

JOHN DEERE
WORLDWIDE COMMERCIAL & CONSUMER
EQUIPMENT DIVISION

Compact Utility Tractors
4000 Twenty Series with Cab

TM2370 DECEMBER 2006

TECHNICAL MANUAL



JOHN DEERE

North American Version
Litho in U.S.A.

INTRODUCTION

Manual Description

This technical manual is written for an experienced technician and contains sections that are specifically for this product. It is a part of a total product support program.

The manual is organized so that all the information on a particular system is kept together. The order of grouping is as follows:

- Table of Contents
- Specifications and Information
- Identification Numbers
- Tools and Materials
- Component Location
- Schematics and Harnesses
- Theory of Operation
- Operation and Diagnostics
- Diagnostics
- Tests and Adjustments
- Repair
- Other

NOTE: Depending on the particular section or system being covered, not all of the above groups may be used.

The bleed tabs for the pages of each section will align with the sections listed on this page. Page numbering is consecutive from the beginning of the Safety section through the last section.

We appreciate your input on this manual. If you find any errors or want to comment on the layout of the manual please contact us.

Safety

Specifications and Information

Engine

Electrical - NA

Electrical - Export

Power Train - eHydro

Power Train - Final Drive

Hydraulics

Steering

Brakes

HVAC

Miscellaneous

SAFETY

Recognize Safety Information



MIF

This is the safety-alert symbol. When you see this symbol on your machine or in this manual, be alert to the potential for personal injury.

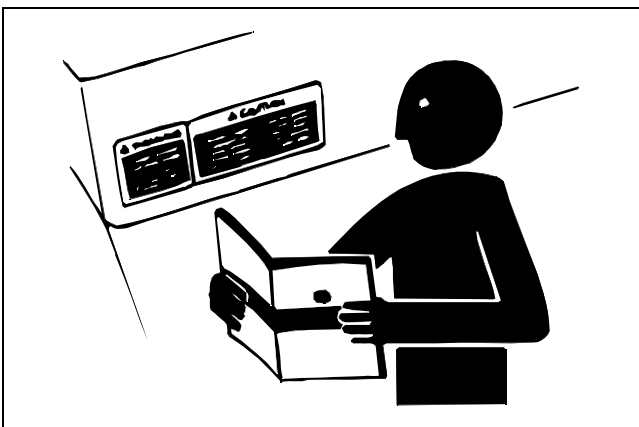
Follow recommended precautions and safe servicing practices.

Understand Signal Words

A signal word - DANGER, WARNING, or CAUTION - is used with the safety-alert symbol. DANGER identifies the most serious hazards.

DANGER or WARNING safety signs are located near specific hazards. General precautions are listed on CAUTION safety signs. CAUTION also calls attention to safety messages in this manual.

Replace Safety Signs

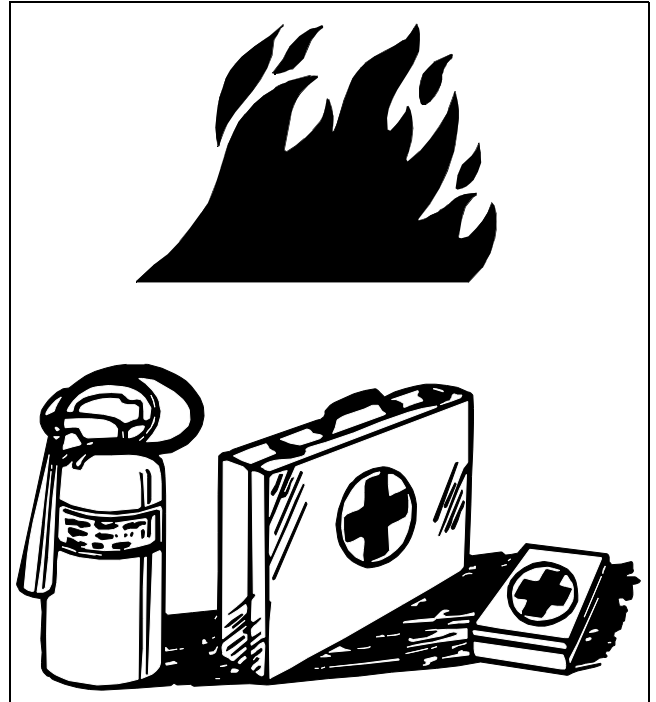


MIF

Replace missing or damaged safety signs. See the machine operator's manual for correct safety sign placement.

Handle Fluids Safely - Avoid Fires

Be Prepared For Emergencies



MIF

- When you work around fuel, do not smoke or work near heaters or other fire hazards.
- Store flammable fluids away from fire hazards. Do not incinerate or puncture pressurized containers.
- Make sure machine is clean of trash, grease, and debris.
- Do not store oily rags; they can ignite and burn spontaneously.
- Be prepared if a fire starts.
- Keep a first aid kit and fire extinguisher handy.
- Keep emergency numbers for doctors, ambulance service, hospital, and fire department near your telephone.

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Hello dear friend!

Thank you very much for reading.

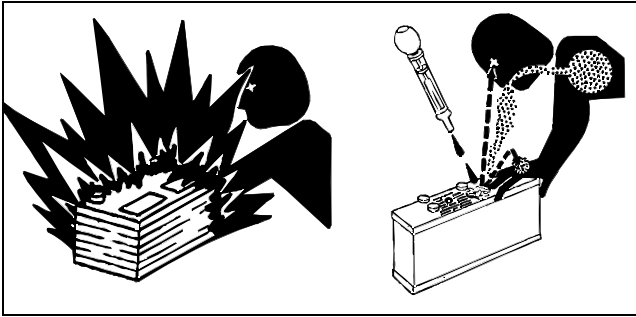
Enter the link into your browser.

The full manual is available for immediate download.

<https://www.ebooklibonline.com>

SAFETY

Use Care In Handling and Servicing Batteries



MIF

Prevent Battery Explosions

- Keep sparks, lighted matches, and open flame away from the top of battery. Battery gas can explode.
- Never check battery charge by placing a metal object across the posts. Use a volt-meter or hydrometer.
- Do not charge a frozen battery; it may explode. Warm battery to 16°C (60°F).

Prevent Acid Burns

- Sulfuric acid in battery electrolyte is poisonous. It is strong enough to burn skin, eat holes in clothing, and cause blindness if splashed into eyes.

Avoid acid burns by:

1. Filling batteries in a well-ventilated area.
2. Wearing eye protection and rubber gloves.
3. Avoiding breathing fumes when electrolyte is added.
4. Avoiding spilling or dripping electrolyte.
5. Use proper jump start procedure.

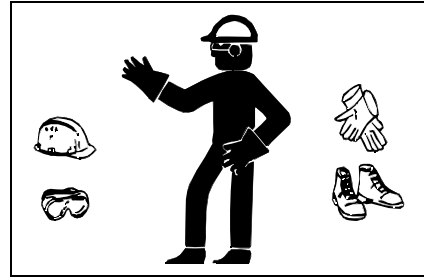
If you spill acid on yourself:

1. Flush your skin with water.
2. Apply baking soda or lime to help neutralize the acid.
3. Flush your eyes with water for 10 - 15 minutes.
4. Get medical attention immediately.

If acid is swallowed:

1. Drink large amounts of water or milk.
2. Then drink milk of magnesia, beaten eggs, or vegetable oil.
3. Get medical attention immediately.

Wear Protective Clothing



MIF

Wear close fitting clothing and safety equipment appropriate to the job.

