coil Installation

7. Connect primary shielded lead cannon plug onto coil.

SPARK PLUG SPECIFICATIONS

Spark plug information and torques are for standard and hazardous location ignition systems. Waukesha Engine recommends dry spark plug installation.

NOTE: *Replace spark plug gaskets every time a spark plug (except P/N 69919) is reinstalled.*

1. Clean and regap spark plugs every 720 hours or as required. Replace spark plugs every 1440 hours or as required. When regapping spark plugs, examine each spark plug for cracked porcelain, leakage and burned electrodes.

2. Examine spark plug firing end for abnormal spark plug conditions (see Table 5.10-2). See Table 5.10-1 and Table 5.10-3 for specifications and spark plug part numbers.

NOTE: *Spark plugs 60999Y and 60999U are for use with early integral coils. Spark plugs 69919, 60999S and 60999W are used with CSA flange mounted coils.*

Table 5.10-1. Spark Plug Specifications

ITEM	SPECIFICATION
Spark Plug Gasket (18 mm)	P/N 209681 or 499865
Spark Plug, P/N 69919, Torque, Dry	29 - 39 ft-lb (39 - 49 N·m)
Spark Plug, P/N 60999Z, Torque, Dry	32 - 38 ft-lb (43 - 52 N·m)
All Other Spark Plugs, Torque, Dry	40 - 45 ft-lb (54 - 61 N·m)
Spark Plug Carrier, Torque, Lubricated With Engine Oil	105 - 115 ft-lb (140 - 155 N·m)

Table 5.10-2. Spark Plug Troubleshooting

FIRING TIP APPEARANCE	CONDITION	REMEDY
Light coating of whitish ash, uniformly deposited.	Normal with medium to high ash lube oils.	No change.
Excessive ash build-up.	High oil consumption. Wrong lube oil; oil has high ash content. Poor oil control around the valve guides and rings.	Change the engine lube oil type. Change the engine lube oil. Inspect and replace worn parts as necessary.
Black oil fouling deposits.	Poor oil control. Engine is too lightly loaded.	Replace worn parts as necessary. Adjust the engine load.
Gap bridging.	Contaminated or “dirty” fuel gas.	Add a fuel filter. Use a more “open” electrode type of plug.
Carbon fouling.	Spark plug firing tip temperature too low. Engine is too lightly loaded. High oil consumption.	Change the plug heat range. Adjust the engine load. Inspect and replace worn parts as necessary.
Electrode is burning.	Spark plug firing tip temperature is too high.	Change the plug heat range.
Wear on side of the electrode.	Reversed polarity of the ignition coils.	Rewire the ignition coils correctly.
Aluminum contamination on plug.	Engine is operated with severe detonation, causing piston damage.	Inspect piston with a bore scope; replace worn parts as necessary. Check the spark timing, fuel gas octane. Reduce the engine load.
Blue or green deposit on plug and valve.	Cobalt fouling from worn Stellite® valve.	Replace the valve and valve seat.

NOTE: *Stellite® is a registered trademark of Stoody Deloro Stellite, Inc.*

Table 5.10-3. Spark Plug Recommendations

ENGINE MODEL	FUEL	DUTY	SIZE AND REACH	UNSHIELDED APPLICATIONS		SHIELDED (CSA) APPLICATIONS	
				P/N	Gap (in.)	P/N	Gap (in.)
F18/H24GL/GLD	Natural Gas	Standard	18 mm - 13/16 in.	60999W	0.010 - 0.013	60999Y 69919 60999S 60999W	0.010 - 0.013
	Natural Gas	High Temp Applications	18 mm - 13/16 in.	69919	0.010 - 0.012	60999Y 69919 60999S 60999W	0.010 - 0.012
	Natural Gas	176 BMEP Applications	18 mm - 13/16 in.	69919	0.010 - 0.012	60999Y 69919 60999S 60999W	0.010 - 0.012
F18/H24GSID	Natural Gas	All	18 mm - 13/16 in.	60999S	0.010 - 0.013	60999U 60999S	0.010 - 0.013

SPARK PLUG POLARITY

The system is designed to deliver negative voltage to the spark plug center electrode. If improper wiring causes positive voltage to be delivered to the plug, the voltage required to jump the gap may increase as much as 45%. If the ignition system cannot deliver the increased voltage, the plug will not fire. Fouling or missing will occur. The center electrode normally runs at a higher temperature than the shell electrodes. The hotter center electrode is better able to discharge a spark than the colder one. If the polarity is correct, the wear will take place on the center electrode rather than the side electrodes.

IGNITION COILS

IGNITION COIL REMOVAL

Flange Mounted (CSA) Coil

1. Disconnect primary shielded lead from flange mounted ignition coil (see Figure 5.10-26).

2. Remove three M8 x 20 mm hex head screws and remove CSA coil (see Figure 5.10-26).

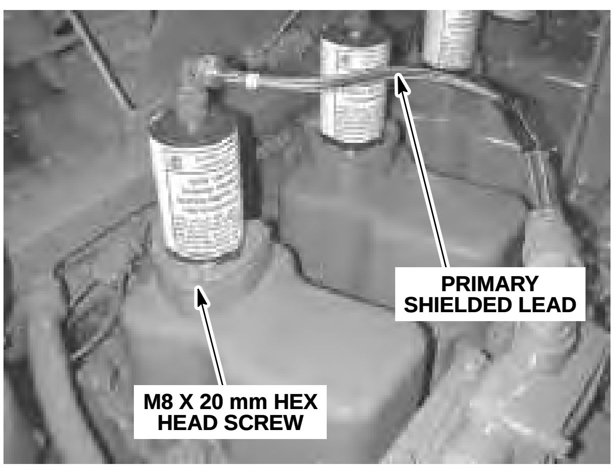


Figure 5.10-26. CSA Ignition Coil

3. Remove all oil, grease and dirt from ignition coils. Pay particular attention to the area around the primary terminals. Thoroughly clean the ignition coil contacts. Use a soft brass wire brush if corrosion or an accumulation of dirt is present. Inspect contacts for damage.

Standard (Non-CSA) Coil

1. Remove rubber boot from coil terminal connection. Remove spark plug cable from ignition coil (see Figure 5.10-27).

2. Remove two M8 x 16 mm hex head screws, lock washers and flat washers from ignition coil brackets. Remove wiring leads and remove coil.

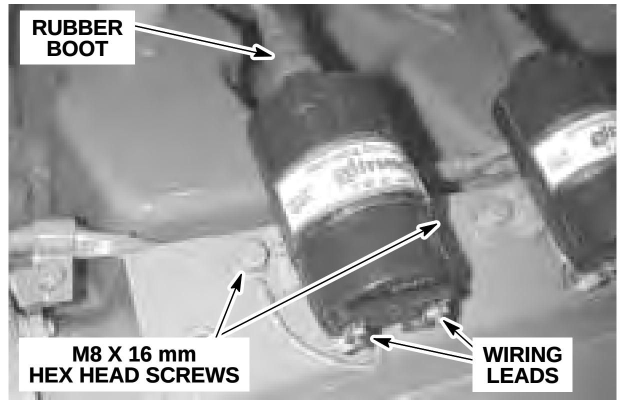


Figure 5.10-27. Standard Ignition Coil

3. Remove all oil, grease, and dirt from ignition coils. Pay particular attention to area around primary terminals. Use a soft brass wire brush if corrosion or an accumulation of dirt is present. Inspect contacts for damage.

IGNITION COIL TESTING

⚠ WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

⚠ WARNING

Certain tests associated with the ignition coils will create an electrical arc. Do not test coils in a combustible atmosphere. Make sure all fuel has been purged from the engine (if testing in the vicinity). Failure to comply can cause severe personal injury or death.

⚠ WARNING

Keep all parts of your body away from the ignition coil when performing tests. Electrical shock can cause severe personal injury or death.

Inspect and test the ignition coils once each year.

Table 5.10-4. Special Tools For Testing Ignition Coil

TOOL P/N	TOOL DESCRIPTION
475077	Ignition Analyzer

NOTE: *An ignition system troubleshooting video (Form P-1249) or CD-ROM (Form P-1250) is available from the Waukesha Product Training Center that highlights the analyzer's use in practical ignition troubleshooting applications on all Waukesha engines. See the AccuTek II® operators manual for a complete list of all ignition coil tests and engine instrument tests. Only basic ignition coil tests are listed in this manual.*

1. Verify 24 VDC at power supply and at CEC Ignition Module. CEC Ignition Module requires 24 VDC for proper operation.

NOTE: *If there is a difference of more than 1 VDC between the power supply and the Ignition Module, the engine ignition system will not function properly.*

If greater than 1 VDC difference between power supply and Ignition Module:

1. Clean power supply and Ignition Module connections.

2. Clean Ignition Module ground wire connections.

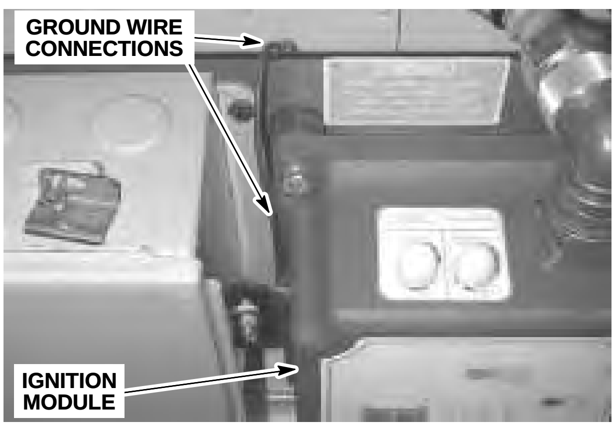


Figure 5.10-28. Ignition Module Ground Wire

3. Verify power supply "ripple" is within limits. Waukesha requires 2 volts peak to peak power.

Energy Test

NOTE: *One technique is to write the energy reading directly on the coil. Compare the past energy readings with those recently taken. Any coil that has an energy reading significantly different than the other coils or past readings, should be replaced. All ignition coils must be the same make and model in order to obtain accurate results.*

1. Set test control dial on AccuTek II ignition analyzer to coil/ign.

2. Set measurement dial to energy.

3. Connect black lead to a common ground (engine block, etc.).

4. Connect red lead to primary coil lead (see Figure 5.10-29).

Figure 5.10-29. Standard Ignition Coil

5. Record energy readings from each coil. Energy units are a product of peak firing voltage and duration.

Peak Voltage Test

NOTE: *One technique is to write the voltage readings directly on the coil. Compare the past voltage readings with those recently taken. Any coil that has a voltage reading significantly different than the other coils or past readings, should be replaced.*

1. Set test control dial on AccuTek II ignition analyzer to coil/ign.

2. Set measurement dial to voltage.

3. Connect black lead to a common ground (engine block, etc.).

4. Connect red lead to shutdown (G) lead (storage capacitor) and record reading.

5. Connect red lead to primary coil lead and record voltage reading (see Figure 5.10-30). Repeat for remaining coils.

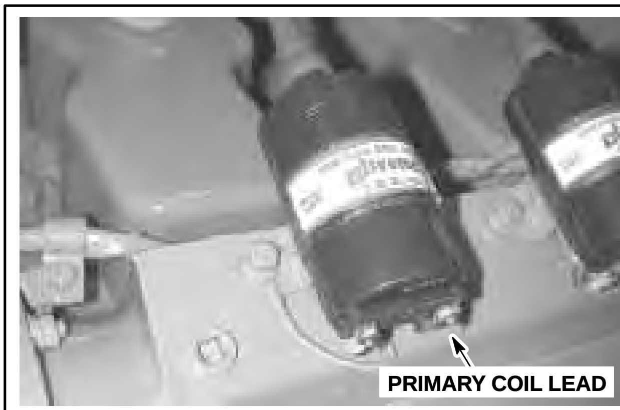


Figure 5.10-30. Standard Ignition Coil

6. Shutdown lead voltage reading should approximate coil readings (160 – 175). If shutdown lead reading differs significantly, investigate lead and ignition wiring.

7. Compare readings between coils. Replace any coils that differ significantly.

Duration Test

NOTE: *The duration test measures the IM's ability to produce current, the ability of the wiring harness to transfer current and the ability of the primary winding of the coil to accept current. Duration values of 30 microseconds (± 4) are typical. Lower duration values indicate a ground short in the primary lead. Higher duration values indicate high resistance. Readings exceeding 6 microseconds apart are usually indicative of problems within the primary or secondary circuits of the coil.*

1. Set test control dial on AccuTek II ignition analyzer to coil/ign.

2. Set measurement dial to duration.

3. Connect black lead to a common ground (engine block, etc.).

4. **Non CSA—**Connect red lead to primary coil lead and record duration (see Figure 5.10-31).

Figure 5.10-31. Standard Ignition Coil

5. **CSA—**Disconnect primary shielded lead from coil (see Figure 5.10-32).

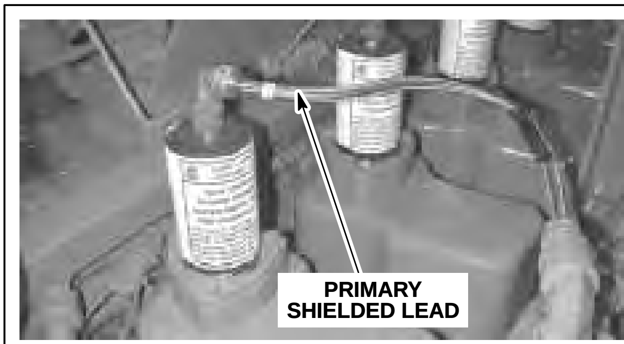


Figure 5.10-32. CSA Ignition Coil

6. **CSA—**Connect red lead to top of CSA coil using adapter and record duration (see Figure 5.10-33).

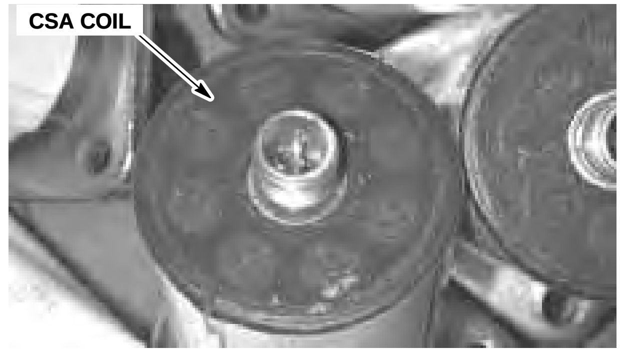


Figure 5.10-33. CSA Ignition Coil

Missing Pulse (Misfire) Test

1. Set test control dial on AccuTek II ignition analyzer to coil/ign.

2. Set measurement dial to missing pulse.

3. Connect black lead to a common ground (engine block, etc).

NOTE: *The ignition analyzer will shut down if 10 or more missing pulses are counted.*

4. **Non CSA—**Connect red lead to primary coil lead and check for missing pulses (see Figure 5.10-34).

Figure 5.10-34. Standard Ignition Coil

5. **CSA—**Connect red lead to primary coil lead located in conduit box and check for missing pulses (see Figure 5.10-35).

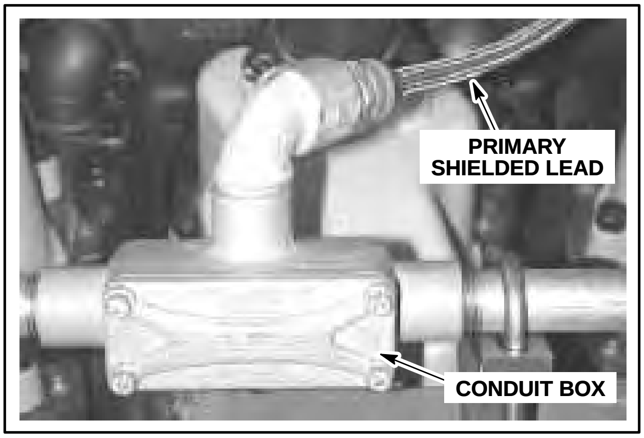


Figure 5.10-35. Conduit Box

Insulation Integrity Test

1. Set test control dial on AccuTek II ignition analyzer to megger.

2. Set measurement dial to volts.

3. Press test button and set voltage to 700.

4. Disconnect wiring harness from junction box.

NOTE: *Refer to the electrical schematics at the end of this section for "pin" identification. Test each pin to verify insulation integrity. A reading of 100 is considered good.*

5. Connect black lead to a common ground (engine block, etc.).

6. Touch red lead to each pin and check insulation integrity.

Coil Resistance Test (Non CSA)

NOTE: *The AccuTek II operations manual lists the primary and secondary resistance for all coils. Check the operations manual to verify the correct resistance specifications.*

1. Measure primary and secondary coil winding resistance. Replace coil if either winding measurement exceeds specified tolerance.

NOTE: *The resistance of the coil secondary winding is measured between the top coil terminal connection and the bottom negative (–) terminal. The primary resistance is measured between the bottom negative (–) terminal and the bottom positive (+) terminal (see Figure 5.10-36).*

2. If a defective coil is suspected, then replace coil with a new one.

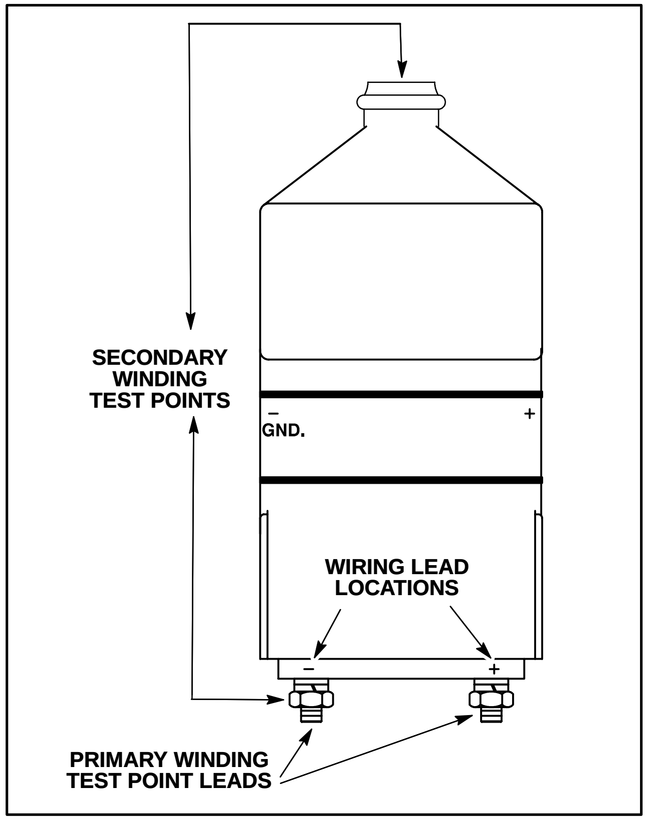


Figure 5.10-36. Standard Ignition Coil – P/N 69694

Coil Resistance Test (CSA–Flange Mounted)

NOTE: *The AccuTek II operations manual lists the primary and secondary resistance for all coils. Check the operations manual to verify the correct resistance specifications.*

1. Measure primary resistance between "A" and "B" pins located on top of coil (Figure 5.10-37). Primary resistance should be 0.1 – 0.2 ohms.

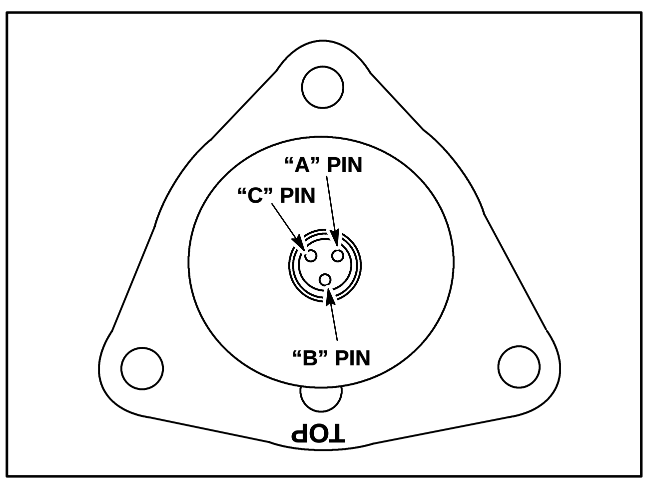


Figure 5.10-37. CSA (Flange Mounted) Coil

2. Measure secondary resistance between flange and high voltage (HV) cup located at bottom of coil. Secondary resistance should be 4,400 – 6,900 ohms (see Figure 5.10-38).

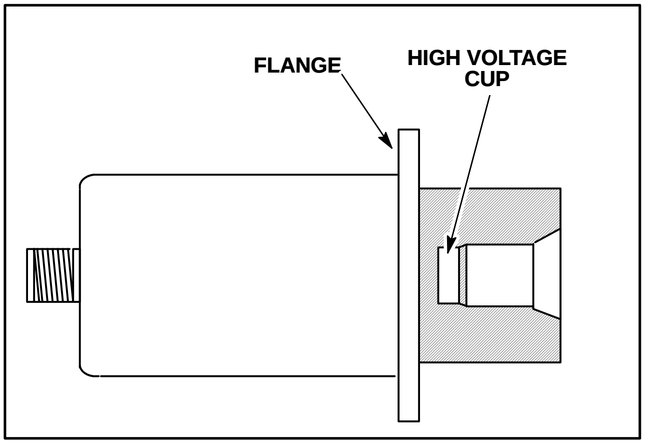


Figure 5.10-38. CSA Flange Mounted Coil

3. If a defective coil is suspected, then replace coil with a new one.

Coil Extension Test

⚠ WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

⚠ WARNING

Keep all parts of your body away from the ignition coil when performing tests. Electrical shock can cause severe personal injury or death.

1. Connect adapter to top of coil extension. Plug lead from adapter into top of ignition analyzer.

2. Set test control dial on AccuTek II ignition analyzer to coil/ign.

3. Set measurement dial to voltage.

4. Press test button and adjust voltage until it reads approximately 200.

5. Set measurement dial to duration. Press test button.

6. Observe electrical arc pattern (see Figure 5.10-39).

NOTE: *An electrical arc should travel from the tip of the spark plug to the bottom of the coil extension. The arc should vary in position on the coil extension (indicates no carbon tracking). The absence of an external arc indicates an electrical leak internally and repairs to the lead are required. If in doubt, compare results to a known good shielded secondary lead.*

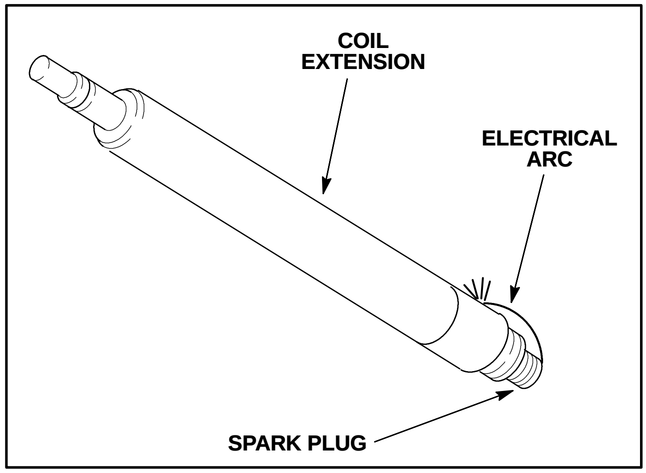


Figure 5.10-39. Spark Plug Extension

IGNITION COIL INSTALLATION

NOTE: *To help seal out moisture and prevent corrosion, use Krytox® GPL–206 (P/N 489341) on the high tension connectors between the coils and the spark plug connectors.*

Standard Coil (Non CSA)

1. Install positive and negative wiring leads. Positive leads are tagged with cylinder location number (see Figure 5.10-40).

NOTE: *The lead with the yellow collar is negative (–) and the lead with the blue collar is positive (+). To find the location of the negative and positive terminals on the coil, look for the stamp on the side of the bottom lip.*

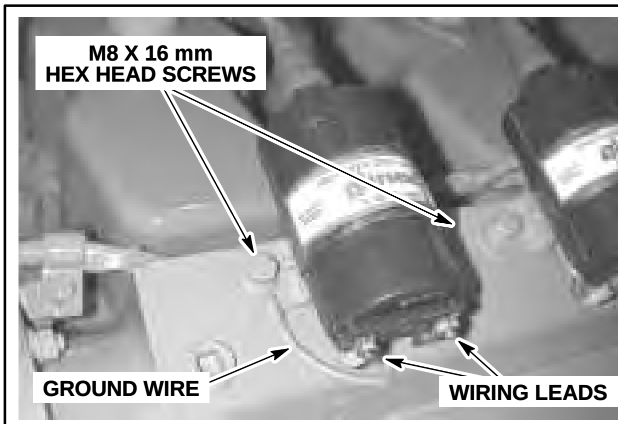


Figure 5.10-40. Standard Ignition Coil

⚠ CAUTION **Do not reverse the polarity of the ignition coils. The spark plugs may not fire and fouling or missing will occur. Disregarding this information could result in product damage and/or personal injury.**

2. Verify wiring leads to each ignition coil are properly installed.

3. Inspect condition of spark plug cable. Replace if cable shows signs of damage.

NOTE: *To help seal out moisture and prevent corrosion, use Krytox® GPL-206 (P/N 489341) on the high tension connectors between the coils and the spark plug connectors.*

4. Attach spark plug cable to ignition coil.

NOTE: *Make sure that the cable terminal connection bottoms out in the ignition coil contact well.*

5. Slide rubber boot over coil terminal connection.

⚠ CAUTION **A poor common ground for the ignition coils can cause misfiring. Disregarding this information could result in product damage and/or personal injury.**

NOTE: *Four cylinders have a ground wire attached to the coil mounting bracket hex head screw. These ground leads originate from the negative coil leads and are located at cylinders #1L, #6L (or #8L), #1R and #6R (or #8R).*

6. Verify that cylinders #1L, #6L (or #8L), #1R and #6R (or #8R) have ground wires secured to mounting brackets using M8 screws (see Figure 5.10-41).

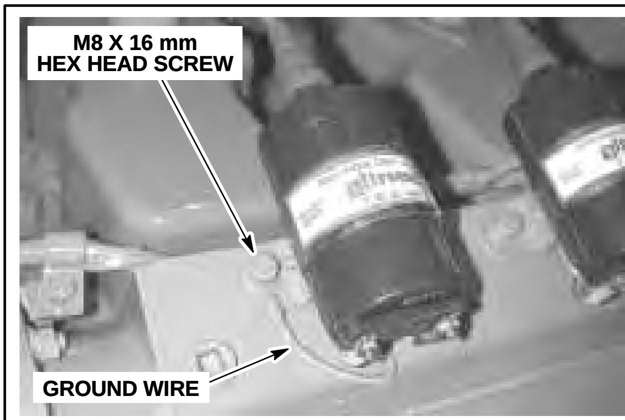


Figure 5.10-41. Coil Ground Wire Attachment

Flange Mounted (CSA) Coil

1. Always replace coil O-ring with a new O-ring whenever the coil is removed (see Figure 5.10-42).

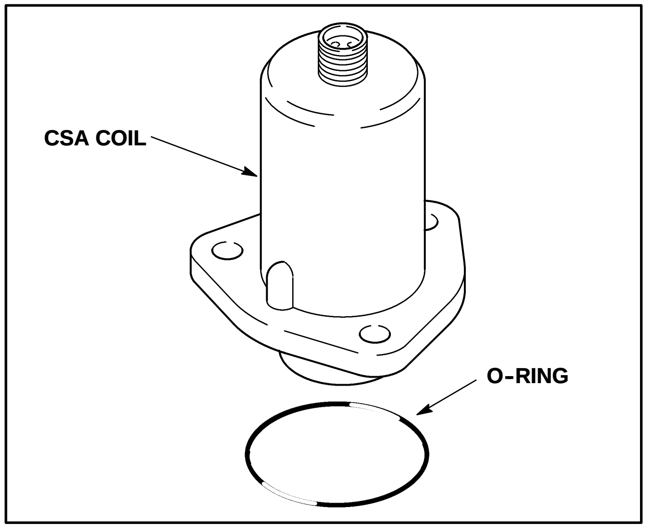


Figure 5.10-42. Current Blue Coil

NOTE: *When installing flange mounted CSA coils, position them on the rocker arm cover so the key way on the cannon plug will align with the ignition lead, without excessive twisting of the lead.*

2. Install flange mounted CSA coil and O-ring.

⚠ CAUTION **Ignition coils that are improperly grounded can cause misfiring. Make sure CSA coils are installed with three M8 x 20 mm hex head screws that are properly tightened. Disregarding this information could result in product damage and/or personal injury.**

3. Secure coil with three M8 x 20 mm hex head screws and tension washers (see Figure 5.10-43). Tighten M8 x 20 mm hex head screws to 16 – 17 ft-lb (21.6 – 23 N·m) (oiled threads).

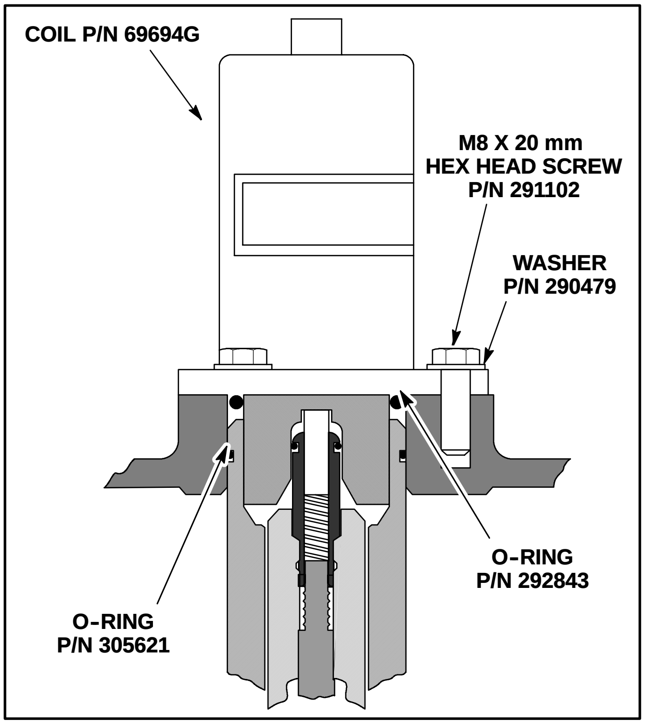


Figure 5.10-43. Coil Installation

4. Connect primary shielded lead to coil (see Figure 5.10-44).

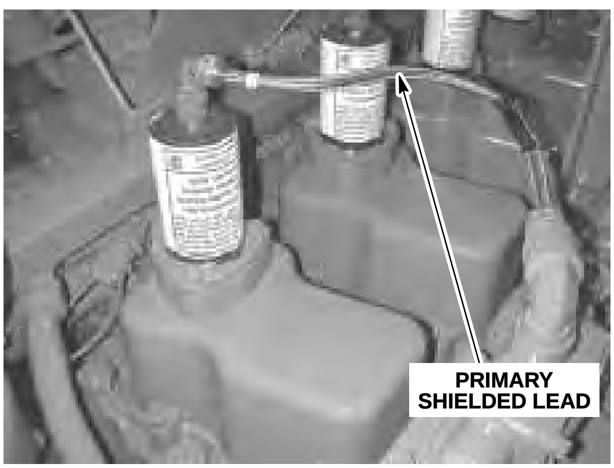


Figure 5.10-44. CSA Ignition Coil

WIRING HARNESS

WIRING HARNESS REMOVAL

Inspect the ignition wiring harness once each year. If the engine is installed indoors, this time frame may be extended provided that no defects are found after a careful examination.

NOTE: *CEC Ignition Module is now standard. This task references both Ignition Module and magneto systems.*

⚠ WARNING

If the ignition switch is left in the ON position when a CEC Ignition Module is disconnected, then the spark plugs may fire when the ignition system harness is reconnected, and could cause severe personal injury or death.

- If ignition harness is disconnected from CEC IM, turn ignition switch “OFF” and go to Step 1.
- If ignition harness is connected to CEC IM, turn ignition switch “OFF” and go to Step 3.

⚠ WARNING

As a safety measure, ground all electrical pins. Some breakerless ignition systems have more than one storage capacitor. Failure to ground all electrical pins and discharge capacitors could result in severe personal injury or death.

1. Verify ignition switch is “OFF.” Attach wire lead to crankcase.

2. Touch opposite end of wire lead to each exposed IM electrical pin. A snap is heard when a capacitor discharges. Go to Step 5.

3. Verify ignition switch is “OFF.” Loosen sleeve and remove ignition harness from connector on IM (see Figure 5.10-45).

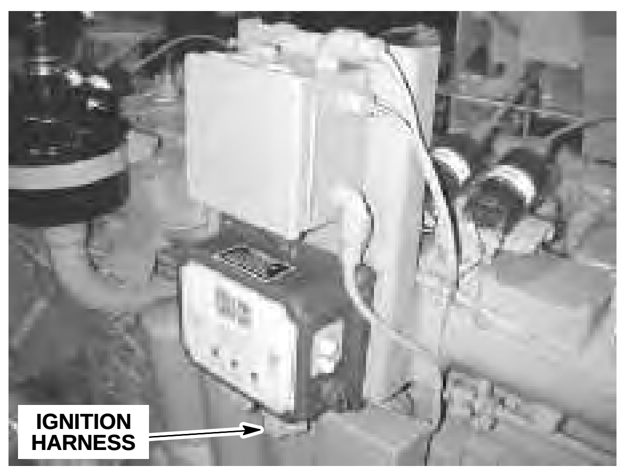


Figure 5.10-45. Current Ignition Module

NOTE: *If the ignition switch is in the “OFF” position, the capacitor is immediately grounded when the ignition harness is reconnected to the CEC IM.*

4. As a precaution, reconnect ignition harness into IM connector to ground all electrical pins (discharge capacitors), then remove ignition harness from IM.

5. **Non-CSA—**Remove wire harness leads from ignition coils (see Figure 5.10-46).

NOTE: *Four cylinders have a ground wire attached to the coil mounting bracket hex head screw. These ground leads originate from the negative coil leads and are located at cylinders #1L, #6L (or #8L), #1R and #6R (or #8R).*

6. **Non-CSA—**Remove coil mounting bracket M8 x 16 mm hex head screw and ground wire from appropriate cylinders (see Figure 5.10-46).

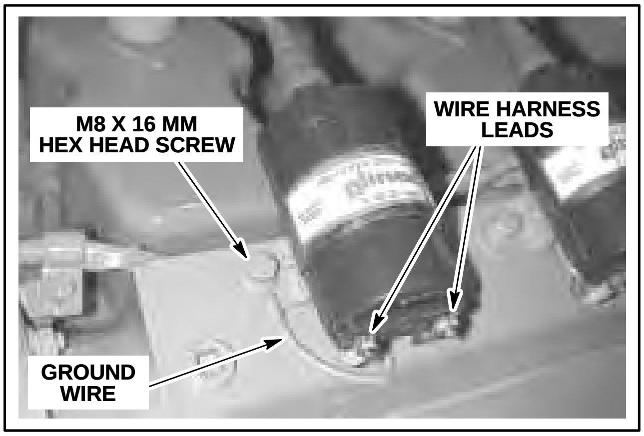


Figure 5.10-46. Harness Ground Wire - Right Rear

7. **Non-CSA—**Remove M8 x 20 mm hex head screws and wire harness clips from intake manifold (see Figure 5.10-47).

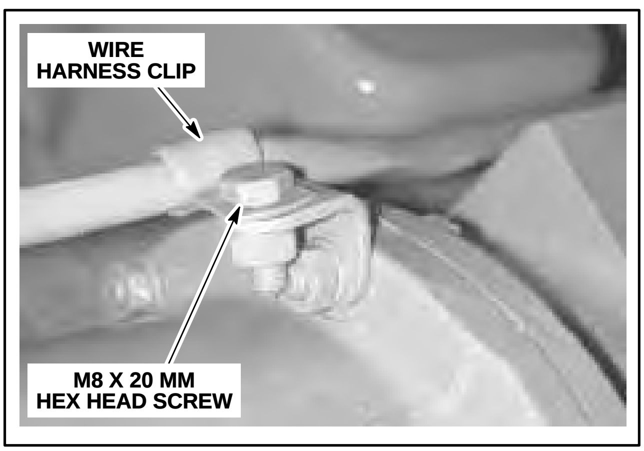


Figure 5.10-47. Non CSA Ignition Harness Clip

8. **CSA—**Open junction box and disconnect ignition harness wires from terminals. Loosen sleeves and remove ignition harness from junction box (see Figure 5.10-48).

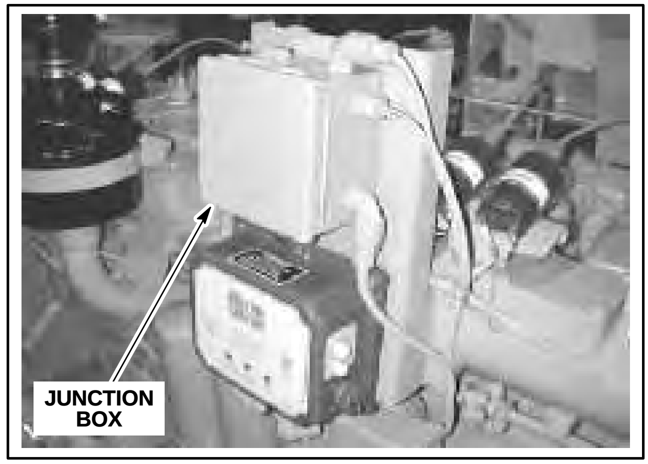


Figure 5.10-48. Current Ignition Module

9. **CSA—**Remove primary shielded lead from either conduit box or CSA coil (see Figure 5.10-49).

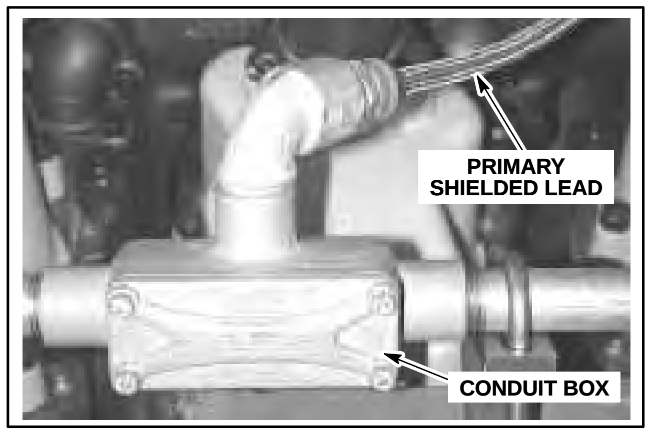


Figure 5.10-49. Conduit Box

10. **CSA—**Remove U-bolts from conduit (see Figure 5.10-50).

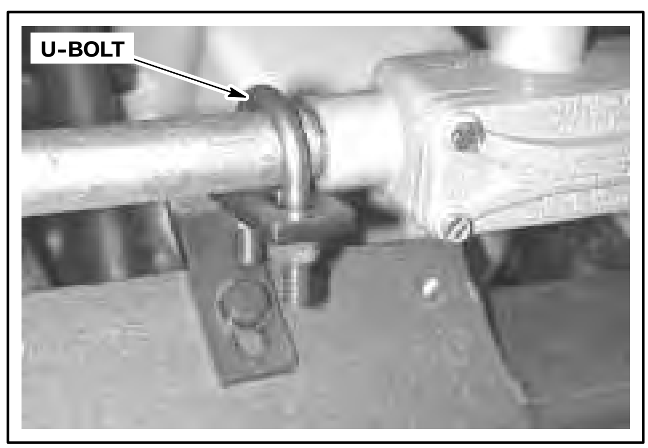


Figure 5.10-50. CSA Conduit U-Bolt

11. Remove intake manifold flange capscrews to detach wire harness cable retaining clips (see Figure 5.10-51).

Figure 5.10-51. Wiring Harness

12. Remove ignition wiring harness from engine and spread out harness on clean flat surface.

WIRING HARNESS INSPECTION

1. Inspect wiring harness for burned, chafed, frayed or cracked insulation. Look for cracks, cuts, tears, oil contamination or any other damage that can cause a short to ground.

2. Inspect harness for pinched, broken or frayed wires.

3. Look for loose, damaged or corroded ignition coil contacts. Use a soft brass wire brush if corrosion or an accumulation of dirt is present.

4. Check condition and security of harness cable plug and receptacle connection.

5. Replace harness if damaged or deteriorated.

6. If wiring harness can be reused, verify that all wire exits and sleeve junctions are securely taped to keep out moisture and dirt. Thoroughly seal or plug all wire exits with Dow Corning RTV #734 or equivalent.

WIRING HARNESS INSTALLATION

NOTE: *CEC Ignition Module is now standard. This task references both Ignition Module and magneto systems.*

⚠ WARNING

If the ignition switch is left in the ON position when a CEC Ignition Module is disconnected, then the spark plugs may fire when the ignition system harness is reconnected and could cause severe personal injury or death.

- If ignition harness is disconnected from CEC IM, turn ignition switch “OFF” and go to Step 1.
- If ignition harness is connected to CEC IM, turn ignition switch “OFF” and go to Step 3.

⚠ WARNING

As a safety measure, ground all electrical pins. Some breakerless ignition systems have more than one storage capacitor. Failure to ground all electrical pins could result in severe personal injury or death.

1. Verify ignition switch is “OFF.” Attach wire lead to crankcase.

2. Touch opposite end of wire lead to each exposed IM electrical pin. A snap is heard when a capacitor discharges. Go to Step 5.

3. Verify ignition switch is “OFF.” Loosen sleeve and remove ignition harness from connector on IM (see Figure 5.10-52).

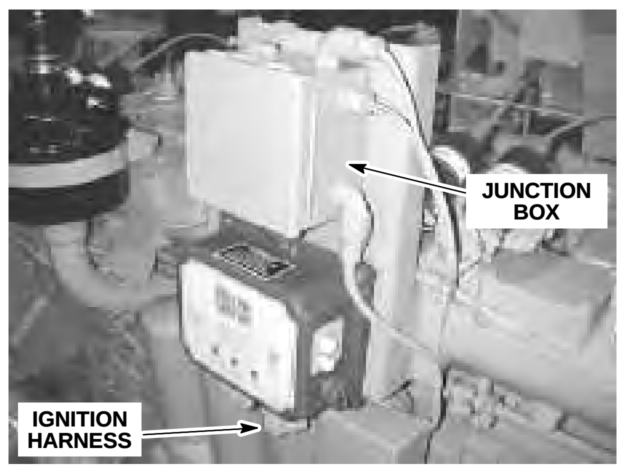


Figure 5.10-52. Current Ignition Module

NOTE: *If the ignition switch is in the OFF position, the capacitor is immediately grounded when the ignition harness is reconnected to the CEC Ignition Module.*

4. As a precaution, reconnect ignition harness into IM connector to ground all electrical pins (discharge capacitors), then unplug ignition harness from IM.

NOTE: *The right side ignition harness has a cannon plug that connects to the CEC IM (or magneto).*

5. Route cannon plug between intake manifold and crankcase (see Figure 5.10-53, Figure 5.10-54 Figure 5.10-55, and Figure 5.10-56).

⚠ WARNING

Do not attach the harness pin connector plug to the magneto (at this time). Rapid rotation of the crankshaft will generate an electrical charge at the coil connections, which may result in electrical shock and/or personal injury or death.

6. Move to right side of engine and lay end of ignition wiring harness on intake manifold. Locate pin connector plug (for hook up to the Ignition Module or magneto) (see Figure 5.10-53, Figure 5.10-54, Figure 5.10-55 and Figure 5.10-56).

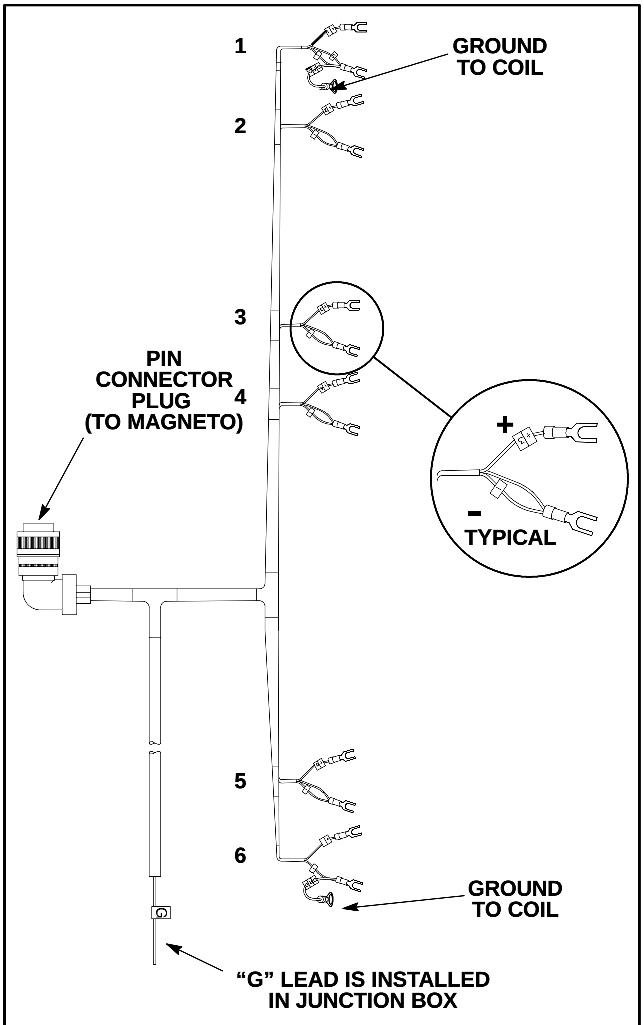


Figure 5.10-53. Six Cylinder Ignition Module Harness

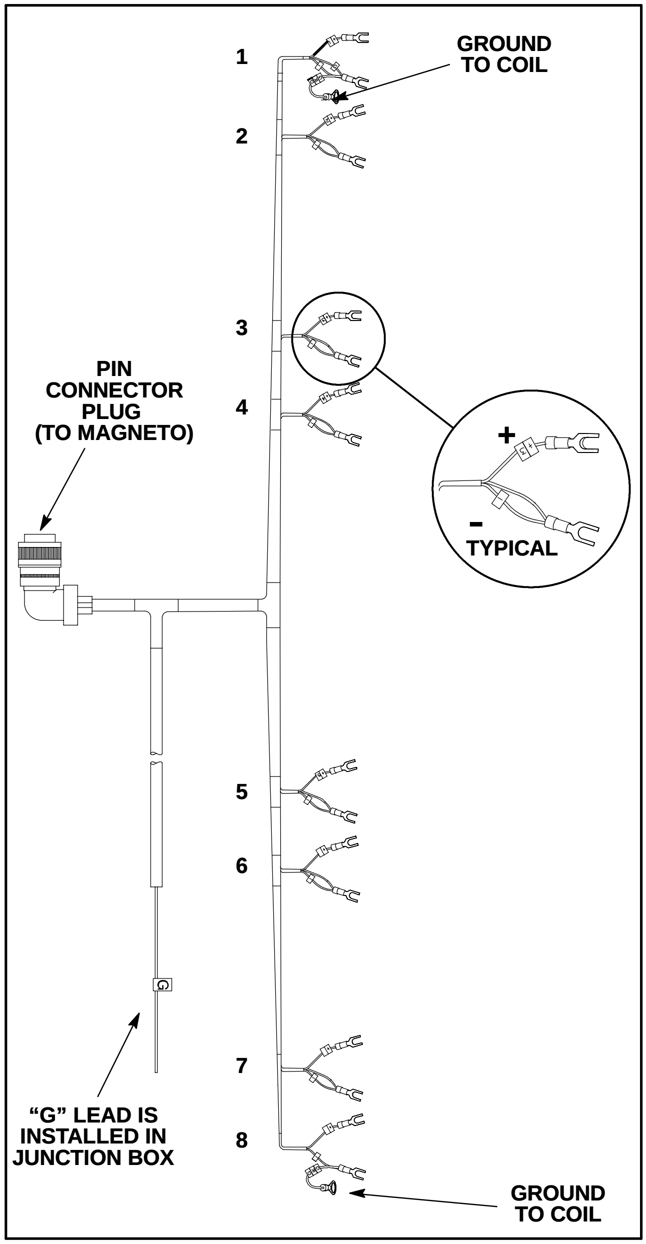


Figure 5.10-54. Eight Cylinder Ignition Module Harness

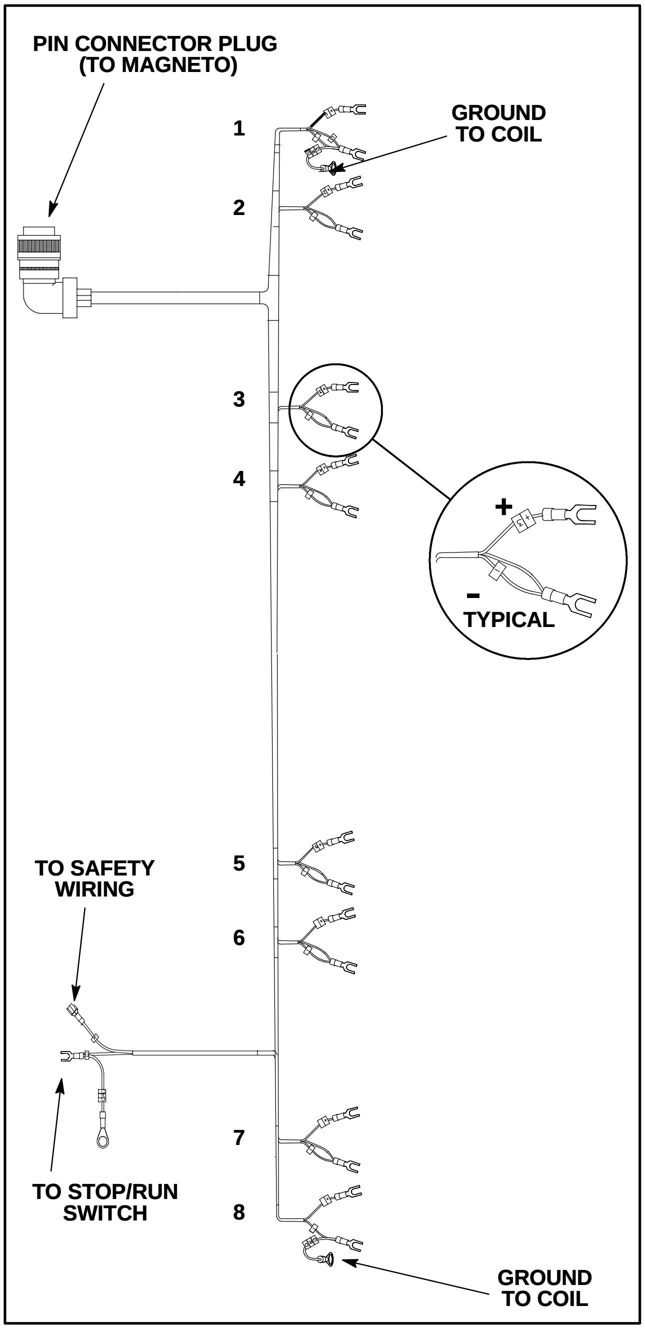


Figure 5.10-55. Eight Cylinder Magneto Harness

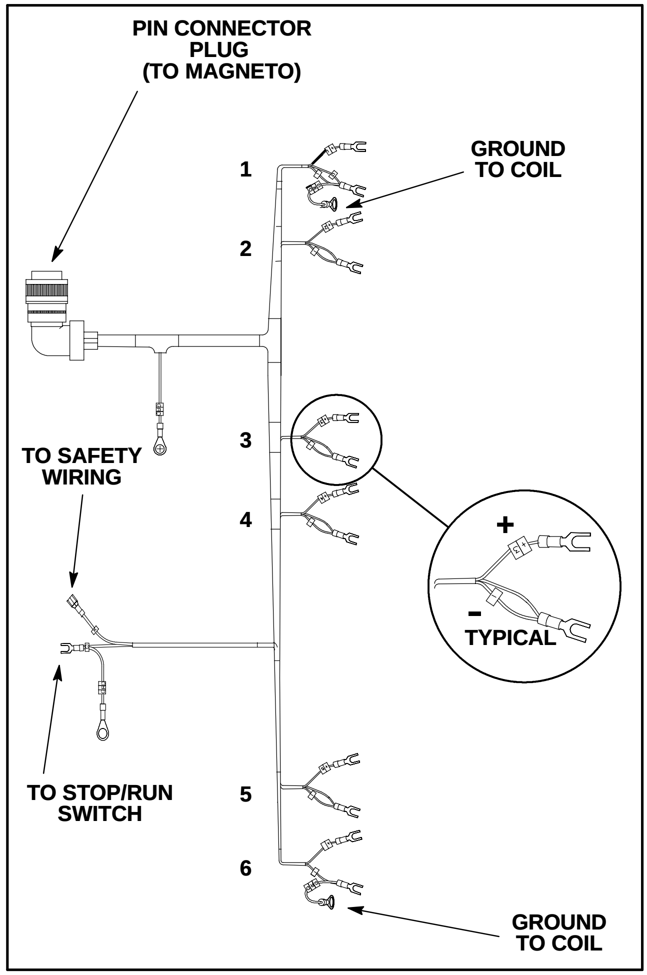


Figure 5.10-56. Six Cylinder Magneto Harness

7. **CSA—**Secure primary shielded lead to either conduit box or CSA coil, as applicable (see Figure 5.10-57).

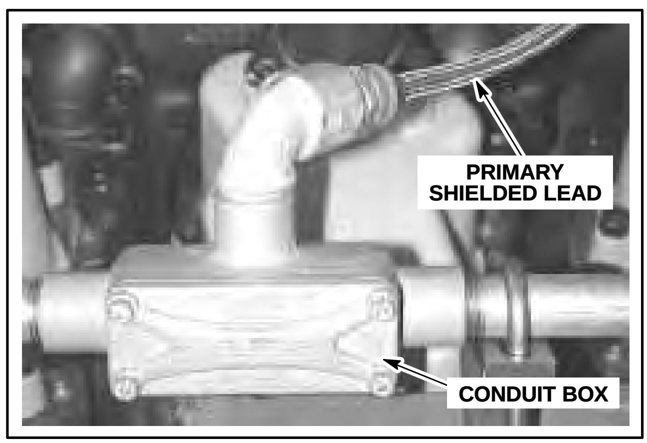


Figure 5.10-57. Conduit Box

8. **CSA—**Secure conduit to manifold with U-bolts (see Figure 5.10-58).

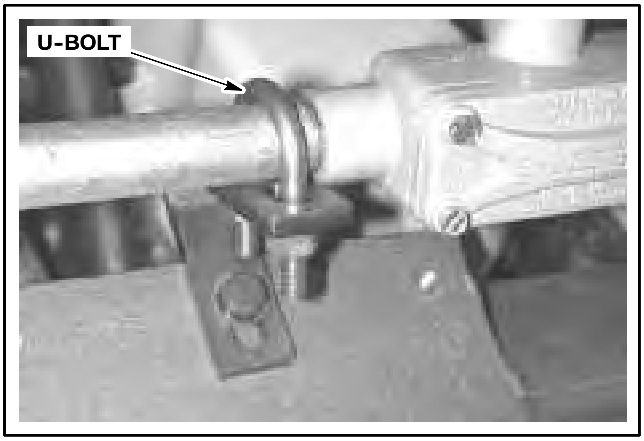


Figure 5.10-58. CSA Conduit U-Bolt

9. Harness attaches to intake manifold with clips and capscrews (3 places) (see Figure 5.10-59 and Figure 5.10-60). Harness clip attaches to support bracket with a M8 x 25 mm capscrew.

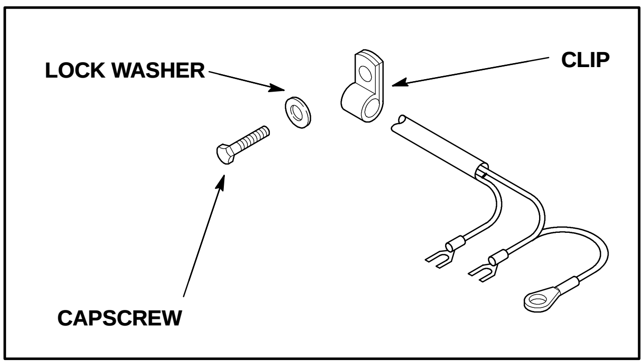


Figure 5.10-59. Wiring Harness Clip Installation

Figure 5.10-60. Wiring Harness

10. Attach wire harness leads to ignition coil. Yellow collar lead is negative (-) and blue collar lead is positive (+). Negative and positive coil terminals are marked.

NOTE: *A tag on each positive lead identifies the cylinder to which the leads are to be attached.*

11. Attach ground wires leading from negative coil leads (#1 and #6 - six cylinder) (#1 and #8 - eight cylinder) to one of the coil mounting bracket capscrews (see Figure 5.10-61).

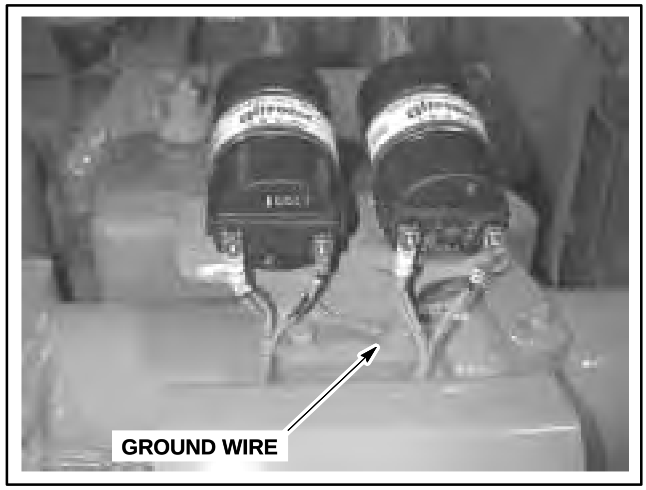


Figure 5.10-61. Coil Ground Wire

12. Connect wiring harness connector to Ignition Module/Junction Box, if applicable.

13. Install harness cable plug into magneto pin connector, if applicable.

14. Tie wrap magneto pin connector cable into a permanent drip loop (see Figure 5.10-62). Drip loop prevents moisture or rain from entering magneto.

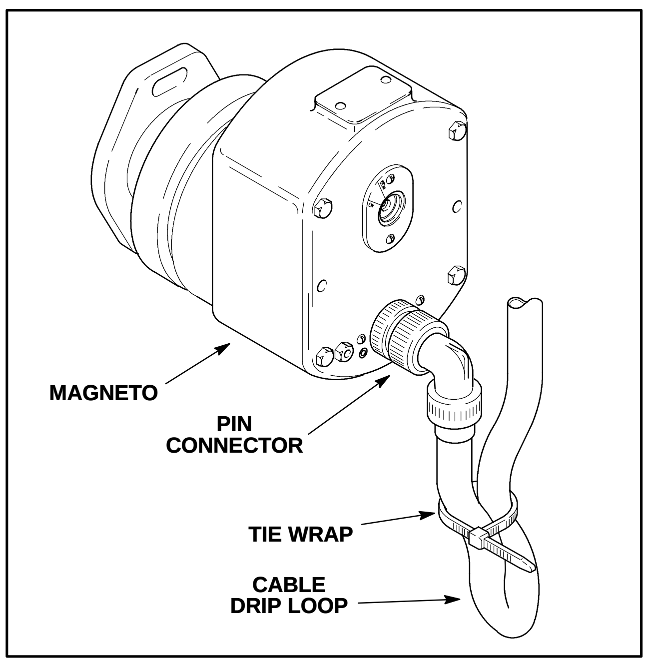


Figure 5.10-62. Magneto Pin Connector Cable

CEC IGNITION MODULE

CEC IGNITION MODULE/ JUNCTION BOX REMOVAL

⚠ WARNING

If the ignition switch is left in the ON position when a CEC Ignition Module is disconnected, then the spark plugs may fire when the ignition system harness is reconnected, and could cause severe personal injury or death.

- If ignition harness is disconnected from CEC Ignition Module, turn ignition switch "OFF" and go to Step 1.
- If ignition harness is connected to CEC Ignition Module, turn ignition switch "OFF" and go to Step 3.

⚠ WARNING

As a safety measure, ground all electrical pins. Some breakerless ignition systems have more than one storage capacitor. Failure to ground all electrical pins and discharge capacitors could result in severe personal injury or death.

1. Verify ignition switch is "OFF." Attach wire lead to crankcase.

2. Touch opposite end of wire lead to each exposed Ignition Module electrical pin. A snap is heard when a capacitor discharges. Go to Step 5.

3. Verify ignition switch is "OFF." Loosen sleeve and remove ignition harness from connector on Ignition Module (see Figure 5.10-63 or Figure 5.10-64).

NOTE: *If the ignition switch is in the "OFF" position, the capacitor is immediately grounded when the ignition harness is reconnected to the CEC Ignition Module.*

4. As a precaution, reconnect ignition harness into Ignition Module connector to ground all electrical pins (discharge capacitors), then remove ignition harness from Ignition Module.

5. Remove remaining wire harness connectors from Ignition Module.

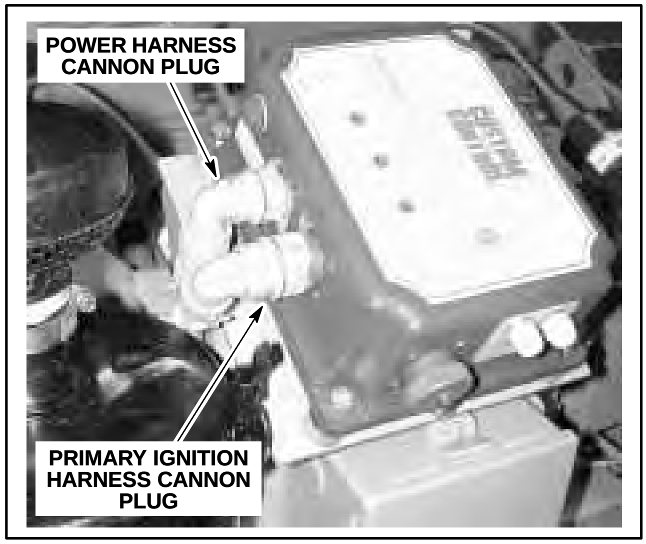


Figure 5.10-63. Previous Ignition Module Position

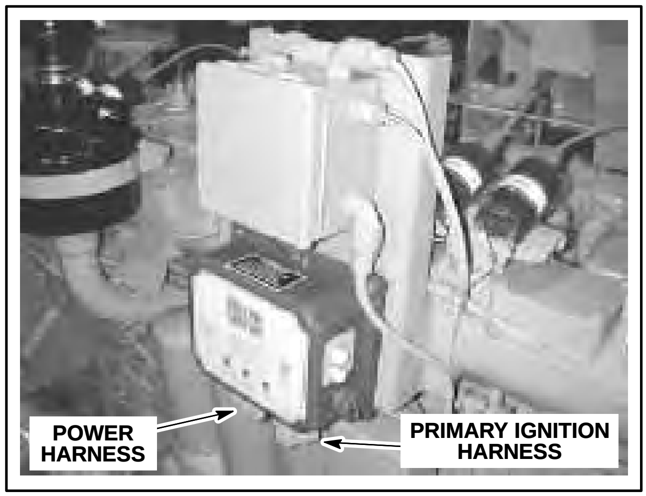


Figure 5.10-64. Current Ignition Module Position

NOTE: *Prior to removing any wiring harness from the junction box, to aid reinstallation, mark the terminal locations inside of the junction box.*

6. If Knock Detection Module (KDM) equipped, disconnect KDM wiring harness from bottom side of junction box (see Figure 5.10-65).

7. Disconnect hall sensor cable from lower right side of junction box (see Figure 5.10-65).

8. Disconnect ignition harness from top right of junction box (see Figure 5.10-65).

9. **Non CSA only**—Disconnect ignition shutdown harness from upper right side of Junction Box (see Figure 5.10-65).

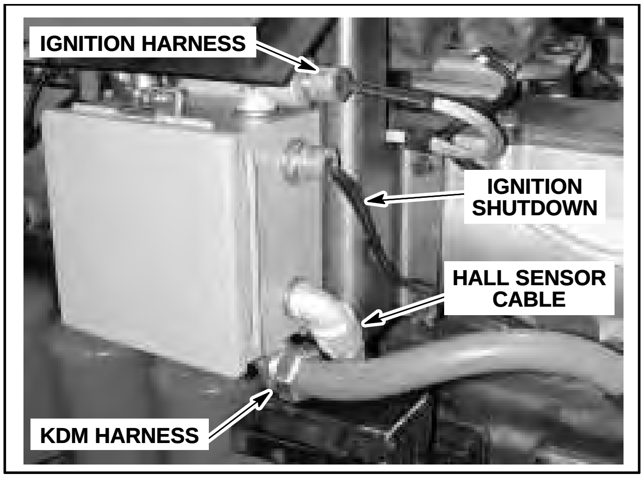


Figure 5.10-65. H24 (Non-CSA) Junction Box

NOTE: *The ground wire from Ignition Module to bracket must be disconnected. Depending on setup, Ignition Module ground wire may either be attached to Ignition Module capscrew or bracket capscrew. Remove appropriate capscrew or nut and disconnect ground wire (see Figure 5.10-66).*

10. Remove from Ignition Module, four capscrews, lock washers, rubber mounts and lock nuts (see Figure 5.10-66). Remove Ignition Module and retain hardware.

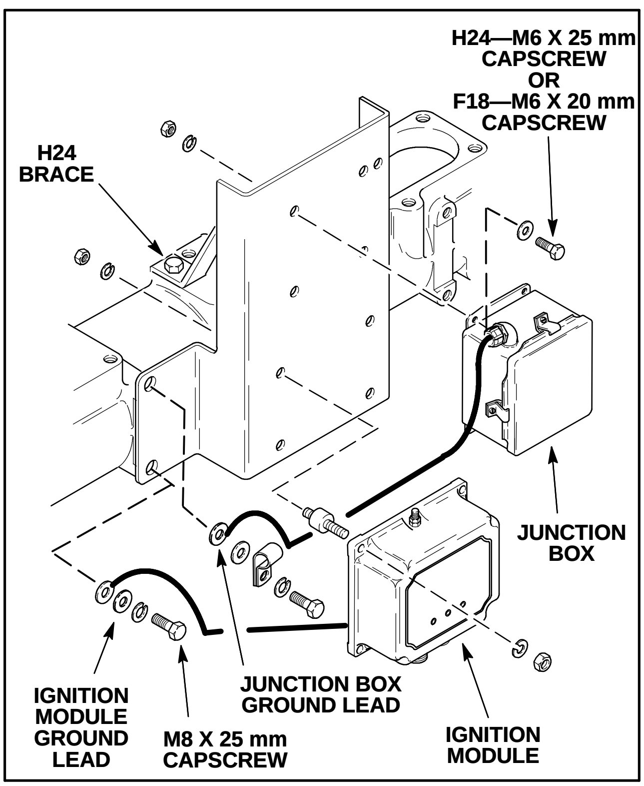


Figure 5.10-66. CEC Ignition Module/Junction Box

NOTE: F18 only—*If installed, Vortox Separator bracket will be located under left side of Ignition Module bracket and secured with M8 x 30 mm capscrews. Right side of Ignition Module bracket is secured with M8 x 30 mm capscrews and spacers.*

11. Remove from left side of bracket, bottom capscrew (either M8 x 25 mm or M8 x 30 mm depending on setup). Remove Junction Box to Chassis ground lead from between capscrew and bracket (see Figure 5.10-67).

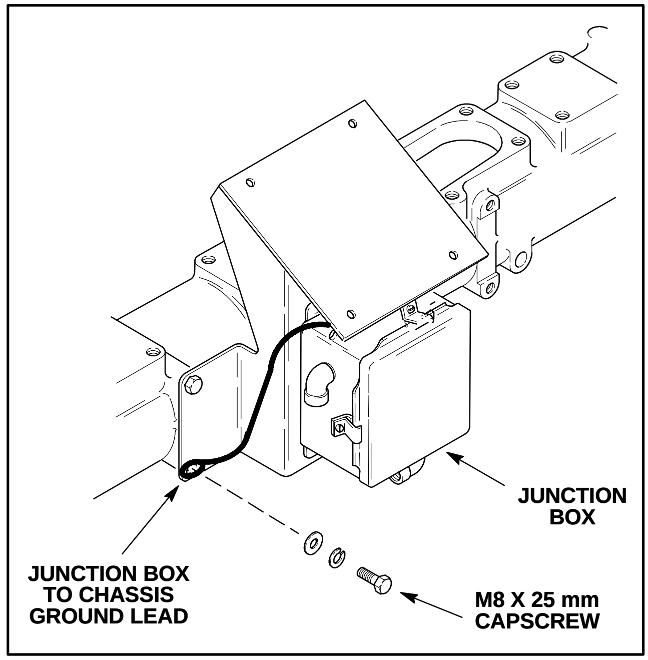


Figure 5.10-67. Junction Box And Bracket Assembly

12. Remove from Junction Box, four capscrews (M6 x 20 mm), flat washers, lock washers and nuts. Remove Junction Box.

13. Remove remaining left capscrew (M8 x 30 mm or M8 x 25 mm depending on setup), lock washer, flat washer and wire clip (see Figure 5.10-68).

14. Remove two right side capscrews (M8 x 30 mm or M8 x 25 mm depending on setup), lock washers, flat washers and wire clips (CSA does not contain lower wire clip). Remove Ignition Module/Junction Box bracket and retain hardware (see Figure 5.10-68).

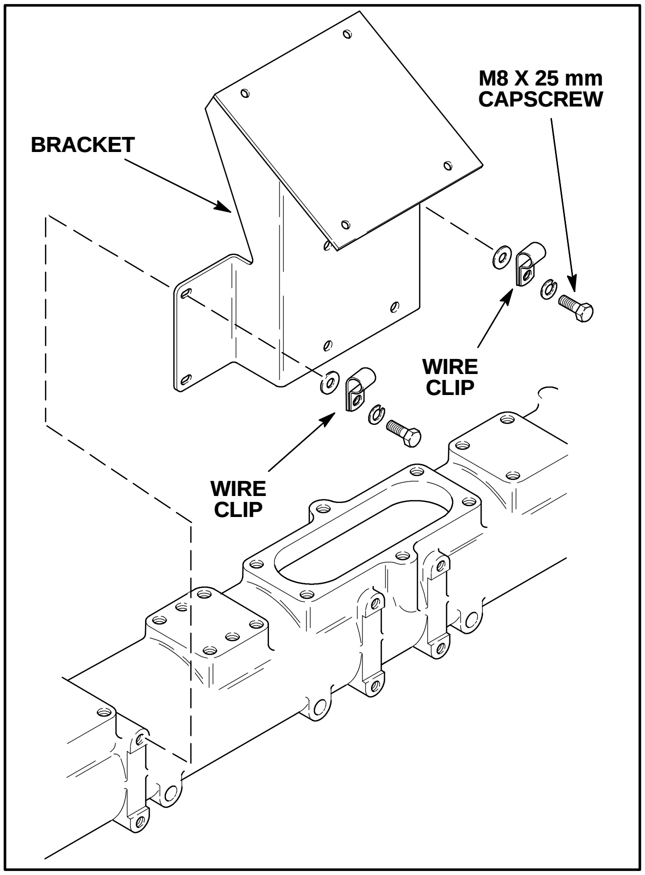


Figure 5.10-68. Ignition Module Bracket

15. If KDM equipped, disconnect KDM to Junction Box wiring harness cannon plug from KDM (see Figure 5.10-69). Disconnect wire clip (location may vary depending on setup—M6 x 20 mm or M10 x 35 mm) and remove KDM harness.

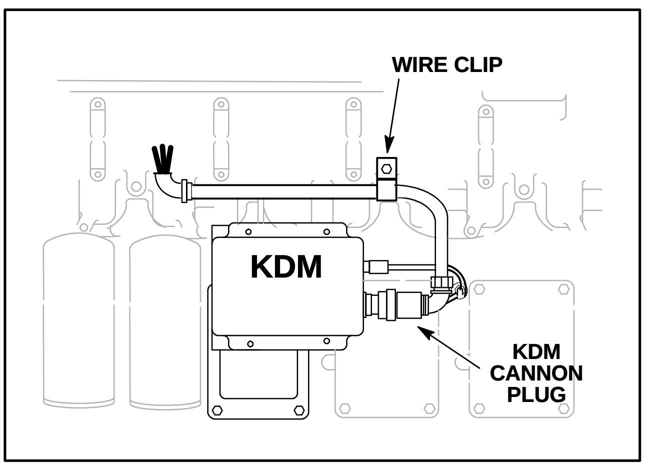


Figure 5.10-69. H24 KDM

CEC IGNITION MODULE/JUNCTION BOX BRACKET INSTALLATION (CURRENT MODEL)

NOTE: *The Junction Box to Chassis Ground is fastened to the upper left bracket capscrew after the Junction Box is installed. Do not install upper left capscrew at this time.*

1. Install bracket and secure with three M8 x 25 mm or M8 x 30 mm capscrews, lock washers and flat washers. Make sure wire clips are installed under both right side capscrews. (CSA does not use lower right wire clip). Do not fully tighten bracket capscrews (F18—see Figure 5.10-70 or H24—see Figure 5.10-71).

F18 Brace Installation

1. Secure top of brace to right side of bracket with M6 x 25 mm capscrew, flat washer, lock washer and nut. Do not fully tighten (see Figure 5.10-70).

2. Secure bottom of brace to exhaust manifold with M8 x 22 mm capscrew, lock washer and flat washer. Do not fully tighten (see Figure 5.10-70).

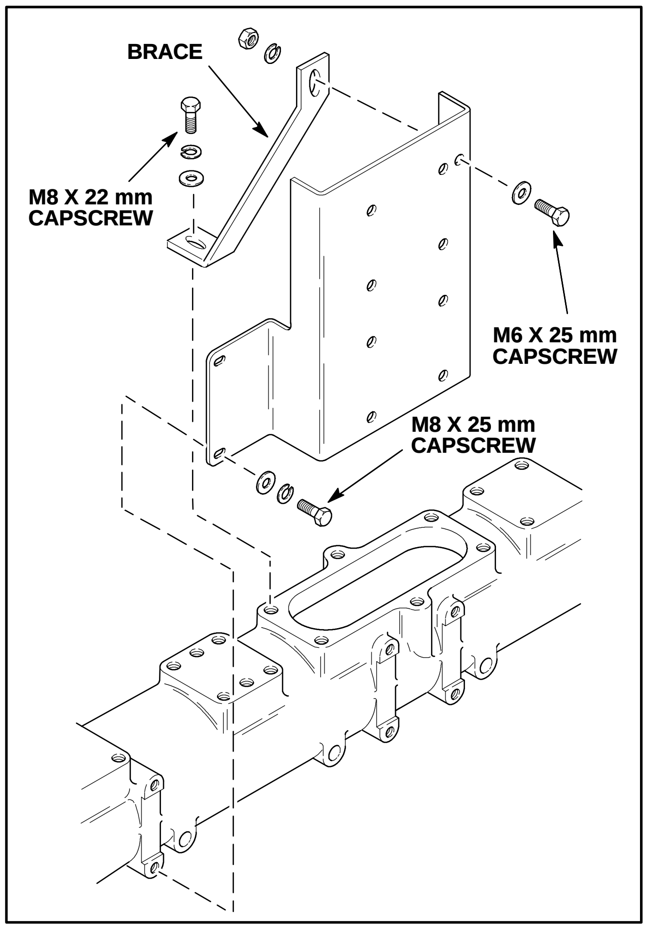


Figure 5.10-70. F18 Bracket And Brace

H24 Brace Installation

1. Align top of brace to left side of junction box mounting hole. Do not secure at this time (see Figure 5.10-71).

2. Secure bottom of brace onto top cover plate with M8 x 22 mm capscrew, lock washer and flat washer. Do not fully tighten (see Figure 5.10-71).

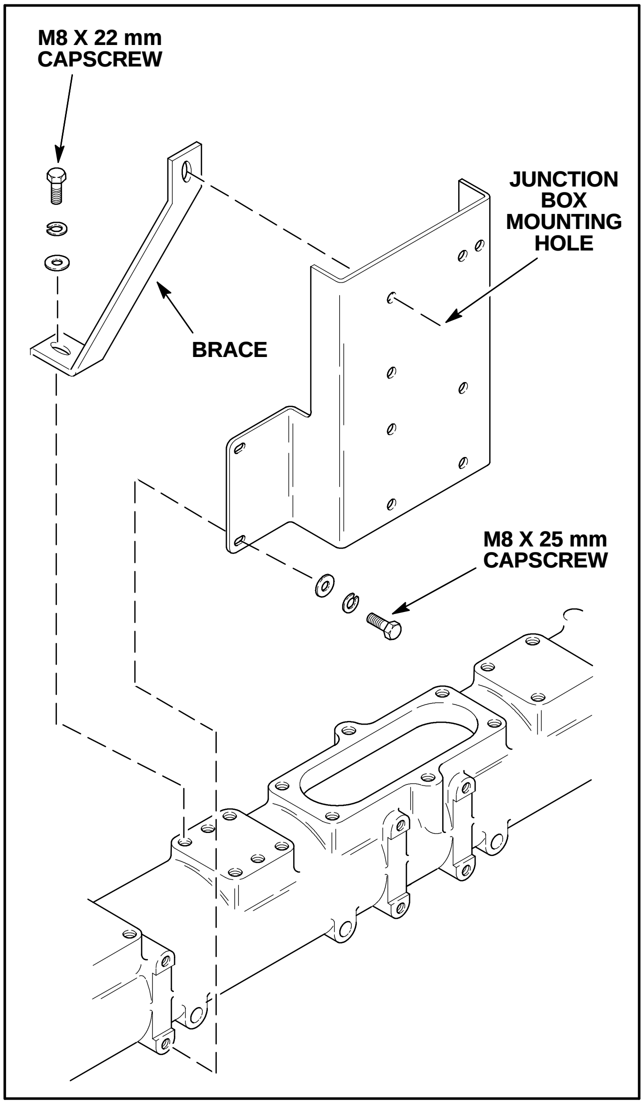


Figure 5.10-71. H24 Bracket And Brace

CEC IGNITION MODULE/JUNCTION BOX INSTALLATION (CURRENT MODELS)

1. H24 only—Install Junction Box on top part of bracket. Secure top left corner of Junction Box and top of brace with new M6 x 25 mm capscrew, flat washer, lock washer and nut. Use original hardware for remaining holes (see Figure 5.10-72).

2. F18 only—Install Junction Box on top part of bracket and secure with original hardware (see Figure 5.10-72).

3. Install upper left bracket capscrew with junction box to chassis ground lead between bracket and flat washer (see Figure 5.10-72).

4. Install ignition module below junction box on bottom part of bracket and secure with original hardware.

5. Install ignition module ground lead underneath lower left bracket capscrew flat washer. This requires the removal and reinstallation of the bracket capscrew (see Figure 5.10-72).

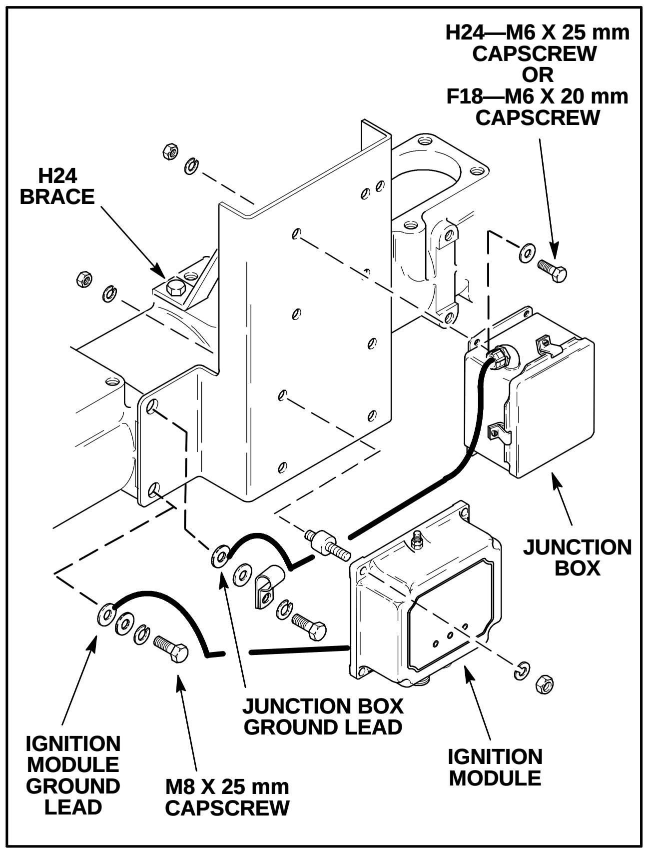


Figure 5.10-72. CEC Ignition Module/Junction Box

6. Tighten M8 bracket capscrews to 97 in-lbs (11 N·m) and M6 brace capscrews to 41 in-lbs (4.6 N·m).

CEC IGNITION MODULE/JUNCTION BOX ELECTRICAL HARNESS CONNECTIONS (CURRENT MODELS)

1. CSA only—Remove or install CSA ignition harness as required (see Figure 5.10-73). If removed, mark terminal locations inside of conduit box to aid assembly.

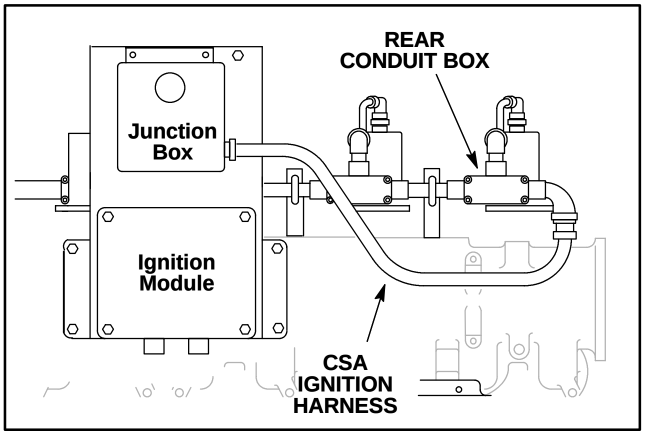


Figure 5.10-73. CSA Ignition Harness (Right Side)

2. Connect Power Harness cannon plug into bottom left Ignition Module inlet (see Figure 5.10-74).

3. Connect Primary Ignition Harness cannon plug into bottom right Ignition Module inlet (see Figure 5.10-74).

NOTE: *Non CSA units have the ignition harness and ignition shutdown harness grouped together using a four wire connector.*

4. Install Hall sensor cable into upper right opening of junction box and connect wires to terminals (see Figure 5.10-74).

NOTE: *Non CSA—Thread ignition harness and ignition shutdown harness through wire clips before installing onto junction box.*

5. Thread ignition harness wires and shutdown wires together through four wire connector. Two wire elbows may be installed instead of four wire connector.

6. Install four wire connector (or two elbows in original positions) into lower right opening of junction box and connect wires to terminals (see Figure 5.10-74).

NOTE: *If KDM equipped, complete KDM installation procedures below.*

7. H24—Install KDM harness onto bottom right inlet of Junction Box (see Figure 5.10-75). Connect KDM wires to terminals located inside of junction box.

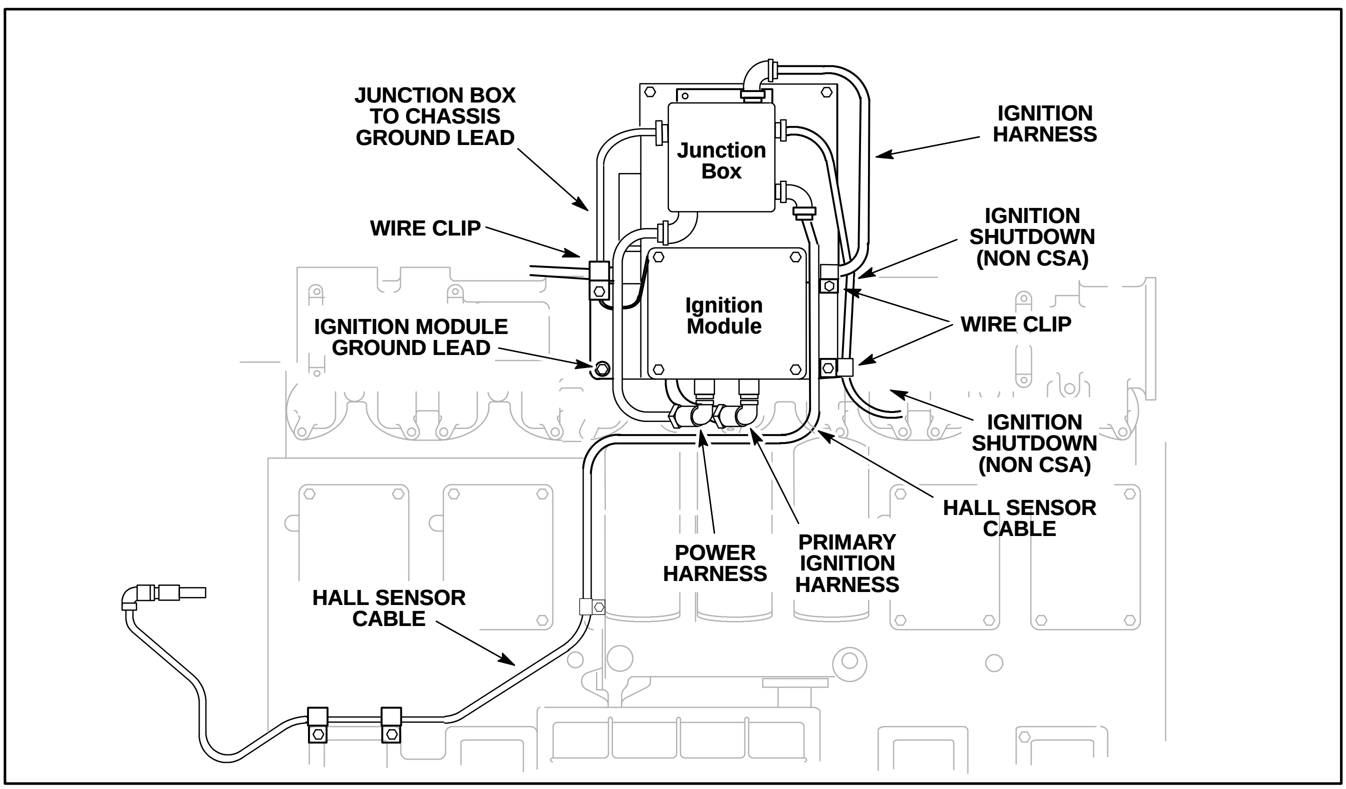


Figure 5.10-74. F18 Standard Ignition

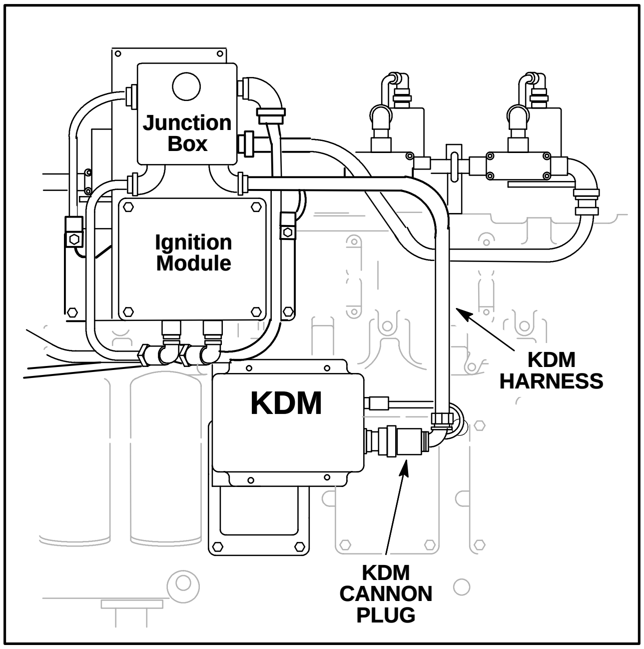


Figure 5.10-75. H24 KDM/CSA

8. H24—Install KDM harness onto bottom right inlet of Junction Box (original position, see Figure 5.10-76). Connect KDM wires to terminals located inside of Junction Box.

9. Install KDM harness clip over wiring harness and secure with original M6 x 20 mm capscrew (see Figure 5.10-76).

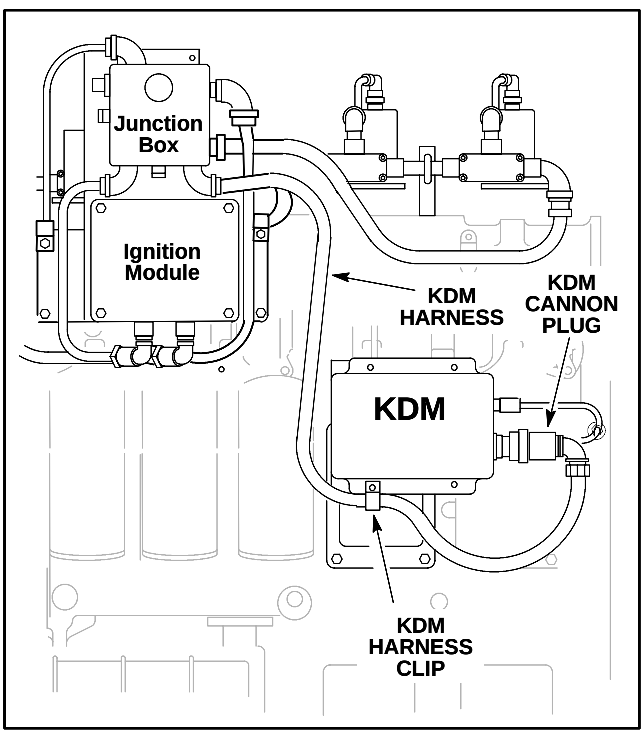


Figure 5.10-76. F18 KDM/CSA

TIMING DISC INSTALLATION

1. Remove ignition timing cover (see Figure 5.10-77).

NOTE: *Early production engine gear covers did not have the ignition timing cover. A different gear cover will have to be installed to accommodate the CEC ignition system.*

Figure 5.10-77. Ignition Timing Cover

2. Align timing disc dowel hole with cam gear dowel hole (see Figure 5.10-78).

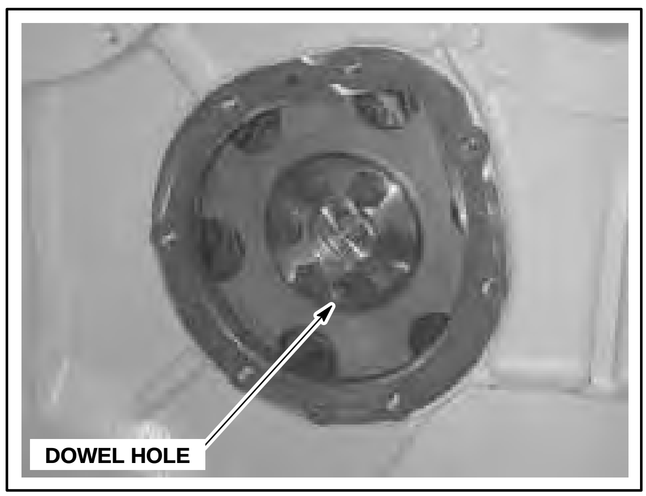


Figure 5.10-78. Camshaft Gear

⚠ WARNING

Do not drop the timing disc. Dropping the disc will cause damage to the embedded magnets, causing erratic ignition timing. If the disc has been dropped, replace with a new disc.

3. Install timing disc on cam gear and secure with hex head screws and two original cam gear hex head screws. Do not fully tighten (see Figure 5.10-79).

4. Insert 3/8 in. dowel pin through timing disc into cam gear (see Figure 5.10-79).

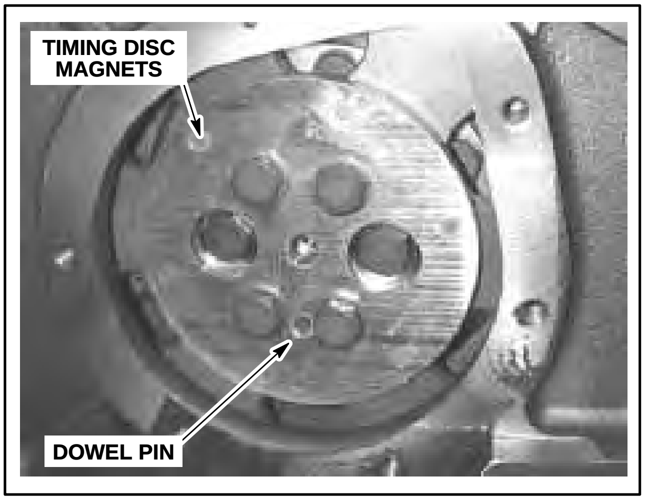


Figure 5.10-79. CEC Ignition Module Timing Disc

5. Secure timing disc and cam gear to camshaft with M10 x 40 mm (Grade 10.9) hex head screws. Tighten hex head screws to 53 ft-lb (72 N·m), use an alternating pattern.

6. Install two locating roll pins in gear housing for timing cover. Install correct ignition timing cover and gasket on gear housing (see Figure 5.10-80).

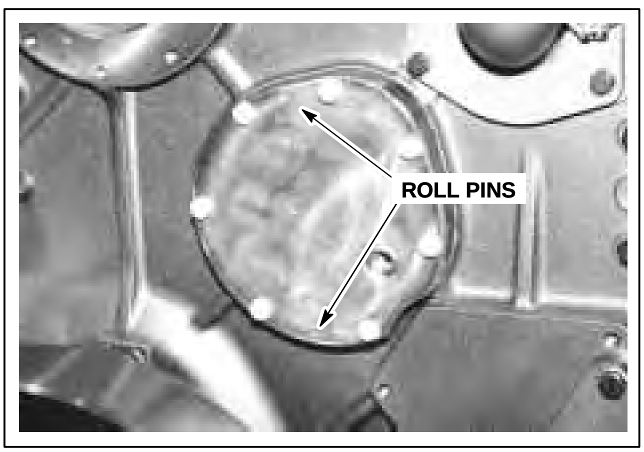


Figure 5.10-80. CEC Ignition Timing Cover

HALL-EFFECT PICKUP INSTALLATION

SETTING THE AIR GAP

To set the air gap specification, complete the following steps.

1. Install Hall-effect pickup into front timing cover.

2. Thread Hall-effect pickup clockwise until pickup touches timing disc (see Figure 5.10-81).

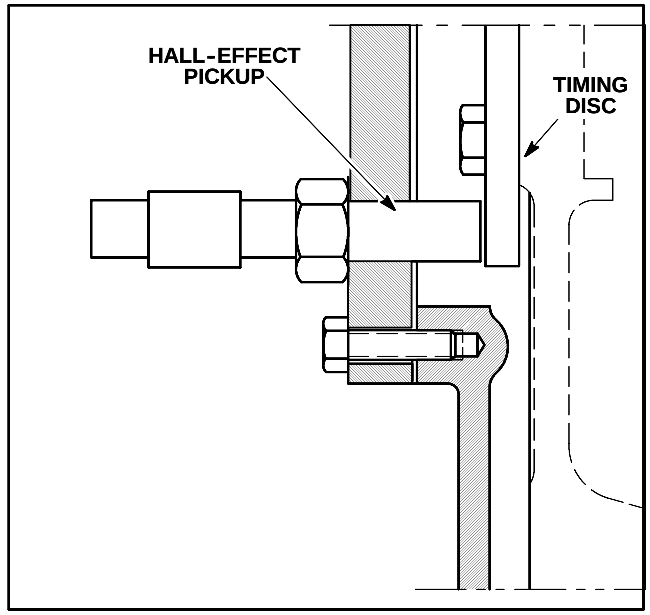


Figure 5.10-81. Hall-effect Pickup Installation

3. Create a "mark" between Hall-effect pickup and front gear cover.

NOTE: *The gap between the Hall-effect pickup and timing disc clearance is 0.031 - 0.047 in. (0.8 - 1.2 mm). Rotating the Hall-effect pickup 3/4 of a turn counterclockwise will provide this clearance.*

4. Using reference mark on pickup as starting point, rotate Hall-effect pickup **3/4** of a turn (± 1/16 of a turn) counterclockwise to set pickup to timing disc clearance.

5. After clearance is set, tighten locking nut.

6. Connect pickup harness to Ignition Module and Hall-effect pickup.

IGNITION MODULE SWITCH SETTINGS

The Ignition Module contains a three position switch that must be set to the appropriate position depending on the type of engine (ATGL, VHP or VGF) (see Figure 5.10-82 and Table 5.10-5).

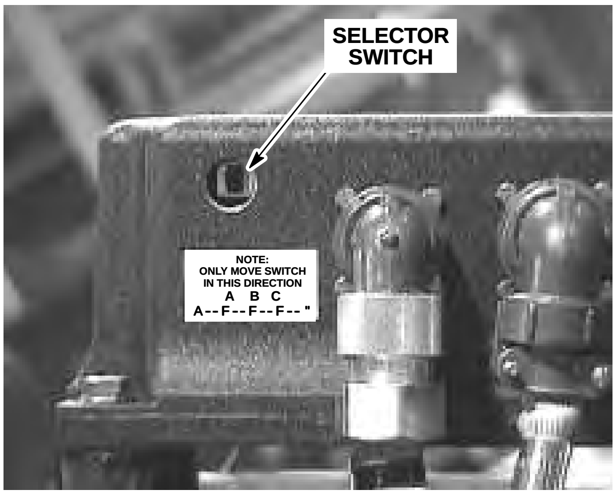


Figure 5.10-82. Previous Ignition Module Selector Switch

Figure 5.10-83. Current Ignition Module Selector Switch

7. Previous Ignition Module – Remove cover from selector switch access hole.

8. Current selector switches use a rotary switch. Use a screwdriver to align the slot in the correct position (see Figure 5.10-84)

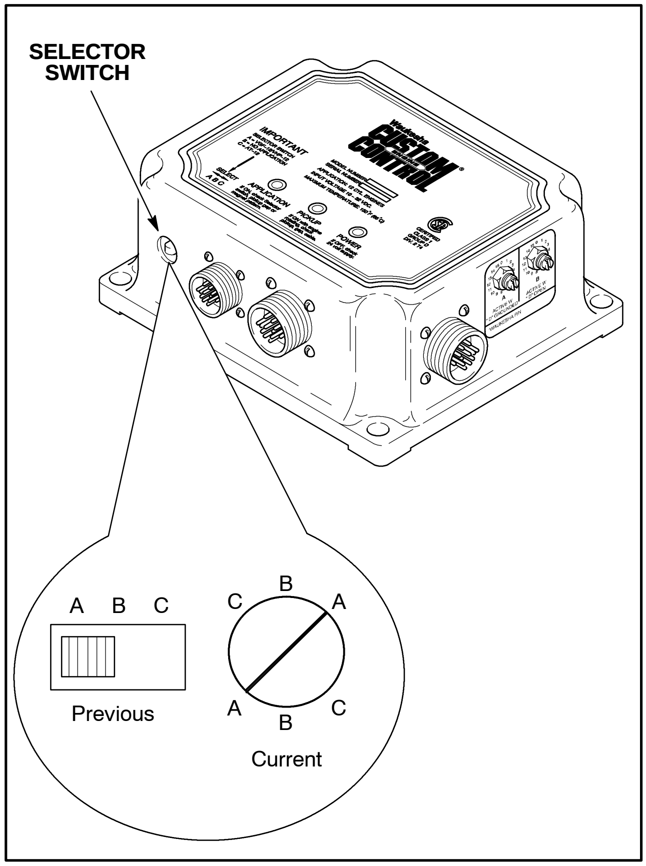


Figure 5.10-84. CEC Ignition Module Selector Switches

9. Set selector switch to appropriate timing application (see Table 5.10-5).

Table 5.10-5. Ignition Module Selector Switch Settings

SELECTOR SWITCH SETTING	IGNITION MODULE MODEL
	Model 811
A	VGF 6 Cylinder
B	No Application
C	VGF 8 Cylinder

10. Replace cover over selector switch (current) or access hole (process).

IGNITION TIMING ADJUSTMENT

CEC IGNITION TIMING ADJUSTMENT

Basic Ignition Timing (° BTDC) (on 900 Btu/ft^3 natural gas)

- F18/H24G: 20° ± 1°
  F18/H24GL/GLD: 13° ±1°
  F18GL, 8.7: 1 CR: 24° ±1 degrees
  H24GL, 8.7: 1 CR: 25° ±1 degrees
  F18/H24GSID: 23° ±1° – normal temperature cooling
  F18/H24GSID: 20° ±1°–high temperature cooling

Ignition timing is adjusted through two 16 position rotary switches labeled "A" or "B" (see Figure 5.10-85). Only one switch is active at any one time, depending on engine application.

The timing switches provide an ignition timing range from 2 to 27 degrees before top dead center (BTDC). The 16 position timing switches contain a small overlap with each other (see Table 5.10–8).

On either timing switch ("A" or "B"), position 15 gives the most advanced timing. Switch "A" is able to advance the timing more than switch "B." At switch position 0 (zero) the timing is fully retarded. The timing advances or retards 1.0 degree between each switch position (see Table 5.10–8).

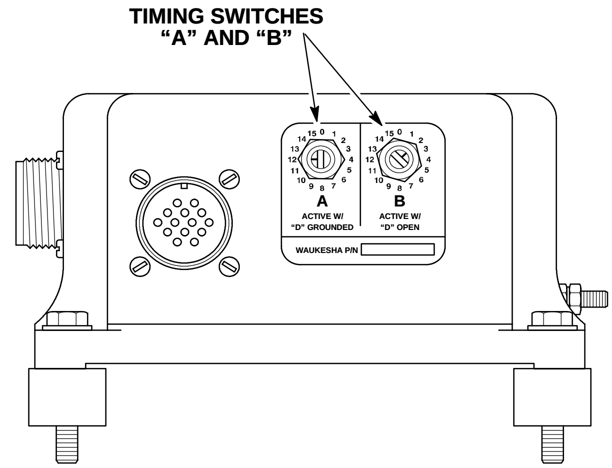
If lead "D" in the power pickup harness (7 pin connector) is grounded, then timing switch "A" is active. If lead "D" is ungrounded, then timing switch "B" is active.

The six and eight cylinder engines have a 6 degree overlap between timing switch "A" and timing switch "B." This overlap gives the Ignition Module a combined timing range of 25 degrees.

Table 5.10–6 lists the Ignition Module firing order for six cylinder VGF engines. Table 5.10–7 lists the Ignition Module firing for eight cylinder VGF engines.

Table 5.10–6. Firing Order For VGF 6 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F
CYLINDERS	1	5	3	6	2	4



NOTE: *Timing selection is made by the dot on the switch, not the screwdriver slot.*

Figure 5.10-85. Ignition Module 16 Position Switches

Table 5.10–7. Firing Order For VGF 8 Cylinder Engines

PIN CONNECTORS*	A	B	C	D	E	F	H	I
CYLINDERS	1	4	2	6	8	5	7	3

NOTE: ** **G**=Shutdown*

CAUTION **Do not switch from position 15 to position 0, or from position 0 to 15 while the engine is running. The timing change is so large that it may damage the engine and/or cause it to shut down. Disregarding this information could result in product damage and/or personal injury.**

CAUTION **To prevent the timing from being altered, always replace the white caps over the timing switches once the desired setting has been selected.**

NOTE: *The outside temperature of the Ignition Module should not exceed 65° C (150° F) in operation.*

Table 5.10–8. F18/H24 CEC Ignition Module Switch Positions

SWITCH	DEGREES BEFORE TOP DEAD CENTER												
	2	3	4	5	6	7	8	9	10	11	12	13	14
A											A0	A1	A2
B	B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
SWITCH	DEGREES BEFORE TOP DEAD CENTER												
	15	16	17	18	19	20	21	22	23	24	25	26	27
A	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
B	B13	B14	B15										

IGNITION TIMING – SINGLE FUEL

NOTE: *Before applying power to the IM (engine not running) complete the Prestart Checklist below:*

1. Visually inspect the installation to be sure that all wiring conforms to the requirements of this manual, local codes, and regulatory agencies.

2. Verify all grounding requirements are met. See "F18/H24 Wiring Diagrams" in this section.

3. Verify all power requirements are met. See "F18/H24 Wiring Diagrams" in this section.

4. Remove white caps from timing switches "A" and "B" located on the IM.

5. **Non CSA Only—**Install timing light on #1 cylinder spark plug wire.

6. **CSA Only—**Remove cover from #1 cylinder conduit box (only if engine does not contain a timing light hookup) (see Figure 5.10-86).

7. **CSA Only—**Install an inductive timing light around wire labeled "A."

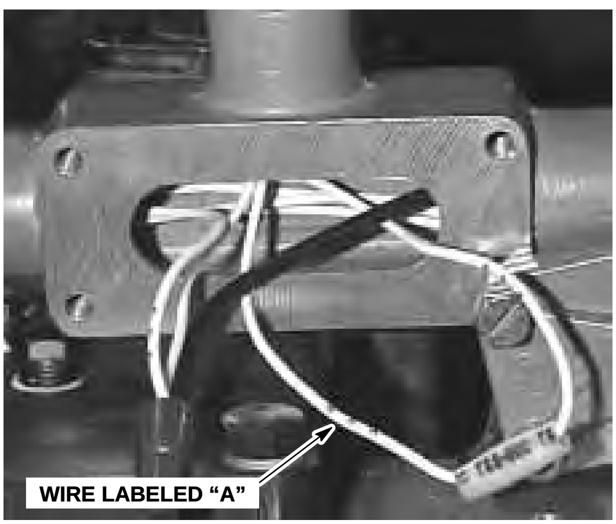


Figure 5.10-86. Conduit Box

NOTE: *If the IM being adjusted is replacing another IM, set the timing switches to the same positions as the IM being replaced. For first time installations, IM timing switches "A" and "B" should be set to position 10. Timing selection uses the dot, not the screwdriver slot.*

8. Check engine nameplate to determine specified engine timing.

CAUTION **If detonation occurs, retard the ignition timing until NO audible detonation exists. Detonation may cause severe engine damage.**

CAUTION **Be sure all engine connections are completed properly before engine startup. Follow all startup procedures. Check that all engine openings are properly closed and that all tools are removed from the engine. Disregarding this information could result in product damage and/or personal injury.**

9. Start engine. Run at normal operating rpm.

10. Aim timing light through inspection hole located on left rear side of flywheel housing (see Figure 5.10-87).

11. Compare actual timing with specified timing.

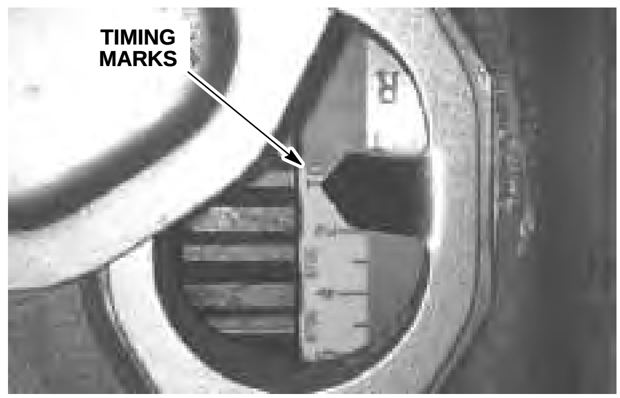


Figure 5.10-87. Flywheel Timing Marks

12. Using Table 5.10–8 determine required "A" or "B" switch settings.

CAUTION **Do not switch from position 15 to position 0, or from position 0 to 15 while the engine is running. The timing change is so large that it may damage the engine and/or cause it to shut down. Disregarding this information could result in product damage and/or personal injury.**

NOTE: *Increasing the timing switch position by one will advance the timing one degree. Decreasing the timing switch position by one will retard the timing one degree.*

NOTE: *The active switch is determined by whether the "D" lead in the 7 pin connector harness is grounded (switch A) or ungrounded (switch B).*

SECTION 5.15

AIR INDUCTION SYSTEM

AIR INDUCTION SYSTEM COMPONENTS

AIR FILTRATION SYSTEM (IF EQUIPPED)

The air intake filtration system removes dirt and other foreign material from air that is used for combustion. A rain shield keeps water from entering the engine. The system supplied by Waukesha is designed to meet the volume and air quality requirements of this engine (see Figure 5.15-1).

Figure 5.15-1. F18 Air Cleaner

TURBOCHARGER

The turbocharger is mounted on the top of the exhaust manifold (see Figure 5.15-2). This high efficiency radial flow unit provides the intake air under pressure required to obtain a dense combustion chamber mixture.

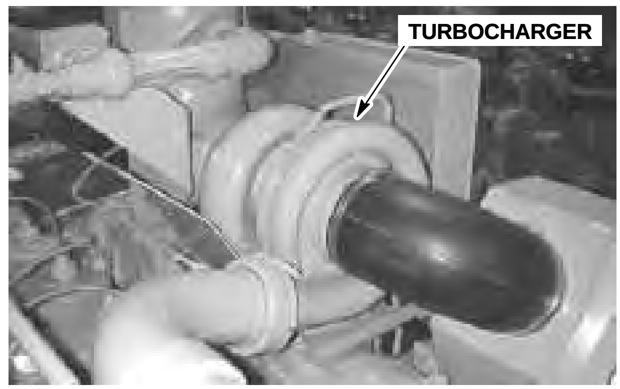


Figure 5.15-2. Turbocharger

INTERCOOLER

The intercooler is used to reduce the temperature of the air after it has been compressed by the turbocharger. This intercooler has tube and fin construction and a plenum which receives air from the turbocharger. By reducing the temperature of the air entering the engine, the charge density is increased and a denser air/fuel charge enters the cylinder. As a result more horsepower is produced for a given cylinder displacement. Cool air/fuel temperatures also help to prevent detonation (see Figure 5.15-3).

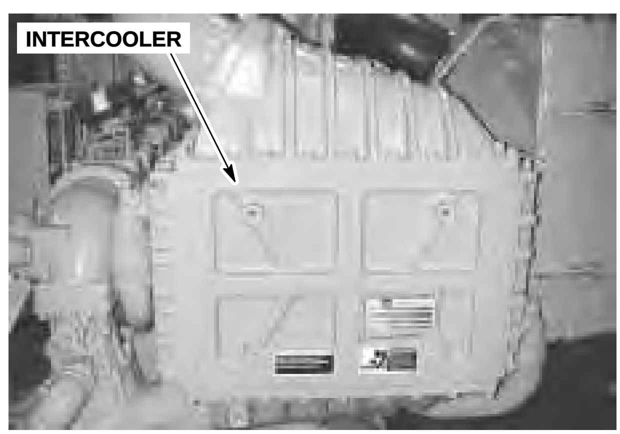


Figure 5.15-3. Intercooler

INTAKE MANIFOLD

The intake manifold for both F18 and H24 engines is on the left side of the engine. The hand throttle and governor controlled butterfly valve are mounted on the rear of the intake manifold (see Figure 5.15-4).

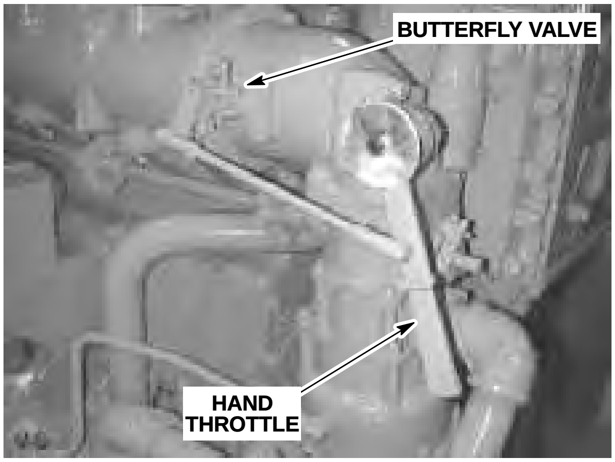


Figure 5.15-4. Throttle Valve

CARBURETOR AND INTAKE MANIFOLD

The carburetor for the F18G/GL and H24GL engine is mounted on the butterfly housing near the rear of the intake manifold (see Figure 5.15-5).

Figure 5.15-5. GL Carburetor

The carburetor for the F18/H24G engine uses an extension to connect to the air cleaner (see Figure 5.15-6).

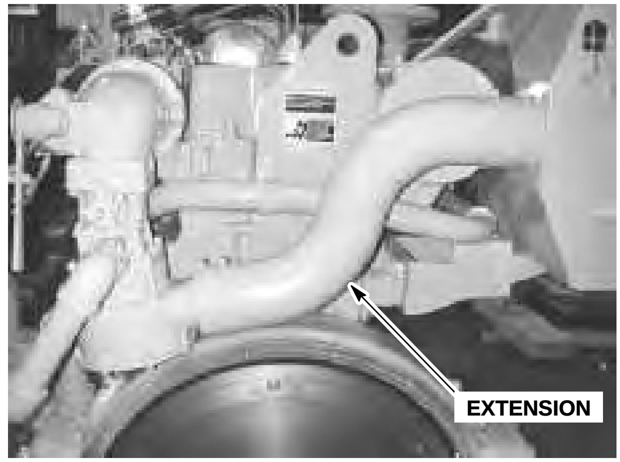


Figure 5.15-6. H18G Carburetor

The carburetor for the F18/H24GSID engine is mounted on the air cleaner duct, on the right side of the engine. Ducting connects the carburetor to the inlet side of the turbocharger (see Figure 5.15-7).

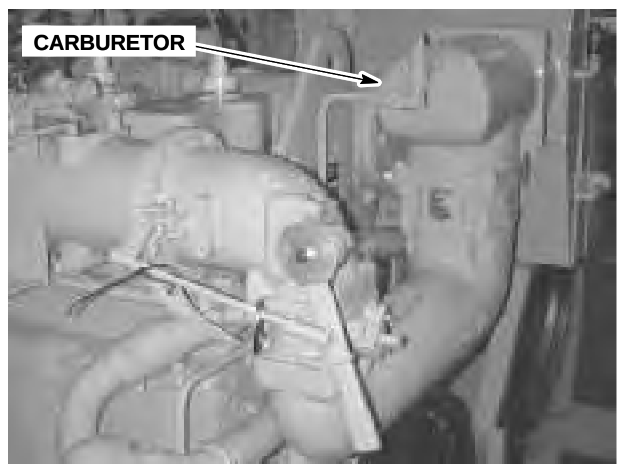


Figure 5.15-7. F18/H24GSID Carburetor

The Deltec carburetor for GLD engines has low inlet restriction for improved performance. The carburetor's flat tracking provides desirable performance and low emissions and allows lean or rich operation with low octane fuels (see Figure 5.15-8).

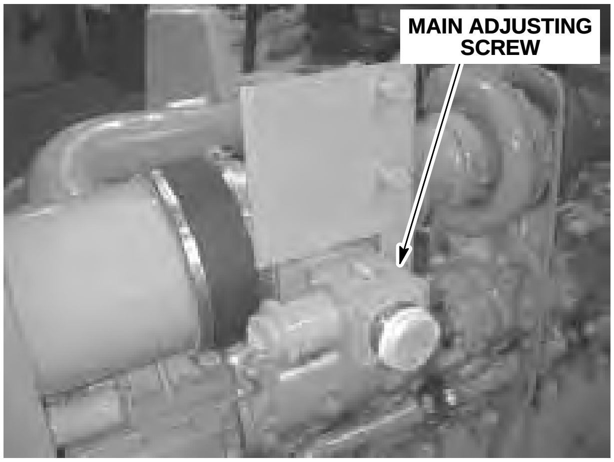


Figure 5.15-8. F18/H24 GLD Deltec Fuel System

The carburetor for the F18/H24GLD (IMPCO carburetor) engine is mounted on the air cleaner duct on the right side of the engine (see Figure 5.15-9). Ducting connects the carburetor to the inlet side of the turbocharger.

Figure 5.15-9. F18/H24 GLD IMPCO 600D Carburetor

AIR RESTRICTION INDICATOR MAINTENANCE

NOTE: *It is always a good idea to check the air/fuel ratio and crankcase breather system adjustment after the air cleaner has been replaced. These systems may have been adjusted to compensate for a partially constricted air cleaner.*

1. Check filter restriction indicator before and after engine shutdown (see Figure 5.15-10).

Figure 5.15-10. Air Filter Restriction Indicator

2. If filter restriction indicator shows "red" [15 in. (38 cm) water column], then service air cleaner. See "Air Filtration System Maintenance" in this section.

3. Reset indicator by depressing black button on plastic housing.

AIR RESTRICTION INDICATOR AND ELEMENT INSPECTION

⚠ WARNING

A restrictor element must be installed in the restriction indicator to dampen high pressure surges from engine backfires. Without the element the indicator may explode if the engine backfires, spreading plastic shrapnel. Disregarding this information could result in severe personal injury or death.

1. Remove 7/16 inch hex nut brass fitting and remove restriction indicator and element (see Figure 5.15-11).

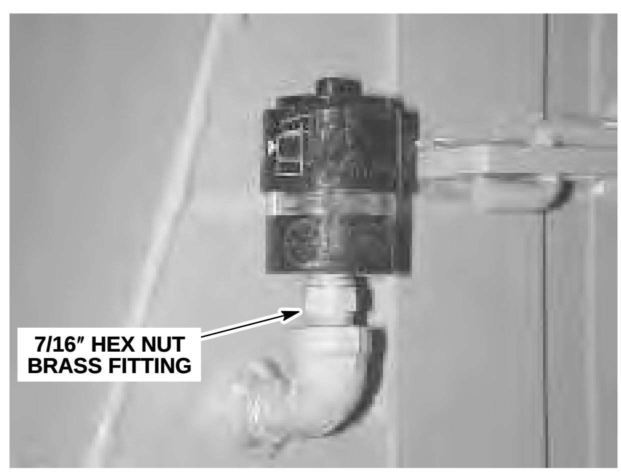


Figure 5.15-11. GL – Filter Restriction Indicator

2. Verify restrictor element is staked in place inside fitting (see Figure 5.15-12). Replace element if any damage is apparent.

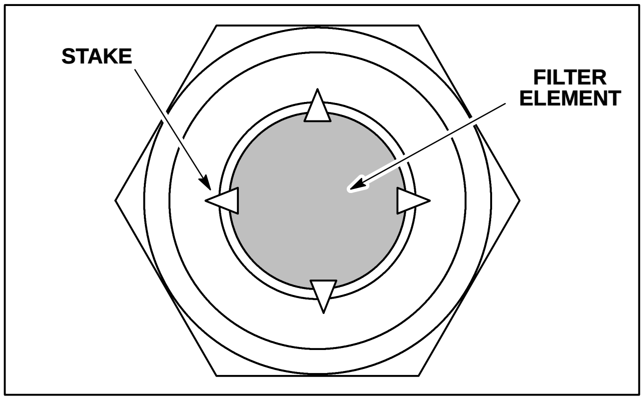


Figure 5.15-12. Restriction Filter

3. Inspect plastic restriction indicator for cracks. Replace indicator if damaged or defective. Install indicator "finger tight."

4. Install restriction indicator and filter into air cleaner housing. Tighten 7/16 inch hex nut on brass fitting.

AIR FILTRATION SYSTEM MAINTENANCE

AIR CLEANER INSPECTION

⚠ CAUTION Do not clean the outside of the engine with petroleum base solvents while the engine is running. Solvents drawn through the air intake system will remove the oil film from the upper cylinder walls, causing scoring of the cylinder and piston.

The air filter elements should be replaced according to the maintenance instructions (see Figure 5.15-13). Common sources of trouble in air intake systems are most often related to inadequate installation or a poorly maintained system.

All ducting as well as cleaner-to-turbocharger connections must be airtight to avoid the intake of unfiltered air.

MAIN AIR FILTER ELEMENT CLEANING AND INSPECTION

1. Clean main air filter element using the following methods.

A. Gently tap element on a flat surface with dirty side of element down.

⚠ WARNING

Compressed air can pierce the skin and cause severe personal injury or death. Never use your hand to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris.

B. Direct compressed air through element opposite direction of normal air flow. Normal air flow direction is indicated with an orange arrow located on instruction label. Air pressure should be a maximum of 30 psi (2.1 Kg/cm^2).

C. Soak element in lukewarm water and nonfoaming detergent for 10 minutes. Outlet side of element must be held above water level. Rinse element with water.

D. Air dry element. Do not use compressed air.

2. Carefully examine element after cleaning. If damaged, replace.

NOTE: *Use only air filter elements supplied by Waukesha.*

3. Do not clean and reuse main air filter element more than three times. Replace with a new element.

4. Inspect air duct for cracks. All combustion air must pass through main air filter element, not through cracks or defects in air cleaner assembly.

NOTE: *If inspection of the intake manifold yields an accumulation of dust and grit, it is an indication that the main air filter element is not properly maintained or that air is getting into the system around or behind the element.*

5. Inspect all air duct hoses. Replace damaged hoses.

PRECLEANER PAD CLEANING AND INSPECTION

1. Wash precleaner pad with soap and water.

⚠ CAUTION Compressed air can easily damage the foam rubber pad. Disregarding this information could result in product damage and/or personal injury.

2. Air dry pad. Do not use compressed air.

FILTER REPLACEMENT – F18/H24G/GL

1. Loosen four outside lock nuts. Lift rain shield off air cleaner (see Figure 5.15-13). Foam precleaner element will be removed along with rain shield.

2. Clean or replace precleaner element with a new element.

NOTE: *The precleaner can be washed with soap and water, then dried.*

3. Loosen four inside lock nuts enough to swing bolts aside and remove air filter frame and air filter.

4. Remove main air filter element.

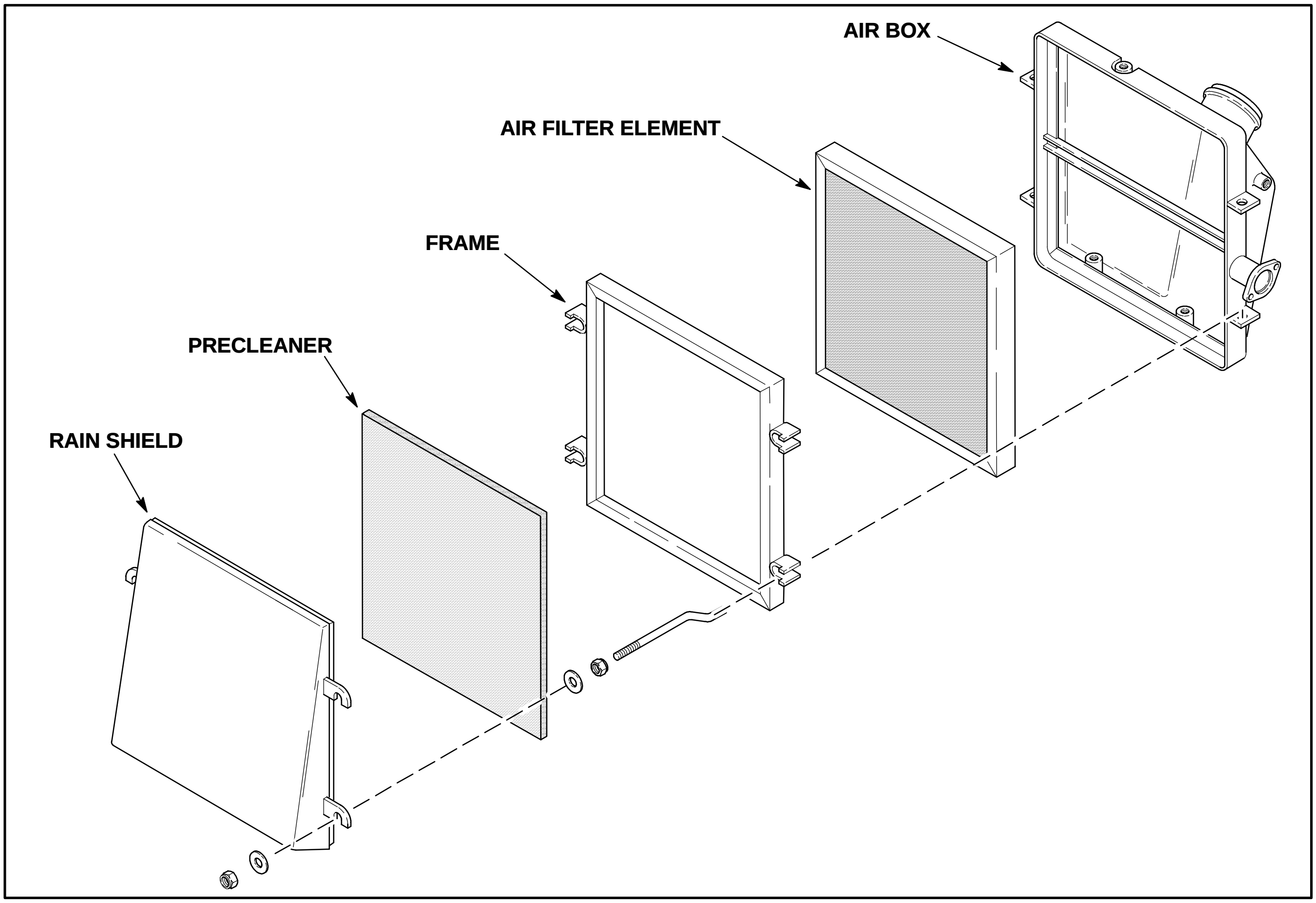


Figure 5.15-13. Typical Air Filter Components – G, GL

5. Inspect air box and duct system. Repair any leaks as necessary.

***NOTE:** A buildup of dust and grit in the air duct system indicates improper air cleaner fit or leaks in the air duct system.*

6. Install a new paper main element according to air flow arrow on filter.

7. Reinstall precleaner, air filter element frame and rain shield.

CAUTION **Engines shipped from Waukesha Engine have a cardboard protector outside the precleaner element which must be removed before startup. Disregarding this information could result in product damage.**

FILTER REPLACEMENT – F18/H24GSID/GLD

1. Loosen two outside lock nuts. Swing rain shield up and away from air box (see Figure 5.15-14).

2. Clean or replace precleaner element with a new element.

***NOTE:** The precleaner can be washed with soap and water, then dried.*

3. Inspect air box and duct system. Repair air leaks as necessary.

***NOTE:** A buildup of dust and grit in the air duct system indicates improper air cleaner fit or leaks in the air duct system.*

4. Install new paper main element according to air flow arrow on filter.

5. Reinstall precleaner, air filter element and rain shield.

6. Install lower offset studs through rain shield hinges. Secure lower offset studs with washers and nuts. Washers and nuts should clamp against hinges (see Figure 5.15-14).

CAUTION **Engines shipped from Waukesha Engine have a cardboard protector outside the precleaner element which must be removed before startup. Disregarding this information could result in product damage.**

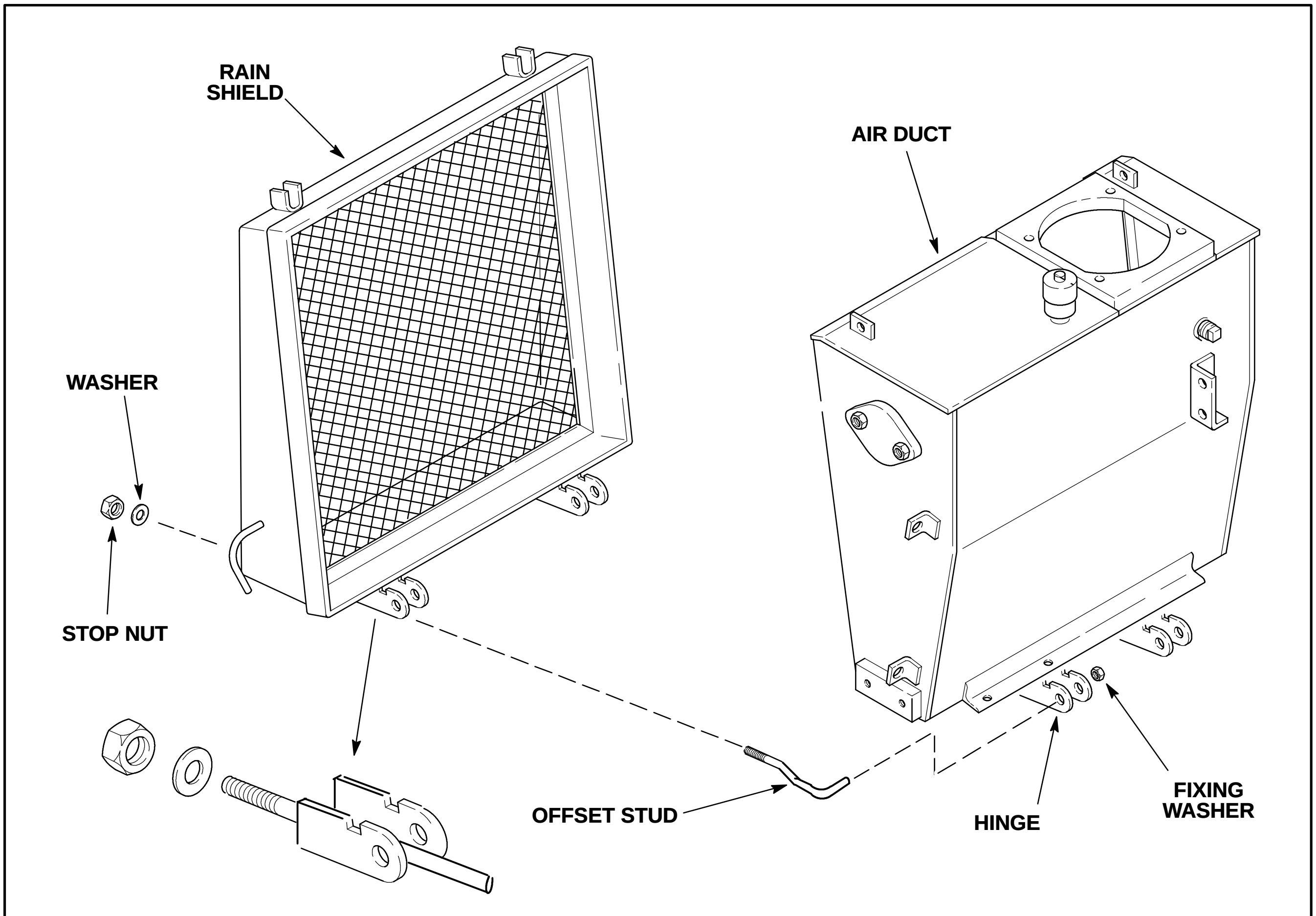


Figure 5.15-14. F18/H24 GSID Air Cleaner With Offset Studs

AIR DUCTS

AIR DUCT REMOVAL – G

NOTE: *To prevent damage, remove the air filter restriction indicator before air duct removal.*

1. Loosen four outside lock nuts. Lift rain shield off air cleaner (see Figure 5.15-15). Foam precleaner element will be removed along with rain shield.

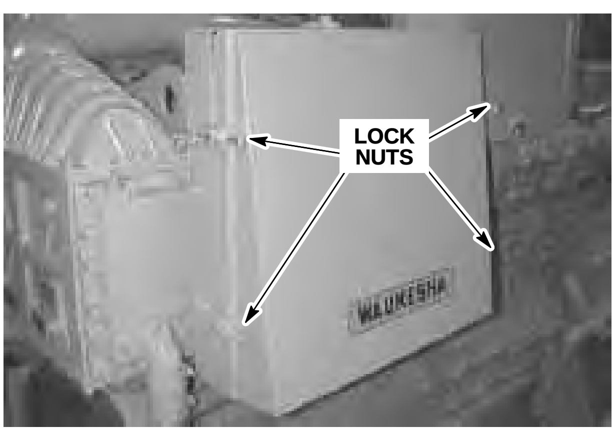


Figure 5.15-15. F18 Air Cleaner

2. Remove support brace from air duct and exhaust manifold (see Figure 5.15-16).

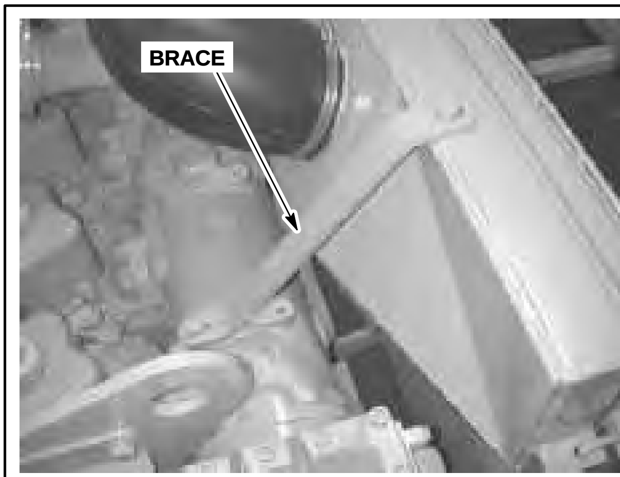


Figure 5.15-16. H24G Air Duct Brace

3. F18/H24G engines equipped with IMPCO 600 carburetors have an additional brace located between air duct and leg (see Figure 5.15-17).

Figure 5.15-17. Dual Fuel Air Duct Support

4. Remove closed breather connections, if equipped (see Figure 5.15-18).

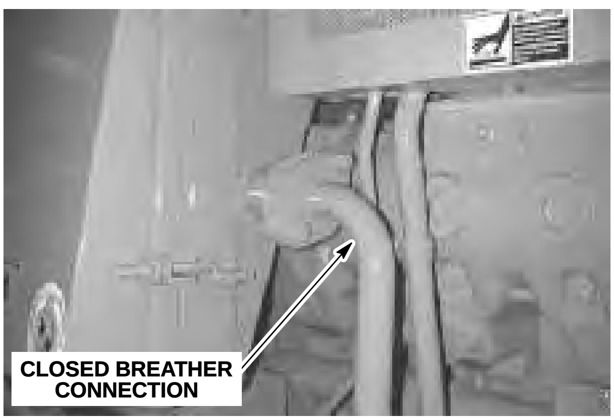


Figure 5.15-18. Closed Breather Connection

5. Remove four hex head screws and lock nuts that secure air duct to carburetor flange (see Figure 5.15-19).

Figure 5.15-19. F18/H24G IMPCO Carburetor

6. Support air duct and remove hex head screws from air duct support bracket (see Figure 5.15-20).

7. Lift air duct from engine.

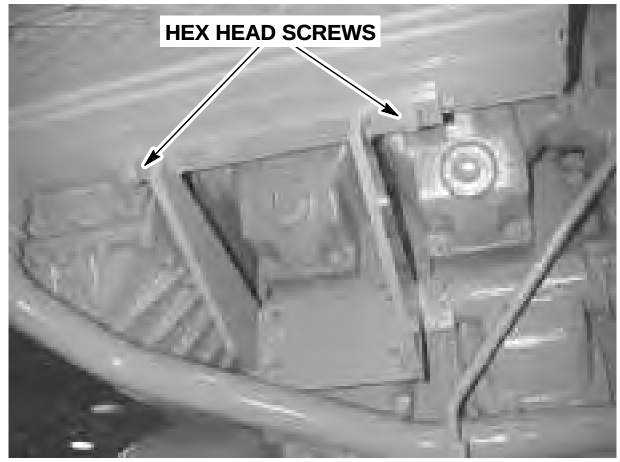


Figure 5.15-20. G Air Duct Support Bracket

AIR DUCT REMOVAL – GL

NOTE: *To prevent damage, remove the air filter restriction indicator before air duct removal.*

1. Loosen four outside lock nuts and remove rain shield and foam precleaner from air cleaner (see Figure 5.15-21).

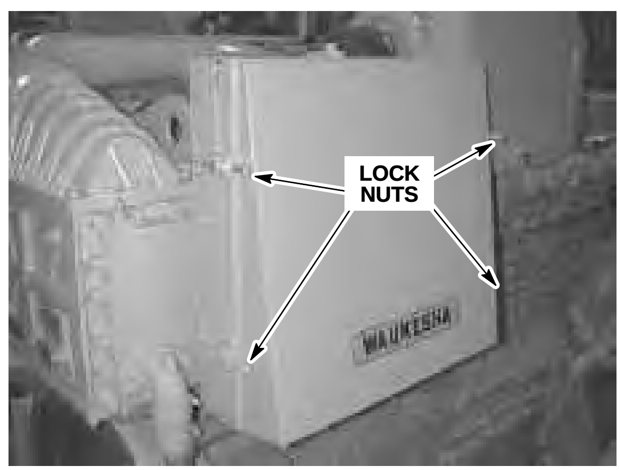


Figure 5.15-21. F18 Air Cleaner

2. Loosen hose clamps and remove air elbow from duct and turbocharger (see Figure 5.15-22).

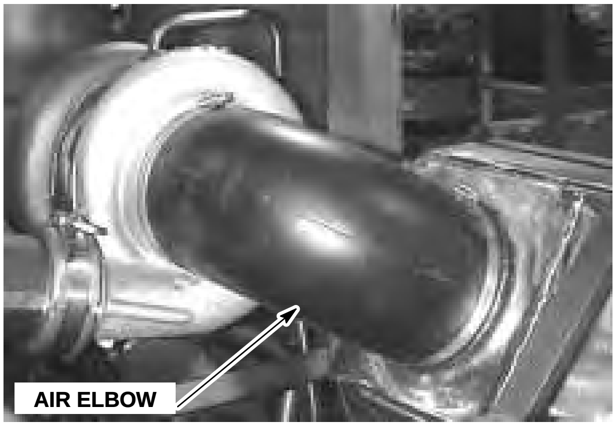


Figure 5.15-22. Turbocharger Air Elbow

3. Remove closed breather system piping if applicable (see Figure 5.15-23).

Figure 5.15-23. Closed Breather Connection

4. Support air duct and remove fasteners from air duct feet and air duct support bracket (see Figure 5.15-24 and Figure 5.15-25).

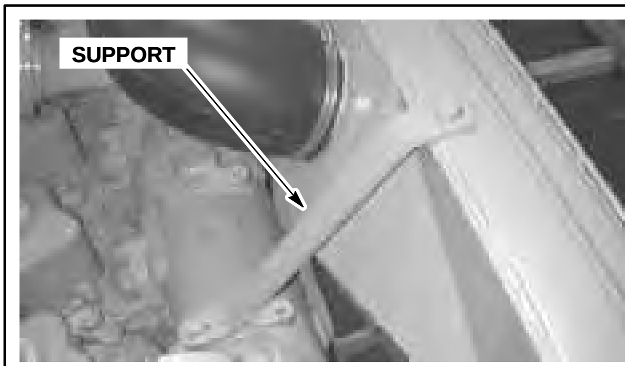


Figure 5.15-24. Air Duct Brace

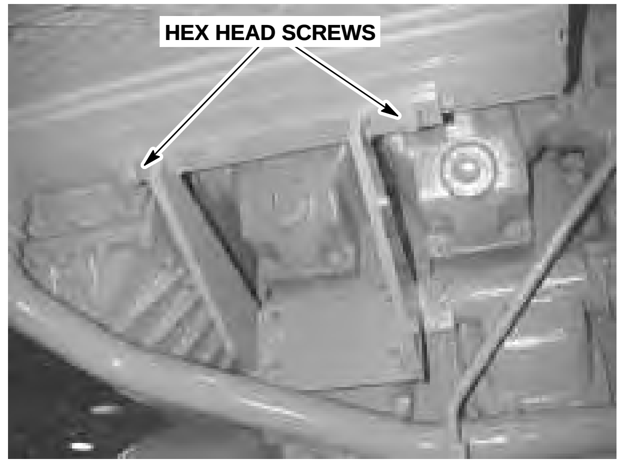


Figure 5.15-25. G Air Duct Support Bracket

5. Lift air duct from engine.

AIR DUCT REMOVAL – DELTEC GLD

NOTE: *To prevent damage, remove the air filter restriction indicator before removing the air duct.*

1. Loosen four outside lock nuts and lift rain shield. Foam precleaner element will be removed along with filter element.

2. To prevent damage, remove air filter restriction indicator before air duct.

3. Loosen hose clamps between air duct and carburetor (see Figure 5.15-26).

4. Remove closed breather connections, if equipped (see Figure 5.15-26).

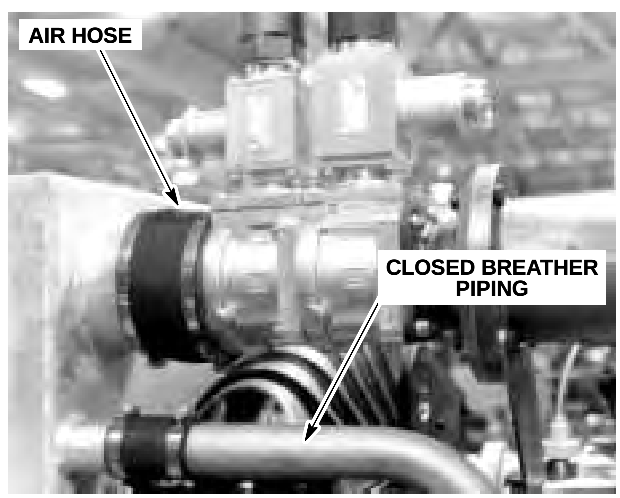


Figure 5.15-26. GLD Deltec Dual Fuel Carburetor

⚠ WARNING

The air duct assembly with rain shield and air filter weighs 75 lb. (34 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

5. Support air duct and remove four capscrews that secure air duct to intercooler. There are special washers located on both sides of air duct wall (see Figure 5.15-27).

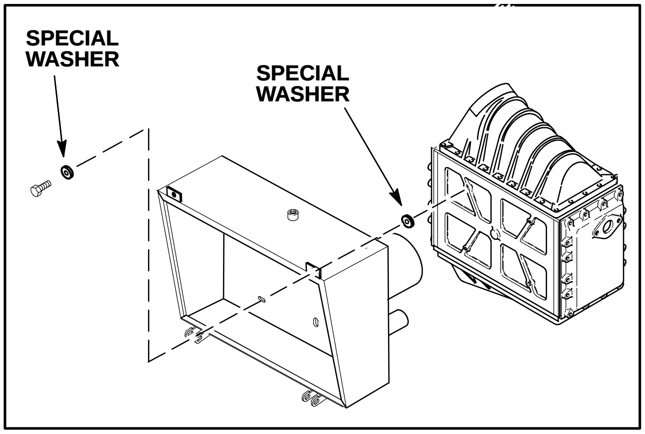


Figure 5.15-27. Deltec Air Duct Mounting

AIR DUCT INSTALLATION – G/GSID/GL AND IMPCO GLD

Air ducts for the G, GSID, GL and IMPCO carbureted GLD engines are mounted on the right rear side of the engine.

NOTE: *The rear water header has a mounting pad for the G, GSID, GL and IMPCO carbureted GLD support bracket (see Figure 5.15-28).*

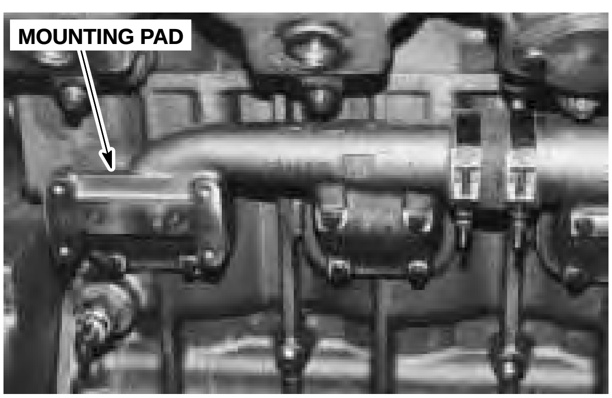


Figure 5.15-28. Air Duct Mounting Pad

Air Duct Installation – G/GL

1. Install G/GL air duct support brackets onto water header (see Figure 5.15-29).

2. Install G/GL air duct on support bracket (see Figure 5.15-29).

NOTE: *Install the air tube, hoses and clamps at this time if the F18G carburetor is already installed.*

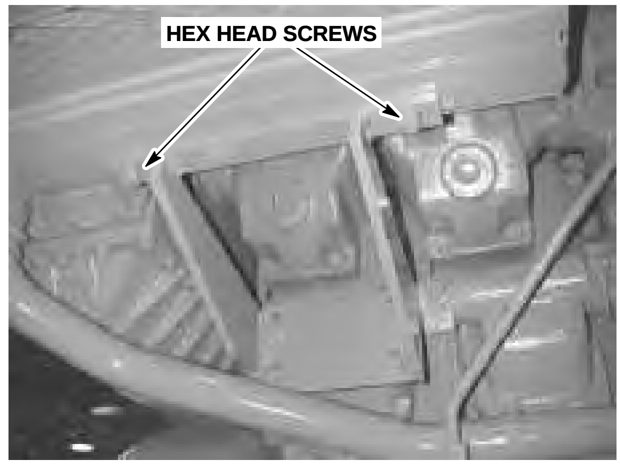


Figure 5.15-29. Air Duct Support Bracket

3. Install brace between air duct and exhaust manifold (see Figure 5.15-30).

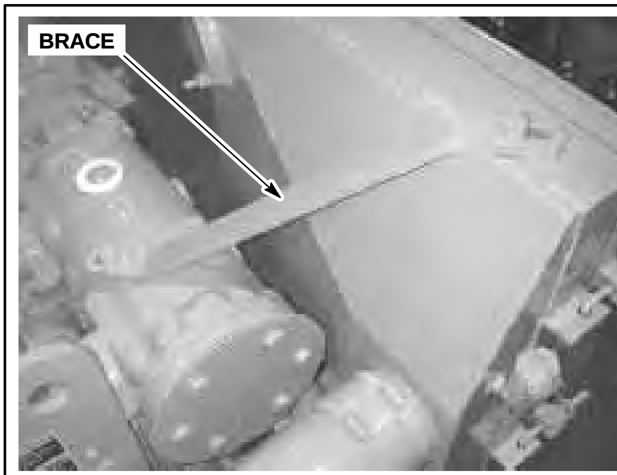


Figure 5.15-30. Air Duct Brace

4. H24G air ducts have an additional brace between air duct and RH rear engine support (see Figure 5.15-31).

Figure 5.15-31. F18/H24G IMPCO Carburetor

5. Install carburetor. See Section 5.05 *Fuel System* in this manual for H24G carburetor installation.

6. Install GL rubber air elbow and clamps between air duct and turbocharger air inlet (see Figure 5.15-32).

Figure 5.15-32. GL Air Elbow Installation

7. Install air cleaner element and rain shield onto air duct.

8. Install filter restriction indicator into air duct.

9. Install closed breather piping onto air duct, if equipped.

Air Duct Installation – GSID And IMPCO GLD

1. Install GSID/GLD upper support bracket on water header (see Figure 5.15-33).

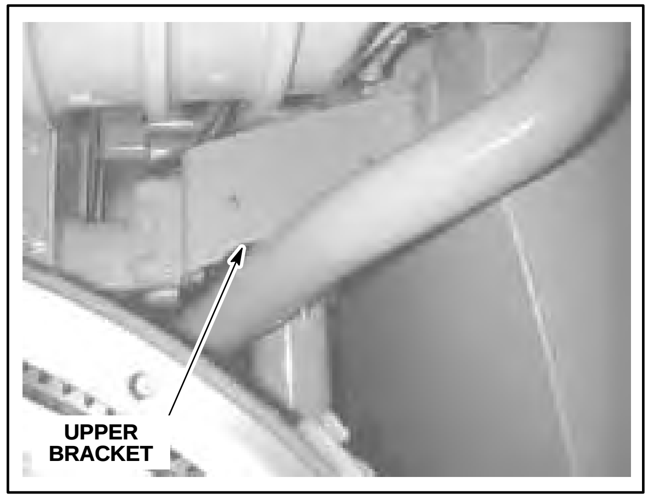


Figure 5.15-33. GSID/GLD Upper Bracket

2. Install lower GSID/GLD air duct bracket onto crankcase above starter (see Figure 5.15-34).

NOTE: *The GLD has an additional fuel pipe support bracket attached to the lower air duct bracket.*

Figure 5.15-34. GSID/GLD Lower Bracket

3. Install GSID/GLD air duct onto upper and lower support bracket (see Figure 5.15-33 and Figure 5.15-34).

4. Install carburetor onto air duct (see Figure 5.15-35). See Section 5.05 *Fuel System* in this manual for carburetor installation.

Figure 5.15-35. GSID Carburetor

5. Install air cleaner elements and rain shields onto air ducts.

6. Install filter restriction indicator onto air duct.

7. Install closed breather piping onto air duct.

AIR DUCT INSTALLATION – DELTEC GLD

1. Install air duct onto intercooler body (see Figure 5.15-36).

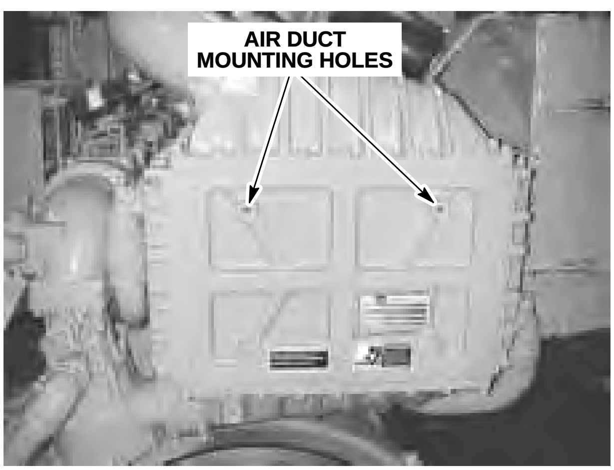


Figure 5.15-36. Intercooler

2. Loosely install air hose and clamps onto carburetor.

⚠ WARNING

The air duct assembly with rain shield and air filter weighs 75 lb. (34 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

3. Install capscrews with two special washers, P/N 305876, per capscrew. Support air duct and install fasteners through air duct and into intercooler (see Figure 5.15-37).

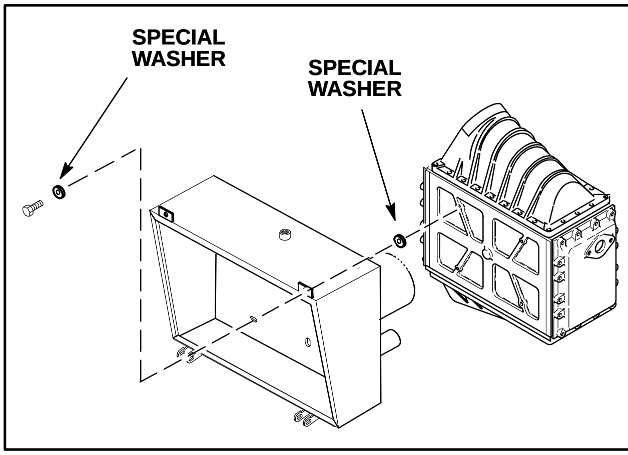


Figure 5.15-37. Deltec Air Duct

4. Slide duct air tube onto carburetor air hose (see Figure 5.15-38). Tighten hose clamps.

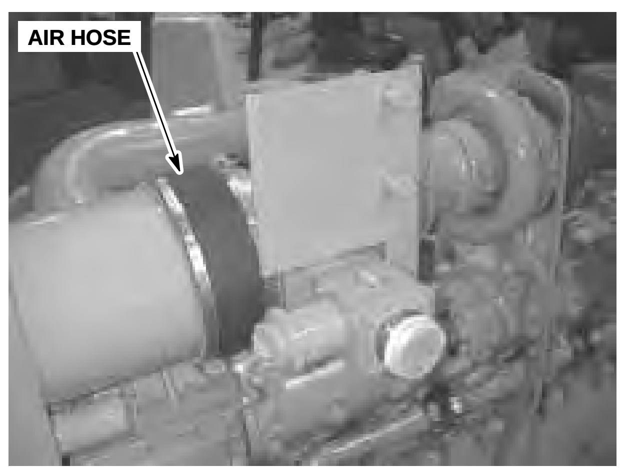


Figure 5.15-38. F18GLD Deltec Dual Fuel Carburetor

5. Install closed breather piping on air duct, if equipped.

6. Install filter restriction indicator in air duct.

7. Install air cleaner elements and rain shield on air duct.

INTAKE MANIFOLD

INTAKE MANIFOLD REMOVAL

Governor System Components

NOTE: *See Section 5.00* Engine Speed Governing System *for additional information.*

1. Remove governor air actuator from front of intake manifold (see Figure 5.15-39).

Figure 5.15-39. Air Actuator

2. Remove 4024 electric governor from top of intake manifold elbow (see Figure 5.15-40). Disconnect linkage and remove governor.

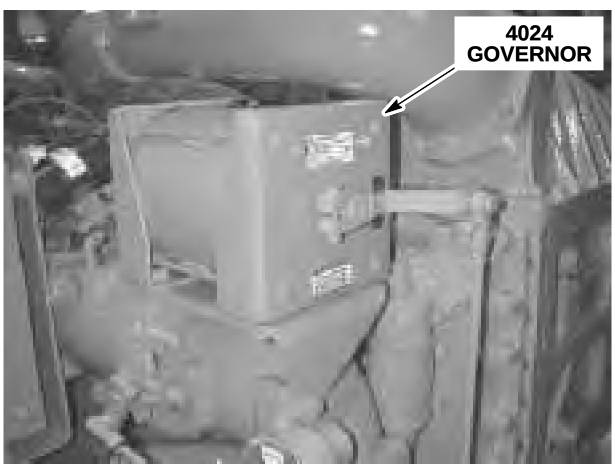


Figure 5.15-40. 4024 Governor

3. Disconnect governor linkage universal joint at butterfly valve (see Figure 5.15-41).

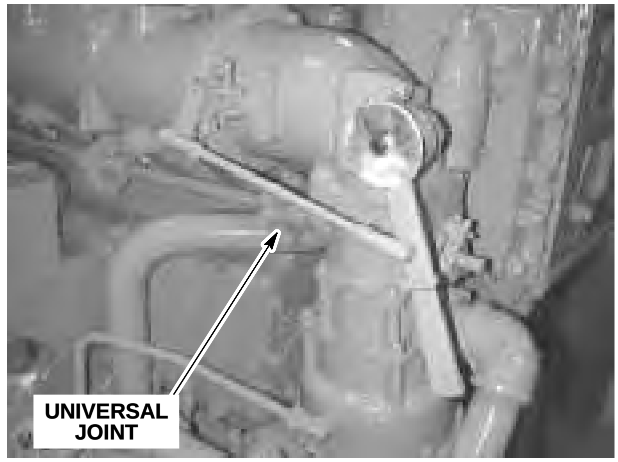


Figure 5.15-41. Throttle Valve

4. Remove governor regulator shaft support brackets located on lower intake manifold (see Figure 5.15-42).

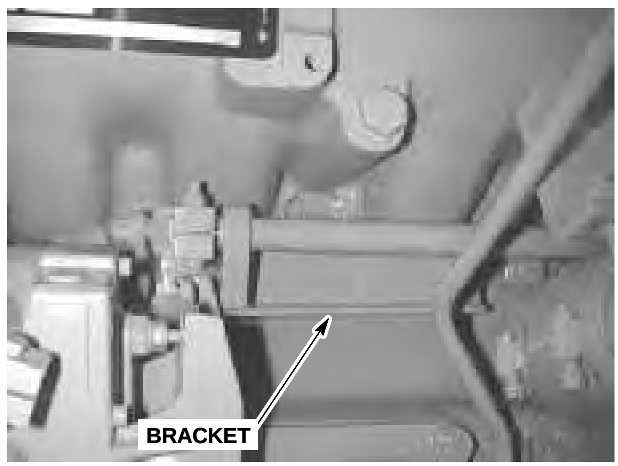


Figure 5.15-42. Shaft Support Bracket

5. Remove CEC Ignition Module, coils and wiring harnesses from intake manifold (see Figure 5.10-2). See Section 5.10 *Ignition System – CEC/Magneto.*

6. Remove control panel assembly from intake manifold (see Figure 5.15-43). See Section 6.00 *Instrument Panel* for complete instructions.

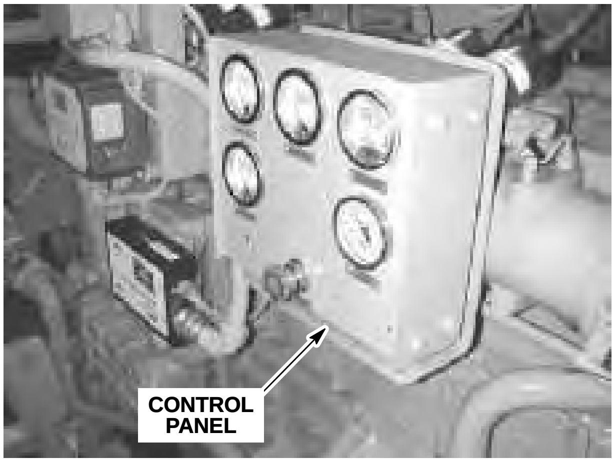


Figure 5.15-43. Control Panel

7. Remove breather system oil separator from support bracket on front of intake manifold (see Figure 5.15-44). Remove support bracket and tubing for closed breather systems. See Section 5.40 *Crankcase Breather System* in this manual for complete instructions.

Figure 5.15-44. Closed Breather System

8. Remove carburetor or air connection from butterfly valve (see Figure 5.15-45).

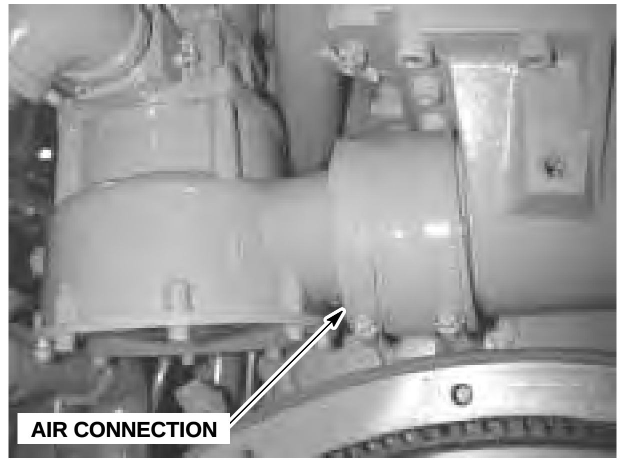


Figure 5.15-45. Carburetor Air Connection

⚠ WARNING

The six cylinder intake manifold and elbow assembly weighs 51 lb. (23 kg). The eight cylinder intake manifold and elbow assembly weighs 65 lb. (30 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

NOTE: *The butterfly valve can be removed from the engine separately or attached to the intake manifold.*

9. Attach suitable lifting brackets to intake manifold (see Figure 5.15-46). Use lifting device to support manifold while removing hex head screws.

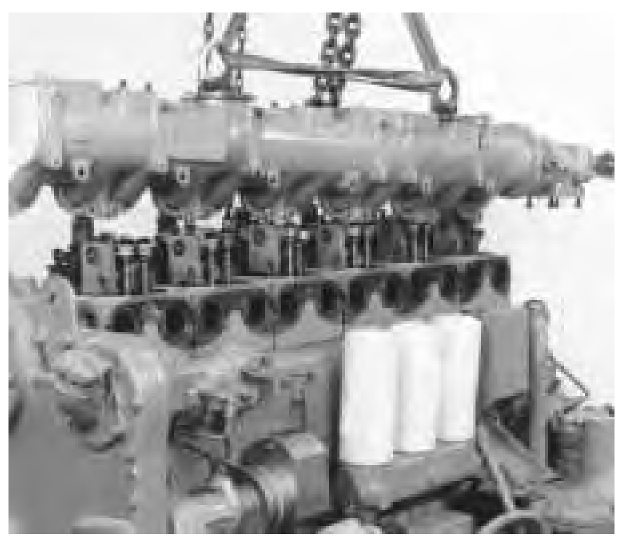


Figure 5.15-46. Intake Manifold Removal

10. Remove O-rings from cylinder heads (see Figure 5.15-47).

NOTE: *Use masking tape to cover inlet port on each cylinder head to protect against dirt.*

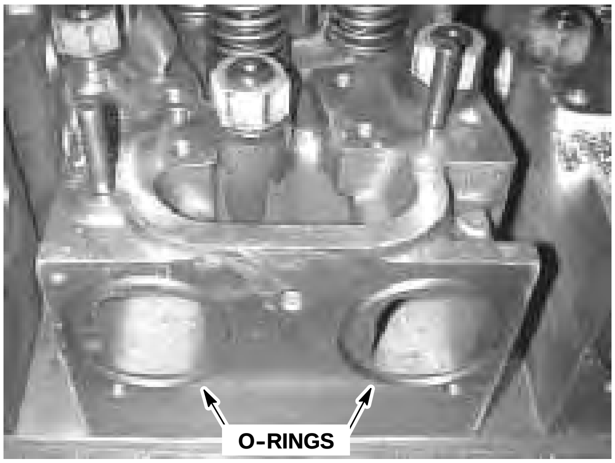


Figure 5.15-47. Intake Manifold O-rings

INTAKE MANIFOLD

INTAKE MANIFOLD ASSEMBLY

1. Install gaskets and covers on intake manifold (see Figure 5.15-50). Apply pipe sealant and install plugs in each manifold cover.

2. Install intake elbow assembly and gasket. Secure with M8 x 25 mm hex head screws and tighten to 19 ft-lb (26 N·m). Check alignment and adjust as necessary.

INTAKE MANIFOLD INSTALLATION

NOTE: *Permatex® High Tack Spray-A-Gasket® may be used keep the O-rings in place during assembly.*

1. Install new O-rings in each cylinder head (see Figure 5.15-47).

⚠ WARNING

The six cylinder intake manifold and elbow assembly weighs 51 lb. (23 kg). The eight cylinder intake manifold and elbow assembly weighs 65 lb. (30 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

NOTE: *The butterfly valve can be installed on the engine separately or attached to the intake manifold.*

2. Attach suitable lifting brackets to intake manifold (see Figure 5.15-48). Use lifting device to support manifold while installing intake manifold hex head screws.

Figure 5.15-48. Intake Manifold Installation

3. Secure intake manifold with M12 x 140 mm and M10 x 40 mm hex head screws. Apply Loctite® 242 onto threads.

4. Tighten M12 hex head screws to 65 ft-lb (88 N·m). Tighten M10 hex head screws to 37 ft-lb (50 N·m).

5. Install carburetor or air connection onto butterfly valve (see Figure 5.15-49).

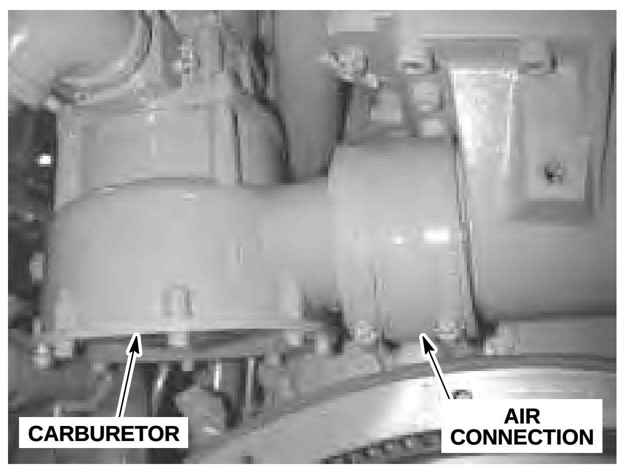


Figure 5.15-49. Carburetor Air Connection

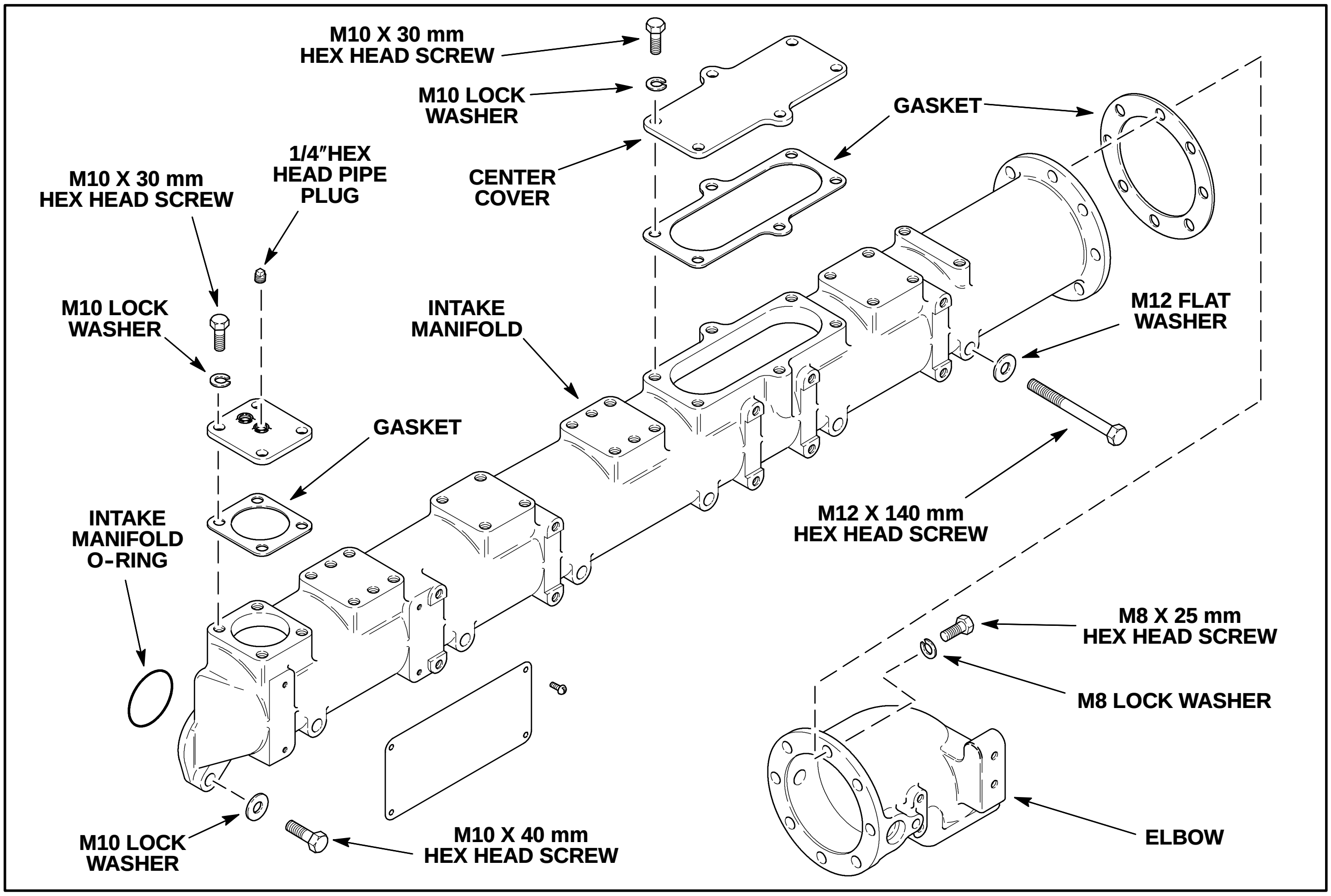


Figure 5.15-50. Intake Manifold Assembly

6. Install breather system oil separator (see Figure 5.15-51). Install support bracket and tubing for closed breather systems. See Section 5.40 *Crankcase Breather System* for complete instructions.

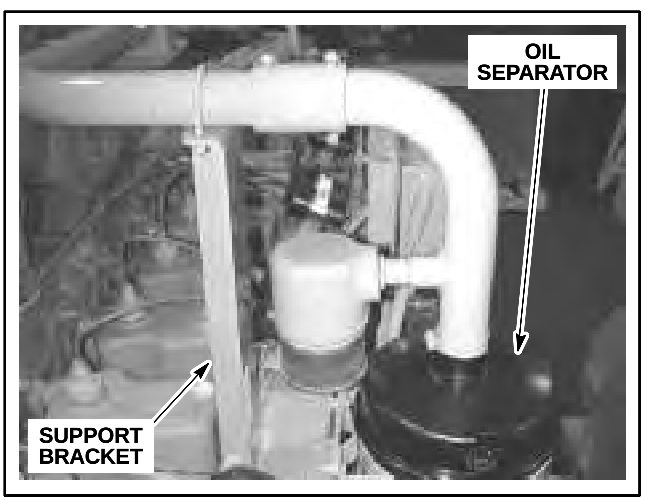


Figure 5.15-51. Closed Breather System

7. Install instrument panel assembly onto intake manifold (see Figure 5.15-52). See Section 6.00 *Instrument Panel* for complete instructions.

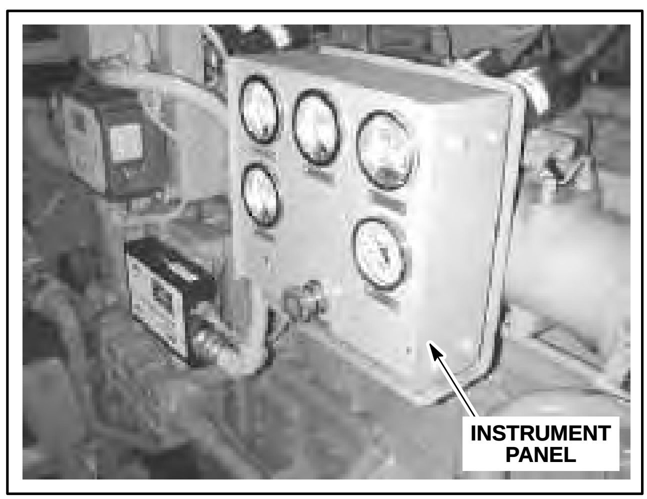


Figure 5.15-52. Instrument Panel

8. Install CEC Ignition Module, coils and wiring harnesses onto intake manifold (see Figure 5.15-53). See Section 5.10 *Ignition System – CEC/Magneto* for complete instructions.

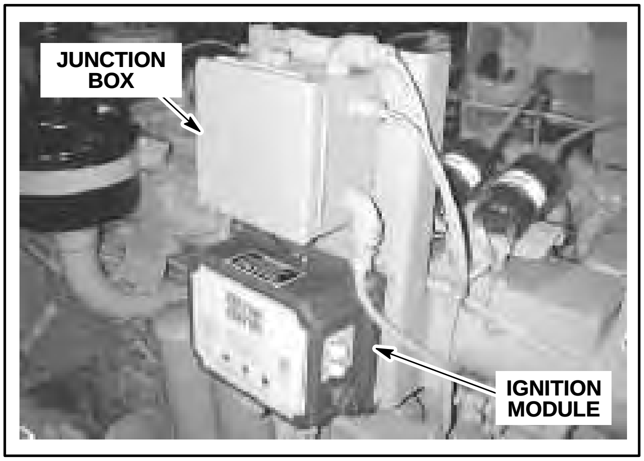


Figure 5.15-53. CEC Ignition Module

9. Install 4024 electric governor on top of intake manifold elbow and throttle butterfly valve (see Figure 5.15-54). See Section 5.00 *Engine Speed Governing System* for complete instructions.

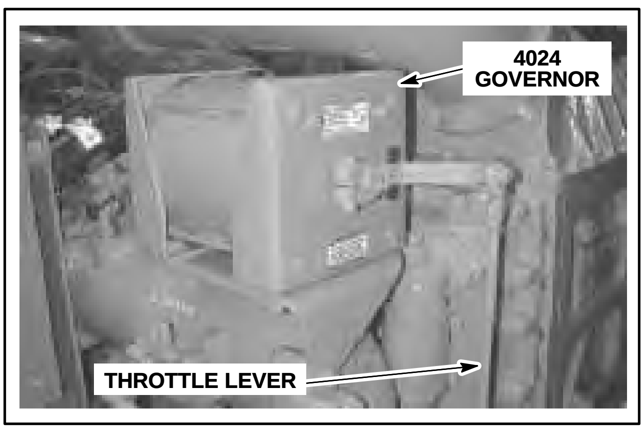


Figure 5.15-54. 4024 Governor

10. Install governor air actuator on front of intake manifold (see Figure 5.15-55). See Section 5.00 *Engine Speed Governing System* for complete instructions.

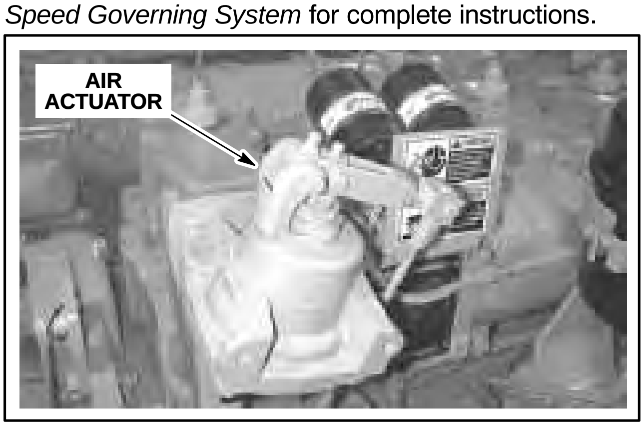


Figure 5.15-55. Air Actuator

11. Install governor linkage universal joint at butterfly valve (see Figure 5.15-56).

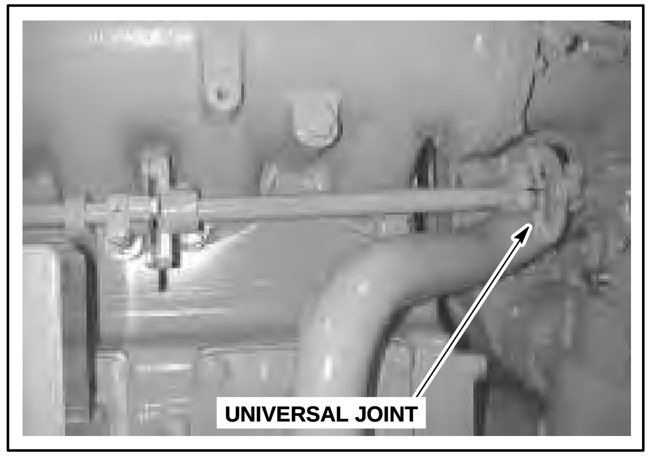


Figure 5.15-56. Butterfly Valve

12. Install governor regulator shaft support brackets onto intake manifold (see Figure 5.15-57 and Figure 5.15-58).

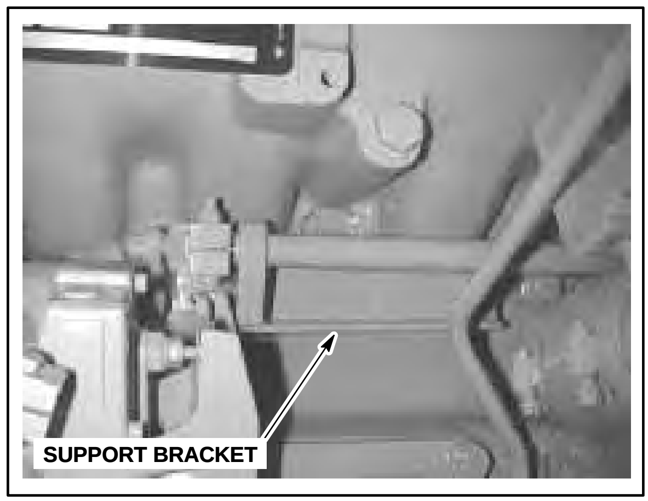


Figure 5.15-57. Shaft Support Bracket

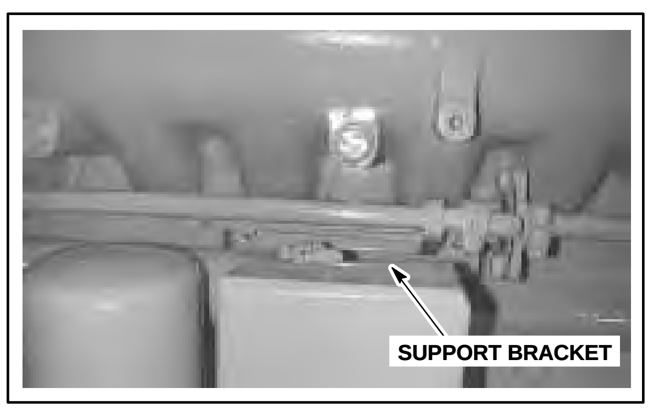


Figure 5.15-58. Shaft Support Bracket

SECTION 5.20

TURBOCHARGER

TURBOCHARGER

NOTE: *Instructions on installing the wastegate are contained in Section 5.35* Exhaust System*.*

⚠ WARNING

DO NOT operate the turbocharger without the air inlet and exhaust outlet connections installed. The turbocharger can generate enough force to draw objects into it. Disregarding this information can result in product damage and/or severe personal injury or death.

⚠ WARNING

Ensure that the turbocharger has cooled before performing any maintenance procedures. Failure to allow the turbocharger to cool could result in severe personal injury or death.

TURBOCHARGER REMOVAL

Heat Shields Removal

Heat shields need to be removed for access to the turbocharger and connections (see Figure 5.20-1).

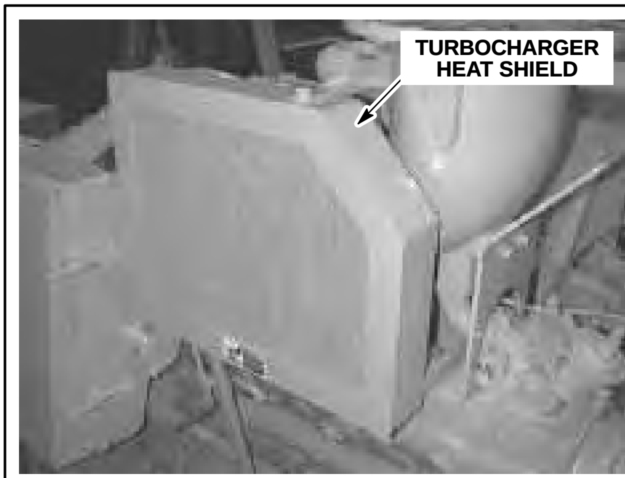


Figure 5.20-1. Heat Shield

1. Remove heat shield support strap from exhaust elbow (see Figure 5.20-2).

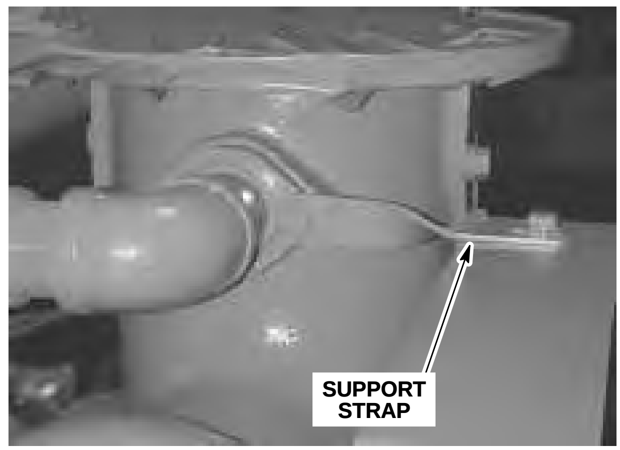


Figure 5.20-2. Heat Shield Attachment

2. Remove wastegate sensing tube support clip from turbocharger inner heat shield (see Figure 5.20-3).

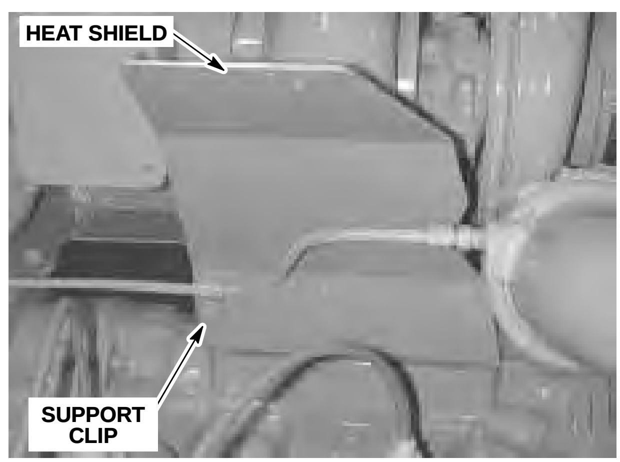


Figure 5.20-3. Heat Shield Attachment

3. Heat shields for flange mounted CSA ignition coils are secured with a 3/8 in. hex head screw and spacer (see Figure 5.20-4). Remove hex head screw and spacer.

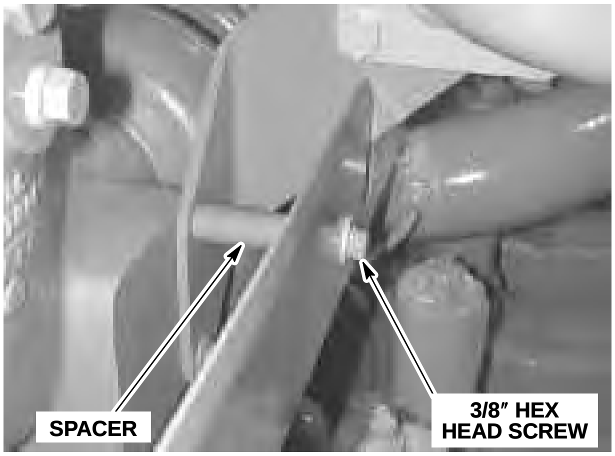


Figure 5.20-4. CSA Coil Heat Shields

4. Remove M8 hex head screws and nuts from heat shield lower mounting (see Figure 5.20-5).

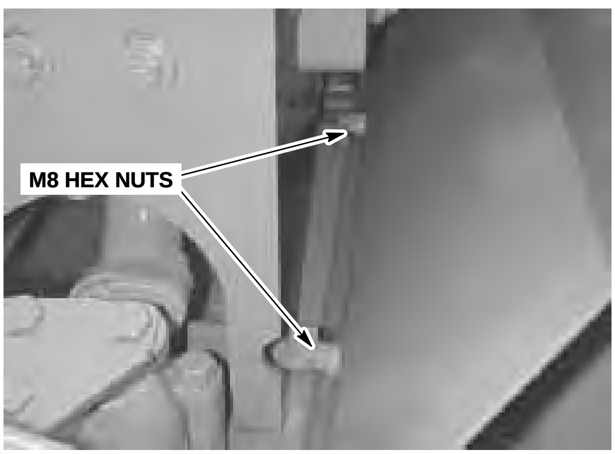


Figure 5.20-5. Heat Shield Attachment

5. **GL only—**Loosen hose clamps and remove inlet hose from lip of turbocharger compressor air inlet and air duct (see Figure 5.20-6).

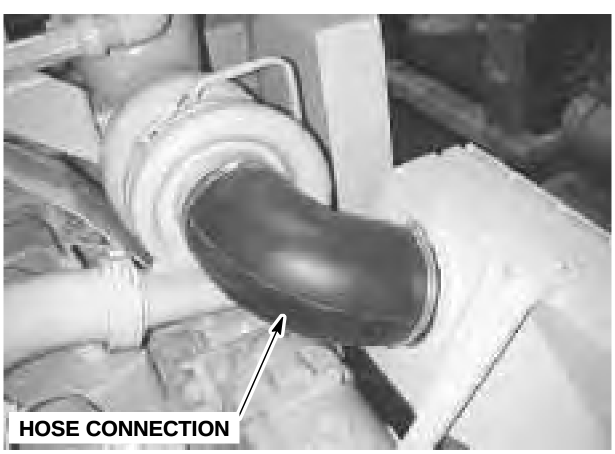


Figure 5.20-6. Turbocharger Connection – GL Engines

6. Loosen clamp and remove retainers to detach turbocharger air inlet from carburetor air connection (GLD and GSID models only). Remove and discard sealing O-ring (see Figure 5.20-7).

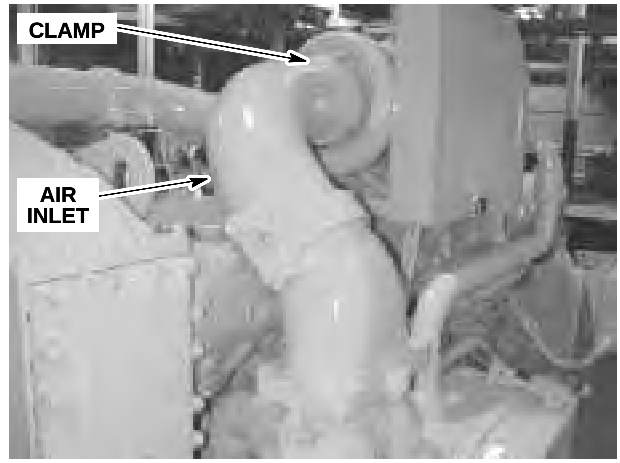


Figure 5.20-7. GLD/GSID Turbocharger Air Inlet

7. Remove clamp and retainers that connect turbocharger air outlet to intercooler inlet elbow. Remove O-ring in connection (see Figure 5.20-8).

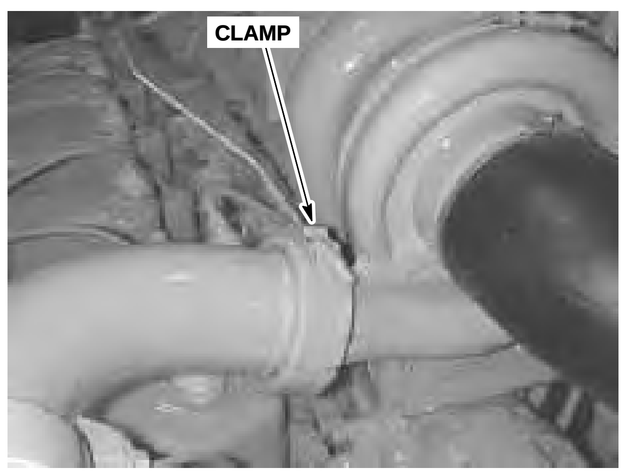


Figure 5.20-8. Turbocharger Connection

EXHAUST OUTLET REMOVAL

NOTE: *The exhaust outlet does not have to be removed from the engine for turbocharger removal.*

1. Remove breather ejector (if equipped) from exhaust outlet (see Figure 5.20-9).

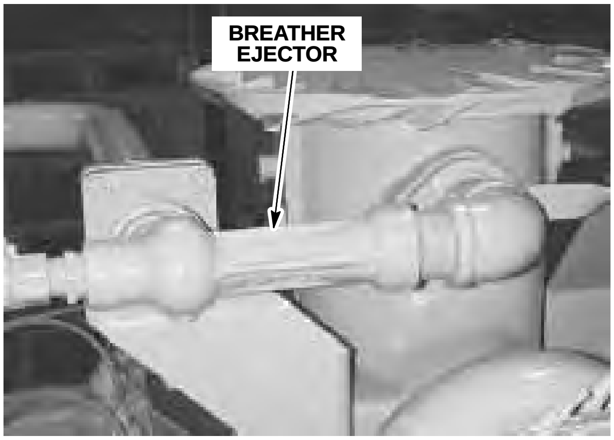


Figure 5.20-9. Breather Ejector

2. Remove M10 x 30 mm socket head screws and 3/8 in. hex head screws from wastegate bypass tube. Remove wastegate bypass tube from exhaust outlet (see Figure 5.20-10).

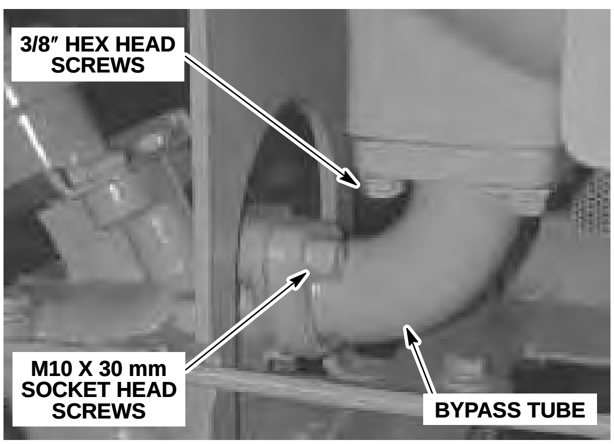


Figure 5.20-10. Wastegate Bypass Tube

3. Loosen V–band clamp and disconnect turbocharger exhaust outlet from engine exhaust elbow (see Figure 5.20-11).

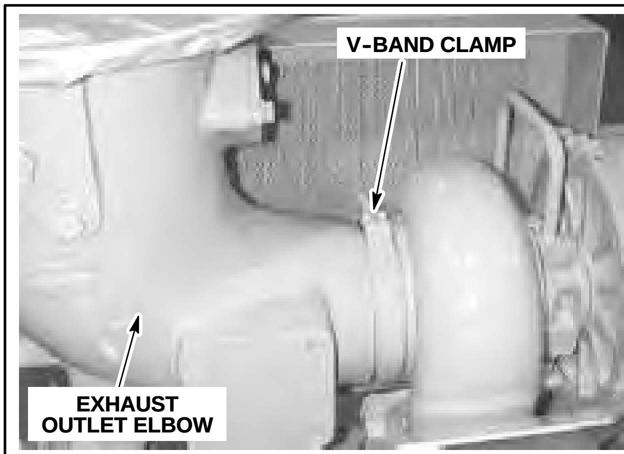


Figure 5.20-11. Exhaust Outlet Elbow

⚠ WARNING

The exhaust outlet weighs approximately 55 lb. (25 kg). Use a suitable lifting device and exercise caution during removal or installation to avoid severe personal injury or death.

4. Remove two hex head screws and washers from front heat shield bracket and lift exhaust outlet from engine (see Figure 5.20-12).

NOTE: *The exhaust outlet does not have to be removed from the engine for turbocharger removal.*

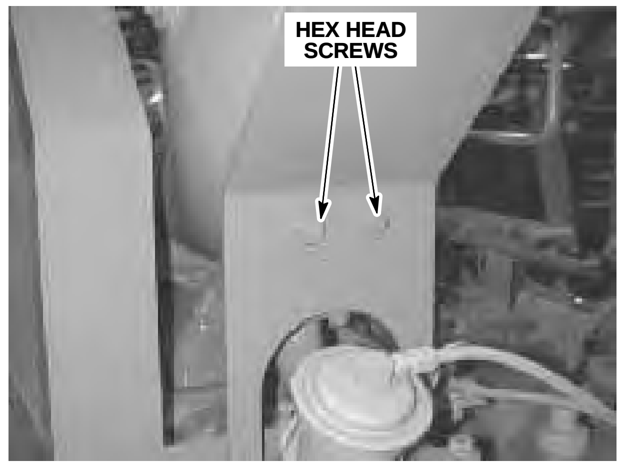


Figure 5.20-12. Exhaust Outlet

5. Remove upper oil supply and drain tubes from turbocharger center housing (see Figure 5.20-13).

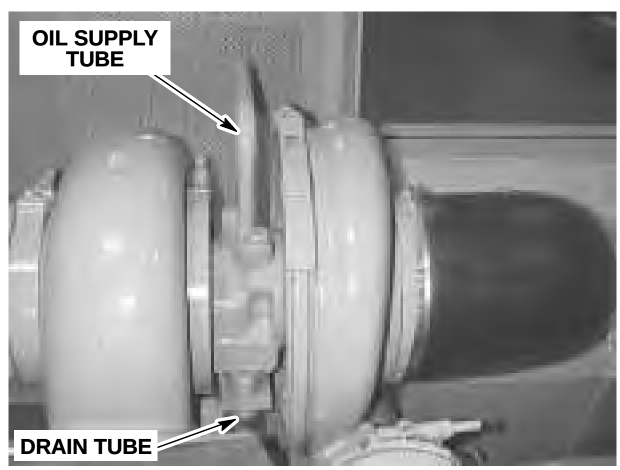


Figure 5.20-13. Turbocharger Oil Supply Tubes

6. Remove oil tubes from crankcase (see Figure 5.20-14).

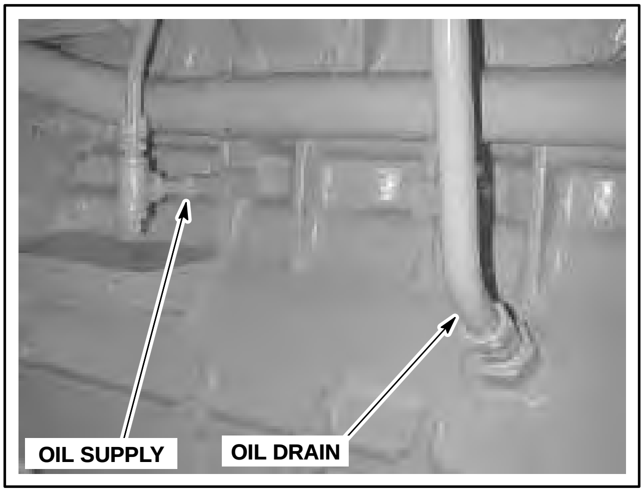


Figure 5.20-14. Turbocharger Oil Supply Tubes

⚠ WARNING

The turbocharger weighs approximately 55 lb. (25 kg). Use a suitable lifting device and exercise caution during removal or installation to avoid severe personal injury or death.

7. Remove M10 x 40 mm hex head screws, gasket and turbocharger from exhaust inlet adapter (see Figure 5.20-15).

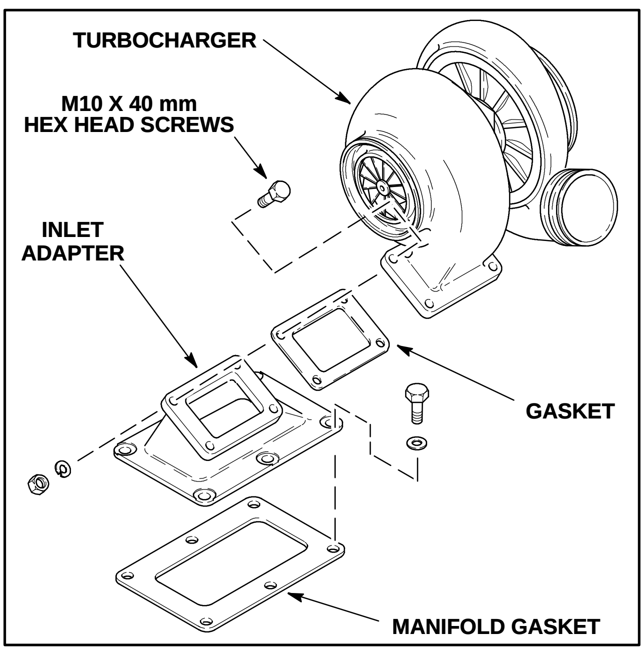


Figure 5.20-15. Turbocharger Removal

TURBOCHARGER DISASSEMBLY

NOTE: *Inspect the turbocharger in an area free of dirt and debris. If the turbocharger becomes contaminated with dirt or debris it could fail or suffer from extreme wear in a short period of time.*

1. Remove V-band coupling between compressor and center housings. Remove compressor housing (see Figure 5.20-16).

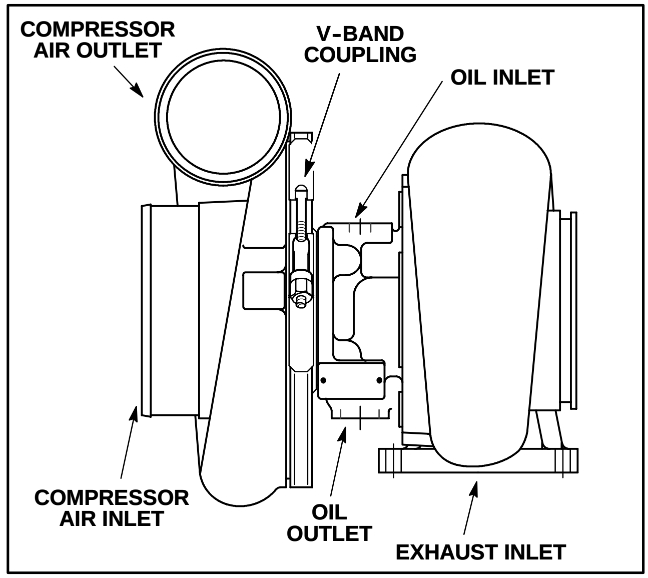


Figure 5.20-16. Turbocharger V-band Coupling

⚠ CAUTION **Do not use a screw driver, dirty rags, sandpaper, emery cloth or steel wool to clean the compressor wheel or housing. Use of abrasive materials or caustic solutions will result in damage. Disregarding this information could result in product damage and/or personal injury.**

2. Clean compressor wheel and housing with a non-caustic cleaning solution. Use a nylon brush and plastic scraper to completely remove all accumulated surface matter.

COMPRESSOR HOUSING O-RING

Sealing O-rings are used in VGF GLD/GSID model turbocharger compressor housings. These O-rings are available as service parts.

Replace the O-rings when found hard and brittle after inspection or when the turbocharger is overhauled.

1. Loosen and remove V-band coupling from compressor air inlet.

2. Remove compressor air inlet.

3. Replace O-ring (see Figure 5.20-17).

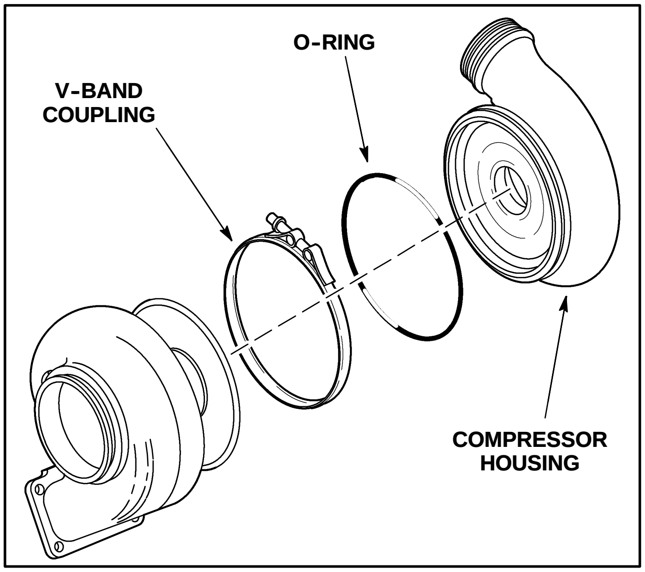


Figure 5.20-17. Turbocharger Compressor Housing

TURBOCHARGER CLEANING AND INSPECTION

Clean and inspect the turbocharger(s) every 6 months (4320 hours).

Table 5.20-1. Turbocharger Shaft Specifications

Turbine Shaft Maximum Radial Play	0.003 - 0.007 in. (0.08 - 0.18 mm)
Turbine Shaft Maximum Axial Play	0.003 - 0.010 in. (0.08 - 0.25 mm)

NOTE: *Inspect the turbocharger in an area free of dirt and debris. If the turbocharger becomes contaminated with dirt or debris it could fail or suffer from extreme wear in a short period of time. Dust, dirt, sand or any other foreign material that enters the compressor housing through a leak in the air inlet system will cause the leading edges of the compressor wheel blades to erode.*

1. Inspect tips or leading edges of compressor blades for any wear or damage (see Figure 5.20-18 and Figure 5.20-19).

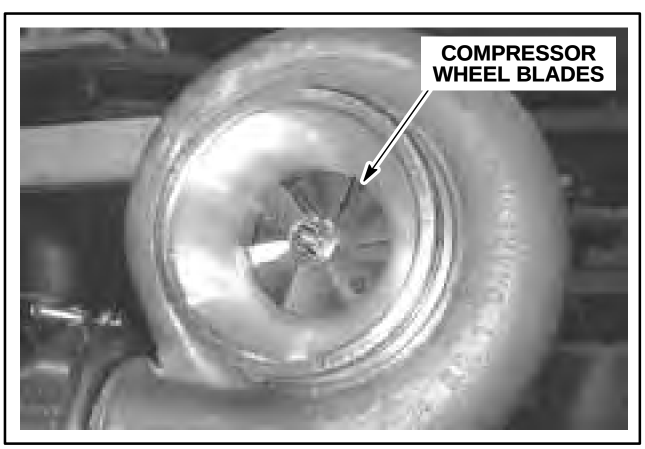


Figure 5.20-18. Turbocharger Compressor Wheel

2. Inspect outer or trailing edges of compressor blades for any wear or damage (see Figure 5.20-19).

NOTE: *Loose material from the engine, such as small pieces of valves or rings, can cause severe damage to the tips or leading edges of the turbine blades. Focus the beam of a flashlight between the turbine blades and the inside of the turbine housing in order to perform a proper inspection.*

3. Check compressor housing wall for rub marks or dirt.

NOTE: *Bearing failure or an excessive accumulation of dirt will cause the compressor wheel blades to make contact with the compressor housing wall.*

CAUTION **Always clean the air induction system and replace the air cleaner element after compressor wheel damage. Pieces from the compressor wheel will become lodged in the air cleaner element and air induction system and if not removed will damage the new turbocharger. Disregarding this information could result in product damage.**

4. Inspect inside of compressor housing for signs of oil leakage.

NOTE: *Look for sludge buildup on the shaft between the bearing journals and the inner walls of the turbocharger center housing. Check from the oil drain opening back to the turbine end. If no sludge is apparent, inspect the oil drain tubes for damage or internal restrictions.*

5. Replace turbocharger if any damage, sludge or carbon coking is found.

6. Push inward on compressor wheel while rotating shaft assembly by hand. Feel for drag, rubbing or binding. Verify compressor wheels turn freely, without contacting the housings, backplate or shroud. Listen for unusual noises. Repeat procedure for turbine side.

7. Rotate assembly by hand while pushing shaft up and down (sideways). Verify shaft turns smoothly without wheel rub.

8. Replace turbocharger if any drag, rubbing, binding or unusual noises are observed.

Check journal bearings for axial (end) play as follows:

9. Mount a dial indicator with a magnetic base on exhaust outlet flange at turbine end of turbocharger.

10. Set dial indicator point on flat end of turbine wheel assembly (see Figure 5.20-19).

11. Push shaft assembly toward compressor end of turbocharger and hold.

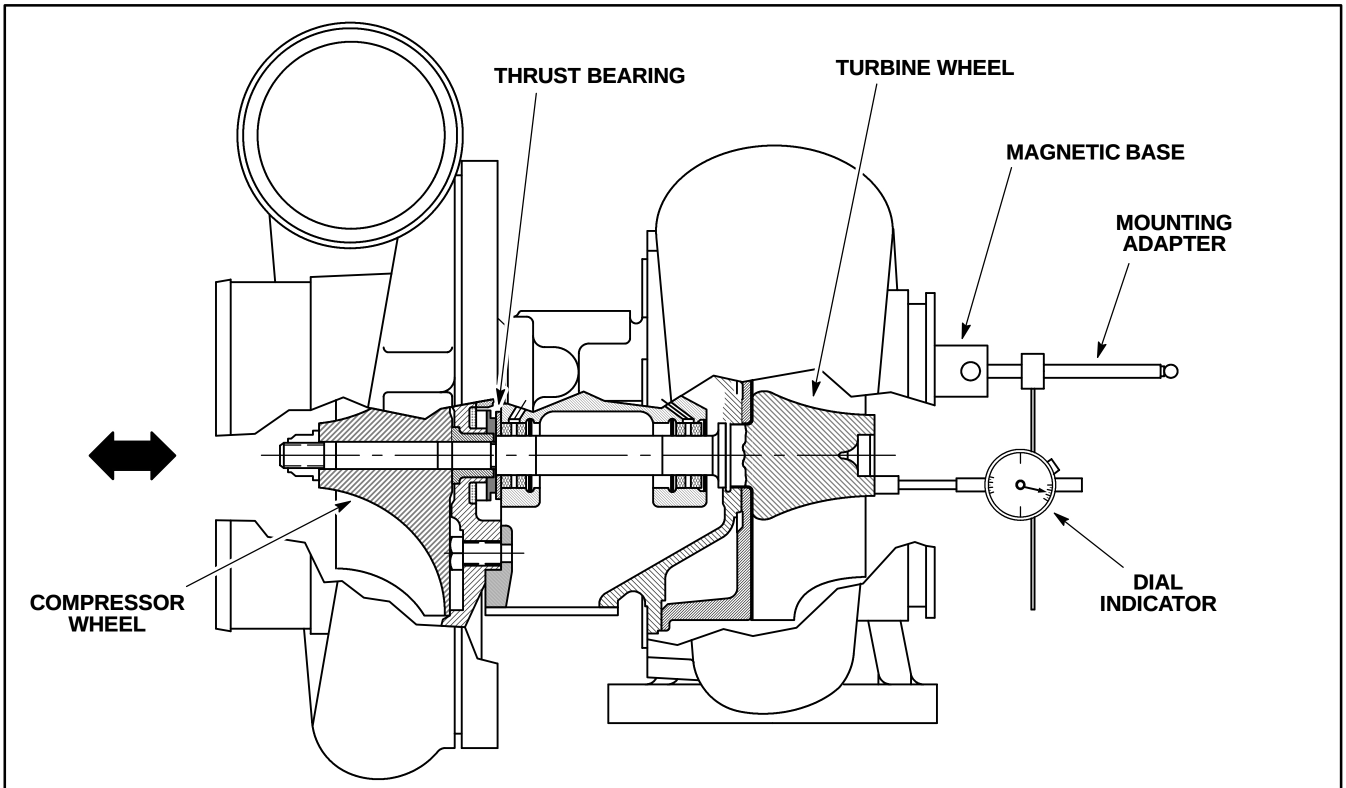


Figure 5.20-19. Turbocharger Axial (End) Play

12. While holding shaft in position, zero dial indicator on turbine end of shaft.

13. Push compressor wheel toward turbine end of turbocharger and hold.

14. While holding shaft in position, record maximum travel of turbine wheel as shown on indicator dial.

15. Push shaft assembly toward compressor end of turbocharger and hold. While holding shaft in position, verify that indicator pointer returns exactly to zero.

16. Repeat Steps 11 – 15 to verify first dial indicator reading.

⚠ CAUTION Continued operation of a turbocharger having excessive axial (end) play or excessive radial (run out) play will result in irreparable damage or possible disintegration of the turbine wheel assembly. Disregarding this information could result in product damage and/or personal injury.

17. Replace turbocharger if maximum axial end play is greater than 0.003 – 0.010 in. (0.08 – 0.25 mm).

Check journal bearings for radial (run out) play as follows:

18. Insert dial indicator plunger through oil outlet port until it contacts turbine shaft (see Figure 5.20-20).

19. Simultaneously press down on both compressor and turbine wheels.

20. While holding shaft in position, set dial indicator to zero.

21. Simultaneously pull up on both compressor and turbine wheels. While holding shaft in position, record maximum movement of shaft as shown on indicator dial.

NOTE: *Make sure that the dial indicator reading is the maximum obtainable, which can be verified by rolling the wheels slightly in both directions while applying pressure.*

22. Simultaneously press down on both compressor and turbine wheels. While holding shaft in position, verify that indicator pointer returns exactly to zero.