Prolonged exposure to loud noise can cause impairment or loss of hearing. Wear a suitable hearing protective device such as earmuffs or earplugs to protect against objectionable or uncomfortable loud noises.

Operating equipment safely requires the full attention of the operator. Do not wear radio or music headphones while operating machine.

Use Care Around High-pressure Fluid Lines

Avoid High-Pressure Fluids



MIF

Escaping fluid under pressure can penetrate the skin causing serious injury.

Avoid injury from escaping fluid under pressure by stopping the engine and relieving pressure in the system before disconnecting or connecting hydraulic or other lines. Tighten all connections before applying pressure.

Search for leaks with a piece of cardboard. Protect hands and body from high pressure fluids.

If an accident occurs, see a doctor immediately. Any fluid injected into the skin must be surgically removed within a few hours or gangrene may result. Doctors unfamiliar with this type of injury should reference a knowledgeable medical source. Such information is available from Deere & Company Medical Department in Moline, Illinois, U.S.A.

SAFETY

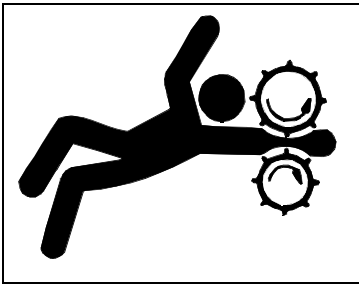
Avoid Heating Near Pressurized Fluid Lines



MIF

Flammable spray can be generated by heating near pressurized fluid lines, resulting in severe burns to yourself and bystanders. Do not heat by welding, soldering, or using a torch near pressurized fluid lines or other flammable materials. Pressurized lines can be accidentally cut when heat goes beyond the immediate flame area.

Service Machines Safely



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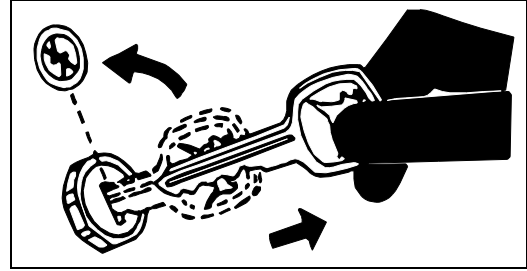
Tie long hair behind your head. Do not wear a necktie, scarf, loose clothing, or necklace when you work near machine tools or moving parts. If these items were to get caught, severe injury could result.

Remove rings and other jewelry to prevent electrical shorts and entanglement in moving parts.

Use Proper Tools

Use tools appropriate to the work. Makeshift tools and procedures can create safety hazards. Use power tools only to loosen threaded parts and fasteners. For loosening and tightening hardware, use the correct size tools. **DO NOT** use U.S. measurement tools on metric fasteners. Avoid bodily injury caused by slipping wrenches. Use only service parts meeting John Deere specifications.

Park Machine Safely

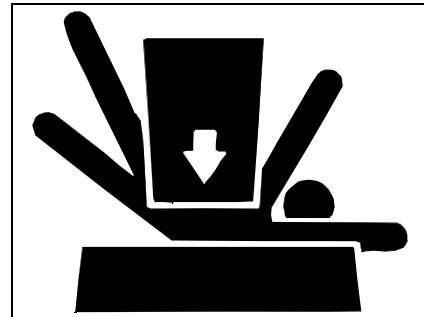


MIF

Before working on the machine:

1. Lower all equipment to the ground.
2. Stop the engine and remove the key.
3. Disconnect the battery ground strap.
4. Hang a "DO NOT OPERATE" tag in operator station.

Support Machine Properly and Use Proper Lifting Equipment



MIF

If you must work on a lifted machine or attachment, securely support the machine or attachment.

Do not support the machine on cinder blocks, hollow tiles, or props that may crumble under continuous load. Do not work under a machine that is supported solely by a jack. Follow recommended procedures in this manual.

Lifting heavy components incorrectly can cause severe injury or machine damage. Follow recommended procedure for removal and installation of components in the manual.

Work In Clean Area

Before starting a job:

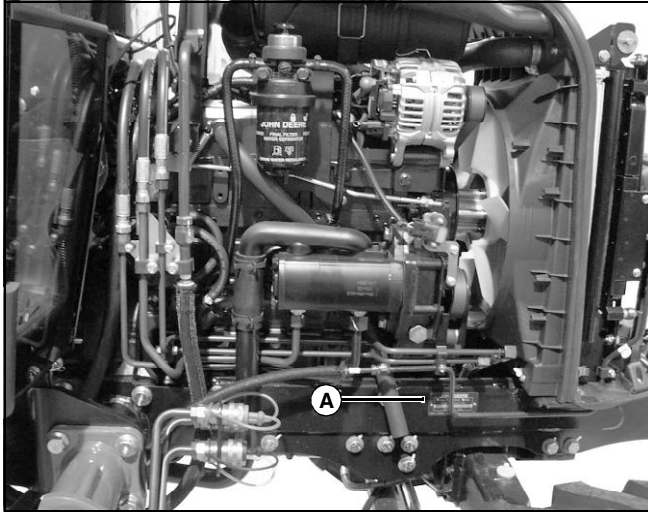
1. Clean work area and machine.
2. Make sure you have all necessary tools to do your job.
3. Have the right parts on hand.
4. Read all instructions thoroughly; do not attempt shortcuts.

SPECIFICATIONS & INFORMATION SERIAL NUMBER LOCATIONS

Serial Number Locations

Machine Product Identification Number

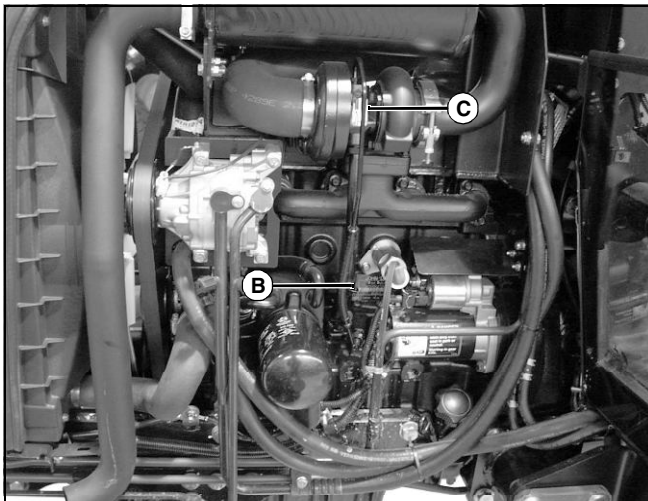
When ordering parts or submitting a warranty claim, it is **IMPORTANT** that the machine product identification number (PIN) and component serial numbers are included. The location of the PIN and component serial numbers are shown.



MX36573

Located on right side of frame (A) above front axle.

Engine and Turbocharger Serial Numbers



MX36572

Located on left side of engine (B) and turbocharger (C).