23. Repeat Steps 19 – 22 to verify first dial indicator reading.

24. Replace turbocharger if maximum radial (run out) play is greater than 0.003 – 0.007 in. (0.08 – 0.18 mm).

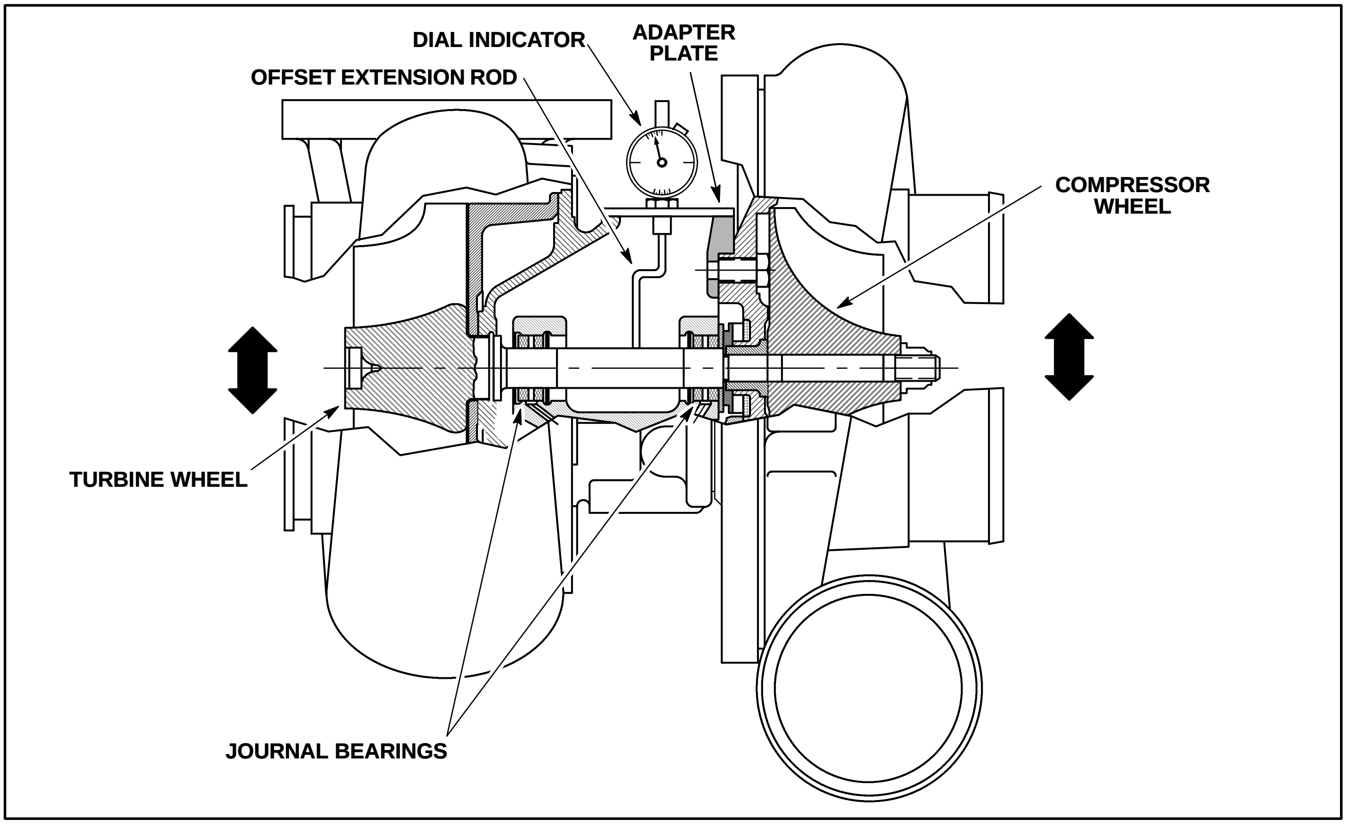


Figure 5.20-20. Check Turbocharger Radial Play

TURBOCHARGER ASSEMBLY

1. Coat threads of turbine housing V–band coupling with copper anti–seize compound (see Figure 5.20-21).

2. Place V–band coupling over center housing and install compressor air inlet.

3. Verify compressor housing is seated squarely against center housing. Place inside groove of V–band coupling over mated housing rims and finger tighten lock nut.

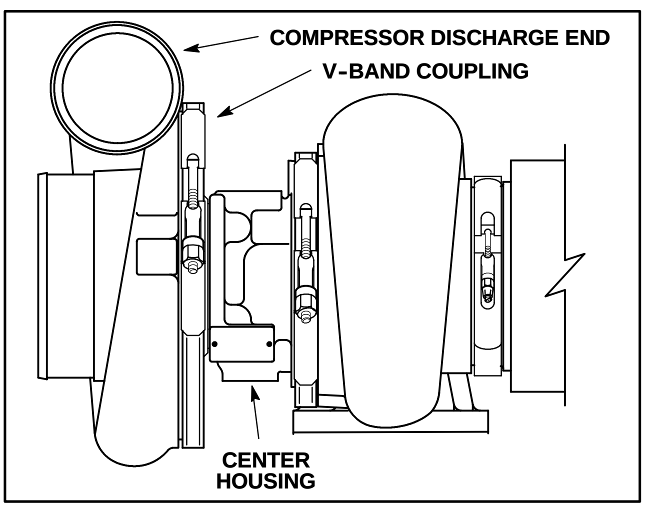


Figure 5.20-21. Garret Turbocharger

4. Verify outlet is positioned correctly.

5. Tighten V–band coupling to 13.3 ft-lb (18.0 N·m) then loosen to 50 in-lb (5.7 N·m).

6. Tighten V–band coupling to 9 – 11 ft-lb (12 – 15 N·m).

TURBOCHARGER INSTALLATION

⚠ CAUTION **Exercise care during installation of the turbochargers to prevent the entrance of dirt or other foreign matter through the oil, air and exhaust openings. Disregarding this information could result in product damage and/or personal injury.**

⚠ WARNING

The turbocharger weighs approximately 50 lb. (25 kg). Use a suitable lifting device and exercise caution during removal or installation to avoid severe personal injury or death.

1. Install turbocharger onto exhaust adapter with new gasket. Secure with M10 x 40 mm hex head screws (see Figure 5.20-22). Apply anti–seize compound and tighten screws to 46 ft-lb (62 N·m).

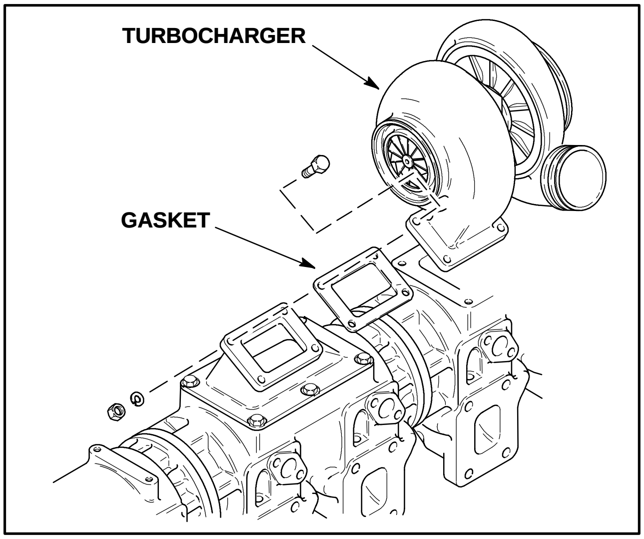


Figure 5.20-22. Turbocharger Installation

NOTE: *Position the gasket with the lip on the inside diameter facing the exhaust adapter (see Figure 5.20-23).*

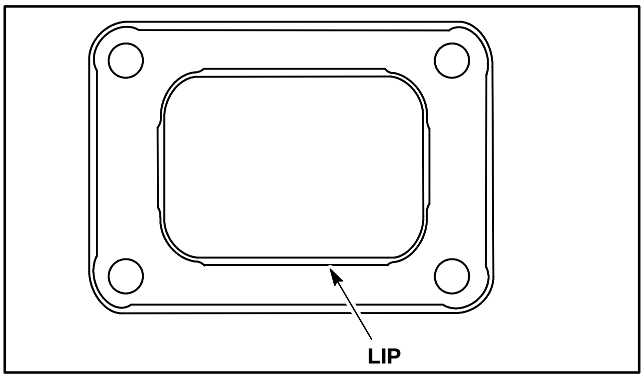


Figure 5.20-23. Turbocharger Exhaust Inlet Gasket

2. Install upper oil supply and lower drain tubes (see Figure 5.20-24). Secure with M10 hex head screws (apply anti-seize compound). Tighten screws to 32 ft-lb (43 N·m).

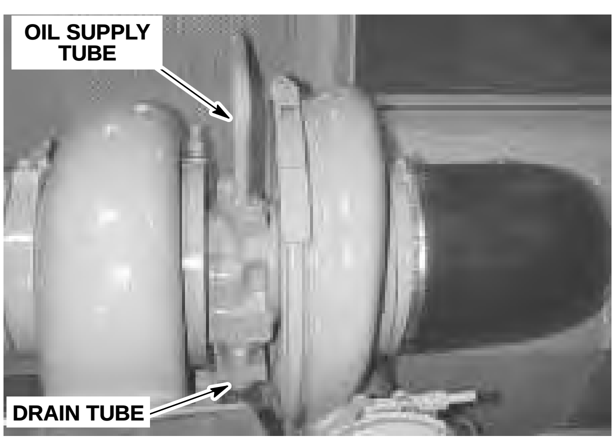


Figure 5.20-24. Turbocharger Oil Supply Tubes

3. Install oil tubes on crankcase (see Figure 5.20-25). Make sure that magnetic drain plug is installed in oil supply tee.

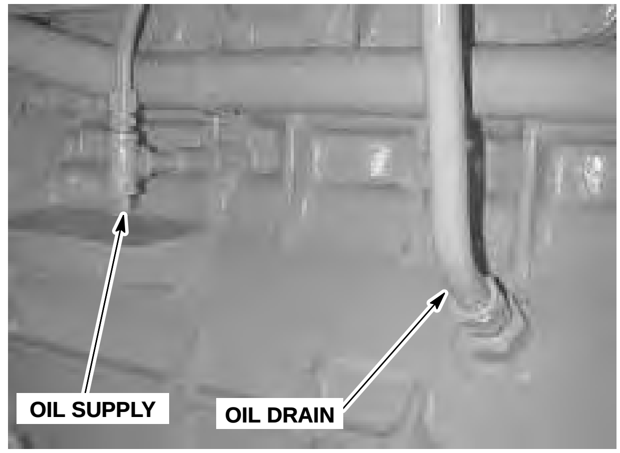


Figure 5.20-25. Turbocharger Oil Supply Tubes

EXHAUST OUTLET INSTALLATION

⚠ WARNING

The exhaust outlet weighs approximately 55 lb. (25 kg). Use a suitable lifting device and exercise caution during removal or installation to avoid severe personal injury or death.

1. Lift exhaust outlet into place on engine (see Figure 5.20-26). Secure with two hex head screws and washers through front heat shield bracket.

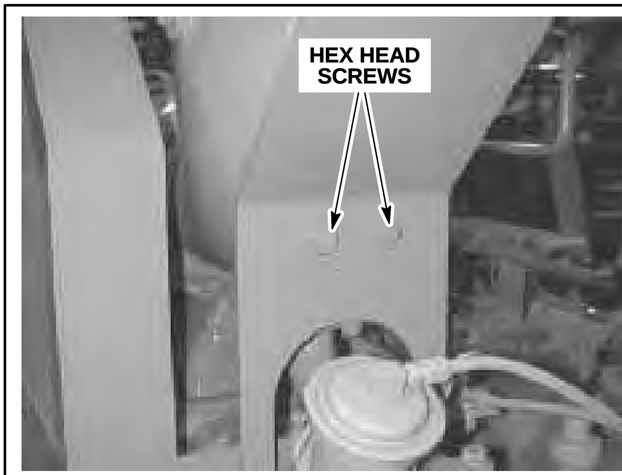


Figure 5.20-26. Exhaust Outlet

2. Position a loosened V-band coupling on exhaust outlet (see Figure 5.20-27).

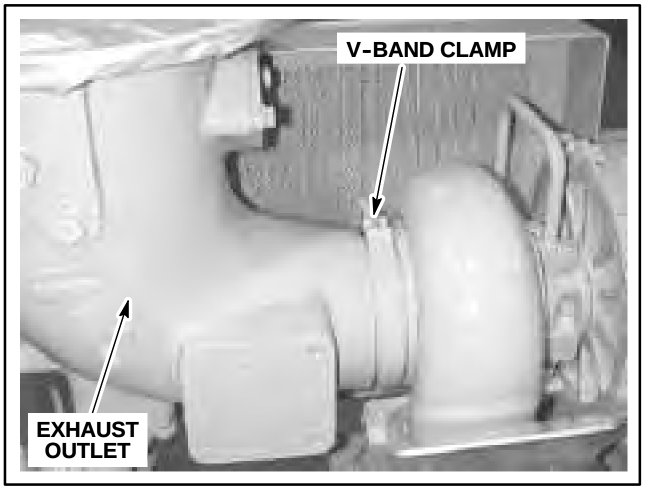


Figure 5.20-27. Exhaust Outlet

3. Verify that rim of exhaust elbow is seated squarely against rim of turbocharger exhaust outlet. Center inside groove of V-band coupling over mated rims (see Figure 5.20-28).

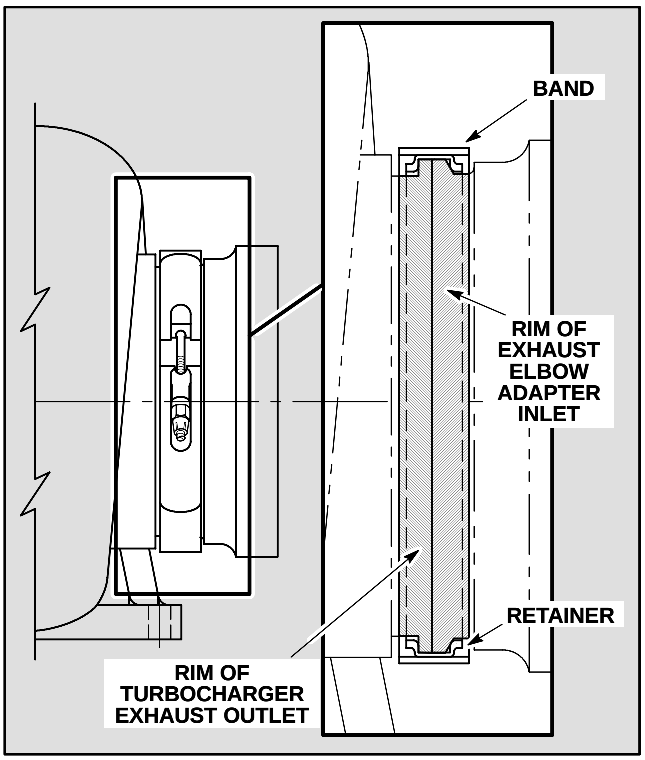


Figure 5.20-28. V-Band Coupling

4. Tighten V-band coupling to 9 - 11 ft-lb (12 - 15 N·m).

5. Install exhaust bypass tube between exhaust outlet and wastegate (see Figure 5.20-29 and Figure 5.20-30). Each tube end is held in place with a gasket and flange. Secure with M10 x 30 mm socket head screws and 3/8 in. hex head screws. Apply anti-seize compound and tighten lower screws to 32 ft-lb (43 N·m).

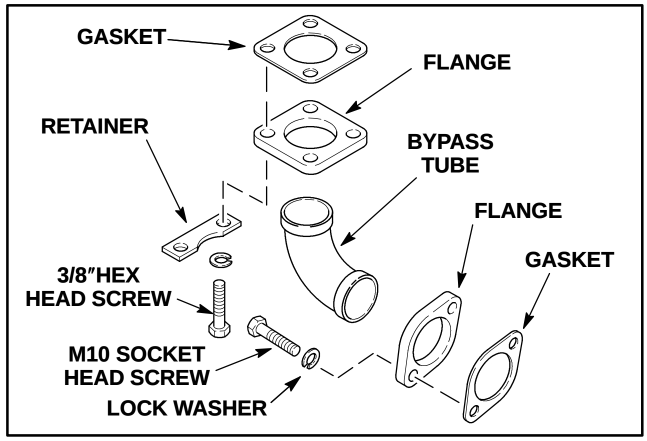


Figure 5.20-29. Wastegate Bypass Tube

6. Upper tube connection also uses a retainer. Apply anti-seize compound and tighten upper screws to 27 ft-lb (36 N·m) (see Figure 5.20-30).

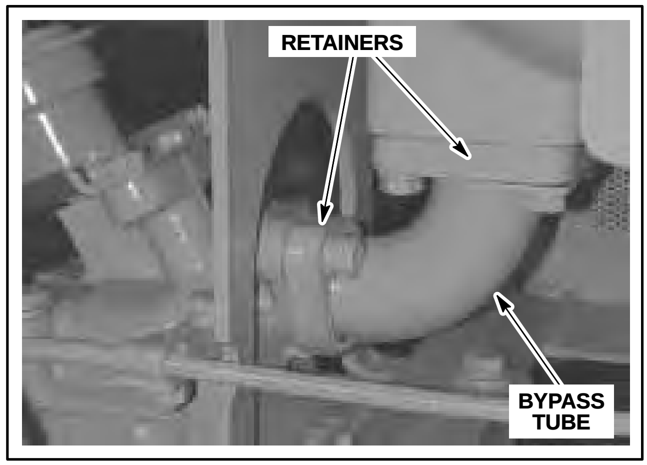


Figure 5.20-30. Wastegate Bypass Tube

7. Install breather ejector (if equipped) and gasket on exhaust outlet (see Figure 5.20-31). Apply anti-seize compound and tighten hex head screws to 32 ft-lb (43 N·m).

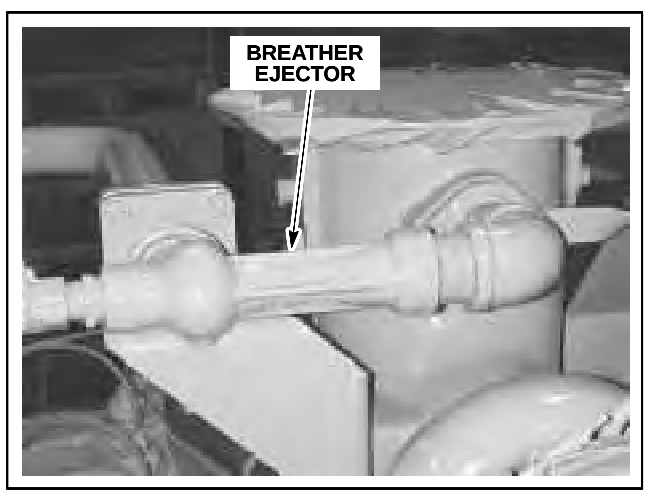


Figure 5.20-31. Breather Ejector

8. Install a new O–ring onto turbocharger air outlet connection (see Figure 5.20-32).

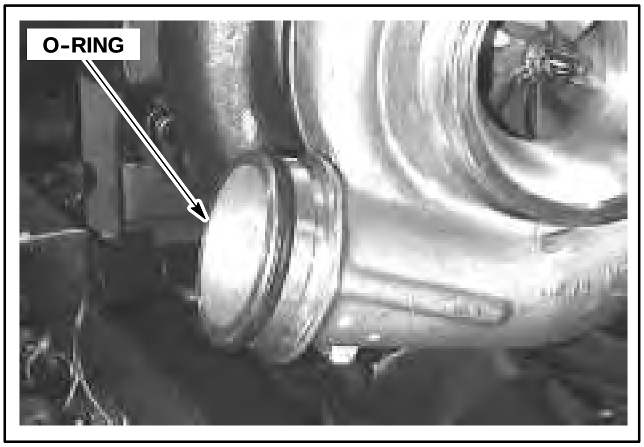


Figure 5.20-32. Turbocharger Air Outlet

9. Install clamp and retainers to connect turbocharger air outlet to intercooler inlet elbow (see Figure 5.20-33).

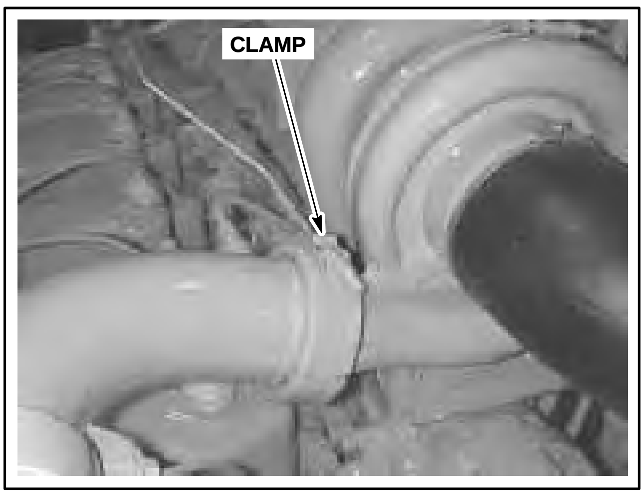


Figure 5.20-33. Turbocharger Connection

NOTE: *If adjustment of the turbocharger compressor air outlet is necessary, loosen the V–band coupling on the compressor side of the turbocharger center housing. Rotate the compressor air outlet until it is aligned with the turbocharger air outlet elbow. Tighten the coupling.*

10. Tighten V–band coupling onto compressor side of turbocharger center housing to 9 – 11 ft-lb (12 – 15 N·m).

11. Tighten hose clamp to secure air cleaner hose connection to turbocharger compressor air inlet (see Figure 5.20-34).

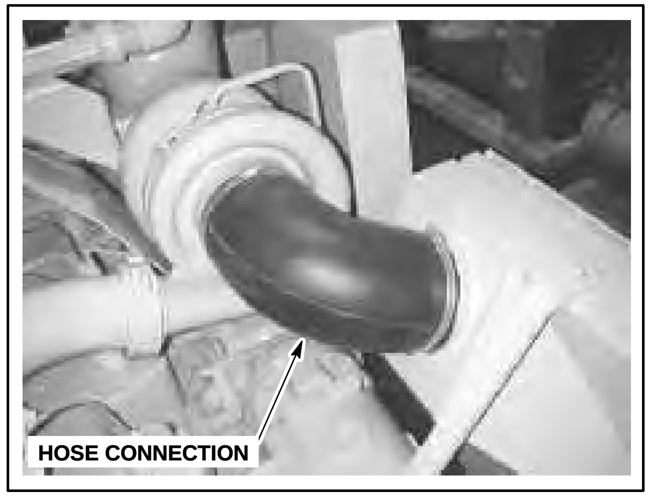


Figure 5.20-34. Turbocharger Connection – GL

12. Install retainers and clamp to attach turbocharger air inlet from carburetor air connection (GLD and GSID models only). Install new O–ring (see Figure 5.20-35).

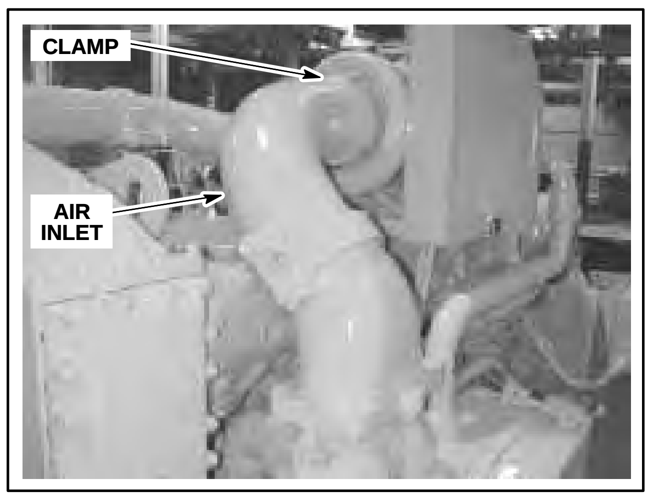


Figure 5.20-35. GLD/GSID Turbocharger Air Inlet

HEAT SHIELDS INSTALLATION

1. Outer heat shield lower legs mount onto turbocharger adapter and wastegate mounting plate (see Figure 5.20-36). Install hex head screws and spacers. Install inner shield fasteners at same time (see Figure 5.20-38).

2. Install inside heat shield and secure with M8 hex nuts and M8 hex head screws (see Figure 5.20-36).

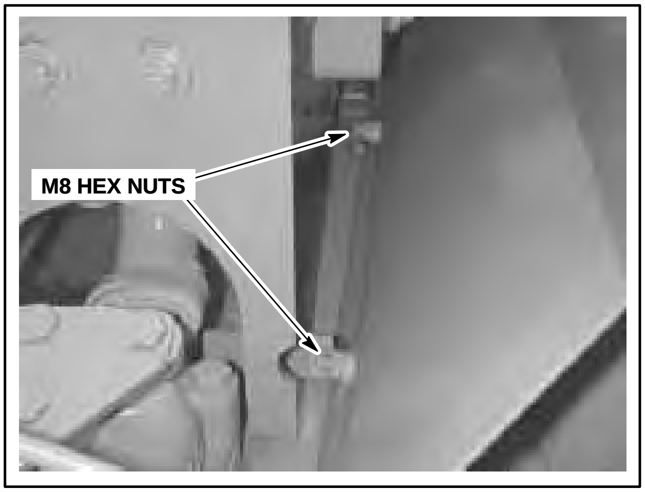


Figure 5.20-36. Heat Shield Attachment

3. Secure CSA coil heat shield with 3/8 in. hex head screws and spacers (see Figure 5.20-37).

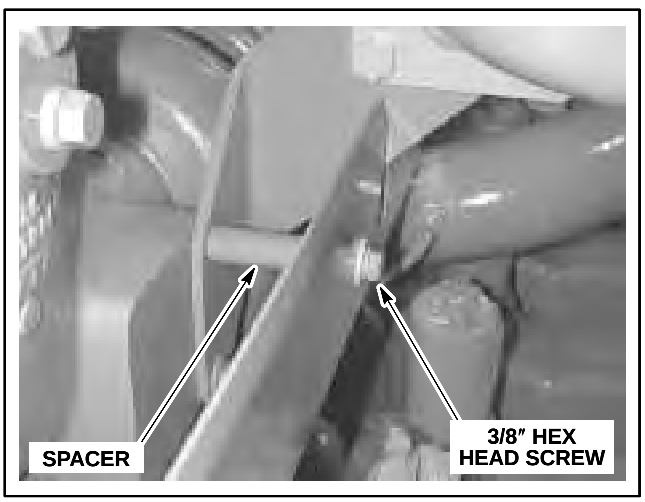


Figure 5.20-37. CSA Coil Heat Shields

4. Install wastegate sensing tube support clip onto turbocharger inner heat shield (see Figure 5.20-38).

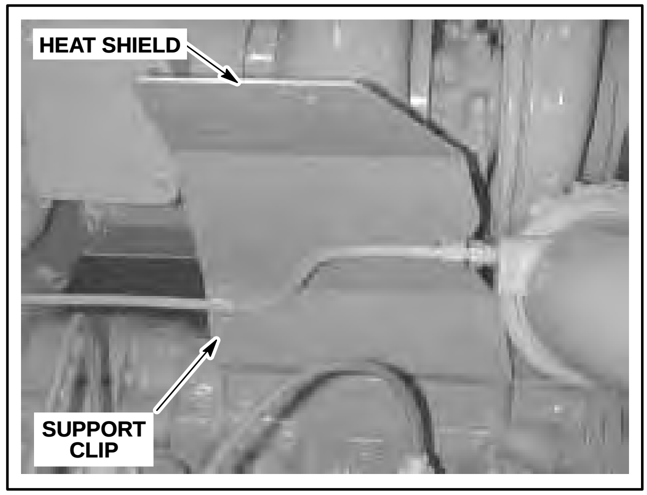


Figure 5.20-38. Heat Shield Attachment

5. Install heat shield support strap onto exhaust elbow (see Figure 5.20-39).

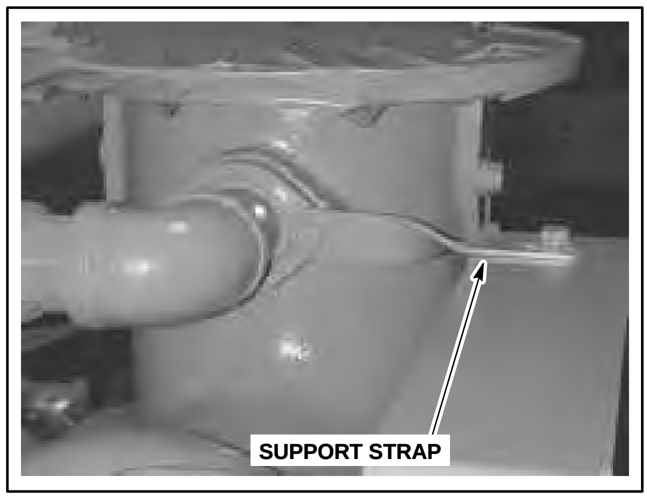


Figure 5.20-39. Heat Shield Attachment

SECTION 5.25

COOLING SYSTEM

COOLING SYSTEM

COOLING SYSTEM DESCRIPTION

The VGF series of engines use a closed, pressure circulating cooling system which is designed to be used with a variety of external cooling devices such as radiators, cooling towers, or heat exchangers.

The engine cooling system consists of the following engine mounted components:

- Jacket water pump (If equipped)
- Auxiliary water pump (If equipped)
- Auxiliary water thermostatic valve
- Thermostat housing
- Jacket water heater (If equipped)
- Surge tank (If equipped)

Coolant is pumped through a gear driven jacket water pump and through the engine crankcase inlet to provide coolant supply for the cylinder liners, cylinder heads, and water jacketed exhaust manifold.

The thermostat housing is located on the front of the exhaust manifold and contains thermostatic valves. If the coolant temperature in the engine is lower than the thermostat's setting, most of the coolant will flow through the bypass to the jacket water pump inlet. If the coolant temperature in the engine is higher than the temperature at which the thermostats start to open, coolant will flow through the open thermostatic valves and flow to the external cooling device.

AUXILIARY COOLING SYSTEM DESCRIPTION

The auxiliary cooling system for GSID, GL and GLD engines maintains the proper air temperature out of the intercooler and oil temperature in the oil cooler. The jacket water pump drives the auxiliary pump to circulate coolant from the intercooler to the oil cooler through external piping. Coolant leaves the intercooler and is directed to the engine mounted oil cooler. From the oil cooler, the coolant flows through the thermostatic control valve in the oil cooler bonnet. The thermostat will bypass some of this flow to the auxiliary pump or direct it to the external cooling device.

The auxiliary cooling water for G series engine oil does not use an auxiliary water pump. Instead cooling water is piped from the jacket water pump through the oil cooler and returns to the jacket water system through the water-cooled exhaust manifold.

JACKET WATER PUMP (IF EQUIPPED)

The gear driven jacket water pump is located on the right front of the engine (see Figure 5.25-1). An external line bleeds trapped air to the thermostat housing.

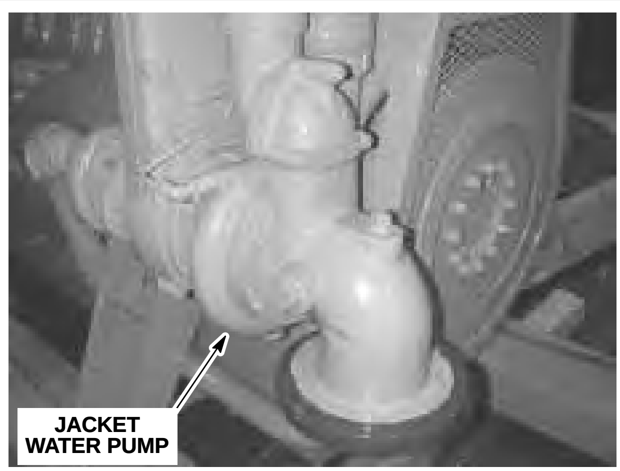


Figure 5.25-1. Jacket Water Pump

AUXILIARY WATER PUMP (IF EQUIPPED)

The auxiliary water pump is located on the right front side of the engine and is driven by the jacket water pump (see Figure 5.25-2). The discharge is piped to the intercooler, oil cooler and the auxiliary cooling system thermostatic control valve.

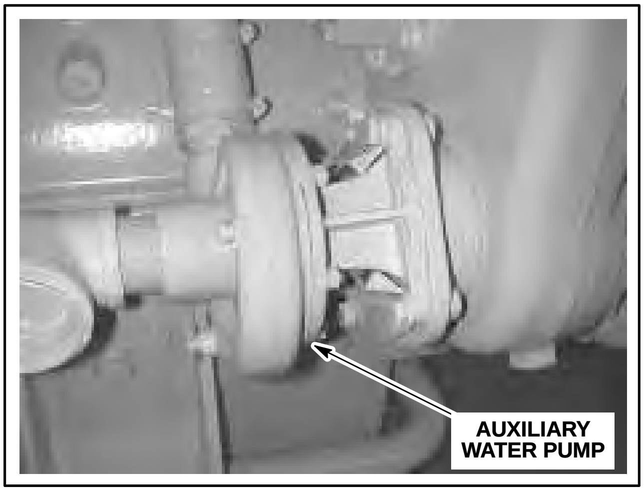


Figure 5.25-2. Auxiliary Water Pump

THERMOSTATIC VALVE HOUSING

The thermostat housing is located on the front of the engine exhaust manifold and contains three thermostatic valves (see Figure 5.25-3). The standard thermostats keep the engine at a constant working temperature of 174 – 195° F (79 – 91° C). If the coolant temperature in the engine is lower than the opening setting of the thermostats, most of the coolant will flow through the bypass to the jacket water pump inlet. If the coolant temperature in the engine is higher than the temperature at which the thermostats start to open, coolant will flow through the open thermostatic valves and flow to the external cooling device.

Figure 5.25-3. Jacket Water Thermostat Housing

AUXILIARY COOLING THERMOSTATIC VALVE

The auxiliary thermostatic valve is located at the water inlet of the oil cooler on the left side of the engine (see Figure 5.25-4). The standard thermostatic valve controls the auxiliary water intercooler temperature to 130° F (54° C). When the operating temperature is reached, the thermostat will bypass the flow of coolant being discharged from the oil cooler outlet to the inlet of the auxiliary water pump.

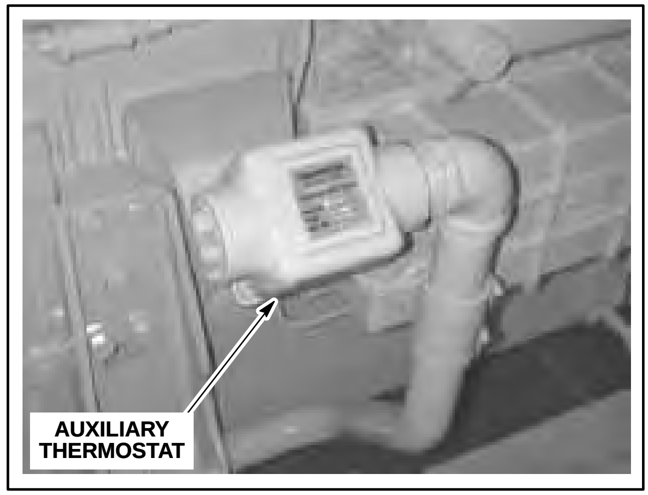


Figure 5.25-4. Auxiliary Thermostat

SURGE TANK (IF EQUIPPED)

An optional surge tank is available for use with closed loop cooling systems. The tank is equipped with a pressure cap, sight glass and drain cock (see Figure 5.25-5).

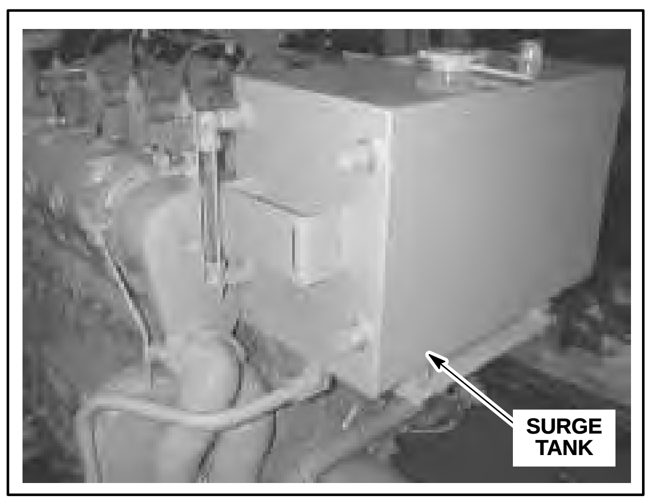


Figure 5.25-5. Surge Tank

COOLING SYSTEM SPECIFICATIONS AND RECOMMENDATIONS

COOLING SYSTEM SPECIFICATIONS

Ensure that the temperature of the cooling water leaving the engine (as indicated by the temperature gauge) does not exceed the temperatures listed in Table 5.25-1. Refer to Section 6.05 *Engine Protection Systems* for alarm and shutdown setpoint temperatures.

Engine overheating, as evidenced by high jacket water temperatures, may be caused by one or more of the following conditions:

- inadequate sizing of the radiator
- defective thermostats
- worn jacket water pump
- excessive jacket water pump suction
- blown head gasket
- faulty temperature gauge
- low coolant level
- overloaded engine
- air bound system
- insufficient air circulation
- exhaust recirculation

JACKET WATER CIRCUITS – INITIAL FILL

JACKET WATER COOLING SYSTEM

1. Open petcock at top of water thermostat housing and jacket water header to vent air when filling jacket water system with coolant (see Figure 5.25-6 and Figure 5.25-7).

2. Add treated coolant to filler neck of surge tank or radiator until coolant begins to escape from water header and top of jacket water thermostat housing.

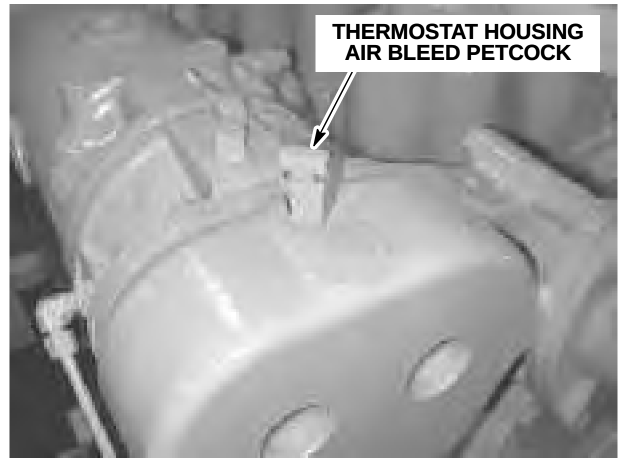


Figure 5.25-6. Thermostat Housing

Figure 5.25-7. Jacket Water Header Air Bleed Petcock

3. Close petcocks and continue filling system until coolant reaches correct level (see Table 5.25-2).

4. Close cooling system and run engine at idle speed. System requires a pressure cap rated at 7 psi (48 kPa).

5. Recheck coolant level and add additional coolant as required.

Table 5.25-1. Jacket Water Outlet Temperature Settings ° F (° C)

JACKET WATER OUTLET TEMPERATURE[1]:	**Standard Cooling System:**	
	Normal:	180° F (82° C) for continuous rating 200° F (93° C) for intermittent rating
	Elevated Temperature Solid Water Cooling System:	
	Normal:	210° – 235° F (82° – 113° C) solid water
	Ebullient Cooling System	
	Normal:	212° – 250° F (100° – 121° C)

NOTE: *[1] Customer supplied fuel shutoff type safety equipment must be provided to prevent engine damage and possible personal injury. See Section 6.05* Engine Protection System *for alarm and shutdown temperatures.*

Table 5.25-2. Jacket Water Capacity - Engine Only

ENGINE MODEL	GALLONS (LITRES)
F18 (six cylinder)	16 (60)
H24 (eight cylinder)	20 (75)

⚠ CAUTION Air in the cooling system speeds up the formation of rust, increases corrosion and produces hot spots within the engine. Disregarding this information could result in product damage and/or personal injury.

6. Bleed trapped air from cooling system (see "Cooling Water System Air Bleed" in this section).

NOTE: *The engine cooling system is properly filled with coolant only when all air has been removed.*

7. Top off surge tank or radiator.

AUXILIARY COOLING WATER CIRCUIT - INITIAL FILL

1. Open petcock at top of intercooler (see Figure 5.25-8).

Figure 5.25-8. Intercooler Air Bleed

2. Add coolant to system until coolant begins to escape from petcock.

3. Close petcock and continue filling system until coolant reaches correct level (see Table 5.25-3).

NOTE: *The engine cooling system is properly filled with coolant only when all air has been removed.*

Table 5.25-3. Auxiliary Water Capacity - Engine Only

ENGINE MODEL	GALLONS (LITRES)
F18 (six cylinder)	6 gallons (23 litres)
H24 (eight cylinder)	6 gallons (23 litres)

4. Close cooling system and run engine at idle speed.

5. Recheck coolant level and add additional coolant as required.

NOTE: *Occasionally open the intercooler and thermostat housing air bleed petcocks in the cooling system to allow any accumulated air to escape.*

⚠ WARNING

Always wear protective equipment when venting the cooling system. Misuse, misapplication, or improper adjustment and maintenance of cooling fans and related parts can result in serious personal injury or death. Always follow basic safety precautions and proper preventive maintenance procedures.

6. Continue filling auxiliary cooling water circuit until level of coolant reaches top of surge tank or radiator.

⚠ CAUTION Air in the cooling system speeds up the formation of rust, increases corrosion and produces hot spots within the engine. Disregarding this information could result in product damage and/or personal injury.

7. Bleed trapped air (see "Cooling Water System Air Bleed" below).

8. Top off surge tank or radiator.

COOLING WATER SYSTEM AIR BLEED

Air bleed the jacket water and auxiliary cooling water circuits at least once each day. Open and close the air bleed petcocks in the order that they are listed below, starting at the lowest petcock in the system and ending at the highest. Bleed one petcock at a time. The number of air bleed petcocks and their locations are as follows (see Table 5.25-4).

Table 5.25-4. Air Bleed Petcocks

COOLING WATER CIRCUIT	NUMBER OF PETCOCKS	LOCATION
Jacket Water	1	Cluster Thermostat Housing
	1	Jacket Water Header
Auxiliary Water	1	Intercooler

1. **Initial Bleed:** Open each air bleed petcock prior to engine startup. A hissing sound often accompanies the escape of trapped air. Close petcock when hissing stops and water begins to flow out in a solid steady stream.

⚠ WARNING

Always wear protective clothing when bleeding the cooling system on a heated engine. Slowly loosen the air bleed petcock to relieve any excess pressure. Escaping steam and/or hot water could result in severe personal injury or death.

2. **Check Bleed:** Start engine and reopen each petcock. Close petcock when hissing stops and water begins to flow out in a solid steady stream.

3. **Final Bleed:** Once temperature of jacket water circuit has stabilized (as indicated by the panel mounted temperature gauge), reopen each petcock. Close petcock when water begins to flow out in a solid steady stream.

⚠ CAUTION **Air can be drawn into the engine through small leaks in the jacket water system. The problem is compounded when the void created by the loss of coolant is filled by more air. If aeration causes the coolant to foam, the probability of engine damage due to overheating is greatly increased. Disregarding this information could result in product damage and/or personal injury.**

4. Carefully inspect jacket water system for coolant leaks while engine is running.

JACKET WATER AND AUXILIARY WATER CIRCUITS – DRAIN AND FLUSH

Unless evidence of corrosion or sediment buildup demonstrates the need for more frequent maintenance, clean and flush both the jacket water and auxiliary water circuits at least once each year.

Antifreeze and water treatment products require a clean system in order to work effectively. If contaminants such as dirt, rust, scale, lime, grease, oil and/or cleaning agents are not completely flushed out, they can destroy the corrosion inhibitors and scale suppressants intended to keep freshly filled cooling systems clean.

NOTE: *To facilitate draining and flushing of the engine jacket water, replace one of the 3/4 inch NPT countersunk headless pipe plugs (just below the level of the jacket water header) with a customer supplied ball valve. The ball valve must be threaded to accept both a hose connection and pipe plug. When finished, always install a pipe plug to prevent inadvertent draining of the cooling system.*

1. Start engine. Run engine for 10 minutes.

⚠ WARNING

Always wear protective clothing when draining the cooling systems on a hot engine. As air bleed petcocks are opened, escaping steam and/or hot water could result in severe personal injury or death.

NOTE: *Drain the coolant from the jacket water and auxiliary water circuits immediately after shutting down the engine. Draining the coolant immediately prevents any sediment from re-settling.*

2. Shut down engine. Open air bleed petcocks located at highest point in jacket water and auxiliary water circuit.

3. Verify that customer supplied ball valve is closed. Remove pipe plug and attach drain line.

4. Open ball valve and drain coolant from jacket water.

5. Open all air bleed petcocks (see Table 5.25-5).

Table 5.25-5. Air Bleed Petcocks

COOLING CIRCUIT	NUMBER OF PETCOCKS	LOCATION
Jacket Water	1	Cluster Thermostat Housing
	1	Jacket Water Header
Auxiliary Water	1	Intercooler

6. Open all water drain petcocks. Remove all drain plugs (see Table 5.25-6).

Table 5.25-6. Water Drain Petcocks

COOLING CIRCUIT	NUMBER OF PETCOCKS	LOCATION
Jacket Water	1	Jacket Water Pump Housing
	2	Crankcase (left side)
Auxiliary Water	1	Intercooler
	1	Auxiliary Water Pump

7. Close all water drain petcocks. Install all drain plugs.

8. Add clean, soft water to the crankcase (through ball valve).

NOTE: *Always fill the engine from the bottom up to minimize the formation of air pockets. As the engine fills, air is pushed up and out (see Table 5.25-7).*

Table 5.25-7. Jacket Water Capacity - Engine Only

ENGINE MODEL	US GALLONS (LITRES)
F18 (6 cylinder)	16 (60)
H24 (8 cylinder)	17 (65)

9. Close each air bleed petcock when water begins to flow out in a solid steady stream.

10. Close thermostat housing petcock(s) and continue filling jacket water system until level reaches top of surge tank or radiator.

11. Add clean, soft water to surge tank or radiator of auxiliary cooling water circuit.

12. Continue filling auxiliary cooling water circuit until level reaches top of surge tank or radiator.

13. Perform "Initial Bleed" procedures. See "Cooling Water System Air Bleed" in this section.

14. Perform "Check Bleed" procedures.

15. Perform "Final Bleed" procedures.

16. Stop engine. Drain crankcase and all cooling system accessories. Drain auxiliary cooling water circuit.

NOTE: *Follow the manufacturer's recommendations for the proper concentration of cleaning solution and length of cleaning time. Use a non-acidic, non-corrosive, biodegradable compound that prevents the loss of metal in engine and avoids damage to internal gaskets and seals.*

17. Fill jacket water and auxiliary cooling water circuits with a suitable cleaning solution.

18. Perform "Initial Bleed" procedures. See "Cooling Water System Air Bleed" in this section.

⚠ WARNING

Always wear protective clothing when draining the cooling systems on a hot engine. As air bleed petcocks are opened, escaping steam and/or hot water could result in severe personal injury or death.

19. Perform "Check Bleed" procedures.

20. Perform "Final Bleed" procedures.

21. Top off surge tank or radiator for jacket water and auxiliary water circuits.

NOTE: *Drain the coolant from the jacket water and auxiliary water circuits immediately after shutting down the engine. Draining the coolant immediately prevents any sediment from re-settling.*

22. Shut down engine and drain cooling systems.

23. Inspect internal surfaces. If the results are not satisfactory, refill the engine with cleaning solution. Repeat Steps 17 through 22 as necessary.

24. Fill jacket water and auxiliary cooling circuits with clean, soft water. Drain immediately.

NOTE: *Inspect the drain water for cleanliness. Fill and flush the systems again, if necessary. The best results are obtained when the drain water runs clear.*

25. Fill jacket water and auxiliary cooling water circuits with coolant.

26. Perform "Initial Bleed" procedures. See "Cooling Water System Air Bleed" in this section.

27. Perform "Check Bleed" procedures.

28. Perform "Final Bleed" procedures.

29. Carefully inspect jacket water and auxiliary cooling water circuits for leaks.

JACKET WATER PUMP SEAL INSPECTION

1. Inspect "weep hole" in bottom of water pump casting (see Figure 5.25-9). The "weep hole" drains coolant that leaks past the ceramic water pump seal.

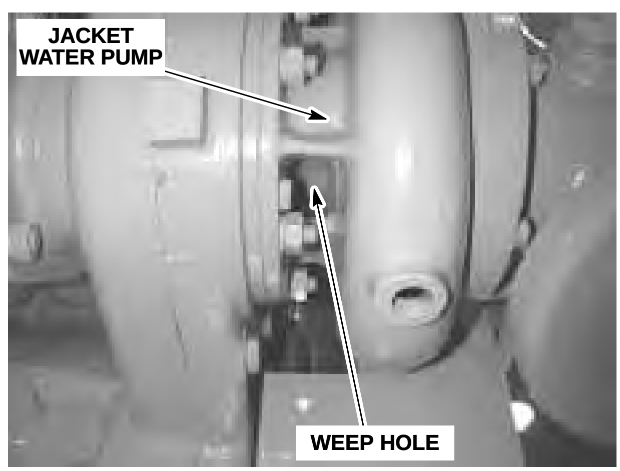


Figure 5.25-9. Jacket Water Pump Seal Inspection

2. Inspect auxiliary water pump seal at sheet metal guard (see Figure 5.25-10).

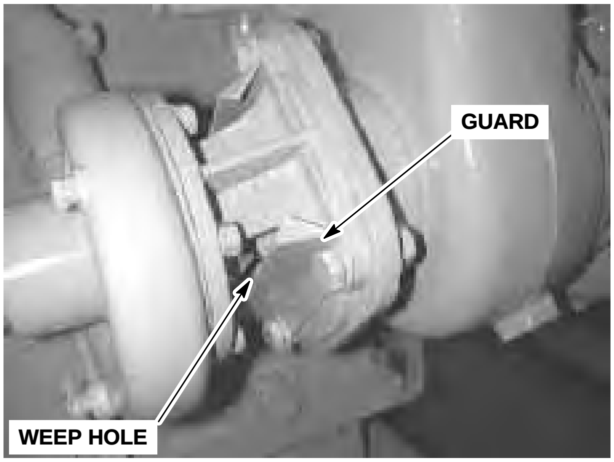


Figure 5.25-10. Auxiliary Water Pump Inspection

⚠ CAUTION The presence of coolant at the “weep hole” indicates that the water pump must be rebuilt. A defective water pump seal results in coolant loss and contamination of the inner ball bearing grease. Disregarding this information could result in product damage and/or personal injury.

3. Overhaul jacket water or auxiliary water pump if any leakage at “weep hole” is observed.

JACKET WATER PUMP ELBOWS

WATER PUMP ELBOW REMOVAL

To service the jacket water pump or thermostat housing, the thermostat outlet connection and jacket water pump inlet elbow will have to be removed (see Figure 5.25-11 and Figure 5.25-12).

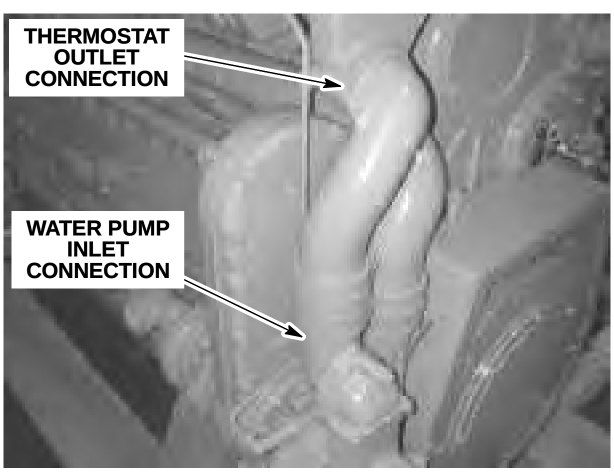


Figure 5.25-11. Jacket Water Pump

NOTE: *The water pump inlet connection and thermostat outlet can be removed as an assembly (see Figure 5.25-14).*

1. Remove M10 hex head screws and remove thermostat housing outlet connection. Remove water pump inlet connection from water pump inlet.

2. Remove M8 hex head screws and remove water inlet elbow from jacket water pump (see Figure 5.25-12).

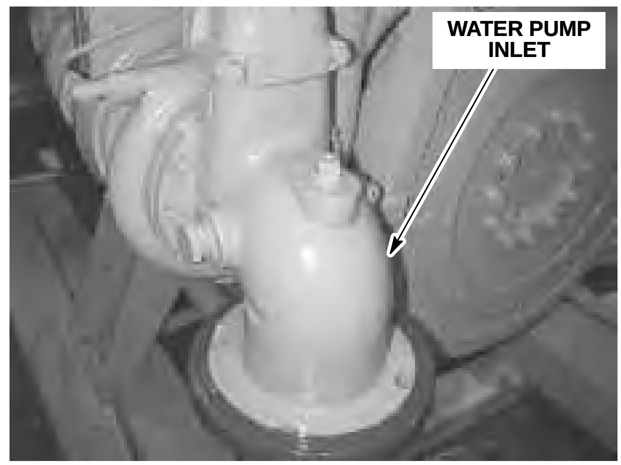


Figure 5.25-12. Jacket Water Pump Inlet

WATER PUMP ELBOW INSTALLATION

1. Clean flange mounting surface of jacket water pump (see Figure 5.25-13).

Figure 5.25-13. Jacket Water Pump

2. Install O-ring between water pump and water inlet elbow (see Figure 5.25-15). Secure elbow to water pump with M8 hex head screws and tighten to 19 ft-lb (26 N·m).

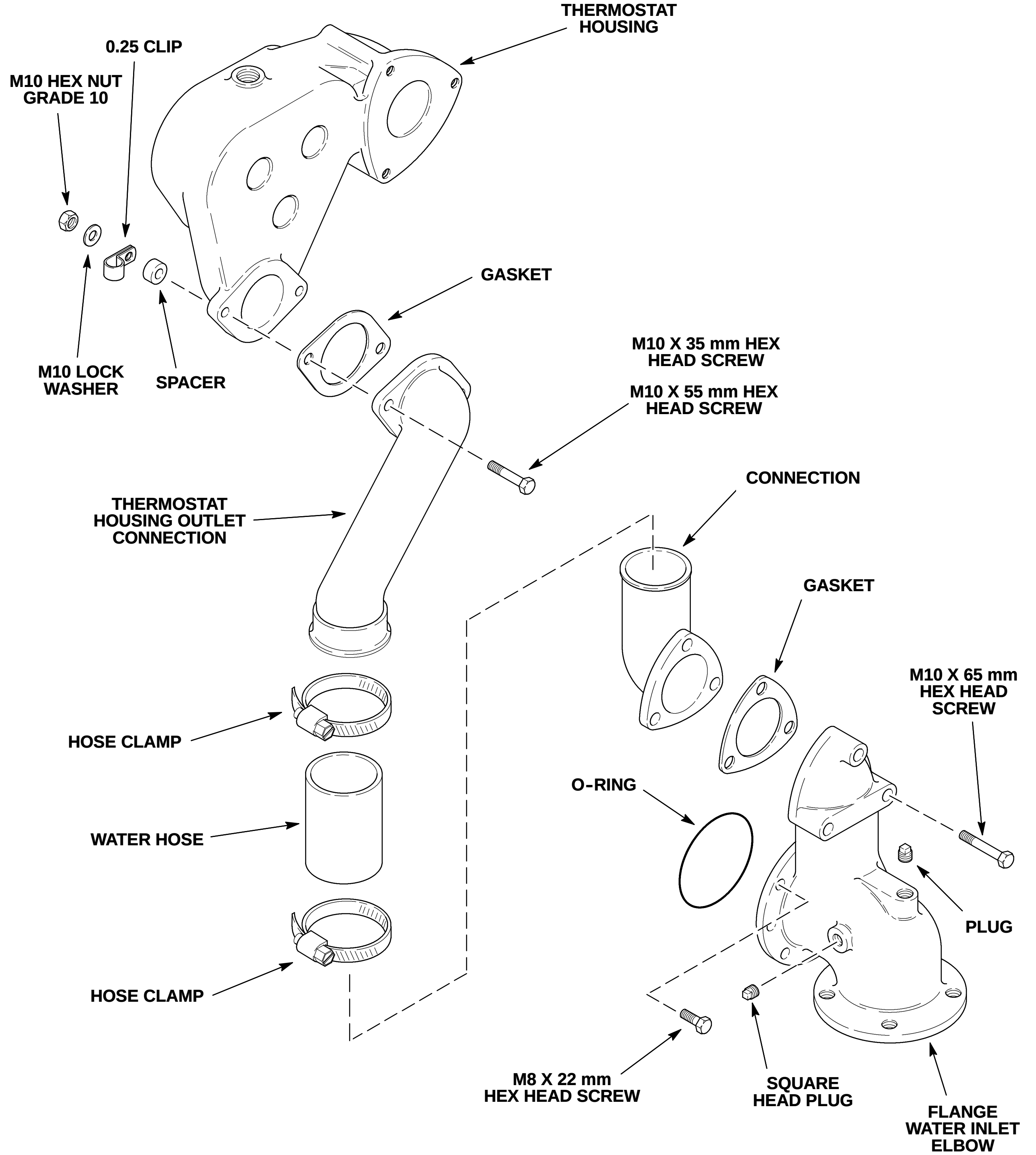


Figure 5.25-14. Water Pump Inlet Assembly

Figure 5.25-15. Jacket Water Pump Inlet

3. Install outlet and inlet connections as an assembly (see Figure 5.25-16).

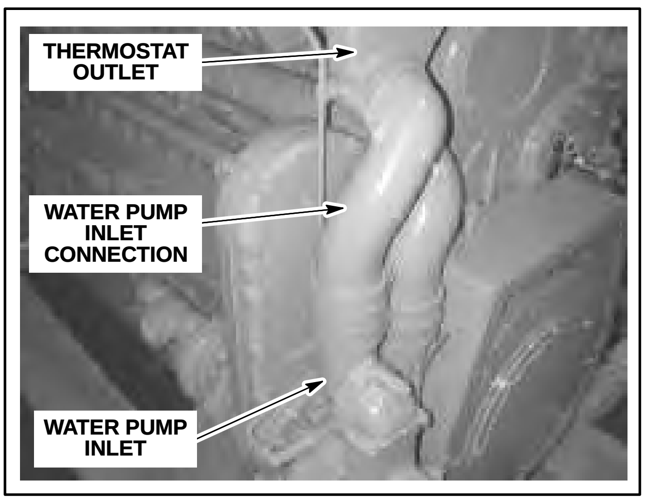


Figure 5.25-16. Jacket Water Connections

4. Install a support clip and spacer to support air bleed tube from jacket water pump to thermostat housing (see Figure 5.25-17).

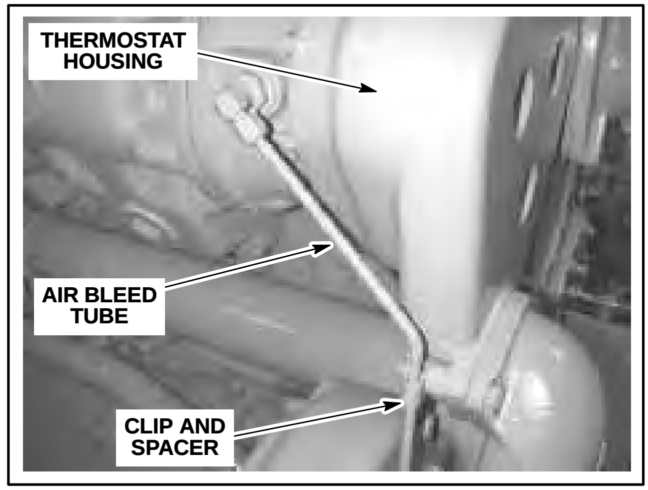


Figure 5.25-17. Air Bleed Tube Support

JACKET WATER PUMP

JACKET WATER PUMP REMOVAL

1. Remove air bleed tube from adapter on jacket water pump housing (see Figure 5.25-18).

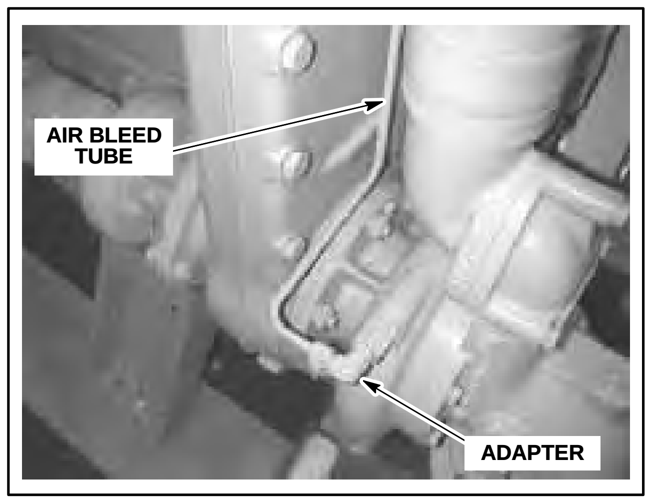


Figure 5.25-18. Jacket Water Pump

2. Remove water pump inlet and connection from jacket water pump (see Figure 5.25-19). See "Jacket Water Pump Elbows" in this section for elbow removal.

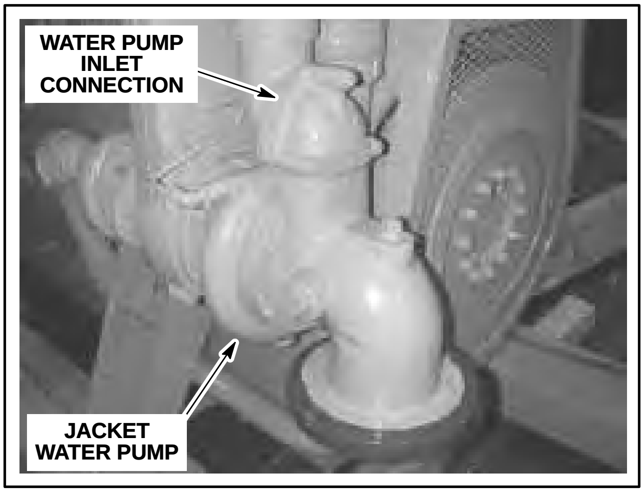


Figure 5.25-19. Jacket Water Pump

3. Loosen hose clamps and remove hose from water header connection (see Figure 5.25-20).

Figure 5.25-20. Jacket Water Pump

NOTE: *There are two styles of F18/H24 jacket water pumps. The pumps used for turbocharged engines have a longer shaft that allows the auxiliary water pump to clamp on the shaft.*

4. The auxiliary water pump shaft clamps to the jacket water pump shaft. Remove hex head screws that hold sheet metal guards and attach pump to adapter (see Figure 5.25-21).

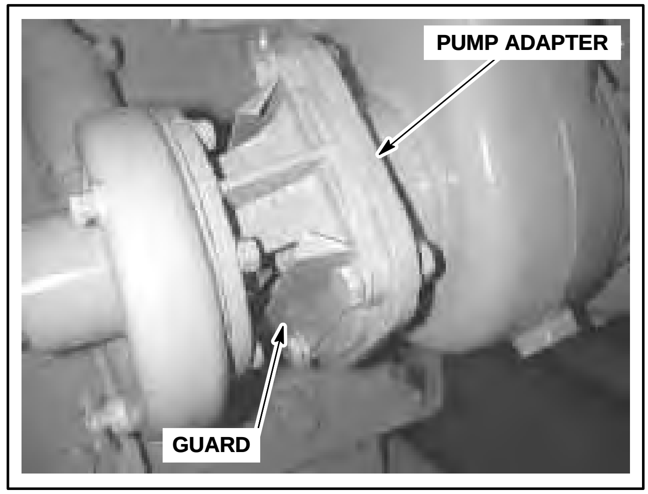


Figure 5.25-21. Auxiliary Water Pump Inspection

5. Loosen two clamping bolts on auxiliary water pump (see Figure 5.25-22).

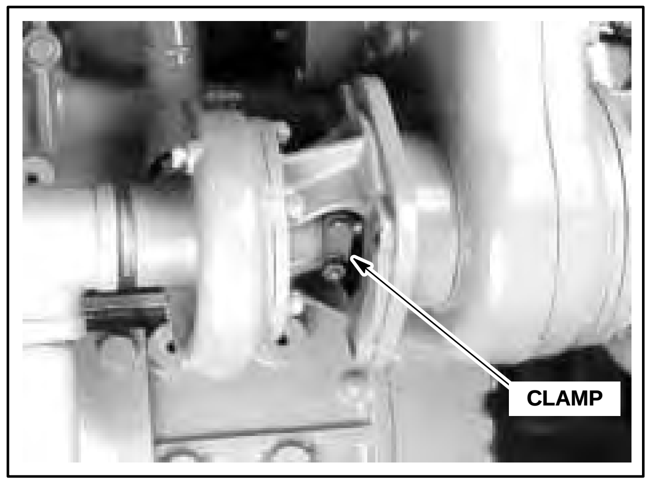


Figure 5.25-22. Auxiliary Water Pump Clamp

6. Remove hex nuts and lock washers that hold jacket water pump to stud on gear housing (see Figure 5.25-23). Pull pump from gear housing.

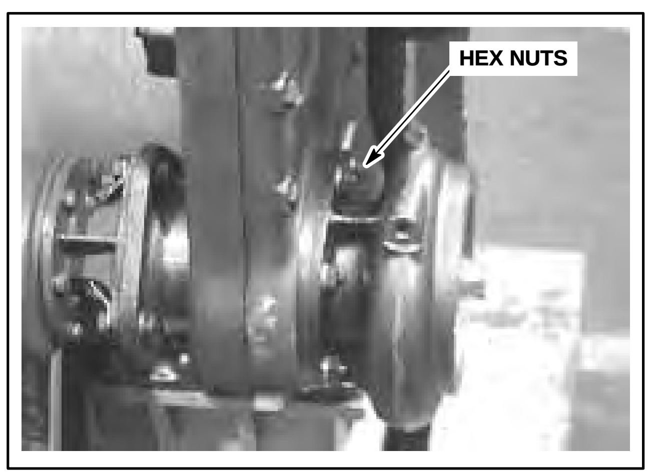


Figure 5.25-23. Jacket Water Pump

JACKET WATER PUMP INSTALLATION

There are two styles of F18/H24 jacket water pumps. The pumps used for turbocharged engines have a longer shaft that allows the auxiliary water pump to clamp on the shaft. Select the correct pump for installation.

1. Inspect drive gear teeth for any wear or damage. Replace as necessary (see Figure 5.25-24).

Figure 5.25-24. Jacket Water Pump Mounting

2. Install a new O-ring on jacket water pump body (see Figure 5.25-25).

Figure 5.25-25. Jacket Water Pump

3. Install M10 hex nuts (Grade 10) that hold jacket water pump to stud on gear housing. Tighten to 37 ft-lb (50 N·m) (see Figure 5.25-26).

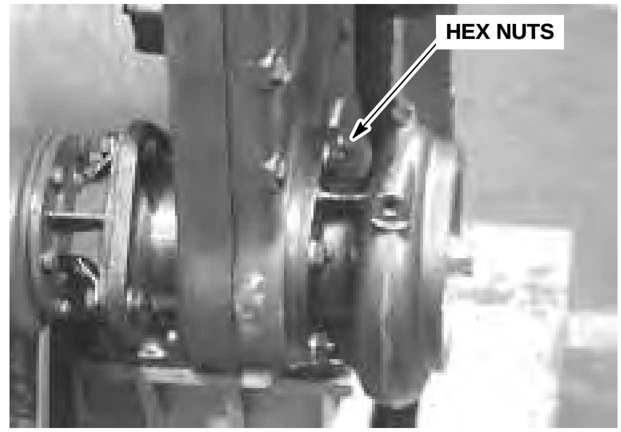


Figure 5.25-26. Jacket Water Pump

4. Tighten two clamping bolts on auxiliary water pump (see Figure 5.25-27). Install sheet metal guards over clamp.

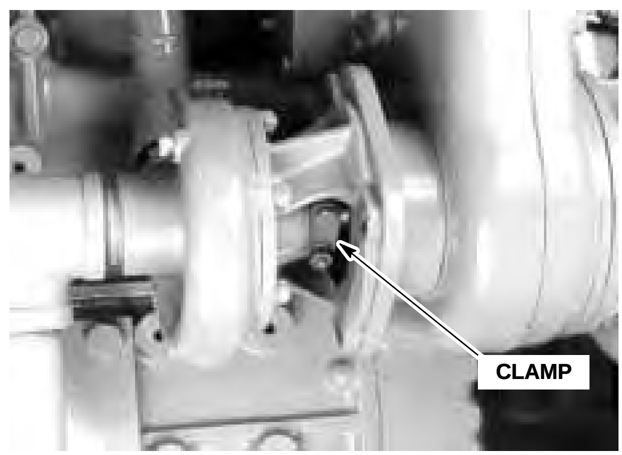


Figure 5.25-27. Auxiliary Water Pump Clamp

5. Slide hose onto pump and tighten clamps (see Figure 5.25-28).

Figure 5.25-28. Jacket Water Pump

NOTE: *Naturally aspirated, G series of engines do not have an auxiliary water pump. A cover with an O-ring seal is used to cover the water pump shaft on the rear of the gear housing.*

6. If applicable, install pump cover and secure with M8 hex head screws (see Figure 5.25-29).

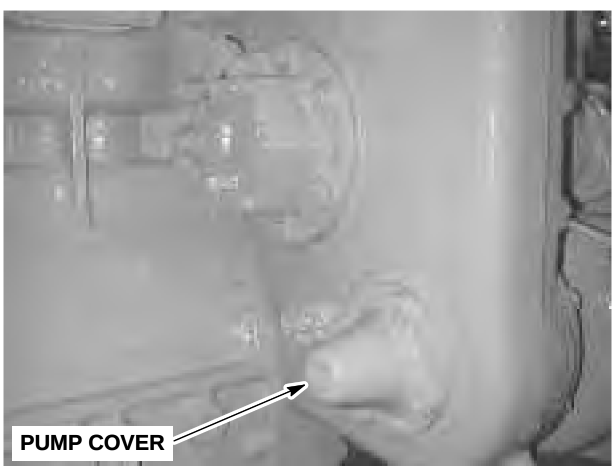


Figure 5.25-29. G Series Water Pump Cover

NOTE: *Engines equipped with a turbocharger do not use auxiliary water extension on water pump housing.*

7. Install plug with a new copper gasket in pump (see Figure 5.25-30).

Figure 5.25-30. Jacket Water Pump

8. Install water pump inlet and connection on jacket water pump (see Figure 5.25-31). See “Jacket Water Pump Elbows” earlier in this section for inlet and elbow installation.

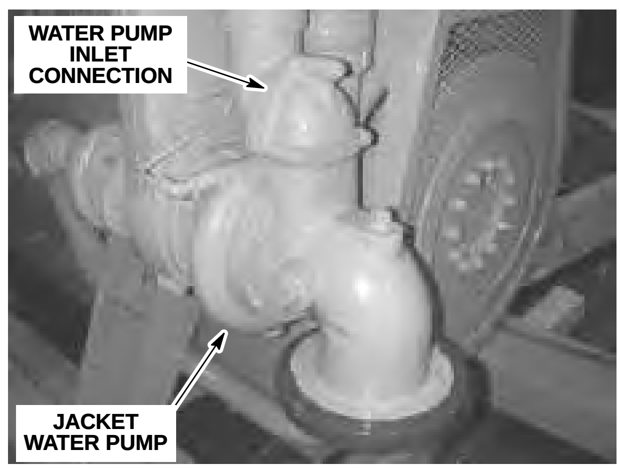


Figure 5.25-31. Jacket Water Pump

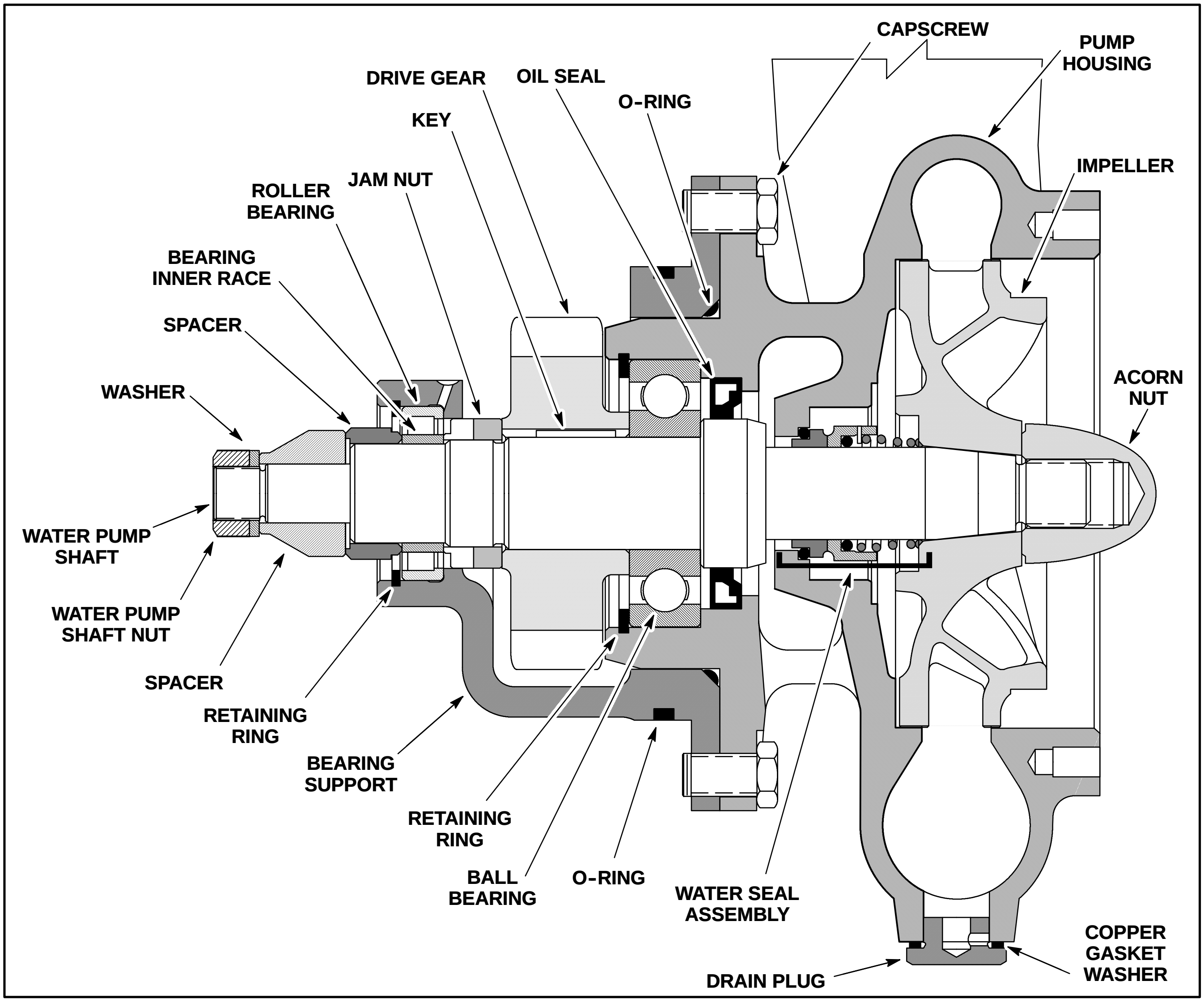


Figure 5.25-32. Pump P/N A301060C For Naturally Aspirated Engines

JACKET WATER PUMP DISASSEMBLY

There are two styles of F18/H24 jacket water pumps. Jacket water pumps for naturally aspirated engines have a short shaft (see Figure 5.25-32). The pumps for turbocharged engines have a longer shaft that allows the auxiliary water pump to clamp on the shaft (see Figure 5.25-34).

1. Remove brass acorn nut that secures impeller onto pump shaft.

2. Use puller (P/N 472031) to remove impeller from pump shaft (see Figure 5.25-33). Remove and discard water seal.

3. Remove two retaining capscrews and separate pump body from bearing support housing. Pump shaft and drive gear will remain with pump body.

4. Remove shaft end nut and spacer(s) from pump shaft. Use Tool P/N 472067 to remove center jam nut from pump shaft. There are two threaded holes in the drive gear. Use two hardened M8 capscrews to pull gear off pump shaft and shaft key.

Figure 5.25-33. Remove Impeller

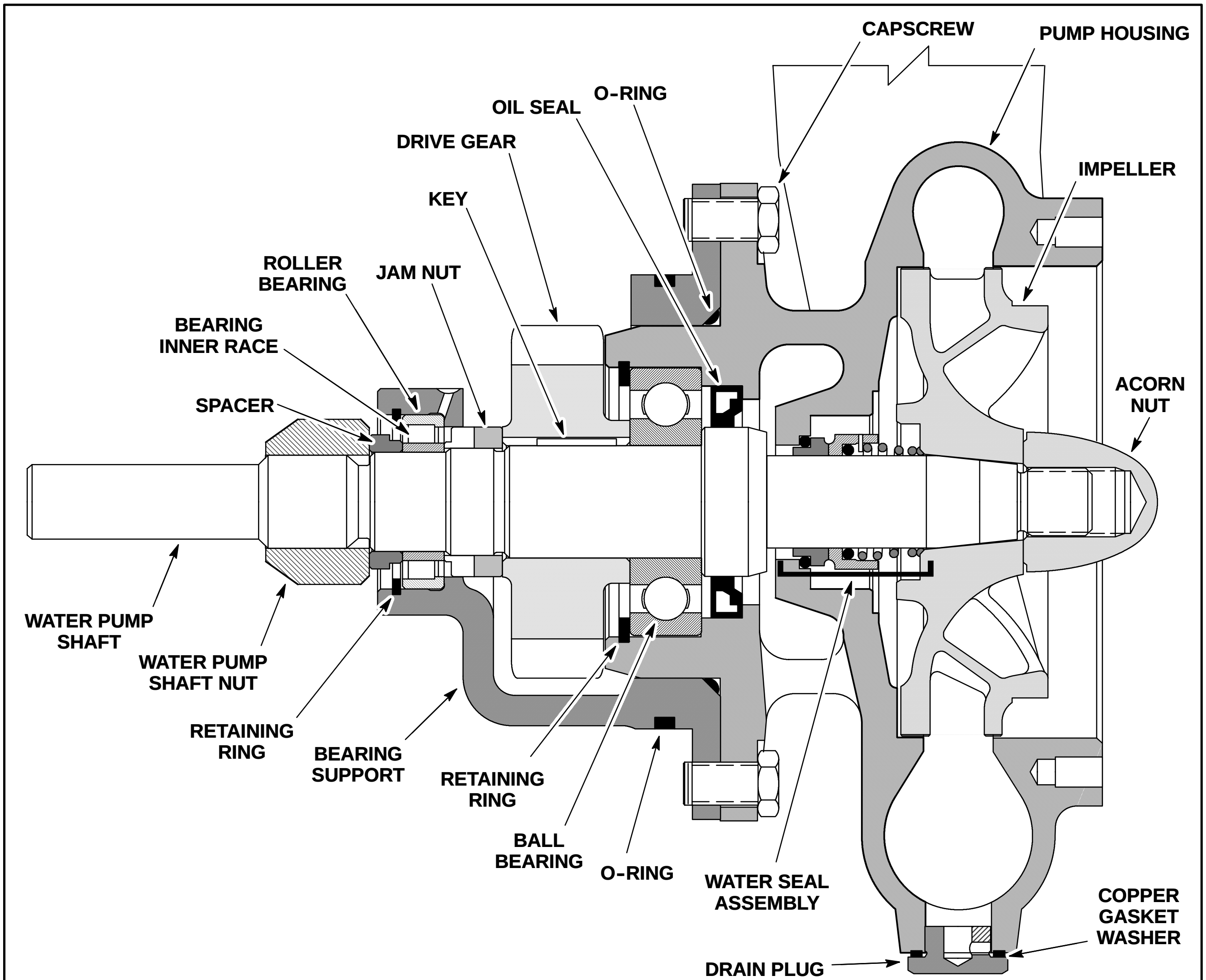


Figure 5.25-34. Pump P/N AC301060C For Turbocharged Engines

⚠ WARNING

Always wear proper eye protection when removing the retaining ring. Slippage may propel the ring with enough force to cause serious eye injury. Use the correct retaining ring pliers. Verify that the tips of the pliers are not excessively worn or damaged.

5. Remove bearing retaining ring from groove in pump body.

6. Press shaft and bearing out of pump body. If pump rebuild kit is being used, discard shaft and bearing assembly.

NOTE: *Pressing the bearing off the shaft will damage the ball bearing. Install a new bearing every time one is pressed off the pump shaft.*

7. Remove and discard oil and water seals from pump body.

8. Remove bearing retaining ring and roller bearing from bearing support housing.

PUMP INSPECTION

Inspect water pump for cracks or corrosion. Replace housing if necessary. Use P/N 301060C when ordering a new housing.

⚠ WARNING

Compressed air can pierce skin and cause severe injury. Never use your hands to check for leaks or to determine air flow rates. Wear safety glasses to shield your eyes from flying dirt and debris.

Hot tank water pump and bearing support housings to remove old gasket material grease and dirt. Blow dry parts with moisture free compressed air.

PUMP MACHINING

Pump Body P/N 301060A Only

The following procedure is for pump body P/N 301060A only (from pumps P/N A301060A and C301060A). After the body is machined and the adapter bushing is installed, the pump body assembly is the same as P/N 301060B.

1. Disassemble water pump and remove all foreign material.

2. Machine water pump body to accept adapter bushing (see Figure 5.25-35 for all dimensions).

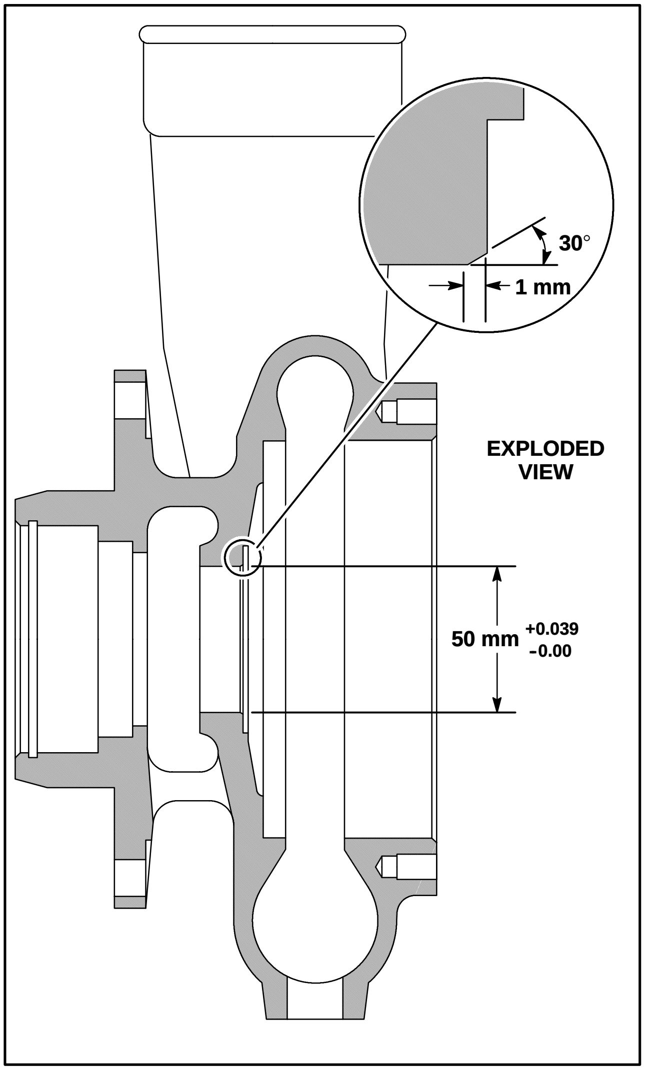


Figure 5.25-35. P/N 301060A Pump Body Rework

3. Press adapter bushing into water pump body. Adapter must bottom in pump body bore (see Figure 5.25-36).

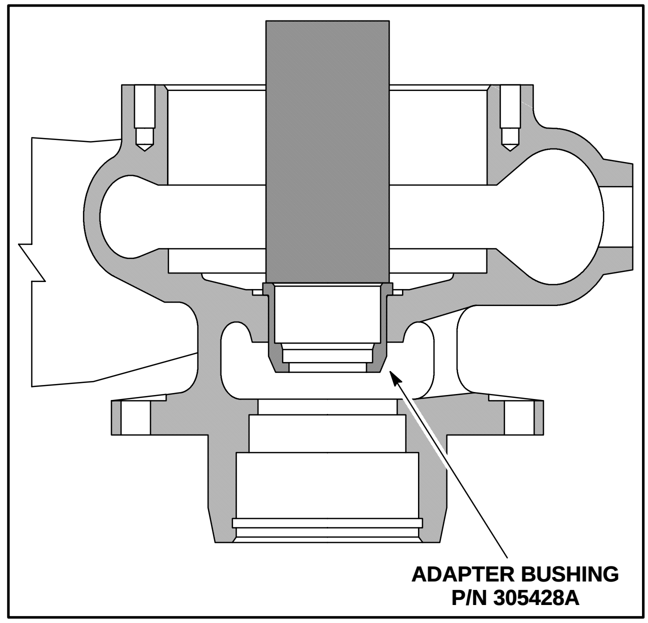


Figure 5.25-36. Press Bushing Into Pump Body

PUMP ASSEMBLY

1. Press oil seal into pump body. Seal must bottom into pump body. Lubricate seal with engine oil (see Figure 5.25-37).

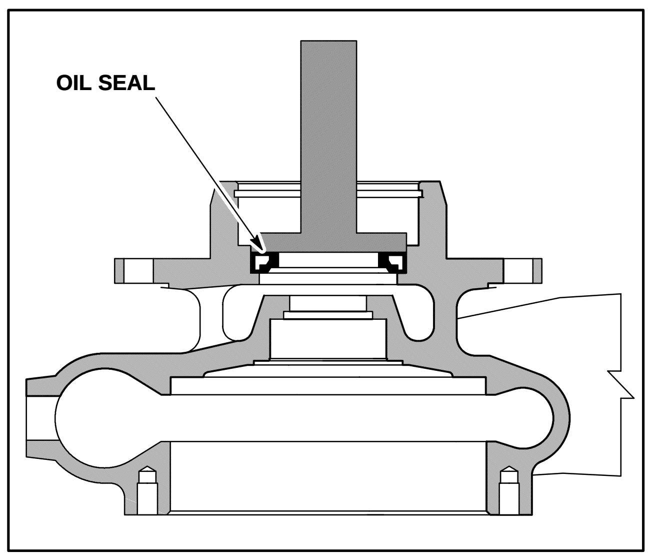


Figure 5.25-37. Water Pump Oil Seal

2. Press large ball bearing onto water pump shaft until bearing bottoms on shoulder of shaft. Press on inner race of bearing to prevent damage (see Figure 5.25-38).

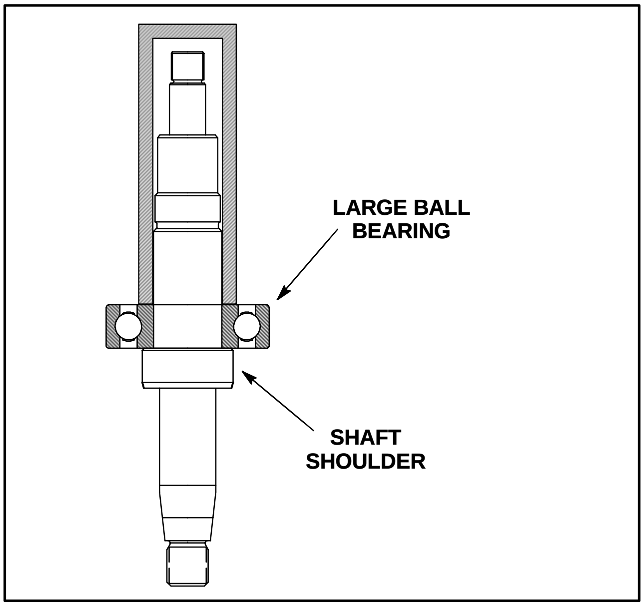


Figure 5.25-38. Water Pump Bearing

3. Lubricate shaft sealing surface with engine oil. Install shaft and bearing assembly into water pump body. Install retaining ring to hold bearing in pump body (see Figure 5.25-39).

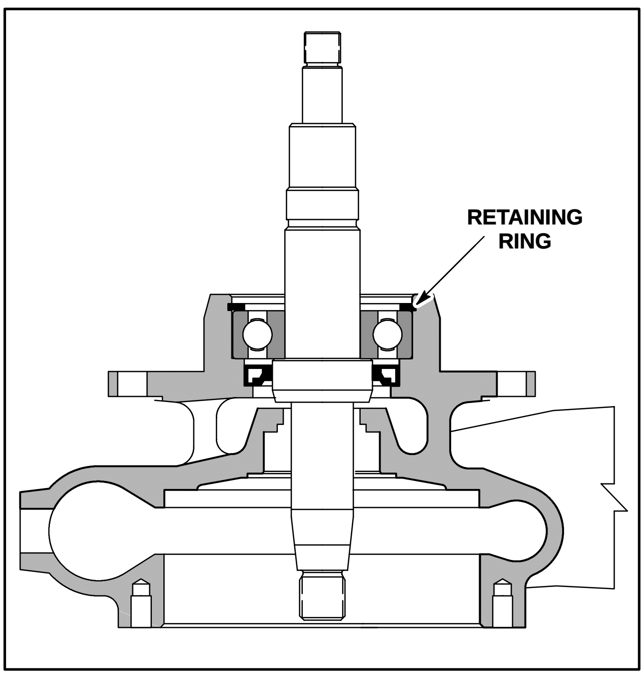


Figure 5.25-39. Water Pump Shaft/Bearing Assembly

4. Press gear and key on water pump shaft. Gear hub must contact bearing on shaft (see Figure 5.25-40).

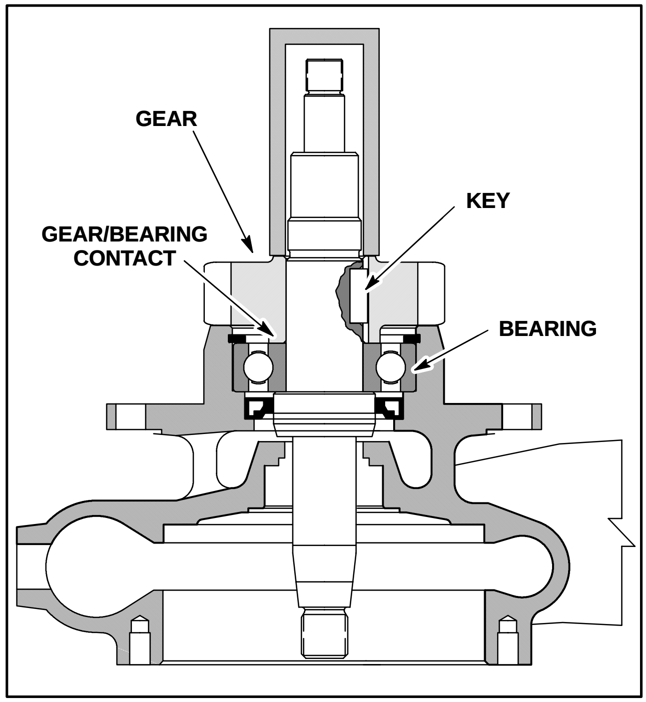


Figure 5.25-40. Water Pump Gear

NOTE: *The long hub of the gear must be towards the bearing. The gear will touch the pump housing if installed backwards.*

5. Install jam nut against drive gear and tighten to144 ft-lb (196 N·m). Use Tool P/N 472067 to tighten center jam nut (see Figure 5.25-41).

NOTE: *The spanner tool is available from your Waukesha Engine Distributor.*

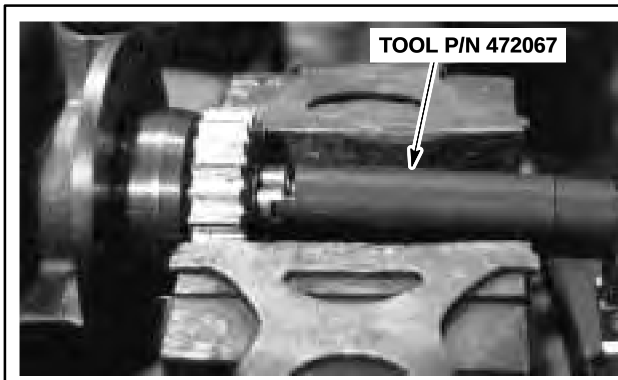


Figure 5.25-41. Water Pump Shaft

6. Lubricate water seal with a 50/50 mix of ethylene glycol and water. Press inner half of seal into pump housing around pump shaft. Install second half of water seal and pump impeller onto pump shaft (see Figure 5.25-42).

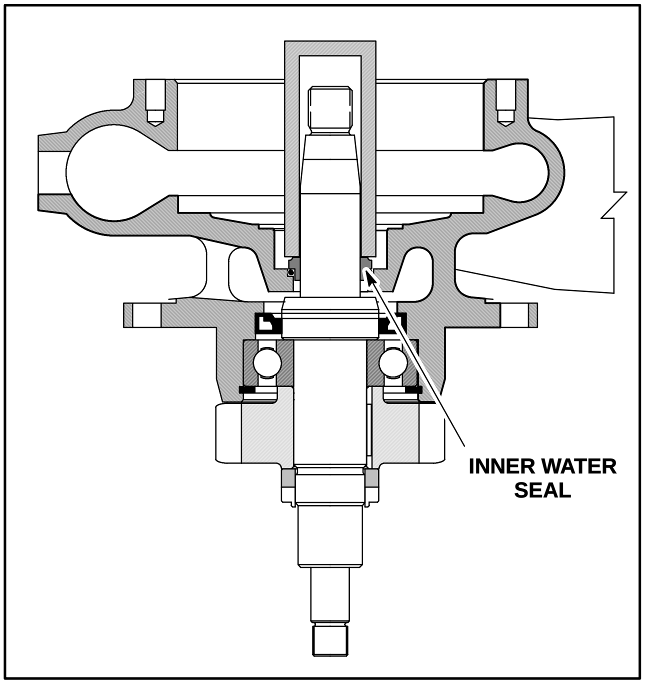


Figure 5.25-42. Water Pump Seal

7. Lubricate shaft threads with Loctite® 242 and install brass acorn nut. Tighten nut to 109 ft-lb (148 N·m) (see Figure 5.25-43).

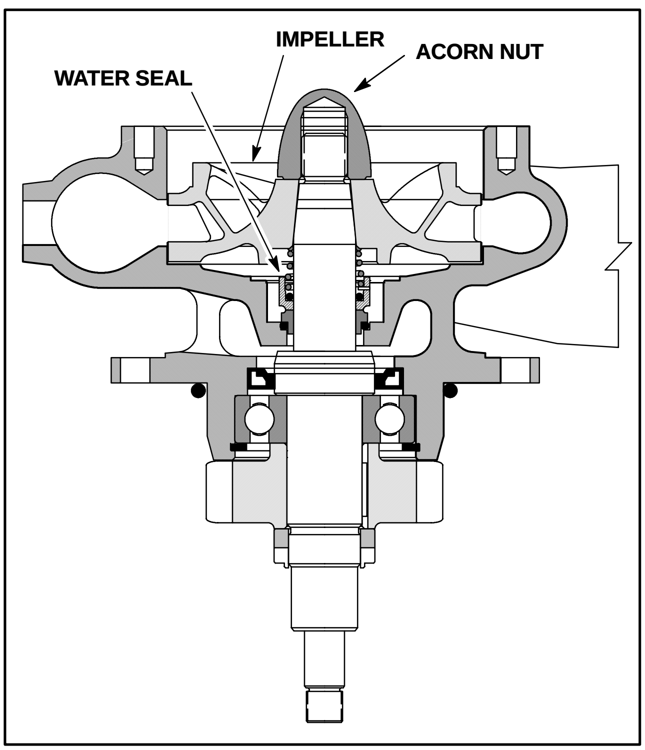


Figure 5.25-43. Water Pump Seal And Impeller

8. Lubricate O–ring with Parker Super O–Lube™ (P/N 475029) and install on pump body.

9. Install rear bearing inner race over pump shaft (see Figure 5.25-44).

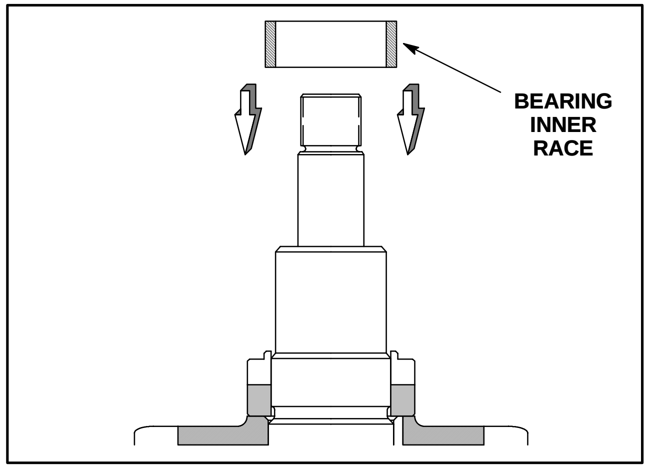


Figure 5.25-44. Install Inner Race On Shaft

10. Press roller bearing in bearing support housing. Press on outer race of bearing to prevent damage (see Figure 5.25-45). Bearing inner race is a separate part to be installed later. Lubricate bearing with engine oil.

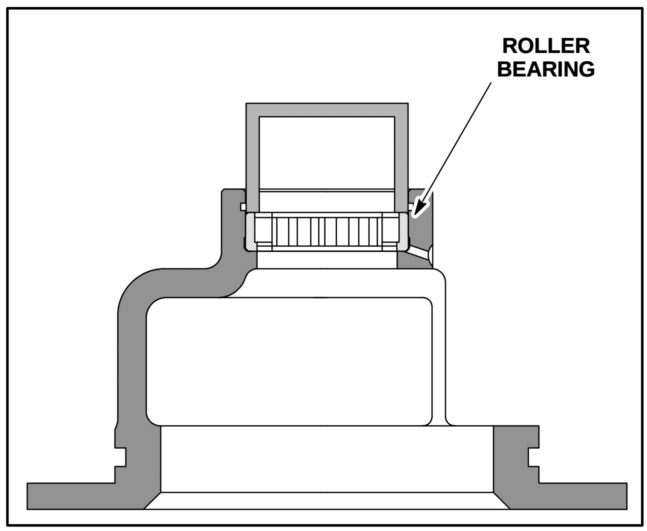


Figure 5.25-45. Water Pump Gear Housing

11. Slide bearing support housing over water pump shaft. Install two M8 retaining hex head screws to hold pump body and bearing support housing together (see Figure 5.25-46).

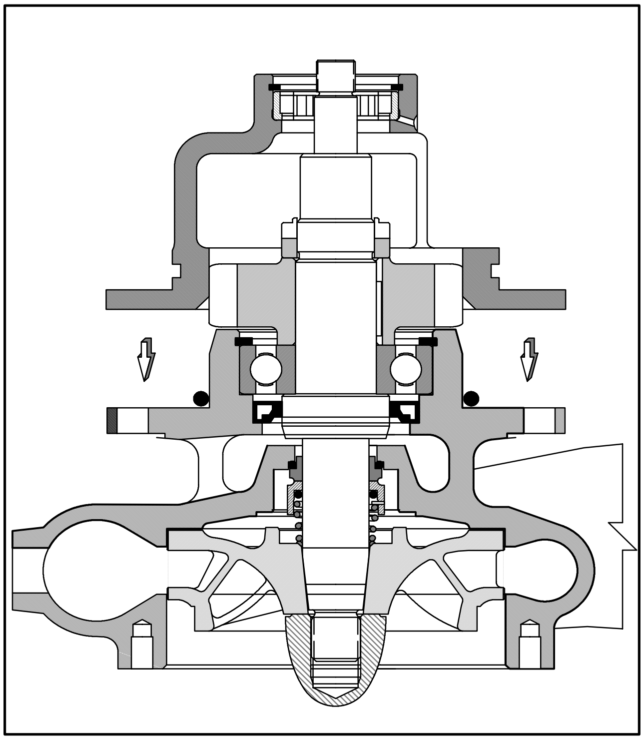


Figure 5.25-46. Water Pump Gear Housing

12. Install spacer on end of shaft. Lubricate shaft threads with Loctite® 242 and install shaft end nut. Tighten nut to 72 ft-lb (98 N·m) (see Figure 5.25-47).

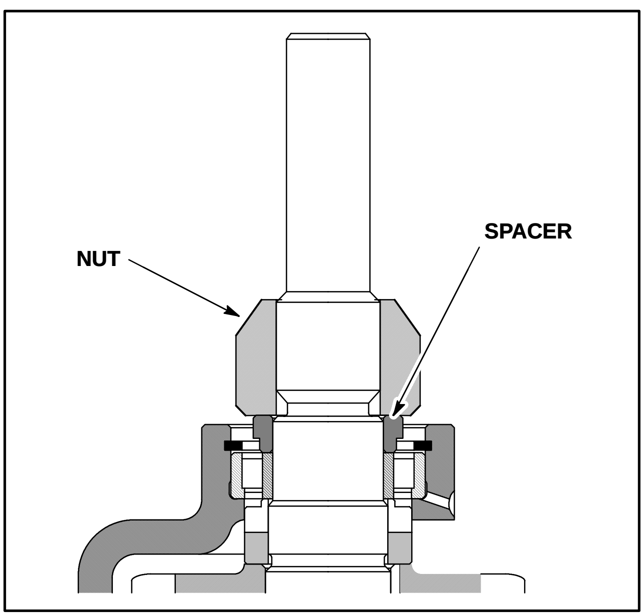


Figure 5.25-47. Pump Nut

13. **Pump P/N D301060B—**Install spacers on end of shaft. Lubricate shaft threads with Loctite® 242 and install shaft end nut. Tighten nut to 72 ft-lb (98 N·m) (see Figure 5.25-48).

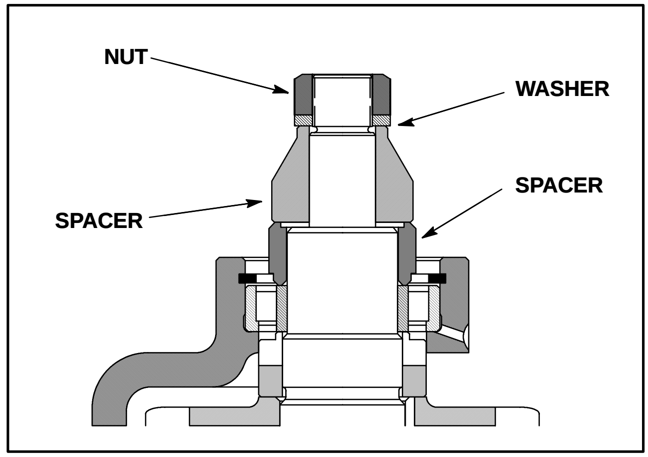


Figure 5.25-48. Pump P/N D301060B

14. Lubricate new O-ring with Parker Super O-Lube™ and install onto pump bearing support housing.

AUXILIARY WATER PUMP

PUMP REMOVAL

The auxiliary water pump is driven by the jacket water pump shaft. The auxiliary pump shaft is secured to the jacket water pump shaft using a clamp.

NOTE: *Part of the auxiliary water piping is removed with the auxiliary water pump. Remove the piping from the pump after the pump is removed from the engine.*

1. Disconnect site piping from auxiliary water pump inlet. Loosen hose clamps that secure water piping (see Figure 5.25-49).

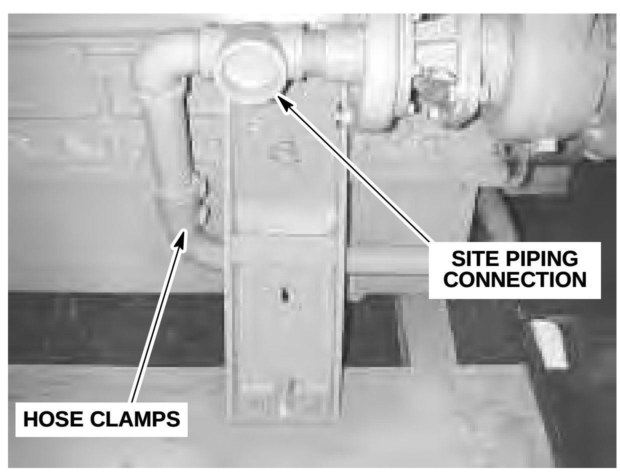


Figure 5.25-49. Auxiliary Water Pump

2. Loosen clamp and slide intercooler water pipe hose off auxiliary water pump fitting (see Figure 5.25-50).

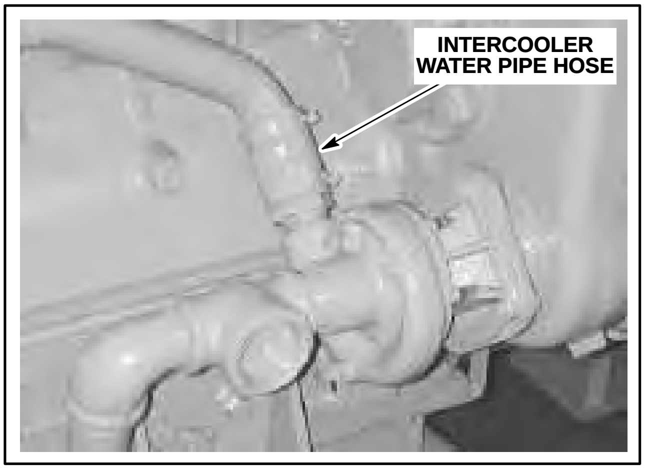


Figure 5.25-50. Auxiliary Water Pump

3. Auxiliary water pump shaft clamps to jacket water pump shaft. Remove four M10 x 35 mm hex head screws that secure sheet metal guards (see Figure 5.25-51).

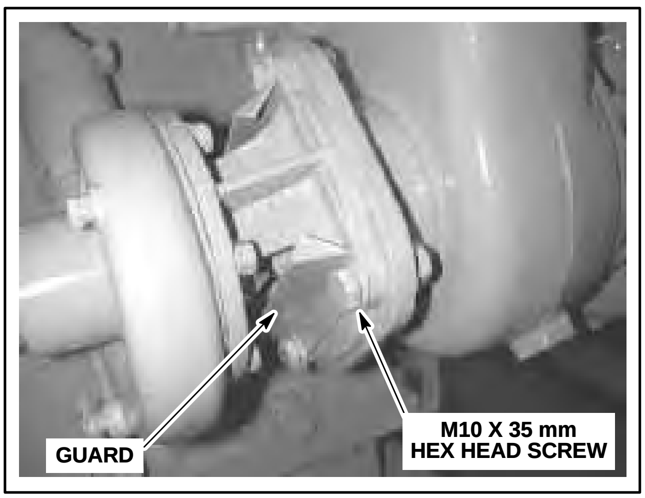


Figure 5.25-51. Auxiliary Water Pump Inspection

4. Remove two clamping bolts from auxiliary water pump (see Figure 5.25-52).

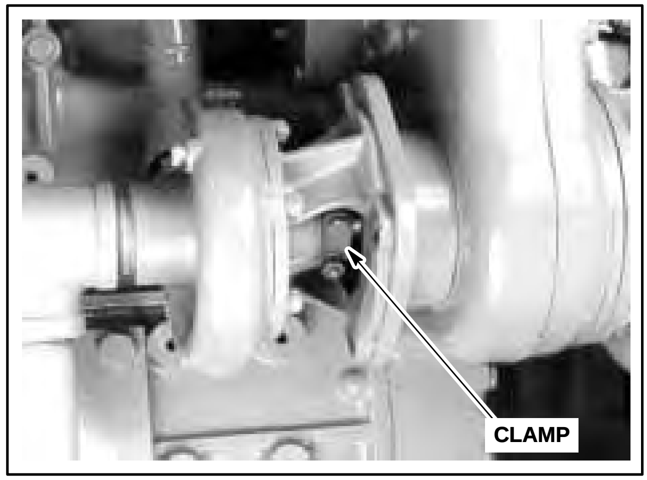


Figure 5.25-52. Auxiliary Water Pump Clamp

5. Remove hose clamp and disconnect piping from auxiliary water pump (see Figure 5.25-53).

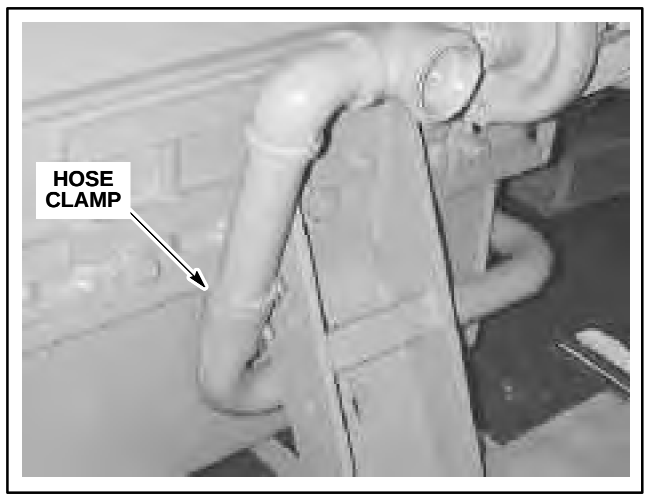


Figure 5.25-53. Auxiliary Water Piping

6. Remove auxiliary water pump with piping from engine (see Figure 5.25-54). Remove piping from pump on bench.

Figure 5.25-54. Auxiliary Water Pump And Piping

7. Auxiliary water pump mounts on an adapter that attaches to front gear housing. Remove four capscrews from adapter (see Figure 5.25-55). Remove adapter and sealing O-ring from gear housing.

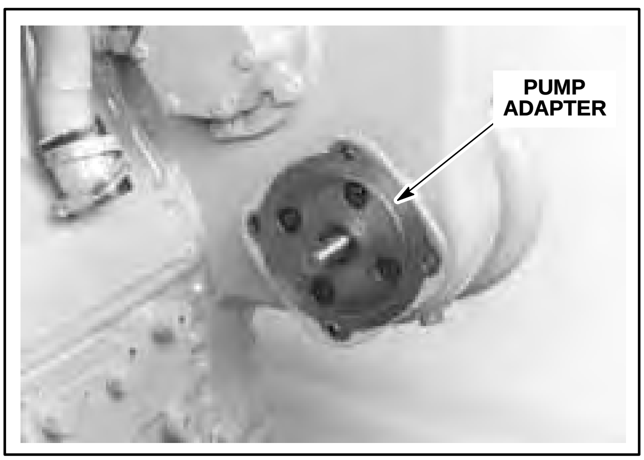


Figure 5.25-55. Auxiliary Water Pump Adapter

JACKET AND AUXILIARY WATER PUMP INSTALLATION

1. Install correct jacket water pump for use with auxiliary water pump and tighten flange nuts (see Figure 5.25-56).

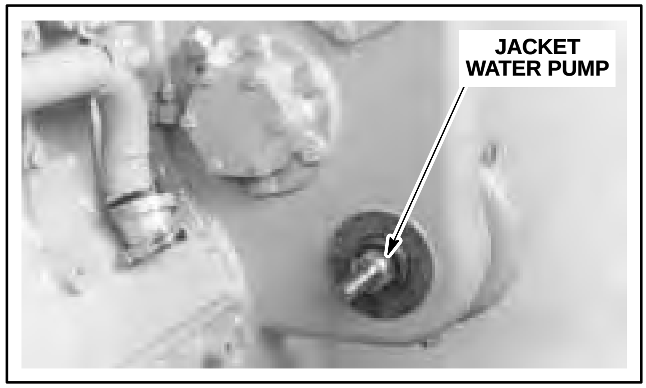


Figure 5.25-56. Water Pump Mounting

2. Clean mating surfaces between housing and pump mounting adapter. Install pump mounting adapter and new O-ring onto gear housing (see Figure 5.25-57).

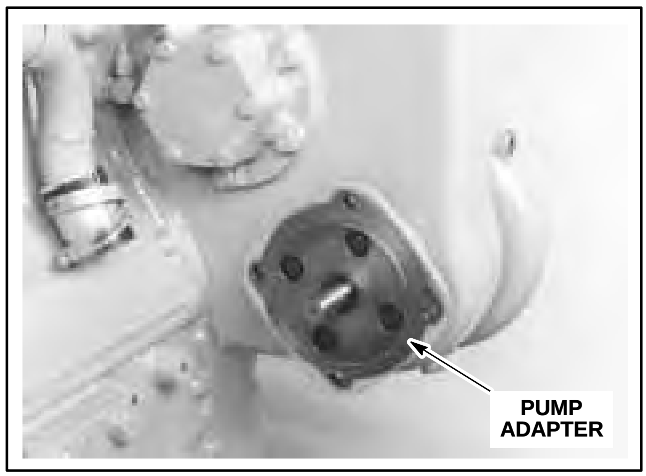


Figure 5.25-57. Auxiliary Water Pump Adapter

SECTION 5.30

LUBRICATION SYSTEM

LUBRICATION SYSTEM

OIL FLOW DESCRIPTION

Lubricating oil is drawn from the crankcase sump through the oil pump (see Figure 5.30-1 and Figure 5.30-4). The high pressure oil from the pump flows past a pump mounted relief valve. The cold start relief valve bleeds excessive oil pressure to the sump. The valve starts to open at 80 psi (552 kPa) and is full open at 142 psi (797 kPa).

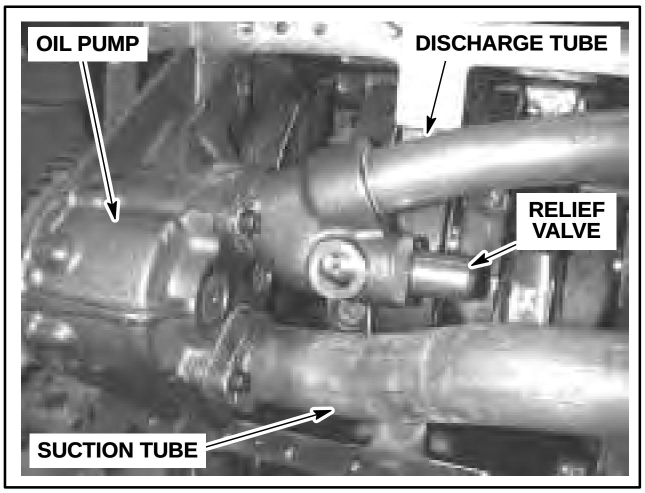


Figure 5.30-1. Oil Pump

The oil is pumped to the oil pressure regulating valve and oil cooler (see Figure 5.30-2). The main oil pressure regulating valve is set to maintain normal operating pressure of 70 - 75 psi (414 - 517 kPa), depending on engine speed and temperature. Normal engine idle speed pressure is 30 psi (207 kPa) minimum.

The oil flows through three full-flow oil filter cartridges (see Figure 5.30-3). Each cartridge is equipped with a bypass valve which opens if filter restriction exceeds 30 psi (207 kPa).

Filtered oil is then directed to the main internal oil gallery. This gallery feeds oil to the main bearings, camshaft journals, valve train and turbocharger.

The oil filter support contains the piston cooling valve. The valve blocks the flow of oil to the piston cooling jets during startup to ensure an adequate flow of oil to the engine bearings. At approximately 30 psi (207 kPa) this valve will open and supply oil to the piston cooling jets which spray oil to cool the underside of the piston crown.

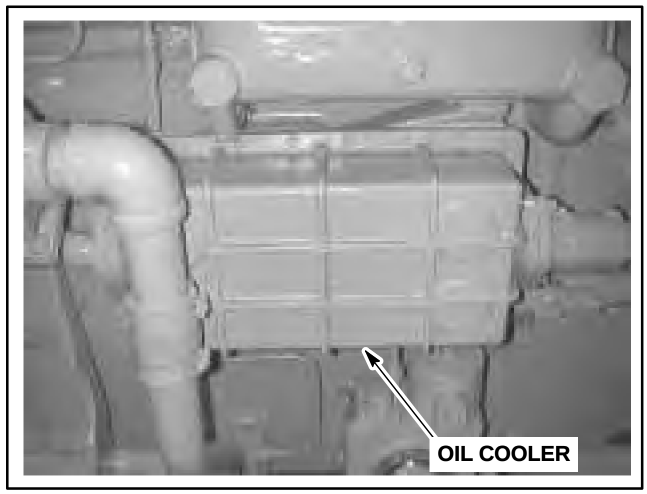


Figure 5.30-2. Lube Oil Cooler Housing

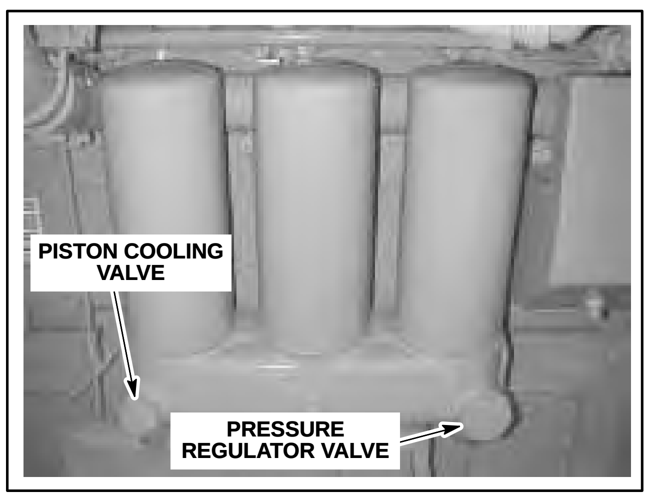


Figure 5.30-3. Piston Cooling Control Valve

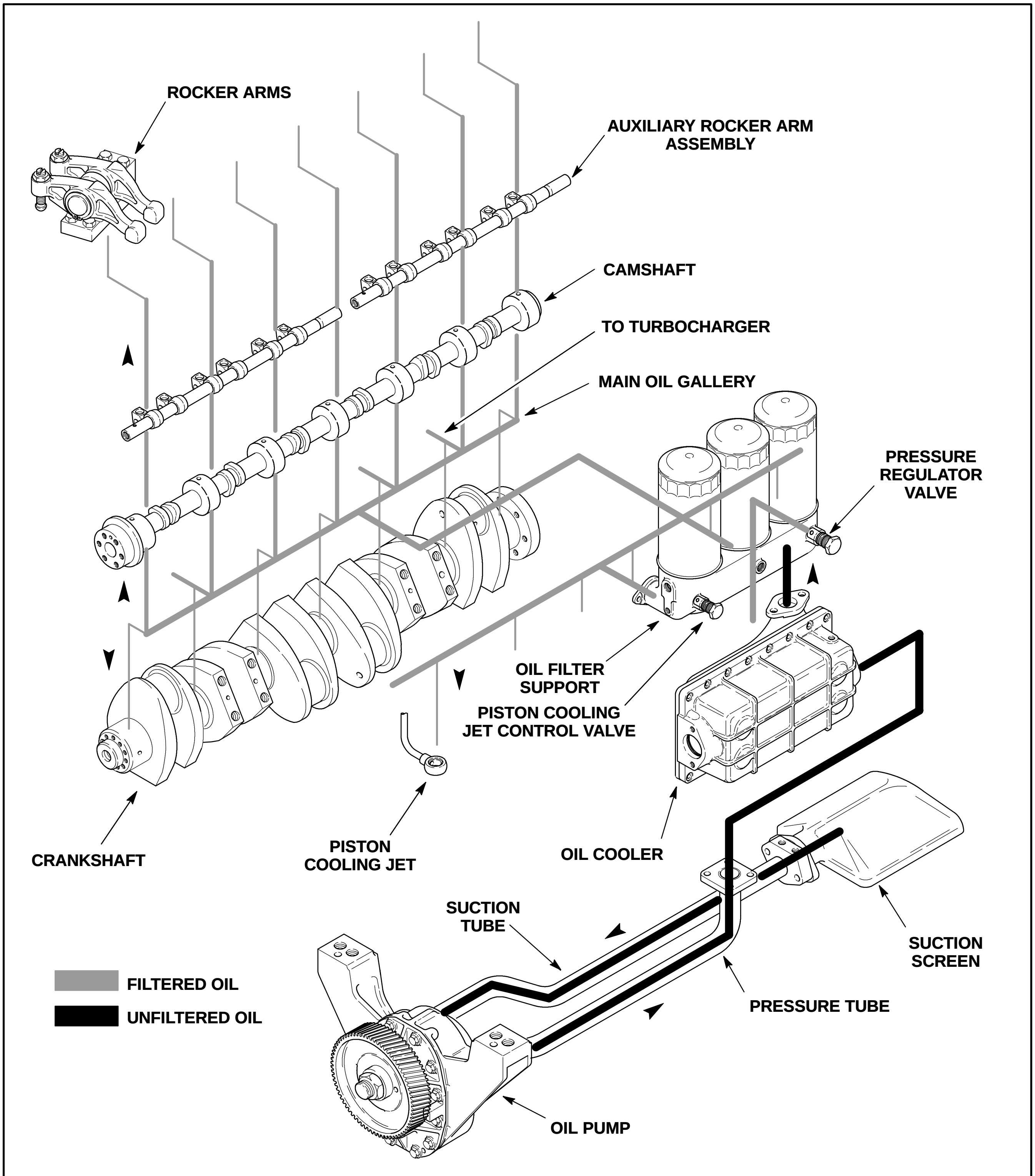


Figure 5.30-4. VGF Inline Engine Lube Oil Schematic

LUBRICATING OIL PERFORMANCE

⚠ CAUTION The performance of a lubricant, like that of any manufactured product, is the responsibility of the refiner and supplier.

Waukesha Engine strongly recommends monitoring the condition of the lube oil through the use of a good oil analysis program.

There are hundreds of commercial crankcase oils marketed today. Engine manufacturers or users cannot completely evaluate the numerous commercial oils. The current edition of the *EMA Engine Fluids Data Book* is available for purchase from:

Engine Manufacturers' Association
Two North LaSalle Street
Chicago, IL 60602
Phone: (312) 827-8700
Fax: (312) 827-8737
Email: ema@enginemanufacturers.org
www.enginemanufacturers.org

This section provides a tabulation of global lubricant producers and marketers, together with the performance classification for which the producers have indicated their products are qualified.

The Waukesha Engine Warranty is limited to the repair or replacement of parts that fail due to defective material or workmanship during the warranty period. The Waukesha Warranty does not include responsibility for lubricating oil performance.

With the exception of cogeneration and special or prototype installations, Waukesha Engine has made it a practice not to recommend oil by brand name.

OIL DESIGNATIONS

Oil is designated in several ways: American Petroleum Institute (API), Society of Automotive Engineers (SAE), American Society for Testing and Materials (ASTM) performance classifications and Military Designation. Since no gas engine industry oil performance designations exist, it is the responsibility of the engine operator to verify with their oil supplier, that the oil they select has proven field performance in their specific engine make and model.

OIL ADDITIVES

Quality oils formulated specifically for natural gas engines have sufficient additives to meet requirements. Waukesha does not recommend the addition of oil additives to these quality oils.

OIL RECOMMENDATIONS

Waukesha recommends the use of oil formulated specifically for gas engines and meeting minimum ash requirements based on engine makes and models (see Table 5.30-1). The ash forming constituents in oil formulations provide detergency, corrosion protection, and anti-wear protection. In addition, the ash produced during combustion of these additives will provide protection against valve face and seat recession.

⚠ CAUTION Waukesha engines use specifically formulated gas engine oils. Waukesha Engine does not recommend gasoline or diesel oil formulations for use with its engines. Use of gasoline or diesel oil formulations may cause severe engine damage.

Table 5.30-1. Oil Recommendations

MODEL	SULFATED ASH %(1, 2)
VGF F18, H24 G, GL, GLD	0.45 - 0.75
VGF F18, H24 GSID	0.35 - 0.5

NOTE: *(1) Oils must be specifically formulated for gas engines using highly refined mineral oil base stocks. The ash requirements are a percentage by weight with both metallic and ashless additive systems. A maximum of 0.10% zinc is recommended.*
(2) Oil with 0.35% ash or less may be used in naturally aspirated and catalyst equipped naturally aspirated or turbocharged engines with the understanding that valve recession may occur, thus shortening the normally expected valve and seat life.

CATALYST CONTAMINANTS

The following contaminants are known catalyst deactivators and should be avoided when selecting lubricating oils for installations with catalysts since they contribute to shortened catalyst life: heavy and base metals such as lead, mercury, arsenic, antimony, zinc, copper, tin, iron, nickel, chrome, sulfur, and phosphorus. These individual elements should not exceed 1 ppm or collectively exceed 5 ppm at the catalyst inlet. Specific exceptions: phosphorus or silicon compounds at the catalyst inlet are not to exceed 1 ppm and sulfur compounds at the catalyst inlet are not to exceed 100 ppm.

Do not confuse the concentration of these elements *AT THE CATALYST INLET* with the concentration of these elements in the lube oil itself.

OIL FILTRATION REQUIREMENTS

The quality of oil filtration will directly affect engine component life.

Waukesha's basic filtration requirement is 90% efficient at 15 microns for all full flow sock and paper elements, and 98% efficient at 25 microns for cleanable full flow metal mesh elements. **Mesh or screen sizes larger than 25 microns are not acceptable.**

Lube oil filter elements should be changed when the lube oil is changed or when the pressure drop across the lube oil filter exceeds 24 psi (165 kPa).

Waukesha's complete oil filter performance specification is shown in Waukesha specification sheets S08486 and S08486-1.

EXTENDED OIL DRAIN INTERVALS

Extended oil drain intervals are not recommended unless a Waukesha Microspin centrifuge as well as Waukesha supplied oil filtration components are installed. The Microspin centrifuge, in conjunction with Waukesha supplied oil filtration components, will remove by-products of combustion, allowing an increase in scheduled oil drain and oil filter element change intervals. See Table 5.30-7 for the maximum number of hours between normal and extended oil drain and oil filter element change intervals.

It is recommended that oil analysis be used to determine when condemning limits are reached.

WAUKESHA COGENERATION INSTALLATIONS

Waukesha Engine does not ordinarily recommend lube oils by brand name. However, based on actual field experience, the oils listed in Table 5.30-2 are specified for cogeneration installations with forced hot water cooling systems 212° F - 265° F (100° C - 129° C) or ebullient cooling 250° F (121° C).

It is especially important that the lube oils used in cogeneration applications use base stocks with good thermal stability. With a minimum of 4000+ hours of experience, the lube oils listed in Table 5.30-2 are known to give satisfactory performance in high temperature cooling systems' applications.

Additions to the list of approved oils may be made if substantiating data is provided for an oil meeting the following criteria:

- Used in similar applications 212° F (100° C) to 265° F (129° C) jacket water temperatures.
- Minimum of 6 months operation. Documented with engine inspection data.
- No signs of oil degradation or lacquering problems (based on normal oil change interval, the engine should be clean).

Table 5.30-2. Recommended Lube Oils For Cogeneration Applications (Using Pipeline Quality Gas)

BRAND	TYPE	PERCENT OF SULFATED ASH
Chevron HDAX Low Ash	SAE 40	0.50
Estor Super	SAE 40	0.45
Estor Elite (Synthetic)	SAE 20 W40	0.45
Estor Select 40	SAE 40	0.95
Mobil Pegasus 1 (Synthetic)	SAE 15 W40	0.48
Mobil Pegasus 805	SAE 40	0.48
Mobil Pegasus 710 (89)	SAE 40	0.99
Petro Canada, CG40	SAE 40	0.92
Q8 Mahler HA (Europe only)	SAE 40	0.90
Q8 Mahler MA (Europe Only)	SAE 40	0.55
Shell Mysella MA SIPC (Outside USA only)	SAE 40	0.90

SOUR GAS, DIGESTER GAS, AND LANDFILL GAS RECOMMENDATIONS

⚠ WARNING

Waukesha Engine assumes no liability or responsibility for damage to the environment or severe personal injury caused by using landfill gases or sour gases. It is the customer's sole responsibility to carefully analyze any gases they choose to use. Use of these gases is at the customer's own risk.

Alternate fuel sources are attracting increasing interest today as a low cost fuel or because of environmental concerns. Waukesha, being the leader in developing engine systems to accommodate these alternate fuels, is aware of problems due to sulfur compounds (H_2S, etc.), siloxanes, and halide constituents in these fuels. Hydrogen sulfide (H_2S), siloxanes, and total organic halide as chloride (TOH/Cl) bring with them totally different problems to the engine and lubricating oils.

Waukesha has limited fuel trace gases to the following:

- Sulfur bearing compounds (H_2S, etc.) content in fuel gas to 0.1%, (1000 ppm) by volume. However, it is not unusual to encounter biomass gas or field gas with much higher percentages of sulfur bearing compounds (H_2S, etc.). Gas exceeding 0.1% sulfur bearing compounds must be treated.

- Maximum organic halide content, expressed as chloride, (TOH/Cl) in landfill gas is limited to 150 micrograms per liter (µg/l).
- Maximum liquid fuel hydrocarbons at the coldest expected engine mounted regulator fuel outlet temperature are limited to 2% total by gaseous volume.
- Maximum permissible free hydrogen content is 12% by volume.
- Maximum total siloxanes for engine models with a prechamber fuel system is 25 µg/l. If greater than 25 µg/l total siloxanes are present at the inlet to the engine mounted fuel regulator, clean commercial quality natural gas must be supplied to the prechamber fuel system. Waukesha currently does not limit total siloxane content in the fuel gas to engines which do not have a prechamber fuel system.

When dealing with halogens or halogen compounds in landfill gas, the subject becomes far too complicated to address here as it relates to the selection of a lubricating oil, used oil analysis, and drain interval. It follows that those customers operating on landfill gas review Waukesha Engine's Fuel Specification S7884-7 (or current revision) to fully understand the ramifications of operating an engine on landfill gas. This document (as well as Service Bulletin 9-2701) prescribes specific fuel gas sampling techniques, fuel gas analysis, handling of abrasive fuel constituents, and limitations on total organic halide as chloride, to achieve reasonable engine life. Lubricating oil requirements change as the TOH/Cl increases.

RECOMMENDED LUBE OILS FOR LANDFILL GAS APPLICATIONS

Table 5.30-3. Recommended Lube Oils Landfill Gas Applications

BRAND	TYPE	PERCENT OF SULFATED ASH
Mobil Pegasus 610 (446)	SAE 40	0.98
Mobil Pegasus 605 (426)	SAE 40	0.48
Chevron HDAX LFG	SAE 40	0.71

Waukesha recommends lubricating oils specifically formulated for landfill gas. However, care must be taken that oils formulated for a particular fuel type not be used beyond their recommendations. When used outside of their recommendations, some landfill gas formulated lube oils can cause excessive build-up of abnormal ash deposits in the combustion chamber. Landfill gas engine oils should only be used for engines applied to landfill gas operation, not digester gas operation.

The best approach would be to filter or absorb corrosives in the fuel gas before they reach the engine. There are increasing claims for filtration and absorption by various companies manufacturing and promoting these types of products. Waukesha makes no endorsement of these products or service. Their performance is solely the responsibility of the manufacturers.

RECOMMENDATIONS FOR FUEL GAS FILTRATION OF SOLIDS AND LIQUIDS

Solid Particulate Removal:

Coalescer shall have an absolute rating of 5 microns (0.3 microns for landfill applications) for solid particulate removal.

Liquid and Aerosol Removal From Fuel Gas:

Coalescer shall remove entrained liquid and aerosol contaminants of 0.3 µm (micron) or larger.

- Fuel gas compressor lubricating oil carryover must be removed from the fuel stream. A coalescing filter with a 0.3 micron rating is adequate in most cases. Even though this oil is hydrocarbon based and combustible, it contains an additive package with calcium and other undesirable elements and compounds. Failure to remove this carryover oil can lead to fuel regulator problems, excessive spark plug and combustion chamber deposits, cylinder varnish, ring sticking, and other problems.
- Liquid water is not allowed in the fuel because it frequently results in fouling and corrosion. Particular attention must be paid to landfill and digester gases since these gases are commonly received saturated with water. Due to extremely small clearances in the admission and check valves, absolutely no water can be tolerated in a prechamber fuel system. To insure that no liquid water forms in the fuel system, Waukesha specifies that the dew point of the fuel gas should be at least 20° F (11° C) below the measured temperature of the gas before all engine mounted regulators and engine remote regulator pilot valves (if so equipped). On engines without prechamber fuel systems, saturated, (100% relative humidity) fuel gas at the carburetor inlet is acceptable. A 0.3 micron coalescing filter will remove any liquid water droplets being carried along with the fuel stream. The water content of the gas can then be reduced to an acceptable level by several methods.

  A. Condensation of excess moisture by refrigerating the fuel gas to no higher than 40° F (4° C) followed by filtering to remove the liquids and reheating of the gas to 85° - 95° F (29° - 35° C). This process will also remove significant amounts of halogenated and heavy hydrocarbons and volatile siloxanes.

B. Selective stripping with a chemical process.

C. By heating: If the gas is 30° F (17° C) or more **above** the ambient temperature, it can be cooled by passing it through a heat exchanger or refrigeration system, then reheated, in a manner similar to Step A. If the gas is 20° F (11° C) or more below the ambient temperature, it can be heated. In both cases, the fuel system after the heating operation should be insulated. Heating of the fuel gas is limited to the maximum allowable temperature of 140° F (60° C).

- Glycol is not permitted in fuel gas because it can affect the engine in adverse ways. The lubricating qualities of the oil may be reduced, resulting in bearing failure, piston ring sticking, excessive wear, and other problems. A 0.3 micron rated coalescing filter will remove liquid glycol from the fuel stream.

Design Criteria:

Coalescer Filter Housing is to be of the cylindrical type, vertically mounted. The housing shall contain two sump chambers, such that the lower sump collects heavier liquid dropouts immediately downstream of the gas inlet, while the upper sump collects liquids draining off the coalescer cartridge(s).

The coalescer design shall use an inside to outside gas flow path through the coalescer cartridge.

Recommended Coalescing Filter:

Pall Process Filtration Company
Model CC3LG7A

The following recommendations will minimize corrosion problems normally encountered with fuel gas containing H_2S and TOH/CI:

- **Recommendation #1**

Select a gas engine lubricating oil with a high alkalinity reserve, 7 to 13 TBN (Total Base Number). Alkalinity reserve in the lube oil is measured in TBN. The higher the TBN, the more reserve.

Contact your oil supplier or consult the *EMA Engine Fluids Data Book* for an appropriate choice. Also follow the appropriate ash content percent by weight for the specific engine model.

- **Recommendation #2**

Used oil analysis is mandatory for alternate fuel applications. Lube oil change periods are determined by TBN, TAN (Total Acid Number), oxidation, and nitration level in the used oil samples. The user must change the oil when the TBN level falls to 30% of the new oil value or TAN increases by 2.5 – 3.0 above the new oil value. The method of measuring TBN in used oil must be ASTM-D2896.

DEXSIL® Corporation has developed the Q2000 field test kit as a test for chlorine contamination of engine oil exposed to chlorine containing fuels, as in landfill gas. This field test kit is highly accurate and allows the operator to obtain timely test results in the field. The oil must be sampled every 50 hours, in order to establish a "trend." Waukesha has experienced good results with this kit. Order information may be obtained from DEXSIL® Corporation, One Hamden Park Drive, Hamden, CT 06517.

⚠ CAUTION **TOH/CI does not affect TBN levels the same as sulfur compounds. Therefore, the 70% depletion as an indicator of a change interval only applies to the applications where fuel gas does not contain halides. Disregarding this information could result in product damage and or personal injury.**

- **Recommendation #3**

Increase the jacket water temperature to 210° - 235° F (99° - 113° C) and lube oil temperatures to 185° - 200° F (85° - 93° C). Increased temperatures will reduce condensation, which will reduce the concentration of acids within the crankcase. High temperature thermostats are available for most models.

If you have any question on lubricants to be used with alternate fuel gases, contact the Field Service Department or Sales Engineering Department prior to selecting a lubricating oil.

LUBE OIL CONDEMNING LIMITS

⚠ WARNING

Engine oil is extremely hot and is under pressure. Use caution when sampling engine oil for analysis. Failure to follow proper procedures could cause severe personal injury or death.

Lubricating oil condemning limits are established by the engine manufacturer's experience and/or used oil testing.

Laboratory testing will determine the used oil's suitability for continued use. Used oil testing should cover the data shown in Table 5.30-4.

Table 5.30-4. Used Oil Testing And Condemnation

TEST	CONDEMNING LIMIT
Viscosity	-20/+30% Change
Flash Point	Below 356° F (180° C)
Total Base Number (TBN) (ASTM-D2896)	30% of New Oil Value (Not applicable to TOH/Cl)
Total Acid Number (TAN)	2.5 - 3.0 Rise Above New Oil Value
Oxidation (Abs/Cm)	25
Nitration (Abs/Cm)	25
Water Content	Above 0.10% Wt.
Glycol	Any Detectable Amount
Wear Metals	Trend Analysis
Chlorine	900 ppm

CAUTION **Actual oil change intervals to be determined by engine inspection and oil analysis in conjunction with the condemning limits. Disregarding this information could result in product damage.**

In the interest of developing a reasonable life expectancy for Waukesha engines operating on fuel gas laden with some level of halogens, our experience dictates the following:

- To achieve the life expectancy of an engine operating on pipeline quality natural gas, remove all halogen compounds and abrasives from the fuel gas.
- Reasonable life can be expected if Total Organic Halide as Chloride Concentration (TOH/Cl) of the fuel does not exceed 150 micrograms per liter (μg/l). Total Organic Halide as Chloride (TOH/Cl) equals the sum of all halogenated compounds expressed as chloride in micrograms/litre as chloride (μCl/L) at STP (Standard Temperature and Pressure). Reasonable life can also be expected with increased maintenance and operating adjustments to the engine.
- Typical changes in maintenance and operation at this level are:
  - •• Decreased oil change interval (150 hours to start)
  - •• Condemn oil when 900 ppm chlorine level in used oil is reached. This will aid in establishing an oil change interval.
  - •• Lubricating oil analysis every 50 hours maximum
  - •• Elevated jacket water temperature 212° F - 235° F (100° C - 113° C)
  - •• Elevated lube oil temperature to 185° F - 200° F (85° C - 93° F)
  - •• Use of high TBN oil (7.0 - 13.0)
  - •• Bypass lubrication oil filtration. Waukesha Engine has introduced the Microspin cleanable lube oil filtering system. The Microspin system uses the cleaning capabilities of a centrifuge, coupled with cleanable filter elements. The Microspin system uses Waukesha's current lube oil filtration canister for the cleanable elements. The centrifuge is installed as a bypass system, working in conjunction with the cleanable filter elements. The Microspin centrifuge can also be used with standard filter elements.
- TOH/Cl above 150 micrograms chloride/litre require pre-treatment of the fuel in order to make it suitable for use in a reciprocating engine.

DEXSIL® Corporation has developed the Q2000 field test kit, as a test for chlorine contamination of engine oil exposed to chlorine containing fuels, as in landfill gas. This field test kit is highly accurate and allows the operator to obtain timely test results in the field. The oil must be sampled every 50 hours, in order to establish a "trend." Waukesha has experienced good results with this kit. Order information may be obtained from DEXSIL® Corporation, One Hamden Park Drive, Hamden, CT 06517.

OIL VISCOSITY SELECTION

The operating temperature of the oil in the sump or header is the best guide for selecting the proper SAE grade of oil. When the oil temperature is unknown, add 120° F (67° C) to the ambient temperature to obtain the estimated sump oil temperature.

Table 5.30-5. VGF Sump And Header Temperatures And SAE Number

SUMP TEMPERATURES	HEADER TEMPERATURE	SAE NUMBER
160° - 230° F (71° - 110° C)	160° - 195° F (71° - 91° C)	40
Below 160° (71°)	Below 160° (71°)	30

NOTE: *Do not operate engines with an oil header temperature below 140° F (60° C). Engines that exceed 195° F (91° C) header temperature or 215° F (102° C) sump temperature should have reduced oil change intervals.*

MULTI-VISCOSITY OILS

Use multi-viscosity oils only for engines in cold starting applications. Multi-viscosity oil may deteriorate in continuous operation, allowing the oil to lose viscosity through shearing. In this state, the oil may not supply sufficient lubricating films and/or pressure. Therefore, use an oil analysis program to determine the oil change intervals.

SYNTHETIC OILS

Based on developments by Exxon Mobil Corporation and the release of their synthetic lubricating oils, Waukesha Engine now recognizes these products as being suitable for all Waukesha stoichiometric and lean burn gas engines. Table 5.30-2 lists the synthetic oils available.

When synthetic lubricating oils are selected, it is suggested that you contact Waukesha Engine for change interval recommendations. Typically, synthetic oil change intervals are 3 to 5 times longer than those of mineral oils. Actual change intervals must be established through oil analysis and visual inspection of engine components. Typical areas to look for oil breakdown are: exhaust valve stems, piston ring area, and piston undercrown. Oil filter change intervals remain at 1000 to 1500 hours of operation.

Synthetic oils are not recommended for digester or landfill gas applications.

LOW AMBIENT TEMPERATURE OPERATION

At low ambient temperatures, use an oil which will provide proper lubrication when the engine is hot and working. For engines of 1000 cu. in. (16.4 L) and above, operating at ambients below 50° F (10° C) lube oil and jacket water heaters are required to warm oil and water for fast starting and loading of engines. Waukesha Engine will supply information on these starting devices upon request.

LUBE OIL CONSUMPTION GUIDELINES

Typical lube oil consumption rates have been updated for all Waukesha engines.

Table 5.30-6. Oil Consumption

MODEL	LBS/ HP-HR	GRAMS/ HP-HR	GRAMS/ kWb-HR
All	0.0002 - 0.002	0.091 - 0.910	0.121 - 1.22

NOTE: *Lube oil consumption rates given above are a general guide and not meant to be used for Condemning Limits or determining overhaul requirements.*

FORMULAS FOR DETERMINING OIL CONSUMPTION RATES

The following formulas may be useful in determining whether the oil consumption rate of the engine is normal.

$$\frac{\text{LBS}}{\text{HP} - \text{HR}} = \frac{7.3 \times \text{Number of Gallons of Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{LBS}}{\text{HP} - \text{HR}} = \frac{1.82 \times \text{Number of Quarts of Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{Grams}}{\text{HP} - \text{HR}} = \frac{875 \times \text{Number of Litres of Oil Used}}{\text{HP} \times \text{Hours of Operation}}$$

$$\frac{\text{Grams}}{\text{kWb} - \text{HR}} = \frac{875 \times \text{Number of Litres of Oil Used}}{\text{kWb(corrected)} \times \text{Hours of Operation}}$$

RECOMMENDED OIL CHANGE INTERVALS

⚠ CAUTION The use of some types of oil, as well as dusty environment, marginal installation, internal engine condition and/or operating the engine with malfunctioning carburetion equipment may require more frequent oil changes. Waukesha Engine recommends that the lubricating oil be monitored with a professional oil analysis program. Extended oil change intervals may cause varnish deposits, oil oxidation, or sludge conditions to appear in the engine, which an oil analysis cannot detect. Disregarding this information could result in engine damage. Contact your local Waukesha Distributor for periodic engine maintenance.

The crankcase oil level should be checked prior to each day's engine operation. The engine oil should be changed, including the oil filter elements and draining the oil cooler, every 1000 hours or sooner based on the engine's use (see Table 5.30-7, Table 5.30-8 and Table 5.30-9). The condition of the oil on the dipstick should be observed carefully. Replace oil any time it is diluted, broken down, thickened by sludge, or otherwise deteriorated. The useful life of the oil will depend on the engine load, temperature, fuel quality, atmospheric dirt, moisture and maintenance. Where oil performance problems rise or are anticipated, the oil supplier should be consulted.

Oil change intervals should not be extended beyond the recommendations (because of additive depletion) without a good oil analysis program. However, laboratory analysis is intended primarily to detect engine problems and will not predict the oil additive "dump out" point precisely. Consequently, close attention to engine conditions by the operator is required when considering an alternate oil change interval.

Table 5.30-7. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance

ENGINE MODEL	ISO STANDARD OR CONTINUOUS POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD POWER	LIGHT LOAD OPERATION	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE 200_ F (93_ C) OR ABOVE	STANDBY DUTY
FOR ENGINES OPERATING WITH OIL HEADER TEMPERATURES 195_ F (91_ C) OR BELOW.					
VGF G,GL,GLD Natural Gas, HD-5 Propane	Normal 1000 hours (Extended 1250 hours*)	500 hours	1000 hours	720 hours	500 hours or annually
VGF GSID Natural Gas, HD-5 Propane	Normal 720 hours (Extended 900 hours*)	500 hours	720 hours	500 hours	500 hours or annually

NOTE: *Change lube oil filter elements when lube oil is changed.*

* *Extended oil drain intervals listed, are acceptable, if a Microspin centrifuge, in conjunction with a Waukesha supplied oil filtration system is used, and an oil analysis program is followed.*

Table 5.30-8. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance And Using Gaseous Fuel Containing H_2S

ENGINE MODEL	ISO STANDARD OR PRIME POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD POWER	LIGHT LOAD OPERATION	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE 200_ F (93_ C) OR ABOVE	STANDBY DUTY
FOR ENGINES OPERATING WITH ELEVATED OIL SUMP TEMPERATURE.					
VGF SERIES	360 hours	250 hours	360 hours	360 hours	250 hours

Table 5.30-9. Duty Cycle Definitions

ISO STANDARD OR CONTINUOUS POWER RATING:	The highest load and speed which can be applied 24 hours a day, 7 days a week, 365 days per year, except for normal maintenance. It is permissible to operate the engine at up to 10% overload or maximum load indicated by the intermittent rating, whichever is lower, for two hours in each 24 hour period.
GENERATOR STANDBY POWER RATING:	In a system used as a backup or secondary source of electrical power, this rating is the output the engine will produce continuously (no overload), 24 hours per day, for the duration of the prime power source outage.
INTERMITTENT POWER RATING:	This rating is the highest load and speed that can be applied in variable speed mechanical system application only. Operation at this rating is limited to a maximum of 3500 hours per year.
GENERATOR PEAK SHAVING:	Peak shaving is operation of an engine for a limited time to meet short term peak power requirements. Speed, loading, and hours per year of operation will affect the recommended oil change interval.
LIGHT LOAD OPERATION:	Power levels less than 50% of the maximum continuous power rating.

OIL CHANGE PROCEDURE

⚠ WARNING

Engine oil is hot and can burn if it contacts bare skin. Disregarding this information could result in severe personal injury or death.

1. Remove drain plug from oil pan and drain oil while still warm.

2. Remove filter canisters from oil filter support (use filter wrench) (see Figure 5.30-5).

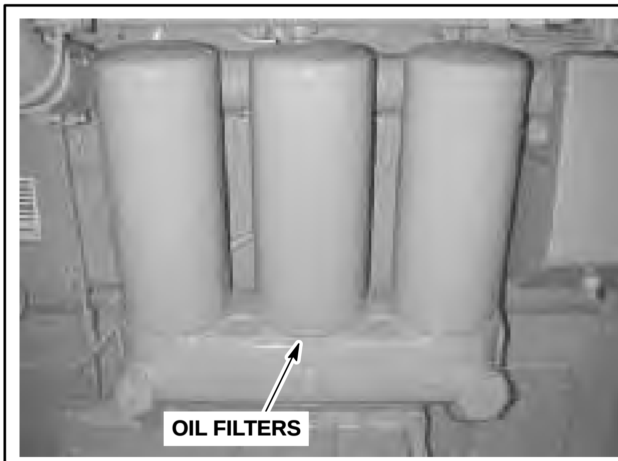


Figure 5.30-5. Lube Oil Filter Canisters

3. Drain oil from oil cooler (see Figure 5.30-6). Replace drain plugs.

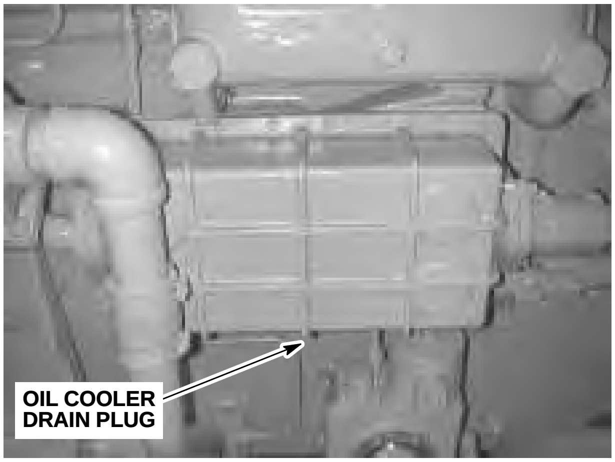


Figure 5.30-6. Oil Cooler

4. Apply a film of oil to seal ring on base of each filter canister. Spin new filter until seal ring contacts base. Turn filter 3/4 of a turn. Hand tighten only.

5. Fill crankcase with proper grade and viscosity of oil. Oil filler cap is located on front gear cover.

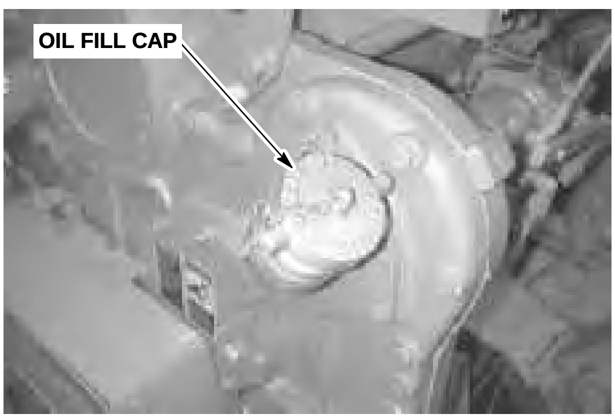


Figure 5.30-7. Oil Fill Location

6. Prelube engine if equipped. If not prelube equipped crank engine over several times (without fuel or ignition) until oil pressure is indicated on oil pressure gauge. Recheck oil level with dipstick and add more oil if required (see Figure 5.30-8).

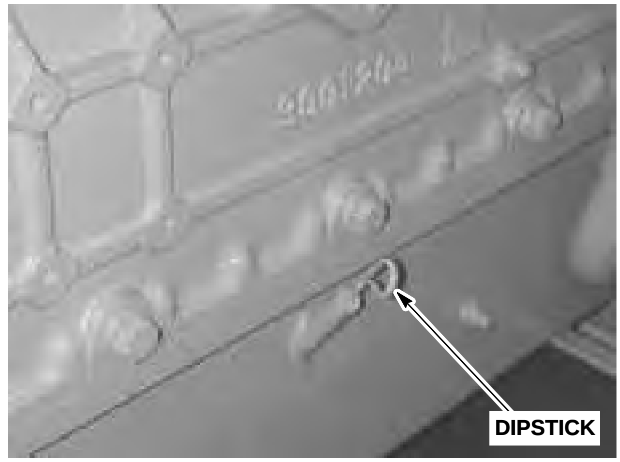


Figure 5.30-8. Dipstick

7. Start engine and check for leaks around oil filters and drain plugs. Re-tighten if necessary.

MICROSPIN CLEANABLE LUBE OIL FILTERING SYSTEM

The Microspin system consists of two major components, a centrifuge using a removable paper insert (see Figure 5.30-9) and cleanable oil filter elements (see Figure 5.30-13). The Microspin system cleanable filter elements are installed in the existing lube oil filtration canister. The cleanable filter elements remove particles as small as 25 microns. The centrifuge is installed as a bypass system, working in conjunction with the cleanable filter elements. The centrifuge is driven by the engine's oil pressure. The spinning action of the centrifuge's internal turbine assembly develops a force that exceeds 2000 G's, this force squeezes the contaminants against the turbine housing. The centrifuge will remove oil contaminating particles as small as 0.5 microns. The Microspin system is more environmentally friendly than systems that utilize disposable elements. Cleaning the elements eliminates the expense of replacement elements and the cost of hazardous waste disposal. Microspin installation and maintenance parts kits are available.

Figure 5.30-9. Microspin Centrifuge - P/N 489300

INITIAL MICROSPIN CENTRIFUGE INSPECTION

1. Inspect Microspin centrifuge for damage that may have occurred during shipping.

2. Remove plastic plugs from 0.5 in. (12.7 mm) supply port and 2 in. (50.8 mm) drain port.

⚠ WARNING

Use caution during initial inspection of the Microspin centrifuge prior to the unit being installed. The rotor vanes are sharp and could cause severe personal injury.

3. Prior to installation of Microspin centrifuge, verify rotor moves freely by inserting your index finger into drain port. Lift rotor to ensure there is end play and then verify rotor spins freely. If restriction is felt, disassemble centrifuge and correct problem.

4. Inspect cleanable filter elements for holes or damage to filter screens.

STARTING

To start the unit, open the oil supply valve. It will take a few minutes for the rotor to come up to speed.

SERVICING MICROSPIN CENTRIFUGE

Initial servicing should be about four weeks after startup, sooner if the oil is heavily contaminated. A maximum buildup of 0.75 in. (19.05 mm) is allowed on the centrifuge paper insert. Noting the buildup will help in establishing a cleaning interval.

Centrifuge

⚠ WARNING

Solvents may be flammable and give off dangerous fumes. Read and follow the manufacturer's recommendations to avoid serious personal injury or death.

Under normal operating conditions, the centrifuge should be cleaned and its paper insert removed at every scheduled oil change, or as experience dictates. The centrifuge can be cleaned while the engine remains running provided the oil supply valve is shut off (see "Disassembly Of Microspin Centrifuge" in this section for proper procedures).

Cleanable Filter Elements

⚠ CAUTION **Do not use high pressure or high temperature water on one part of the filter element for prolonged periods of time. Prolonged exposure to high pressure or heat may damage the filter element.**

The cleanable oil elements (see Figure 5.30-10 and Figure 5.30-11) should be removed from the oil filtration canister, and cleaned at every other regularly scheduled oil change or when the oil pressure differential between the canister inlet and outlet, exceeds 24 psi (165 kPa). Two methods of cleaning the filter element cleaning are recommended:

- Immerse filter in a parts washer and flood inside and outside of filter. Drain filter and dry with air spray.
- Spray inside and outside of filter with a Steam Jenny or common water spray. Drain filter and dry with air spray.

NOTE: *Before moving or drying with an air spray, allow the filter to cool to room temperature. Do not bang or bounce filter ends to dislodge water or solvent.*

Figure 5.30-10. Microspin Cleanable Oil Filters

Figure 5.30-11. Cleanable Oil Filter Assembly - (Inline)

It is recommended that an oil pressure differential gauge be installed to monitor the oil pressure differential (“ΔP”) between the oil inlet and outlet of the oil filter assembly (see Figure 5.30-12). The engine must be shut down to service the cleanable oil filters.

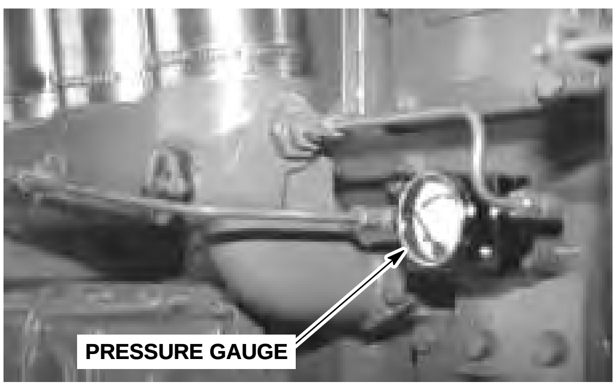


Figure 5.30-12. Oil Pressure Differential Gauge

Disassembly Of Microspin P/N 489300 Centrifuge

⚠ WARNING

The oil supply valve must be shut off before servicing the Microspin centrifuge. Allow two minutes before proceeding with servicing the Microspin centrifuge to allow the rotor to stop spinning and the oil pressure to drop to zero. Failure to shut off the oil supply valve can cause severe oil burns.

1. Shut off oil supply valve and wait two minutes for oil pressure to drop to zero and rotor to stop spinning.

⚠ WARNING

Oil and parts may be extremely hot. Always use caution when servicing the unit to avoid severe personal injury.

2. Loosen 3/4 in. (19 mm) nut and remove top cover (see Figure 5.30-13). This will separate cover from base and expose turbine assembly.

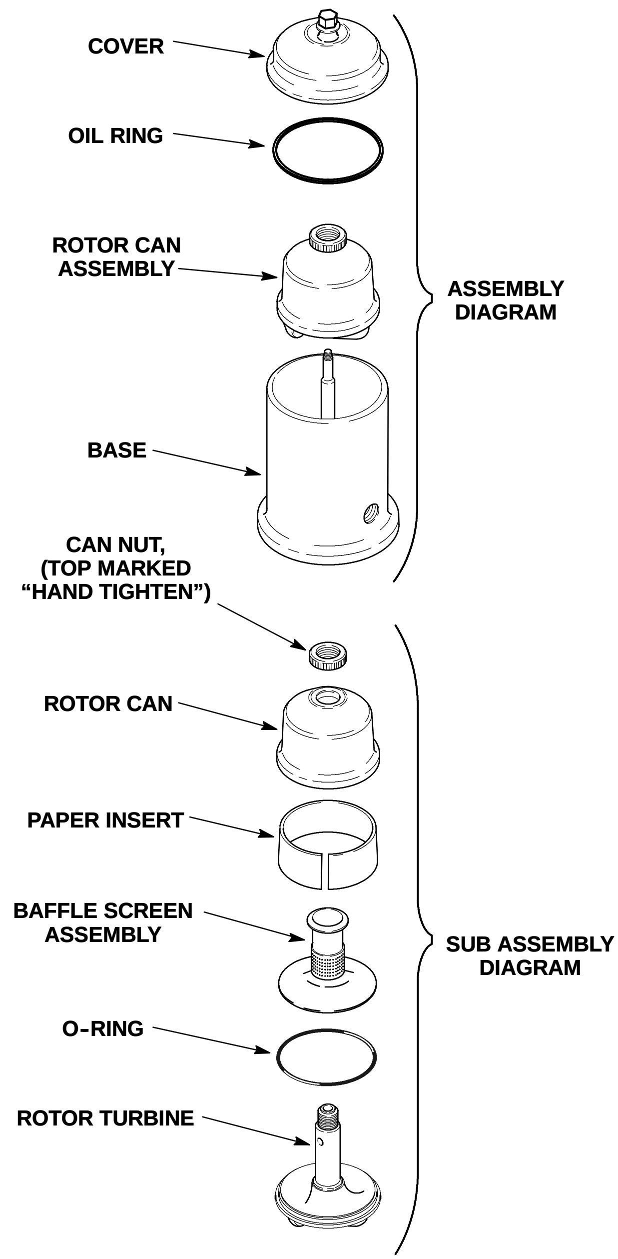


Figure 5.30-13. Service And Cleaning Of Microspin Centrifuge - P/N 489300

3. Remove and replace O-ring if necessary.

4. Lift rotor assembly up 1 to 2 in. (25.4 to 50.8 mm) to allow oil to drain from rotor turbine into body base. Once oil stops draining from turbine assembly, lift it straight up until it clears base shaft.

5. Loosen knurled can nut until it is above bronze bushing in rotor turbine assembly.

⚠ CAUTION **Use caution during disassembly to avoid damage to the top brass bushing.**

6. Invert rotor assembly and place on clean work table.

7. Holding rotor can with both hands, press down until can separates from rotor turbine.

8. Remove knurled can nut.

9. Remove turbine and baffle screen from turbine can.

10. Remove and replace rotor O-ring if necessary.

Cleaning The Rotor

1. Remove paper insert from rotor. Insert narrow flat tool between paper insert and rotor can. Run tool around inside of can and remove paper insert. Clean contaminant build up in rotor can and install new paper insert.

⚠ WARNING

Solvents may be flammable and give off dangerous fumes. Read and follow the manufacturer's recommendations to avoid serious personal injury or death.

⚠ CAUTION **Remove rubber O-rings prior to placing parts in the solvent tank, to prevent damage to equipment.**

2. Clean baffle screen assembly, rotor turbine, rotor can, covers and jets, in a suitable solvent tank.

Assembly Of Microspin P/N 489300 Centrifuge

1. Install baffle screen and new O-ring onto turbine.

⚠ CAUTION **The knurled can nut must be tightened hand tight only or damage to equipment could result.**

2. Position rotor can with a new paper insert in place (see Figure 5.30-13) on turbine rotor. Install knurled can nut, hand tighten only.

3. Position turbine rotor assembly onto base (over base shaft). Check to ensure rotor spins freely.

4. Install top cover onto base using new O-ring (if necessary). Secure with 3/4 in. (19.05 mm) hex nut.

5. Open oil supply valve to start centrifuge. Check for oil leaks.

OIL COOLER

OIL COOLER REMOVAL

⚠ WARNING

Allow the oil to cool prior to removing oil system components to prevent burns from hot oil. Disregarding this information could result in severe personal injury or death.

⚠ WARNING

Do not remove the bonnets until all pressure is relieved and both oil and coolant are completely drained. Failure to follow proper procedures could cause severe personal injury or death.

NOTE: *Since the other lube oil accessories may also have to be drained, schedule the oil cooler cleaning during a regular oil change interval.*

1. Remove oil drain plug at bottom of oil cooler (see Figure 5.30-14). Drain oil from oil cooler.

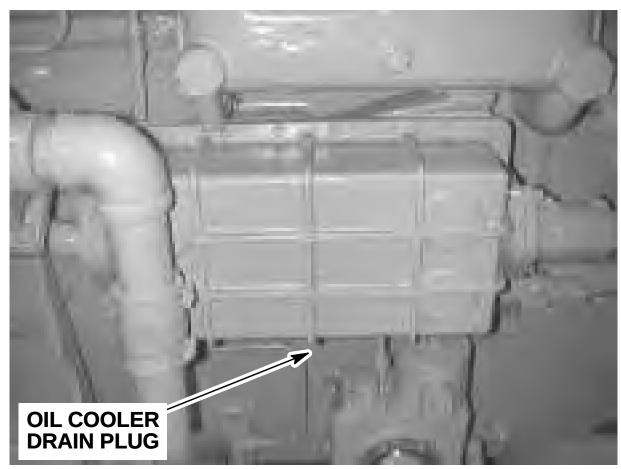


Figure 5.30-14. Oil Cooler

NOTE: *If the engine is turbocharged, then the auxiliary water supply must be drained or shut off.*

2. Disconnect auxiliary water thermostat elbow from oil cooler (see Figure 5.30-15).

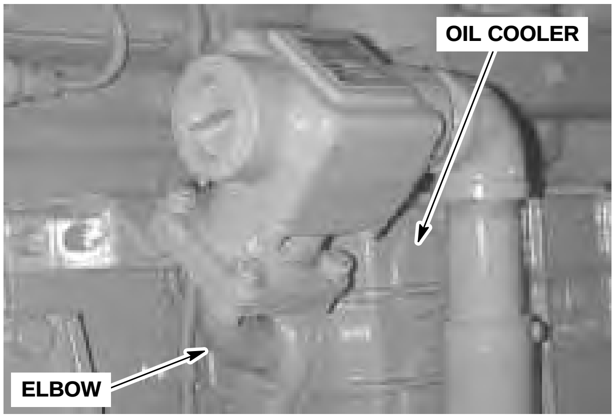


Figure 5.30-15. Auxiliary Water Thermostat

NOTE: *The "G" series engines do not use an auxiliary water pump. Instead the jacket water pump has an additional tube that runs to the oil cooler without a thermostat (see Figure 5.30-16). The jacket water system will require draining during oil cooler removal.*

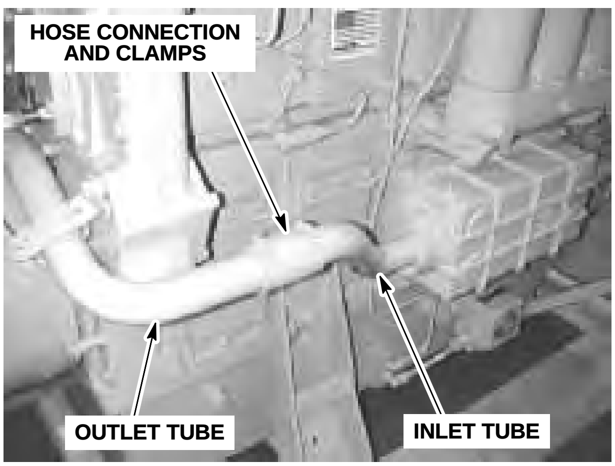


Figure 5.30-16. Inlet Oil Cooler Water Tube

3. **G Engines Only—**Disconnect water pipe from rear of oil cooler (see Figure 5.30-17).

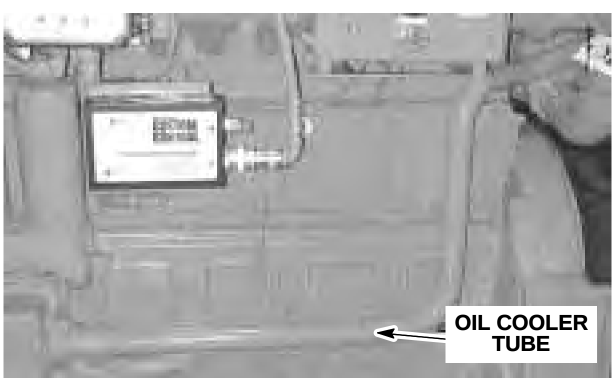


Figure 5.30-17. Oil Cooler Water Tube

4. Remove outlet elbow from oil cooler and crankcase (see Figure 5.30-18).

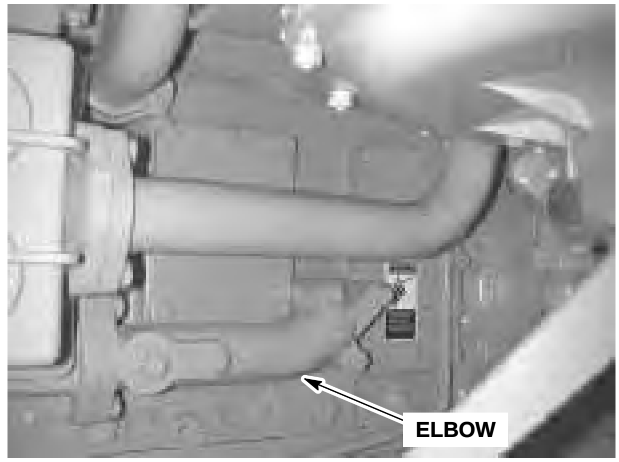


Figure 5.30-18. Oil Cooler Outlet Elbow

5. Oil cooler and oil filter support can be removed from the engine as an assembly. Remove oil filters.

⚠ WARNING

The oil cooler weighs 101 lb. (46 kg). The oil cooler and oil filter support assembly weighs 130 lb. (59 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

6. Wrap lifting sling around oil cooler body (see Figure 5.30-19).

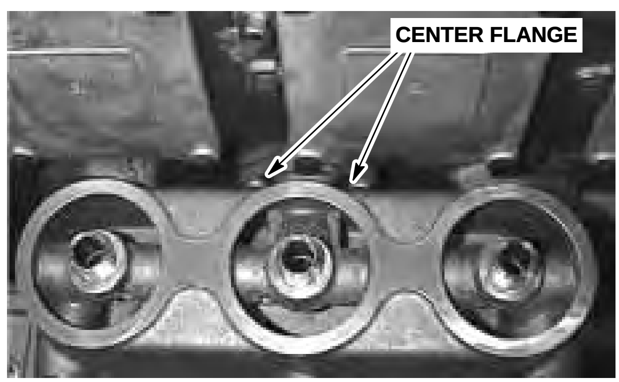


Figure 5.30-19. Oil Filter Support Mounting

OIL COOLER DISASSEMBLY

1. Remove six socket head hex head screws from back side of oil cooler (see Figure 5.30-20 and Figure 5.30-27).

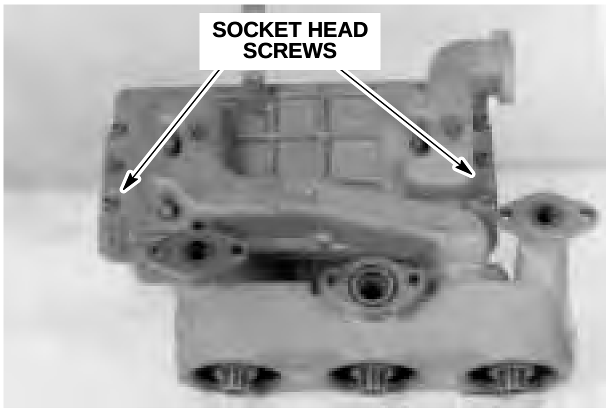


Figure 5.30-20. Oil Filter And Cooler Assembly

2. Remove eight top and eight bottom socket head hex head screws from front side of oil cooler (see Figure 5.30-21).

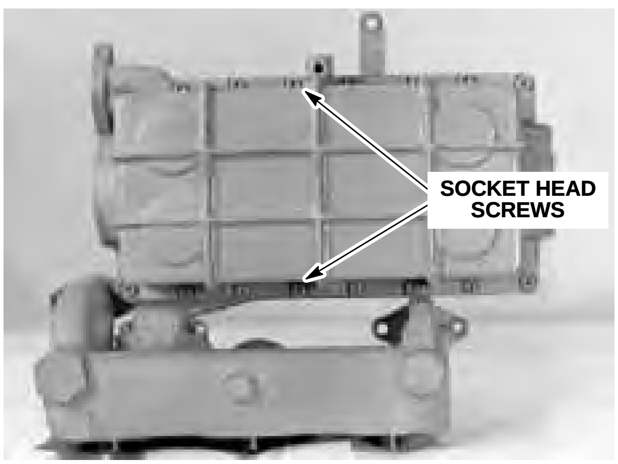


Figure 5.30-21. Oil Filter And Cooler Assembly

3. Separate oil cooler housing exposing cooler elements (see Figure 5.30-22). Discard housing gasket.

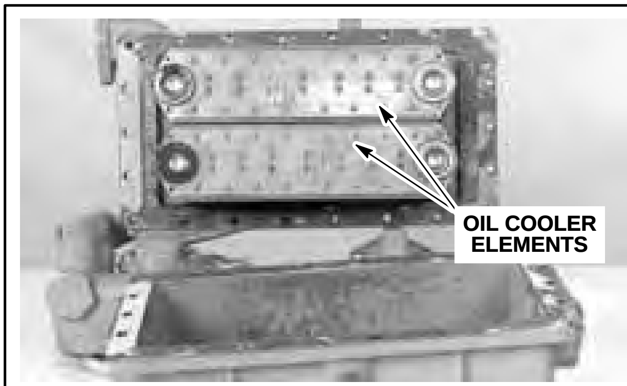


Figure 5.30-22. Oil Cooler Elements

4. Remove four acorn nuts that retain each cooler element to housing and remove elements (see Figure 5.30-23 and Figure 5.30-24).

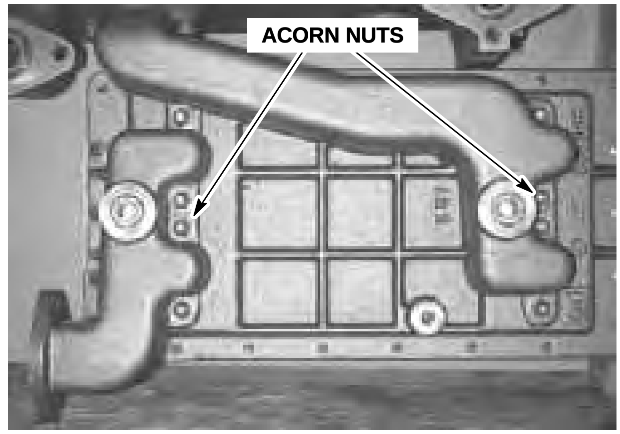


Figure 5.30-23. Oil Cooler Cover

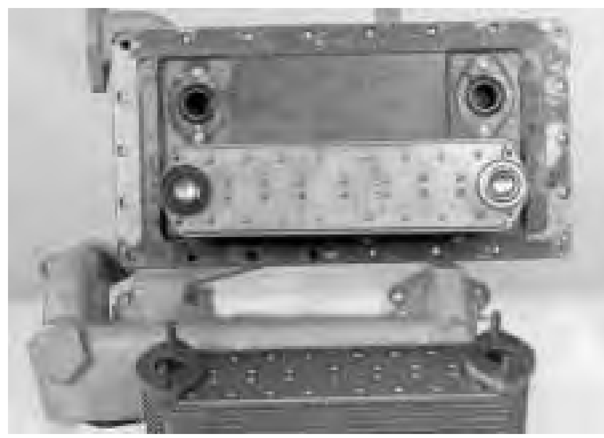


Figure 5.30-24. Oil Cooler Elements

5. Oil cooler to filter connection is held by two studs, lock washers and nuts (see Figure 5.30-25). When separated, remove and discard the sealing O-ring.

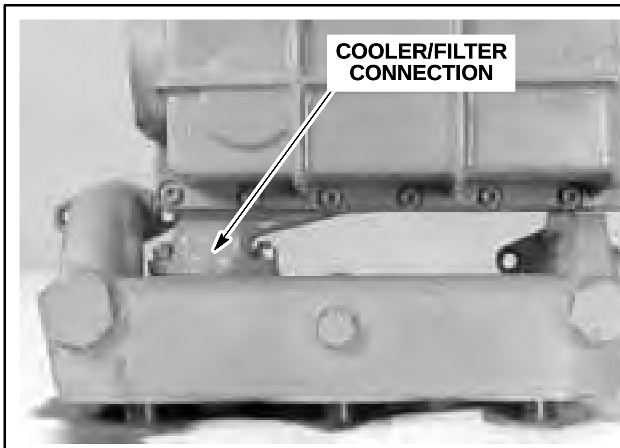


Figure 5.30-25. Oil Cooler To Filter Connection

OIL COOLER CLEANING AND INSPECTION

At each oil change drain and clean the oil cooler.

⚠ WARNING

Use of mechanical removal equipment may cause flying debris. Wear protective eye and face shields, gloves and coveralls. Failure to take adequate precautions can result in serious personal injury or death.

⚠ CAUTION **Do not blow steam through individual tubes; localized overheating can result in expansion strain.**

NOTE: *Inspect the oil cooler regularly. Plugged tubes or scale deposits inhibit the flow of coolant which reduces oil cooling effectiveness. Clean the oil cooler if an increase in oil temperature cannot be traced to a malfunctioning auxiliary water pump, loose belts, a faulty thermostat or excessive engine load.*

The tube bundle assembly fits inside the outer shell of the oil cooler. The tubes are water passageways secured to a fixed tube sheet at the inlet bonnet end. The tube sheet is held in place between the inlet bonnet and a protruding flange on the oil cooler shell at the inlet bonnet end. The opposite end of the tube bundle is held in place by pressure between the rear bonnet and the packing seals, which encircle the rear tube sheet.

1. Protect all gasket and seal surfaces.

2. Clean the oil cooler by either mechanical or chemical means. The selected method largely depends upon the type of deposit and the materials available.

Any of the following methods may be considered:

A. Backflushing.

B. Circulate hot wash oil or light distillate to remove sludge or other soft deposits.

C. Circulate hot fresh water to remove soft salt deposits.

D. Commercial cleaning compounds may be used to remove sludge or scale not removed by the above methods. If such compounds are used, then check material compatibility to avoid possible damage.

E. Use of a high pressure water jet.

F. Scrapers, rotating brushes or other mechanical means. Nylon brushes are preferred over wire brushes if mechanically cleaning copper alloy tubes.

3. Use only cold fluid for pressure testing. Hydraulic pressure may be used to locate splits or leaking joints.

OIL COOLER ASSEMBLY

NOTE: *When reassembling the oil cooler, use a new gasket on the body and cover. Be sure that the gaskets and seals are properly positioned before any attempt is made to retighten the body bolts.*

1. Install a new O-ring between oil cooler and filter housing (see Figure 5.30-26).

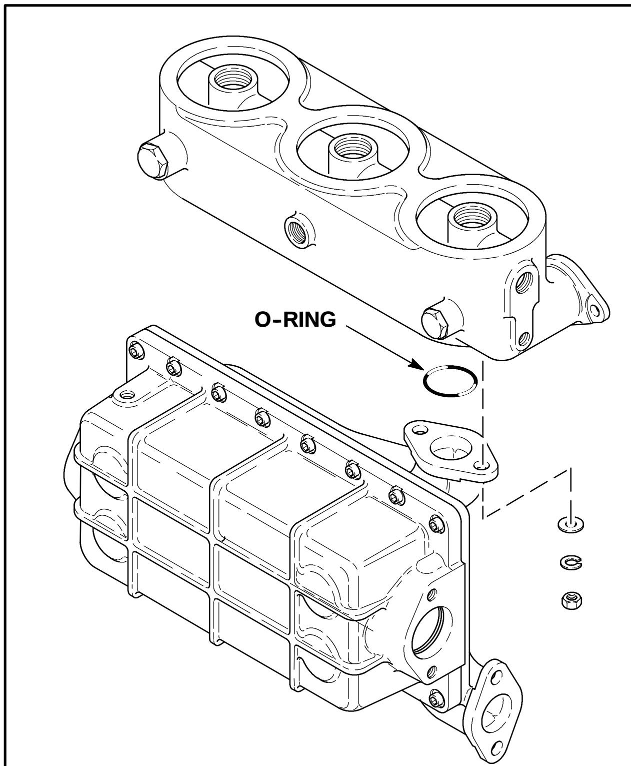


Figure 5.30-26. Oil Filter To Oil Cooler Installation

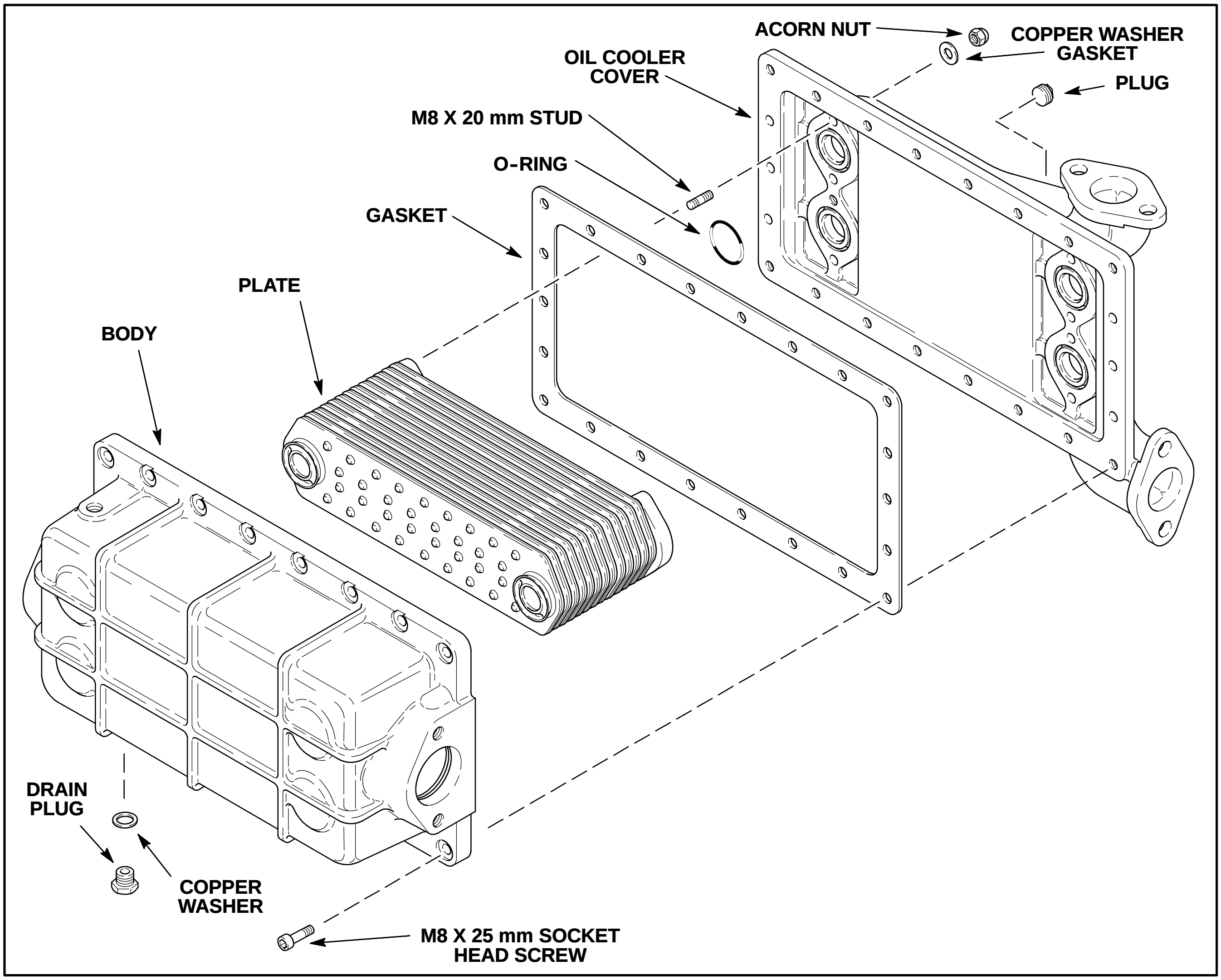


Figure 5.30-27. Oil Cooler Assembly

2. Install new O-rings in cooler housing (see Figure 5.30-28).

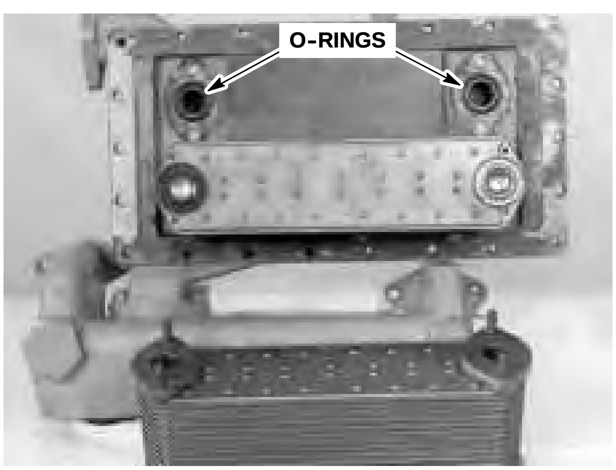


Figure 5.30-28. Oil Cooler Elements

3. Install elements and secure cover with acorn nuts (see Figure 5.30-29).

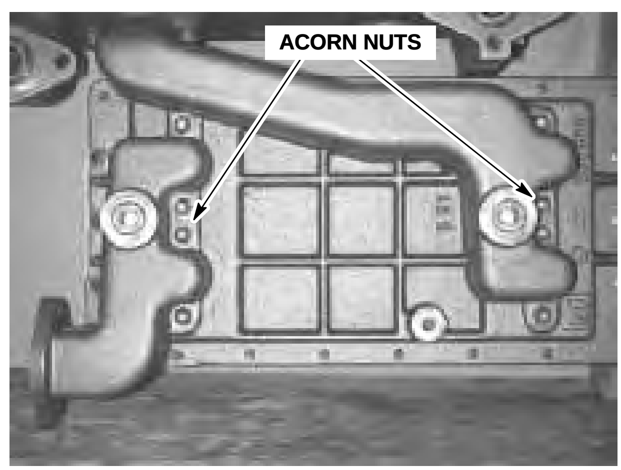


Figure 5.30-29. Oil Cooler Cover

4. Install new gasket between oil cooler housing halves (see Figure 5.30-30).

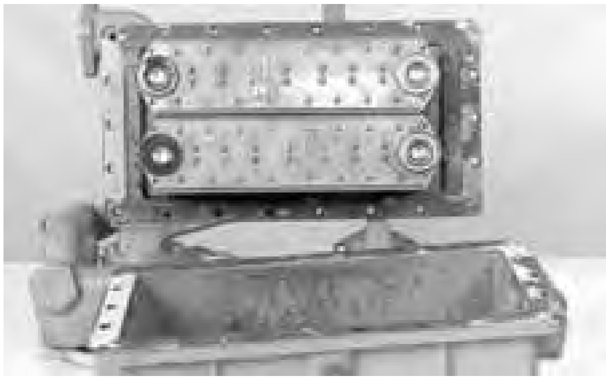


Figure 5.30-30. Oil Cooler Elements

5. Install eight top and eight bottom M8 x 25 mm socket head screws in front side of oil cooler (see Figure 5.30-31).

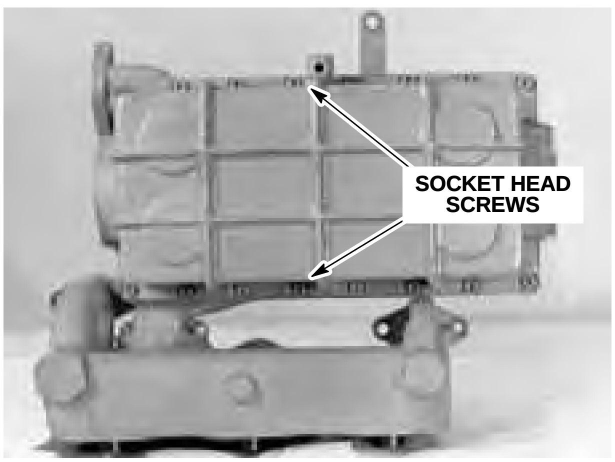


Figure 5.30-31. Oil Filter And Cooler Assembly

6. Install six socket head screws from back side of oil cooler (see Figure 5.30-32).

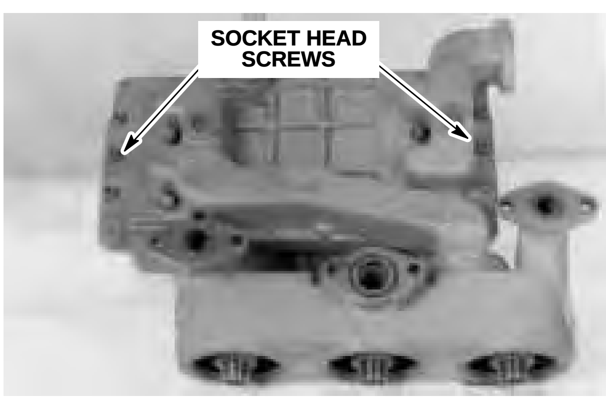


Figure 5.30-32. Oil Filter And Cooler Assembly

OIL COOLER INSTALLATION

1. Install new oil cooler gaskets on oil pan and thermostat housing.

⚠ WARNING

The oil cooler weighs 101 lb. (45.8 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

2. Install new O-rings on oil cooler housing (see Figure 5.30-33). Wrap a lifting sling around oil cooler body and lift cooler up to crankcase.

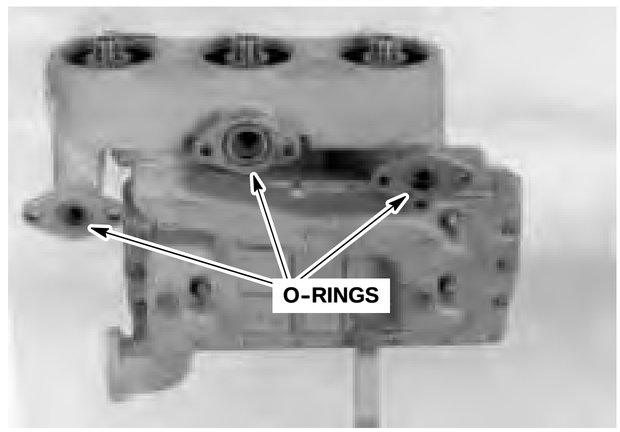


Figure 5.30-33. Oil Filter And Cooler Assembly

3. Secure oil filter support and oil cooler support with M10 x 25 mm hex head screws (see Figure 5.30-34). Tighten hex head screws to 37 ft-lb (50 N·m).

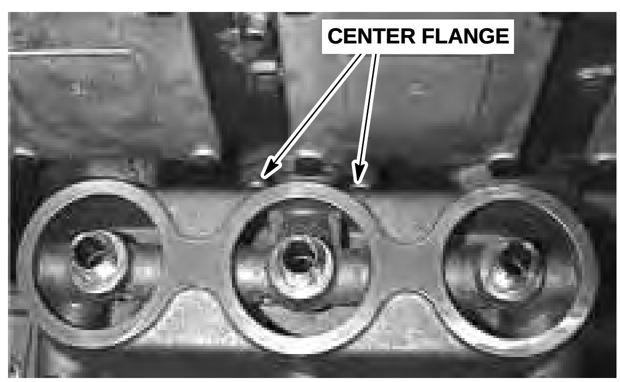


Figure 5.30-34. Oil Filter Support Mounting

SECTION 5.35

EXHAUST SYSTEM

EXHAUST SYSTEM

COMPONENTS

The engine exhaust system consists of the following component parts:

- Exhaust manifold assembly
- Turbocharger
- Exhaust thermocouples (If equipped)
- Turbocharger wastegate (If equipped)

DESCRIPTION

The exhaust port of each cylinder is connected to the water-jacketed exhaust manifold. The water-cooled exhaust manifold assembly is comprised of 2 or 3 segments rigidly bolted together.

Optional thermocouples are used to monitor engine exhaust temperatures. High exhaust temperatures greatly increase the potential for detonation and have a direct impact on the life of many engine components.

One thermocouple is mounted in each exhaust port of the exhaust manifold to measure the temperature of the exhaust exiting the respective cylinder head. A thermocouple is also mounted before each turbocharger and reflects the exhaust temperature of the cylinder bank (an average of the exhaust temperatures of each individual cylinder).

The leads from the exhaust thermocouples enter a thermocouple conduit. Exiting the conduit through a flexible cable, the wires lead into the back of the instrument panel where they are connected to the exhaust pyrometer selector switch. The pyrometer selector switch is used with the portable pyrometer to monitor engine exhaust temperatures.

A turbocharger is provided for GSID, GL and GLD engines. The compressor side of the turbocharger is part of the air induction system; the turbine side is part of the exhaust system. When the turbine spins through the expansion of exhaust gases exiting the engine, the movement of the compressor wheel causes the air passing through the air cleaner enroute to the carburetor to be compressed.

An exhaust wastegate is attached to the exhaust manifold. The wastegate is a load limiting device. The wastegate can also protect the turbocharger from overspeed conditions, depending on the application. At a predetermined point, intake manifold pressure counteracts the tension of a spring and a valve opens to bypass a portion of the engine exhaust pressure around the turbocharger turbine. In this way, the air intake boost pressure is held within an acceptable range.

Exhaust gases driving (or bypassing) the turbine exit the engine through the exhaust stack. Exhaust gases passing the flexible exhaust connection are directed into the atmosphere through customer supplied exhaust piping.

EXHAUST SYSTEM SPECIFICATIONS

MEASURING EXHAUST SYSTEM BACK PRESSURE

Monitor the exhaust system backpressure annually. The maximum backpressure must not exceed specification.

1. Install tubing connector into 1/4 in. NPT hole of exhaust outlet tee. Use only non-corroding stainless steel fittings.

2. Secure one end of a water manometer to connector and vent free end to atmosphere. Manometer line fitting must not extend past inner surface of exhaust pipe or an inaccurate reading may result.

3. Measure exhaust backpressure at rated speed and load. Measurement must be taken before catalytic converter or silencer, if installed, and should be away from any bend or elbow in exhaust piping. Corrective action must be taken if backpressure exceeds specified limit.

4. Excessive exhaust backpressure may be due to one or more of the following conditions:

- undersized piping
- elbows, bends or sudden enlargements in the piping
- plugged catalytic converter
- pipe obstructions
- exit losses

CHECKING EXHAUST GAS TEMPERATURES

Exhaust temperatures can be an important diagnostics tool. A very high exhaust temperature might indicate that the air/fuel ratio is too rich. A very low temperature may mean that a cylinder is not firing.

One exhaust thermocouple is mounted in each exhaust manifold port (see Figure 5.35-1).

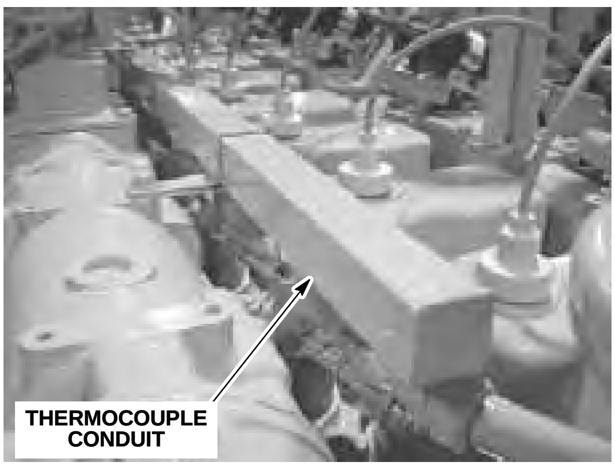


Figure 5.35-1. Thermocouple Conduit

A thermocouple is also mounted below the turbocharger and in the exhaust outlet (see Figure 5.35-2 and Figure 5.35-3). Six cylinder engines have 7 thermocouples and eight cylinder engines have 9 thermocouples.

Check engine exhaust temperatures for each cylinder daily. Monitor the exhaust temperatures when the engine is running at rated speed and load.

Figure 5.35-2. Exhaust Manifold Thermocouple

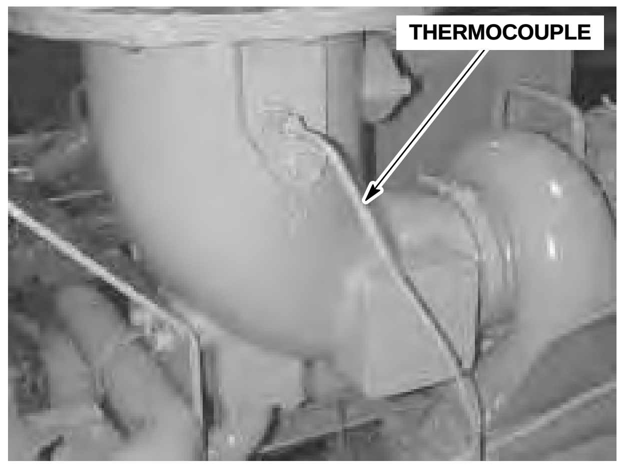


Figure 5.35-3. Exhaust Outlet Thermocouple

Be on the alert for wide differences between cylinders or between cylinder banks. The actual exhaust temperature readings are not as important as the variations that may occur.

NOTE: *The cylinder farthest from the flywheel is the #1 cylinder. Those closest to the flywheel are the #6 or #8 cylinders.*

1. Rotate selector switch to determine EGT of each cylinder.

2. Record temperature value for each cylinder.

TURBOCHARGER EXHAUST OUTLET

EXHAUST OUTLET REMOVAL – GSID/GL/GLD

1. Disconnect exhaust system from exhaust outlet. See Section 5.20 *Turbocharger* in this manual for complete information about removing exhaust outlet, heat shields and turbocharger (see Figure 5.35-4).

Figure 5.35-4. Turbocharger And Heat Shield

2. Remove breather ejector (if equipped) from exhaust outlet (see Figure 5.35-5). Disconnect ejector tube from intercooler inlet bonnet. See Section 5.40 *Crankcase Breather System* for breather system removal and installation.

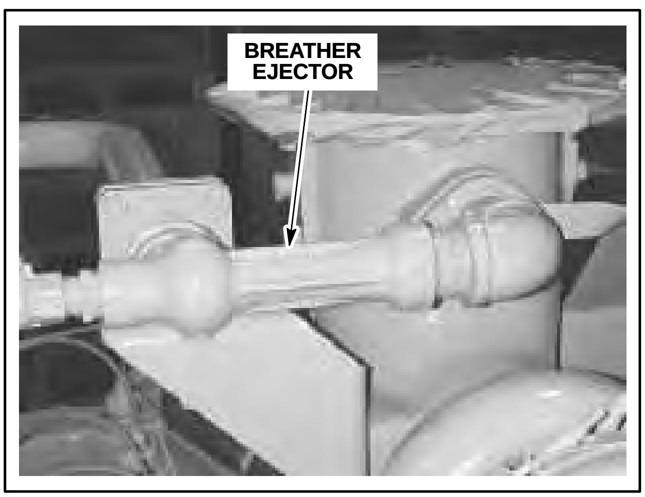


Figure 5.35-5. Breather Ejector

3. **GSID and GLD—**Remove closed breather support clamps and tubing (see Figure 5.35-6). See Section 5.40 *Crankcase Breather System* for removal and installation information.

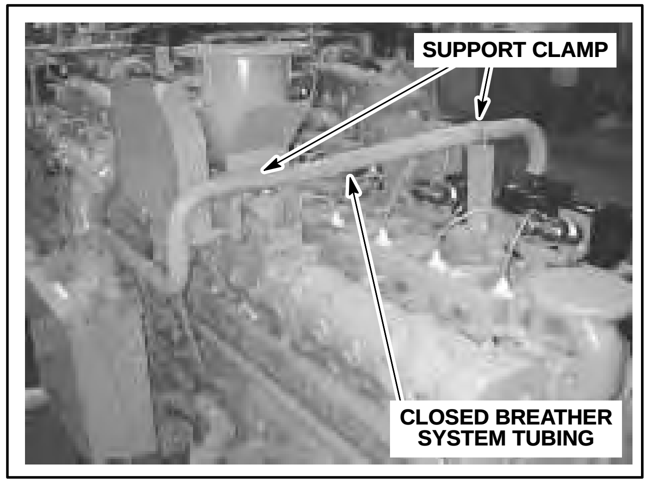


Figure 5.35-6. Wastegate Actuator Vent Tube

4. Remove thermocouple (if equipped) from exhaust outlet (see Figure 5.35-7).

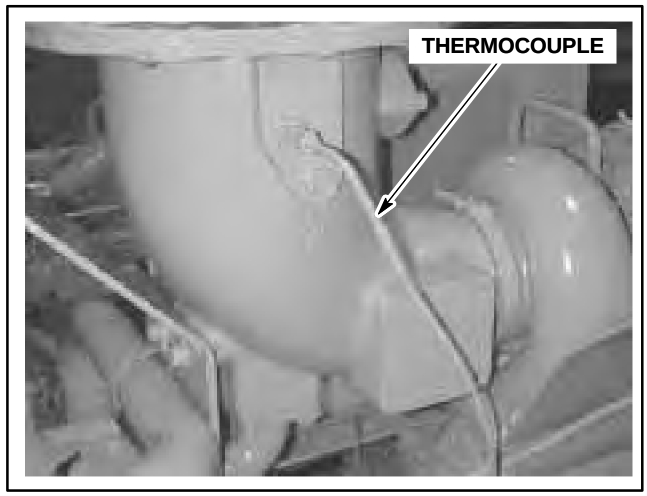


Figure 5.35-7. Exhaust Outlet Thermocouple

5. Remove hex head screws and flanges. Remove exhaust bypass tube (see Figure 5.35-8).

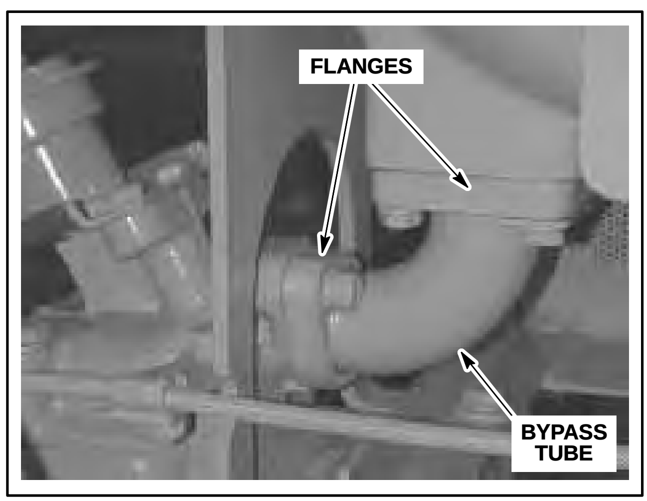


Figure 5.35-8. Wastegate Bypass Tube

NOTE: *The wastegate may remain installed on the exhaust manifold during removal.*

⚠ WARNING

The exhaust outlet weighs 54 lb. (24 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

6. Remove two hex head screws and washers from front heat shield (see Figure 5.35-9).

Figure 5.35-9. Exhaust Outlet

7. Loosen band clamp from exhaust elbow to turbocharger. Remove exhaust elbow from turbocharger (Figure 5.35-10).

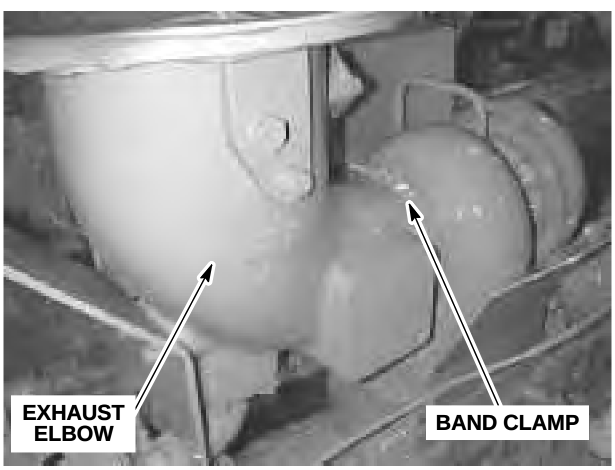


Figure 5.35-10. Exhaust Outlet

8. Remove front heat shield from wastegate mounting plate (see Figure 5.35-11).

EXHAUST OUTLET INSTALLATION – GSID/GL/GLD

1. Install front heat shield on wastegate mounting plate (see Figure 5.35-11).

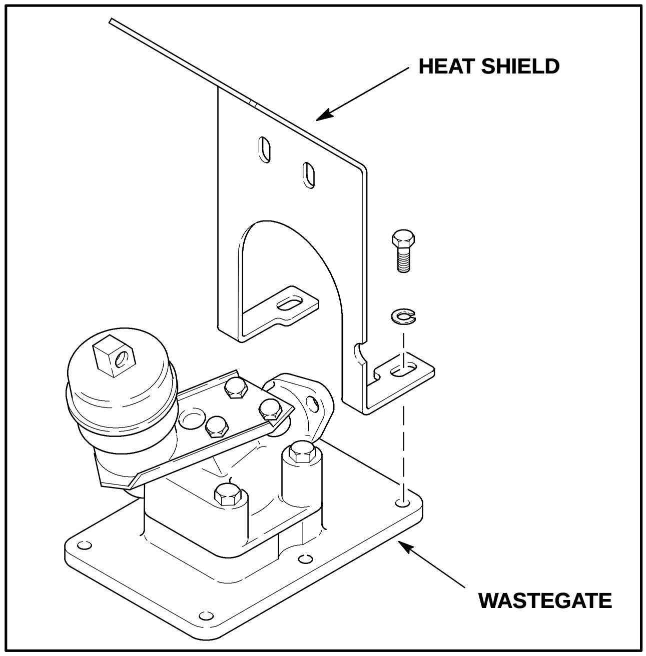


Figure 5.35-11. Exhaust Outlet Heat Shield

⚠ WARNING

The exhaust outlet weighs 54 lb. (24 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

2. Install exhaust elbow onto turbocharger. Secure exhaust elbow and turbocharger together with band clamp (see Figure 5.35-12).

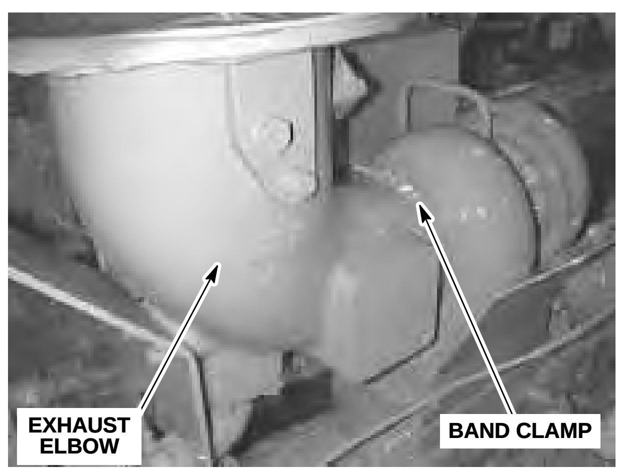


Figure 5.35-12. Exhaust Outlet

3. Install two hex head screws, lock washers and washers through front heat shield (see Figure 5.35-13).

Figure 5.35-13. Exhaust Outlet

4. Install exhaust bypass tube to exhaust outlet and wastegate. Each tube end is held in place with a gasket and flange (see Figure 5.35-14). See “Wastegate Installation” in this section.

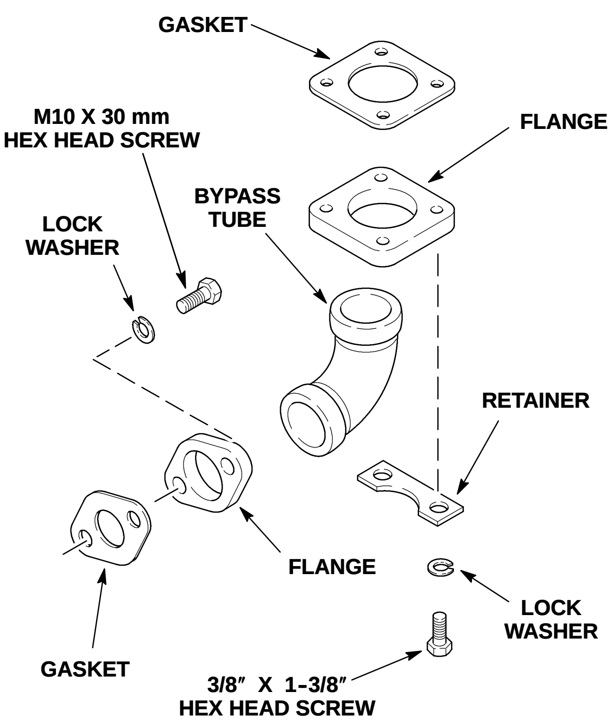


Figure 5.35-14. Wastegate Bypass Tube

5. Install breather ejector exhaust inlet flange (if equipped) onto exhaust outlet (see Figure 5.35-15). Tighten screws to 32 ft-lb (43 N·m).