Cab Serial Number



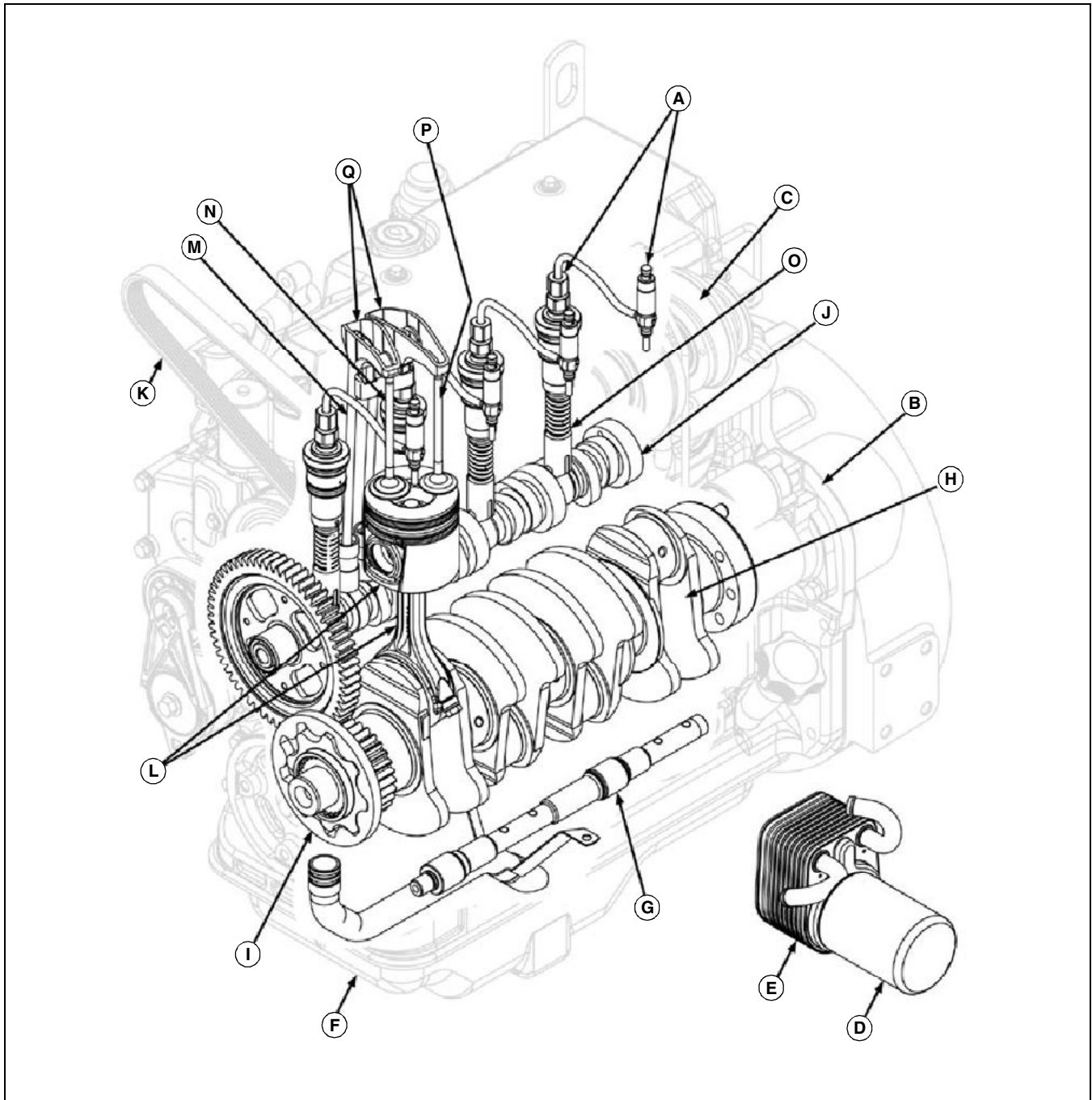
MX35852

Located inside cab on left rear cab support post (D).

ENGINE - DIESEL THEORY OF OPERATION

Theory of Operation

General Engine Operation



MX32886

Picture Note: General Engine Operation

A - Unit Injector Pump and Nozzle

B - Cylinder Block

C - Turbocharger

D - Oil Filter

E - Oil Cooler

F - Oil Pan

G - Balancer Shaft

H - Crankshaft

I - Oil Pump

J - Camshaft

K - Poly Vee Belt

L - Piston and Connecting Rod

M - Push Rod

N - Intake Valve

O - Hydraulic Cam Followers

P - Exhaust Valve

Q - Rocker Arm

ENGINE - DIESEL THEORY OF OPERATION

The engines are vertical, inline, two valve in head, four cycle (stroke), four cylinder diesel engines.

Direct fuel injection is provided by an integral pumping unit and compact nozzle assembly, and a roller hydraulic camshaft follower (lifter), (A) for each cylinder. A fuel transfer pump draws fuel from the tank and provides pressure to and through the fuel filter and cylinder block fuel galley. The fuel galley, integral with the cylinder block to avoid external fuel lines, supplies fuel to the pumping units and nozzles. The quantity of fuel delivered to each pumping unit is controlled by a mechanical governor and throttle assembly, located in the timing gear cover, and a rack assembly, located in the cylinder block. The fuel rack, similar to those used in inline injection pumps used on Series 350 and 450 engines, is located in the block and is parallel to the fuel galley. The pumping units, driven by hydraulic cam followers, pressurizes and delivers the fuel to the nozzle.

Glow plugs for each cylinder are included in the design as standard equipment to aid during cold weather starts. The cold start advance (CSA) feature is also included as standard equipment to aid in cold starts. This feature is regulated by the lubrication system, and advances unit pump injection timing to reduce white smoke present during a cold start.

The engines are equipped with a turbocharger (C). The turbocharger uses energy from exhaust gases to compress and deliver intake air to the intake manifold and, subsequently, the combustion chambers. The compressed air means additional air is being delivered to the cylinders. The additional air results in a higher power output by the engine, as well as cleaner emissions.

The cylinder block (B) is a one piece casting with integral cylinder bores.

The camshaft (J) is timed to the crankshaft through the timing gear train. The camshaft rotates in honed bores in the cylinder block. The engines use a bearing in the number one camshaft bore, with bushings in the other journals. The camshaft lobe design controls not only the lift and duration of each intake and exhaust valve opening and closing, but they also actuate the pumping and injection of fuel within the pumping units and nozzles for each bore. The camshaft followers, or lifters (O), for both the valves and pumping units, are a hydraulic design. This eliminates the need for regular valve lash adjustment intervals.

Intake (N) and exhaust (P) valves are actuated by the hydraulic cam followers, or lifters (O), running off the camshaft lobes. Push rods (M) and rocker arms (Q) complete the camshaft-to-valve actuation assembly.

The crankshaft (H), is a one piece, heat treated, nodular iron forging. The crankshaft is dynamically balanced, and the journals are machined with undercut and rolled fillets for additional strength. Each crankshaft journal is encased

in a two piece, replaceable, main or rod bearing assembly. Additional two piece main journal thrust bearing inserts are used to control crankshaft end play.

Pistons (L) are manufactured from a high grade, cast aluminum alloy, with internal ribbing. The piston skirt is cam ground to allow for heat expansion during the combustion process. The piston crown has a cut out combustion bowl with a truncated cone center. All piston rings are located above the piston pin. Two compression rings and one oil control ring are utilized. The top compression ring is a rectangular, steel, 2 mm thick, barrel face shaped design, and is located close to the top of the piston, by design, for improved starting and engine performance.

The hardened, fully floating piston pins are held in place in the piston bore by snap rings. Piston spray jets, located in the cylinder block, spray pressurized oil to the underside of the piston to lubricate the pins, and cool the piston.

The forged steel connection rods have replaceable bushing inserts to support the piston pin during the combustion process. Rods and caps are manufactured with an angled PRECISION JOINT™

The engines are designed with a crankshaft driven, gerotor oil pump (I) and a full flow oil filter (D). The oil filter has an internal bypass valve, which opens if the filter element becomes restricted. The filter is mounted on a “donut style” oil cooler (E), which is located on the side of the cylinder block. The engines are also designed with a pressure regulating valve, located in the front timing gear cover, to relieve excessive oil pressure that may build up in the lubrication system.

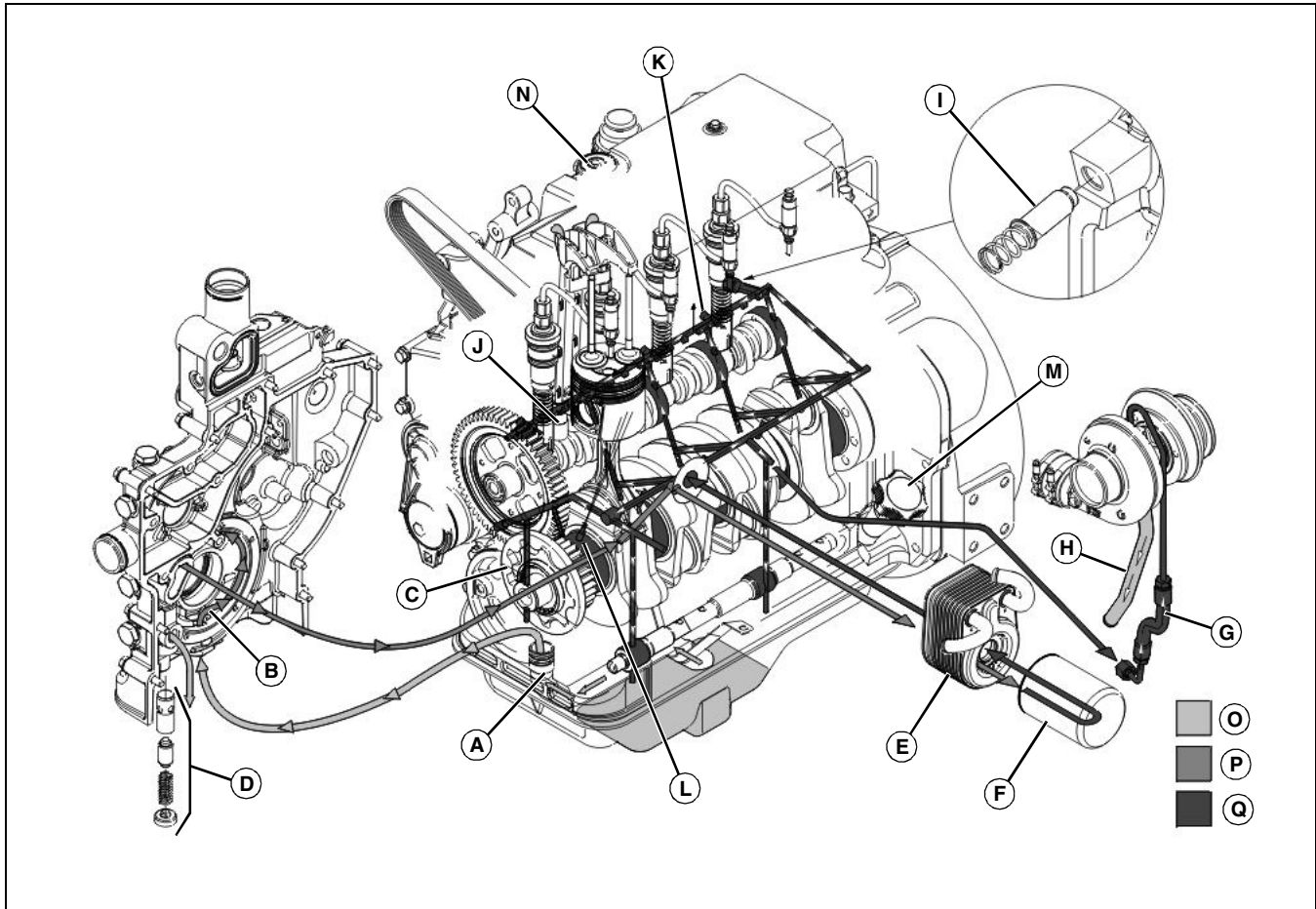
Balancer shafts (G) are used on four cylinder engines to reduce the natural vibration that exists with four cylinder four stroke diesel engine designs. The two shafts, located in integral bores on each side of the crankshaft in the cylinder block, are counter rotating to each other and rotate at twice the engine speed.

The engine has a pressurized cooling system, consisting of a radiator, water pump, multi blade fan, and a thermostat housing.

For additional details on fuel, lubrication, cooling, and air systems, see later in this section.

ENGINE - DIESEL THEORY OF OPERATION

Lubrication System Operation



MX32887

Picture Note: Lubrication System (2.4 L Engine Shown)

- A - Oil Suction Line
- B - Oil Pump Housing
- C - Oil Pump
- D - Oil Pressure Regulating Valve
- E - Oil Cooler
- F - Oil Filter
- G - Turbocharger Oil Supply Line
- H - Turbocharger Drain Line
- I - Cold Start Advance Valve
- J - Hydraulic Lifter
- K - Cold Start Oil Inlet
- L - Piston Cooling Orifice
- M - Oil Fill/Dipstick
- N - Rocker Arm Cover Oil Fill
- O - Pressure Free Oil
- P - Pressurized, Unfiltered Oil
- Q - Pressurized, Filtered Oil

The engine lubrication system consists of a crankshaft driven, gerotor design oil pump (C), a full flow oil filter (F),

oil cooler (E), oil pressure regulating valve (D), and a cold start advance valve (I).

The gerotor oil pump draws oil from the oil pan sump through a strainer and suction line (A). The oil pump forces pressurized oil to the main oil galley in the cylinder block through a separate drilled passage. Oil is then routed through the oil cooler and filter, and back into the main oil galley, to be fed to the remainder of the engine.

The main oil galley runs the length of the cylinder block and delivers oil to cross-drilled oil passages that feed oil to the camshaft journals, and main bearing bushings. Additional cross-drilled passages intersect with cam and crank oil passages and provide lube oil to the balancer shaft bushings (when equipped).

Oil flows past the camshaft journals to the cold start advance galley. This galley provides oil for the hydraulic valve lifters (J), to activate the cold start advance feature, and the push rods. The push rods are hollow and allow oil to flow up to the rocker arm area.

From the main bearings, oil flows to the connecting rod bearings through drilled passages in the crankshaft. Oil from the main bearings also supply the piston cooling orifices (L).

ENGINE - DIESEL THEORY OF OPERATION

The piston cooling orifice (L) sprays oil to the underside of the piston to keep the piston crown cool during combustion. The oil spray also provides splash lubrication for the piston pin and bushing via a drilled hole through the top end of the connecting rod.

At the front of the cylinder block, oil flows from the oil passage into a machined groove in the front face of the block. This groove connects with the idler gear shaft to provide oil to the idler gear bushing.

The turbocharger oil supply line (G) supplies oil from the main oil galley to the turbocharger housing to cool and lubricate the turbocharger shaft and bearings. The oil returns to the crankcase from the turbocharger through a separate drain line (H). Turbocharger components operate at extremely high speeds, so a constant oil supply and an unrestricted return to sump is critical.