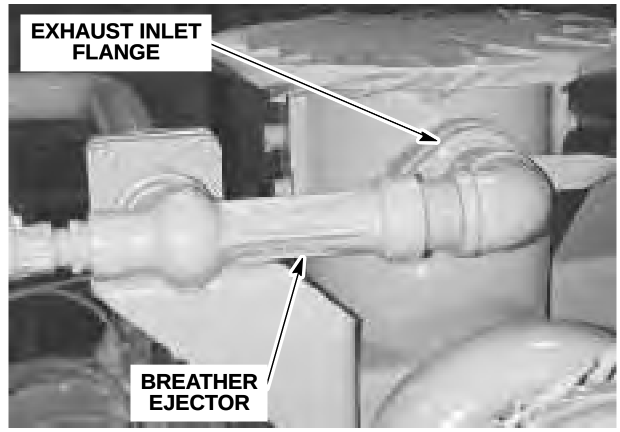


Figure 5.35-15. Breather Ejector

6. Install thermocouple (if equipped) in exhaust outlet (see Figure 5.35-16).

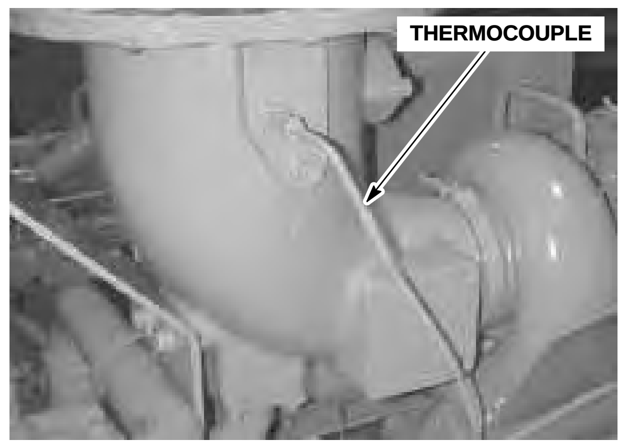


Figure 5.35-16. Exhaust Outlet Thermocouple

7. **GSID and GLD—**Install closed breather tubing and secure to supports using clamps (see Figure 5.35-17). See Section 5.40 *Crankcase Breather System* for breather system removal and installation.

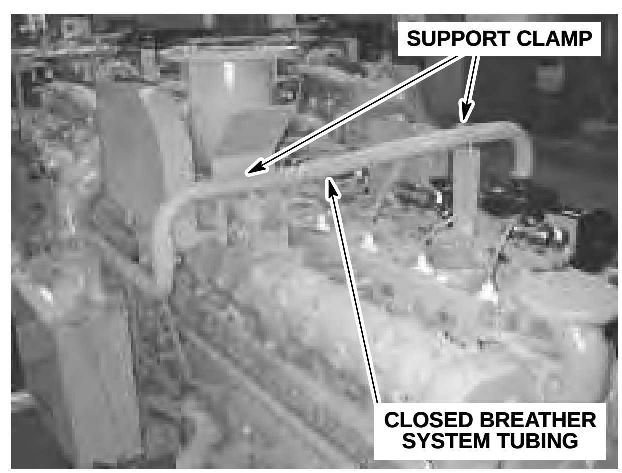


Figure 5.35-17. Wastegate Actuator Vent Tube

8. Install turbocharger heat shield onto exhaust manifold and exhaust outlet (see Figure 5.35-18).

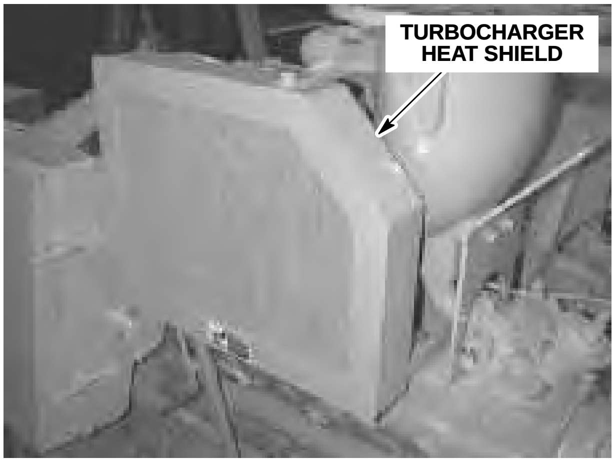


Figure 5.35-18. Heat Shield

9. Install inside heat shield and secure wastegate sensing tube with support clips (see Figure 5.35-19 and Figure 5.35-20).

Figure 5.35-19. CSA Coil Heat Shield

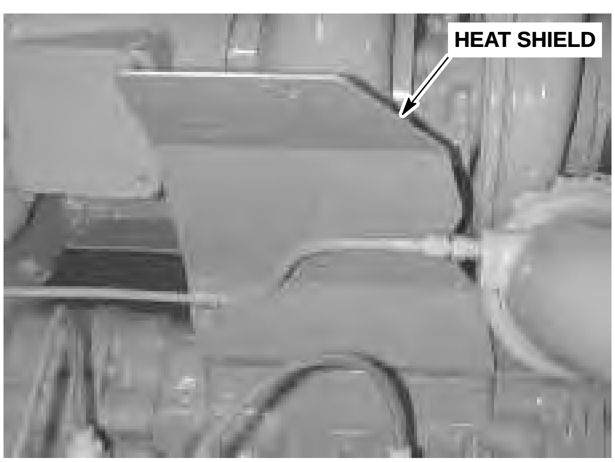


Figure 5.35-20. Standard Heat Shield

10. **CSA Coil Heat Shield—**Secure heat shield to exhaust elbow with 3/8 in. - 16 x 4 in. long capscrew, flat and lock washers and spacer (see Figure 5.35-21).

Figure 5.35-21. CSA Coil Heat Shields

WASTEGATE

WASTEGATE REMOVAL

NOTE: *The turbocharger and exhaust outlet do not have to be removed before removing the wastegate.*

1. Remove wastegate sensing tube between actuator and turbocharger discharge elbow (see Figure 5.35-22).

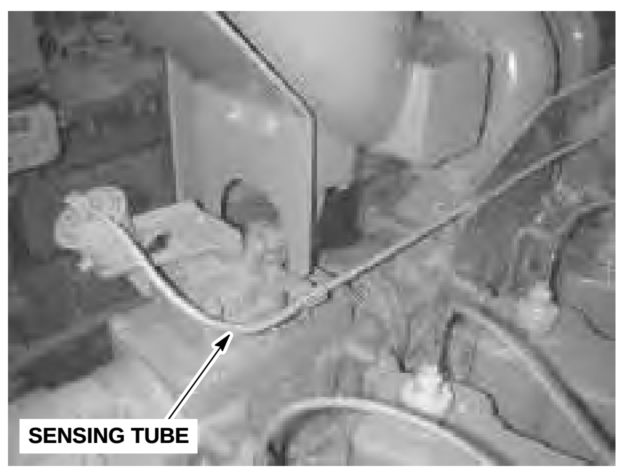


Figure 5.35-22. Wastegate Sensing Tube

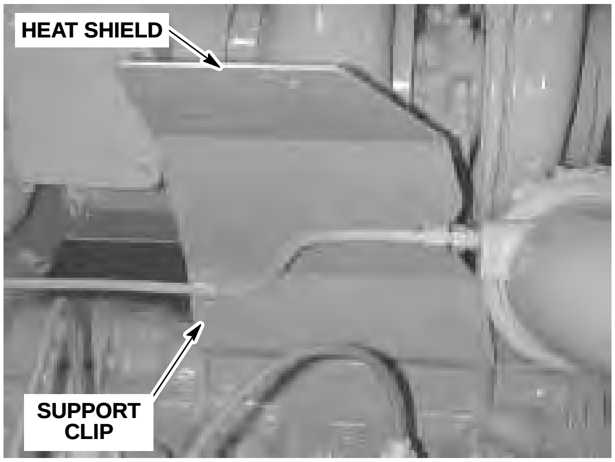


Figure 5.35-23. Wastegate Sensing Tube

2. **GLD and GSID—**Remove vent tube that runs from actuator body to air cleaner (see Figure 5.35-24).

Figure 5.35-24. Wastegate Actuator Vent Tube

3. Remove exhaust bypass tube from wastegate and exhaust outlet (see Figure 5.35-25).

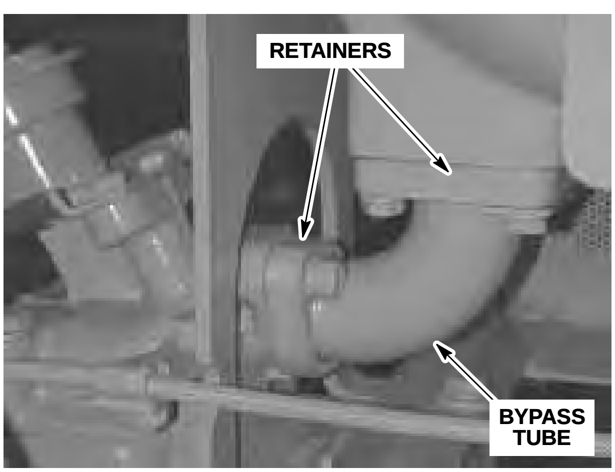


Figure 5.35-25. Wastegate Bypass Tube

4. Remove M10 hex head screws that secure wastegate to mounting plate (see Figure 5.35-26).

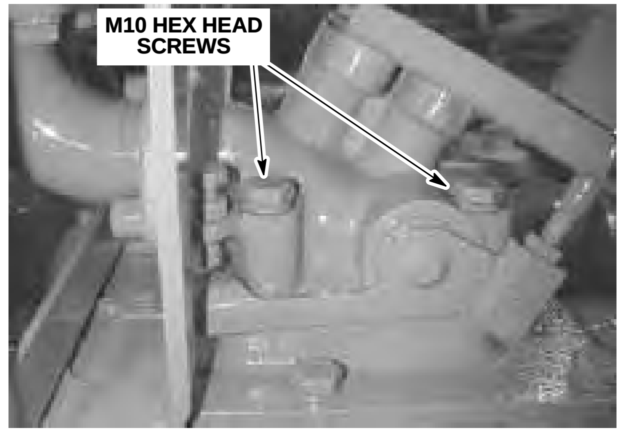


Figure 5.35-26. Wastegate

5. Clean gasket surface of wastegate mounting plate.

WASTEGATE INSTALLATION

1. Install wastegate mounting plate onto exhaust manifold (see Figure 5.35-33). Secure with M10 hex head screws. Apply anti-seize and tighten to 46 ft-lb (62 N·m).

2. Install wastegate and gasket on mounting plate (see Figure 5.35-33). Secure with M10 x 50 mm hex head screws. Make sure support clip is installed under right front hex head screw (see Figure 5.35-28). Apply anti-seize and tighten hex head screws to 32 ft-lb (43 N·m).

3. Install the exhaust bypass tube between the wastegate and exhaust outlet (see Figure 5.35-27 and Figure 5.35-28).

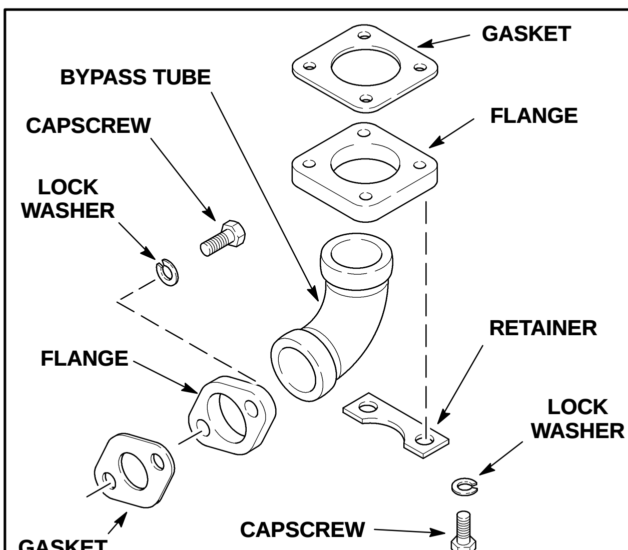


Figure 5.35-27. Wastegate Bypass Tube

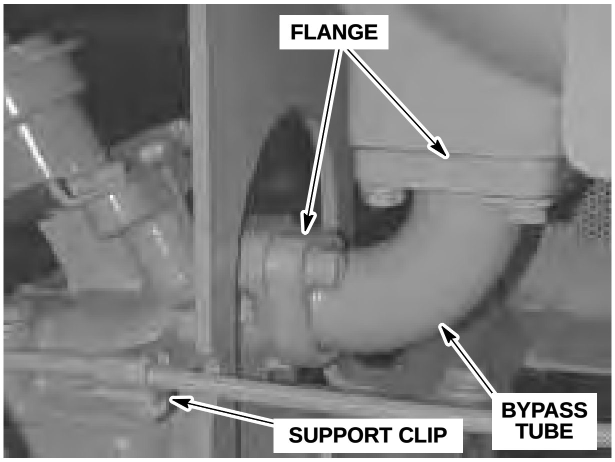


Figure 5.35-28. Wastegate Bypass Tube

4. Install wastegate sensing tube between actuator and turbocharger discharge elbow (see Figure 5.35-29 and Figure 5.35-30). Secure wastegate sensing tube to heat shield and wastegate (if applicable) with support clips.

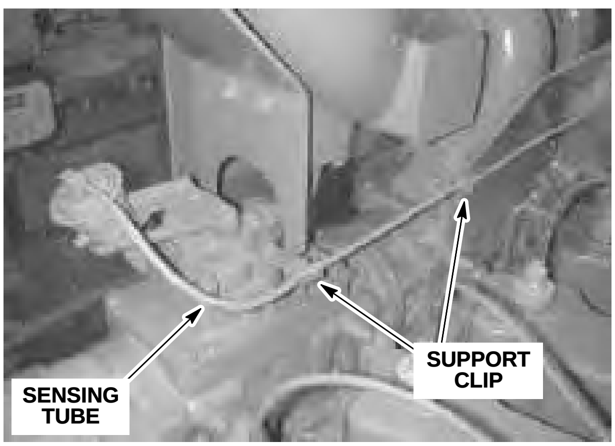


Figure 5.35-29. Wastegate Sensing Tube

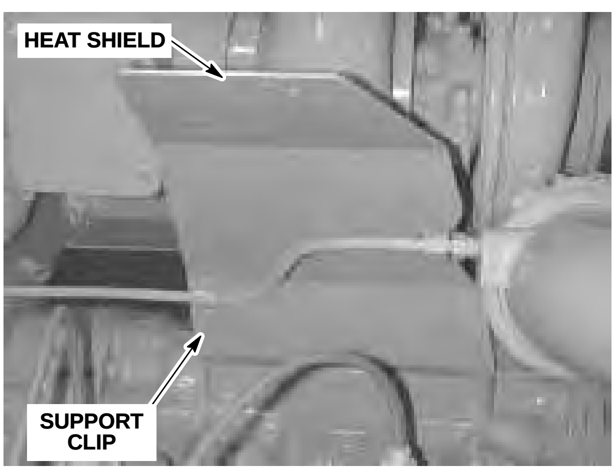


Figure 5.35-30. Heat Shield Attachment

⚠ CAUTION **The GLD and GSID engines must not be operated without the actuator vent tube in place. If the actuator diaphragm ruptures, air/gas mixture from the intake system will be vented to atmosphere without the tube. Disregarding this information could result in product damage and/or personal injury.**

5. Install vent tube onto actuator body. Route vent tube from actuator to air cleaner intake (GLD and GSID models only) (see Figure 5.35-31 and Figure 5.35-32). Make sure vent tube is properly supported with clips secured to exhaust manifold and air cleaner.

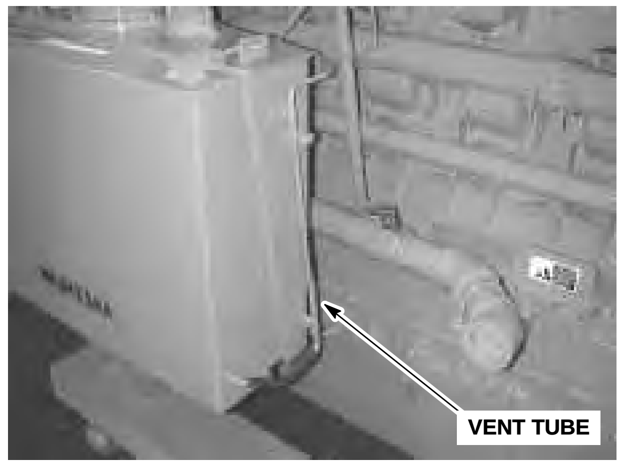


Figure 5.35-31. GSID/GLD Air Cleaner

Figure 5.35-32. Deltec GLD Vent Tube Installation

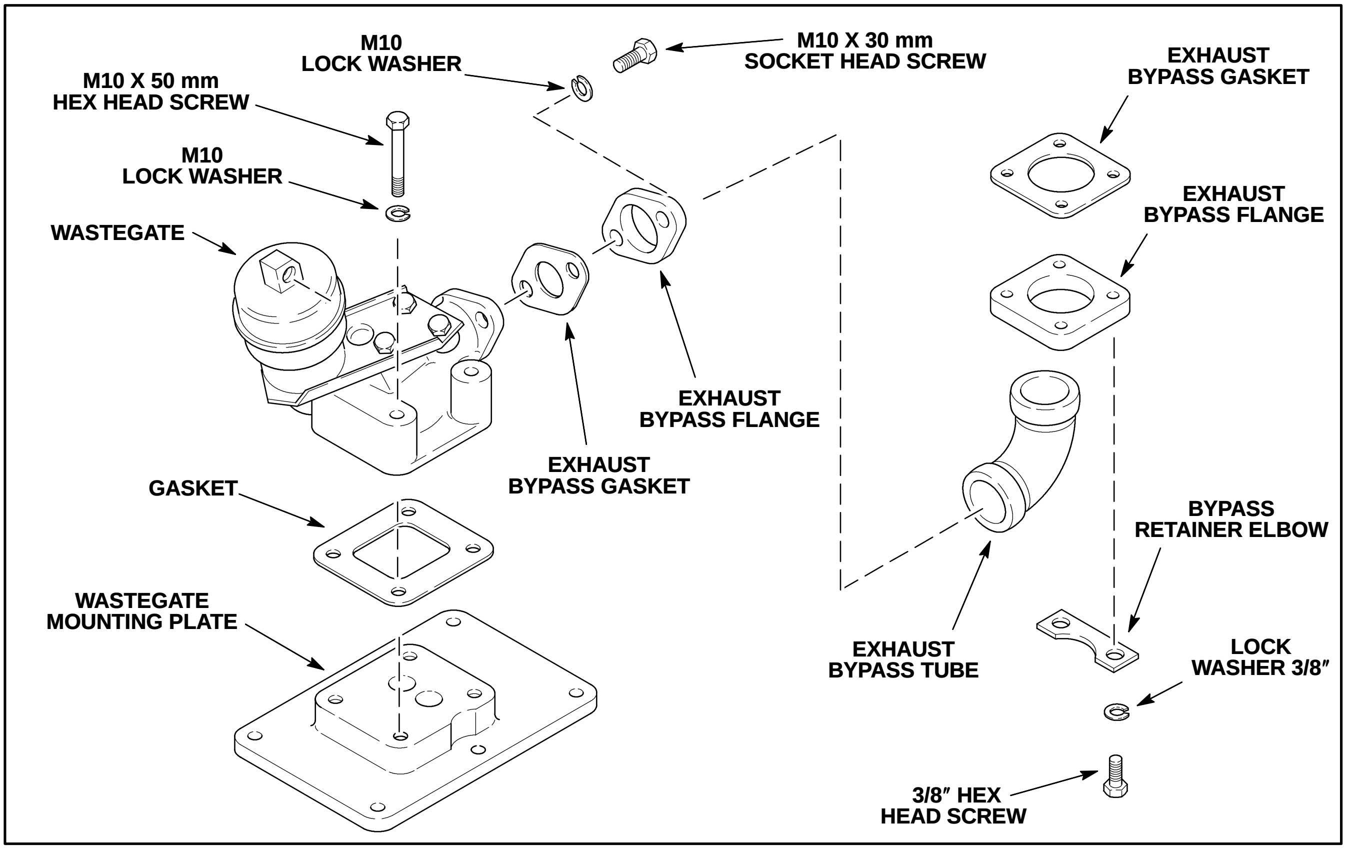


Figure 5.35-33. Wastegate Assembly

ENGINE ELEVATION ADJUSTMENTS

⚠ CAUTION Engines must be derated for altitude. Adjusting wastegates to obtain rated load at high altitudes can result in turbocharger overspeed and failure. Disregarding this information could result in product damage and/or personal injury.

Wastegates on VGF GL engines are set to produce rated load at sea level up to 1500 ft. (457 m). Apply the standard derate to all intermittent and continuous duty engines: deduct 2% for each 1000 ft. (305 m) above 1500 ft. (457 m).

WASTEGATE ADJUSTMENT—F18GL AND H24GL (LCR ONLY)

The F18GL (LCR) and H24GL (LCR) wastegates are factory set for operation from 4001 – 5000 ft. (1220 – 1542 m) in elevation. For more stable engine operation at or below 4000 ft. (1219 m), wastegate adjustment may be necessary.

Before attempting to adjust the wastegate, the engine must be in good operating condition and the ignition system properly timed with the fuel system adjusted according to Waukesha Engine's recommendations.

⚠ CAUTION Do not adjust the wastegate to compensate for engine wear, incorrect timing or fuel system adjustment. Disregarding this information could result in product damage.

⚠ CAUTION Verify that all cylinders are firing before adjusting the wastegate. Disregarding this information could result in product damage.

WASTEGATE REMOVAL

1. Loosen tube fitting to remove wastegate sensing tube from top of actuator housing (see Figure 5.35-34).

2. Remove three hex head screws from actuator bracket (see Figure 5.35-34).

3. Slide entire actuator assembly (actuator bracket, actuator housing, actuator linkage rod and actuator block) off of wastegate linkage rod (see Figure 5.35-34).

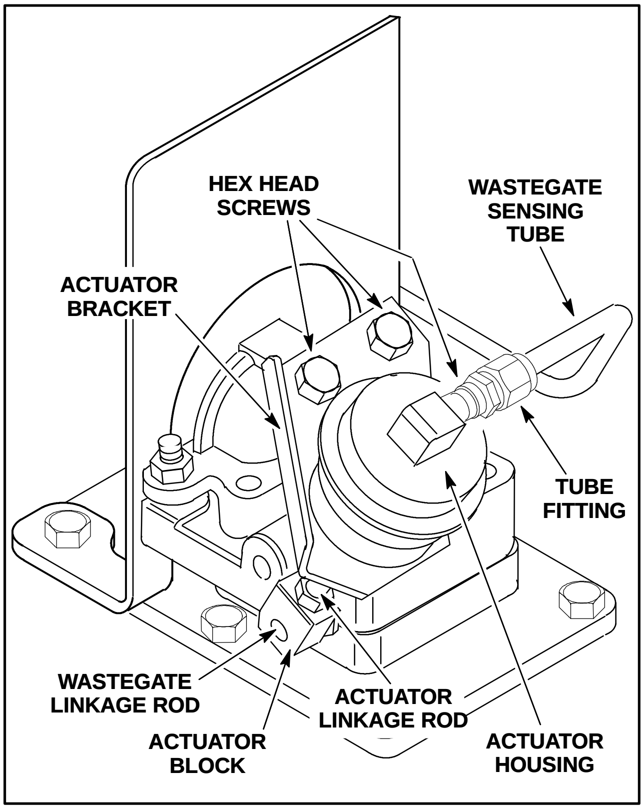


Figure 5.35-34. Wastegate Actuator

WASTEGATE ADJUSTMENTS

Wastegate Actuator Preliminary Settings

1. Determine engine "A" dimension from Table 5.35-1. Proceed to step 2.

Table 5.35-1. Preliminary Wastegate Adjustments

ENGINE	TURBO P/N	RPM	"A" DIMENSION
H24GL/GLD	305865	1400 – 1800	30 mm
F18GL/GLD	305864	1400 – 1800	30 mm
F18/H24GSID	305864B	1350 – 1800	21 mm
F18GL	305865	1400 – 1800	22 mm
F18/H24GL-LCR	305864	1400 – 1800	30 mm

Wastegate Actuator Settings For Elevation

1. **F18 and H24 GL LCR Only—**Determine the engine location's elevation. Enter Table 5.35-2 with the engine location's elevation and determine the corresponding "A" dimension. Proceed to Step 2.

Table 5.35-2. F18GL And H24GL LCR Wastegate "A" Dimensions

ELEVATION	"A" DIMENSION
0 – 1000 ft (304 m)	1.18 in. (30 mm)
1001 – 2000 ft (305 – 609 m)	1.14 in. (29 mm)
2001 – 3000 ft (610 – 914 m)	1.10 in. (28 mm)
3001 – 4000 ft (915 – 1219 m)	1.06 in. (27 mm)
4001 – 8000 ft (1220 – 2438 m)	1.02 in. (26 mm)

2. Measure "A" dimension length (distance from bottom of actuator bracket to top of actuator block) (see Figure 5.35-35).

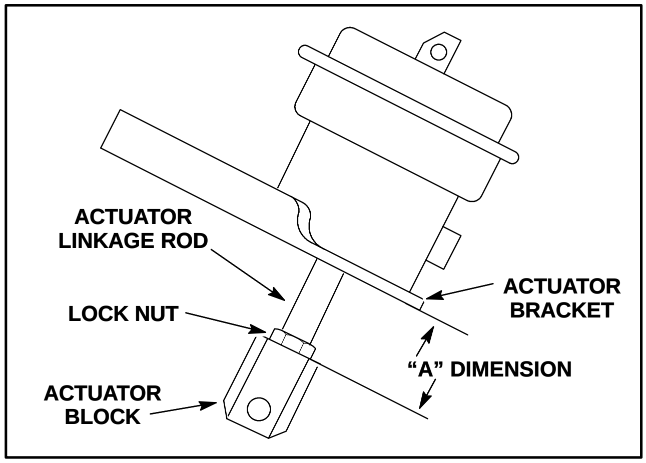


Figure 5.35-35. Actuator Adjustment

CAUTION **DO NOT turn the actuator linkage rod when attempting to adjust the "A" dimension length. The "A" dimension length must be adjusted by turning the actuator block. Turning the actuator linkage rod will result in damage to the wastegate diaphragm.**

NOTE: *To adjust "A" dimension, loosen lock nut and turn* ***actuator block*** *either clockwise or counterclockwise depending on length required (see Figure 5.35-35).*

3. Adjust "A" dimension to required length based on elevation (see Table 5.35-2).

4. Tighten actuator lock nut after adjustment is complete.

5. Install actuator assembly and secure with three hex head screws.

6. Install wastegate sensing tube into fitting on top of actuator housing.

7. To verify the correct “A” dimension length, install a Δ P pressure gauge between the compressor discharge and intake manifold (see Figure 5.35-36). The pressure gauge scale must read from 0 – 30 in. Hg (0 – 76 cm Hg) or 0 – 15 in. psi (0 – 103 kPa).

NOTE: *If a control panel manifold pressure gauge is installed, use the intake manifold fitting on the opposite end of the manifold to install the Δ P gauge. An alternative method would be to read the compressor discharge pressure using a standard pressure gauge then subtract the reading from the control panel manifold pressure gauge reading to obtain reserve pressure.*

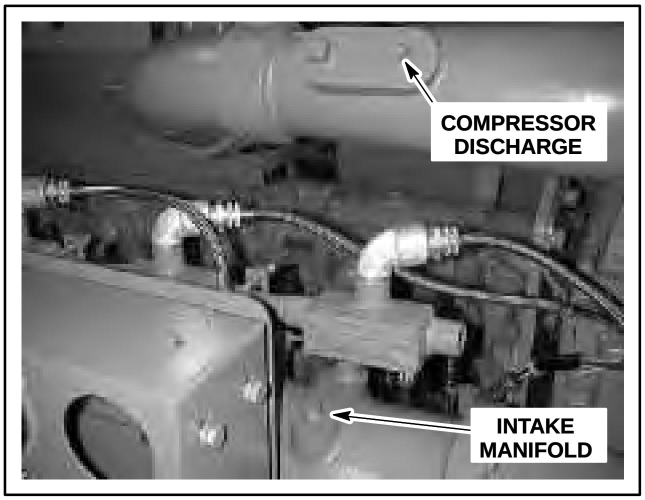


Figure 5.35-36. Compressor Discharge And Intake Manifold

8. Start engine and maintain 1800 rpm at 160 psi BMEP (1103 kPa BMEP). These settings approximate a F18GL @ 400 BHP or H24 GL @ 530 BHP. Reserve pressure (compressor discharge pressure minus intake manifold pressure) should be between 8 and 10 in. Hg (20.3 – 25.4 cm Hg). Refer to Service Bulletin 14–2749D or latest revision for BHP estimation.

NOTE: *During periods of high temperature (> 100 °F or 37.7 °C) and high humidity (> 50% relative humidity) the reserve pressure will be reduced. During these high temperature and humidity periods avoid resetting the wastegate or set to 1 – 6 in. Hg (2.5 – 15.2 cm Hg) reserve.*

9. If reserve pressure is incorrect, remove actuator assembly and readjust dimension “A” length (See “Wastegate Removal” and “Wastegate Adjustments”).

NOTE: *The relationship between reserve pressure and dimension “A” length is as follows: 0.04 in. (1 mm) change in dimension “A” length is equal to approximately 1 in. (25.4 mm) Hg change in reserve pressure.*

a. If the reserve pressure is too high increase the “A” dimension.

b. If the reserve pressure is too low decrease the “A” dimension.

EXHAUST MANIFOLD

EXHAUST MANIFOLD REMOVAL

1. Remove turbocharger and outlet from exhaust manifold (see Figure 5.35-37). See Section 5.20 *Turbocharger* for turbocharger removal and installation.

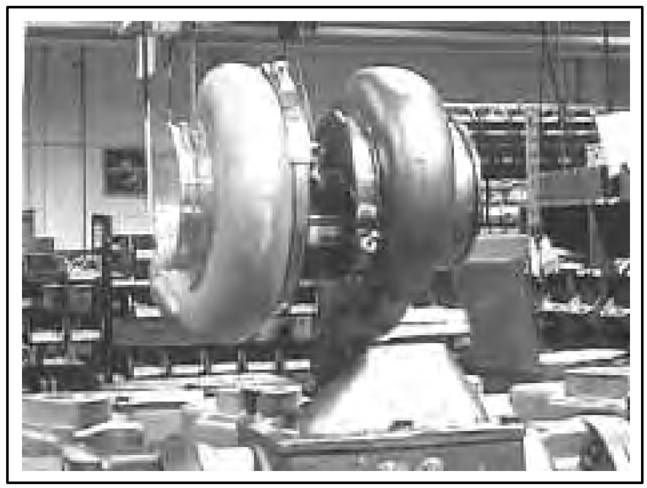


Figure 5.35-37. F18/H24 Turbocharger

1. Drain jacket water system.

2. Disconnect site cooling piping from jacket water inlet. Remove water tube and outlet piping from thermostat housing (see Figure 5.35-38).

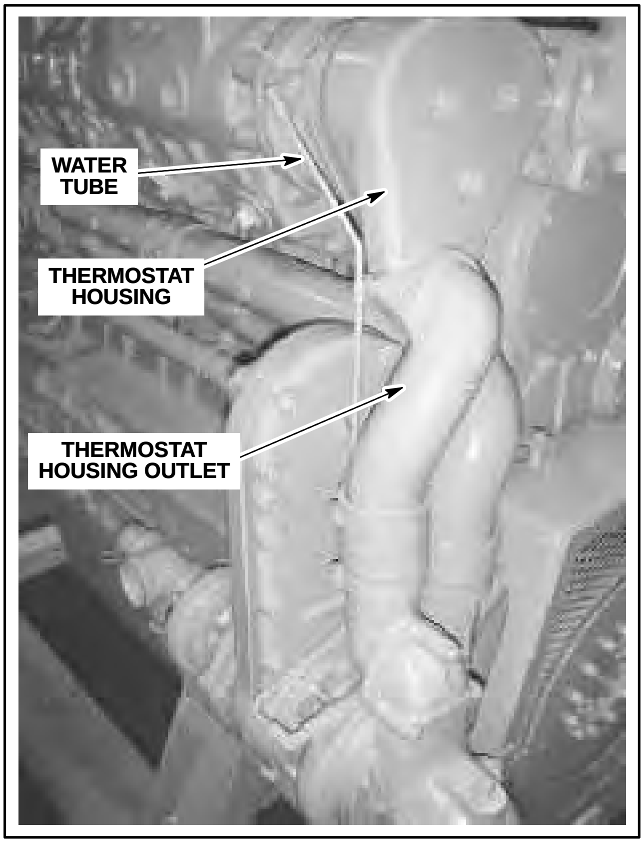


Figure 5.35-38. Jacket Water Connections

3. Remove thermocouples (if equipped) and thermocouple conduit from exhaust manifold and exhaust outlet (see Figure 5.35-39). See Section 6.05 *Engine Protection Systems* for information on removing exhaust outlet, heat shields and turbocharger.

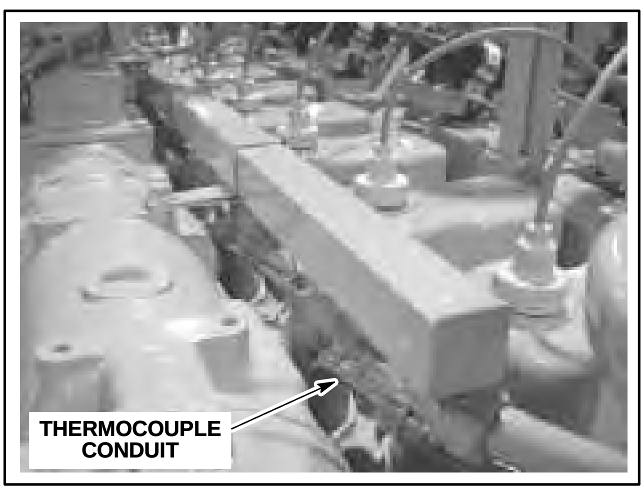


Figure 5.35-39. Thermocouple Conduit

4. Remove water elbows between exhaust manifold and cylinder heads (see Figure 5.35-40).

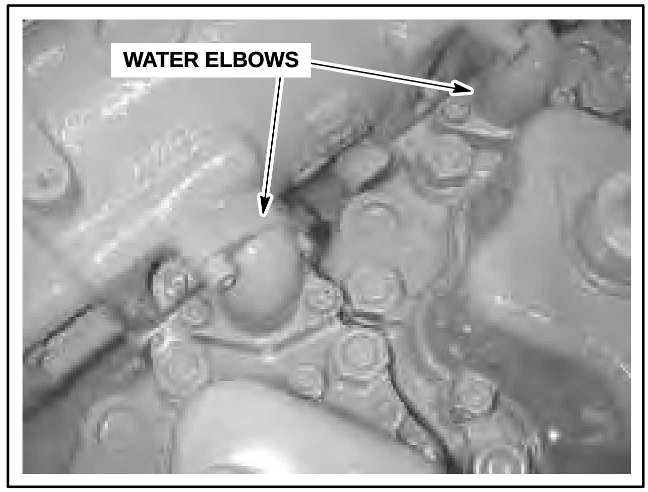


Figure 5.35-40. Cylinder Head Water Elbow

NOTE: *F18/H24G engines have an auxiliary water pipe running from the oil cooler to the exhaust manifold (see Figure 5.35-41).*

5. **F18/H24G—**remove water piping from exhaust manifold. See Section 5.25 *Cooling System* for complete information.

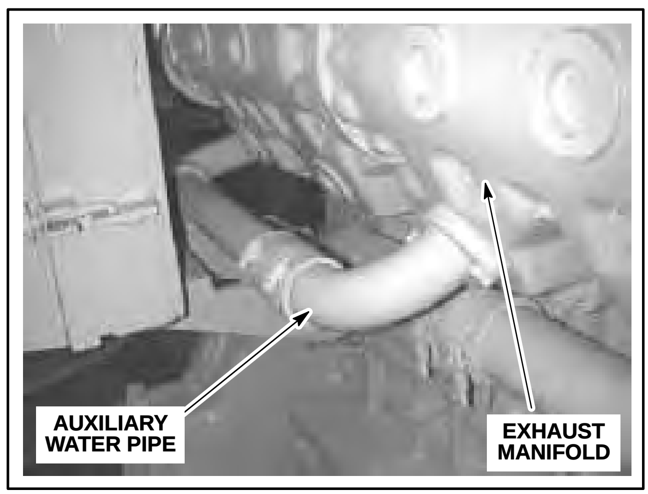


Figure 5.35-41. F18/H24G Auxiliary Water Pipe

⚠ WARNING

The six cylinder exhaust manifold weighs 270 lb. (122 kg). The eight cylinder exhaust manifold weighs 345 lb. (156 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

6. Attach suitable lifting device to exhaust manifold. Remove two upper M12 x 140 mm hex head screws and two lower M10 x 40 mm hex head screws from each manifold section (see Figure 5.35-42).

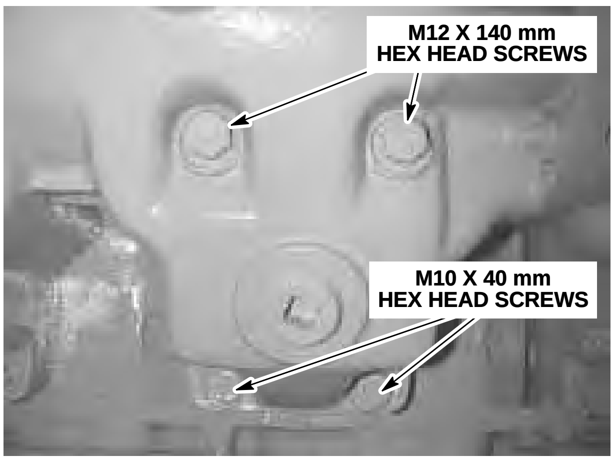


Figure 5.35-42. Exhaust Manifold

7. Using a suitable lifting device remove exhaust manifold assembly from engine.

8. Remove and discard exhaust manifold gaskets from cylinder heads or exhaust manifold sections (see Figure 5.35-43).

Figure 5.35-43. Cylinder Head Exhaust Ports

9. Cover exhaust outlet port and water outlet elbow flange on each cylinder head with masking tape to protect against dirt.

EXHAUST MANIFOLD DISASSEMBLY

NOTE: *Mark each manifold section with the cylinder number for later reference prior to separating the exhaust manifold into sections.*

1. If required, remove pipe plugs and cup plugs from exhaust manifold sections.

2. Verify small coolant drain hole below exhaust manifold port is open (see Figure 5.35-44).

Figure 5.35-44. Exhaust Manifold Drain Hole

3. Install cup plugs in manifold segments with Permatex® item No. 3D sealant or equivalent.

4. Align gasket hole pattern with pattern in manifold segments (matching large square holes in gasket and manifold). Manifold segments are held together with M12 x 35 mm ferry head screws. Install screws and check alignment of manifold ports with a straight edge.

EXHAUST MANIFOLD ASSEMBLY

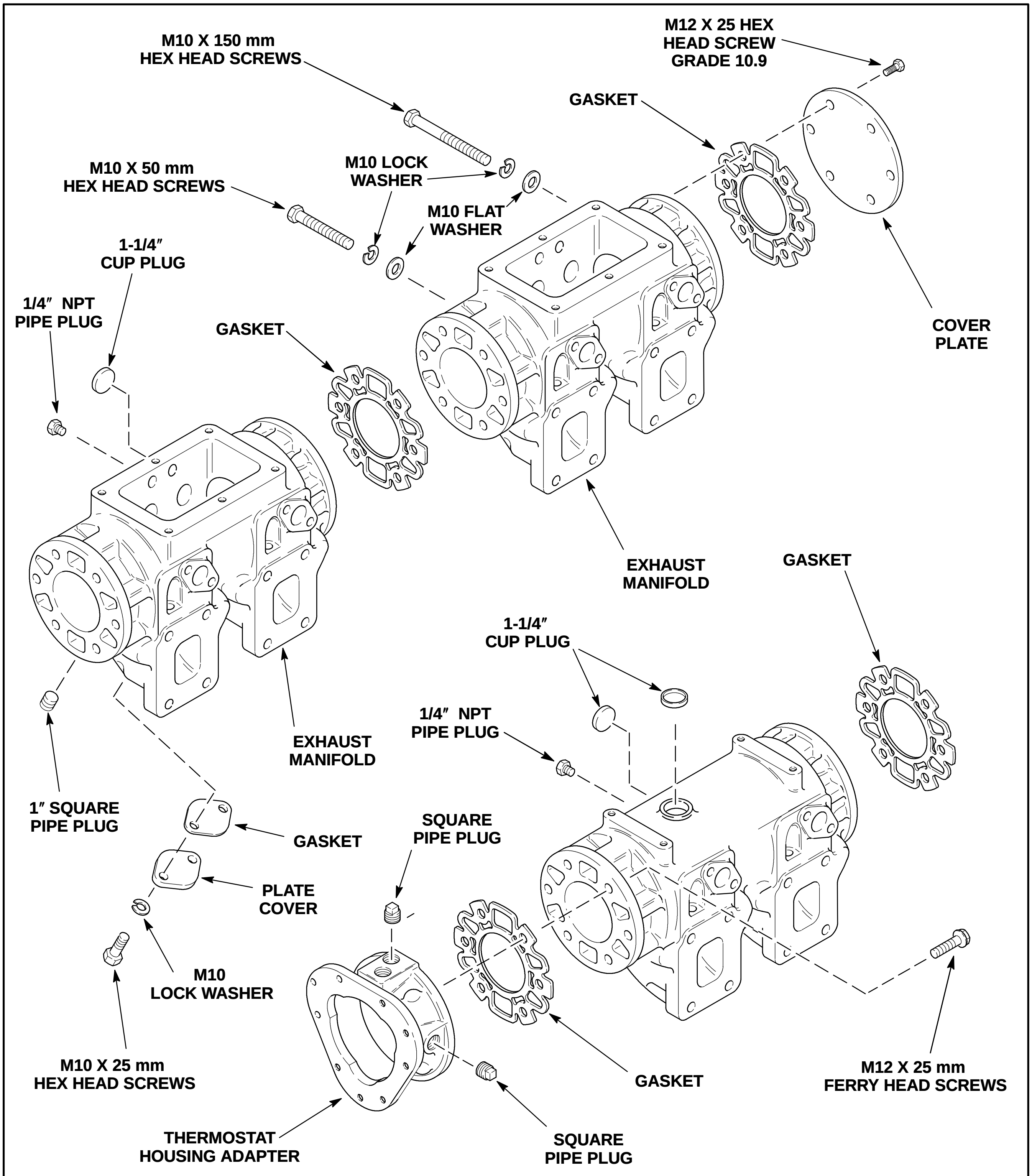


Figure 5.35-45. Exhaust Manifold

5. Tighten exhaust manifold segment M12 x 35 mm ferry head screws using pattern shown in Figure 5.35-46. Tighten ferry head screws to 37 ft-lb (50 N·m).

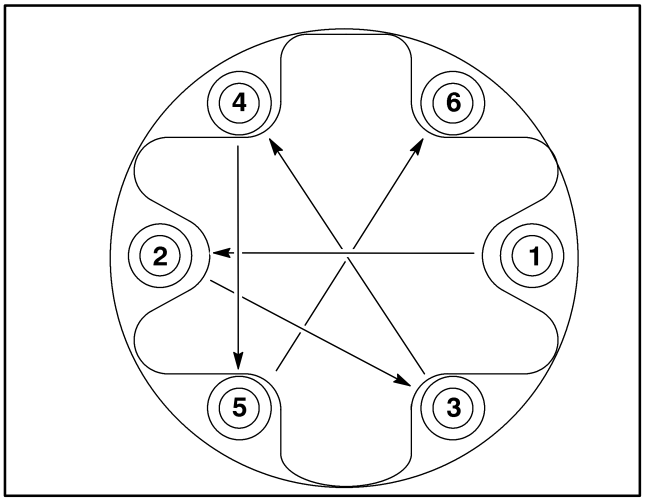


Figure 5.35-46. Exhaust Manifold Torque Sequence

NOTE: *The exhaust manifold end cover plate must be installed with the recessed hole in the top position (see Figure 5.35-47). This recess provides clearance for the intercooler mounting bracket bolt (GSID, GL and GLD engines).*

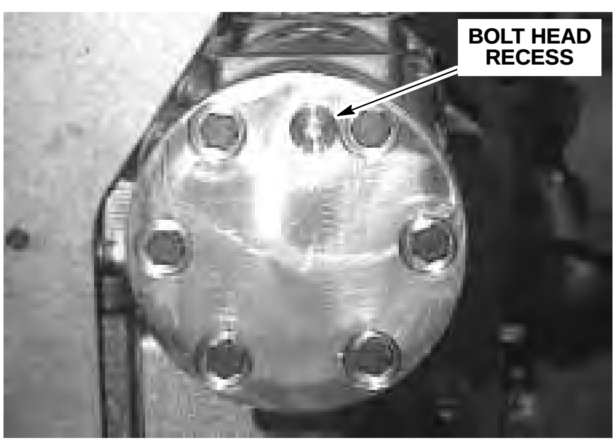


Figure 5.35-47. Exhaust Manifold End Cover

6. **F18/H24G—**Install gasket, cover plate, spacer and heat shield. Secure with six M12 x 45 mm hex head screws and spacers (see Figure 5.35-48 and Figure 5.35-49). Tighten hex head screws to 37 ft-lb (50 N·m). Use same pattern as shown in Figure 5.35-46.

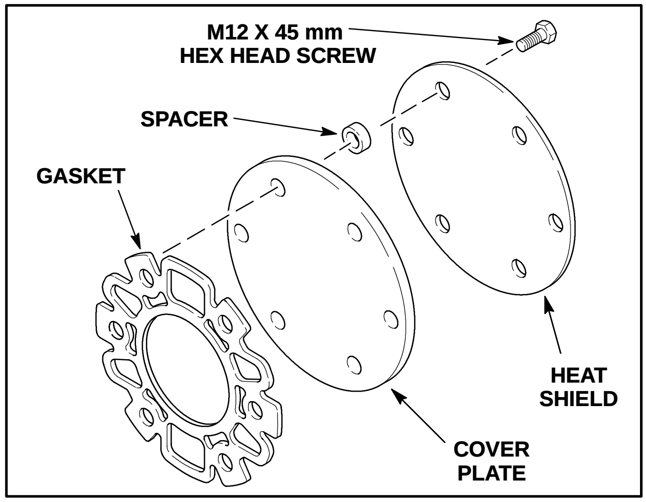


Figure 5.35-48. F18/H24G Manifold Heat Shield

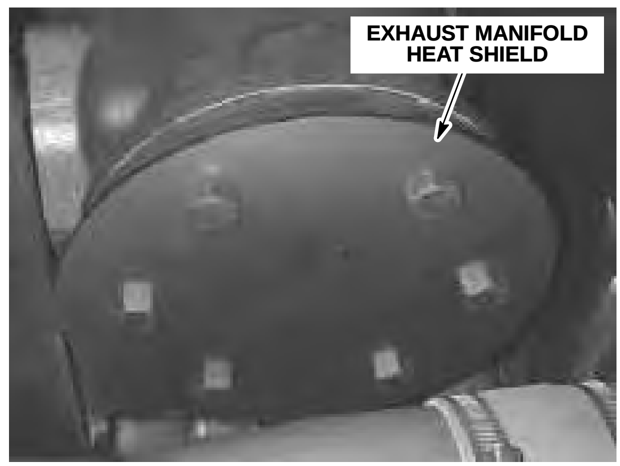


Figure 5.35-49. F18/H24G Manifold Heat Shield

7. Install thermostat housing adapter onto front of exhaust manifold assembly (see Figure 5.35-50). Secure with M12 x 35 mm ferry head screws. Apply Loctite® 242 and tighten to 65 ft-lb (88 N·m) using same pattern as shown in Figure 5.35-46.

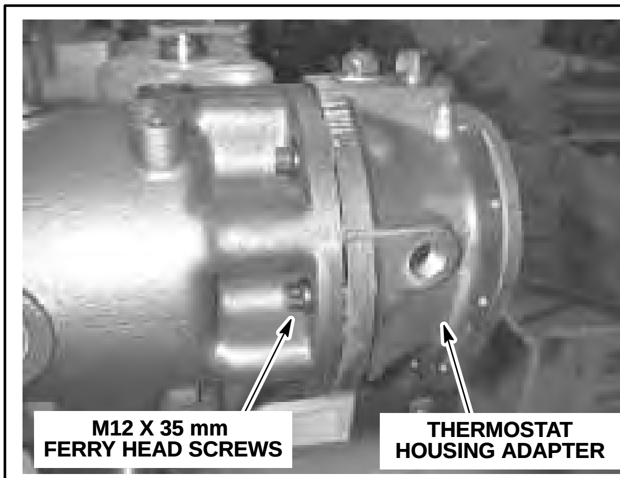


Figure 5.35-50. Thermostat Housing Adapter

8. Install wastegate mounting plate and gasket to manifold (see Figure 5.35-51). Secure with M10 hex head screws and lock washers. Apply Loctite® 242 to screw threads and tighten to 46 ft-lb (62 N·m).

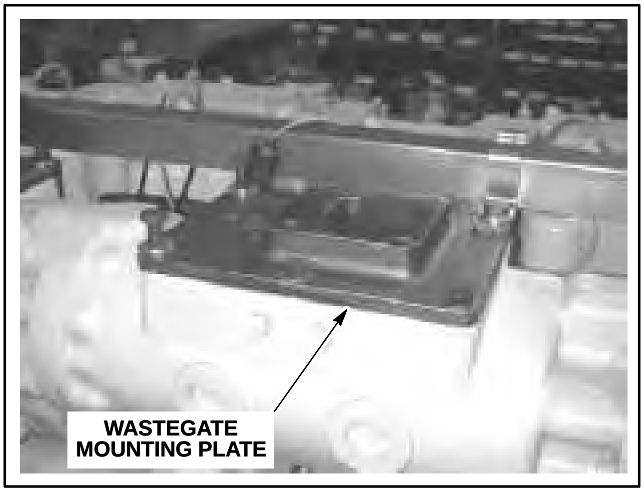


Figure 5.35-51. Wastegate Mounting Plate

EXHAUST MANIFOLD INSTALLATION

NOTE: *If applicable, remove protective tape from exhaust outlet port and water outlet elbow flange on each cylinder head.*

1. Install M10 guide studs in exhaust side of cylinder heads. Place exhaust manifold gaskets on guide studs (see Figure 5.35-52).

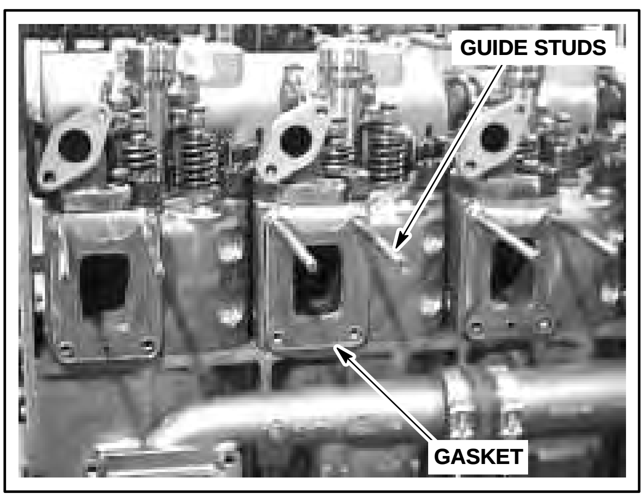


Figure 5.35-52. Cylinder Head Exhaust Port

NOTE: *The gasket must be installed with the coolant drain hole in the lower position (see Figure 5.35-53).*

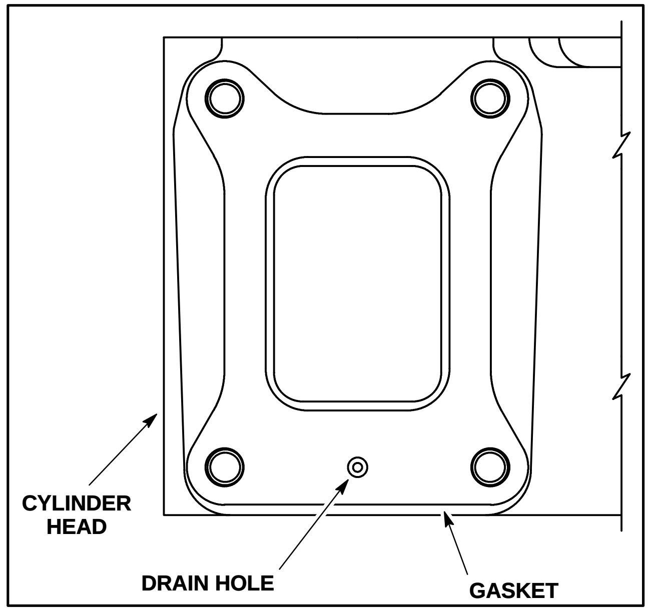


Figure 5.35-53. VGF Exhaust Manifold Drain Hole

⚠ WARNING

The six cylinder exhaust manifold weighs 270 lb. (122 kg). The eight cylinder exhaust manifold weighs 345 lb. (156 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

2. Use a suitable lifting device and lift exhaust manifold onto cylinder heads.

3. Secure with M10 x 150 mm and M10 x 50 mm hex head screws and washers. Tighten exhaust manifold hex head screws to 53 ft-lb (72 N·m) (see Figure 5.35-54).

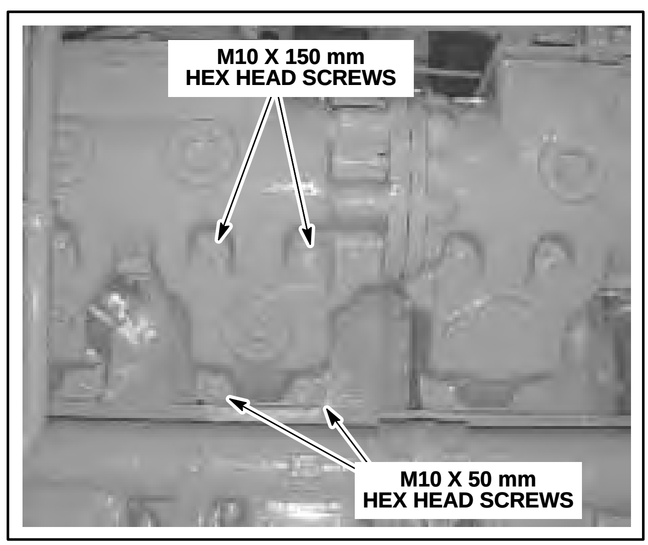


Figure 5.35-54. F18GL Bracket Location

NOTE: *Install the exhaust thermocouple fittings into the exhaust manifold before securing the manifold onto the engine.*

4. Apply anti-seize compound to exhaust thermocouple fittings (1/4 NPT pipe plug) before installation.

5. Insert thermocouples (if equipped) into male connector tube fittings in each section of exhaust manifold (see Figure 5.35-55).

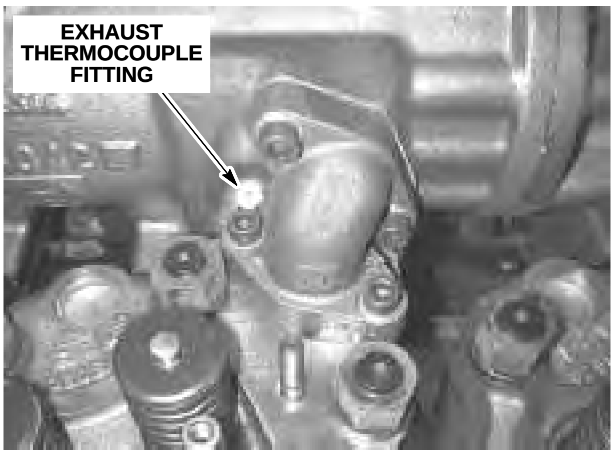


Figure 5.35-55. Thermocouple Installation

⚠ CAUTION The thermocouple must not make contact with the exhaust manifold casting or an inaccurate pyrometer reading will result. Disregarding this information could result in product damage and/or personal injury.

6. Center tip of stem in exhaust passage. Distance from exhaust manifold to tip of stem should be 2-7/8 in. (73 mm) (see Figure 5.35-56).

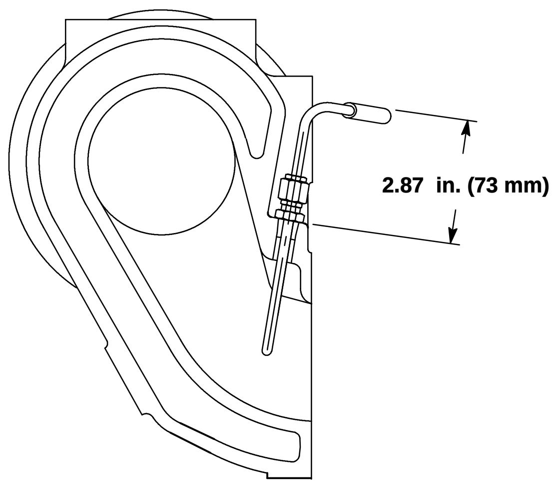


Figure 5.35-56. Inline Engine Exhaust Thermocouple Installation

7. See Section 6.05 *Engine Protection Systems* for complete thermocouple service information.

8. **Current Engines—**Install water elbow between cylinder head and exhaust manifold. Make sure gaskets are installed on both ends of water elbow. Secure with M10 x 35 mm socket head screws and tighten to 37 ft-lb (50 N·m).

NOTE: *Tighten socket head screws in an "X" pattern to prevent water leaks (see numbered pattern in Figure 5.35-57).*

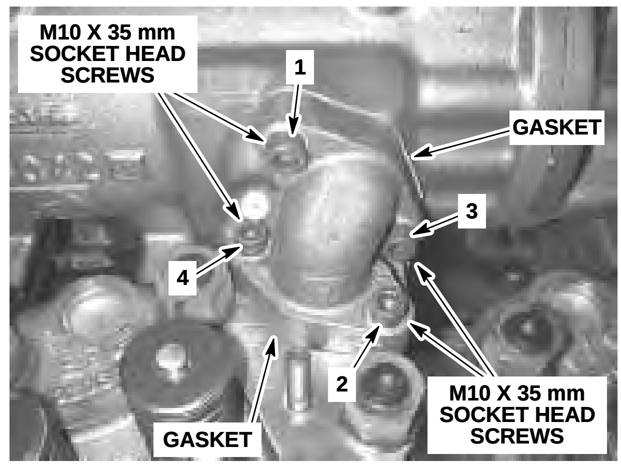


Figure 5.35-57. Water Elbow Assembly

9. **Previous Engines—**Install water elbow and secure with four M10 x 35 mm hex head screws and tighten to 37 ft-lb (50 N·m) (see Figure 5.35-58).

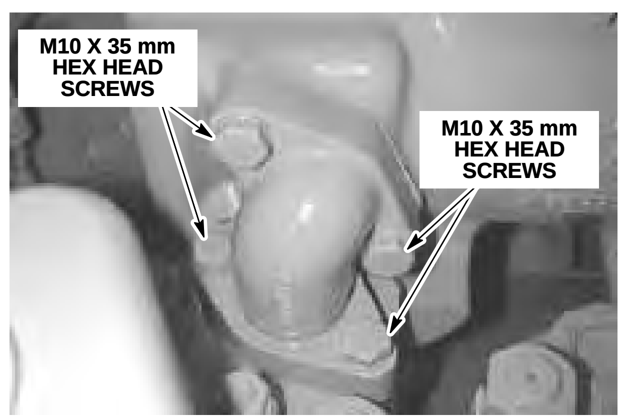


Figure 5.35-58. Previous—Water Elbow Assembly

⚠ WARNING

The thermostat housing with water inlet and outlet elbows weighs 50 lb. (30 kg). Lift only with properly rated lifting device and rigging to avoid serious personal injury or death.

10. Use a suitable lifting device and lift thermostat housing into position onto front exhaust manifold adapter (see Figure 5.35-59).

11. Secure with M8 hex nuts and tighten to 19 ft-lb (26 N·m) (see Figure 5.35-59).

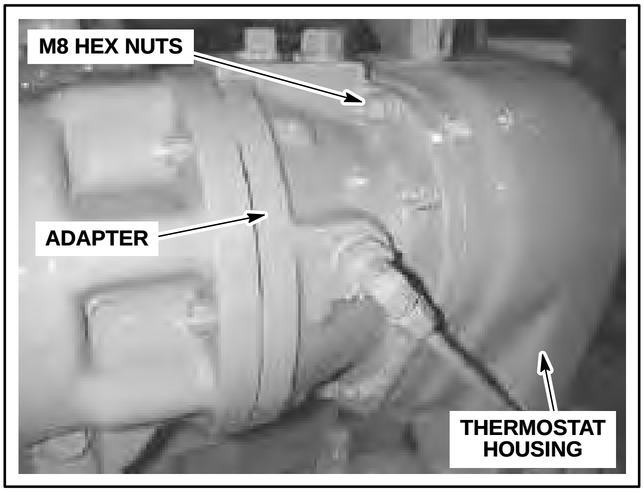


Figure 5.35-59. Jacket Water Thermostat Housing

NOTE: *F18/H24G series of engines have an auxiliary water pipe running from the oil cooler to the exhaust manifold (see Figure 5.35-60).*

12. **F18/H24G—**Install auxiliary water pipe onto exhaust manifold. See Section 5.25 *Cooling System* for complete information.

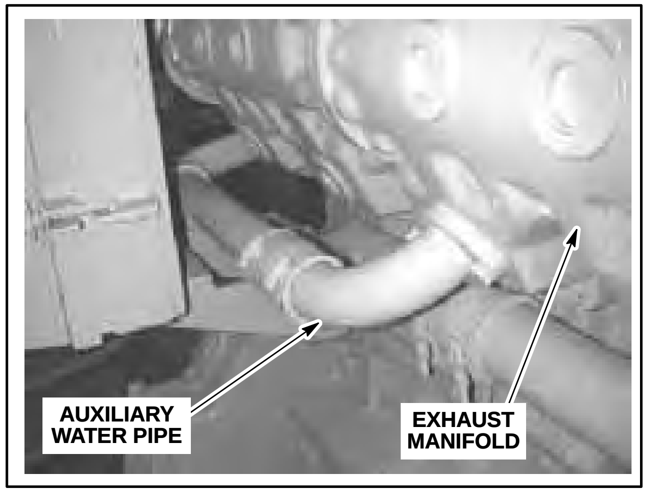


Figure 5.35-60. F18/H24G Auxiliary Water Pipe

SECTION 5.40

CRANKCASE BREATHER SYSTEM

CRANKCASE BREATHER SYSTEM

COMPONENTS

The purpose of the crankcase breather system is to remove crankcase oil vapors from the engine. There are three systems available, depending on engine model:

- Open
- Closed
- Closed ejector

The standard crankcase ventilation system is an open breather design. The crankcase vapors are vented to the atmosphere through an oil separator. A rain cap is used on top of the oil separator for the open systems (see Figure 5.40-1).

Figure 5.40-1. Open Breather

OIL SEPARATOR

As the crankcase vapors and oil mist pass through the oil separator, much of the oil adheres to the steel mesh element contained in the inlet side of the separator housing (see Figure 5.40-2). This surplus oil condenses and drops into the base of the separator. The condensed oil returns to the oil pan through a drain tube in the base of the separator housing and returns to the oil pan.

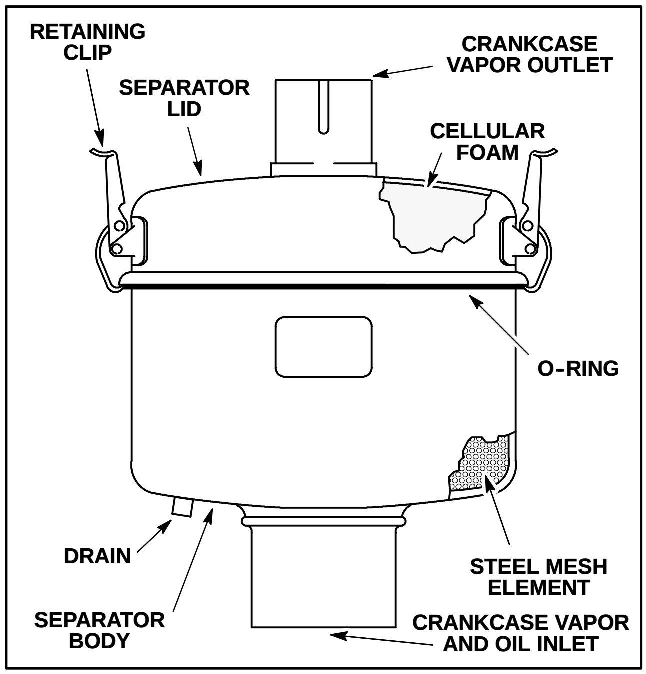


Figure 5.40-2. Oil Separator

The crankcase vapors are drawn through the cellular foam contained in the outlet side of the separator and pass through breather tubes either to the venturi extractor, the intake system or to the atmosphere depending on the system.

All current production breather systems have an oil drain from the oil separator to the oil pan.

The G and Impco carburetor GLD breather systems have a baffle box mounted on the right side of the engine next to the oil filters (see Figure 5.40-3).

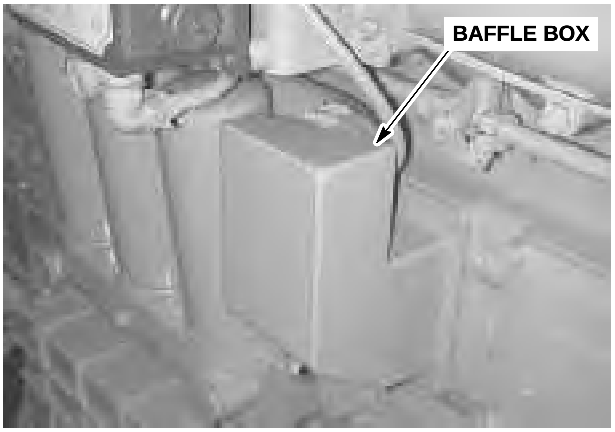


Figure 5.40-3. Ventilation System Baffle Box

The closed breather design allows a slight negative pressure to be maintained in the engine crankcase. The crankcase is vented to the air cleaner on GSID and GLD models (see Figure 5.40-4).

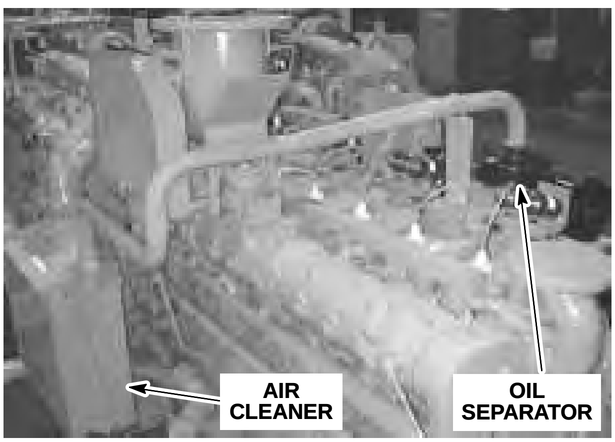


Figure 5.40-4. Closed Breather System

Figure 5.40-5. Closed Breather System

The GSID and GLD Deltec breather systems are similar in that the right side baffle box is not used. The breather system is connected to the left side of the gear housing (see Figure 5.40-5).

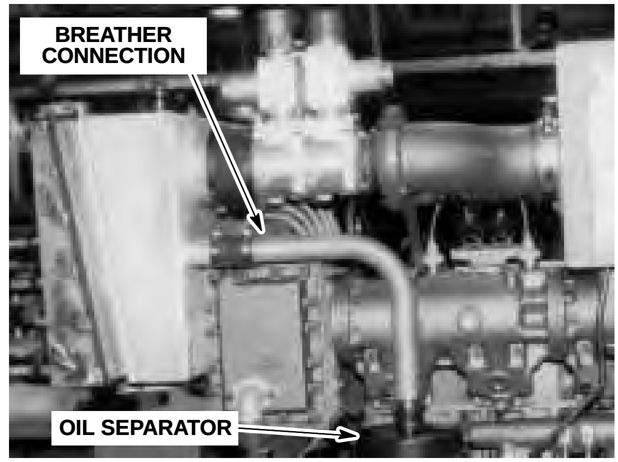


Figure 5.40-6. F18/H24 Deltec GLD Breather

VACUUM REGULATOR

The crankcase breather regulator assembly is connected to the ejector breather or venturi extractor through a tee and pipe nipple arrangement.

While the manual crankcase pressure adjustment procedures represent coarse adjustments to the breather system, the crankcase vacuum regulator automatically performs the fine adjustments that are necessary to compensate for variations in speed and load. Maintaining a negative crankcase pressure is recommended to prevent oil leaks and remove harmful vapors, but too much pressure pulls in dust and dirt.

With less load, less vacuum is required to remove crankcase vapors. When the turbocharger compressor discharge air is reduced, a floating disc or plate within the crankcase breather regulator assembly drops down to restrict the amount of outside air pulled into the system (see Figure 5.40-7).

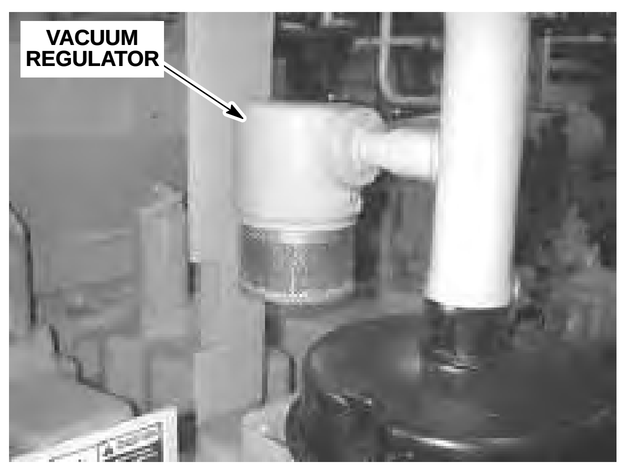


Figure 5.40-7. Vacuum Regulator

With an increase in load, the amount of compressor discharge air from the turbochargers increases and the plate within the regulator floats up. More outside air is drawn in as the plate rises, which allows the breather system to maintain a more constant crankcase vacuum.

The closed design for the GLD and GSID allows a slight negative pressure to be maintained in the engine crankcase. Due to the draw-thru carburetion, the crankcase is vented to the air cleaner.

BREATHER EJECTOR

The ejector breather system has a venturi that is used to create a vacuum in the separator, baffle box and connecting tube (see Figure 5.40-8). This draws the oil vapor from the crankcase. The venturi extractor is mounted in a horizontal position at the top of the oil separator on the front of the engine. A ball valve is used to adjust the vacuum flow through the ejector.

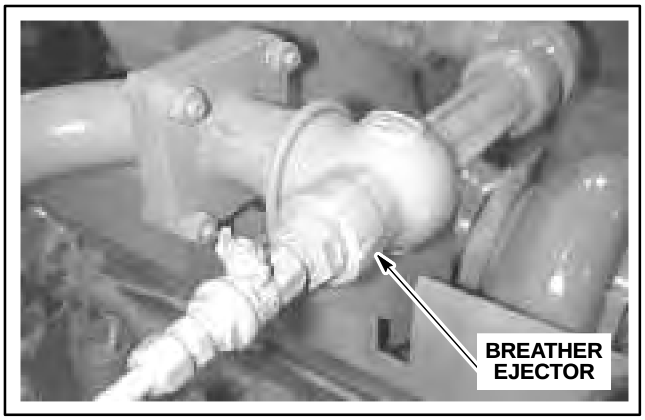


Figure 5.40-8. GL Breather Ejector

Closed Breather Systems

Different fuel systems and air ducts have different ways of connecting the closed breather system to the air duct.

GLD Deltec: Separator outlet tube is secured to the air cleaner duct with hose and clamps (see Figure 5.40-9).

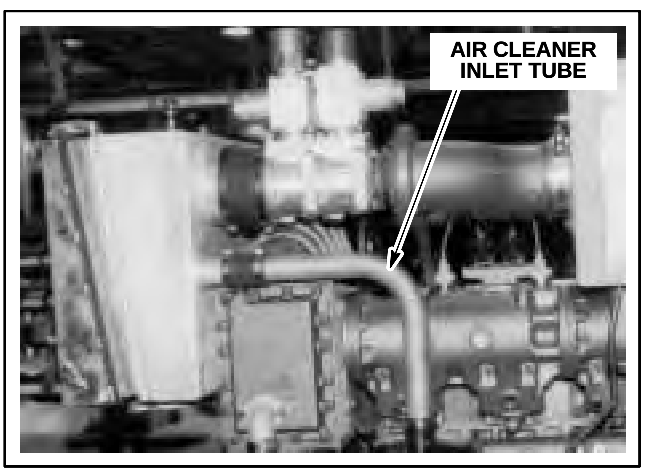


Figure 5.40-9. Deltec Closed Breather System

GSID: Flanged separator outlet tube is secured to air cleaner duct using hex nuts (see Figure 5.40-10).

Figure 5.40-10. GLD Closed Breather System

GL: Previous production engines had an adjusting valve in the closed breather system that regulates vacuum (see Figure 5.40-11 and Figure 5.40-12).

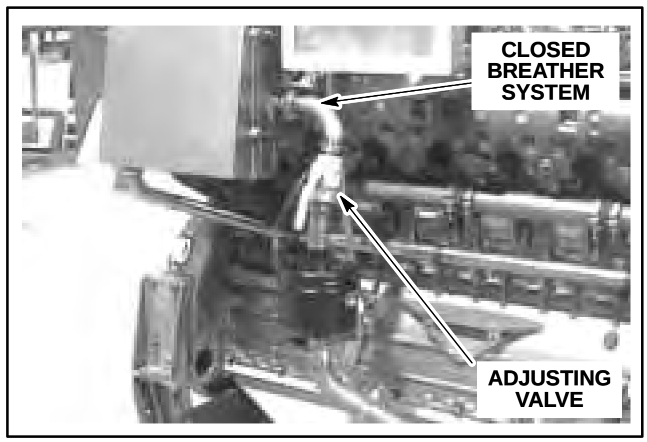


Figure 5.40-11. Previous Closed Breather System

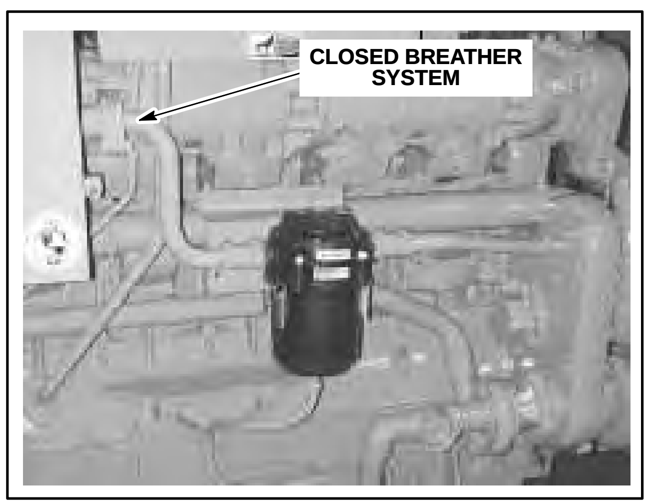


Figure 5.40-12. Current Closed Breather System

CRANKCASE PRESSURE MEASUREMENT

NOTE: *Measure the crankcase pressure at least once every 3 months (2160 hours).*

Table 5.40-1. Crankcase Pressure

Open System	zero to +3 in. (76 mm) (in. H_2O)
Closed System	-3 in. (76 mm) to zero (in. H_2O)

G, GL AND GLD IMPCO

NOTE: *Certain engines have a baffle box attached to the side of the crankcase that draws oil vapors into the oil separator. If the engine has a baffle box attach the manometer to the baffle box.*

1. Remove pipe plug (1/4 in. NPT) and install tube connector (see Figure 5.40-13, Figure 5.40-14 and Figure 5.40-15).

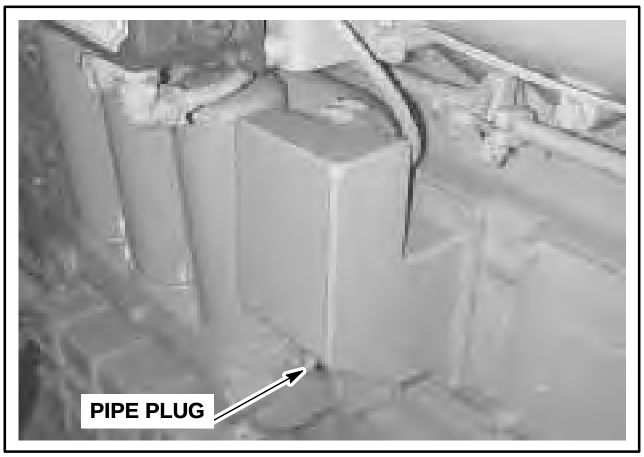


Figure 5.40-13. Ventilation System Baffle Box

NOTE: *If the engine has no baffle box, install the manometer onto the upper breather tube located on the rear of the front gear housing.*

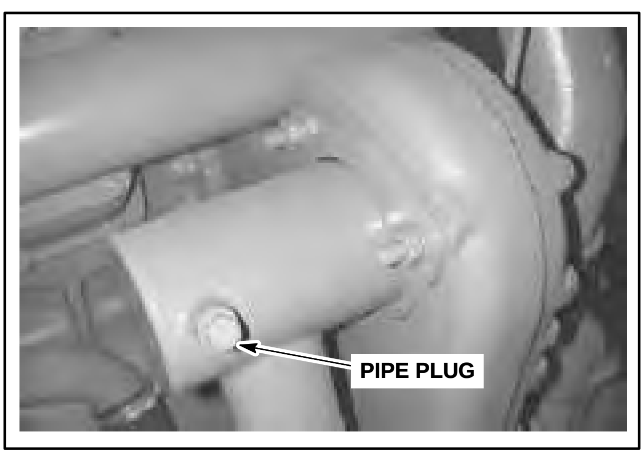


Figure 5.40-14. Previous Upper Oil Separator Inlet Tube

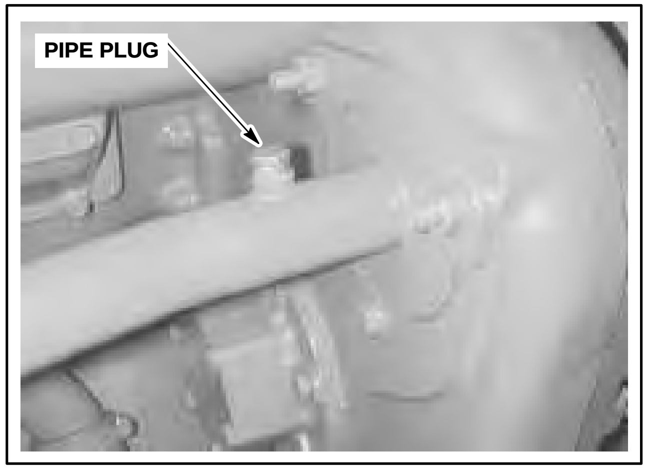


Figure 5.40-15. Current Upper Oil Separator Inlet Tube

2. Install one end of water manometer onto tube connector and vent opposite end to atmosphere. Manometer line must not protrude beyond inner surface of gauge support or an inaccurate reading may result.

NOTE: *Crankcase pressure can only be adjusted on engines that contain either a breather ejector or previous closed breather.*

3. Measure crankcase pressure and perform all pressure adjustments while engine is operating at rated speed and load (see “Crankcase Pressure Adjustment”).

4. Remove manometer line and tube connector. Install pipe plug.

BREATHER EJECTOR ADJUSTMENT

CRANKCASE PRESSURE ADJUSTMENT

GL engines have an optional breather ejector system with an adjusting valve.

The breather ejector assembly uses turbocharger compressor discharge pressure to create a vacuum that pulls the oil vapors out of the crankcase. These vapors are pulled through the oil separator and then discharged into the atmosphere through the exhaust stack.

The amount of air forced through the breather ejector controls the amount of vacuum drawn. The more air, the greater the vacuum. The greater the vacuum, the higher the negative pressure in the crankcase.

Crankcase pressure is manually adjusted by turning the ball valve on breather ejector engines or by adjusting the butterfly valve on closed breather engines.

NOTE: *Before starting a new or rebuilt engine, turn the adjusting valve 3/4 open. After starting the engine, install a water manometer. Adjust the valve to obtain either a positive or negative 1.5 in. (38 mm) H_2O vacuum (depending on breather system).*

1. Install a water manometer to measure crankcase pressure.

2. Run engine at rated speed and load.

3. Slowly open ball valve until recommended negative crankcase pressure is obtained (see Figure 5.40-16).

Figure 5.40-16. GL Breather Ejector

4. Remove engine load.

5. Measure crankcase pressure again. Readjust ball valve if crankcase pressure is not within specification.

6. Retest at rated speed and load. If crankcase pressure is within specification, remove handle to prevent inadvertently changing valve setting.

CLOSED BREATHER BUTTERFLY VALVE ADJUSTMENT (PREVIOUS)

1. Install a water manometer to measure crankcase pressure.

2. Run engine at rated speed and load.

NOTE: *A reading from –3 in. (76 mm) to zero H_2O is desirable at all speeds and loads.*

3. The lever of the shaft is inline with the valve. When the lever is inline with the tube, the valve is in the wide open position. When the lever is across the tube, the valve is in the full closed position (see Figure 5.40-17).

4. With the engine running under normal operating conditions, open the valve until the recommended negative crankcase pressure is obtained.

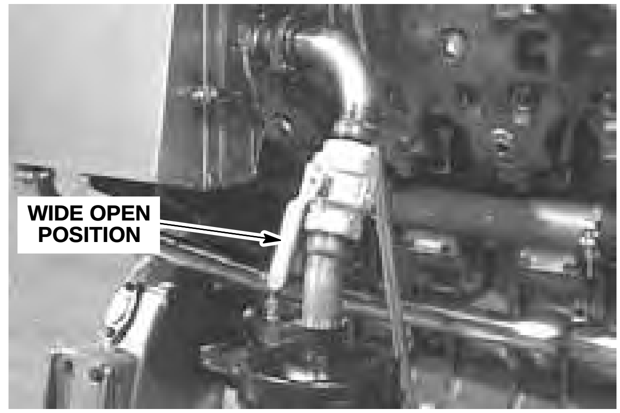


Figure 5.40-17. Previous F18/H24 Breather System Adjusting Valve

5. Remove engine load.

6. Measure crankcase pressure again. Readjust valve if crankcase pressure is not within specification.

7. Retest at rated speed and load.

OIL SEPARATOR CLEANING AND INSPECTION

Clean oil separator at each oil change.

1. Release two latches on separator and remove cover.

2. Lift screen out of cover and remove foam filter (see Figure 5.40-18).

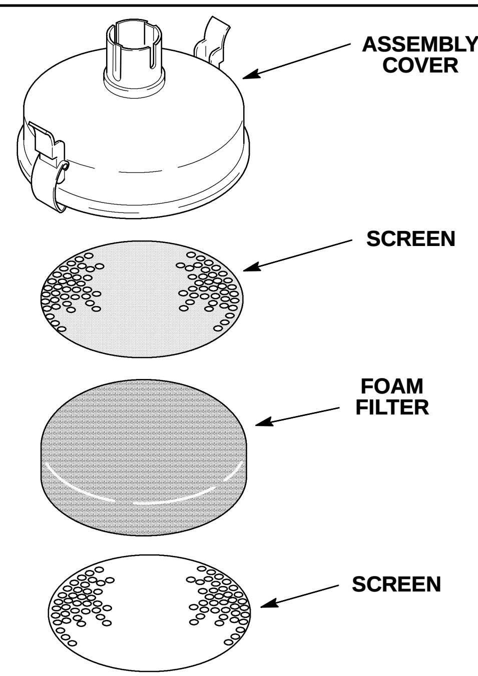


Figure 5.40-18. Oil Separator

3. Wash foam filter in a detergent solution and wring dry by hand.

4. Place foam into screen. Press screen and foam into cover.

5. Disconnect separator drain tube (if equipped).

6. Clean separator body with solvent (see Figure 5.40-19). Allow separator body to dry.

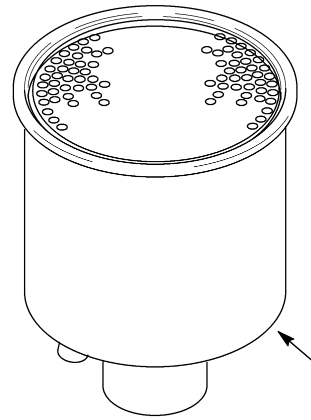


Figure 5.40-19. Separator Body

BREATHER REGULATOR DISASSEMBLY

NOTE: *On previous models, the valve hub is located in a different position. However, all procedures remain the same.*

1. Remove elastic stop lock nut (5/16 inch hex) from end of regulator rod (see Figure 5.40-20).

2. Slide screen off regulator rod (see Figure 5.40-20).

3. Remove O-ring from groove in regulator housing ID.

4. Slide valve plate off rod.

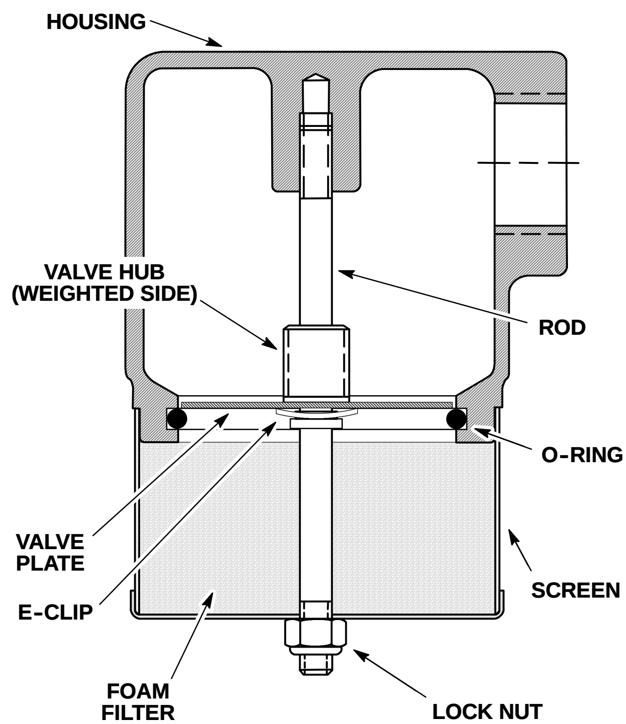


Figure 5.40-20. Current Breather Regulator Assembly

REGULATOR FOAM CLEANING AND INSPECTION

Clean the regulator foam at each oil change. Use the following procedure.

1. Wash foam in a detergent solution and wring dry by hand.

2. Place foam into screen (see Figure 5.40-21).

3. Press screen and foam into cover.

BREATHER REGULATOR ASSEMBLY

1. Apply Loctite® 242 to tapped hole inside regulator housing. Install threaded end of hub through hole in center of valve plate (see Figure 5.40-21).

2. Install E-clip in groove of hub with concave side facing valve plate. Verify that hub is tightly locked to plate.

3. If removed, apply Lithoplex® Grease No. 2 (Multipurpose Lithium Complex Formula Containing Molybdenum Disulfide) to coarsely threaded end of regulator rod.

4. Drive rod into regulator housing until it bottoms out in bore. Use a collet type stud driver for best results. If necessary, tap end of rod with a rubber mallet to center it in bore.

5. Lubricate regulator rod with a light oil. Apply a thin even film.

6. **Previous Production—**Slide on valve plate with threaded side of hub facing open end of rod.

7. **Current Production—**Slide on valve plate with threaded side of hub facing housing. Hub must not contact foam air cleaner.

NOTE: *Verify that the valve plate moves freely on the rod without cocking or sticking.*

8. Slide O-ring over rod and into groove in regulator housing ID.

9. Turn breather regulator right side up. Outer edge of valve plate should make complete contact with O-ring.

10. Slide foam air cleaner into screen (current production only).

11. Slide screen over rod until it seats against step machined into regulator housing OD.

12. Install elastic stop lock nut (5/16 inch hex) on end of rod. Replace lock nut after it is removed second time.

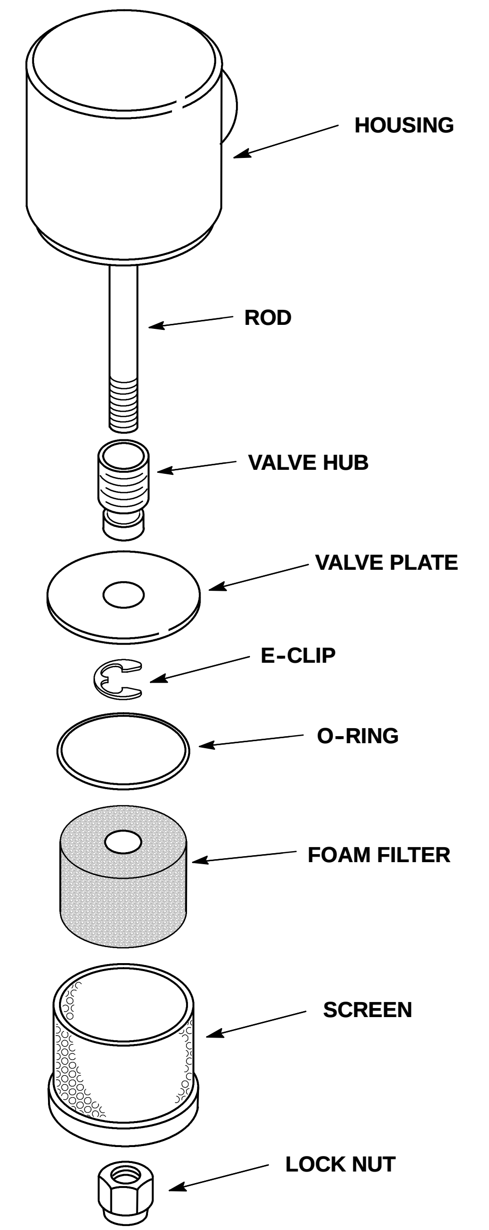


Figure 5.40-21. Breather Regulator

BREATHER SYSTEM

BAFFLE BOX MOUNTED SYSTEM

NOTE: *The baffle box to oil separator connections are the same for open, closed and closed ejector breather systems.*

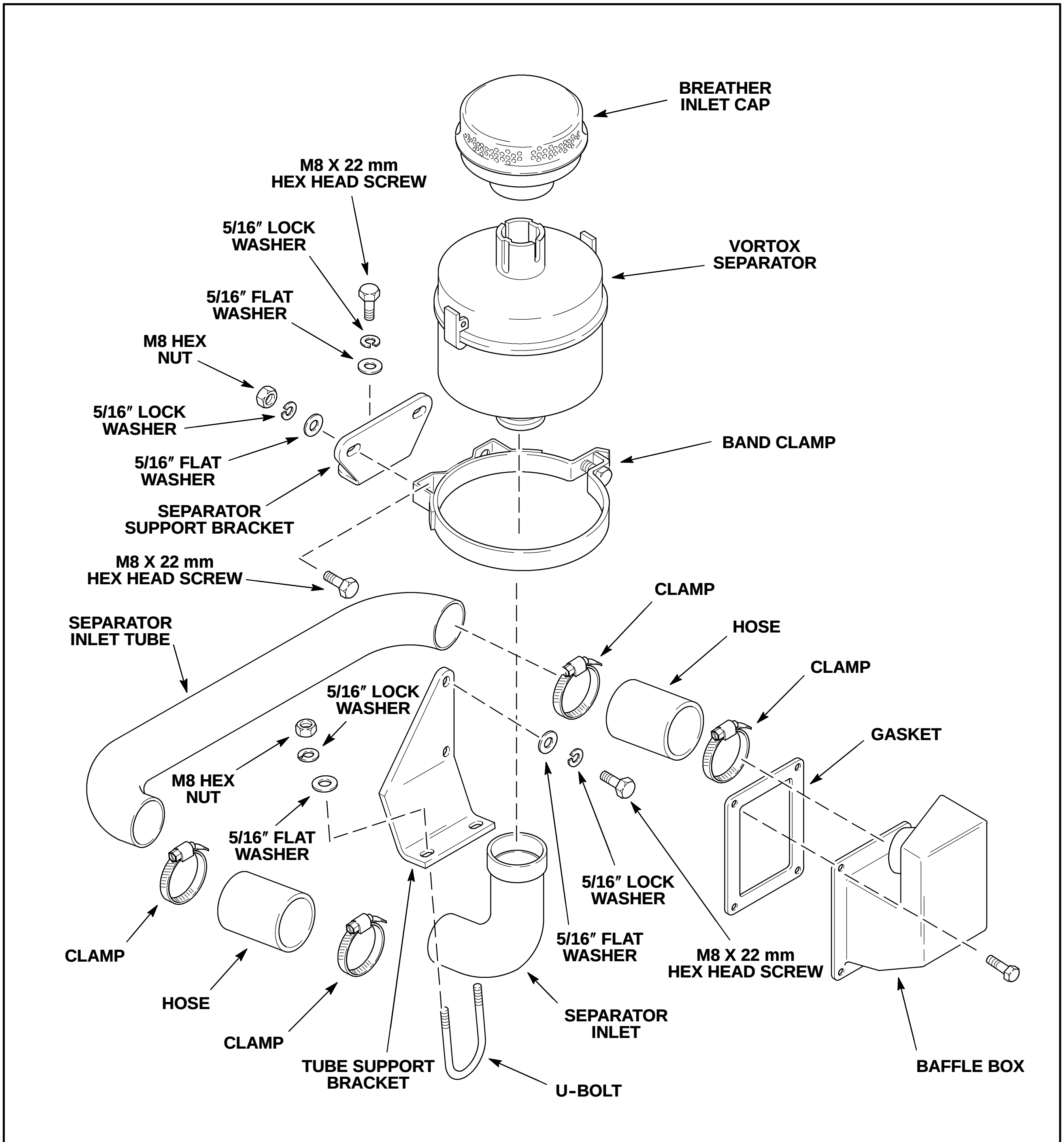


Figure 5.40-22. Baffle Box Breather System Common Parts

OIL SEPARATOR INSTALLATION (G AND GLD)

1. Install baffle box and gasket onto fifth cam door from front of engine (see Figure 5.40-23 and Figure 5.40-24).

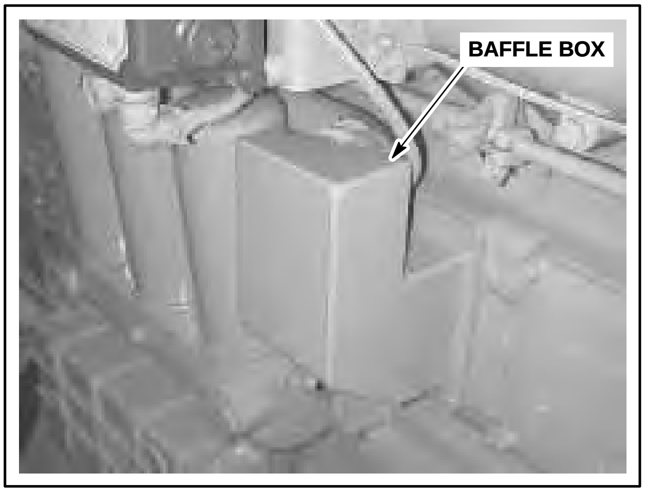


Figure 5.40-23. Ventilation System Baffle Box

NOTE: *KDM equipped engines require a baffle box equipped with a mounting plate (see Figure 5.40-24).*

Figure 5.40-24. KDM Bracket/Baffle Box

2. Install oil separator tube support bracket onto intake manifold. Bracket overlaps CEC Ignition Module bracket on six cylinder engines (see Figure 5.40-25). Oil separator tube support bracket mounts separately on eight cylinder engines (see Figure 5.40-26).

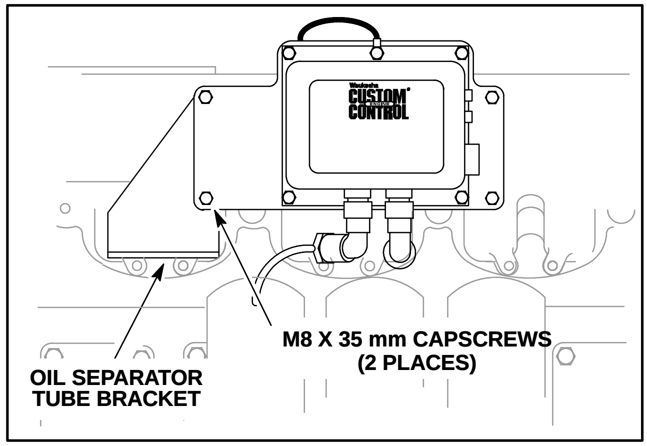


Figure 5.40-25. Six Cylinder Module Installation

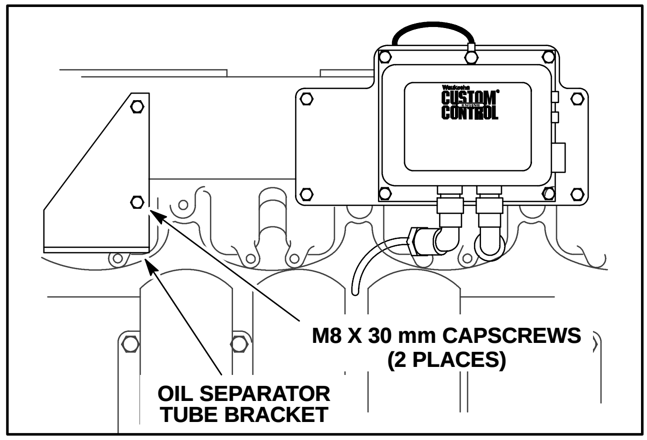


Figure 5.40-26. Eight Cylinder Module Installation

3. Install separator inlet tube with hose and clamps between separator inlet tube and baffle box (see Figure 5.40-27).

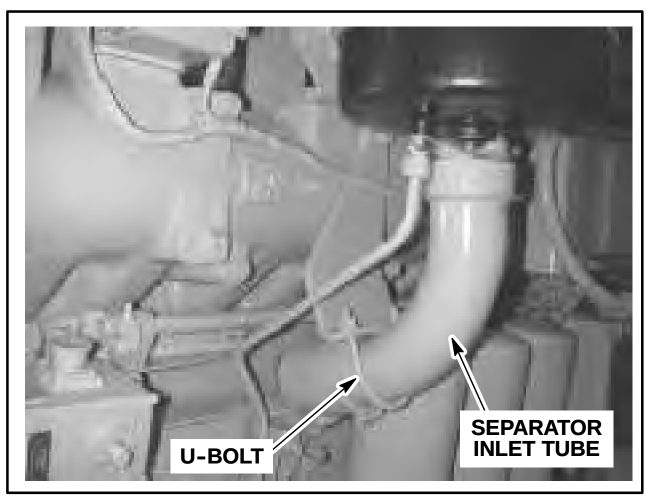


Figure 5.40-27. Separator Inlet Tube

4. Install separator support bracket and band clamp on intake manifold (see Figure 5.40-28).

Figure 5.40-28. Oil Separator Support Bracket

5. Screw oil separator onto inlet tube. Position drain port towards gear housing. Fasten band clamp around separator and support bracket (see Figure 5.40-29).

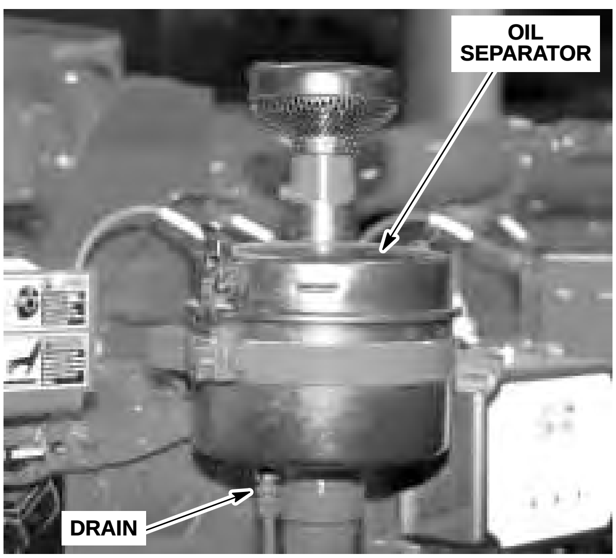


Figure 5.40-29. Open Breather

6. **Open Breather System—**Install drain cap on separator.

Separator Oil Drain

1. Current production oil separators have a drain tube to remove condensed oil. Connect drain tube between separator and oil pan (see Figure 5.40-30).

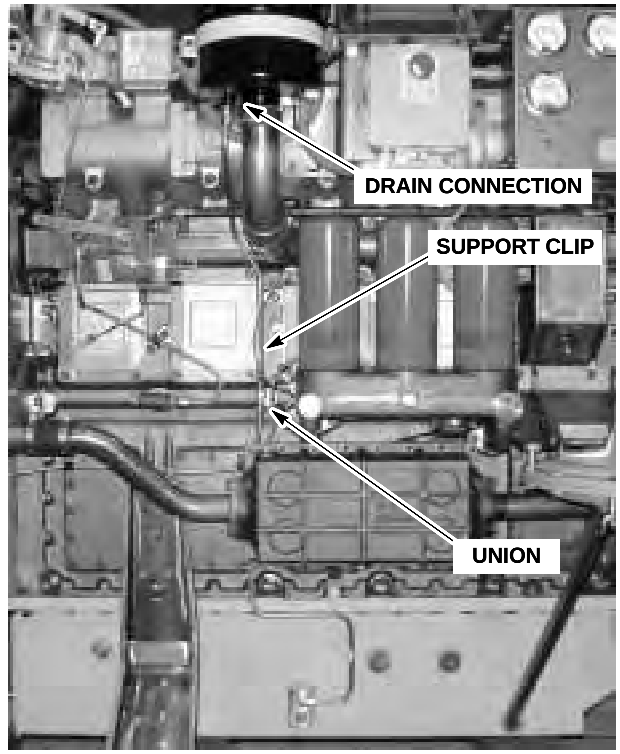


Figure 5.40-30. Breather System Oil Drain

2. Support upper drain tube with a clip attached to cam cover capscrew. Lower drain tube installs on oil pan with a tube elbow.

3. Eight cylinder engine lower drain tube also has two support clips attached to oil pan capscrews with short brackets (see Figure 5.40-31).