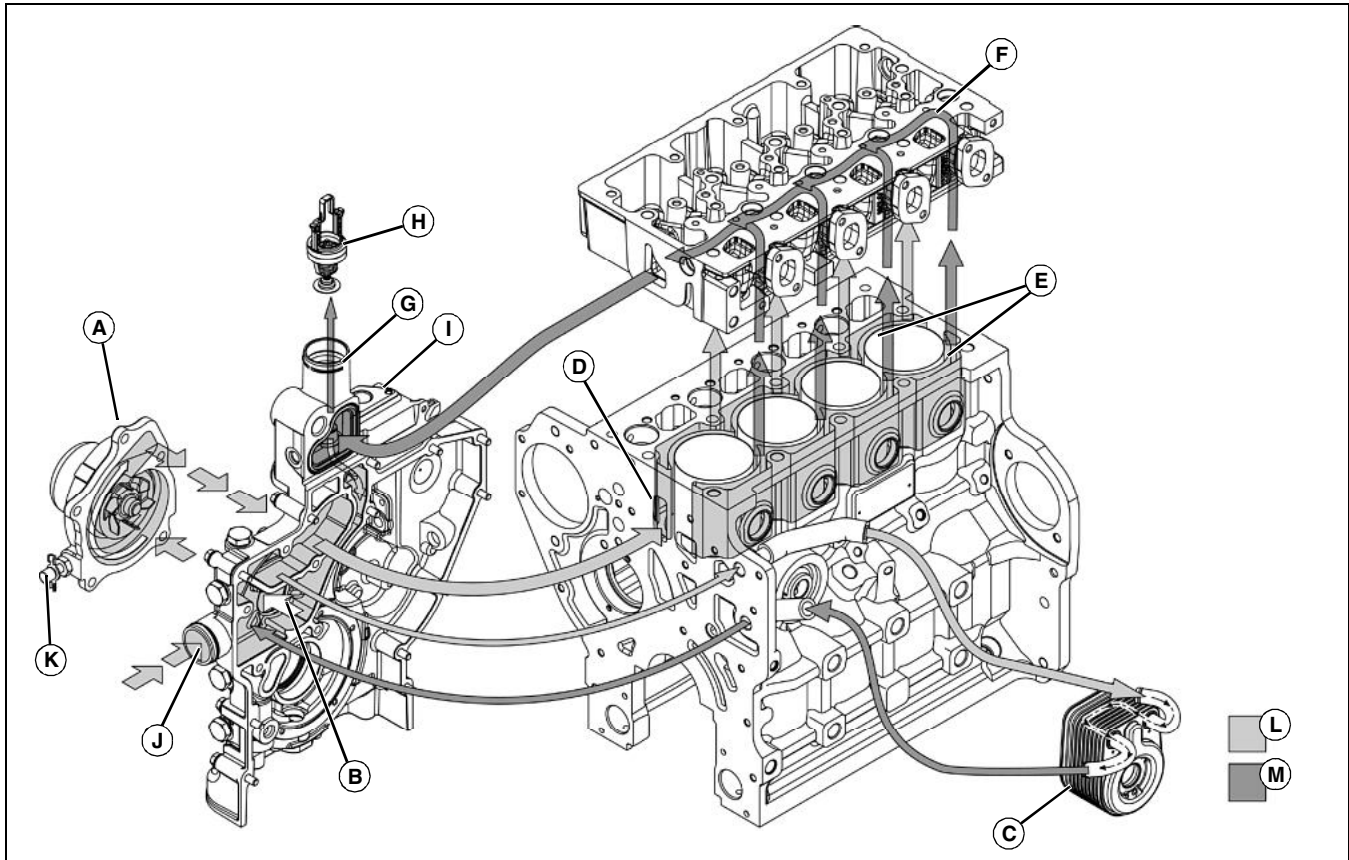
Oil pressure is regulated by a valve assembly (D) located in the front timing gear cover. Excessive oil is returned to the engine crankcase.

The oil fill locations are on left side of the engine, with right side fill optional. Oil can be added through either the oil dipstick location (M), or through the top of the rocker arm cover (N).

A cold start advance (I), activated by oil pressure, is located at the rear of the block. When the engine is cold, oil pressure expands the cold advance piston in the unit pump follower. This, in effect, makes the hydraulic follower "longer". This moves the plunger higher in the pump barrel, advancing timing. The advanced timing helps smooth out the engine at cold start idle, and reduces the white smoke present at cold starts.

ENGINE - DIESEL THEORY OF OPERATION

Coolant System Operation



MX32888

Picture Note: Coolant System (2.4 L Engine Shown)

- A - Water Pump**
- B - Coolant Flow to Water Pump (Suction Side)**
- C - Oil Cooler**
- D - Coolant Flow to Block**
- E - Coolant Flow - Block to Cylinder Head**
- F - Coolant Flow in Cylinder Head**
- G - Thermostat Housing**
- H - Thermostat**
- I - Thermostat Bypass Port**
- J - Coolant Return from Radiator**
- K - Drain Valve**
- L - Low Temperature Coolant**
- M - High Temperature Coolant**

When the engine is warm, the coolant partially opens the thermostat (H) and the coolant is routed through the radiator and back to the coolant inlet, located in the front timing gear housing.

When the engine is at operating temperature, the coolant fully opens the thermostat, increasing coolant flow through the radiator. Under operating temperature conditions, the bypass port (I) is closed. All of the coolant circulates through both the radiator and oil cooler assembly, and back to the water pump inlet (B).

Coolant continues flowing through the radiator circuit until the coolant temperature drops below the thermostat opening temperature.

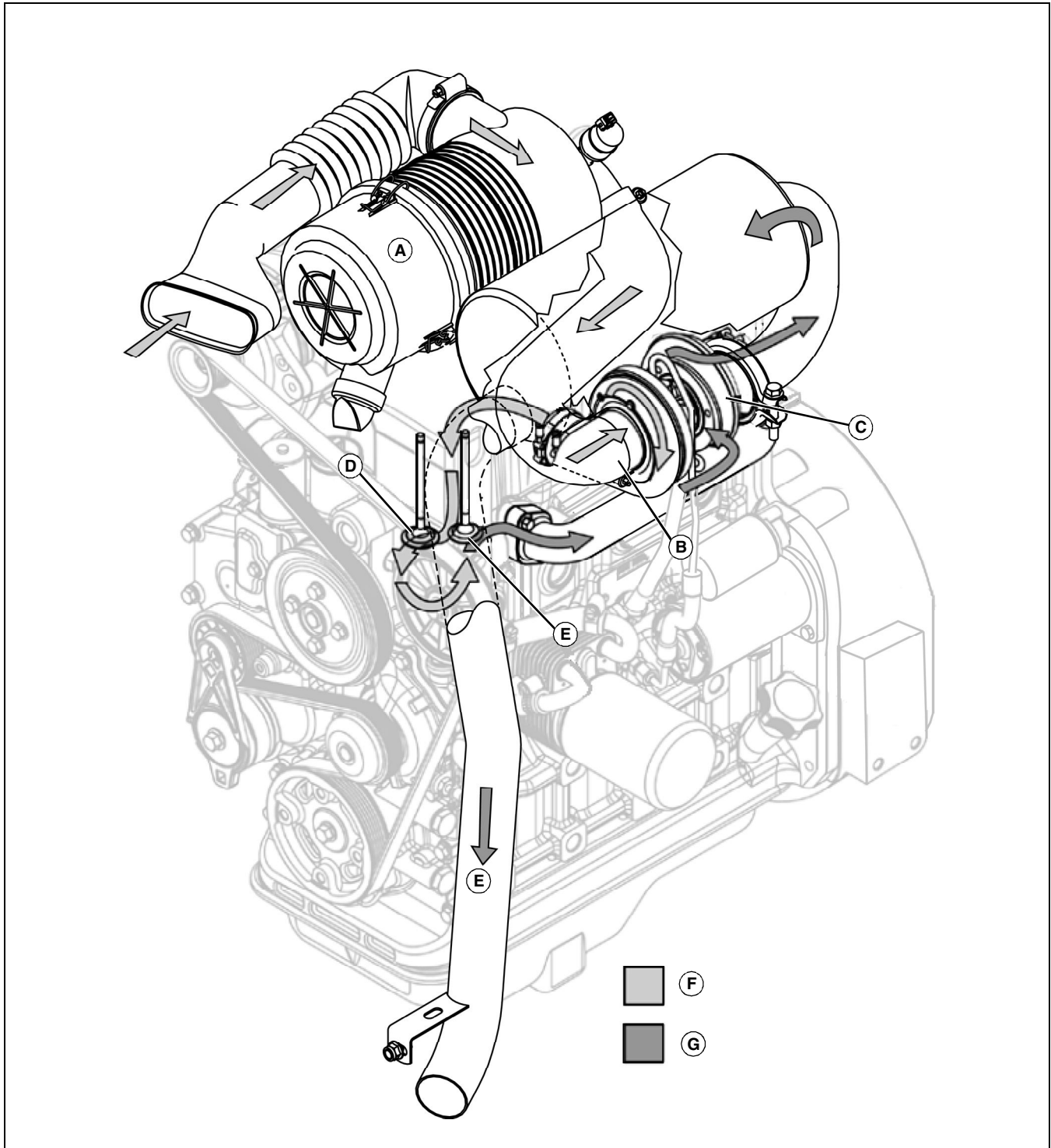
The coolant system includes the radiator, water pump, thermostat and housing, and coolant passages.

When the engine is cold, the water pump (A) forces coolant through the engine block, around the cylinders (E), and into the cylinder head (F).

From the cylinder head, the coolant routes to the thermostat housing (G) and back to the bypass port (I). Regardless of engine temperature, the water pump also forces coolant through the oil cooler (C).

ENGINE - DIESEL THEORY OF OPERATION

Air Intake and Exhaust System Operation



Picture Note: Air Intake and Exhaust System

- A - Air Cleaner**
- B - Clean Air Intake**
- C - Turbocharger Turbine Housing (exhaust side)**
- D - Intake Valve/Combustion Chambers**
- E - Exhaust Valve/Gases**

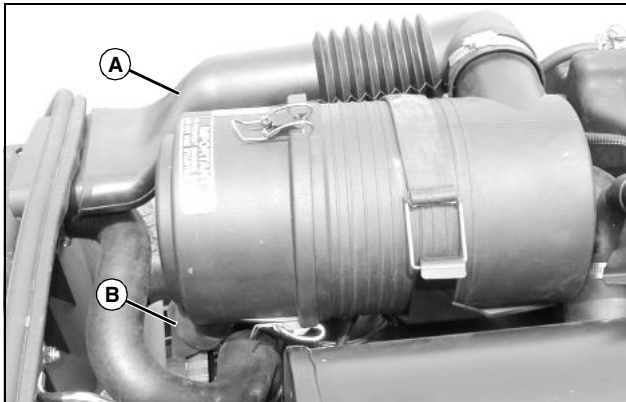
- F - Intake Air**
- G - Exhaust Air**

Engine suction draws dust laden outside air through an air inlet stack into the air cleaner (A). Air is filtered through dry type primary and secondary (safety) filter elements in the air cleaner canister. Clean air (F) travels through the air intake hose to the turbocharger and into the air intake side of the cylinder head (D).

ENGINE - DIESEL THEORY OF OPERATION

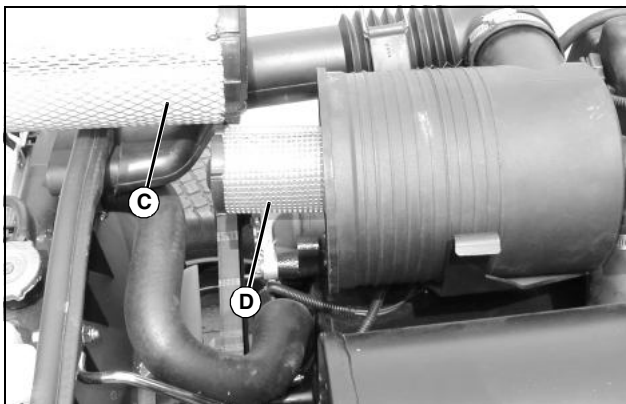
Exhaust gases (E) drive the turbocharger turbine (A), which in turn drives the turbocharger compressor to compress the intake air and thus deliver a larger quantity of air to the combustion cylinders. The quantity of air delivered to an engine intake by a turbocharger is not possible with naturally aspirated, or non-turbocharged, applications.

Air Cleaner Operation



MX32986

Picture Note: Air Cleaner Assembly



MX32987

Picture Note: Air Cleaner Primary and Secondary Elements

- A - Air Inlet Tube**
- B - Dust Unloading Tube**
- C - Primary Air Filter Element**
- D - Secondary, or Safety, Filter Element**

Under suction generated by the engine, unfiltered air flows through the air inlet tube (A) and is forced into a high speed centrifugal motion. By this circulating action, most of the dust and dirt particles are separated from the air and collected in the dust unloading tube (B).

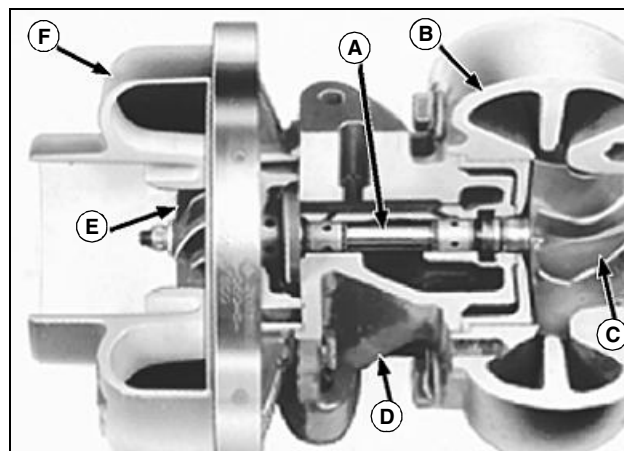
The remaining dirt is removed as the air flows through the primary element (C) and the secondary (safety) filter (D), before being drawn into the engine.

The secondary (safety) filter ensures that, should the

primary element fail, no unfiltered air is drawn into the engine.

Under normal operating conditions, maximum air intake restriction is 6.25 kPa (0.06 bar) (1.0 psi) (25 in. water). However, a clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine. An air restriction indicator aids the operator to know when an air cleaner needs servicing.

Turbocharger Operation



MX33024

Picture Note: Turbocharger Components

- A - Shaft**
- B - Turbine Housing**
- C - Turbine Wheel**
- D - Center Housing**
- E - Compressor Wheel**
- F - Compressor Housing**

The turbocharger, which is basically an air pump that is driven by exhaust gases, allows the engine to produce added power without increasing displacement.

Turbochargers are specially matched to the engine for the power ratio requirements of each specific application.

The turbine wheel (C) is driven by the hot engine exhaust gases. These gases flowing through the turbine housing (B) act on the turbine wheel, causing the shaft (A) to turn.