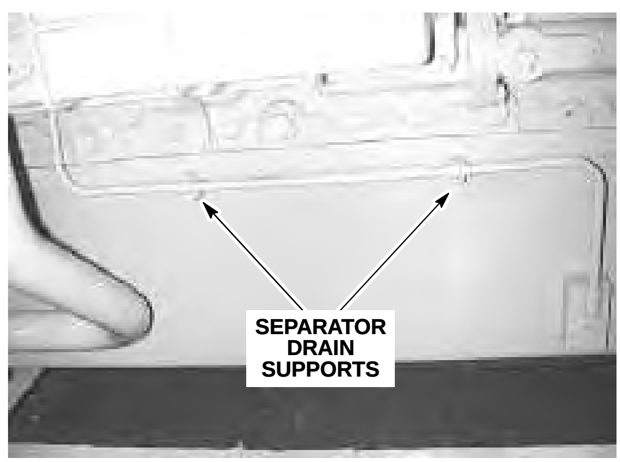


Figure 5.40-31. H24 Oil Drain Tube

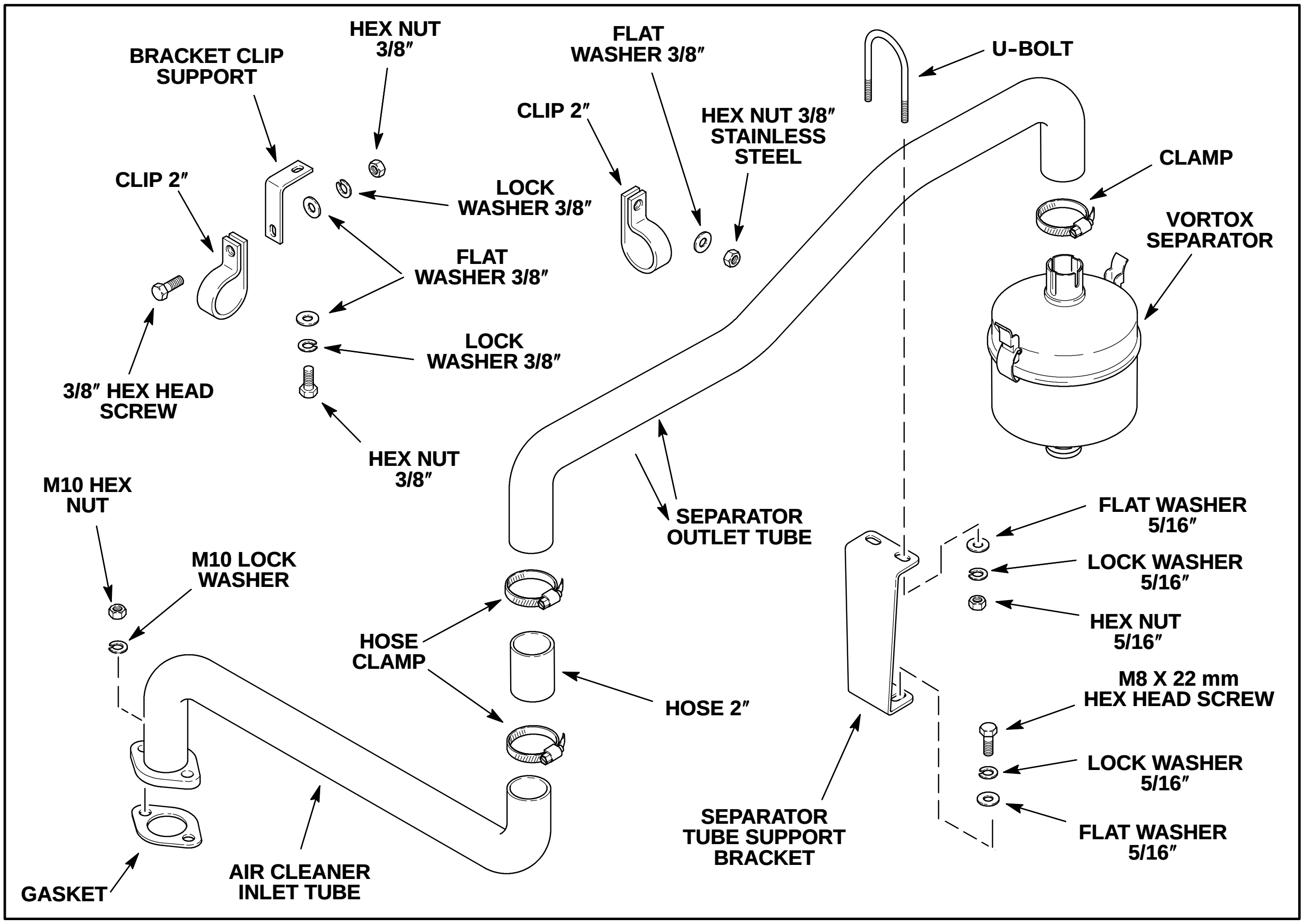


Figure 5.40-32. GLD Closed Breather

CLOSED BREATHER SYSTEMS – GLD/GSID

G, GL and GLD Impco closed breather systems with baffle boxes have tubing that crosses over the top of the engine to connect to the air cleaner (see Figure 5.40-32 and Figure 5.40-33). The oil separator and baffle box is common to the open breather system.

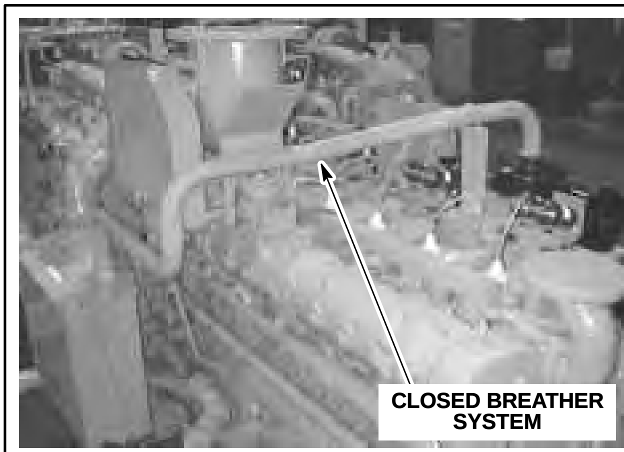


Figure 5.40-33. F18/H24 Impco GLD

1. Install pipe support bracket onto intake manifold (see Figure 5.40-34).

2. Secure separator outlet tube to support bracket using tube clip (see Figure 5.40-34).

3. Connect separator outlet tube to air cleaner inlet tube with hose and clamps (see Figure 5.40-34).

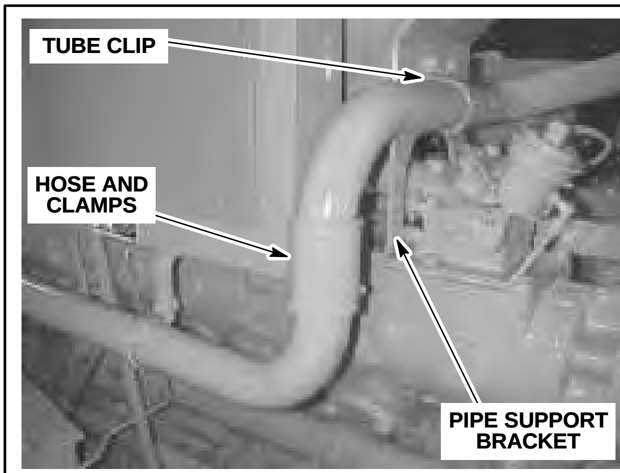


Figure 5.40-34. GLD Closed Breather System

4. Attach air cleaner inlet tube to air duct. Use new gasket and secure inlet tube to air duct with hex nuts (see Figure 5.40-35).

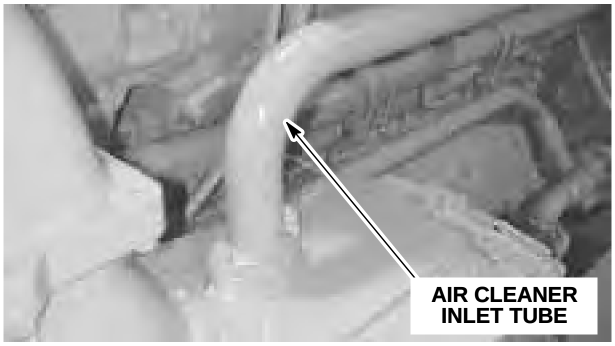


Figure 5.40-35. GLD Closed Breather System

CLOSED BREATHER SYSTEMS – G

NOTE: *The G series closed breather system has a tube running from the oil separator to the air cleaner duct (see Figure 5.40-36).*

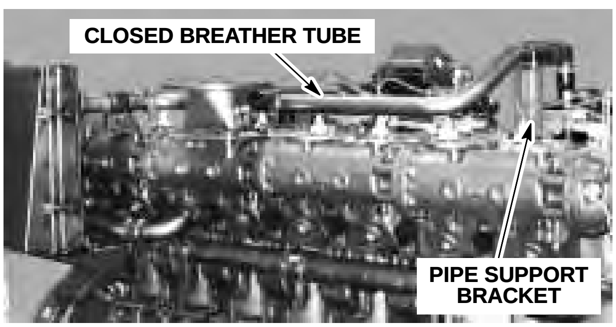


Figure 5.40-36. G Closed Breather System

1. Install closed breather pipe support bracket on intake manifold. Connect separator outlet tube to air cleaner inlet tube with hose and clamps.

2. Support breather tube with brackets and U–bolts on exhaust manifold and exhaust outlet (see Figure 5.40-37).

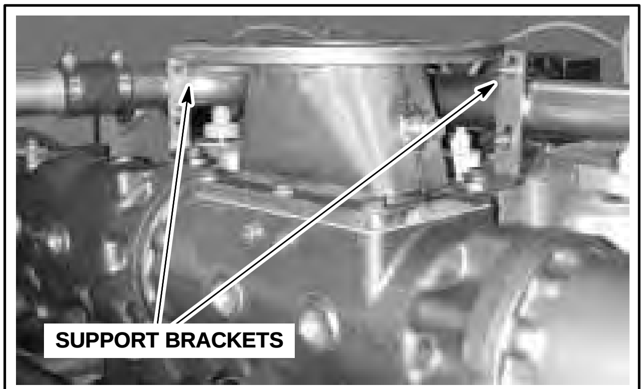


Figure 5.40-37. G Closed Breather System

CLOSED BREATHER SYSTEMS – GL EJECTOR

GL engines have an optional ejector closed breather system. The oil separator and baffle box is common to the open breather system.

NOTE: *If removed, apply Perma Lok® Heavy Duty Pipe Sealant with Teflon to the threads of the following components during assembly.*

1. Install pipe support bracket onto intake manifold (see Figure 5.40-38 and Figure 5.40-46).

2. Connect separator outlet tube to air cleaner inlet tube with hose and clamps (see Figure 5.40-38).

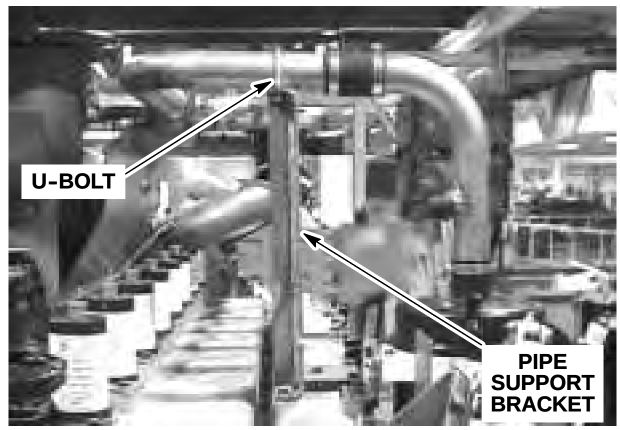


Figure 5.40-38. Breather Ejector Installation

3. Install ejector support bracket on exhaust outlet (see Figure 5.40-39).

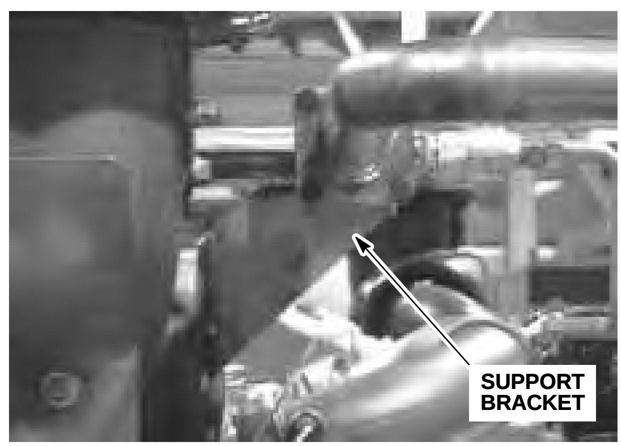


Figure 5.40-39. Ejector Support Bracket

4. Install exhaust flange inlet, elbow and pipe nipple onto ejector (see Figure 5.40-40). Install pipe flange onto adapter.

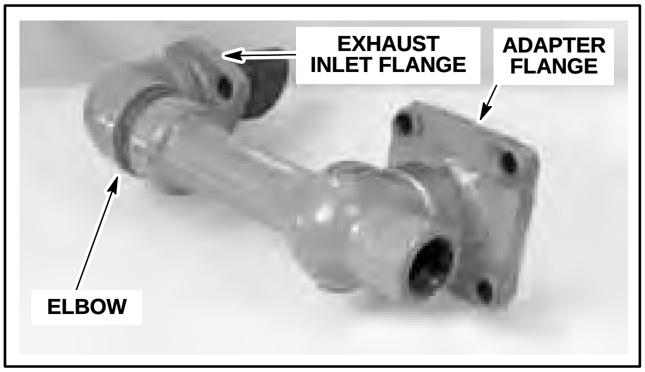


Figure 5.40-40. Ejector Assembly

5. Install ejector adapter flange with gasket onto separator outlet tube (see Figure 5.40-41). Secure with M10 x 40 mm hex head screws. Tighten to 19 ft-lb (26 N·m).

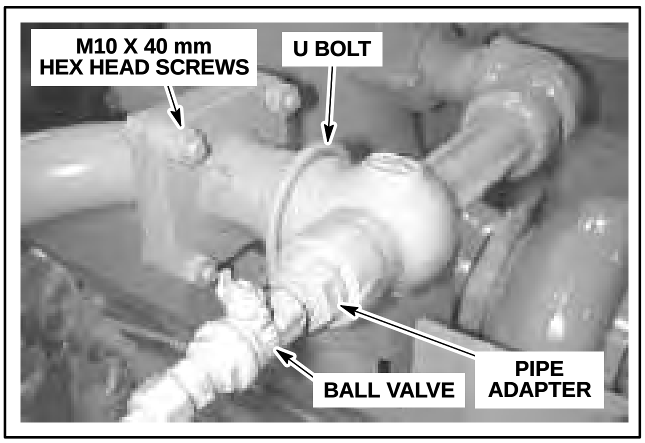


Figure 5.40-41. GL Breather Ejector

6. Install ejector onto exhaust outlet (see Figure 5.40-42). Secure with 3/8 in. hex head screws. Apply anti-seize compound and tighten to 32 ft-lb (43 N·m).

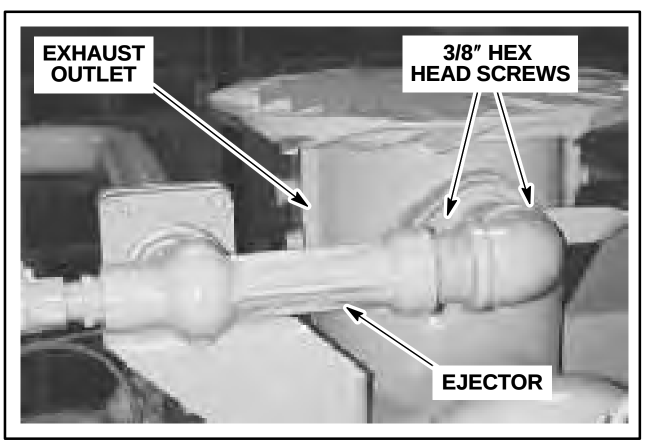


Figure 5.40-42. Breather Ejector

7. Secure ejector to support bracket with U-bolt. Install ball valve and pipe adapters on both sides of ball valve (see Figure 5.40-41).

8. Install turbocharger to ejector tube and tube elbow between intercooler inlet tube and ball valve (see Figure 5.40-43).

NOTE: *The F18GL turbo to ejector tube has a 3/8 in. ID. The H24GL turbo to ejector tube has a 3/4 in. ID (see Figure 5.40-43).*

9. Install vacuum regulator and pipe nipple onto separator outlet tube (see Figure 5.40-44).

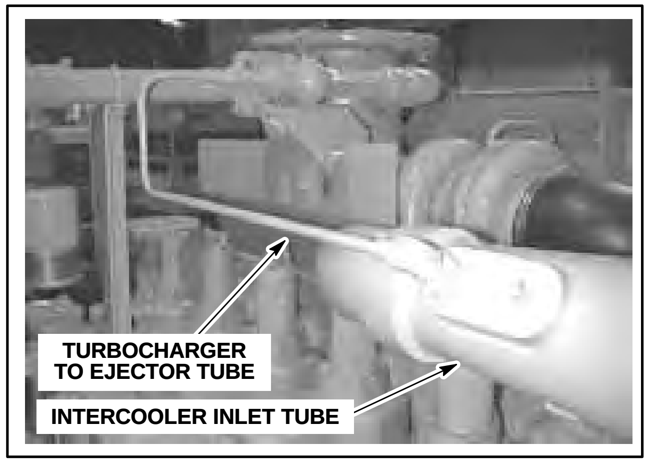


Figure 5.40-43. F18GL Ejector Breather

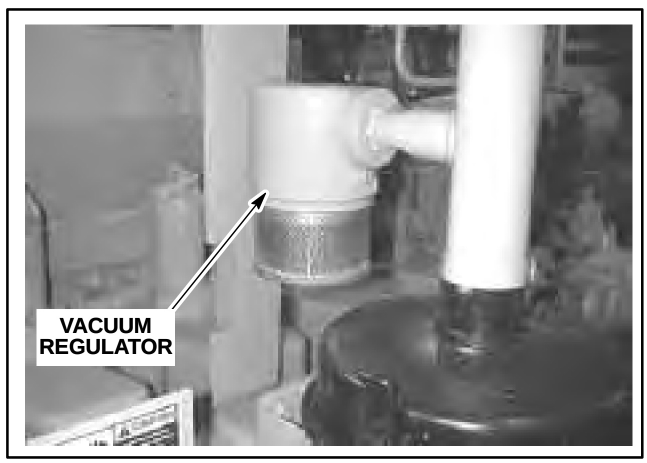


Figure 5.40-44. Vacuum Regulator

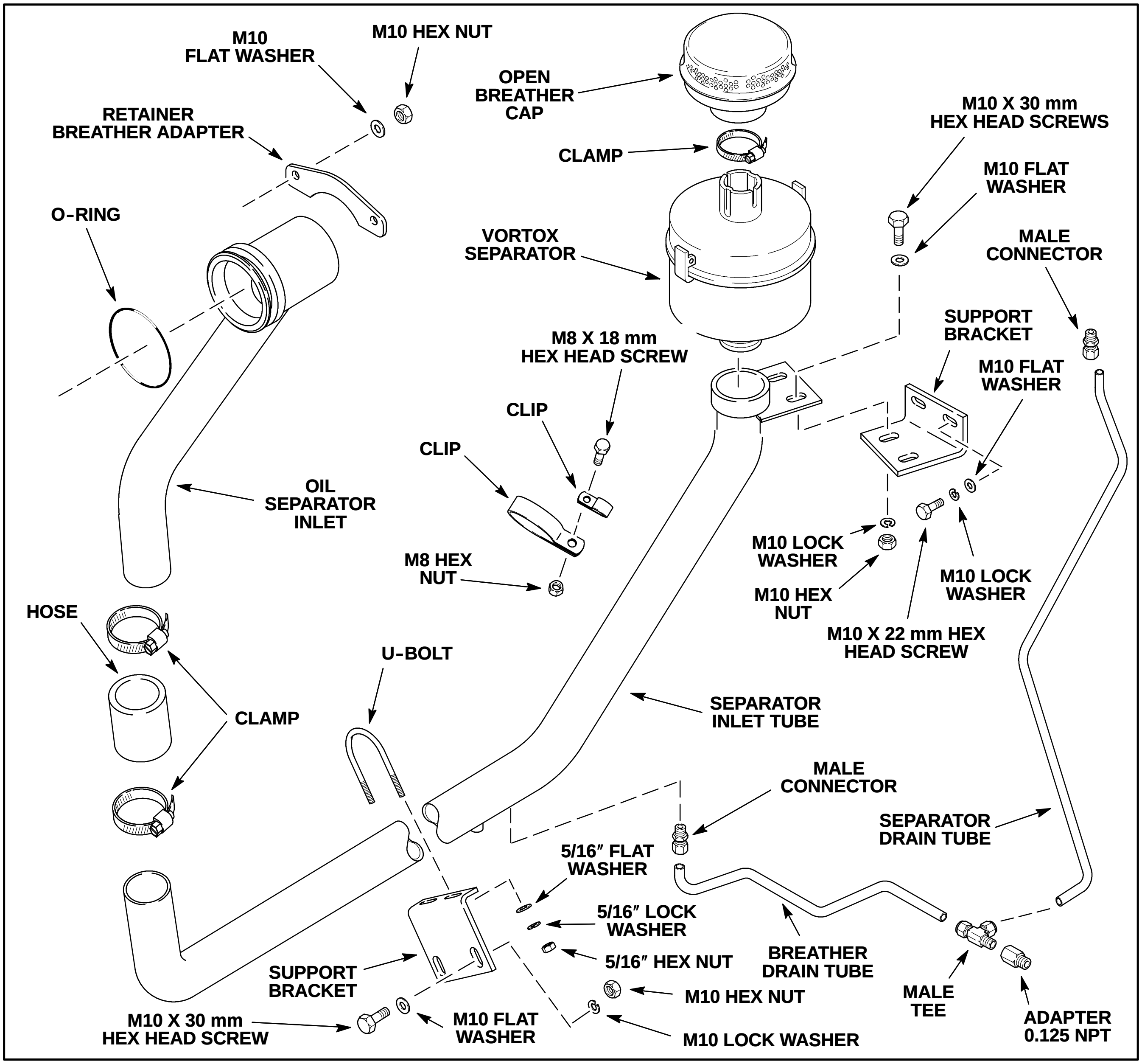


Figure 5.40-45. Closed Breather System – GSID/Deltec GLD

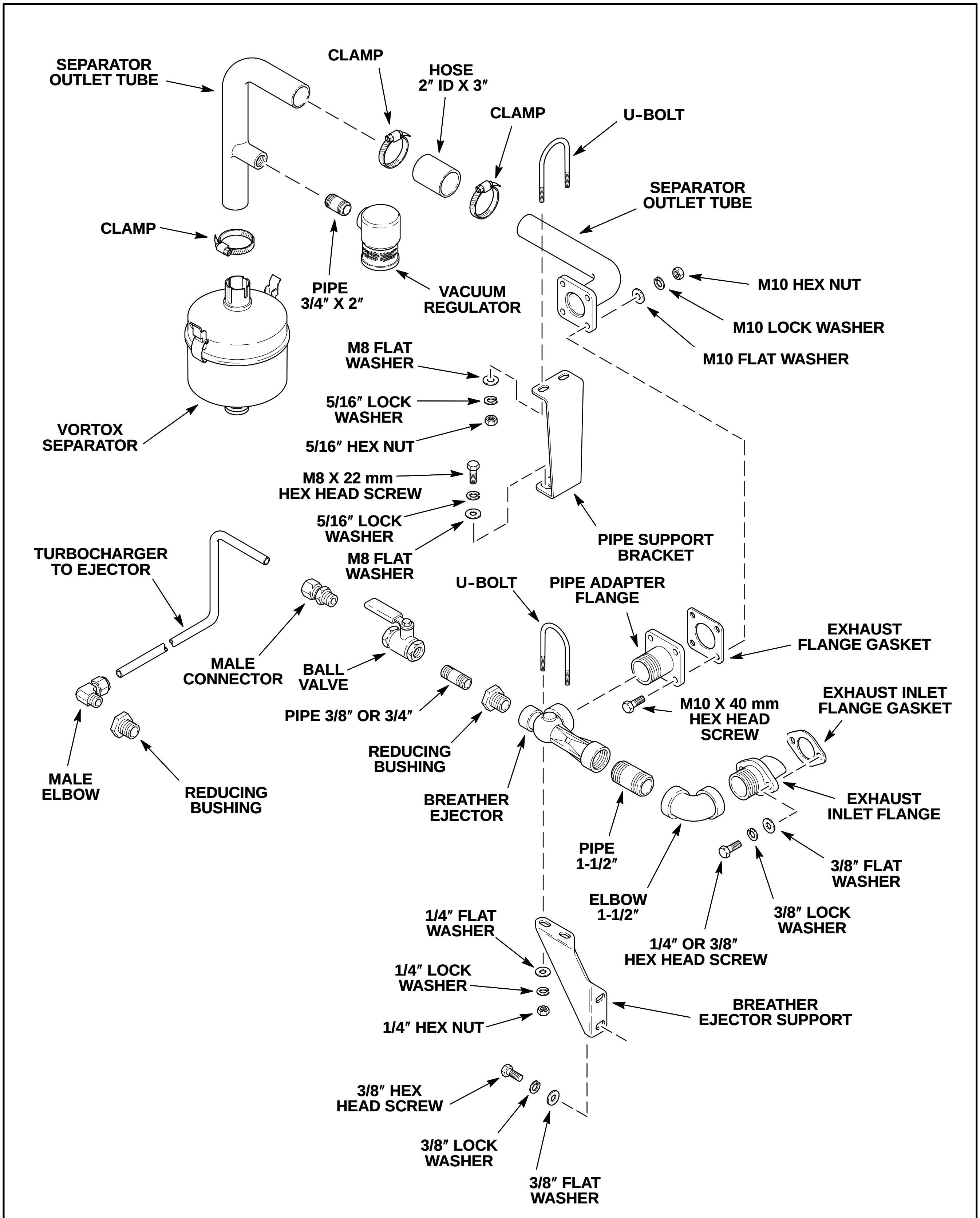


Figure 5.40-46. Closed Breather Ejector System

GL ENGINE CLOSED BREATHER SYSTEM REMOVAL (PREVIOUS)

1. Remove two M10 hex nuts, flat washers and adapter retainer located on right front gear housing (see Figure 5.40-47).

2. Remove breather and separator drain tubes from tee fitting (located on right side of crankcase, below lower oil separator inlet tube) (see Figure 5.40-48).

3. Remove tee fitting and install M10 hex head pipe plug (see Figure 5.40-48). Apply sealant or pipe tape to pipe plug before installation.

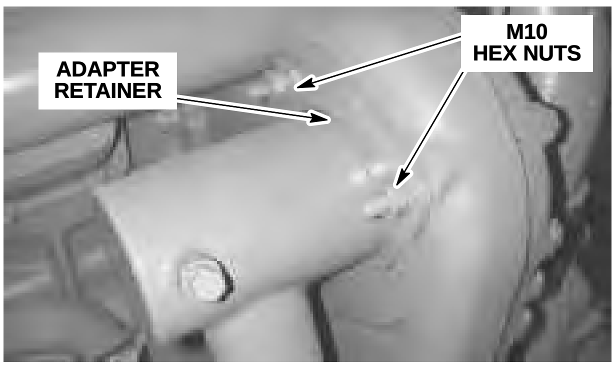


Figure 5.40-47. Upper Oil Separator Inlet Tube

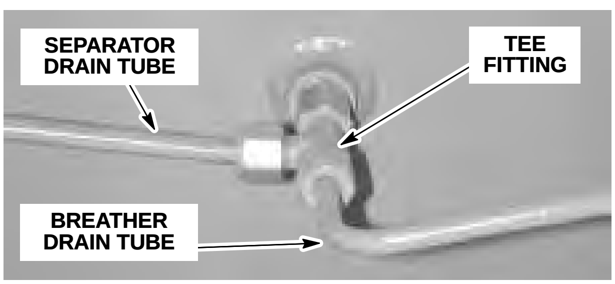


Figure 5.40-48. Drain Connections

4. Remove U-bolt from lower oil separator inlet tube (located on right front engine mount) (see Figure 5.40-49).

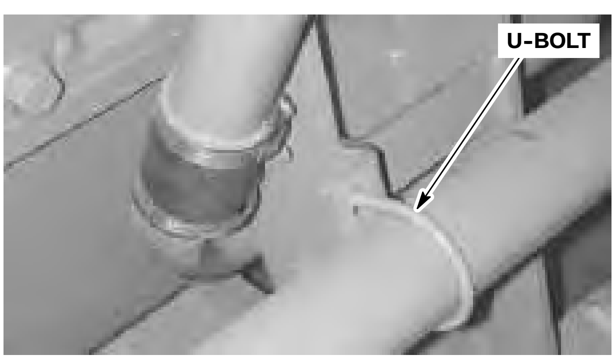


Figure 5.40-49. Lower Oil Separator Inlet Tube

5. Remove two M10 x 25 mm hex head screws from oil separator support bracket (see Figure 5.40-50).

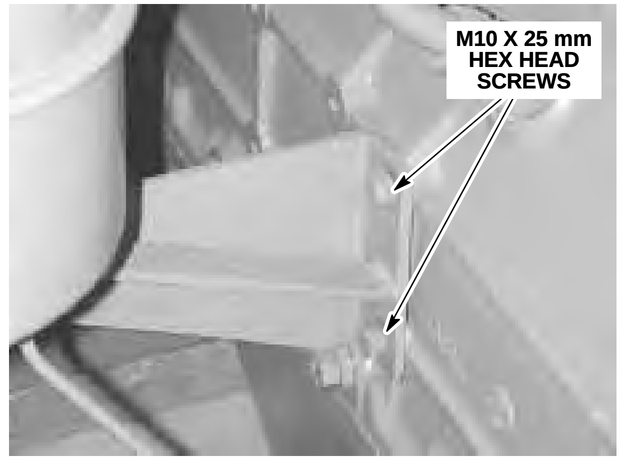


Figure 5.40-50. Oil Separator Support Bracket

NOTE: *With the removal of the final two hex head screws, the breather assembly will be free from the engine. Support the assembly while removing the final two screws, then remove the breather assembly from the engine.*

6. Remove two M10 x 35 mm hex head screws holding closed breather outlet tube to air cleaner (see Figure 5.40-51). Remove crankcase breather assembly.

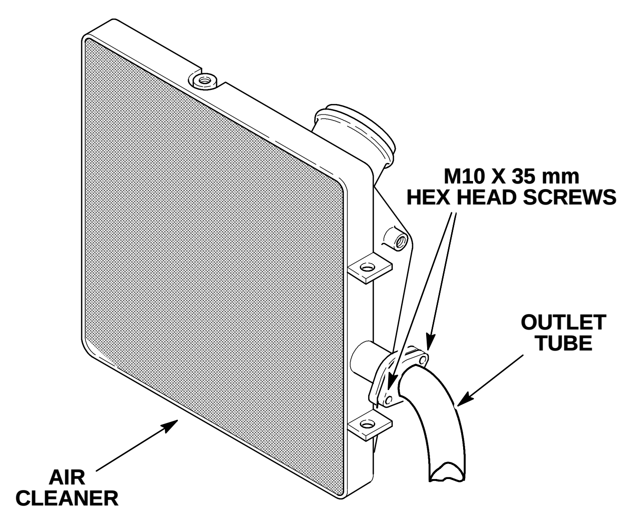


Figure 5.40-51. Air Cleaner

CLOSED BREATHER SYSTEM (CURRENT GL)

With the GL closed breather system, the contaminated crankcase gases enter the oil separator (inlet) and flow through the valve diaphragm into the filter element. The valve maintains a slight negative crankcase pressure to reduce engine weeping and prevent damage to the engine seals. Soot and other contaminants are trapped by the filter element media and then the oil is separated from the air. The oil collects at the bottom of the filter housing and is returned to the crankcase through a drain hose. A check valve is incorporated into the drain hose to prevent reverse oil flow from the crankcase. The filtered gases then flow through the oil separator outlet and into the air box inlet.

The oil separator uses a replaceable filter element that is composed of microglass fiber. When the filter becomes restricted (through normal use), the crankcase pressure will change from slightly negative to slightly positive. When this occurs a new filter element should be ordered and installed.

Filter Element Replacement

1. To replace filter element, pull up on latching mechanisms while holding oil separator bottom half (see Figure 5.40-52).

2. Remove oil separator bottom half and filter element (see Figure 5.40-52).

NOTE: *F18GL engines use replaceable filter element P/N 489604. H24GL engines use replaceable filter element P/N 489605.*

3. Install new filter element into oil separator. Make sure O-ring is installed and seated properly (see Figure 5.40-53).

4. Install and "latch" bottom half of oil separator onto top half.

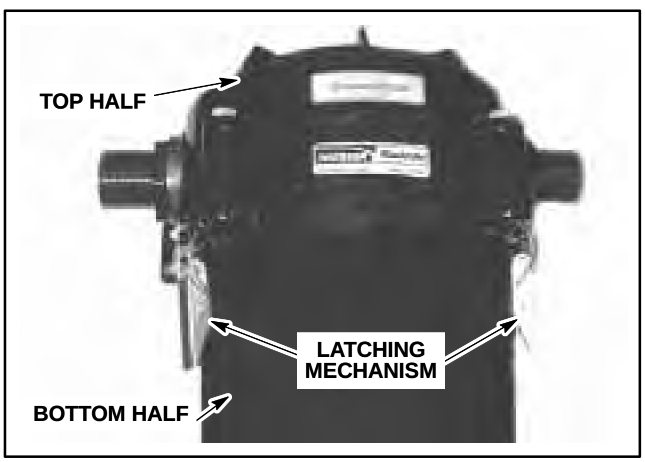


Figure 5.40-52. Oil Separator

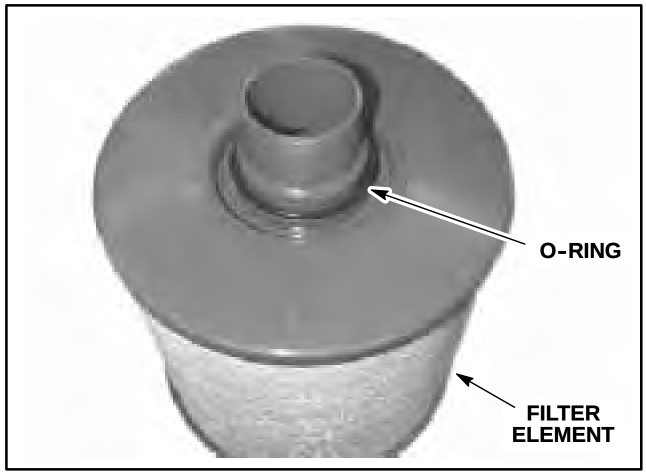


Figure 5.40-53. Oil Separator Filter Element

GL CLOSED BREATHER SYSTEM INSTALLATION

NOTE: *Identify the appropriate mounting location for the oil separator bracket before removing any hex head screws. See Figure 5.40-54 for F18GL engines or Figure 5.40-55 for H24GL engines.*

1. Remove two M10 hex head screws, lock washers and flat washers from exhaust manifold (see Figure 5.40-54 or Figure 5.40-55).

2. Remove two M8 hex head screws, lock washers and flat washers from center water header (see Figure 5.40-54 or Figure 5.40-55).

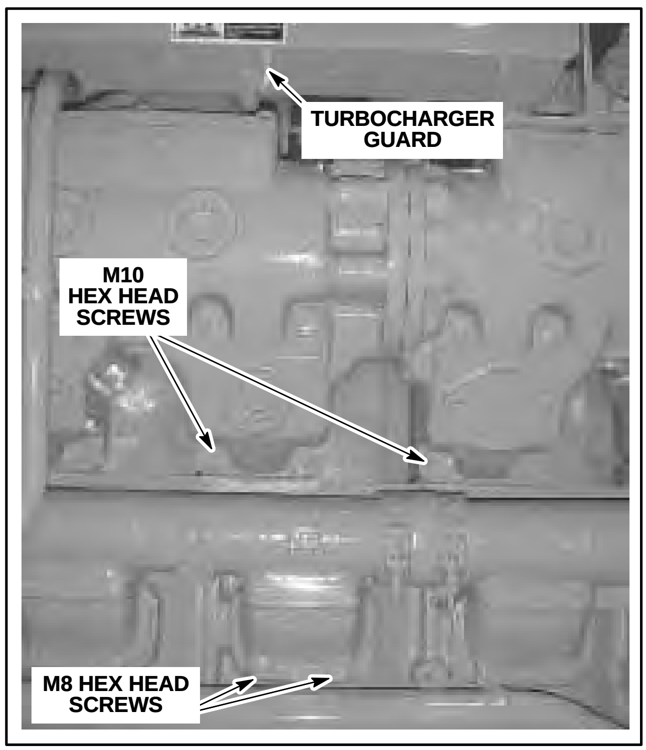


Figure 5.40-54. F18GL Bracket Location

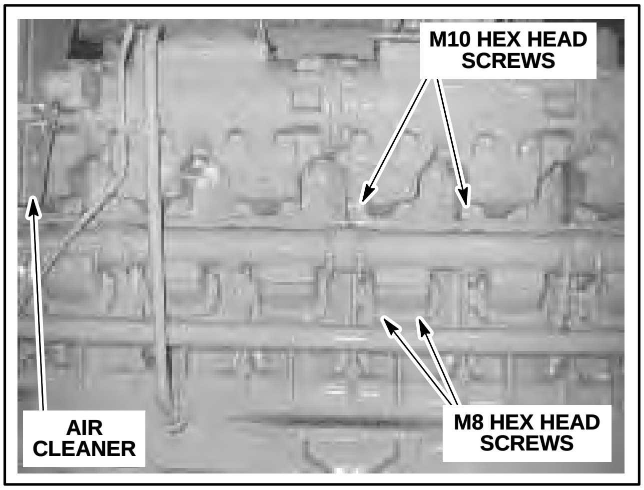


Figure 5.40-55. H24GL Bracket Location

3. Install mounting bracket and secure exhaust side with new M10 x 120 mm Grade 10.9 hex head screws, lock washers and flat washers. Use spacers (two 2.44 in. thick) between bracket and exhaust manifold. Do not fully tighten.

4. Secure water header side of bracket with M8 x 90 mm Grade 10.9 hex head screws, lock washers and flat washers. Use spacers (two 2.25 in. thick) between bracket and water header. Do not fully tighten.

5. Tighten M10 x 120 mm Grade 10.9 hex head screws to 53 ft-lb (72 N·m). Tighten M8 x 90 mm Grade 10.9 hex head screws to 36 ft-lb (27 N·m).

NOTE: *The same mounting bracket is used for both the F18GL and the H24GL engine. However, different size oil separators are used for both engines. Because of this, the mounting bracket will contain extra screw holes that are not used when mounting the oil separator.*

6. **F18GL—**Install oil separator onto mounting bracket. Secure with four M8 x 40 mm hex head screws, lock washers, flat washers and hex nuts.

7. **F18GL—**Tighten M8 x 40 mm hex head screws to 8 ft-lb (11 N·m).

8. **H24GL—**Install oil separator onto mounting bracket. Secure with four M10 x 40 mm hex head screws, lock washers, flat washers and hex nuts.

9. **H24GL—**Tighten M10 x 40 mm hex head screws to 16 ft-lb (22 N·m).

10. Install both rubber hoses onto oil separator. Each hose should have two clamps around it. Do not tighten clamps (see Figure 5.40-57).

11. Install new O-ring into flange of oil separator inlet tube. Lubricate O-ring with Parker Super-O-Lube™.

12. Install M10 hex head pipe plug into oil separator inlet tube (see Figure 5.40-57).

13. Insert oil separator inlet tube into oil separator hose (see Figure 5.40-57).

14. Install oil separator inlet tube into front gear housing. Secure with adapter retainer, M10 hex nuts and flat washers (see Figure 5.40-47). Tighten M10 hex nuts to 16 ft-lb (22 N·m).

15. Tighten hose clamps that secure oil separator inlet tube and oil separator to hose.

16. Install gasket onto air duct assembly tube (see Figure 5.40-60).

17. Insert air duct assembly tube through adapter and into air duct. Tube should point up at turbocharger inlet (see Figure 5.40-60).

18. Insert oil separator outlet tube into oil separator hose. Do not tighten clamps (see Figure 5.40-57).

19. Install oil separator outlet tube and gasket onto adapter located on air duct. Secure with two M10 x 45 mm hex head screws, lock washers, flat washers and hex nuts (see Figure 5.40-60). Tighten M10 screws to 16 ft-lb (22 N·m).

20. Verify all hose clamps are tight.

NOTE: *Apply thread tape or sealant to all pipe threads to prevent oil leaks.*

21. **F18GL—**Install reducing bushing and pipe adapter into pipe tee (see Figure 5.40-56).

22. **F18GL—**Install 0.375 in. pipe plug into pipe tee (see Figure 5.40-56).

23. **F18GL—**Install check valve into pipe adapter (see Figure 5.40-56).

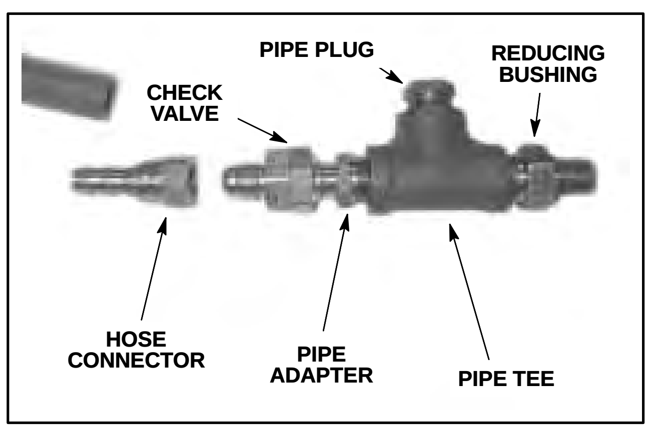


Figure 5.40-56. Pipe Tee Assembly - F18GL

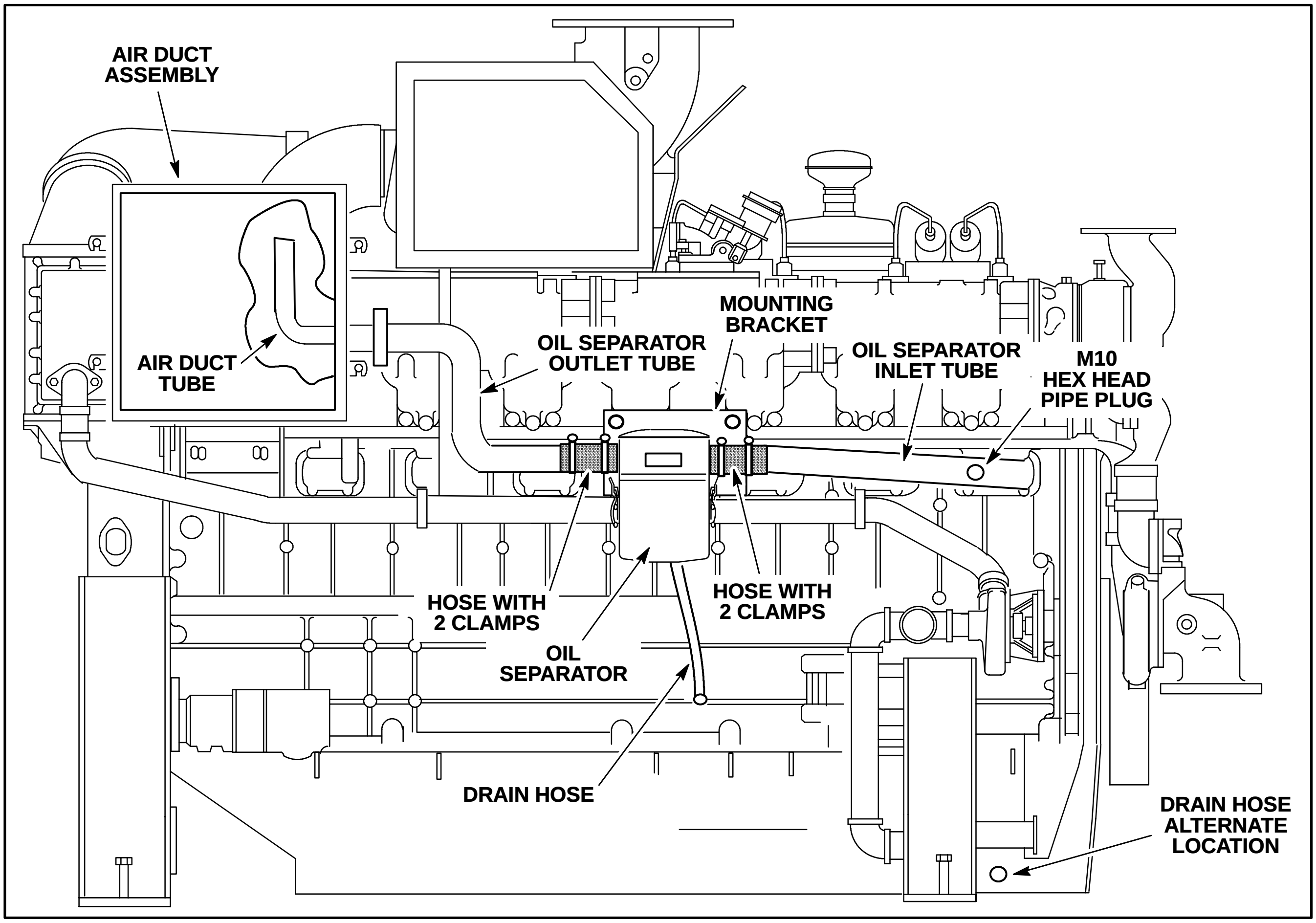


Figure 5.40-57. H24 GL Breather Assembly Depicted

24. **H24GL—**Install reducing bushing into pipe tee (see Figure 5.40-58).

25. **H24GL—**Install 0.375 in. pipe plug into pipe tee (see Figure 5.40-58).

26. **H24GL—**Install check valve into pipe tee (see Figure 5.40-58).

27. **H24GL—**Install hose connector onto check valve (see Figure 5.40-58).

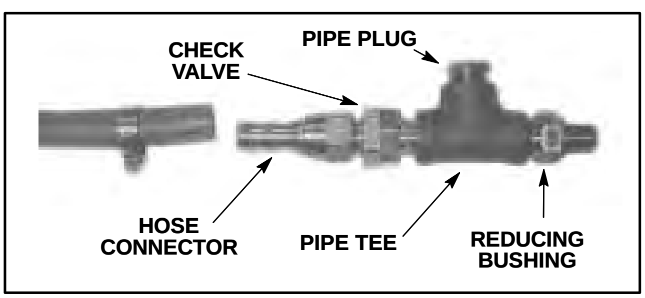


Figure 5.40-58. Pipe Tee Assembly – H24GL

NOTE: *As an alternate, the oil drain hose can be connected to the crankcase through a fitting located on the front right side of the oil pan (see Figure 5.40-59). The alternate oil drain fitting is located below the engine oil level. Drain the engine oil before removing the alternate plug.*

28. Remove crankcase plug and install pipe tee assembly (see Figure 5.40-59).

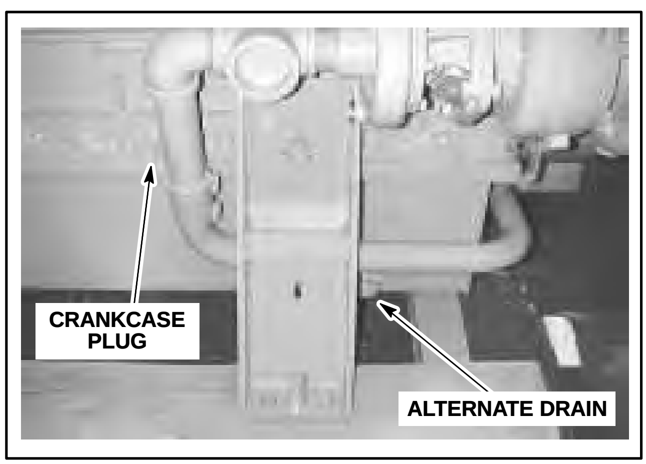


Figure 5.40-59. Crankcase Oil Drains

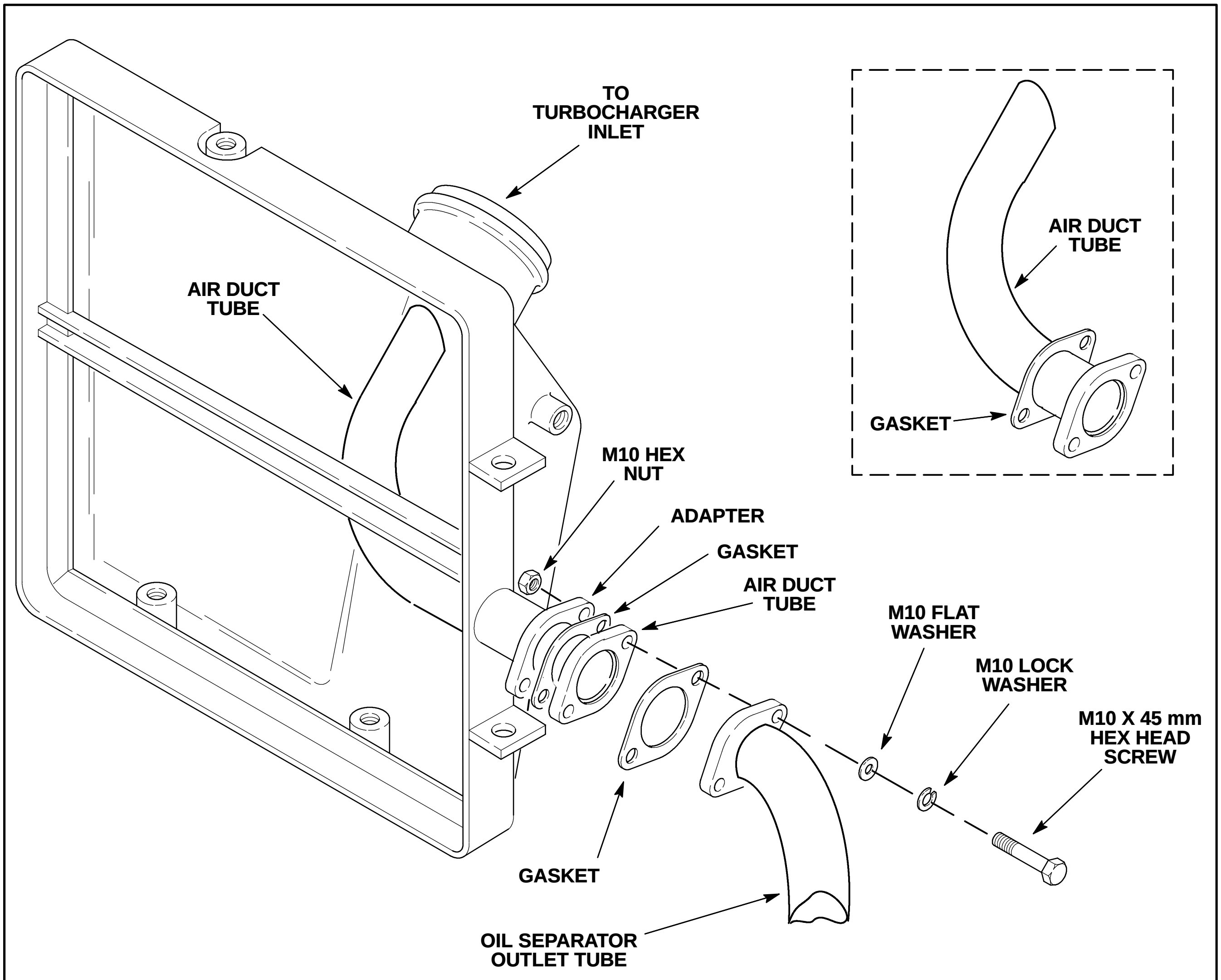


Figure 5.40-60. Air Duct Assembly

29. Install hose connector onto bottom of oil separator. Slide drain hose onto connector. Install and tighten hose clamp (see Figure 5.40-61).

30. Install opposite end of drain hose onto pipe tee assembly and secure with hose clamp. Trim hose length if required.

31. Verify drain hose clamp connections are tight.

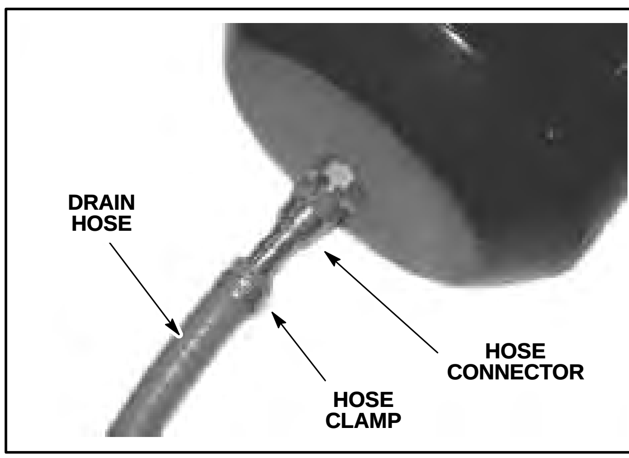


Figure 5.40-61. Oil Separator Drain Hose

SECTION 5.45

STARTING SYSTEM

AIR/GAS STARTER MAINTENANCE

A self-lubricator is used to provide bearing lubrication for the air/gas starters (see Figure 5.45-1).

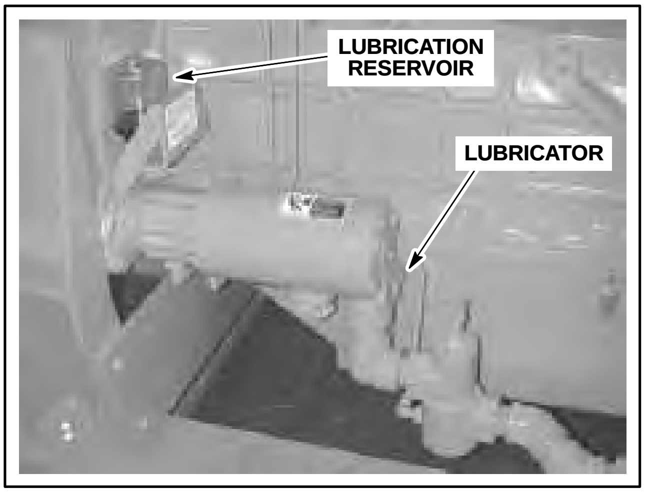


Figure 5.45-1. Air/Gas Starter Motor

When operating correctly, the in-line lubricator will provide a light oil vapor at the starter exhaust (about 1 to 3 drops per second).

Keep the in-line lubricator reservoir filled to level with SAE 10W oil for temperatures above 32° F (0° C) or No. 2 Diesel oil for temperatures below 32° F (0° C).

AIR/GAS STARTER

AIR/GAS STARTER REMOVAL

⚠ WARNING

Ensure that the fuel source is completely shut off prior to working on fuel system components. Clear the engine supply lines and piping of accumulated gas before performing any maintenance work on the fuel system or severe personal injury or death could result.

NOTE: *Tag all tubes and lines before removal to aid during assembly.*

1. Disconnect site piping from air/gas starter.

2. Disconnect site air/gas exhaust pipe from air/gas starter (if equipped).

3. Disconnect oil supply tube from inline lubricator on air/gas starter (see Figure 5.45-2 and Figure 5.45-4).

Figure 5.45-2. Air/Gas Starter Motor

4. Remove U-bolt from supply pipe and support bracket (see Figure 5.45-3).

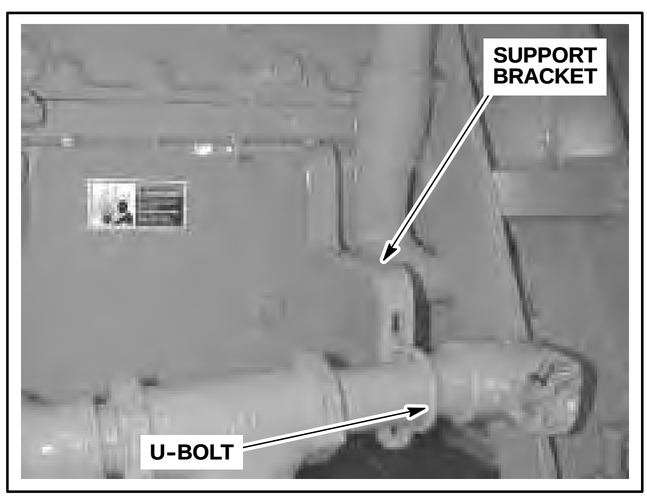


Figure 5.45-3. Air/Gas Starter Motor Connections

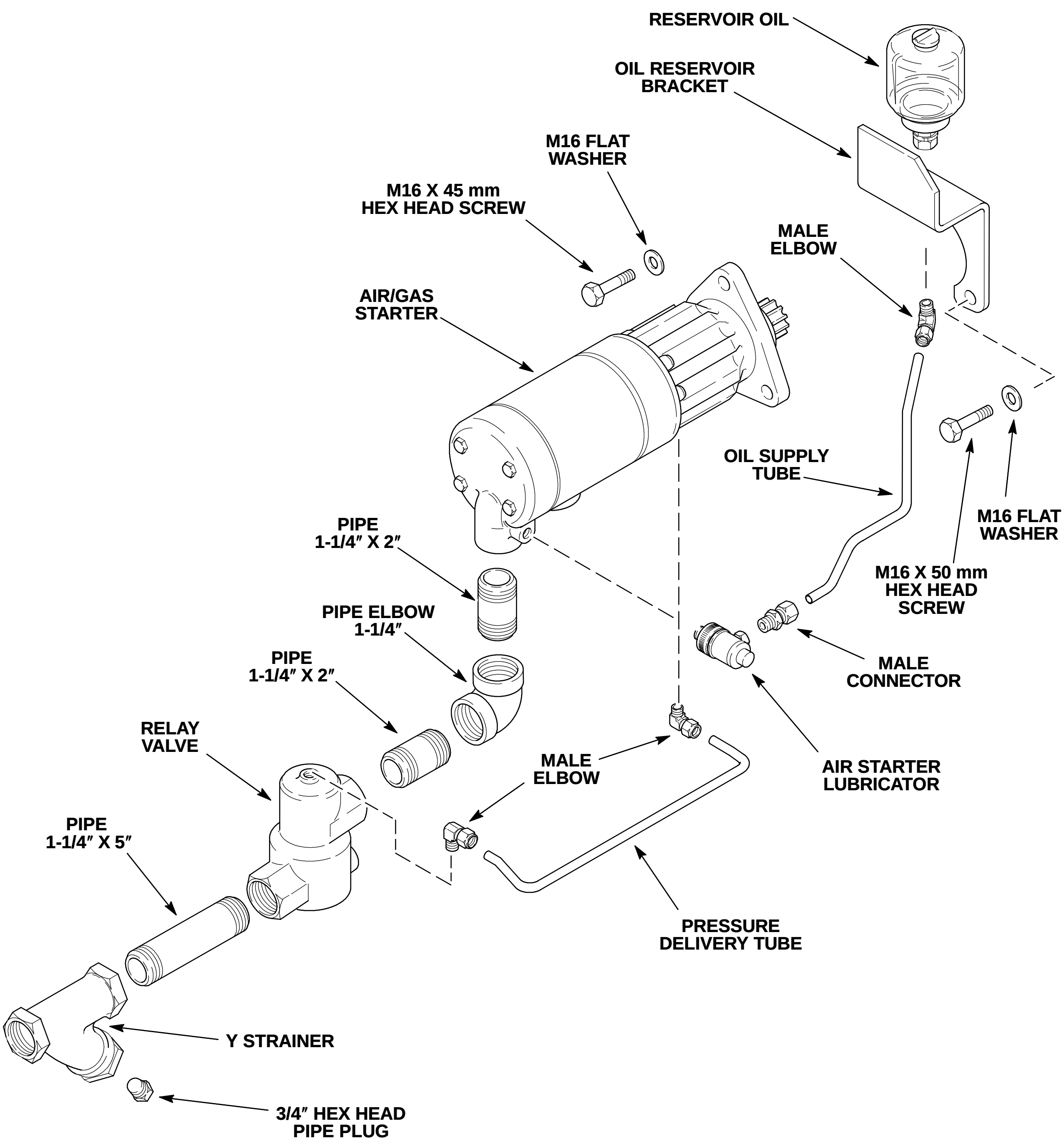


Figure 5.45-4. Air/Gas Starter

⚠ WARNING

The air starter assembly weighs approximately 130 lb. (63 kg). Use a suitable lifting device and exercise caution during removal or installation to avoid severe personal injury or death.

5. Using a suitable lifting device, remove three M16 hex head screws, lock washers and air starter from rear gear housing.

AIR/GAS STARTER INSTALLATION

⚠ WARNING

The air starter weighs approximately 130 lb. (63 kg). Use a suitable lifting device and exercise caution during removal or installation to avoid severe personal injury or death.

1. Assemble starter lubricator, relay valve and Y strainer (see Figure 5.45-4 and Figure 5.45-5). Apply Perma Lok® Heavy Duty Pipe Sealant with Teflon to all pipe threads.

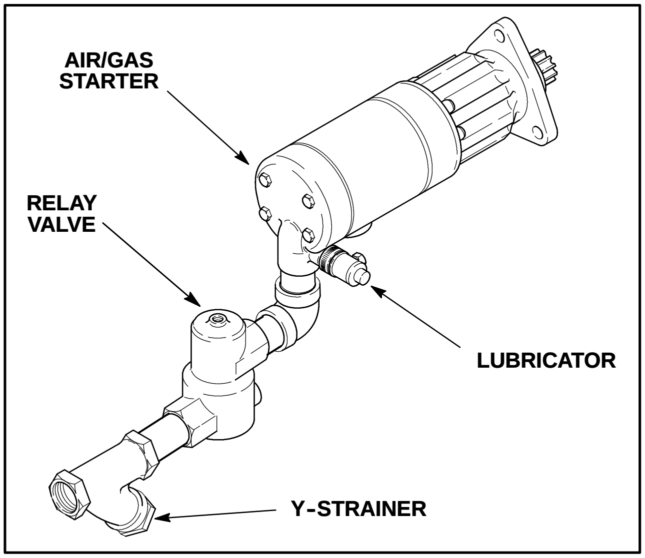


Figure 5.45-5. Air/Gas Starter Assembly

2. Using a suitable lifting device, install air starter onto rear gear housing. Secure with three M16 hex head screws and lock washers. Oil reservoir bracket is secured with right lower hex head screw.

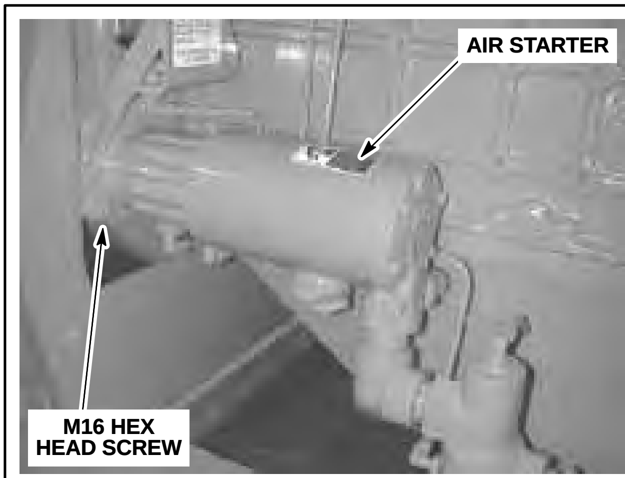


Figure 5.45-6. Air/Gas Starter Motor

3. Secure support bracket to crankcase with M10 hex head screws, lock washers and washers (see Figure 5.45-7). Secure pipe to bracket using U-bolt.

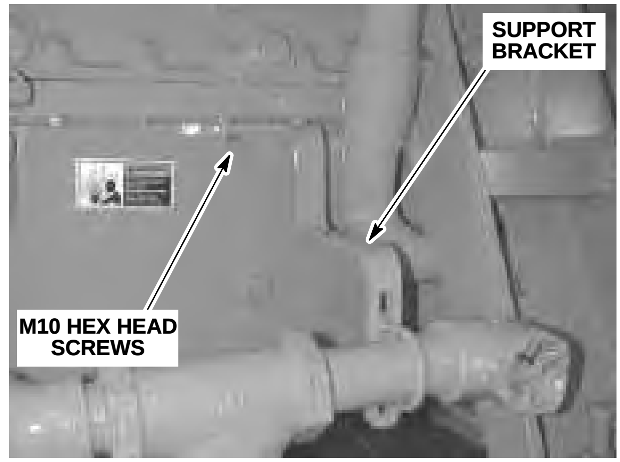


Figure 5.45-7. Air/Gas Starter Support

4. Install reservoir and oil supply tube onto lubricator (see Figure 5.45-8).

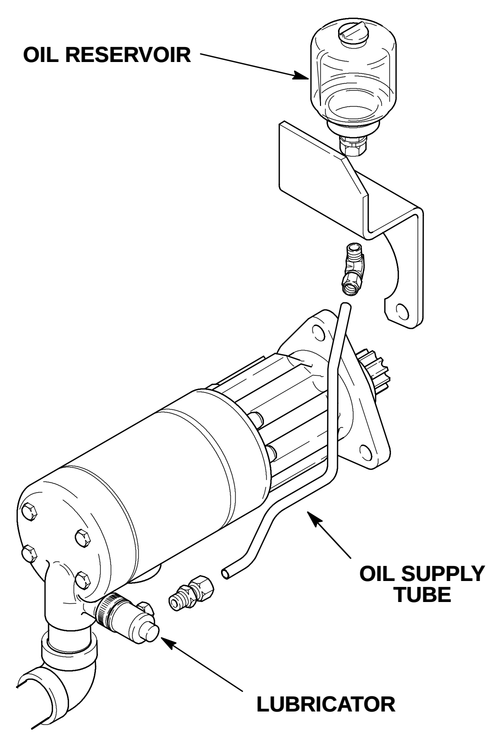


Figure 5.45-8. Air/Gas Starter Lubricator Oil Supply

AIR/GAS STARTER LOCAL CONTROL

CONTROL VALVE

The local control push button control valve is mounted on the control or instrument panel with guarding (see Figure 5.45-9).

Figure 5.45-9. Air/Gas Starter Control

The control valve is mounted on a button guard bracket mounted on the inside of the control panel. A second guard bracket is attached to the outside of the panel as a guard to prevent accidental actuation (see Figure 5.45-10).

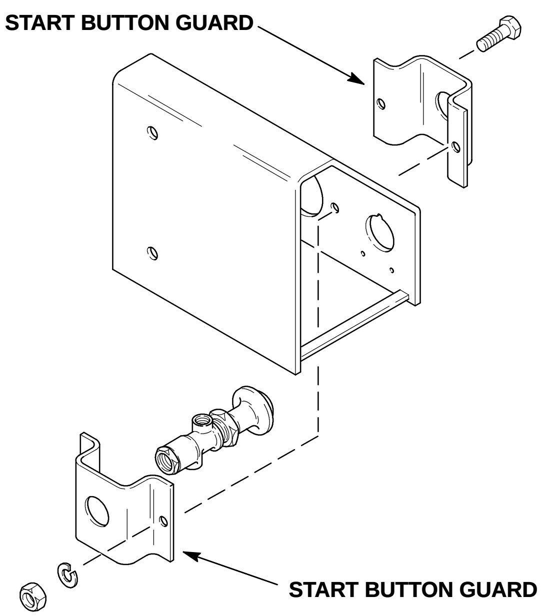


Figure 5.45-10. Control Valve Mounting

The valve supply tube runs between the "SUP(PLY)" port of the push button valve to the starter port labeled "I" (see Figure 5.45-11).

The valve delivery tube runs between the "DEL(IVERY)" port of the push button valve to the relay valve mounted on the starter.

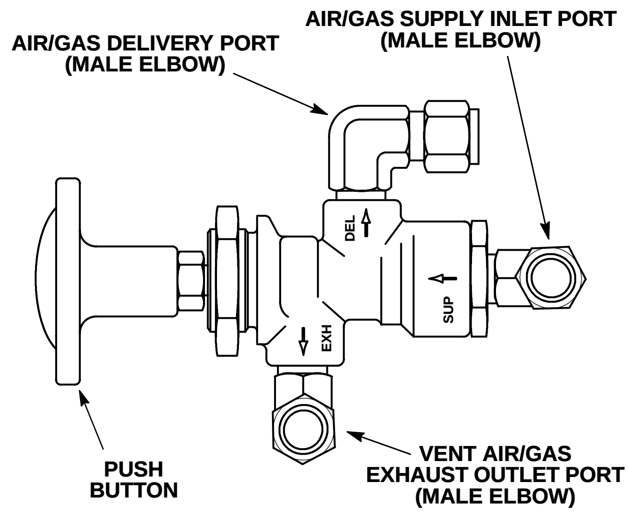


Figure 5.45-11. Start Push Button Valve

Vented gas is piped away from the "EXH(AUST)" port of the push button valve, out the back of the control panel through an exhaust muffler.

⚠ WARNING

When natural gas is used for engine starting through the air motor, the air motor's exhaust and breather openings should be connected and piped to a safe distance from the engine. The starter motor should be checked periodically for gas leaks at all points where gaskets and seals are used. Failure to follow proper procedures could cause severe personal injury or death.

The air/gas starter push button will vent air/gas to the atmosphere (see Figure 5.45-12). When natural gas is used for engine starting through the air motor, the air motor's push button vent exhaust must also be routed to a safe distance from the engine.

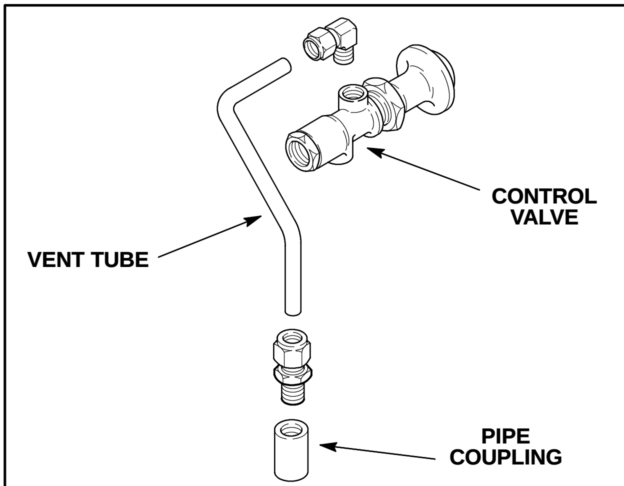


Figure 5.45-12. Air/Gas Starter Push Button Vent

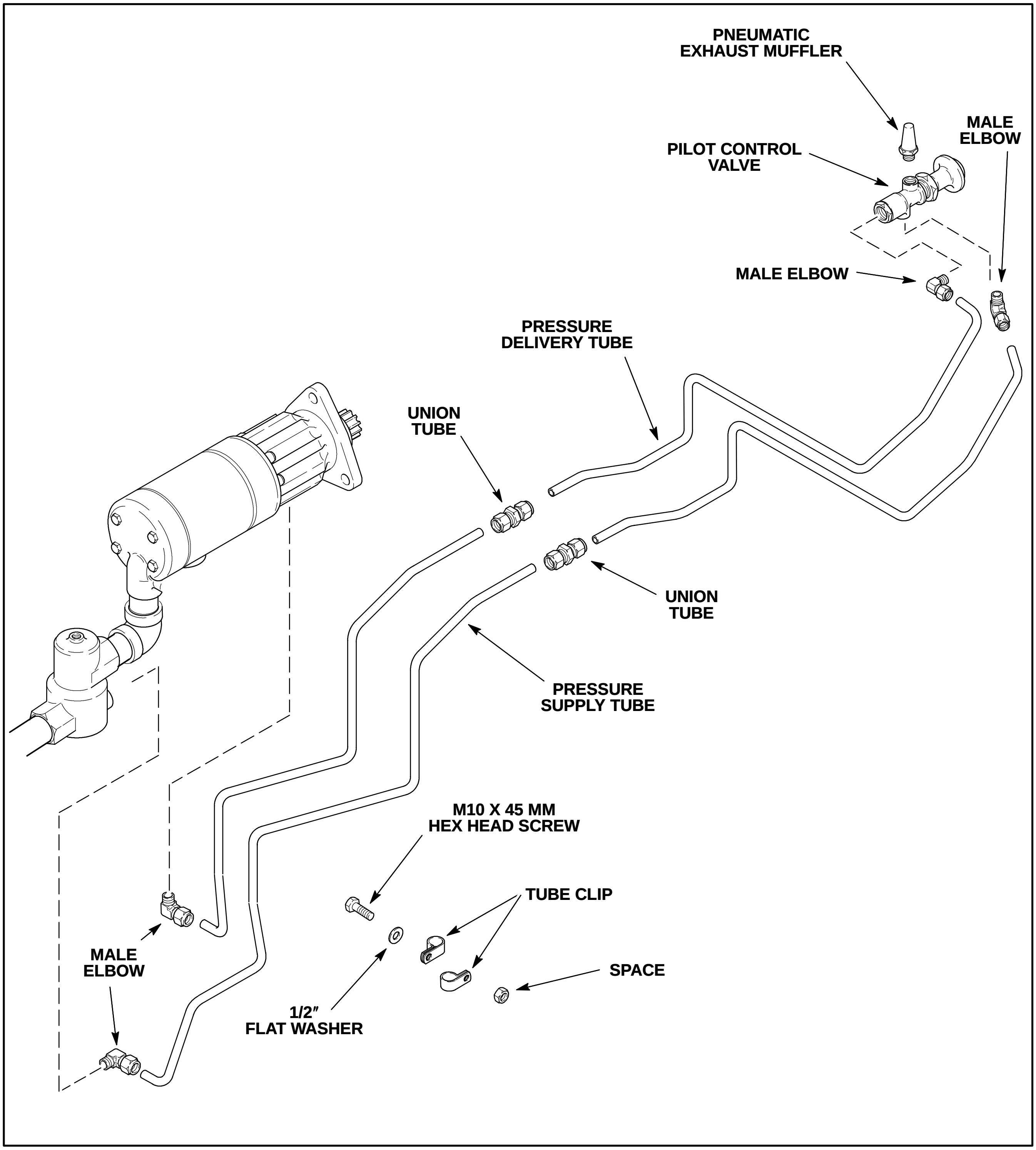


Figure 5.45-13. Air/Gas Starter Local Control

TUBE INSTALLATION

Local control air/gas starter tubes are secured to the crankcase using clips and spacers (see Figure 5.45-13 and Figure 5.45-14).

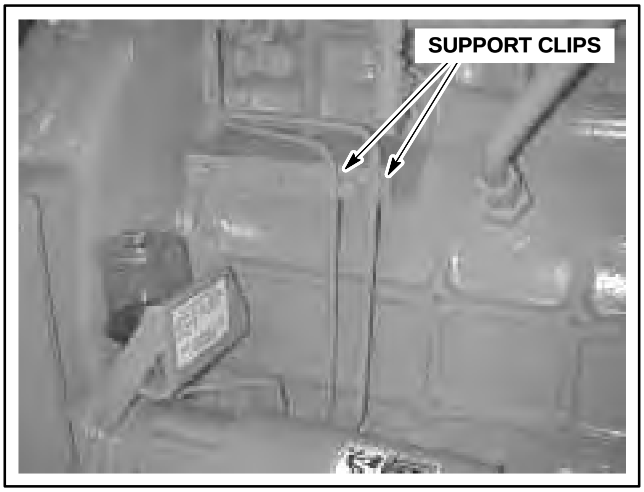


Figure 5.45-14. Air/Gas Starter Local Control Tubes

Additional clips hold the tubes together from the rear of the crankcase, over the flywheel housing. One set of clips fasten to a drilled hole in the rear lifting eye with a capscrew and spacer.

Control tubes are secured to the rear camshaft cover using a capscrew and spacer (see Figure 5.45-15).

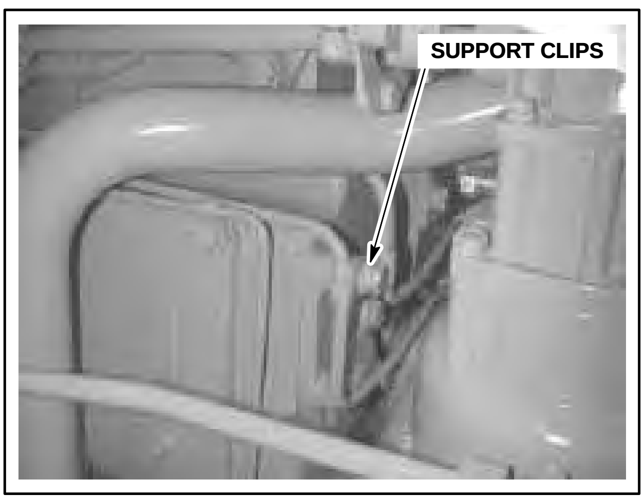


Figure 5.45-15. Air/Gas Starter Local Control Tubes

The starter control tubes are routed along the left side of the crankcase and installed on the control valve (see Figure 5.45-16).

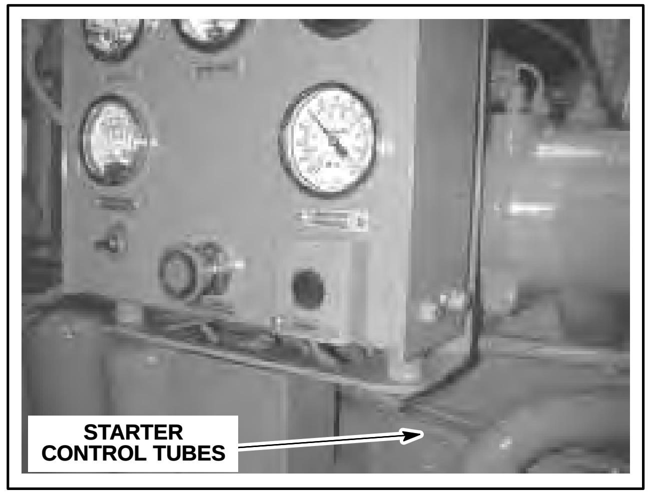


Figure 5.45-16. Air/Gas Starter Control

The remote start option for air/gas starters uses a solenoid valve mounted close to the starter (see Figure 5.45-17 and Figure 5.45-18). Different pressure supply and delivery tubes are used from the local control option.

The solenoid valve is mounted on a support bracket secured to the crankcase with M10 hex head screws (see Figure 5.45-17).

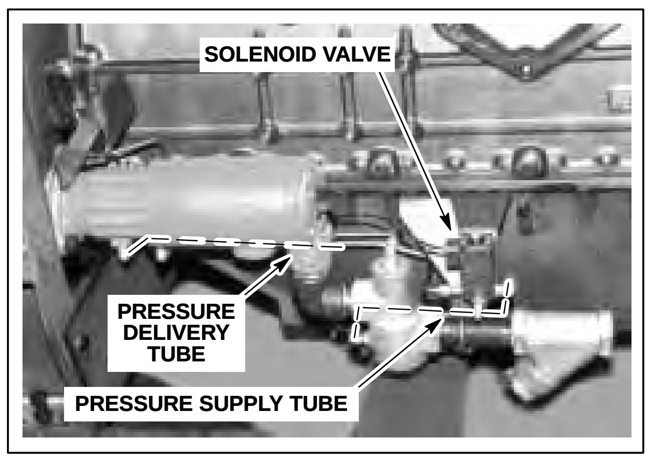


Figure 5.45-17. Remote Start Solenoid Valve

Secure the starter pressure delivery tube to the crankcase with a bracket and clip (see Figure 5.45-18).

AIR/GAS STARTER REMOTE START OPTION

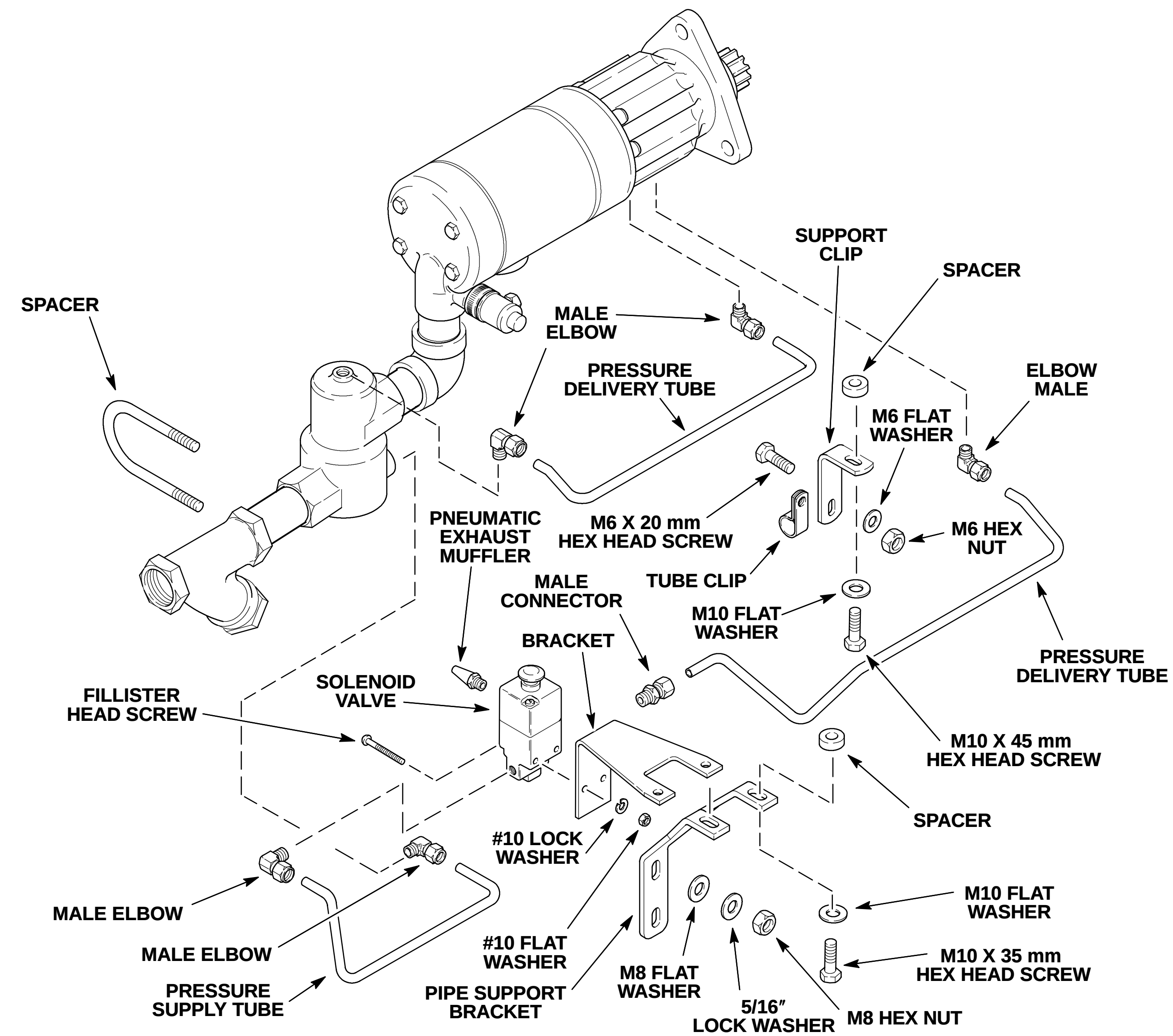


Figure 5.45-18. Air/Gas Starter Remote Start Option

ELECTRIC STARTER MAINTENANCE

⚠ WARNING

Battery fluid is a sulfuric acid solution which can cause serious personal injury or property damage. Wear appropriate, protective, personal equipment and do not allow battery fluid to contact skin, eyes or clothing. Do not allow smoking or open flame in battery charging areas. Always disconnect the battery ground connection before performing any work on an engine or equipment. This prevents sparks or burns if an electrical connection is shorted.

Inspect the starting circuit to make sure that all connections are clean and tight. Check for worn or damaged insulation on the wires.

ELECTRIC STARTER

ELECTRIC STARTER REMOVAL

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

1. Disconnect all electrical power supplies. Tag all electrical wires before removal to aid during installation.

2. Disconnect starter wires (see Figure 5.45-19).

3. Remove three hex head screws and lock washers. Remove starter from flywheel housing (see Figure 5.45-19).

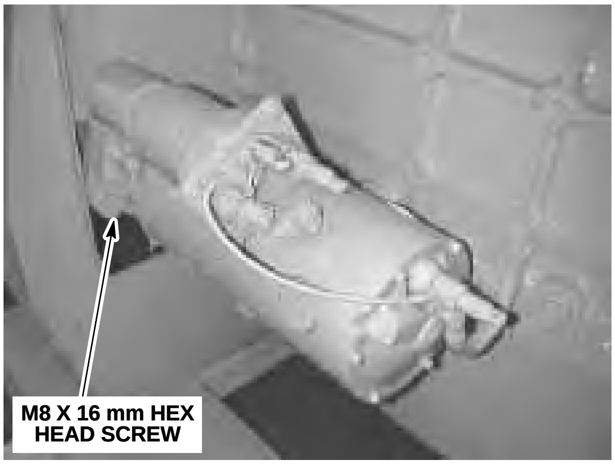


Figure 5.45-19. Electric Starter

ELECTRIC STARTER INSTALLATION

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

1. Disconnect all electrical power supplies.

2. Position starter on flywheel housing and secure with three M8 x 16 mm hex head screws and lock washers.

3. Refer to wire tags from starter removal and connect wires.

ALTERNATOR

ALTERNATOR SERVICING

The frequency of inspection is determined largely by the type of operating conditions. High speed operation, high temperatures and dust and dirt all increase the wear of brushes, slip rings and bearings.

At regular intervals, inspect the terminals for corrosion and loose connections. Inspect the wiring for frayed insulation, inspect the mounting bolts for tightness, and the belt for alignment, proper tension and wear. Belt tension should be adjusted on a routine basis (see Figure 5.45-20). Refer to "Alternator V‑belt Tension" in this section for further information.

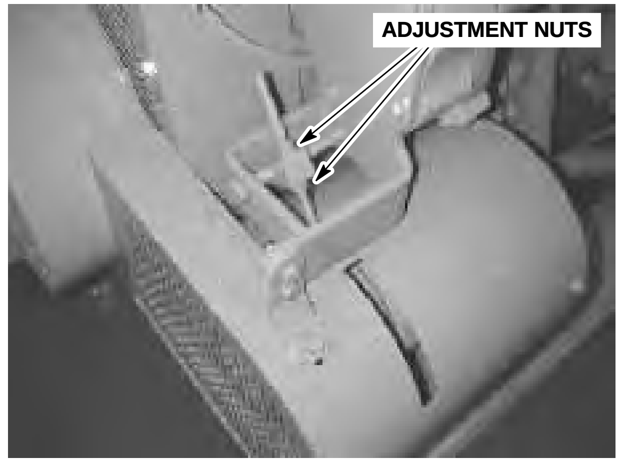


Figure 5.45-20. Alternator Adjustment

ALTERNATOR NOISE

Noise from an alternator may be caused by worn or dirty bearings, loose mounting bolts, a loose drive pulley, a defective diode, or a defective stator. Inspect for any of these causes and repair or replace as necessary.

V‑BELT MAINTENANCE

⚠ WARNING

To prevent severe personal injury or death, always stop the unit before cleaning, servicing or repairing the unit or any driven equipment.

1. Always use new, matching belt sets.

2. When replacing belts, always replace entire set of belts, not just the ones that look worn. This will ensure proper belt operation.

3. To check belt tension, depress belt with your fingers. A tensioned belt will feel alive and springy. Belts that are too tight will will not deflect and loose belts will feel dead.

4. Keep belts at proper tension. New belts will stretch shortly after installation. Loose belts will slip, causing power loss and heat buildup. Belts that are too tight will deteriorate rapidly and wear out engine shaft bearings.

5. To avoid belt damage, always loosen pulley adjustment when installing belts. Never pry a belt off a pulley.

ALTERNATOR V-BELT TENSION

1. Loosen lock nut on upper end of adjusting rod. Adjust belt tension with lower nut on adjusting rod (see Figure 5.45-21).

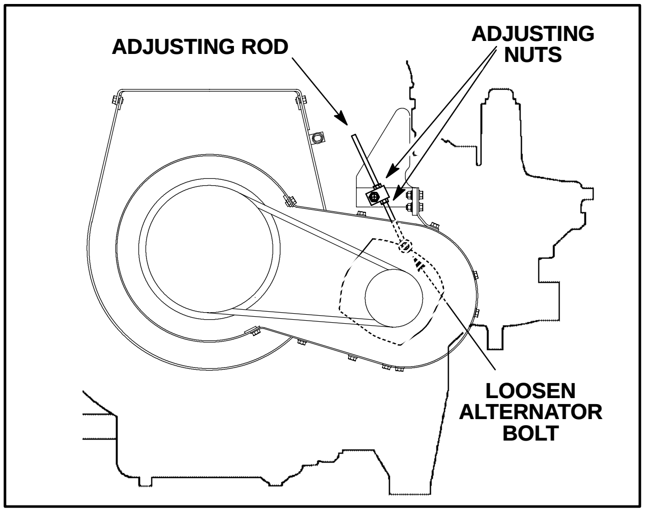


Figure 5.45-21. Alternator Belt Adjustment

2. When desired belt tension is reached, tighten adjusting rod lock nut and capscrew.

NOTE: *A new set of belts are adjusted to a greater tension due to tension loss which occurs during break-in.*

NOTE: *These belts are a matched set and must be replaced as a pair to ensure proper operation.*

ALTERNATOR INSTALLATION

The alternator is driven by a pulley fastened to the crankshaft through the vibration dampener (see Figure 5.45-23 and Figure 5.45-25).

NOTE: *Install the alternator mounting bracket before installing the vibration dampener on H24 engines. There is not enough clearance to install the hex head screws between the vibration dampener and gear housing.*

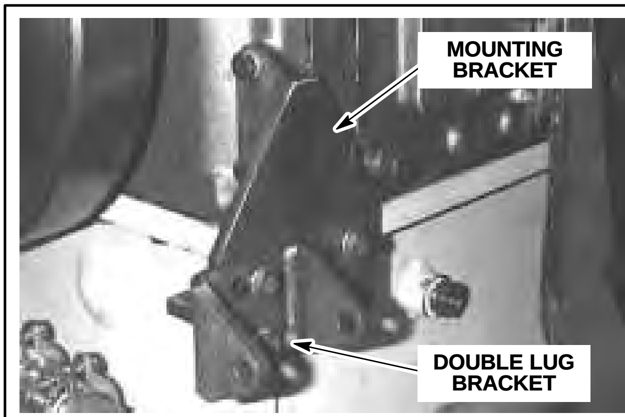


Figure 5.45-22. Alternator Mounting Brackets

1. Secure alternator drive pulley onto vibration dampener with M12 x 80 mm Grade 12.9 hex head screws. Tighten hex head screws to 101 ft-lb (137 N·m).

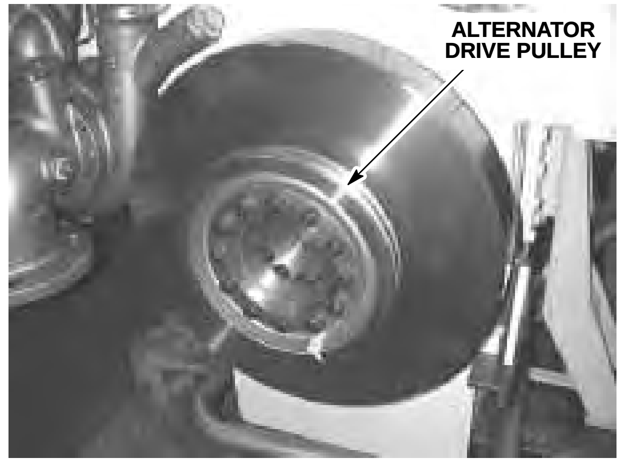


Figure 5.45-23. Alternator Drive Pulley

2. Secure mounting bracket onto gear housing with two M10 x 100 mm hex head screws (see Figure 5.45-22 and Figure 5.45-25). Install double lug bracket onto mounting bracket.

3. Install adjusting bracket onto gear housing with three M10 x 85 mm hex head screws (see Figure 5.45-24). Secure adjusting block with a M12 x 130 mm hex head screw.

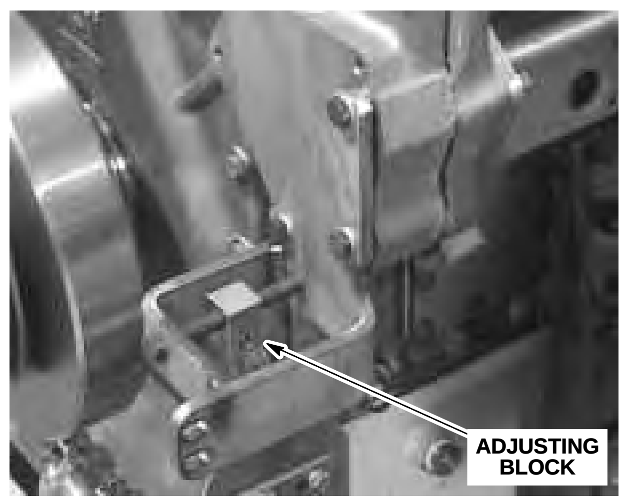


Figure 5.45-24. Alternator Adjusting Bracket

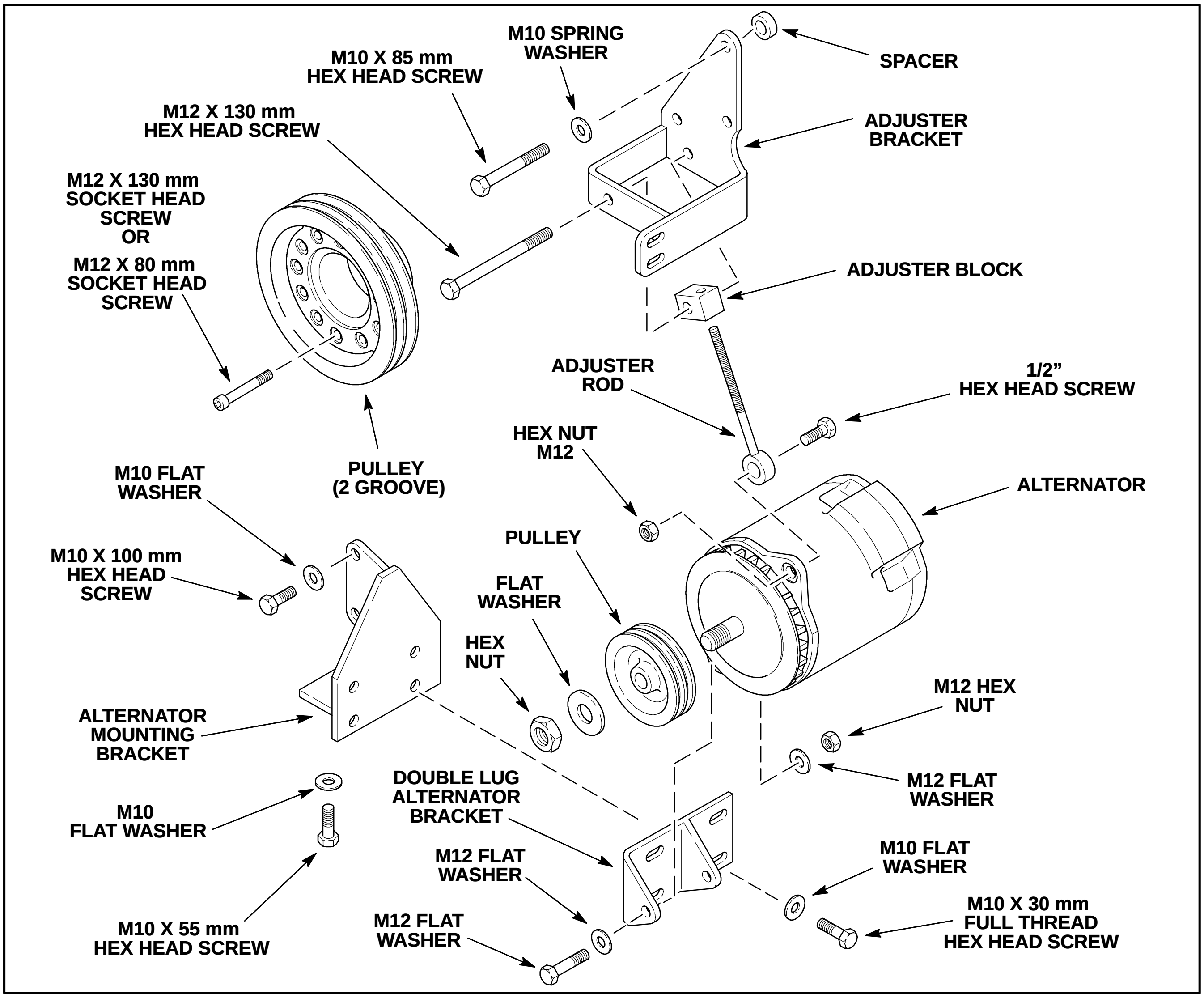


Figure 5.45-25. 24 Volt Alternator Installation

4. Secure alternator onto double lug bracket with two M12 x 50 mm hex head screws and lock washers. Install adjuster rod through adjuster block and alternator (see Figure 5.45-26). Make sure M8 hex nuts are located on either side of adjuster block.

5. Install matched drive belts on alternator and drive pulley.

6. See Section 6.10 *Miscellaneous Equipment* for alternator guard installation.

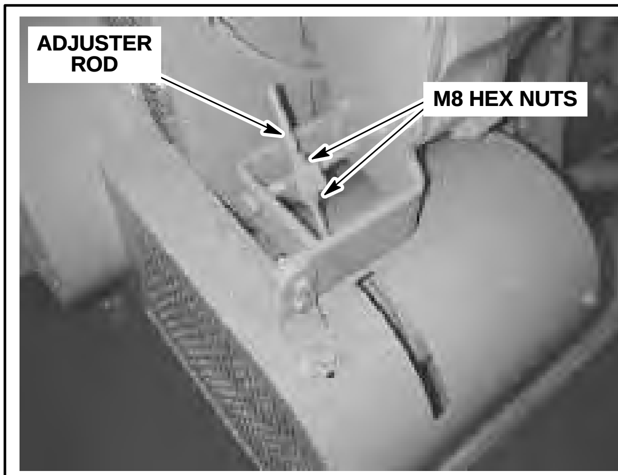


Figure 5.45-26. Alternator Adjustment

SECTION 6.00

INSTRUMENT PANEL

INSTRUMENT PANEL

COMPONENTS

The control panels consist of the following components.

- Starter Push Button Valve
- Ignition Push Button Switches
- Control Panel Housings
- Gauges

The instrument panel is mounted on the front of the intake manifold (see Figure 6.00-1).

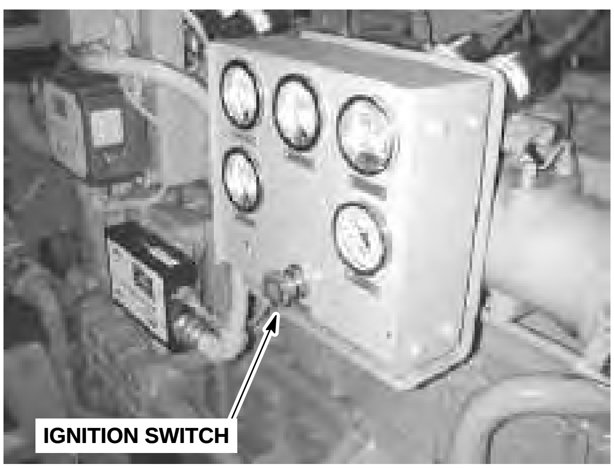


Figure 6.00-1. Control Panel

INSTRUMENT PANEL REMOVAL

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

NOTE: *Tag all tubes, lines and wires before removal to aid during assembly.*

1. Tag and disconnect wires from ignition switch (see Figure 6.00-2).

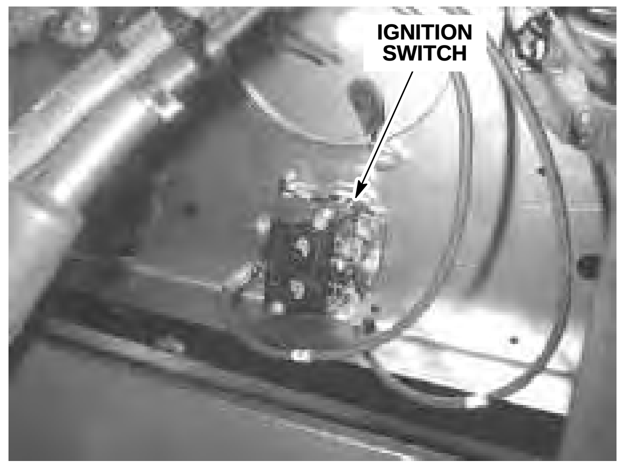


Figure 6.00-2. Ignition Switch

2. Remove nut, locking ring, switch and foam gasket from ignition switch. Remove ignition switch (see Figure 6.00-3).

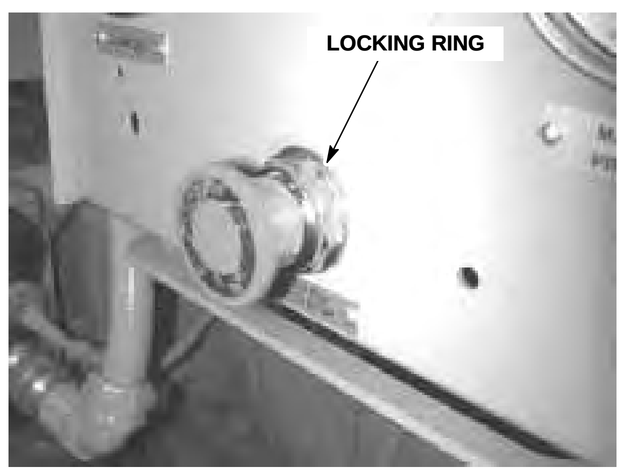


Figure 6.00-3. Ignition Switch

3. Loosen nut and remove reset button (see Figure 6.00-4).

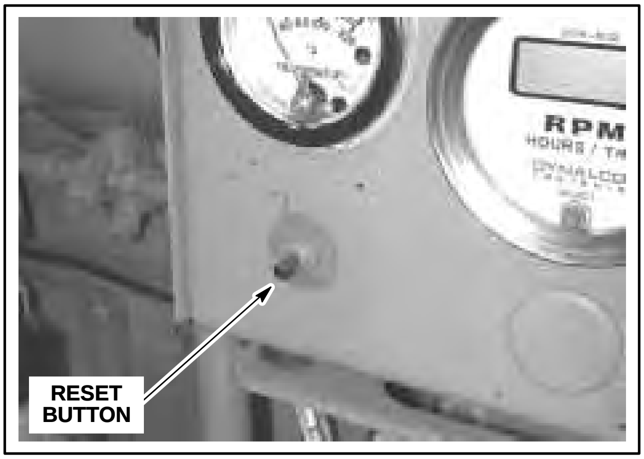


Figure 6.00-4. Control Panel

4. Disconnect wires from both temperature gauges (see Figure 6.00-5). Disconnect flexible hose from oil pressure gauge.

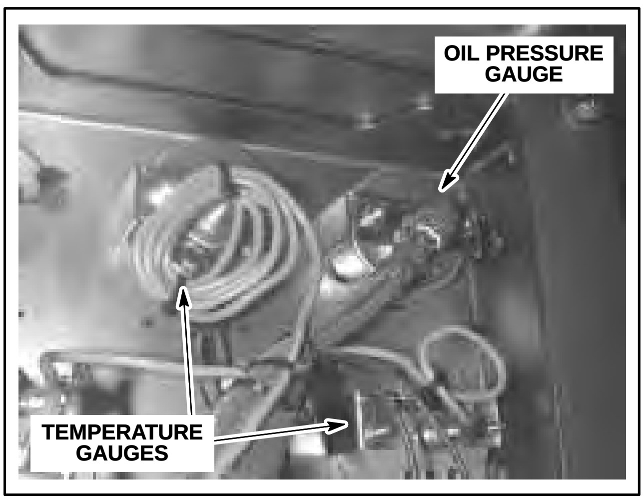


Figure 6.00-5. Temperature and Oil Pressure Gauge

5. Remove intake manifold pressure gauge connections from both left and right manifolds (see Figure 6.00-6).

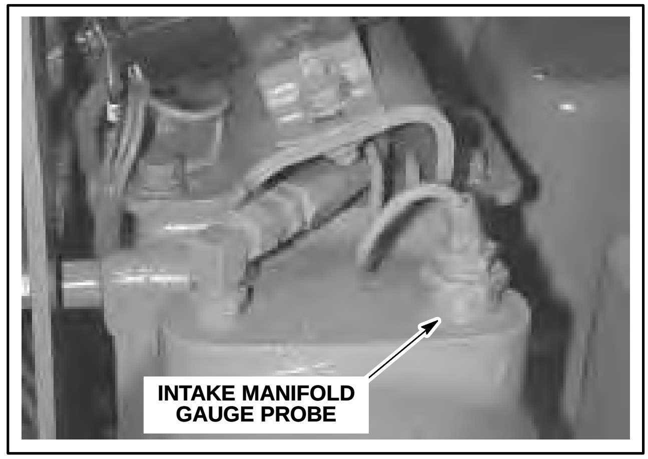


Figure 6.00-6. Manifold Pressure Gauge Connections

6. **Bracket and Panel—**Remove M8 x 35 mm hex head screws and flat washers (see Figure 6.00-7).