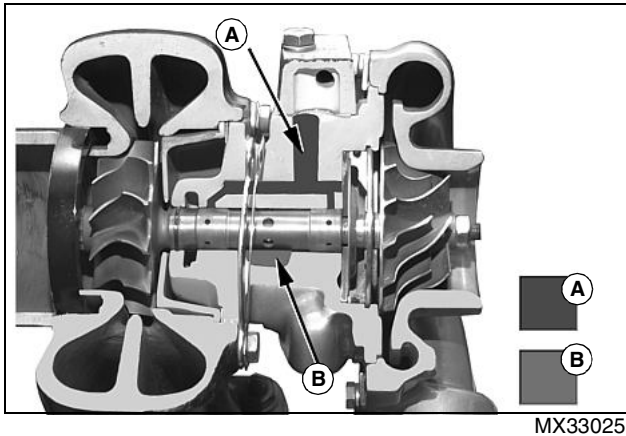
The compressor wheel (E) draws in filtered air and discharges the compressed air into the intake manifold, where it is then delivered to the engine combustion chambers.

Since exhaust gas pressure varies with engine speed and load, the power available to operate the turbocharger also varies.

Engine oil, under pressure from the engine lubricating system, is provided to the turbocharger center housing (D) to lubricate and cool the shaft and bearings.

ENGINE - DIESEL THEORY OF OPERATION

Turbocharger Lubrication



Picture Note: Turbocharger Pressure and Discharge Oil

A - Pressure Oil

B - Discharge Oil

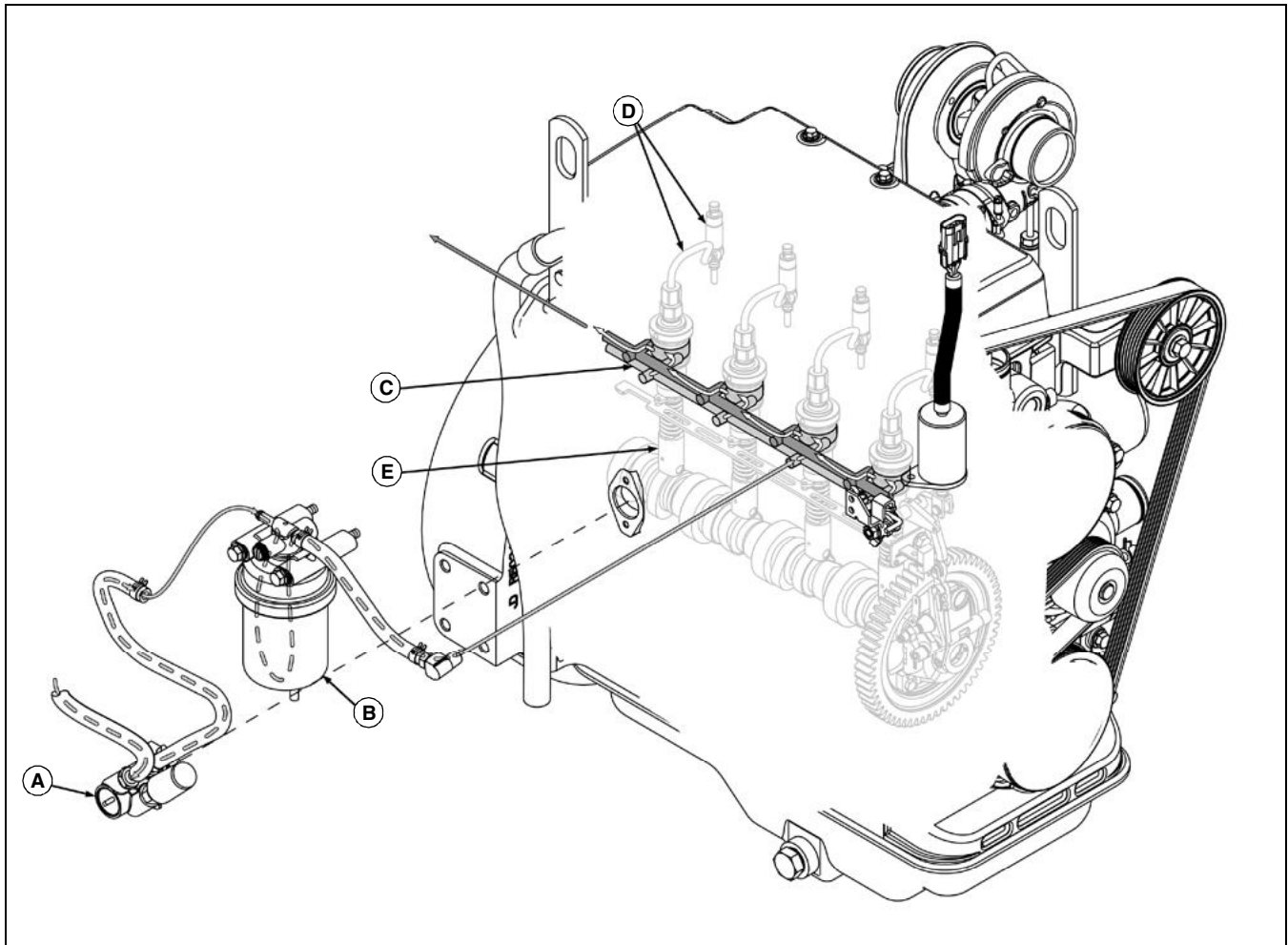
Engine oil, under pressure from the lubricating system, is pumped through a passage in the bearing housing and directed to the bearings, thrust plate, and thrust sleeve. Oil is sealed from the compressor and turbine by a piston ring at both ends of the bearing (center) housing.

The turbocharger contains two floating bearings. These bearings have clearance between the bearing OD and the housing bore, as well as clearance between the bearing ID and shaft OD. These clearances are lubricated by the oil supply pressure oil (A), and the bearings are protected by a cushion of oil. Discharge oil (B) drains by gravity from the bearing, or center, housing to the engine crankcase.

ENGINE - DIESEL THEORY OF OPERATION (AIR AND FUEL)

Theory of Operation (Air and Fuel)

Fuel System Operation



MX33026

Fuel Supply Pump

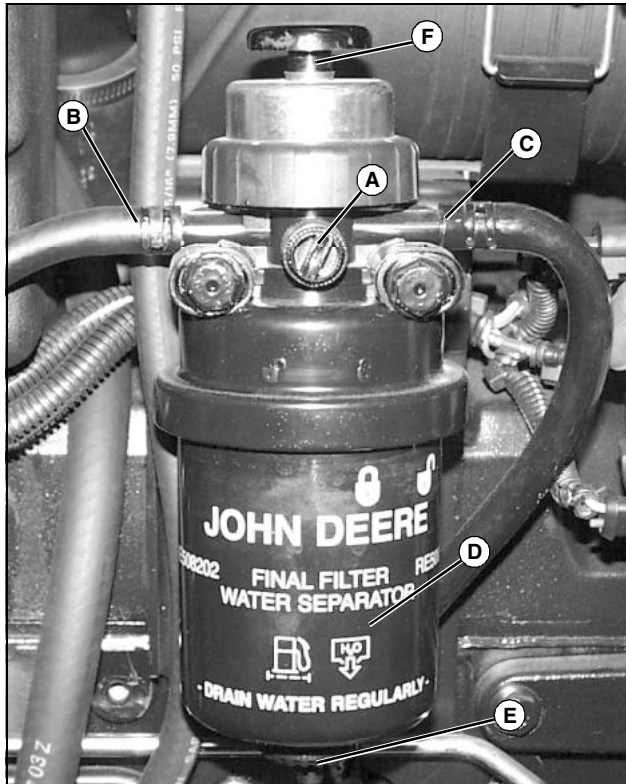
Picture Note: Fuel System

Direct fuel injection is provided by an integral pumping unit and compact nozzle assembly for each cylinder. A fuel transfer pump (A) draws fuel from the tank and provides pressure to and through the fuel filter (B) and cylinder block fuel galley (C). The fuel galley, integral with the cylinder block to avoid external fuel lines, supplies fuel to the pumping units and nozzles (D). The quantity of fuel delivered to each pumping unit is controlled by a mechanical governor and throttle assembly, located in the timing gear cover, and a rack assembly, located in the cylinder block. The fuel rack is located in the block and is parallel to the fuel galley. The pumping units, driven by hydraulic cam followers (E), pressurizes and delivers the fuel to the nozzle.