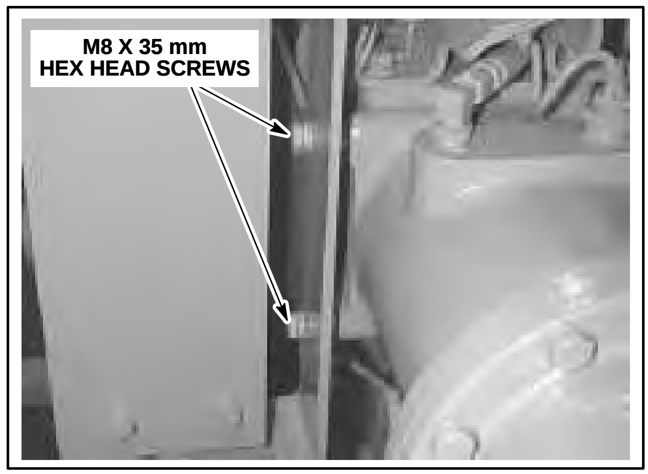


Figure 6.00-7. Instrument Panel

7. **Panel—**Remove hex nuts (upper and lower) to remove instrument panel (see Figure 6.00-8).

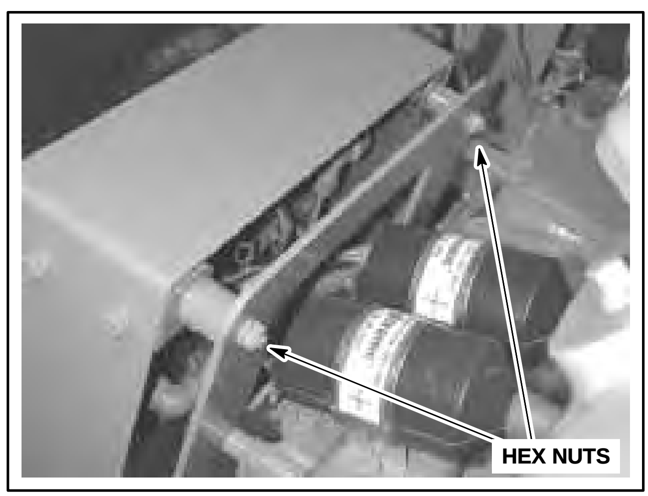


Figure 6.00-8. Instrument Panel

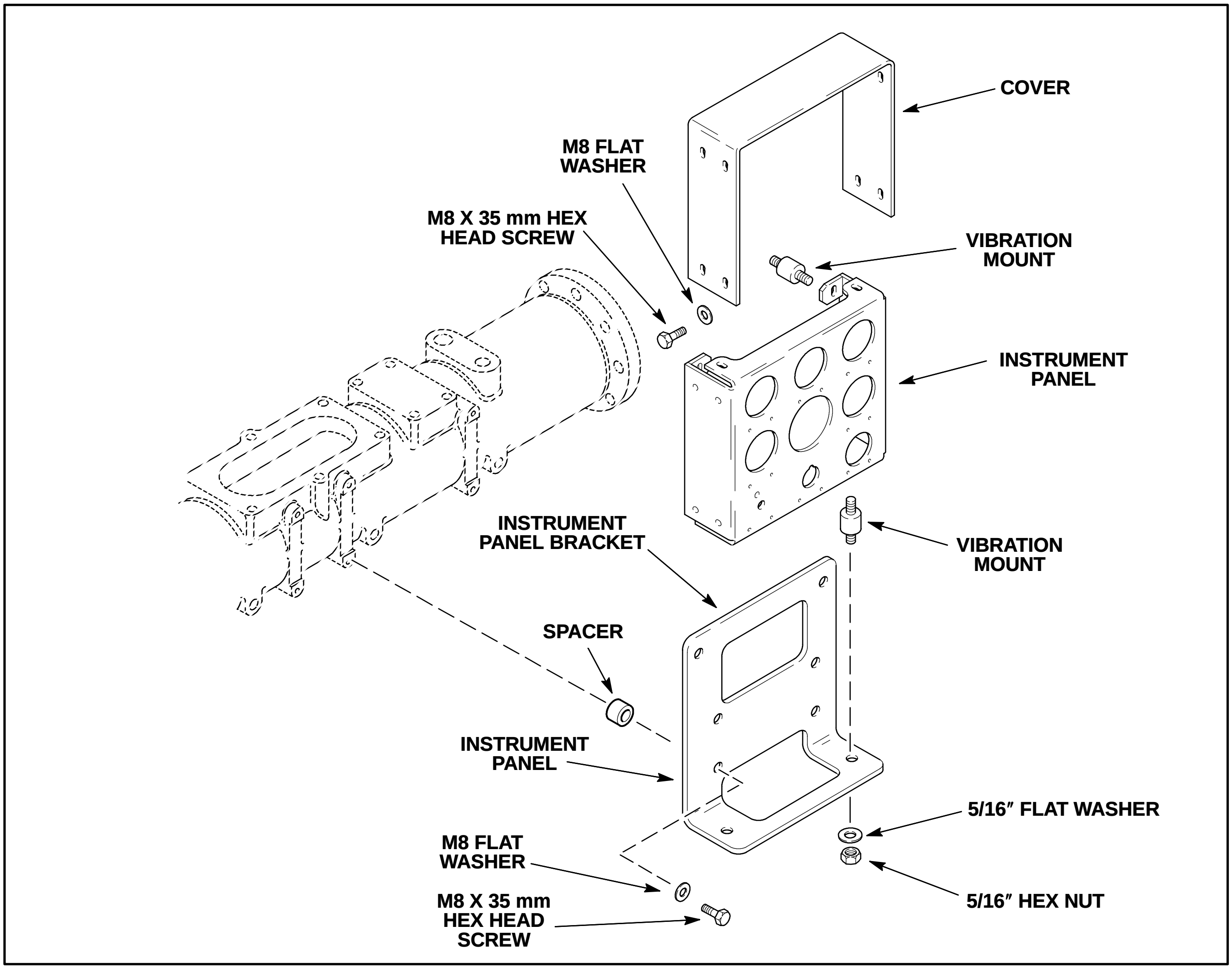


Figure 6.00-9. Instrument Panel Installation

INSTRUMENT PANEL INSTALLATION

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

NOTE: *Install the gauges, control switches and vibration mounts on the instrument panel before installing the panel on the mounting bracket.*

1. Secure control panel bracket onto intake manifold using four M8 x 35 mm hex head screws, flat washers and spacers (see Figure 6.00-10). If applicable, secure ground wire with hex head screw.

2. Secure panel cover onto control panel using four hex head screws and lock washers.

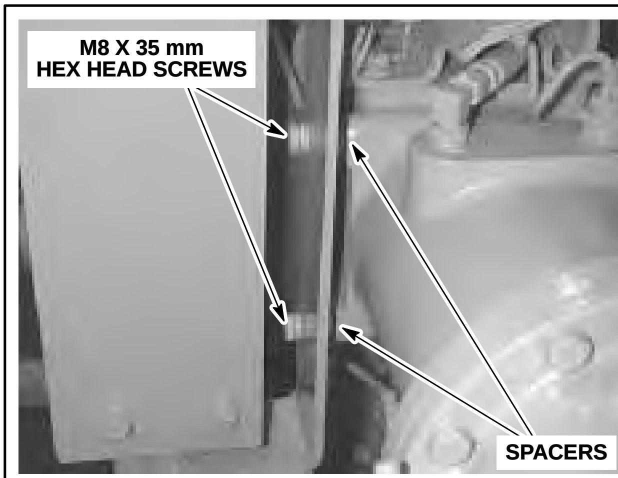


Figure 6.00-10. Instrument Panel

Auxiliary Control Panel

An auxiliary panel is available for additional gauges (see Figure 6.00-11). The auxiliary panel is bolted to the control panel, requiring a different panel cover.

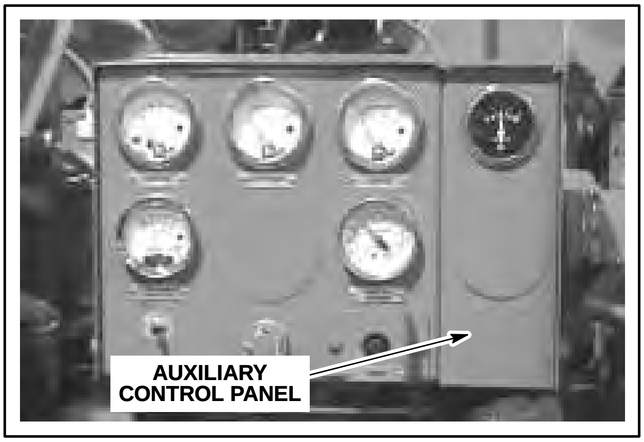


Figure 6.00-11. Auxiliary Control Panel

INSTRUMENT PANEL GAUGE INSTALLATION

Oil Temperature Gauge

1. Install oil temperature gauge probe inside of oil filter housing (see Figure 6.00-12).

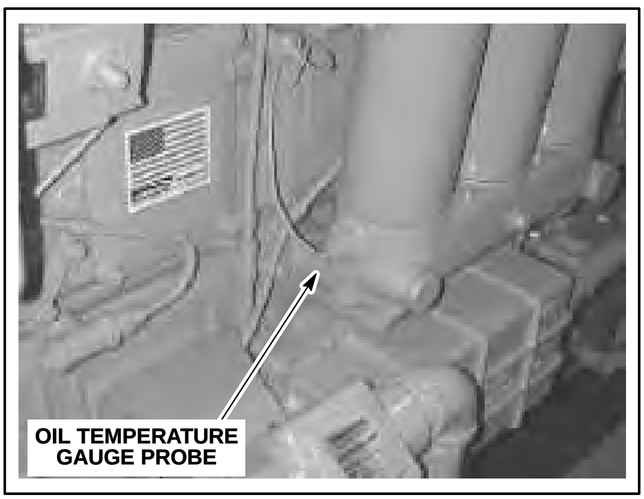


Figure 6.00-12. Oil Temperature Gauge Probe

2. Install clip around wire. Secure clip to connecting rod inspection cover with M10 x 20 mm hex head screw (see Figure 6.00-13).

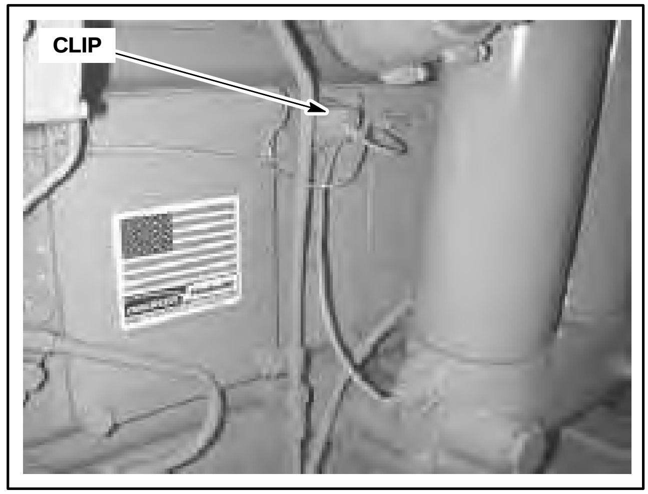


Figure 6.00-13. Oil Temperature Gauge Probe

3. Secure wiring into a bundle using tie wraps (see Figure 6.00-14).

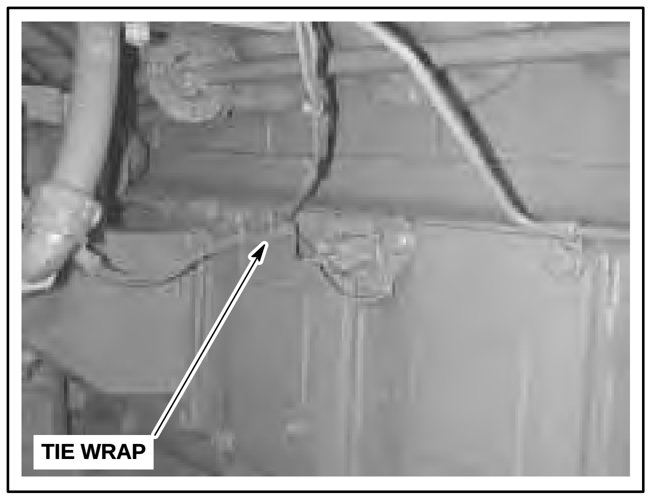


Figure 6.00-14. Oil Temperature Gauge Wiring

4. Secure any excess wiring with tie wraps at back of gauge (see Figure 6.00-15).

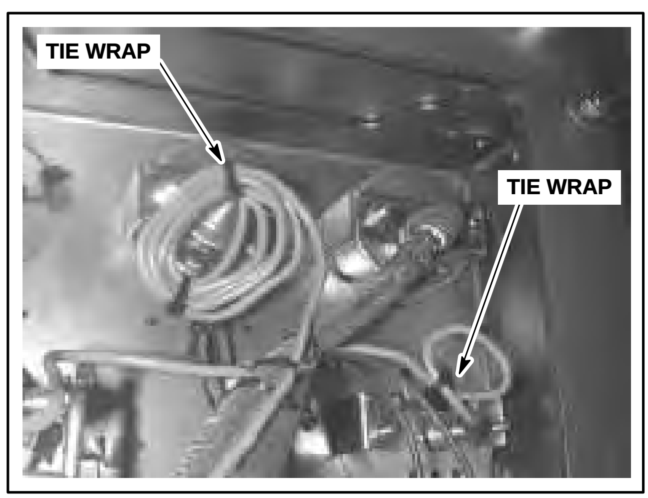


Figure 6.00-15. Control Panel – Rear View

Jacket Water Temperature

1. Install jacket water temperature gauge probe inside of jacket water thermostat housing (see Figure 6.00-16).

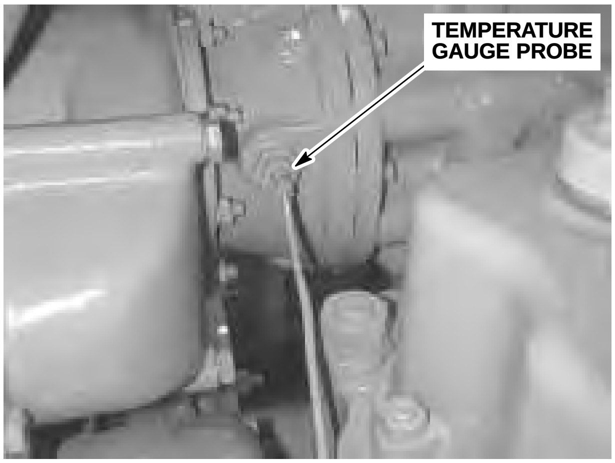


Figure 6.00-16. Jacket Water Temperature Gauge

2. Install gauge and secure excess wiring with tie wraps (see Figure 6.00-17).

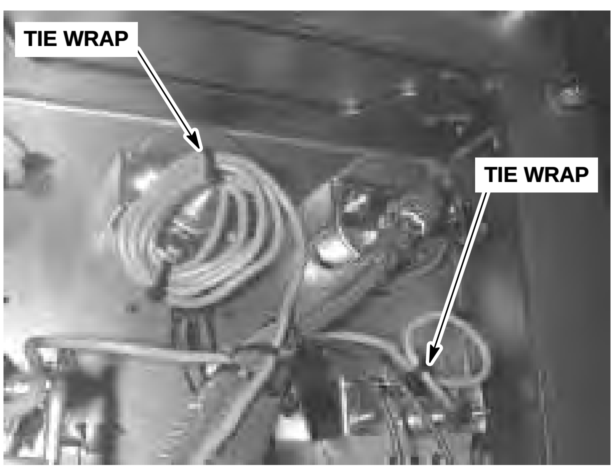


Figure 6.00-17. Control Panel – Rear View

Tachometer/Hourmeter

The magnetic speed sensor reads engine speed from the flywheel teeth for use with the electric tachometer (see Figure 6.00-18).

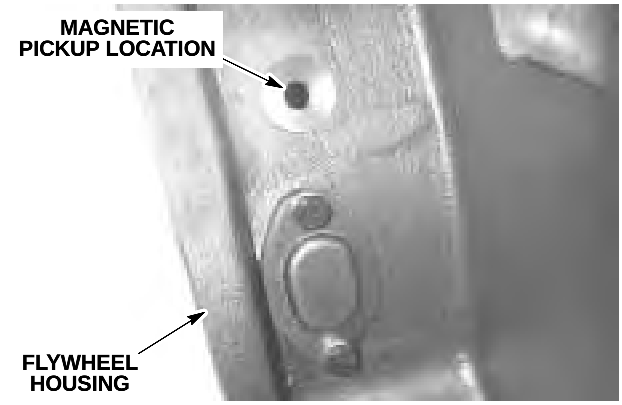


Figure 6.00-18. Tachometer Magnetic Pickup Location

NOTE: *A second sensor port is located at the bottom of the flywheel housing, below the barring device (see Figure 6.00-19).*

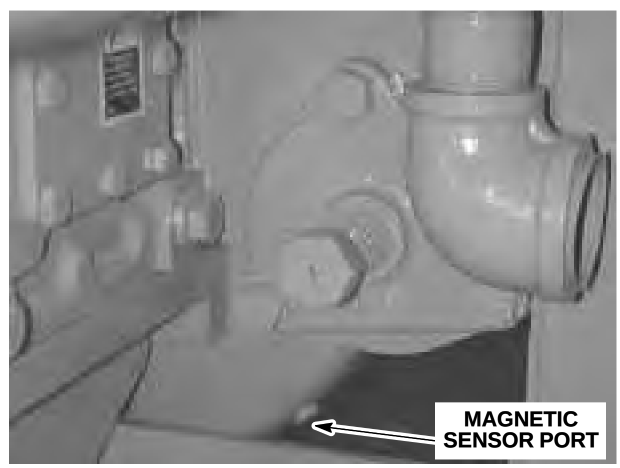


Figure 6.00-19. Alternative Speed Sensor Location

Tachometer/Hourmeter Gauge Installation

1. Locate installation hole on flywheel housing (see Figure 6.00-18).

NOTE: *Do not adjust the speed sensor gap when the engine is running or damage to the sensor will occur.*

2. Rotate flywheel until one tooth is centered in sensor hole (see Figure 6.00-20).

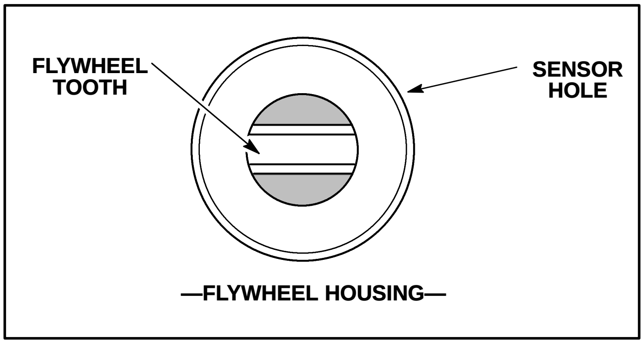


Figure 6.00-20. Ring Gear Tooth Alignment

⚠ CAUTION Always follow recommended procedures for magnetic pickup sensor installation. If the top of the flywheel tooth is able to make contact with the sensor "pole face" (bottom), then rotation of the flywheel will damage the pickup sensor.

3. Thread sensor (magnetic pickup) into flywheel housing hole until "pole face" makes contact with flywheel tooth, **then back sensor out 1/4 turn** (see Figure 6.00-21).

NOTE: *The above procedure will ensure the required pole face clearance, 0.012 – 0.020 in. (0.3 – 0.5 mm), is maintained. A feeler gauge can only be used if the driven equipment is removed.*

4. **Engine driven equipment removed—**Measure gap between pole face and ring gear tooth with feeler gauge. Gap must be 0.012 – 0.020 in. (0.3 – 0.5 mm), readjust if necessary (see Figure 6.00-21).

5. Tighten jam nut (7/8 inch hex) against flywheel housing. **Do not allow sensor to turn while tightening jam nut.**

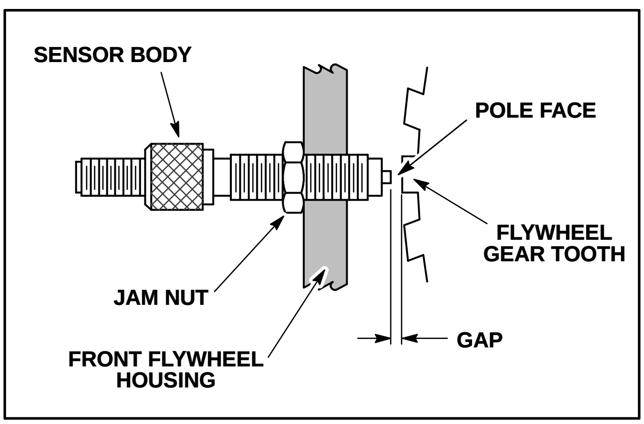


Figure 6.00-21. Install Pickup Sensor

6. Connect pickup harness to tachometer. Tachometer operation requires a minimum of 1.5 volts AC from sensor.

7. Secure excess wiring with tie wraps.

Intake Manifold Temperature Gauge

1. Install manifold temperature gauge probe into rear intake manifold (see Figure 6.00-22). Apply pipe sealant to threads.

Figure 6.00-22. Manifold Pressure Gauge Connections

2. Secure any excess wiring with tie wraps at back of gauge (see Figure 6.00-23).

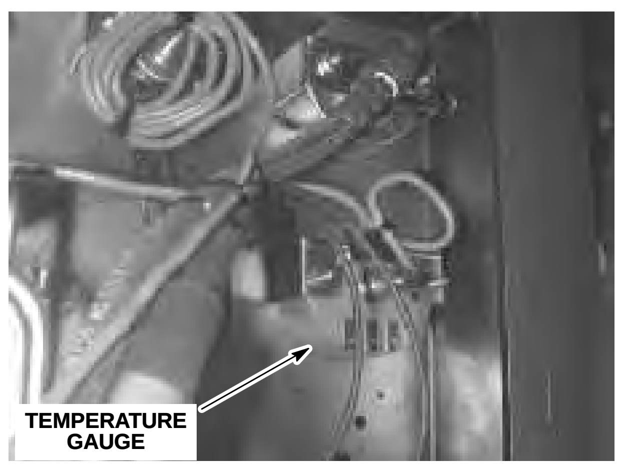


Figure 6.00-23. Manifold Temperature Fitting

Oil Pressure Gauge

1. Oil pressure gauge connection is installed onto standard oil supply elbow at rear of crankcase (see Figure 6.00-24).

2. Apply pipe sealant to all threads of reducer bushings and pipe adapters. Secure tubing to camshaft inspection covers with retaining clip (see Figure 6.00-24).

Figure 6.00-24. Oil Gauge Supply Tube

3. Install elbow onto oil pressure gauge in instrument panel (see Figure 6.00-25). Elbow must point down.

4. Secure oil pressure tube onto elbow (see Figure 6.00-25).

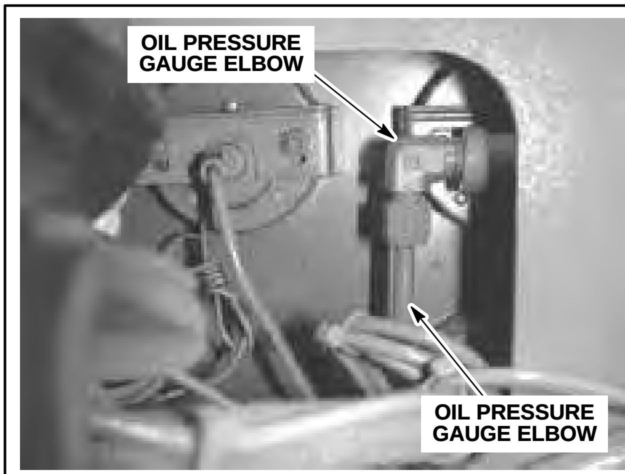


Figure 6.00-25. Oil Pressure Gauge

Intake Manifold Pressure Gauge Installation

1. Apply pipe sealant and install adapter, elbow and flexible hose onto intake manifold. Install flexible hose onto elbow (see Figure 6.00-26).

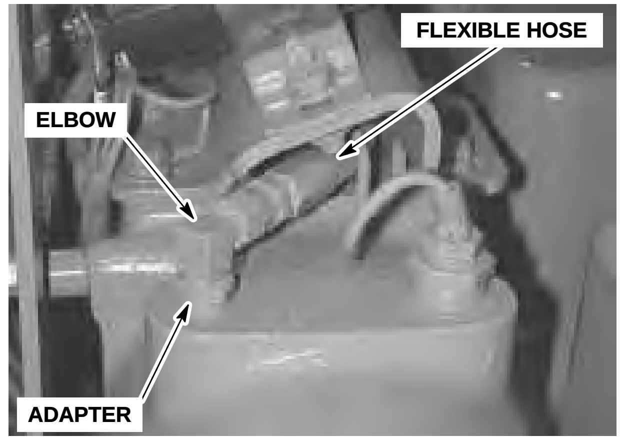


Figure 6.00-26. Manifold Pressure Gauge Connections

Ignition Switch Installation

1. Connect wires to ignition switch. Refer to wire tags to aid installation (see Figure 6.00-27).

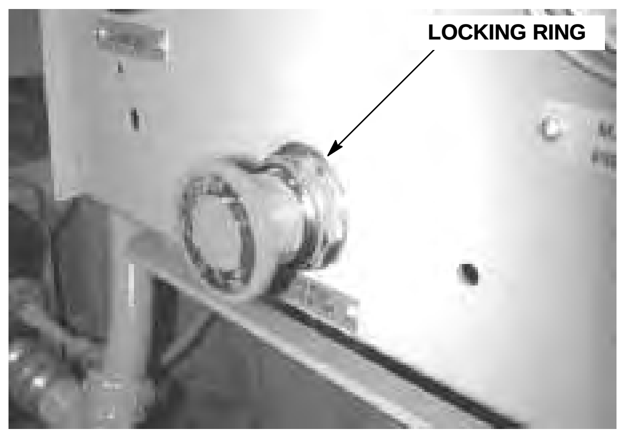


Figure 6.00-27. Ignition Switch

NOTE: *The air/gas starter control valve is installed on the instrument panel before mounting the panel on the support bracket (see Figure 6.00-28). See Section 5.45* Starting System *for air/gas starter instructions.*

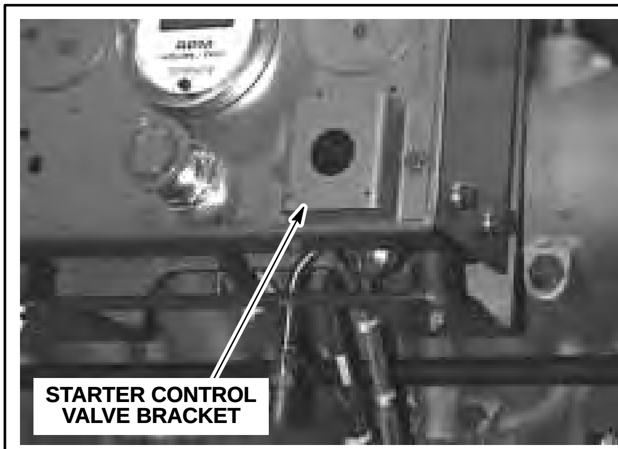


Figure 6.00-28. Air/Gas Starter Control Valve And Vent

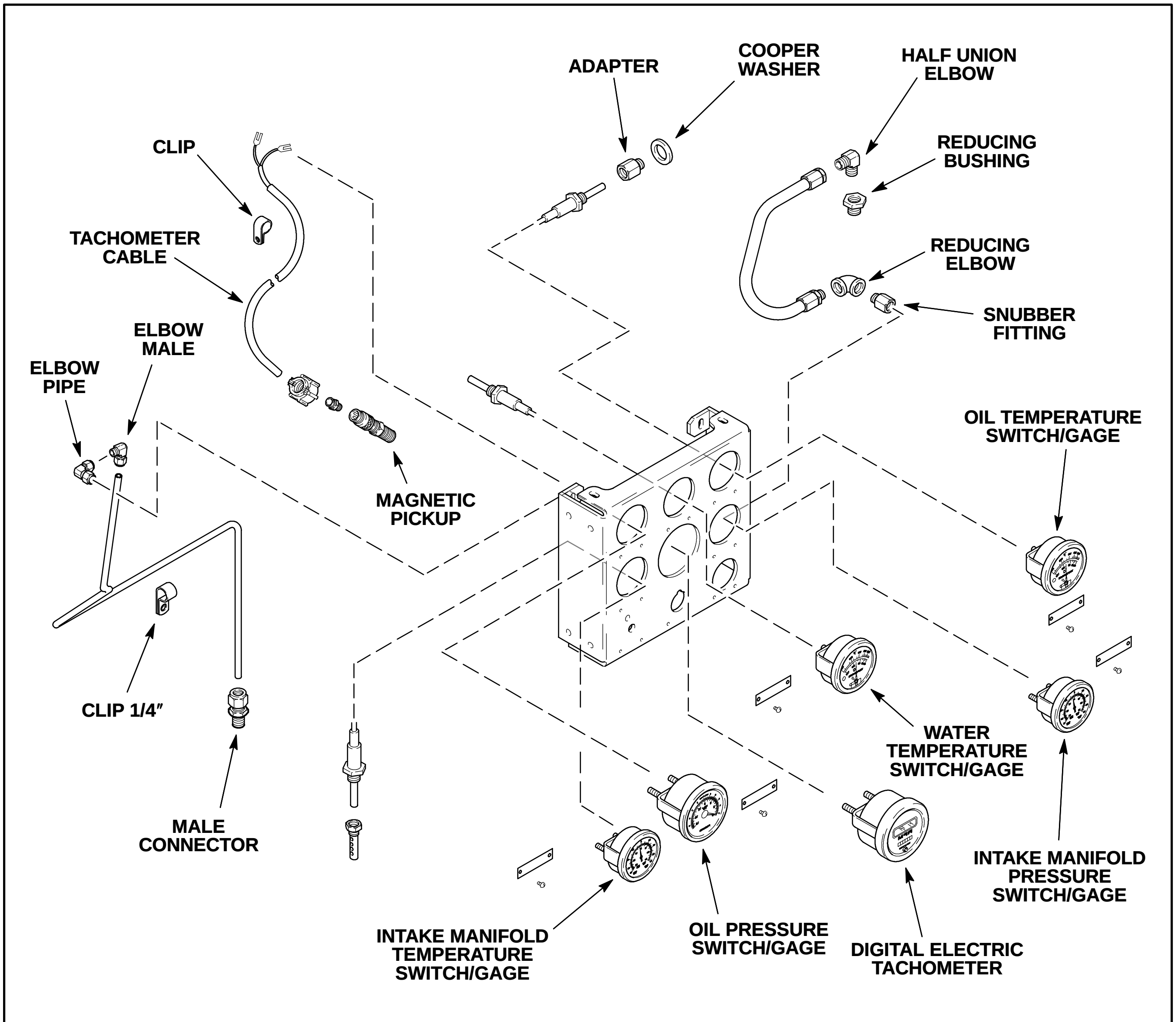


Figure 6.00-29. Instrument Panel Gauge Installation

2. Install ignition reset switch onto lower left corner of control panel (see Figure 6.00-30).

The gauges have specific locations in the control panel (see Figure 6.00-29). Locations are determined by wire and tube routing requirements.

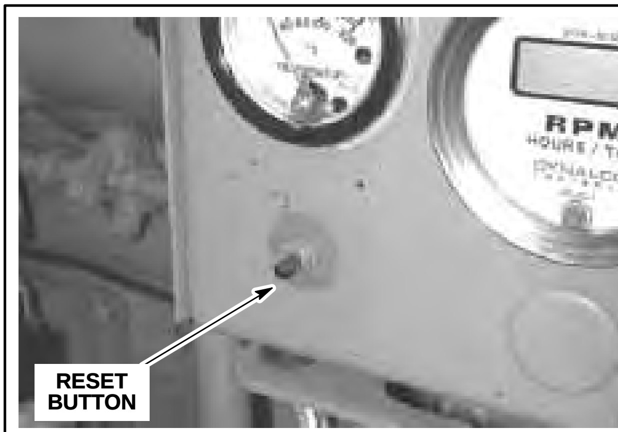


Figure 6.00-30. Control Panel Reset Switch

SECTION 6.05

ENGINE PROTECTION SYSTEMS

ENGINE PROTECTION SYSTEM OPERATION

MANUAL SHUTDOWN LEVER

⚠ WARNING

Always ensure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.

All engines have a manual shutdown lever located on the intake manifold elbow (Figure 6.05-1). This lever will return the engine to idle speed. Under some conditions, the engine may shut down completely when using these levers. After the engine reaches idle speed, close the fuel gas valve to completely shut down the engine. Always close the fuel gas supply after engine shutdown.

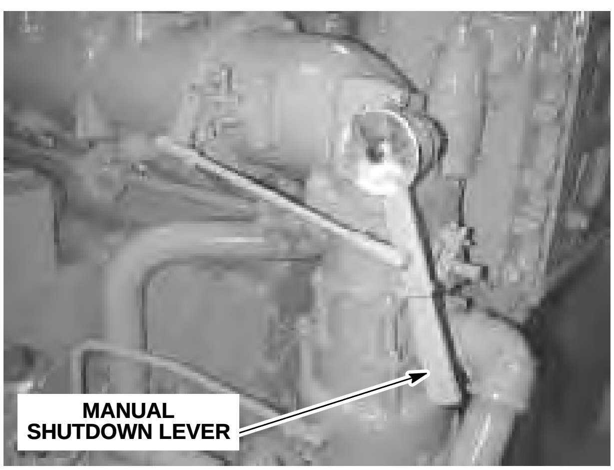


Figure 6.05-1. Manual Shutdown Lever

CONTROL SWITCHES

IGNITION SWITCH

⚠ WARNING

Always ensure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.

IGNITION (Emergency Stop) switch is located on the left side of the engine (Figure 6.05-2). Depressing an IGNITION (Emergency Stop) switch will stop the engine by de-energizing the ignition and electrical fuel supply solenoid valves. Always close the fuel gas supply after engine shutdown. To restart the engine after depressing IGNITION (Emergency Stop) switch, pull the depressed shutdown switch back out to its original position.

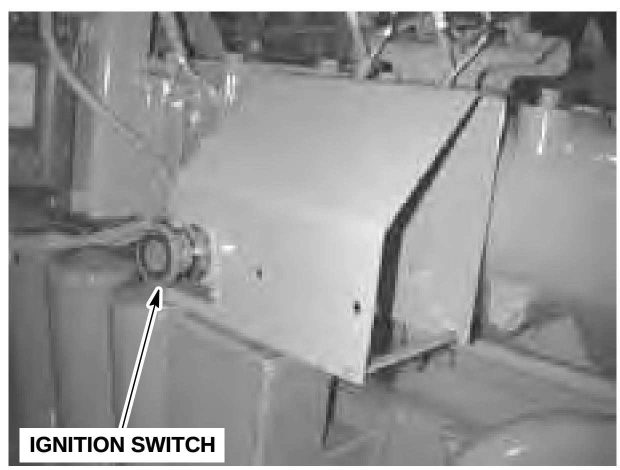


Figure 6.05-2. Ignition Switch

CUSTOMER SUPPLIED SAFETY SHUTDOWN SWITCHES

The control switches that make up the engine protection shutdown system must be supplied by the customer. Waukesha provides the following:

- Sensors and Thermocouples
- Thermocouple Junction Box
- Manual Shutdown Switches

WARNING

Switches for alarms and automatic engine shutdown must be supplied by the customer. The sensors provided are for measuring and monitoring temperatures and WILL NOT shut the engine down if potentially harmful temperatures are reached. Waukesha will not be responsible for any property damage or severe personal injury or death, due to the failure to follow these instructions.

Safety shutdown switches must be supplied by the customer. Safety shutdown switches must include, but are not limited to: low oil pressure, high coolant temperature, high lube oil temperature, high intake manifold air temperature, and an overspeed switch. Switches should be wired to an alarm to warn of high temperatures and low pressure, as well as provide for automatic engine shutdown if potentially harmful temperatures, pressure, or overspeed conditions exist.

NOTE: *The customer supplied control switches must be incorporated into the remote engine control panel logic.*

OPTIONAL INSTRUMENT PANEL

Waukesha Engine offers an optional instrument panel (see Figure 6.05-3).

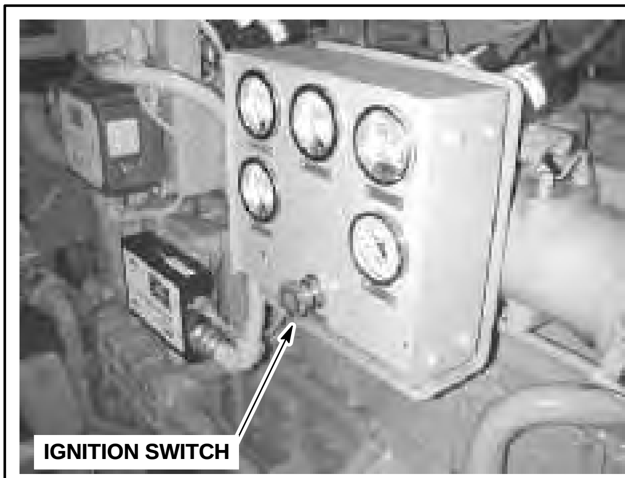


Figure 6.05-3. Optional Instrument Panel

The instrument panel includes switchgages for jacket water temperature, lube oil pressure, intake manifold temperature, intake manifold pressure, tachometer and hourmeter.

PRESSURE AND TEMPERATURE SWITCH CALIBRATION

A qualified service technician should test and calibrate the pressure and temperature switchgages every 90 days.

CAUTION **Switches that respond to low oil pressure or high jacket water temperature are required for unattended engine operation. Additional safety switches may be needed depending on engine configuration. Disregarding this information could result in product damage and/or personal injury.**

WARNING

Always ensure that the fuel gas valve(s) are closed after engine shutdown. Failure to close fuel gas valve(s) could cause severe personal injury or death.

Automatic shutdown devices consist of two main parts:

- A sending unit which is inserted into water jacket, lubrication system, or other system to be monitored.
- A set of contact points located in the switchgage or related device (see Figure 6.05-4).

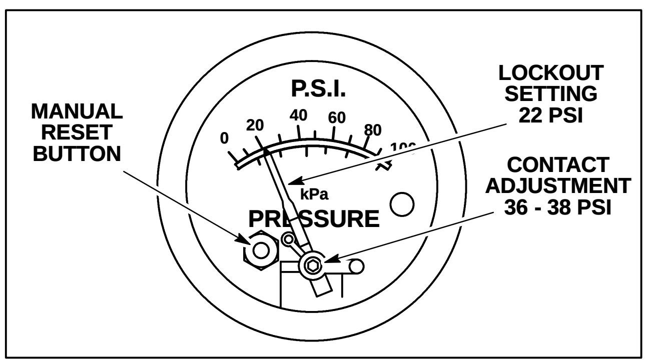


Figure 6.05-4. Typical Switchgage

This system is used as protection against the possibility of the engine continuing to run after the loss of oil pressure, high intake manifold temperature, or overheating of the cooling system. If the oil pressure drops below a set value or the water temperature or intake manifold above a set value, the switchgage contacts will close and trip the gas valve to shut off the engine fuel supply.

The Switchgage could also be connected to the magneto, in which case the gauge will ground out the magneto through the safety adapter as well as tripping the fuel shutoff valve. This stops the magneto from producing ignition current and turns off the fuel supply.

In either case, the engine is stopped before extensive engine damage can occur.

Table 6.05-1 lists “Alarm” and “Shutdown” setpoints for various engine operating parameters. These values can be used as a guide when designing engine protection or monitoring systems.

The “Alarm” values shown are suggested values; they can be changed to suit a specific application or measurement device.

⚠ WARNING

Do not allow an engine to operate in excess of temperature shutdown limits or below pressure shutdown limits. Engine shutdown limits are set to ensure the engine will operate within its designed parameters. Engine operation outside of the shutdown limits may cause severe engine damage, severe personal injury or death.

The temperature “shutdown” values shown in the tables are maximum permissible values which cannot be exceeded regardless of application. The pressure “shutdown” values shown in the tables are minimum permissible values which cannot be reduced regardless of application.

Alarm and shutdown values shown are based on dry natural gas (900 Btu/cu. ft. SLHV). Refer to the following Specification Sheets and Service Bulletins (latest revision) for changes in operating temperatures when running on landfill or digester gas fuels.

- Specification Sheets - S7884-7 and S1015-29
- Service Bulletins - 9-2702A and 12-1880Y

By utilizing controls which simultaneously shut off the fuel supply and ignition system upon reaching a “shutdown” value, the potential for engine damage is reduced.

⚠ CAUTION **When setting engine overspeed shutdown, do not exceed the lesser of engine or driven equipment’s speed limits. To avoid equipment damage consult the driven equipment manufacturer for maximum overspeed value.**

NOTE: *Switchgages are not approved for or supplied with CSA approved ignition equipped engines.*

RECOMMENDED SHUTDOWN LIMITS

Table 6.05-1. VGF Shutdown Limits

JACKET WATER OUTLET TEMPERATURE	
Standard Cooling System (176 BMEP Engines)	
Normal	180° F (82° C) for continuous rating 200° F (93° C) for intermittent rating
Alarm	10° F (5.5° C) above normal/design temperature
Shutdown	20° F (11° C) above normal/design temperature
Elevated Temperature Solid Water Cooling System (176 BMEP Engines)	
Normal	210° F - 265° F (99° C - 130° C) solid water
Alarm	5° F (3° C) above normal/design temperature[1]
Shutdown	10° F (5.5° C) above normal/design temperature [1]
Elevated Temperature Solid Water Cooling System (200 BMEP Engines)	
Normal	210° F (99° C) solid water
Alarm	10° F (5.5° C) above normal/design temperature[1]
Shutdown	15° F (8.5° C) above normal/design temperature [1]
LUBE OIL HEADER TEMPERATURE	
With A Jacket Water Temperature of 180° F (82° C) And Intercooler Temperature Of 85° F - 130° F (29° C - 54° C) (176 BMEP Engines Only)	
Normal	170° F - 195° F (76.5° C - 90° C)
Alarm	200° F (93° C)
Shutdown	205° F (96° C)
With A Jacket Water Temperature of 265° F (129° C) And Intercooler Temperature Of 85° F - 130° F (29° C - 54° C) (176 BMEP Engines Only)	
Normal	170° F - 195° F (76.5° C - 90.5° C)
Alarm	200° F (93° C)
Shutdown	205° F (96° C)
With A Jacket Water Temperature of 210° F (99° C) And Intercooler Temperature Of 158° F - 176° F (70° C - 80° C) (200 BMEP GLD Engines Only)	
Normal	190° F (88° C)
Alarm	200° F (93° C)
Shutdown	205° F (96° C)
LUBE OIL HEADER PRESSURE	
Normal	67 - 83 psi (462 - 572 kPa)
Alarm	40 psi (276 kPa)
Shutdown	35 psi (241 kPa)
INTAKE MANIFOLD TEMPERATURE	
With Standard Intercooler Water Temperatures 85° F - 130° F (29° C - 54° C) (176 BMEP GL/GLD/GSID Engines)	
Normal	Up to 10° F (5.5° C) above design intercooler water inlet temperature
Alarm	15° F (8.5° C) above design intercooler water inlet temperature
Shutdown	20° F (11° C) above design intercooler water inlet temperature

(Continued)

With Elevated Intercooler Water Temperatures 131° F – 176° F (55° C – 80° C) (176 BMEP GL/GLD/GSID Engines)	
Normal	Up to 10° F (5.5° C) above design intercooler water inlet temperature
Alarm	10° F (5.5° C) above design intercooler water inlet temperature
Shutdown	15° F (8.5° C) above design intercooler water inlet temperature
With Elevated Intercooler Water Temperatures 158° F – 176° F (70° C – 80° C) (200 BMEP GLD Engines Only)	
Normal	Up to 10° F (5.5° C) above design intercooler water inlet temperature
Alarm	10° F (5.5° C) above design intercooler water inlet temperature
Shutdown	15° F (8.5° C) above design intercooler water inlet temperature
INTAKE MANIFOLD PRESSURE	
See SB 14–2749D “Formulas For Predicting BHP And Intake Manifold Pressure” or most current revision	
MAIN BEARING TEMPERATURE	
Shutdown	Contact Waukesha Engine Sales Engineering
OVERSPEED	
Shutdown	Not to exceed 15% over governed speed or drive machine limits

NOTE: *[1] Waukesha Power Systems Code 1105, 1105A, or equivalent pressure/temperature shutdown system is recommended when jacket water temperature exceeds 210° F (99° C).*

THERMOCOUPLES

THERMOCOUPLE REPLACEMENT

Waukesha recommends that K–type exhaust thermocouple leads with quick disconnect plugs be used on all engines (see Figure 6.05-5). Keep spare K–type exhaust thermocouple with quick disconnect plugs in stock. Use of the quick disconnect plug allows thermocouple to be changed without removing the entire assembly.

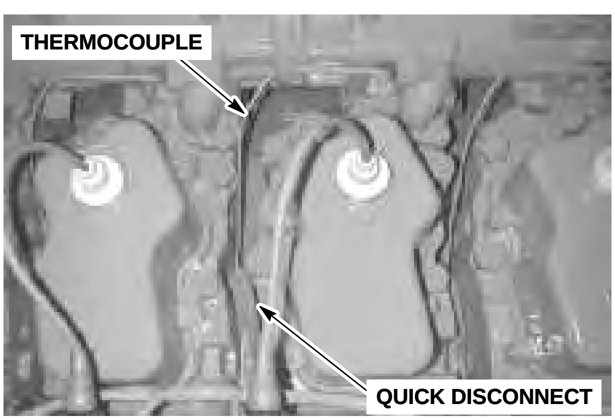


Figure 6.05-5. Thermocouple Quick Disconnect

1. Loosen ferrule nuts (9/16 inch hex) to remove thermocouple from exhaust manifold (see Figure 6.05-6).

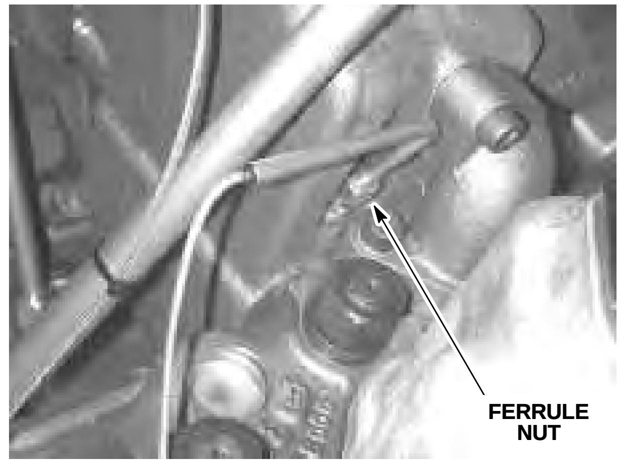


Figure 6.05-6. Thermocouple Installation

QUICK DISCONNECT INSTALLATION

NOTE: *Variations in thermocouple wire lengths adversely affect the pyrometer readings. Errors will not usually exceed ±1% of the total reading if the variations in wire length do not exceed 22 ft (6.7 m).*

1. Remove faulty thermocouple by cutting lead (cut approximately 12 in. (30.5 cm) from stem). Do not cut thermocouple harness short. Verify there will be enough thermocouple wiring left to reach exhaust manifold (with new thermocouple lead attached).

2. Slide quick disconnect rubber boot over thermocouple harness.

3. Peel back stainless steel braid 1-1/4 in. (3.2 cm). Remove any excess material.

4. Peel back insulation beneath braid 3/4 in. (1.9 cm). Remove any excess material.

5. Separate positive and negative conductors. Positive (+) conductor is yellow and negative (–) conductor is red.

6. Peel back insulation of each conductor 3/8 in. (9.5 mm) to expose bare wire. Remove any excess material.

7. Separate male and female ends of quick disconnect plug, if applicable.

8. Loosen retaining screw from side of each prong.

9. Slide red negative (–) conductor into larger diameter prong until contact is made with the pinhole (see Figure 6.05-7).

10. Slide yellow positive (+) conductor into smaller diameter prong until contact is made with pinhole. Tighten retaining screws.

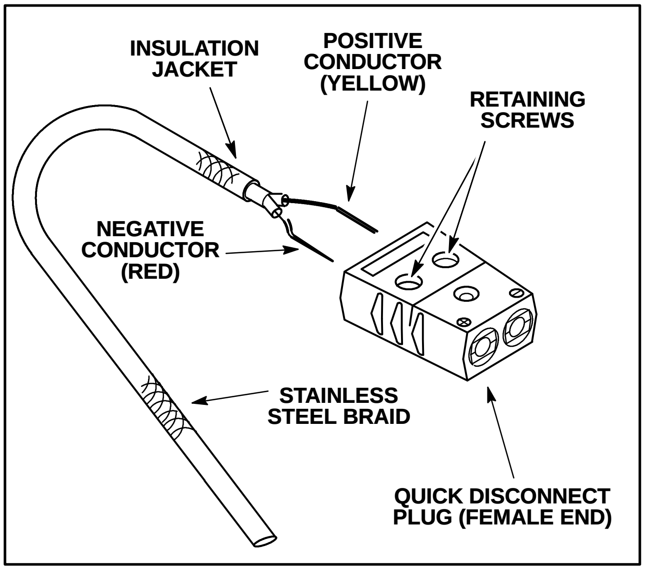


Figure 6.05-7. K-type Thermocouple

11. Snap male end of plug into female end.

Thermocouple Stem (K-type Plug)

1. Unthread ferrule nut (9/16 inch hex) from thermocouple connector (see Figure 6.05-8).

2. Disconnect male from female end of quick disconnect plug. Remove faulty thermocouple stem and discard.

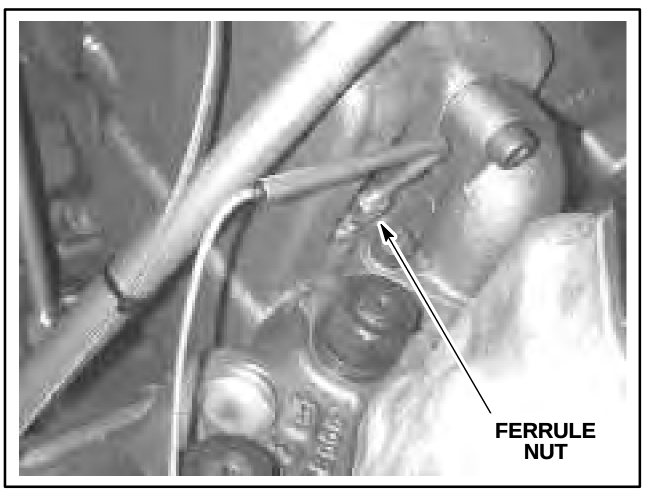


Figure 6.05-8. Thermocouple Installation

3. Slide new ferrule nut, back ferrule and front ferrule onto thermocouple stem (see Figure 6.05-9).

NOTE: *The lip on the back ferrule must face the large end of the front ferrule (see Figure 6.05-9).*

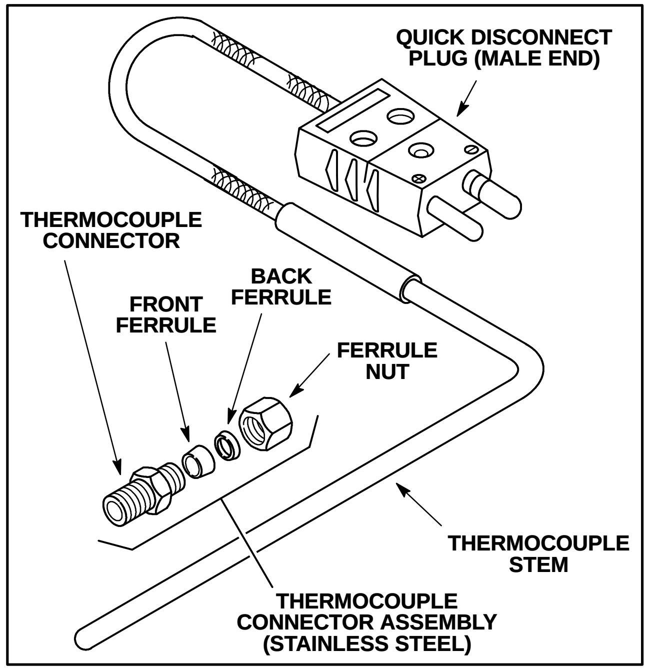


Figure 6.05-9. K-type Thermocouple

NOTE: *If possible, install the exhaust manifold thermocouple before installing the water elbow located between the cylinder head and exhaust manifold.*

4. Inspect thermocouple connector for galled or stretched threads. Remove and discard connector if damaged.

5. Apply Bostik Never-Seez® Anti-Seize and Lubricating Compound to thermocouple connector. Install and tighten connector in exhaust manifold.

6. Insert stem of thermocouple into connector and finger tighten ferrule nut.

7. Verify stem height is 2-7/8 in. (73 mm) (see Figure 6.05-10). Adjust if necessary.

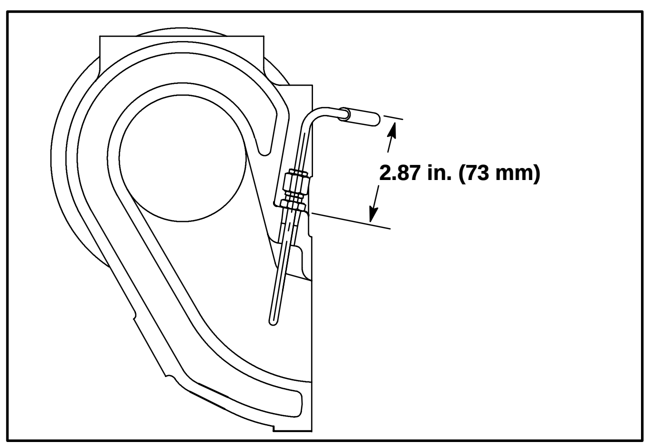


Figure 6.05-10. Exhaust Thermocouple Installation

8. Tighten ferrule nut. Snap male end of plug into female end.

EXHAUST THERMOCOUPLES INSTALLATION

1. Install thermocouples and fittings before installing conduit (see Figure 6.05-11).

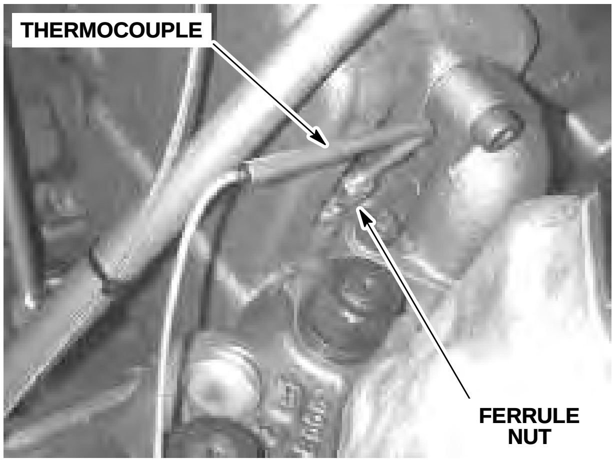


Figure 6.05-11. Thermocouple Installation

2. Position thermocouple conduit over exhaust manifold. Flexible conduit with elbow is located at front of engine (see Figure 6.05-14).

⚠ CAUTION The thermocouple must not contact the exhaust manifold casting or an inaccurate pyrometer reading will result. Disregarding this information could result in product damage and/or personal injury.

3. Connect thermocouple quick disconnect plugs (see Figure 6.05-12).

Figure 6.05-12. Thermocouple Connector

4. Secure conduit with clamps. Use spacers to level conduit (see Figure 6.05-13). There are two sizes of conduit clamps.

Figure 6.05-13. Thermocouple Conduit Mounting

5. Secure flexible conduit to gear housing with wire clip (see Figure 6.05-14).

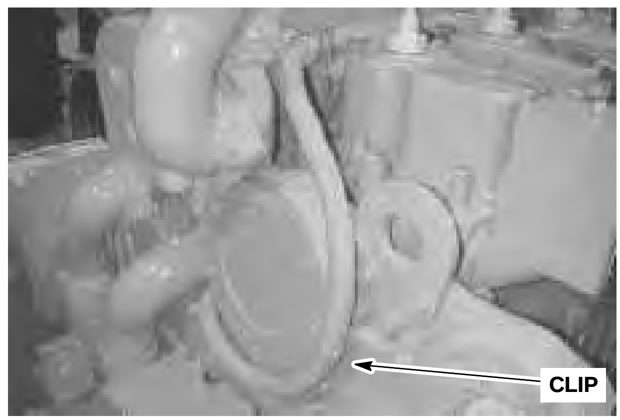


Figure 6.05-14. Flexible Conduit Routing

6. Install junction box and mounting bracket onto gear housing. Secure with M10 x 55 mm and M10 x 20 mm hex head screws. Install spacer on M10 x 55 mm hex head screw (see Figure 6.05-15).

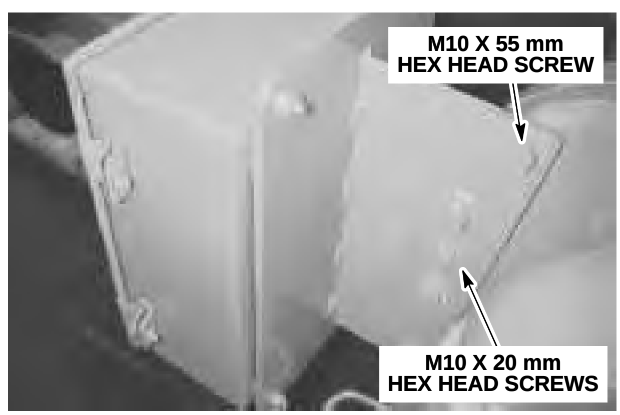


Figure 6.05-15. Current Junction Box Mounting

7. Secure flexible conduit to housing with clip (see Figure 6.05-16).

8. Connect flexible thermocouple conduit to junction box located on right side of engine (see Figure 6.05-16).

NOTE: *The function of the thermocouple junction box (see Figure 6.05-16) is to serve as the main junction point for the wiring of engine protection shutdowns and customer wiring. When attaching the thermocouple leads to the junction box terminal blocks, all red leads are positive (+) and all yellow leads are negative (–).*

Figure 6.05-16. Thermocouple Junction Box

NOTE: *A thermocouple is installed in the exhaust manifold below the turbocharger (see Figure 6.05-17). The lead is labeled "PT" (Pre–Turbocharger).*

Figure 6.05-17. Exhaust Manifold Thermocouple

NOTE: *A thermocouple is installed in the exhaust outlet, on either side (see Figure 6.05-18). The lead is labeled "STK" (exhaust STacK).*

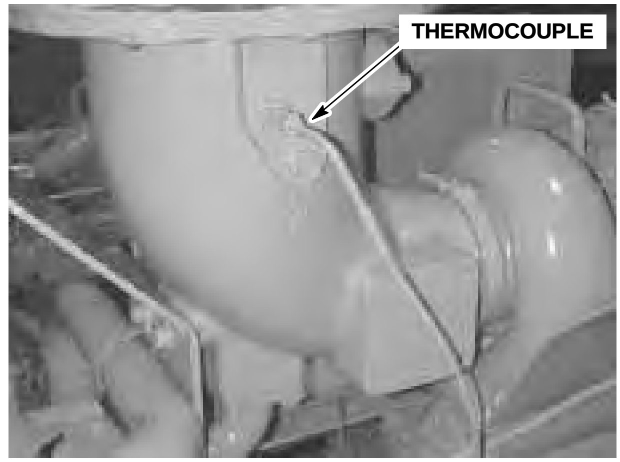


Figure 6.05-18. Exhaust Outlet Thermocouple

9. Secure exhaust outlet and pre–turbo connectors to thermocouple conduit. Connector should not contact exhaust manifold (see Figure 6.05-19).

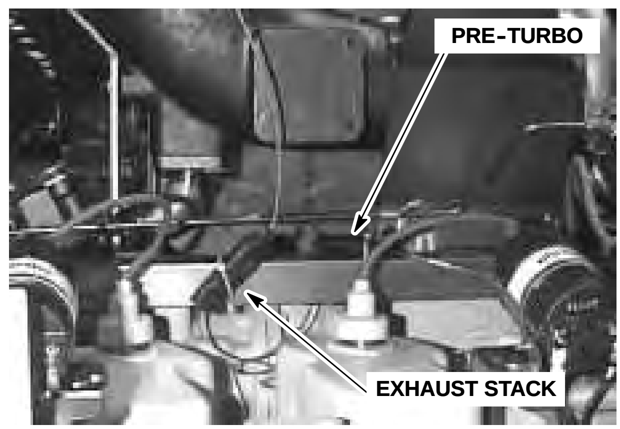


Figure 6.05-19. Thermocouple Connections

THERMOCOUPLE CLEANING AND INSPECTION

A wide variation between one cylinder and another, or one bank and another, may indicate a dirty or faulty thermocouple. Clean or replace the thermocouples as required.

⚠ CAUTION **Do not use a battery powered test light or similar device to check the thermocouple circuit without completely disconnecting the pyrometer. Applying uncontrolled voltage to the pyrometer will damage the instrument. Disregarding this information could result in product damage and/or personal injury.**

NOTE: *The thermocouple assembly consists of two wires made of dissimilar metals covered with a metal stem. A portable pyrometer measures the small electric current generated by the thermocouple and translates the voltage into a temperature reading. A thermocouple connector is mounted in the exhaust manifold and in turbocharger exhaust inlet elbow(s).*

1. Verify electrical connections are in good condition. Wire ends and terminal connections must be clean and dry.

2. Verify pyrometer dial reading increases when thermocouple is heated. If dial reading decreases, then thermocouple wiring was reversed during installation.

3. Turn pyrometer selector to "Off" position. Pyrometer temperature reading should be equivalent to ambient air temperature.

4. Remove ferrule nut from thermocouple connector (see Figure 6.05-20).

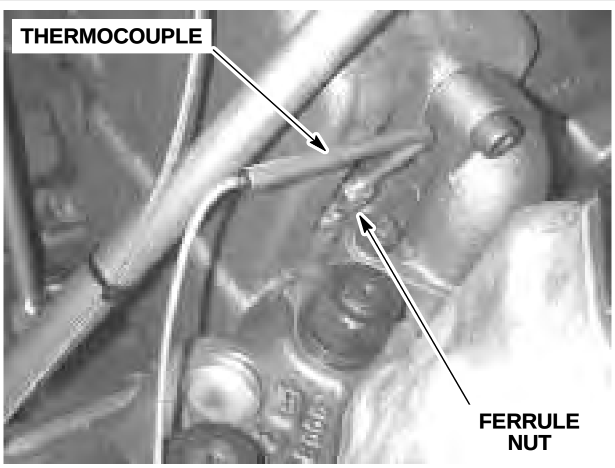


Figure 6.05-20. Thermocouple Installation

5. Pull thermocouple out of exhaust passage.

6. Check thermocouple stem for carbon buildup. If necessary, thoroughly clean thermocouple using solvent and a soft wire brush.

7. Insert stem of thermocouple back into exhaust passage and tighten ferrule nut.

ENGINE OVERSPEED SHUTDOWN SYSTEM OPERATION

The engine may be equipped with an optional overspeed shutdown system. This system measures engine speed from the ignition system (CEC or magneto ignition). Waukesha adjusts the shut down speed to 15% over engine governed speed. If an optional switchgage trips and shuts down the engine, the overspeed switch will not require resetting.

The control box is mounted on the left rear mounting leg. The reset control is on the side of the control box (see Figure 6.05-21). The reset button must be depressed to restart the engine.

⚠ CAUTION If the overspeed shutdown system trips, find and correct the cause before restarting the engine. Failure to do so may damage the engine or driven equipment.

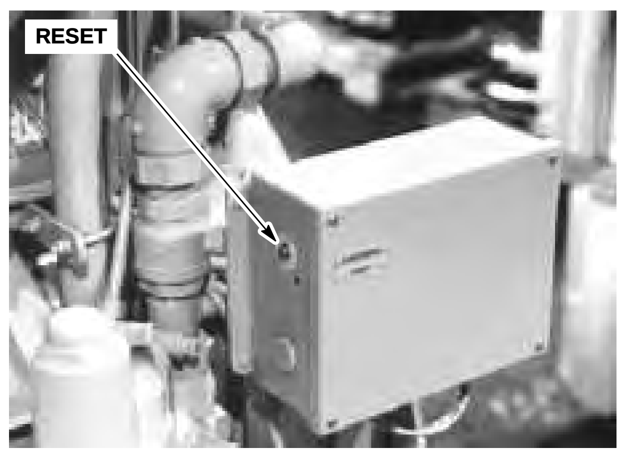


Figure 6.05-21. Overspeed Shutdown

CUSTOM ENGINE CONTROL KNOCK DETECTION MODULE SYSTEM

SYSTEM DESCRIPTION

In order to detect detonation or knock, Waukesha Engine has developed an electronic Custom Engine Control (CEC) Knock Detection Module (KDM) system for VGF F18/H24 GL, GLD, and GSID engines (see Figure 6.05-22). The KDM system protects Waukesha VGF spark ignited gas engines from catastrophic damage due to detonation.

NOTE: *For maximum engine protection, the KDM system must be connected to a safety shutdown.*

The KDM does not have all the same capabilities of the CEC Detonation Sensing Module (DSM), though it works with some of the same technologies.

OPERATOR INTERFACE

The KDM is equipped with a light (LED) on the front panel that informs site personnel of the system status (see Figure 6.05-22). The light is on when the KDM is powered and functioning properly with the knock sensors connected. The light is off when there is a fault or there is no power to the KDM.

Figure 6.05-22. Knock Detection Module

COMPONENTS

The KDM system includes the KDM module, two knock sensors, and harnesses that may vary depending on the application.

IGNITION SYSTEMS SERVED

The KDM was designed to operate with the CEC Ignition Module (IM) or Altronic III Magneto. The KDM uses the G-lead and the positive lead of #1 coil of these systems to determine the number of cylinders and engine speed.

NOTE: *Refer to* KDM Custom Engine Control Detonation Sensing Module Installation, Operation, And Maintenance Manual Form 6285 *for further information.*

KNOCK SENSOR INSTALLATION

1. Thoroughly clean knock sensor mounting hole and area around mounting hole.

⚠ CAUTION Drilled and tapped hole (knock sensor surface) must be flat, smooth (RMS 63), and be perpendicular to the drilled hole. Make sure knock sensor mounting surface is free of paint. If the knock sensor is not mounted flush with the mounting surface or if the surface is not within RMS 63, the knock sensor WILL provide incorrect signals to the DSM or KDM system.

2. Verify that the mounting surface is flat and smooth (RMS 63) using a Profilometer. Although it is recommended to use a Profilometer, if one is not available, lightly run your finger over mounting surface. The surface should be free of any ripples and imperfections and should be polished smooth.

3. IMPORTANT! When completing Step 4 and Step 5, verify that the knock sensor is seated flat against the mounting surface. See next section, "Verifying Knock Sensor Is Seated Flat," for necessary steps.

⚠ CAUTION Do not drop or mishandle knock sensor. Knock sensor damage may occur if knock sensor is mishandled.

4. Install knock sensor into the threaded mounting hole (see Figure 6.05-23).

Figure 6.05-23. Rear Knock Sensor

⚠ CAUTION Do not over-tighten knock sensor. Over-tightening will cause damage to the knock sensor.

5. Tighten knock sensor to 35 – 40 ft-lb (47 – 54 N·m) dry.

6. Repeat this mounting procedure for each knock sensor. *For DSM Systems only:* When all knock sensors are installed, continue with Step 7.

CAUTION **After doing any removal or replacement of knock sensors, the DSM system must be AutoCaled using the DSM Terminal Program and a personal computer. Disregarding this information could result in product damage.**

7. *For DSM systems only:* Rerun AutoCal following the programming steps provided in Section 4.05 “Running The DSM AutoCal Program” of the *CEC DSM Installation, Operation, and Maintenance Manual,* Form 6278, First Edition.

VERIFYING KNOCK SENSOR IS SEATED FLAT

1. Use the method provided below to verify that the knock sensor is seated flat against the mounting hole surface.

2. Apply a very thin coat of a blueing paste, such as Permatex® Prussian Blue (or equivalent), to seating surface of knock sensor (see Figure 6.05-24).

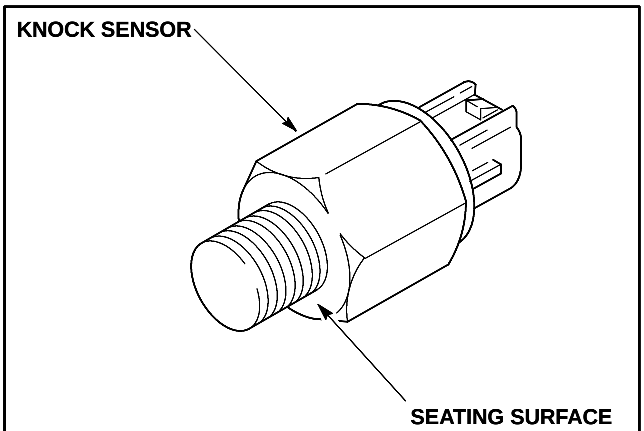


Figure 6.05-24. Knock Sensor Seating Surface

3. Complete Step 4 and Step 5 of knock sensor installation.

4. Remove knock sensor.

5. Examine imprint left by blueing agent on the crankcase and sensor seating surface.

- If the imprint on the crankcase and sensor seating surface is uniform, the sensor has full-face contact with mounting surface.
- If the imprint on the crankcase and sensor seating surface is NOT uniform, the sensor does not have full-face contact with mounting surface. The mounting hole will have to be plugged and re-tapped to make the hole perpendicular to the mounting surface.

6. Reinstall knock sensor by completing Step 4 and Step 5 of knock sensor installation.

SECTION 6.10

MISCELLANEOUS EQUIPMENT

JACKET WATER HEATER

SYSTEM DESCRIPTION

The optional jacket water heater is mounted on the right side of the engine and is used for starting in ambient temperatures below 50° F (10° C). The thermally controlled 2500 watt unit will maintain jacket water temperature at 120° F (48.9° C) for standby applications (see Figure 6.10-1).

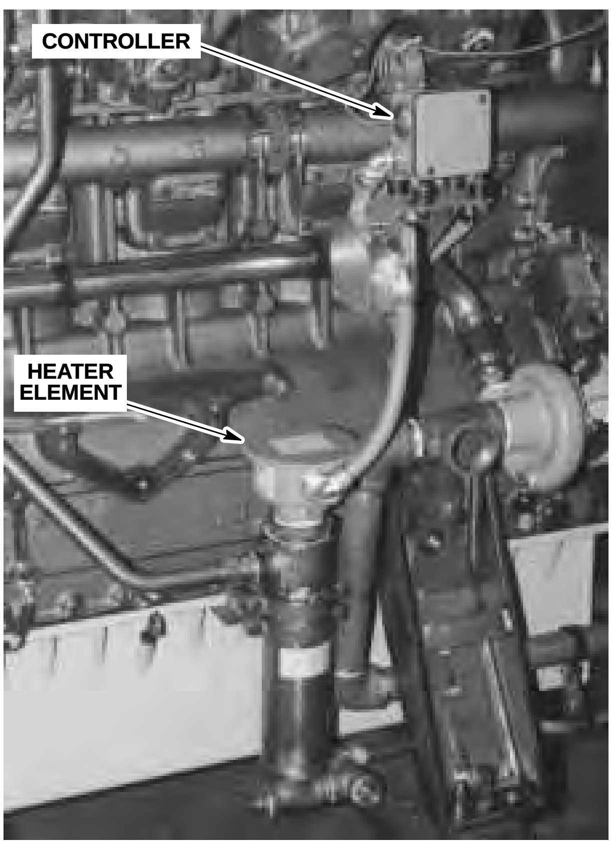


Figure 6.10-1. Current Production Jacket Water Heater

JACKET WATER HEATER ELEMENT REMOVAL

⚠ WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical components involved. Electrical shock can cause severe personal injury or death.

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

The previous production jacket water heater system was not equipped with shutoff valve in the water circuit. In this system the element cannot be serviced unless the jacket water cooling system has been drained.

1. Turn off electrical power to heater.
2. Drain jacket water cooling system. Close valves.
3. Use a wrench to remove heater element from heater housing (see Figure 6.10-2).

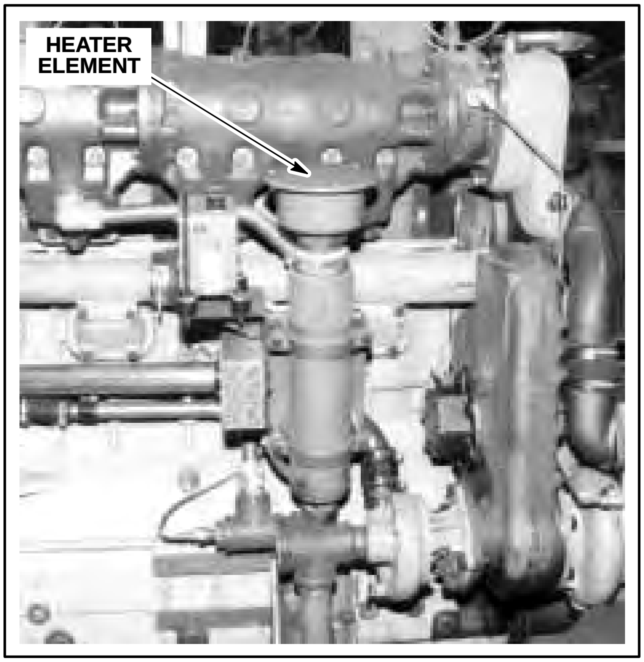


Figure 6.10-2. Jacket Water Heater

4. Install new element into heater housing. Apply pipe sealant to element threads and housing.

5. Refill engine with coolant and check for leaks.

6. Turn on electrical power to heater.

JACKET WATER HEATER ELEMENT REMOVAL – F18/H24

The current production F18/H24 jacket water heater element can be serviced without draining the cooling system. The heater water circuit has two shutoff valves to isolate the heater.

1. Turn off electrical power to heater.

2. Close both shutoff valves (see Figure 6.10-3).

NOTE: *When the valve handle is in–line with the valve, the valve is open. When the valve handle is moved away from the valve, the valve is closed.*

3. Open heater element cover, tag and disconnect controller wiring. Remove heater element from heater housing.

4. Install new element in heater housing. Apply pipe sealant to element threads and housing.

5. Open both shutoff valves.

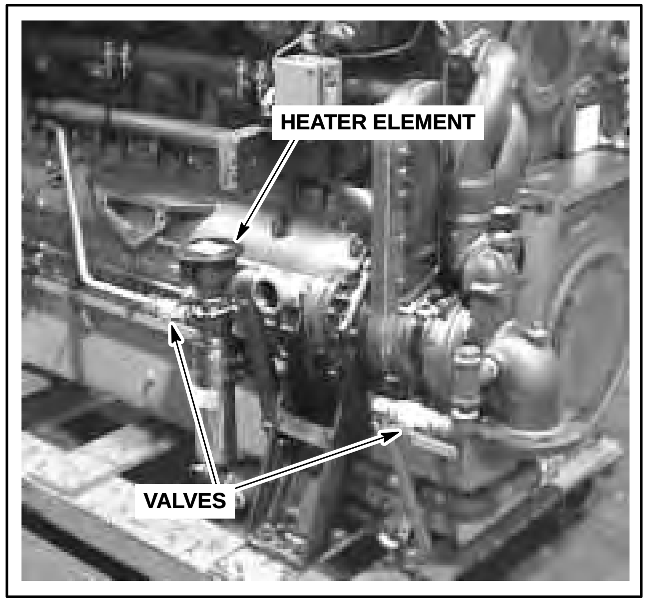


Figure 6.10-3. F18/H24 Jacket Water Heater

6. Refill engine with coolant and check for leaks.

7. Bleed trapped air from jacket water system (see Section 5.25 *Cooling System* for complete instructions).

8. Turn on electrical power to heater.

JACKET WATER HEATER CLEANING AND INSPECTION

WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners or other highly volatile fluids for cleaning.

1. Clean all metal parts using an approved cleaning solvent.

2. Inspect jacket water heater for cracks, broken wires, or other damage.

3. Inspect all wiring for cracked insulation, broken wires or damage. Replace if necessary.

4. Inspect all threaded parts for stripped or damaged threads. Replace parts if damage is apparent.

5. Inspect tubes for cracks, kinks, breaks or wear. Replace tubes if necessary.

JACKET WATER HEATER INSTALLATION

⚠ WARNING

Do not install, set up, maintain or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical components involved. Electrical shock can cause severe personal injury or death.

⚠ WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

NOTE: *Seal all pipe connections with pipe thread sealant.*

1. Install pipe tees, drain petcock and adapter onto heater body (see Figure 6.10-4).

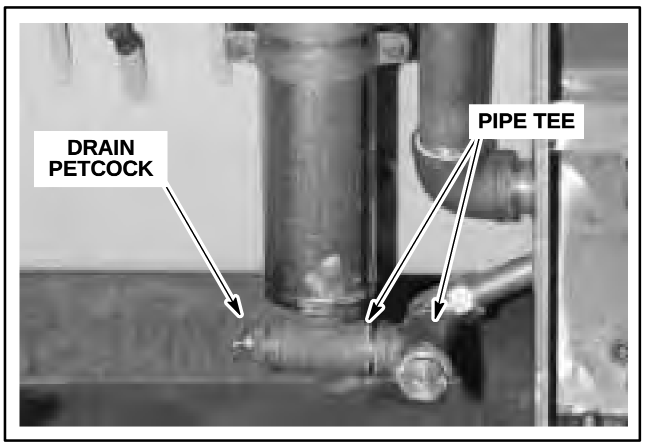


Figure 6.10-4. Water Heater Fittings

2. Install heater support bracket and secure by replacing oil pan screws with M10 x 40 mm hex head screws (see Figure 6.10-5). Secure heater housing to bracket with four support straps, spacers, M8 x 75 mm hex head screws, washers and hex nuts.

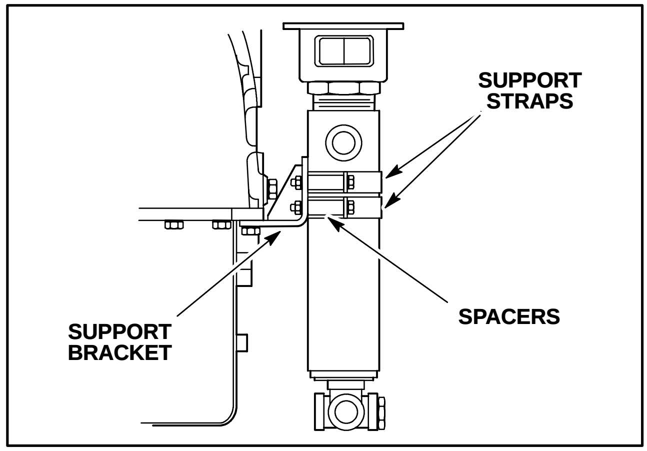


Figure 6.10-5. Jacket Water Heater Mounting

3. Install heater outlet tube into crankcase drain fittings on rear of engine (see Figure 6.10-6). Support heater tube with clips on auxiliary water tube.

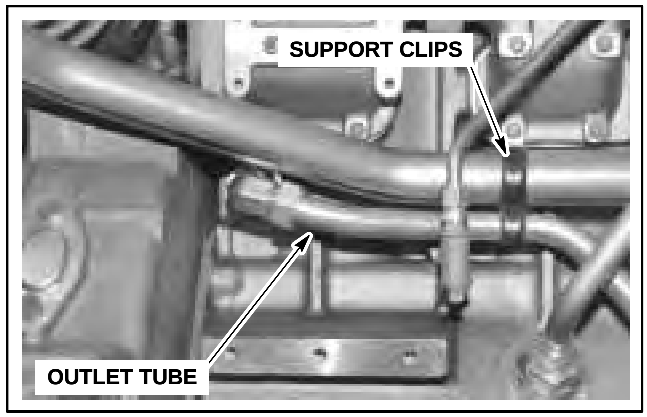


Figure 6.10-6. Heater Outlet Tube

4. Install heater supply inlet tube into jacket water pump inlet housing (see Figure 6.10-7).

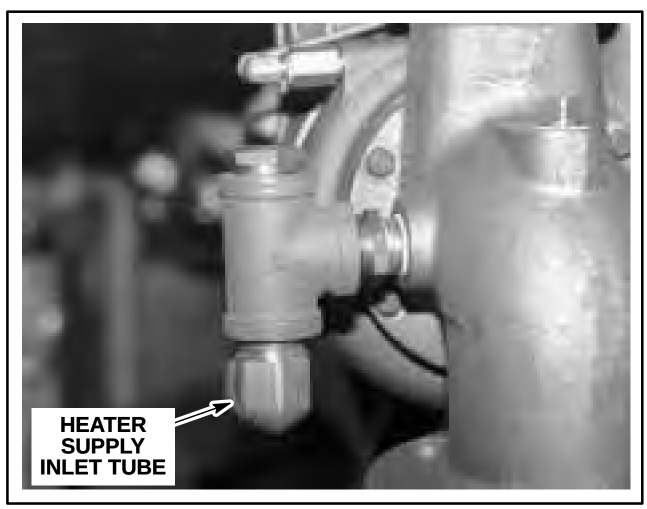


Figure 6.10-7. Jacket Water Heater Connection

5. Secure heater tube with clips onto jacket water pump and auxiliary water pipe (see Figure 6.10-8).

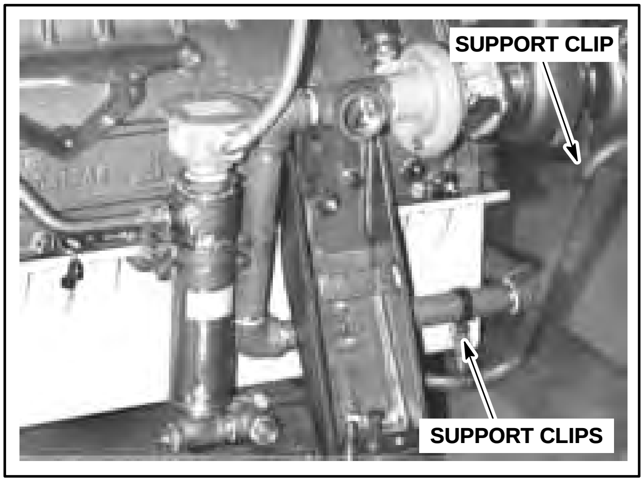


Figure 6.10-8. Heater Inlet Tube

6. Secure temperature controller support bracket by replacing water header screws with four M8 x 90 mm hex head screws (see Figure 6.10-9). Two different sized spacers are used when installing bracket.

7. Secure temperature controller to anti-vibration mounts (see Figure 6.10-9). Attach junction box directly to bracket.

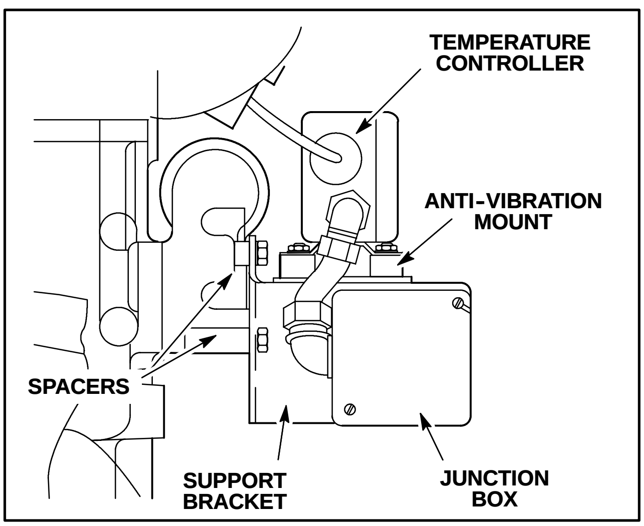


Figure 6.10-9. Temperature Controller Support Bracket

8. Install temperature controller probe into thermostat housing adapter (see Figure 6.10-10). Secure cable with a clip and attach to thermostat housing adapter. Secure any excess cable with tie wraps.

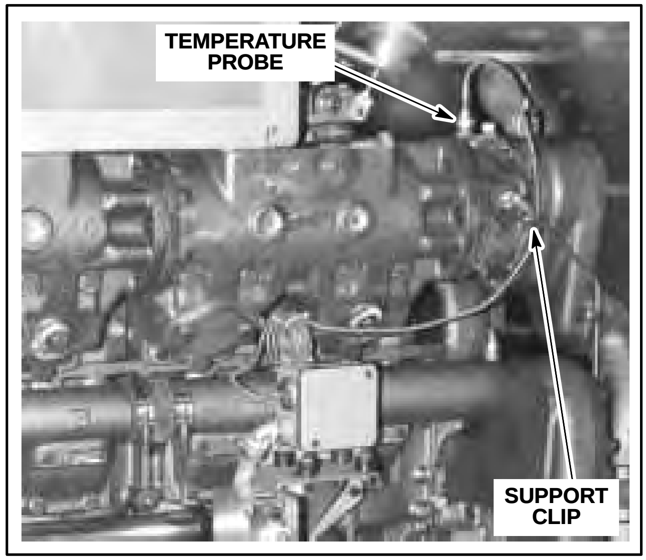


Figure 6.10-10. Temperature Controller Probe

9. Connect controller to heater element through junction box using No. 10 stranded primary wire. Use flexible conduit to shield wiring (see Figure 6.10-11).

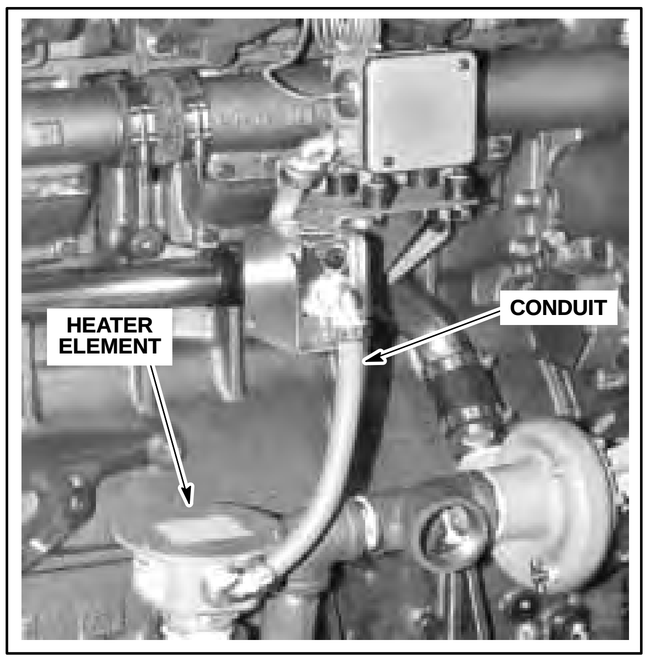


Figure 6.10-11. Heater Wiring Conduit

SURGE TANK

An optional surge tank is available for use with closed loop cooling systems. The tank is equipped with a pressure cap, sight glass and drain cock (see Figure 6.10-12).

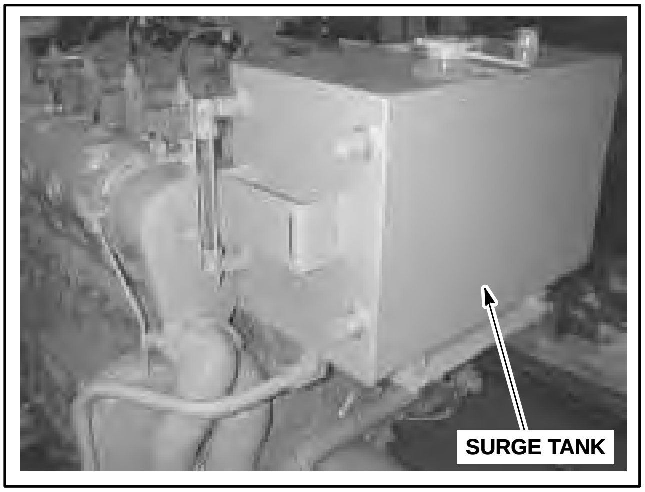


Figure 6.10-12. Surge Tank

SURGE TANK REMOVAL

1. Allow system to cool down. Loosen pressure cap on surge tank.

2. Drain cooling system.

3. Disconnect tube connection between surge tank and jacket water pump (See Figure 6.10-13).

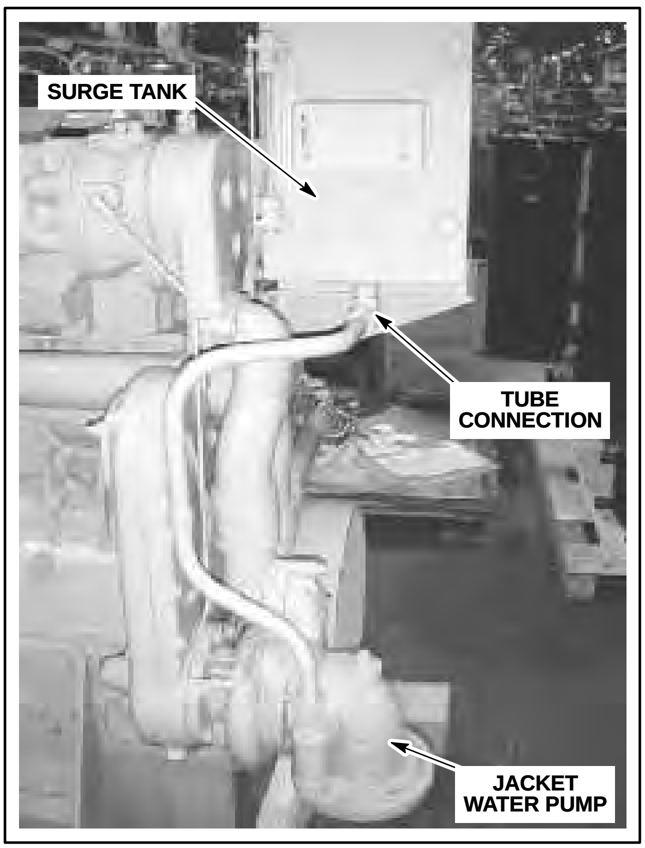


Figure 6.10-13. Surge Tank

4. Remove M10 hex head screws from thermostat housing connection (See Figure 6.10-14).

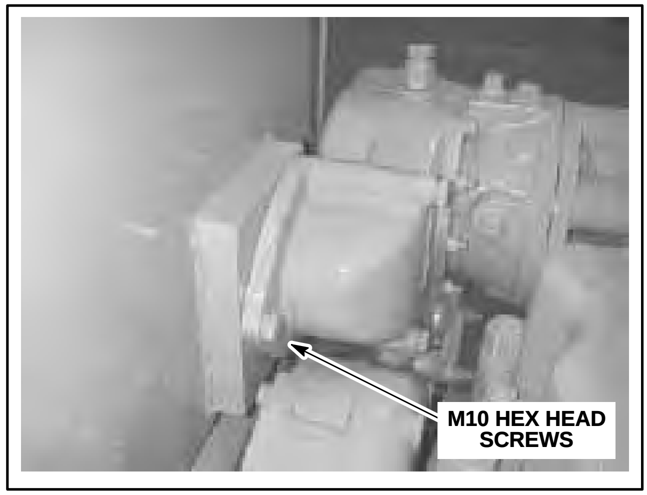


Figure 6.10-14. Surge Tank Thermostat Housing

⚠ WARNING

The surge tank weighs approximately 65 lb. (30 kg). Lift only with a properly rated lifting device and rigging to avoid serious personal injury or death.

5. Install a lifting device of sufficient capacity around surge tank.

NOTE: *Care should be taken not to damage the sight gauge during removal.*

6. Remove four 3/8 in. – 16 x 1 in. hex head screws at bottom of tank and lift tank from mounting bracket (see Figure 6.10-15).

Figure 6.10-15. Surge Tank Bracket

7. Remove surge tank bracket and support bracket from gear housing.

SURGE TANK CLEANING AND INSPECTION

⚠ WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners or other highly volatile fluids for cleaning.

1. Wipe surge tank with a clean shop cloth dampened in an approved cleaning solvent.

2. Inspect sight gauge for tightness of connections and broken glass.

3. Inspect pressure cap for damage of any kind.

4. Inspect all plugs to be sure they are tight and not damaged.

5. Inspect mounting hardware for stripped or damaged threads. Replace hardware if damage is apparent.

SURGE TANK INSTALLATION

⚠ WARNING

The surge tank weighs approximately 65 lb. (30 kg). Lift only with a properly rated lifting device and rigging to avoid serious personal injury or death.

1. Install surge tank support bracket on gear housing. Install tank bracket on support bracket (see Figure 6.10-17).

2. Install gasket between surge tank and thermostat housing.

3. Lift surge tank using a properly rated lifting device and position tank on mounting bracket.

NOTE: *When mounting the surge tank be sure the tank is mounted above the engine water outlet connection and the heat exchanger. The surge tank should be the highest point in the system.*

4. Install four mounting screws in bottom of tank.

5. Remove lifting device after mounting screws are tightened.

6. Install tube elbows with pipe sealant.

7. Install water tube between tank and jacket water pump (see Figure 6.10-16).

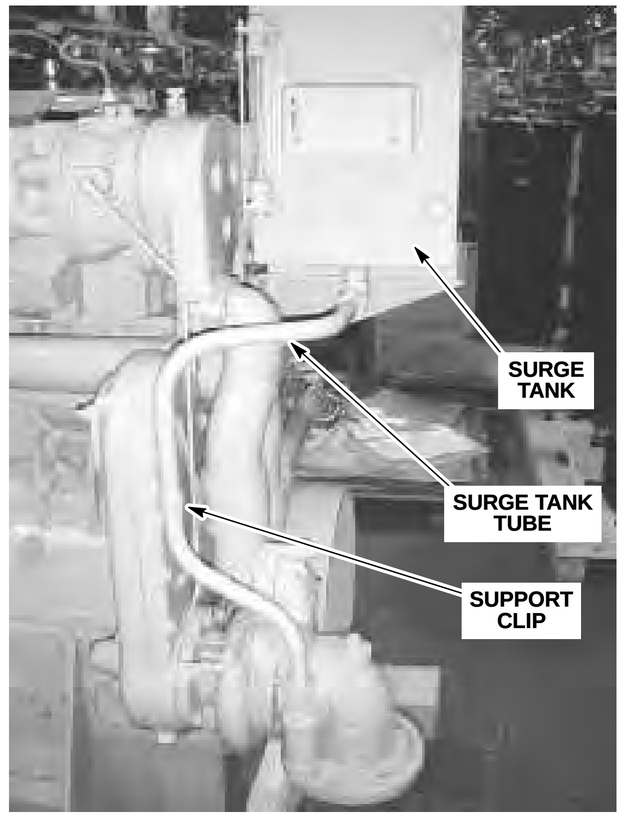


Figure 6.10-16. Surge Tank

8. Fill cooling system and check for leaks in system. If leaks are found, repair or replace components as necessary before putting engine into service.

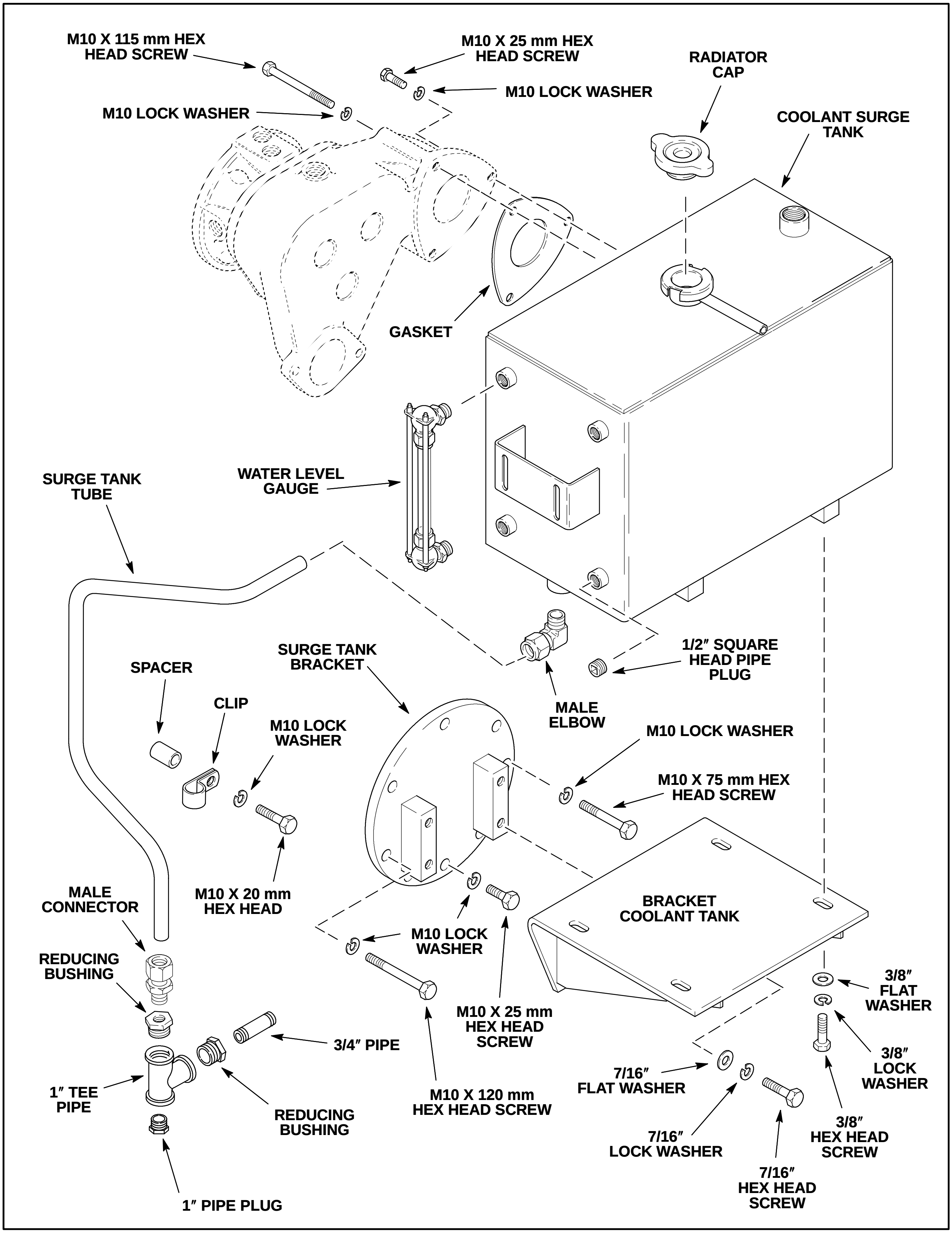


Figure 6.10-17. Surge Tank Installation

LUBE OIL LEVEL REGULATOR

The oil level regulator is mounted on the lower left side of the engine. The regulator will maintain the oil to the correct level in the engine crankcase. Make-up oil at atmospheric pressure (or slightly greater) is supplied to the regulator inlet. If the oil level should drop for any reason, the float will also drop, opening the float valve and allowing make-up oil to be added. A contact is available for low oil shutdown or warning.

1. Oil level regulator is secured onto two oil pan mounting pads (see Figure 6.10-18).

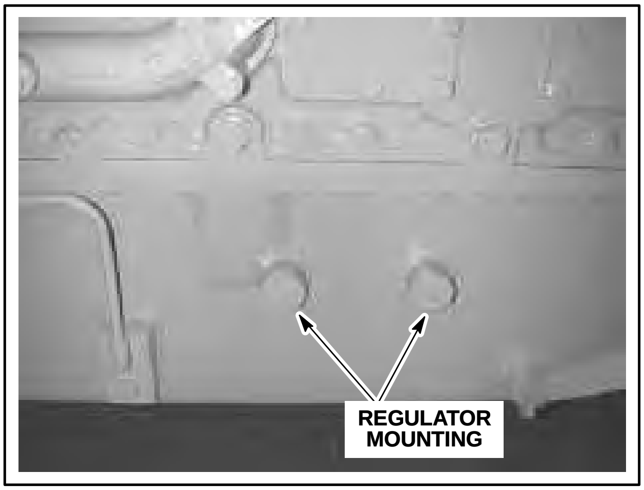


Figure 6.10-18. Oil Level Regulator Mounting

2. Loosely install regulator onto oil pan. Use pipe sealant on tube elbows and adapters installed in oil pan and regulator. Install supply tube and tighten tube elbows and regulator hex head screws (see Figure 6.10-19).

NOTE: *The regulator should be adjusted so that when the engine lube oil is at the proper level, the regulator sight glass is full to the midpoint.*

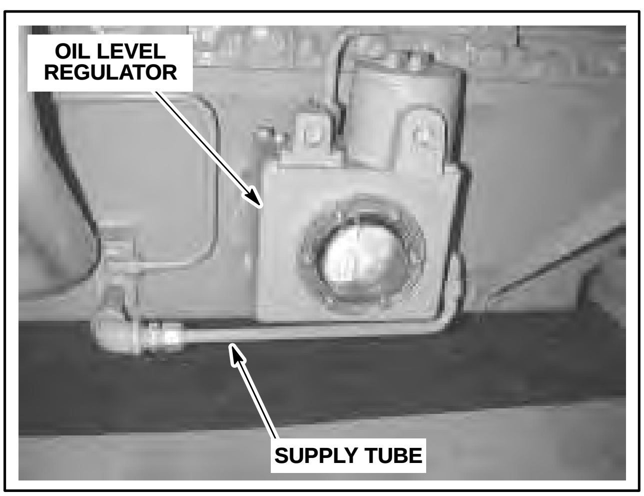


Figure 6.10-19. Oil Level Regulator

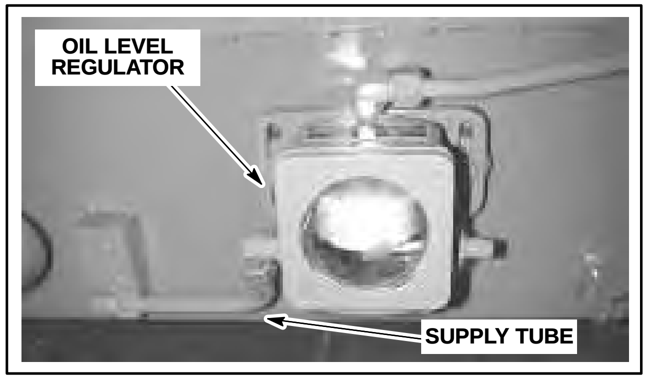


Figure 6.10-20. Oil Level Regulator

3. Install regulator vent tube (with elbow) into tapped hole located on #6 camshaft inspection cover (see Figure 6.10-21). Apply pipe sealant to tube elbow in cover and tube fitting in regulator.

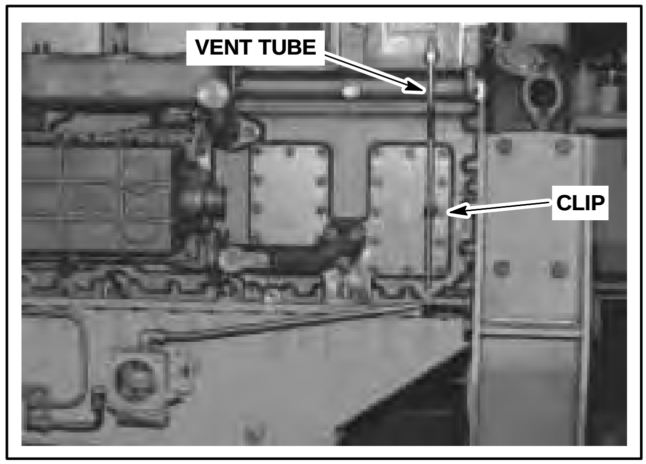


Figure 6.10-21. Oil Level Regulator Vent Tube

4. Install vent tube onto support clip and secure to crankcase inspection cover.

NOTE: *The previous production lube oil level regulator vent tube was attached to the breather system baffle box (see Figure 6.10-22).*

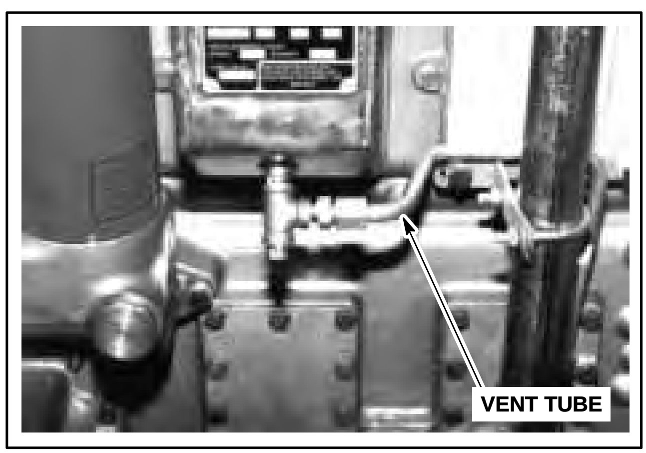


Figure 6.10-22. Oil Level Regulator Vent Tube

CRANKSHAFT PULLEY

NOTE: *Different crankshaft drive pulleys are available for optional equipment. The alternator is driven by a pulley fastened to the crankshaft vibration damper.*

1. Install M12 x 80 mm Grade 12.9 hex head screws to secure alternator drive pulley onto vibration damper. Tighten hex head screws to 101 ft-lb (137 N·m) (see Figure 6.10-23).

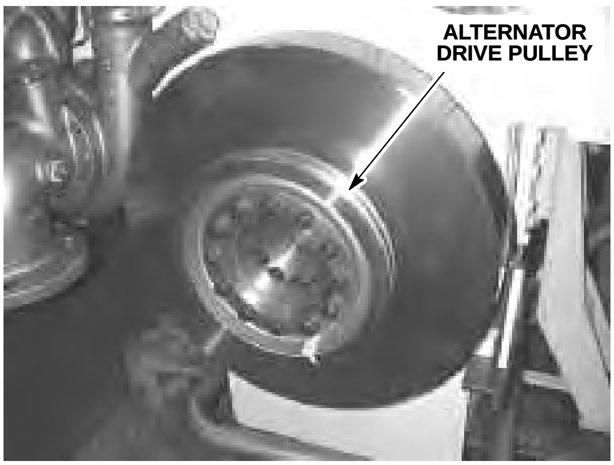


Figure 6.10-23. Alternator Drive Pulley

2. If applicable use Grade 12.9 M12 x 130 mm long hex head screws when installing alternator drive pulley onto vibration damper (see Figure 6.10-24). Tighten screws to 101 ft-lb (137 N·m).

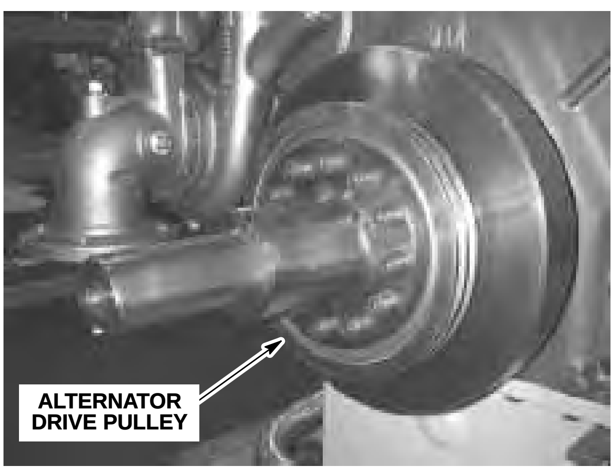


Figure 6.10-24. Crankshaft Pulleys

3. Install protective guards over belt and pulley assembly (see Figure 6.10-25). See "Protective Guards" in this section for alternator guard installation.

Figure 6.10-25. Alternator Guards

PROTECTIVE GUARDS

F18 VIBRATION DAMPER GUARD (STANDARD)

⚠ WARNING

Provide guarding to protect persons or structures from rotating or heated parts. It is the responsibility of the engine owner to specify and provide guarding. Refer to OSHA standards on "machine guarding" for details on safety rules and regulations concerning guarding techniques. Contact with rotating or heated parts can result in severe personal injury or death.

1. Install guard assembly and secure with M10 x 130 mm and M10 x 100 mm hex head screws. Install spacer with M10 x 100 mm hex head screw (see Figure 6.10-26).

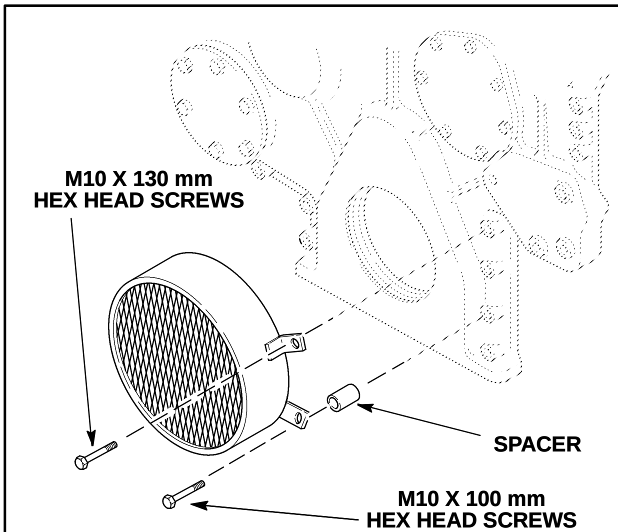


Figure 6.10-26. F18 Vibration Damper Guard

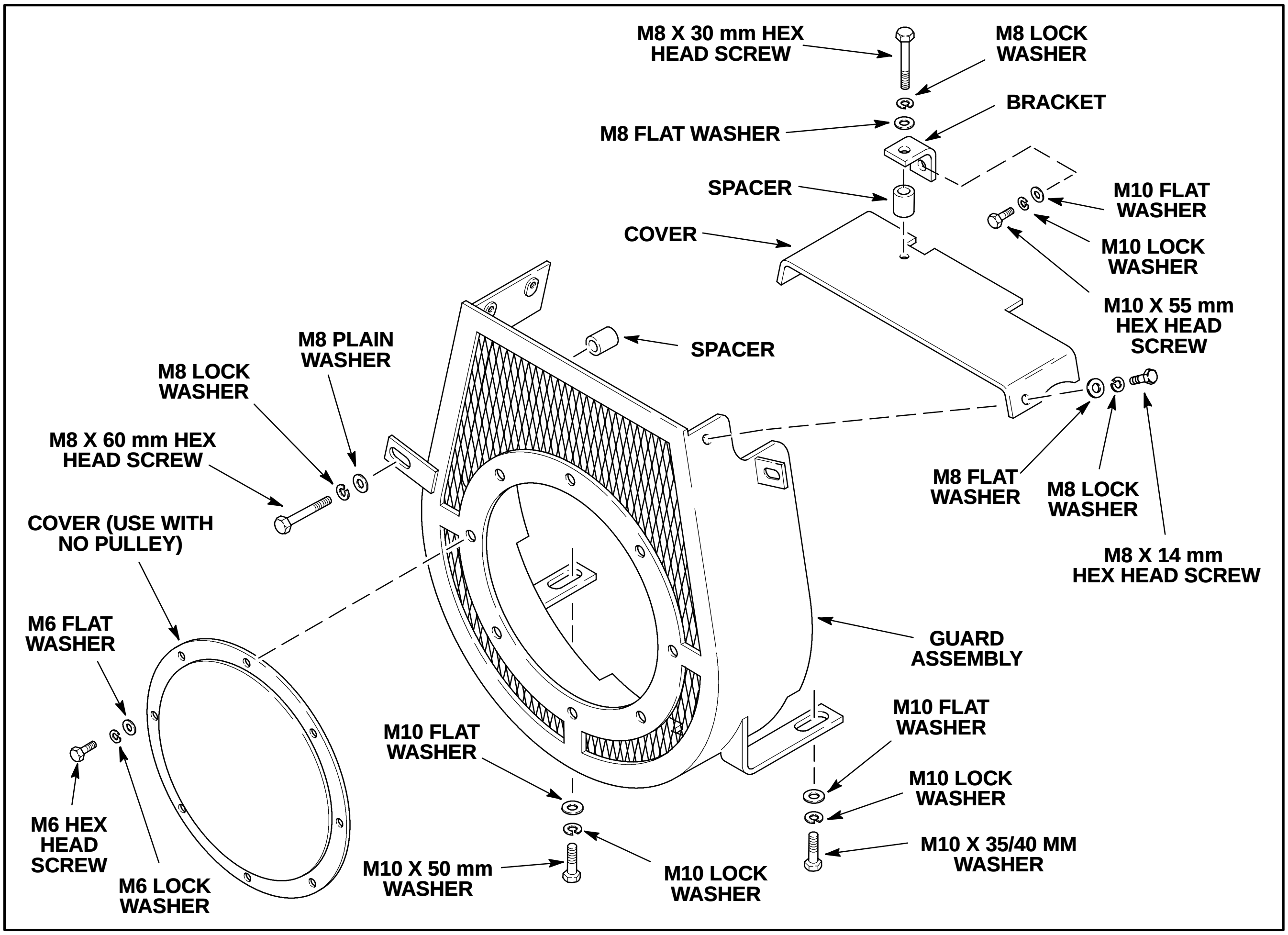


Figure 6.10-27. F18/H24 Vibration Damper Guard

F18/H24 VIBRATION DAMPER GUARD

1. Install vibration damper guard left and right lower brackets to oil pan. Secure with M10 hex head screws, lock washers and flat washers (see Figure 6.10-27 and Figure 6.10-28).

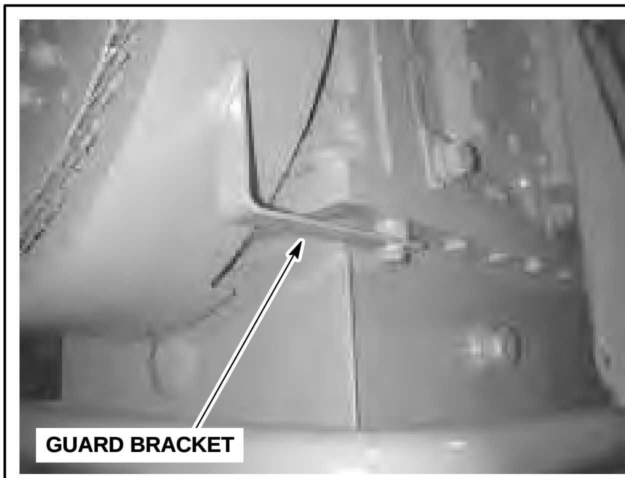


Figure 6.10-28. Vibration Damper Guard

2. Secure right side support bracket to water pump inlet with a spacer and M8 x 60 mm hex head screw (see Figure 6.10-29).

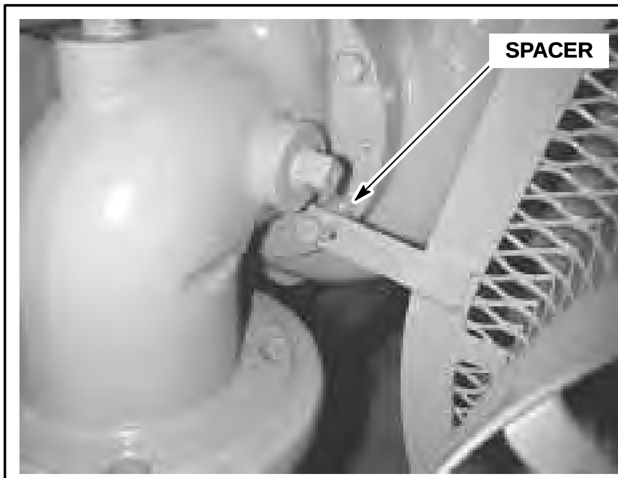


Figure 6.10-29. Vibration Damper Guard

3. Secure left side support bracket with M8 x 35 mm hex head screw and spacer (see Figure 6.10-30).

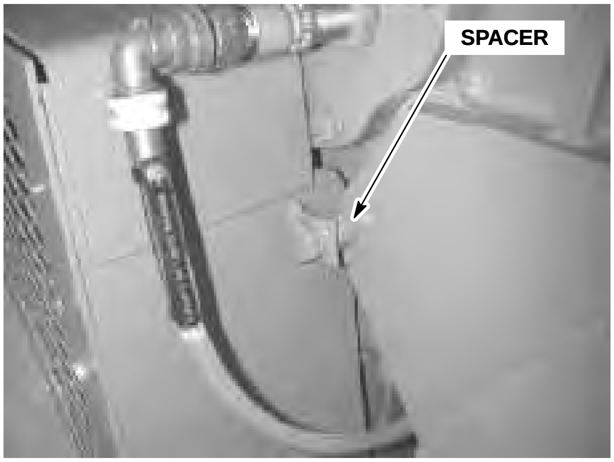


Figure 6.10-30. Vibration Damper Guard

NOTE: *The top guard used depends on the engine model. Engines without an auxiliary water pump have an auxiliary water pipe from the jacket water pipe to the oil cooler (see Figure 6.10-31). Use the top that has a cutout to clear the piping. Engines with an auxiliary water pump have auxiliary water piping on the right side of the engine. Use the top that is square cut (see Figure 6.10-32).*

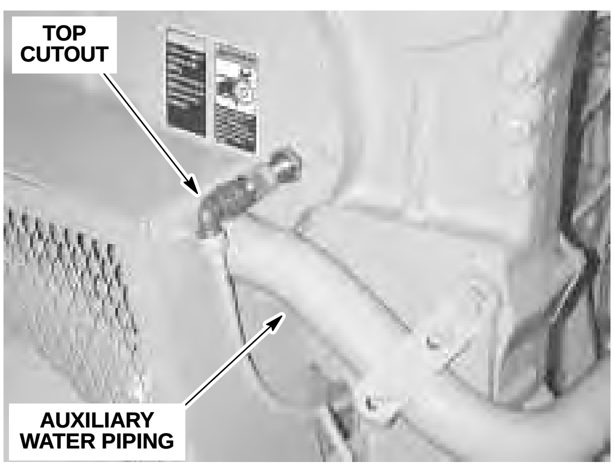


Figure 6.10-31. Vibration Damper Guard

Figure 6.10-32. Vibration Damper Guard

4. Secure guard top to support bracket with M8 x 30 mm hex head screw, washer, lock washer and spacer (see Figure 6.10-33).

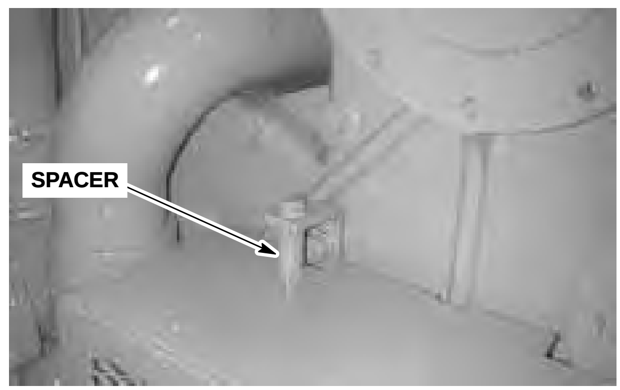


Figure 6.10-33. Vibration Damper Guard

5. Install the front cover on the vibration damper guard with eight M8 capscrews, washers and lock washers (see Figure 6.10-34).

Figure 6.10-34. Guard Cover

PULLEY GUARD

1. Install pulley guard onto vibration damper guard and secure with M8 hex head screws, washers and lock washers (see Figure 6.10-36). Rotate guard so that open area is located for optional driven equipment.

2. Install cover on pulley guard with M8 hex head screws, washers and lock washers (see Figure 6.10-36).

ALTERNATOR GUARD

1. Install front alternator belt guard onto pulley guard (see Figure 6.10-37). Install support bracket between belt guard and adjusting bracket.

2. Install rear belt guard behind front guard (see Figure 6.10-37).

3. Install right and left guards around alternator (see Figure 6.10-35). Attach fasteners through front belt guard and to rear belt guard.

4. Install rubber wiring grommet into lower right alternator guard.

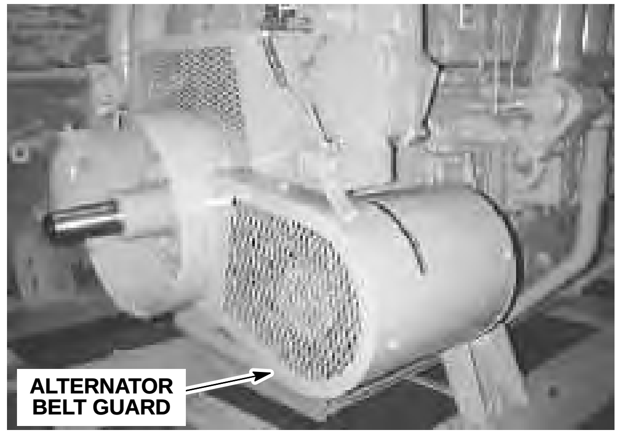


Figure 6.10-35. Alternator Guard

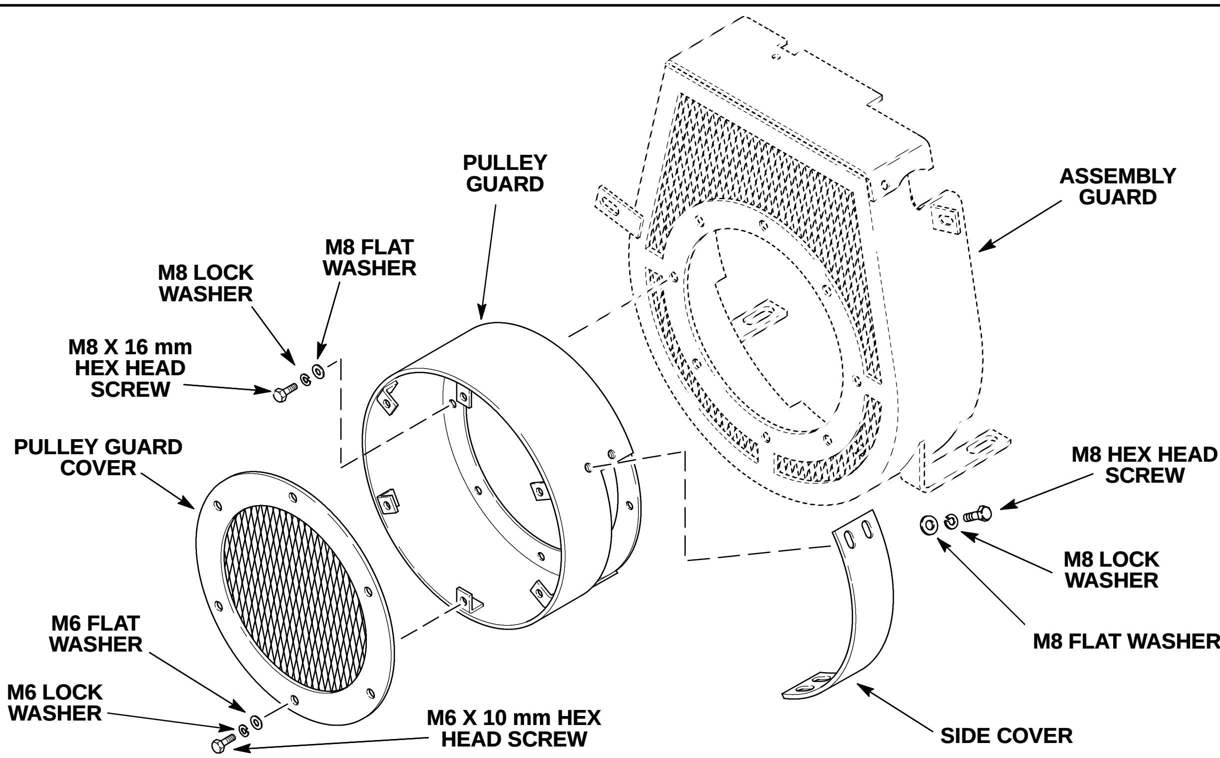


Figure 6.10-36. Pulley Guard

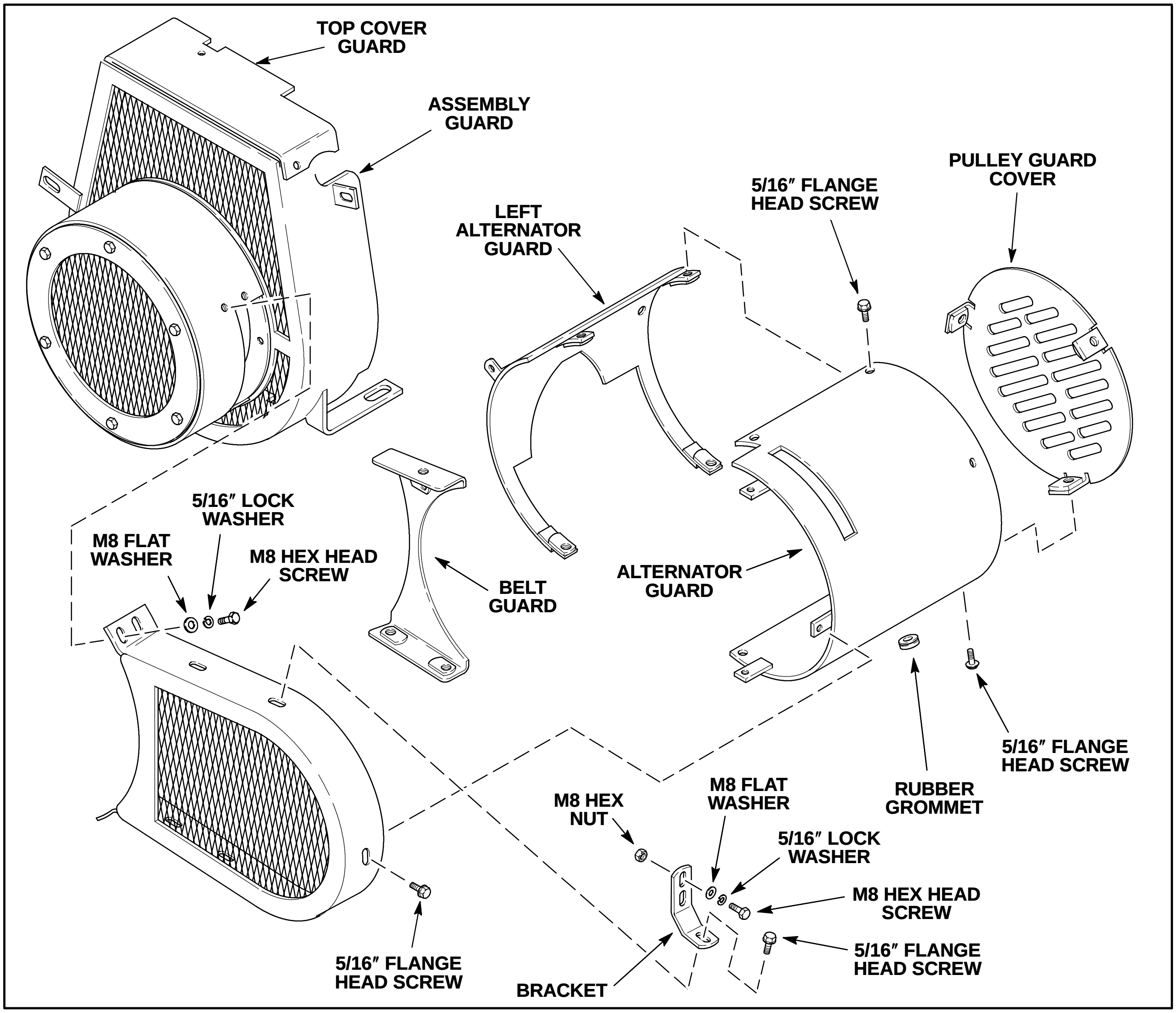


Figure 6.10-37. Alternator Guard

NOTE: *The alternator belt is tightened by turning the adjusting rod (see Figure 6.10-38).*

5. Install rear cover and secure to left and right guards (see Figure 6.10-39).

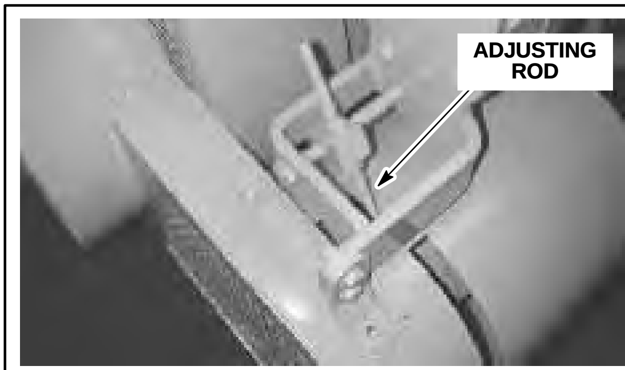


Figure 6.10-38. Alternator Adjusting Rod

Figure 6.10-39. Alternator Rear Guard

REAR STUB SHAFT

An optional flywheel mounted stub shaft is available for driven equipment (see Figure 6.10-40). The stub shaft is machined for a 1 inch square key.

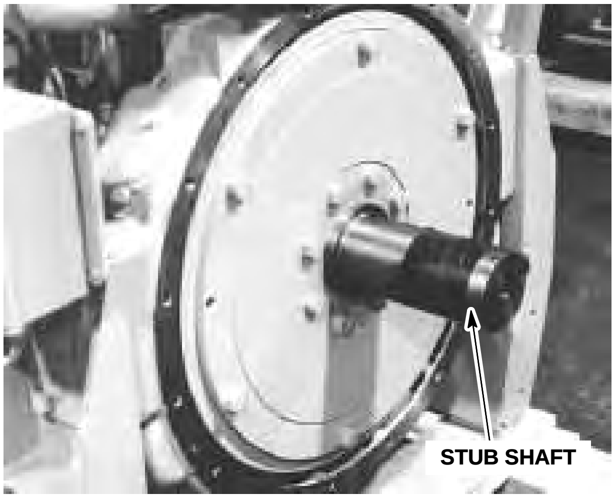


Figure 6.10-40. Flywheel Stub Shaft

FRONT STUB SHAFT

An optional vibration damper mounted stub shaft is available for driven equipment. The stub shaft is machined for a 1/2 inch square key (see Figure 6.10-41).

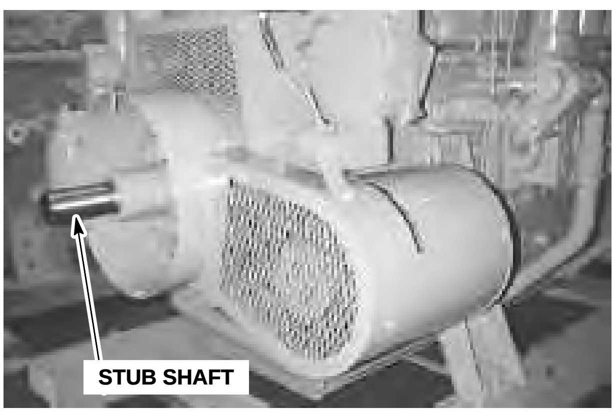


Figure 6.10-41. Alternator Guard

STUB SHAFT REMOVAL

1. Support stub shaft with a suitable sling before removing hex head screws.

⚠ WARNING

The stub shaft assembly weighs 145 lb. (66 kg). Make sure that the crankcase is properly supported and that a properly rated lifting device and rigging are used. Failure to take adequate precautions can result in severe personal injury or death.

2. Remove two 5/8 in. – 18 hex head screws and replace with two guide studs long enough to support stub shaft.

3. Remove remaining four hex head screws and washers from stub shaft plate.

4. Slide stub shaft off of guide studs.

STUB SHAFT CLEANING AND INSPECTION

⚠ WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners or other highly volatile fluids for cleaning.

NOTE: *Make match marks between the plate and the stub shaft before disassembly. High points between the shaft and plate are aligned 180 degrees apart at assembly.*

1. Clean metal parts using approved cleaning solvent.

2. Inspect stub shaft for wear, cracks or other damage.

3. Inspect hex head screws for stripped or damaged threads. Replace if damaged.

4. Lightly oil threads and secure plate to stub shaft using 5/8 in. – 18 hex head screws. Tighten hex head screws to 170 – 173 ft-lb (230 – 235 N·m) (see Figure 6.10-42).

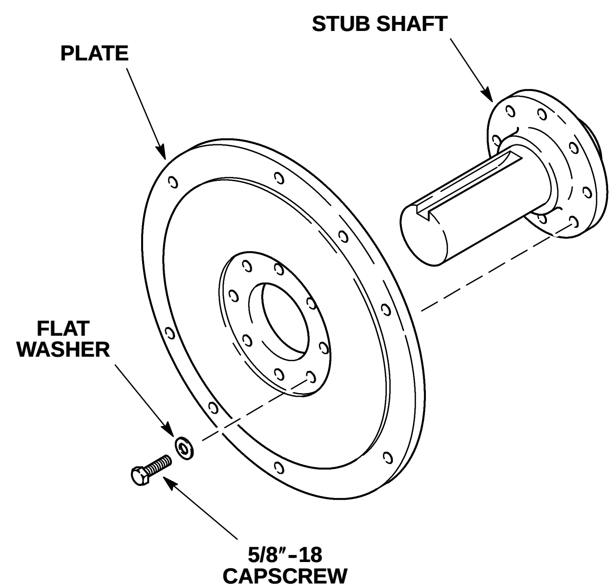


Figure 6.10-42. Stub Shaft Assembly

STUB SHAFT INSTALLATION

⚠ WARNING

The stub shaft assembly weighs 145 lb. (66 kg). Make sure that the crankcase is properly supported and that a properly rated lifting device and rigging are used. Failure to take adequate precautions can result in severe personal injury or death.

1. Slide stub shaft plate assembly over guide studs and onto flywheel.

2. Install four 5/8 in. – 11 hex head screws that secure stub shaft plate to flywheel.

3. Remove two guide studs and install remaining two hex head screws.

4. Tighten hex head screws alternately to 210 ft-lb (256 N·m).

5. Check stub shaft runout.

STUB SHAFT RUNOUT

Allowable runout limit is 0.020 in. (0.508 mm) plus 0.0005 in. (0.0127 mm) for every 1.0 in. (25.4 mm) of shaft length to within 1 in. (25.4 mm) of shaft end. To determine stub shaft misalignment use a dial indicator as shown in Figure 6.10-43.

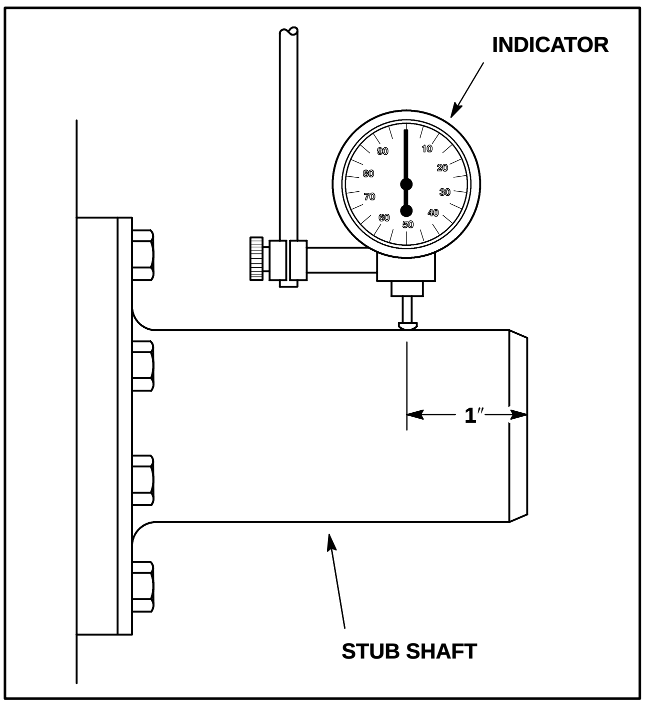


Figure 6.10-43. Checking Stub Shaft Runout

1. With indicator in place rotate stub shaft and record reading. Reading should not exceed limit as specified.

2. If reading is above limit, relocate stub shaft assembly with respect to flywheel.

NOTE: *This procedure will correct for excessive runout due to angular misalignment between the flywheel and the stub shaft mounting flange.*

3. To relocate, remove hex head screws, rotate shaft and replace hex head screws. Retighten hex head screws.

NOTE: *Install indicator again and recheck runout.*

4. If a high spot on mounting surface of stub shaft is known, it will be necessary to indicate flywheel face as shown in Figure 6.10-44.

5. When a high spot on flywheel face is located, stub shaft should be mounted so that high spots on both mounting surfaces are 180° apart.

NOTE: *After installing the stub shaft , repeat the runout checking procedure again to verify it is within the specified limits.*

6. Lightly oil threads and secure plate to stub shaft using 5/8 in. – 18 hex head screws. Tighten hex head screws to 170 – 173 ft-lb (230 – 235 N·m).

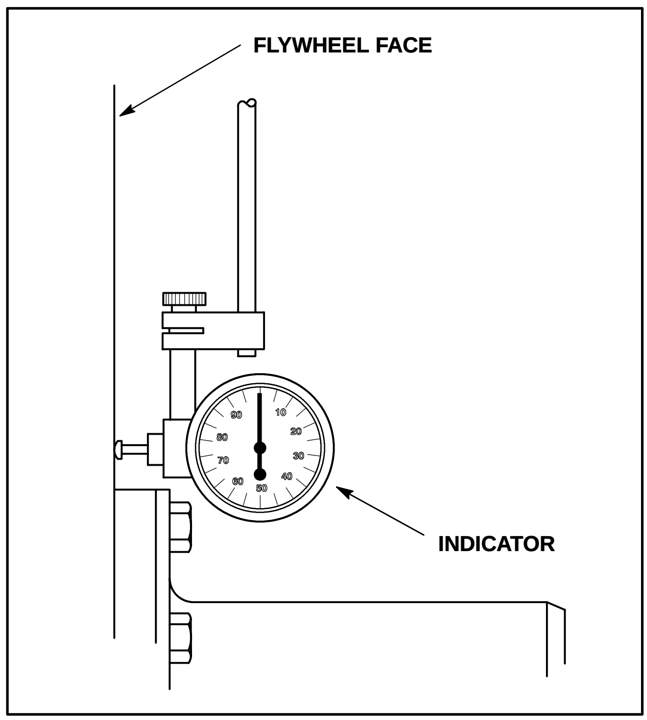


Figure 6.10-44. Indicate Flywheel Face

SECTION 6.15

CEC GENERATOR

CEC GENERATOR

COMPONENT DESCRIPTION

The optional Custom Engine Control (CEC) generator system supplies voltage to the CEC Ignition Module as well as being compatible with future CEC module components.

The CEC generator system consists of the following components:

- Generator
- Wiring harness
- Solid state voltage regulator
- Battery pack

The CEC generator supplies AC power to the voltage regulator. The voltage regulator converts and regulates the power to a nominal 24 VDC (30.0 volts VDC maximum open circuit) (see Figure 6.15-1).

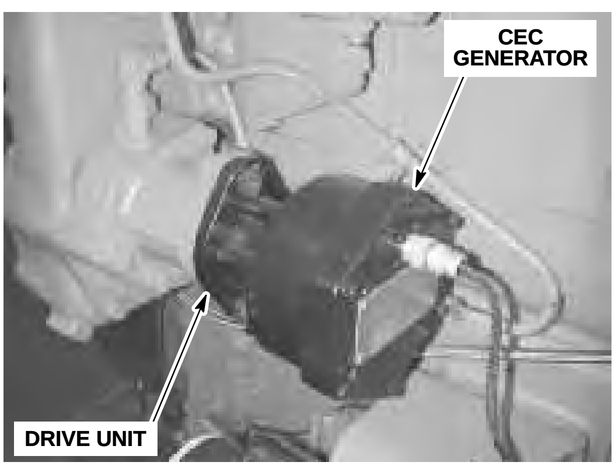


Figure 6.15-1. CEC Generator System

The solid state voltage regulator is mounted below the CEC generator.

The CEC Type I generator provides more power than the Ignition Module currently requires in order to supply future CEC module needs. The CEC generator is equipped with a battery that is mounted off the engine.

The CEC Type II generator is not equipped with a battery and is used to power only the CEC Ignition Module.

GENERATOR SERVICING

The frequency of inspection is determined largely by the type of operating conditions. High speed operation, high temperatures and dust and dirt all increase the wear of coupling sleeve and bearings.

At regular intervals, inspect the terminals for corrosion and loose connections. Inspect the wiring for frayed insulation. Inspect the mounting bolts for tightness.

Inspect the drive coupling for wear or damage. Replace the coupling every 4000 hours or when wear in the slots can be seen.

⚠ CAUTION **Do not weld on or around an engine unless the CEC generator and voltage regulator have been unplugged. Failure to do so may damage the CEC generator, voltage regulator, battery or Ignition Module.**

⚠ CAUTION **The ambient temperature around the CEC generator and voltage regulator must not exceed 150° F (66° C). Disregarding this information could result in product damage and/or personal injury.**

GENERATOR INSTALLATION

1. Install flexible coupling sleeve onto drive unit output shaft. Mount generator onto drive unit. Use two M10 x 45 mm hex head screws, four M10 flat washers, two lock washers and two M10 hex nuts to secure generator to drive (see Figure 6.15-2).

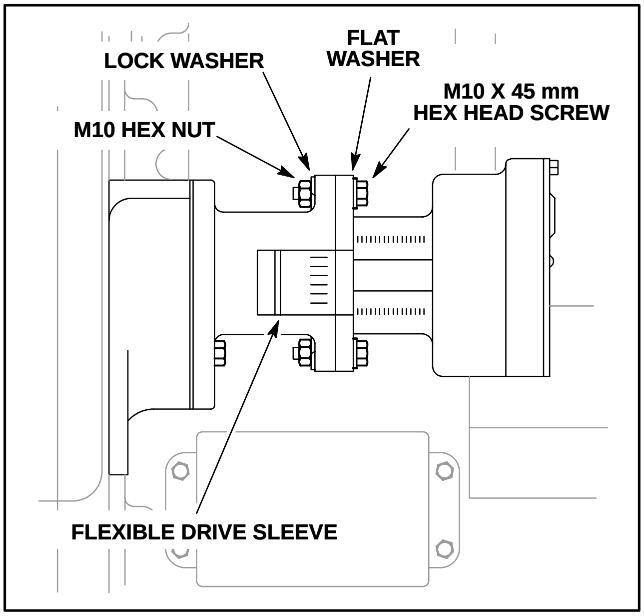


Figure 6.15-2. CEC Generator Installation

VOLTAGE REGULATOR INSTALLATION

1. Install regulator mounting bracket onto first inspection door and secure with two M10 x 30 mm hex head screws and two M10 lock washers (see Figure 6.15-3).

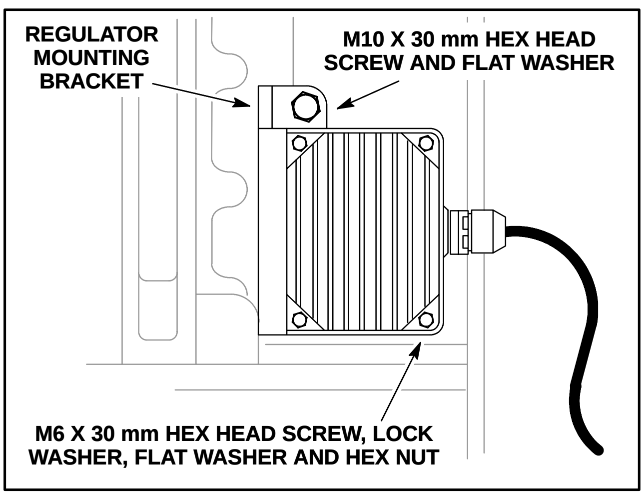


Figure 6.15-3. Voltage Regulator Installation

WIRING HARNESS INSTALLATION

NOTE: *Refer to the wiring diagrams at the end of this section for the Ignition Module power supply (see Figure 6.15-5 and Figure 6.15-6).*

1. Connect wiring harness three pin connector to generator. Connect wiring harness six pin connector to voltage regulator (see Figure 6.15-4). Bundle extra length of wiring harness with tie wraps. Make sure that harness does not interfere with any other parts of engine.

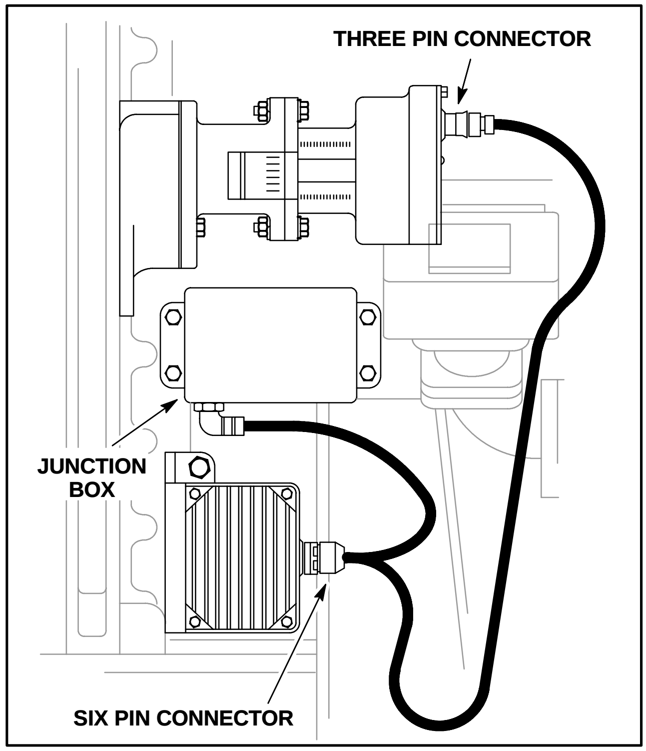


Figure 6.15-4. Wiring Harness Routing

GENERATOR SERVICING

The frequency of inspection is determined largely by the type of operating conditions. High speed operation, high temperatures and dust and dirt all increase the wear of coupling sleeve and bearings.

At regular intervals, inspect the terminals for corrosion and loose connections. Inspect the wiring for frayed insulation. Inspect the mounting bolts for tightness.

Inspect the drive coupling for wear or damage. Replace the coupling every 4000 hours or when wear in the splines can be seen.

GENERATOR DRIVE SERVICING

The generator drive is the same part number as the magneto drive. See Section 5.10 *Ignition System – CEC/Magneto* for drive service and repair.

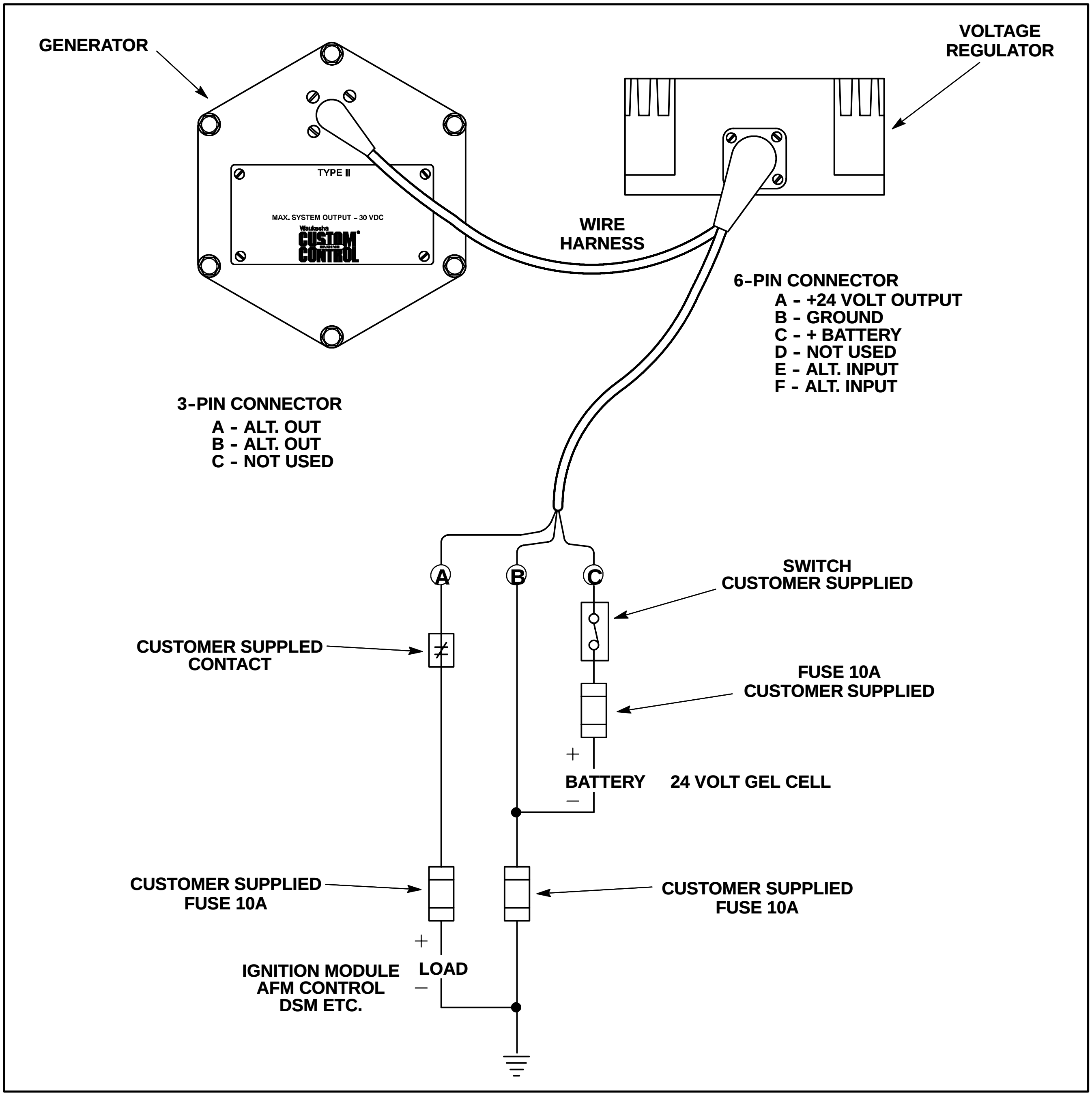


Figure 6.15-5. CEC Type I Generator Wiring Schematic

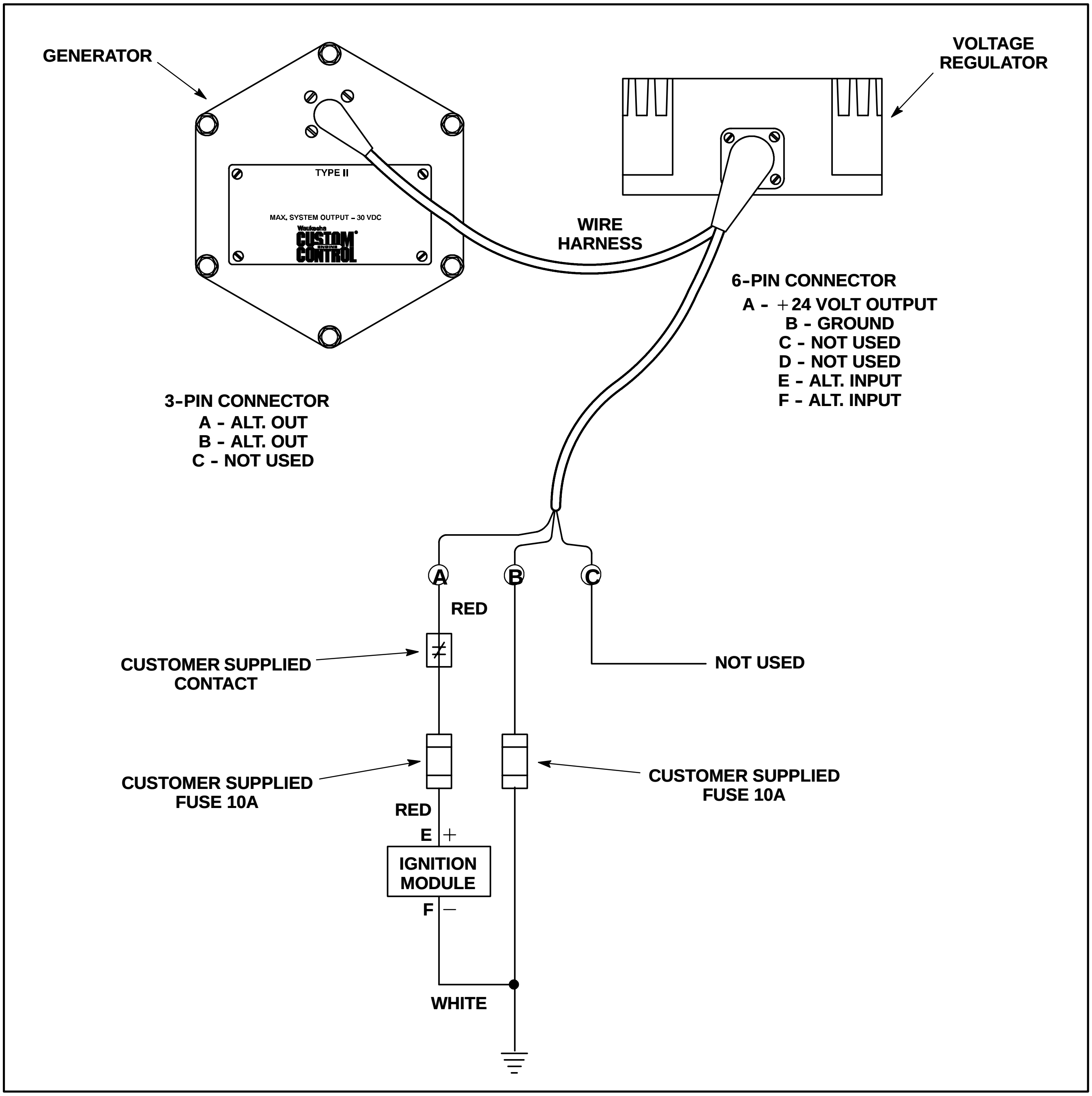


Figure 6.15-6. CEC Type II Generator Wiring Schematic

The CEC Type I generator (equipped with battery) provides more power then the Ignition Module currently requires in order to supply future CEC module needs.

See Figure 6.15-7 for available generator output to plan future CEC module installations as they become available.

Contact Waukesha Engine or your distributor with any questions concerning the availability and installation of CEC products.

NOTE: *The CEC Detonation Sensing Module requires the use of the Ignition Module.*

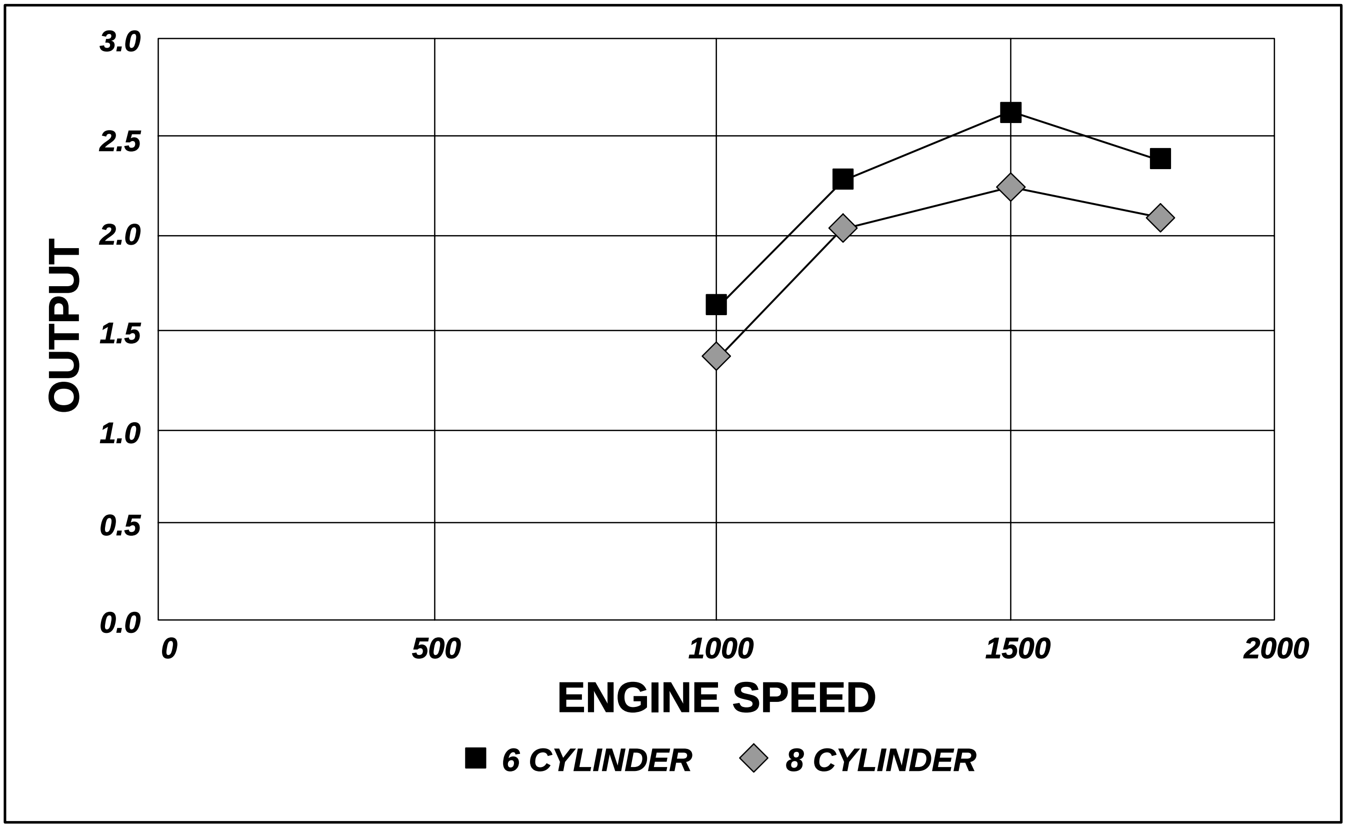


Figure 6.15-7. CEC Type I System With Battery

SECTION 7.00

TROUBLESHOOTING

TROUBLESHOOTING

The following table is provided to assist the user in determining the possible causes of unsatisfactory engine operation, as well as point out the corrective action that may be undertaken to remedy the problem. Knowledge of how the engine operates along with the current readings from the engine instrument panel can be combined with this information to provide a framework for resolving actual or potential problems.

NOTE: *This chart is only provided as a service to our customers. It should not be viewed as a reflection of Waukesha Engine's actual experience with this product.*

Table 7.00-1. Troubleshooting

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine crankshaft cannot be barred over. **⚠ CAUTION Do not attempt to rotate crankshaft with the starter. Internal engine damage could occur.**	Load not disengaged from engine.	Disengage load.
	Coolant or obstruction in cylinder: a. Cracked exhaust manifold. b. Leaking head gasket. c. Cracked head. d. Cracked sleeve. e. Cracked crankcase.	***NOTE:*** *Remove spark plugs to vent cylinders of accumulated coolant.* a. Replace exhaust manifold. b. Replace head gasket. c. Replace head. d. Replace sleeve. e. Replace crankcase.
	Seized piston.	Determine cause of seizure: insufficient lubrication, inadequate cooling, overload, etc. Replace piston and sleeve as required.
	Main bearings too tight: a. Main bearing caps installed out of location. b. Improper bolt torque. c. High spots on bearings.	a. Check each bearing cap; place in proper location. b. Adjust bearing caps. Torque to specification. c. Replace.
Engine will crank but will not start.	On-off switch in OFF position or defective (if used). Engine protection device may be energized.	Place switch in the ON position or replace if defective.
	Fuel throttle or manual shutoff control in OFF position.	Place fuel throttle or manual shutoff control in ON position.
	Oil pressure switchgage not reset.	Reset switchgage.
	Insufficient cranking speed: a. Low starting air/gas pressure. b. Low battery voltage. c. Excessive starter current draw. d. Lube oil viscosity too high.	a. Build up air/gas pressure. 100 rpm required to start engine. b. Charge batteries. c. Repair starter motor. d. Change lube oil or raise the oil temperature if too cold.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will crank but will not start (cont'd).	Fuel system inoperative: a. Insufficient fuel supply or fuel pressure. b. Fuel system settings incorrect. c. Incorrect ignition timing. d. Damaged carburetor diaphragm. e. Worn carburetor mixing valve assembly. f. Ruptured line pressure regulator diaphragm. g. Butterfly valve closed tight (Impco 200 only).	 a. Check gas pressure. b. Reset regulators. c. Reset timing. d. Replace diaphragm. e. Replace assembly. f. Replace diaphragm. g. Open butterfly valve adjustment screw 1-1/2 turns open.
	Faulty ignition system: a. CEC Ignition Module malfunctions. b. Breakerless ignition generator power board faulty (Magneto). c. Breakerless ignition generator distributor pulser faulty (Magneto). d. Low or no magneto output (Magneto). e. Drive assembly broken (Magneto). f. Drive coupling broken (Magneto). g. Broken or damaged wiring. h. Incorrect ignition timing. i. Spark plug gap too wide.	 a. Check all wiring. Clean timing disc. Check voltage to Ignition Module. Check pick-up and regap. Replace Ignition Module. b. Replace power board. c. Replace distributor pulser. d. Repair or replace magneto. e. Replace drive. f. Replace coupling; check timing. g. Repair or replace. h. Reset the timing. i. Gap per specification.
	Knock Detection Module inoperative or in shutdown condition (Inline Engines): a. KDM in shutdown mode. b. Wiring from sensors to KDM damaged.	 a. Check KDM diagnostic display codes, and perform appropriate procedures as outlined in Form 6285 *KDM Custom Engine Control Knock Detection Module Installation, Operation, And Maintenance Manual.* Contact your Waukesha Engine Distributor for assistance. b. Repair or replace wiring as required. Refer to Form 6285 *KDM Custom Engine Control Knock Detection Module Installation, Operation, And Maintenance Manual.* Contact your Waukesha Engine Distributor for assistance.
	Insufficient or no air intake: a. Clogged intake air filters. b. Clogged/Dirty intercooler (air side).	***NOTE:*** *Bar the engine over by hand to verify that cylinders are clear. Inspect the intake manifold for accumulations of lube oil.* a. Remove and clean. b. Remove and clean.
	Poor compression: a. Worn rings. b. Leaking valves. c. Leaking head gasket.	 a. Replace. b. Check valve lash. c. Replace.
	Camshaft gear not in time with crankshaft gear.	Set crankshaft at T.D.C. #1. Align the camshaft, idler and crankshaft gear match marks.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine will crank but will not start (cont'd).	Governor inoperative:	
	a. Insufficient oil.	
	1. Oil supply tube blocked.	1. Repair tube.
	2. Gasket blocks off oil supply hole (after repair).	2. Re-position or replace gasket.
	3. Water/sludge in oil passages.	3. Clean or replace governor.
	b. Binding control linkage:	
	1. Linkage is dirty.	1. Clean.
	2. Linkage is broken.	2. Repair.
	3. Linkage pivot points are tight.	3. Re-adjust or replace pivot point bearing surfaces.
	c. Electric governor actuator not opening.	c. Check wiring and correct. Check controller for power and ground.
	d. Governor geometry incorrect.	d. Correct as necessary.
Engine stops suddenly.	Fuel:	
	a. Insufficient fuel supply.	a. Check gas pressure.
	b. Loose fuel control linkage.	b. Readjust and tighten.
	Low oil pressure causes engine protection control to shut down engine.	Inspect lubricating oil system and components; correct cause.
	High coolant temperature causes engine protection control to shut engine down.	Inspect cooling system and components; correct cause.
	Faulty ignition system.	Repair or replace components as required.
	High manifold temperature.	Correct cause.
	Engine overspeed causes engine protection control to shut down engine.	Loose linkage. Determine and correct cause.
	High lube oil temperature.	Correct cause.
	Excessive load causes engine to stall.	Determine and correct cause of overload.
	Insufficient intake air:	
	a. Clogged intake air filter.	a. Remove and clean.
	b. Clogged intercooler (air side).	b. Remove and clean.
	Obstructed exhaust manifold.	Locate and remove obstruction.
	Piston seizure:	
	a. Insufficient cooling.	a. Replace scored piston, sleeve and rings. Clean and/or fill the cooling system, including the heat exchangers.
	b. Insufficient lubrication.	b. Replace scored piston, sleeve and rings. Clean oil passages, and/or determine cause.
	c. Insufficient ring gap (applicable only immediately after overhaul).	c. Replace scored piston, sleeve and rings. Adjust ring gap.
	Obstruction in cylinder.	Replace parts.
	Seizure of bearings – main, connecting rod, piston pin or camshaft.	Replace bearings – clean up or replace crankshaft, camshaft or piston pins, as required.
	a. Lack of lubrication.	a. Check lube oil system; correct cause.
	b. Dirt in lube oil.	b. Check lube oil filters.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine loses power.	Insufficient fuel: a. Low gas pressure. b. Misadjusted wastegate (altitude compensation).	a. Check gas fuel system. b. Consult Waukesha factory representative for correct setting.
	Air intake system malfunction: a. Dirty intake air filters. b. Clogged intercooler.	a. Remove and clean. b. Remove and clean. **⚠ CAUTION** **Bar the engine over by hand to verify that the cylinders are clear. Inspect the intake manifold for accumulations of lube oil. Failure to follow these precautions could cause internal engine damage.**
	Air leaks in intake system.	Find and correct as required.
	Turbocharger malfunction or failure: a. Lack of lubrication. b. Foreign material. c. Excessive backpressure.	a. Determine cause; repair or replace turbocharger. b. Repair or replace turbocharger. c. Determine and correct cause.
	Low compression pressure: a. Leaking exhaust/intake valve. b. Misadjusted intake and exhaust valves. c. Worn rings (excessive blow-by). d. Worn pistons/liner.	a. Recondition seats and valves. b. Readjust. c. Replace. d. Replace as necessary.
	Ignition system timing incorrect.	Correct cause for change and reset timing.
	Excessive exhaust system backpressure.	Correct as required.
	Engine misfiring: a. Worn spark plugs. b. Incorrect carburetor and/or regulator adjustment. c. Faulty ignition system.	a. Replace. b. Check for cause and repair. c. Repair or replace components as required.
Engine will not shut down using normal stopping procedures.	Defective ON-OFF switch.	Replace.
⚠ WARNING **Shut off the gas supply for positive shutdown of gas engines. Inspect the intake manifold for accumulations of lube oil. Failure to follow these precautions could cause severe personal injury or death.**	Overheated combustion chamber deposits cause the engine to “diesel”.	Allow engine to cool down before attempting to stop.
Engine will not reach rated speed.	Engine overloaded.	Determine and correct cause.
	Insufficient fuel supply.	Check fuel supply system.
	Restricted air intake.	Correct cause.
	Governor misadjusted.	Readjust.
	Ignition not properly timed.	Re-time.
	Tachometer inaccurate.	Calibrate or replace tachometer.
Engine will not accept rapid load changes.	Engine misfiring: a. Fuel system settings incorrect. b. Faulty ignition system. c. Governor misadjusted.	a. Readjust per fuel system specifications. b. Repair or replace components as required. c. Adjust the governor.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine misfires at light load.	Faulty ignition system.	Repair or replace components as required.
	Fuel system setting incorrect.	Readjust per fuel system specifications.
	Fuel regulator valve stuck shut.	Repair or replace regulator.
Individual cylinders misfire.	Faulty ignition system.	Repair or replace components as required.
Engine will not deliver rated power.	Determination of actual power produced is inaccurate.	Determine and correct cause.
	Clogged air filter.	Clean the air filter.
	Foreign material lodged in compressor impeller or turbine.	Disassemble and clean. Overhaul turbocharger.
	Excessive dirt build-up in compressor assembly.	Thoroughly clean compressor assembly. Service air cleaner and check for leakage.
	Leak in engine intake or exhaust manifold.	Tighten loose connections or replace manifold gaskets as necessary.
	Rotating assembly bearing seizure.	Overhaul turbocharger.
	Wastegate opening too soon.	Readjust.
	Engine misfiring: a. Fuel system setting incorrect. b. Faulty ignition system.	 a. Readjust per fuel system specifications. b. Repair or replace components as required.
Engine detonates.	Engine overloaded.	Determine and correct cause of overload.
	Incorrect ignition timing.	Reset to specification.
	Air/fuel ratio too rich.	Reset to specification.
	Faulty ignition system.	Repair or replace components as required.
	Knock Detection Module inoperative or in shutdown condition (Inline Engines): a. KDM in shutdown mode. b. Wiring from sensors to KDM damaged.	 a. Check KDM diagnostic display codes, and perform appropriate procedures as outlined in Form 6285 *KDM Custom Engine Control Knock Detection Module Installation, Operation, And Maintenance Manual.* Contact your Waukesha Engine Distributor for assistance. b. Repair or replace wiring as required. Refer to Form 6285 *KDM Custom Engine Control Knock Detection Module Installation, Operation, And Maintenance Manual.* Contact your Waukesha Engine Distributor for assistance.
Emission levels too high.	Incorrect ignition timing.	Reset to specification.
	Air/fuel ratio incorrect.	Reset to specification.
	Faulty ignition system.	Repair or replace components as required.
Low or fluctuating lube oil pressure. **⚠ CAUTION Shut down the engine immediately to prevent severe internal engine damage.**	Insufficient oil.	Add oil as required.
	Lube oil pressure gauge inaccurate.	Compare to master gauge. Replace gauge if necessary.
	Oil gauge line plugged or valve shut.	Renew gauge line; open valve.
	Lube oil filters plugged.	Change elements; clean filter.
	Lube oil pressure regulating valve stuck in open position.	Clean and polish valve.
	Lube oil of low viscosity.	Change to higher viscosity oil as recommended.
	Lube oil foaming.	Use oil grade recommended. Check for water leaks into oil.
	Clogged oil inlet screen.	Remove and clean screen(s).
	Engine is operated at angles that exceed the maximum safe tilt specification.	Operate within maximum safe tilt angles (see Specifications).
	Dirty oil cooler.	Clean.
	Worn lube oil pump.	Repair or replace pump.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Low or fluctuating lube oil pressure (cont'd.)	Worn bearings (main, connecting rod and camshaft).	Replace worn bearings.
	Cracked or leaking lube oil piping.	Repair or replace piping.
High lube oil pressure.	Lubricating oil temperature too low.	Check/replace lube oil thermostats.
	Lubricating oil of high viscosity.	Change to lower viscosity oil as recommended.
	Lubricating oil pressure regulating valve stuck in closed position.	Clean and polish valve.
Low gas/air pressure.	Incorrectly adjusted gas regulator.	Readjust.
	Insufficient line pressure.	Increase line pressure.
	Incorrect orifice and/or spring in gas regulator.	Replace orifice and/or spring.
	Undersize gas regulators.	Replace with gas regulators of adequate size.
	Undersize piping.	Replace with piping of adequate size.
	Gas regulators mounted too far from engine.	Remount gas regulators as close to carburetors as possible.
High gas/air pressure.	Incorrectly adjusted gas regulator.	Readjust.
	Incorrect spring in gas regulator.	Replace spring.
	Excessive line pressure.	Reduce line pressure.
Low jacket water temperature.	Gauge inaccurate.	Compare to master gauge; replace if necessary.
	Inoperative or malfunctioning thermostat(s).	Replace thermostatic element or thermostat(s).
High jacket water temperature.	Gauge inaccurate.	**WARNING** **Allow the engine to cool. Failure to follow this precaution could cause severe personal injury or death.** Compare to master gauge; replace if necessary.
	Low coolant level.	Fill cooling system.
	Inoperative or malfunctioning thermostat(s).	Replace thermostatic element or thermostats (as applicable).
	Air bound cooling system.	Check vent and balance lines. Purge air from cooling system.
	Dirty or coated cooling passages.	Clean the cooling system.
	Engine overloaded.	Determine and correct cause.
	Poor coolant circulation.	Check the entire cooling system.
	Worn jacket water pump or seals.	Overhaul or replace pump.
	Frozen coolant.	Completely thaw cooling system before restarting engine.
	Cracked exhaust manifold.	Replace manifold.
	Leaking head gasket.	Replace head gasket.
	Incorrect ignition timing.	Reset ignition timing.
	Cracked head.	Replace head.
	Cracked sleeve.	Replace sleeve.
High lube oil consumption.	Oil leaks in lube oil system.	Locate and repair leaks.
	Leaking crankshaft oil seals rear and/or front.	Change seals.
	Worn valve guides; improperly installed, worn valve stem seals.	Change head; renew guides, or valve guide internal seals.
	Stuck/worn piston rings.	Renew rings.
	One or more pistons with rings upside down (after overhaul).	Remove piston; correct position of rings.
	Improper viscosity.	Change to a viscosity recommended for operating temperatures.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
Lube oil contamination.	Lube oil contaminated with water: a. Cylinder sleeve cracked or seals leaking. b. Oil cooler leaking. c. Cracked cylinder head. d. Blown head gasket.	***NOTE:*** *Change oil.* a. Replace sleeve O-rings. b. Repair or replace oil cooler. c. Repair or replace cylinder head. d. Replace.
	Lube oil contaminated with dirt: a. Dirty oil make up container. b. Lube oil filter by-pass valves opening because elements are plugged. c. Lube oil filter elements punctured. d. Air intake filters punctured.	a. Clean. b. Replace elements. c. Replace elements. d. Replace air intake filters.
High lube oil temperature.	Gauge inaccurate.	Compare to master gauge; replace gauge if necessary.
	Engine overloaded.	Determine and correct cause.
	Insufficient cooling: a. Dirty lube oil cooler. b. Defective lube oil cooler thermostatic control.	a. Clean or replace. b. Repair or replace.
	Dirty jacket water heat exchanger or radiator.	Clean or replace.
	Low lubricating oil pressure.	See *Low or Fluctuating Lube Oil Pressure*.
Excessive fuel consumption.	Leaks in fuel system.	Repair as required.
	Faulty ignition system.	Repair or replace components.
	Retarded ignition timing.	Set timing to specifications.
	Engine overloaded.	Determine and correct cause.
	Improper air/fuel ratio.	Set to specifications.
	Poor synchronization of multi-engine installations.	Balance loads.
	Improper matching of torque convertor to engine and load.	Replace torque convertor.
	Poor compression.	Determine cause(s) and repair.
	Inaccurate fuel and load measurement.	Determine cause(s) and repair.
Excessive vibration. **CAUTION** **Shut down the engine immediately to prevent severe internal engine damage. Investigate for cause of vibration.**	Foundation bolts: a. Loose. b. Cracked.	a. Torque to specification. b. Replace and torque all bolts to specification.
	Unbalanced cylinders; misfiring ignition system.	Repair or replace components as required.
	Vibration damper: a. Loose. b. Malfunctioning.	a. Replace all securing bolts; torque to specs. b. Replace damper.
	Crankshaft: a. Broken. b. Connecting rod and/or main bearing nuts loose.	a. Conduct a complete investigation of entire engine for damage. b. Determine the reason for loosening; investigate the entire lower crankcase before torquing the bolts to specification and running the engine.
	Loose flywheel.	Determine cause and correct.
Knocking or unusual noises.	Low octane fuel.	Adjust timing for the fuel used.
	Engine overloaded.	Determine and correct cause.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
	Overly advanced ignition timing.	Re-time.
	Excessive valve clearance.	Adjust to specification.
	Sticking valves or rocker arms.	Free up or replace.
	Damaged or excessively worn accessory drives.	Repair or replace components as required.
	Loose bearings (failed).	Replace bearings.
	Loose piston pins (failed).	Replace piston pins and/or pin bushings as required.
	Excessive crankshaft end play.	Replace main bearing thrust rings.
	Misfit or excessively worn timing gears.	Replace.
	Knock Detection Module inoperative or in shutdown condition (Inline Engines): a. KDM in shutdown mode. b. Wiring from sensors to KDM damaged.	a. Check KDM diagnostic display codes, and perform appropriate procedures as outlined in Form 6285 *KDM Custom Engine Control Knock Detection Module Installation, Operation, And Maintenance Manual.* Contact your Waukesha Engine Distributor for assistance. b. Repair or replace wiring as required. Refer to Form 6285 *KDM Custom Engine Control Knock Detection Module Installation, Operation, And Maintenance Manual.* Contact your Waukesha Engine Distributor for assistance.
TURBOCHARGER: Excessive noise or vibration.	Low lube oil pressure. Improper bearing lubrication. Load engine before warm oil is supplied to the turbocharger.	Provide required oil pressure. Clean or replace oil line. If trouble persists, overhaul turbocharger.
	Dirty impeller/turbine.	Clean.
	Damaged impeller/turbine.	Replace as necessary.
	Leak in engine intake or exhaust manifold.	Tighten loose connections or replace manifold gaskets as necessary.
GOVERNOR: Engine hunts or surges.	Compensation adjustments incorrect.	Adjust needle valve to specification.
	Dirty oil in governor.	Drain oil, clean governor and refill.
	Foamy oil in governor.	Drain oil and refill.
	Low oil level.	Add oil to correct level on gauge glass. Check for leaks, especially at drive shaft.
	Lost motion in engine linkage.	Repair linkage.
	Binding in engine linkage.	Repair and realign linkage.
	Governor worn or not correctly adjusted.	Repair and adjust governor.
	Compensating spring incorrectly adjusted.	Adjust.
	Low oil pressure. Normal operating pressure is 110 - 120 psi.	Replace governor.
	Power piston sticking inside (PSG or SG).	Replace governor.
	Misadjusted linkage.	Adjust.
	Fluctuating or unstable fuel gas pressure.	Adjust.
	Rough drive.	Repair or replace.

(Continued)

SYMPTOM	PROBABLE CAUSE	REMEDY
GOVERNOR: Terminal shaft/engine linkage jiggles.	Compensating spring adjustment at critical setting.	Change compensating spring pre-compression approximately 0.005 in. (0.13 mm) either way.
	Speed droop (if used) at critical setting.	Increase droop to eliminate critical setting. Load division will be affected if this is done. Readjust droop on units affected.
	Governor base not bolted down evenly.	Loosen bolts, realign and secure.
	Load does not divide properly in interconnected engines.	Speed droop adjustment incorrect: a. Adjust droop to divide load properly. b. Increase droop to resist picking up (or dropping off) load. c. Reduce droop to increase picking up (or dropping off) load.
	Speed droop shaft vibrating out of position.	Increase tension of speed droop friction spring.
	Rough engine drive.	a. Check alignment of gears. b. Check gear backlash.
GOVERNOR: Load does not divide properly in inter-connected engines.	***NOTE:*** *If droop adjustment is not provided, the governor is isochronous only, and cannot be used for parallel operation. Speed droop is not essential in a DC electrical system. The equivalent of speed droop in a DC system is obtained by changing the compounding of the generators at the bus between generators. An under-compounded generator is equivalent to a speed droop governor. Governors with speed droop adjustment are commonly used for DC service since the droop adjustment may be used to correct errors or inequalities of generator compounding.*	
	Slippage in hydraulic or electric couplings (if used).	Adjust coupling.
GOVERNOR: Engine is slow to respond to speed or load changes.	Needle valve adjustment incorrect.	Readjust compensating needle valve. Open further only if possible to do so without causing instability when running without load.
	Governor may be intentionally designed to protect engine from overloading during a load change.	No field correction.
	Pivot valve not centered. It must open control ports equally in both directions.	Adjust pivot valve.
	Low oil pressure in governor.	See *Low oil pressure.*
	Engine overloaded.	Reduce load.
	Restricted fuel supply.	Clean fuel supply line and filters.
	Load limit knob set to restrict fuel.	Open up the load limit.
	Lean air/fuel ratio.	Adjust carburetor mixture value.
GOVERNOR: Engine will not pick up rated load.	Butterfly valves will not open far enough.	a. Adjust engine-to-governor fuel linkage. b. Adjust load limiting device.
	Restricted fuel supply.	Clean fuel supply line and filters.
	Voltage regulator (if used) not functioning.	Adjust or repair.
	Slipping clutch (if used) between engine and driven load.	Foaming oil or low oil level in hydraulic clutch.
	Speed adjustment of the governor is restricted.	a. Check the maximum speed limit adjustment on dial control governor. b. Inspect speed adjusting linkage for interference on lever control governor.

COMPRESSION PRESSURE CHECK PROCEDURE

NOTE: *See compression pressure check worksheet on next page.*

1. Determine engine's compression ratio from name tag, timing tag, or by researching engine's serial number.

2. Using Figure 7.00-1, determine compression pressure range based on engine's compression ratio. Example: The compression pressure range for an engine with an 8.7:1 compression ratio is 190 – 212 psi (1,310 – 1,461 kPa).

3. Adjust compression pressure range for altitude by multiplying compression pressure range by correction factor (CF) (see Figure 7.00-2).

NOTE: *Using the previous example, an altitude of 5,000 ft. (1,524 m) gives a CF of 0.84. Multiplying high and low values of compression pressure range [190 psi and 212 psi (1,310 and 1,461 kPa)] by CF (0.84) gives an adjusted compression range of approximately 160 – 178 psi (1,103 – 1,227 kPa).*

4. Measure engine compression using following procedure:

CAUTION Ensure ignition and fuel supply are shut off before cranking engine. Failure to do so could cause serious personal injury or product damage.

a. Shut off ignition and fuel supply to engine.

b. Remove spark plugs.

c. Attach an appropriate compression test device to the first cylinder to be tested.

d. With throttle wide open, crank engine at a minimum 100 rpm until gauge reading stabilizes. Record gauge reading.

e. Repeat on remaining cylinders.

5. Compare measurements in Step 4 to calculations in Step 3. Average of measurements in Step 4 should fall within high and low limits calculated in Step 3. No cylinder should deviate more than 15 psi (103 kPa) from average value.

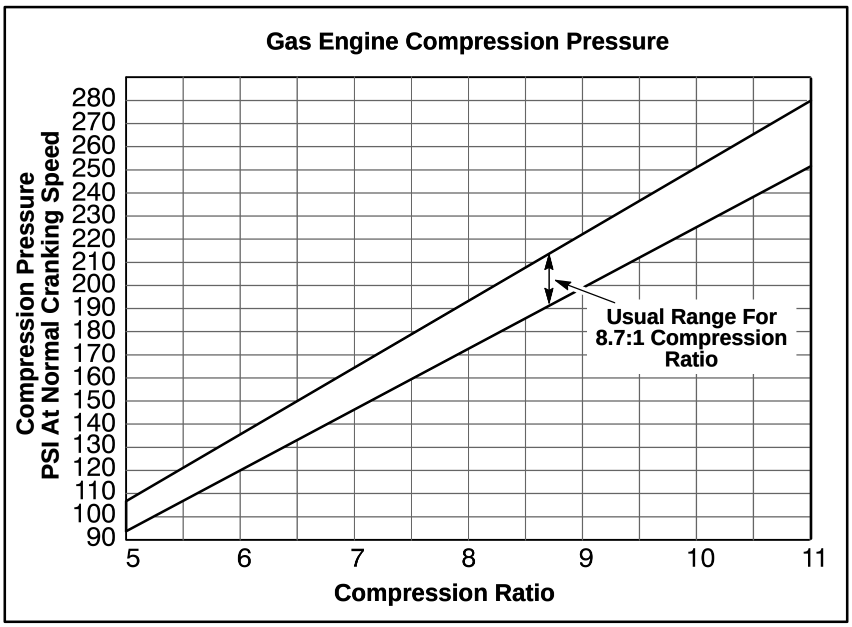


Figure 7.00-1. Engine Compression Pressures

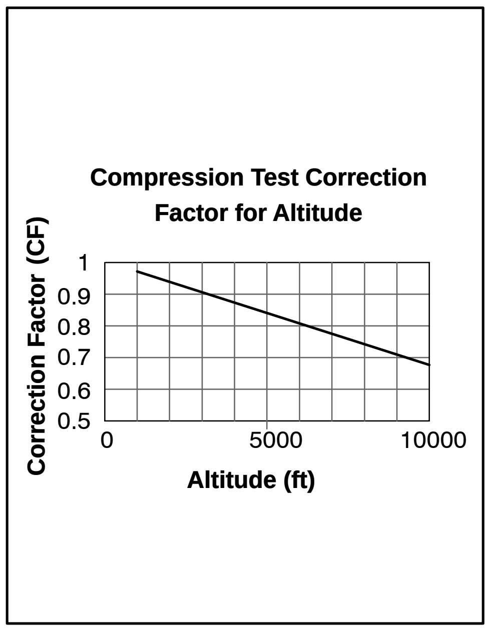


Figure 7.00-2. Correction Factor

COMPRESSION PRESSURE CHECK WORKSHEET

1. Compression Ratio: ______

2. Compression Pressure Range: ______ Low ______ High

3. Compression Factor (CF) Figure 1 ______ X Compression Pressure (Low) ______ = ______

Compression Factor (CF) Figure 1 ______ X Compression Pressure (High) ______ = ______

4. Compression Pressures:

Cylinder #1 ______

Cylinder #2 ______

Cylinder #3 ______

Cylinder #4 ______

Cylinder #5 ______

Cylinder #6 ______

Cylinder #7 ______

Cylinder #8 ______

Total ______

Average ______
(Total / # Cyl.)

(Total / # Cyl.)

Maximum ______

Minimum ______

5. Low Pressure Value (Step 3): ______ Average (Step 4): ______

High Pressure Value (Step 3): ______ Average (Step 4): ______

							Yes	No
Maximum	______	-	Average	______	=	______ < 15 psi	☐	☐
Average	______	-	Minimum	______	=	______ < 15 psi	☐	☐

SECTION 7.05

MAINTENANCE AND STORAGE

ENGINE PERFORMANCE RECORD

Engine operating information recorded during regular inspections is necessary to apply proper routine maintenance schedules. Accurate records will help to control costs by avoiding unnecessary servicing, ensuring needed servicing, and providing trend information on the general engine condition. It is recommended that a record of the following information be kept.

Date __________ Time __________

Serial No. ____________________ Spec. No.____________________ Model ______________________

Hourmeter Reading ____________ RPM ________________________ Ambient Temp. ________________

Ignition Timing ________________ Load ________________________ Hours on Spark Plugs __________

Oil Temperature ______________ Oil Pressure __________________

Jacket Water Temperature _______ Outlet ______________________ Inlet_________________________

Gas/Air Pressure ______________ Supply Pressure _______________

Intake Manifold Press. __________ Intake Manifold Temperature ______

Exhaust Manifold Oxygen % ______

Exhaust Backpressure __________ Crankcase Pressure (Pos/Neg)____

Auxiliary Water Temperature ______ In __________ Out________

Unusual Noise(s) Vibration ______________________________________

Oil Leaks (Location) ____

Coolant Leaks (Location) ______________________________________

Exhaust Manifold Temperatures:	Exhaust Manifold Temperature, Preturbine
1____________________________	____________________________
2____________________________	____________________________
3____________________________	____________________________
4____________________________	____________________________
5____________________________	____________________________
6____________________________	____________________________
7____________________________	____________________________
8____________________________	____________________________

ROUTINE MAINTENANCE

Table 7.05-1. VGF F18/H24 Routine Maintenance Chart

ITEM	SERVICE	DAILY OR AS REQUIRED	WEEKLY	EVERY 3 MONTHS	EVERY 6 MONTHS	ANNUALLY	500 HOURS	720 HOURS	1000 HOURS	1440 HOURS	2500 HOURS	4000 HOURS	8000 HOURS
Air Cleaner Filter Element	Clean or Replace	•											
Air Cleaner Precleaner Element	Clean	•											
Air Starter Lubricator	Fill	•											
Control Rod Ends and Linkage	Lubricate	•											
Cooling System Level	Check	•											
Crankcase Oil Level	Check	•											
Governor Rod Ends	Lubricate		•										
Ignition Cables - Primary and Secondary Connections	Inspect		•										
Cooling Water Analysis	Check			•									
Crankcase Pressure	Check			•									
Oil Pressure Safety	Calibrate/Test			•									
Regulator	Adjust			•									
Shutdown Controls	Calibrate/Test			•									
Water Temperature Shutdown	Calibrate/Test			•									
Cylinder Compression	Check				•								
Quick Start Governor Oil Filter	Change				•								
Cooling System - Jacket Water and Auxiliary Water	Clean and Flush					•							
Cooling System Thermostats	Remove and Test					•							
Cooling System Tube Bundle	Clean					•							
Crankcase Oil Pickup Screens	Clean					•							
Crankcase Pressure Relief Valves	Exercise and Inspect					•							
Exhaust Backpressure	Check					•							
Full-Flow Filter Relief Valve	Inspect					•							
Governor - Synchronizer or Speed Control	Adjust					•							
High Tension Wires	Replace					•							
Ignition Primary Terminals - Harness Plug	Inspect					•							
Intercooler	Clean					•							
Main and Rod Bearings	Inspect					•							
Oil Pan	Clean					•							
Turbochargers	Clean and Inspect					•							
Rocker Cover Gasket	Replace					•							
CEC Ignition Timing Magnets	Check					•							
Engine Oil (Continuous Duty)	Analyze						•						

ITEM	SERVICE	DAILY OR AS REQUIRED	WEEKLY	EVERY 3 MONTHS	EVERY 6 MONTHS	ANNUALLY	500 HOURS	720 HOURS	1000 HOURS	1440 HOURS	2500 HOURS	4000 HOURS	8000 HOURS
Ignition Timing – Magneto	Check							•					
Engine Oil* (Continuous Duty) GSID	Change							•					
Engine Oil* (Continuous Duty) GL, GLD	Change								•				
Magnetic Plug – Turbo Supply	Clean								•				
Oil Cooler (Oil Side)	Drain	At Oil Change – 1000 Hours											
Oil Filter Elements And Seals	Change	At Oil Change – 1000 Hours											
Spark Plugs	Replace									•			
Valve Clearance	Adjust									•			
Ignition Timing – CEC Ignition Module	Check										•		
Crankcase Breather	Clean										•		
Engine Mounting and Alignment	Check										•		
Governor Compensating Needle Valve	Adjust											•	
Ignition Magneto Drive Coupling	Replace											•	
Carburetor – Air/Gas Valve	Clean and Inspect												•
Carburetor – Diaphragm	Replace												•
Carburetor Gasket	Replace												•
Ignition Magneto/Harness Plug	Test and Inspect												•
Ignition Transformer Coils	Test and Inspect												•

NOTE: ** For ebullient cooled engines, hot water systems with engine water temperature of 200° F (93° C) or above, engines using gaseous fuel containing H_2S in excess of published limits, or alternate fuels such as landfill gases, refer to "Recommended Oil Change Intervals" this section or Section 5.30* Lubrication System*.*

RECOMMENDED OIL CHANGE INTERVALS

⚠ CAUTION The use of some types of oil, as well as dusty environment, marginal installation, internal engine condition and/or operating the engine with malfunctioning carburetion equipment may require more frequent oil changes. Waukesha Engine recommends that the lubricating oil be monitored with a professional oil analysis program. Extended oil change intervals may cause varnish deposits, oil oxidation, or sludge conditions to appear in the engine, which an oil analysis cannot detect. Disregarding this information could result in engine damage. Contact your local Waukesha Distributor for periodic engine maintenance.

Table 7.05-2. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance

ENGINE MODEL	ISO STANDARD OR CONTINUOUS POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD POWER	LIGHT LOAD OPERATION	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE 200° F (93° C) OR ABOVE	STANDBY DUTY
FOR ENGINES OPERATING WITH OIL HEADER TEMPERATURES 195° F (91° C) OR BELOW.					
VGF G,GL,GLD Natural Gas, HD-5 Propane	Normal 1000 hours (Extended 1250 hours*)	500 hours	1000 hours	720 hours	500 hours or annually
VGF GSID Natural Gas, HD-5 Propane	Normal 720 hours (Extended 900 hours*)	500 hours	720 hours	500 hours	500 hours or annually

NOTE: *Change lube oil filter elements when lube oil is changed.*
** Extended oil drain intervals listed, are acceptable, if a Microspin centrifuge, in conjunction with a Waukesha supplied oil filtration system is used, and an oil analysis program is followed.*

Table 7.05-3. Recommended Oil Change Intervals For Engines Receiving Normal Maintenance And Using Gaseous Fuel Containing H_2S

ENGINE MODEL	ISO STANDARD OR PRIME POWER RATING	ENGINES OPERATED IN EXCESS OF ISO STD POWER	LIGHT LOAD OPERATION	EBULLIENT COOLED OR HOT WATER SYSTEM WITH ENGINE WATER TEMPERATURE 200° F (93° C) OR ABOVE	STANDBY DUTY
FOR ENGINES OPERATING WITH ELEVATED OIL SUMP TEMPERATURE.					
VGF SERIES	360 hours	250 hours	360 hours	360 hours	250 hours

Table 7.05-4. Duty Cycle Definitions

ISO STANDARD OR CONTINUOUS POWER RATING:	The highest load and speed which can be applied 24 hours a day, 7 days a week, 365 days per year, except for normal maintenance. It is permissible to operate the engine at up to 10% overload or maximum load indicated by the intermittent rating, whichever is lower, for two hours in each 24 hour period.
GENERATOR STANDBY POWER RATING:	In a system used as a backup or secondary source of electrical power, this rating is the output the engine will produce continuously (no overload), 24 hours per day, for the duration of the prime power source outage.
INTERMITTENT POWER RATING:	This rating is the highest load and speed that can be applied in variable speed mechanical system application only. Operation at this rating is limited to a maximum of 3500 hours per year.
GENERATOR PEAK SHAVING:	Peak shaving is operation of an engine for a limited time to meet short term peak power requirements. Speed, loading, and hours per year of operation will affect the recommended oil change interval.
LIGHT LOAD OPERATION:	Power levels less than 50% of the maximum continuous power rating.

MAINTENANCE PARTS REFERENCE

Table 7.05-5 and Table 7.05-6 are recommended spare parts lists for the VGF F18/H24 G, GSID, GL and GLD engines. The following tables list the parts required for 11,500 hours of engine operation.

Table 7.05-5. F18 Maintenance Parts Reference

QTY.	P/N	ITEM
5	169180L	Air Filter Element, GL
5	169180K	Air Filter Element, GLD
5	169180L	Air Filter Element, GSID
5	208349	Air Precleaner Element, G, GL, GSID
5	208349A	Air Precleaner Element, GLD
42	As Required	Spark Plug
42	209681	Spark Plug Gasket
12	304745L	Rocker Arm Cover O-ring
6	304707B	Camshaft Cover O-ring
1	305067A	Baffle Box Gasket
6	304708A	Connecting Rod Inspection Cover Gasket
2	Variable	Gas Regulator Diaphragm (As Equipped)
12	304126	Oil Filter (Use 3 per change)
1	493668 G	Carburetor, 200D Diaphragm, G, (GL 493670)
1	489444	Carburetor, 400VF Diaphragm, GL
2	499222	Carburetor, 600D VFI Diaphragm, GSID, GLD, G (G Qty 1)
1	305845B	Oil Pan Gasket
4	305922	Governor Quick Start Oil Filter (As Equipped)

Table 7.05-6. H24 Maintenance Parts Reference

QTY.	P/N	ITEM
5	169180L	Air Filter Element, G, GL
5	169180K	Air Filter Element, GLD
5	169180L	Air Filter Element, GSID
5	208349	Air Precleaner Element, G, GL, GSID
5	208349A	Air Precleaner Element, GLD
56	As Required	Spark Plug
56	209681	Spark Plug Gasket
16	304745L	Rocker Arm Cover O-ring
8	304707B	Camshaft Cover O-ring
1	305067A	Baffle Box Gasket
8	304708A	Connecting Rod Inspection Cover Gasket
2	Variable	Gas Regulator Diaphragm (As Equipped)
12	304126	Oil Filter (Use 3 per change)
1	493668 G	Carburetor, 200D Diaphragm, G, (GL 493670)
1	489444	Carburetor, 400VF Diaphragm, GL
2	499222	Carburetor, 600D VFI Diaphragm, GSID, GLD, G (G Qty 1)
1	305845C	Oil Pan Gasket
4	305922	Governor Quick Start Oil Filter (As Equipped)

ENGINE STORAGE

Consider the following factors before deciding how much preservation is required:

1. Whether the engine was used, the length of service since the last oil change.

2. The period of time the engine is likely to be idle or inoperative.

3. The atmospheric conditions at the time and place of storage. For example, the storage problems encountered in a tidewater warehouse will differ greatly from those that may be experienced in a dry and dusty location.

4. The hostility of the environment and the accessibility of the equipment for periodic inspection. An engine on a showroom floor that is turned over and oiled occasionally requires less treatment than an engine abandoned in a dusty warehouse.

WAUKESHA ENGINE PRESERVATIVE OIL

During storage, protect internal metal surfaces from the effects of dampness, salt and other corrosive substances. Waukesha Engine Preservative Oil (P/N 166709A) offers a practical and economical solution to these storage problems. It contains volatile corrosion-inhibiting chemicals that slowly vaporize and diffuse throughout any closed void. The chemicals form an invisible protective layer on all surfaces contacted and allow the engine to be safely stored for one year.

⚠ WARNING

Waukesha Preservative Oil contains a petroleum distillate which is harmful or fatal if swallowed. If taken internally, do not induce vomiting. Remove ingested material by gastric lavage with 2 to 4 quarts or litres of tap water or milk. Follow with fruit juice or vinegar to neutralize the alkali. Failure to follow these precautions could cause severe personal injury or death.

⚠ WARNING

Avoid prolonged or repeated breathing of vapor. Vapor is harmful and may cause irritation to eyes, nose and throat. Use only with adequate ventilation. If affected by exposure, move to fresh air immediately and get medical help. Failure to follow these precautions could cause severe personal injury or death.

⚠ WARNING

Avoid contact with eyes, skin and clothing. If skin contact occurs, immediately flush the affected area with plenty of water. If eye contact occurs, flush for at least 15 minutes and seek medical attention. If clothing is contaminated, remove and wash before using again. Failure to follow these precautions could cause severe personal injury or death.

⚠ WARNING

Keep container closed and away from heat. Always read and observe the CAUTION labels on the containers. Do not remove or deface the container labels. Failure to follow these precautions could cause severe personal injury or death.

PRESERVATIVE OIL USAGE

1. Verify engine temperature is below 100_ F (37_ C).

NOTE: *The preservative oil will do an effective job only if added to clean engine oil. If a high sulfur fuel or a corrosive oil was used in the engine, change the oil and then run the engine long enough to ensure complete circulation of the clean oil.*

2. Verify both oil and oil filter elements are clean.

3. Add Waukesha Engine Preservative Oil (P/N 166709A) to existing crankcase oil. Preservative oil should equal 2% of total oil capacity (see Table 7.05-9).

4. If possible, crank engine for at least 20 seconds to ensure adequate circulation of preservative oil.

5. Add preservative oil to each cylinder through spark plug holes. Install spark plugs.

6. Remove rocker arm cover and brush or pour preservative oil onto cylinder heads. Replace rocker arm covers.

NOTE: *While it may not be practical to completely seal an engine in the field, try to block the paths through which any vaporized preservative oil may escape.*

7. Engine may be stored for one year. If storage is to exceed this period, inspect engine annually and repeat preservation routine.

OTHER PRESERVATIVE OILS AND MATERIALS

⚠ WARNING

Do not heat preservative compounds to temperatures that exceed 200° F (93° C). Direct heating always presents a dangerous and unnecessary fire hazard. Failure to follow these precautions could cause severe personal injury or death.

In addition to Waukesha Engine Preservative Oil, the preservative oils listed in Table 7.05-7 will also protect the internal engine components. The properties that make an oil suitable for preservative requirements are good aging stability; high resistance to gumming, oxidation and polymerization; low pour point and viscosity; freedom from acids, asphalts, resins, tars, water and other contaminants.

Waukesha Engine Preservative Oil is not formulated as a protective coating for external surfaces. Excellent products for polished and machined surfaces are available on the market and should be used when needed (see Table 7.05-8).

Table 7.05-7. Preservative Oils

SUPPLIER	BRAND NAME
American Oil Company	Amoco Anti-Rust Oil 4-V
Gulf Oil Corporation	No rust Engine Oil Grade 1
Mobil Oil Company	Mobil Arma 522
Shell Oil Company	Donax T-6
Atlantic Richfield Company	Dexron
Texaco, Inc.	#800 Regal Oil A (R O)

Table 7.05-8. Protective Materials

INTERNAL SURFACES	EXTERNAL SURFACES
U. S. Army Spec. 2-126 (Available as SAE 10 or SAE 30)	U.S. Army Spec. 2-121 (Waxy Coating)
Waukesha Engine Division Preservative Oil, Mil Spec. MIL-L46002 Grade 2	U. S. Army Ordinance Spec. AXS 673 (Harder Black Coating)

Table 7.05-9. Preservative Oil Capacity

NUMBER OF CYLINDERS	UPPER CYLINDER		CRANKCASE		TOTAL CC'S OF ENGINE PRESERVATIVE OIL REQUIRED
	CC'S OF PRESERVATIVE OIL PER CYLINDER	CC'S OF PRESERVATIVE OIL ALL CYLINDERS	STANDARD OIL PAN CAPACITY LITERS	CC'S OF PRESERVATIVE OIL	
Six	1-1/2 oz. (45 cc)	9 oz. (270 cc)	22 gal. (83.3 liters)	55 oz. (1626 cc)	44 oz. (1896 cc)
Eight	1-1/2 oz. (45 cc)	12 oz. (360 cc)	28 gal. (106 liters)	70 oz. (2070 cc)	92 oz. (2430 cc)

ENGINE STORAGE – NEW

NOTE: *Engines stored according to these instructions using Waukesha Engine Preservative Oil will normally be protected for one year. If storage is to exceed this period, inspect the engine annually and repeat the preservation routine.*

OPERATIONAL

Internal Component Protection

1. Mix an inhibitive type preservative oil with clean engine oil (use ratio recommended by manufacturer). Run engine until oil is hot.

2. Treat cooling water with proper inhibitors recommended by manufacturer.

3. Drain oil and cooling water while still hot.

4. Remove spark plugs and pour 1-1/2 oz. (45 cc) of preservative oil into each cylinder.

NOTE: *For extra protection, remove the rocker arm covers and pour a quantity of preservative oil over the rocker arm and valve mechanisms.*

5. Refill crankcase with proper engine oil/preservative mixture.

External Component Protection

1. Engine should be clean and dry.

2. Apply masking tape or similar material over engine openings (air cleaners, exhaust outlets, breathers, magneto vents, open line fittings, etc.).

3. Relieve tension on all belts to avoid deterioration.

4. Use a brush and apply heavy preservative coating to all exposed machined surfaces (i.e. flywheels).

5. Protect accessory equipment (carburetors, gas regulators, magnetos, starters, generators, fan belts, etc.) from corrosion, dirt, moisture and deterioration.

6. Protect cooling system and intercoolers against freezing, rusting or seizure of water pump seals.

7. Protect against rain, snow and temperature extremes.

8. Disconnect batteries and place indoors. Place batteries on a wood board, never cement. Connect “trickle” charger or similar device to keep batteries fully charged.

NON-OPERATIONAL

1. Drain all oil and water from engine.

2. Remove spark plugs and pour 1-1/2 oz. (45 cc) of preservative oil into each cylinder.

3. Crank engine in normal direction about 1/4 turn, then lubricate each cylinder again. Repeat procedure at least eight times or until engine has been turned two complete revolutions.

4. Remove all access doors, valve rocker covers, gear cover plates and spray, squirt or pour oil over interior engine parts. Replace all plugs and covers removed.

ENGINE STORAGE – USED

OPERATIONAL

During normal engine operation, residues of various combustion products accumulate in the combustion area and in the lubricating oil. Portions of these residues combine with atmospheric moisture to form acids and other corrosive compounds. The following treatment will help reduce damage from this source:

1. Run engine until oil is hot. Drain oil.

2. For best results, refill engine with a good flushing oil. Run engine until flushing oil is hot. Drain both oil and cooling water while still hot.

3. Refill crankcase with proper engine oil/preservative mixture.

4. Remove spark plugs and add 45 cc (1-1/2 oz.) of preservative oil to each cylinder/combustion chamber (see Table 7.05-9). Replace spark plugs.

NON-OPERATIONAL

1. Protect fuel system against gumming effects of gas residues.

NOTE: *In those cases where fuels with high sulfur concentrations have been used or where extremely harsh climatic or environmental conditions prevail, the engine may need to be disassembled, thoroughly cleaned and then reassembled for treatment as a new engine.*

ENGINES RETURNED TO SERVICE AFTER STORAGE

WARNING

Remove all accumulations of oil, water or preservative compounds. These accumulations may thin out as the engine warms up and be burned as fuel, resulting in a runaway engine. Disregarding this information could result in severe personal injury or death.

CAUTION **Never attempt to start an engine that has been stored without first cranking it over with the spark plugs removed. Any oil, water or preservative compound that might spurt from these openings must be removed to prevent a hydraulic lock. Disregarding this information could result in product damage and/or personal injury.**

WARNING

Never attempt to start an engine that has been stored without first cranking it over with the spark plugs removed. Any oil, water or preservative compound that might spurt from these openings must be removed to prevent a hydraulic lock. Continue to crank the engine with the starter until liquid is no longer being ejected from the openings. Inspect the intake passages and manifolds for thickened preservative oil. Accumulations of this type may thin out as the engine warms up and be burned as fuel, resulting in a runaway engine. Disregarding this information could result in severe personal injury or death.

1. Remove old spark plugs and crank engine over to remove any accumulation of oil, water or preservative compounds.

2. Crank engine with starter until liquid is no longer ejected from openings.

3. Inspect intake passages and manifolds for thickened preservative oil.

4. Install new spark plugs.

Refer to *VGF 6, 8, 12 & 16 Cylinder Operation And Maintenance Manual Form 6284* “Prestart Inspection and Start-up Procedures” for complete instructions to bring an engine into active service. The steps needed are about the same as those normally carried out on a new engine.

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