The fuel supply pump (A) is a mechanical pump, driven off a lobe on the camshaft. The pump draws fuel from the vented fuel tank and directs and maintains pressurized flow through the fuel filter and the fuel galley within the cylinder block. It also contains an optional plunger for bleeding air from and priming the fuel system.

ENGINE - DIESEL THEORY OF OPERATION (AIR AND FUEL)

Fuel Filter/Water Separator Operation



MX33049

Picture Note: Fuel Filter

- A - Bleed Screw
- B - Fuel Inlet
- C - Fuel Outlet
- D - Filter
- E - Drain Valve
- F - Primer Pump

Fuel enters the filter at the inlet (B), then flows through the five micron filter element (D) and exits through the outlet (C) to the fuel galley of the cylinder block.

Since water and other contaminants settle at the bottom of the filter, a drain plug (E) is provided to drain water from the filter between scheduled filter changes.

The priming pump (F) draws fuel from the fuel tank to fill the filter after the fuel filter element has been changed or the machine has been run out of fuel. Air in the fuel system can be bled through the air vent when the bleed screw (A) is loosened and the primer pump is operated.

Governor Operation

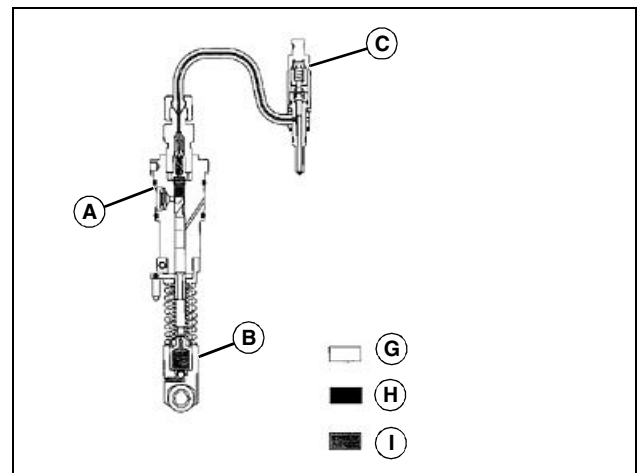
The purpose of the governor is to maintain and limit maximum engine speed. The governor system is located as part of the camshaft gear assembly. Flyweights and springs are mounted to the camshaft gear and are used to detect the speed of the engine.

To maintain engine speed, the flyweights are positioned in a manner that holds the fuel rack in a constant position. This holds the throttle control lever (plunger) of each pumping unit in the same position so that fuel delivery is neither increased, nor decreased.

As the engine load increases, engine speed decreases. Fuel delivery must increase to maintain engine speed. As engine speed decreases, the flyweights move inward and the rack rotates the throttle control lever (plunger) to increase fuel delivery.

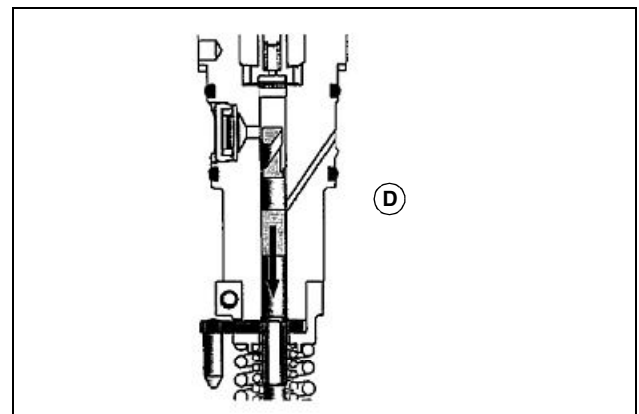
As the engine load decreases, engine speed increases. Fuel delivery must decrease to maintain engine speed. As engine speed increases, the flyweights move out and the rack rotates the pump plunger control lever to decrease fuel delivery.

Integrated Fuel System (IFS) Operation



MX33028

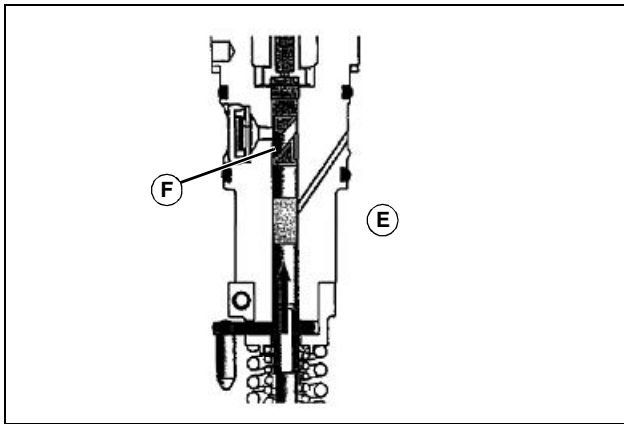
Picture Note: Integrated Fuel System (IFS)



MX33029

Picture Note: Charging Cycle

ENGINE - DIESEL THEORY OF OPERATION (AIR AND FUEL)



MX33030

Picture Note: Pumping Cycle

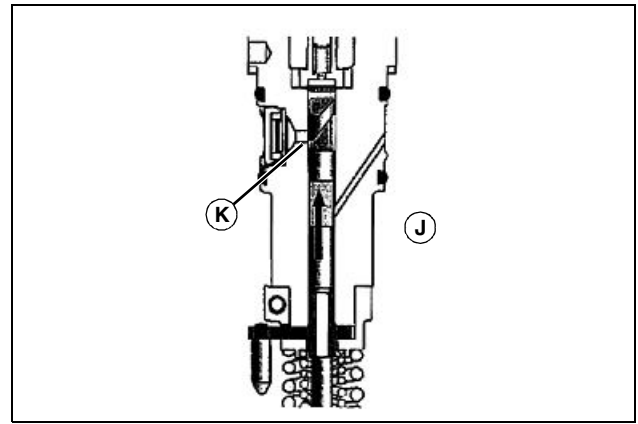
- A - Unit Pump**
- B - Camshaft follower**
- C - Injector**
- D - Charging Cycle**
- E - Pump Body**
- F - Inlet Port**
- G - Inlet Pressure**
- H - Injection Pressure**
- I - Oil Pressure**

The integrated fuel system, or IFS, consists of a unit pump (A) with a hydraulic roller camshaft follower (B), and an injector (C). The unit pump is capable of pressures of 1200 bar (17,400 psi), with a maximum fuel delivery of 100 mm³/stroke at 3,600 engine rpm. The injector is a compact pencil nozzle (CPN) designed to operate at pressures up to 1,500 bar (21,750 psi). Since the injector is designed with a no leak-off feature, the entire system can be installed under the engine rocker arm cover.

At the pumping end of the plunger, a precision ground helix covers and uncovers, depending on the plunger position; the charging port in the unit pump body.

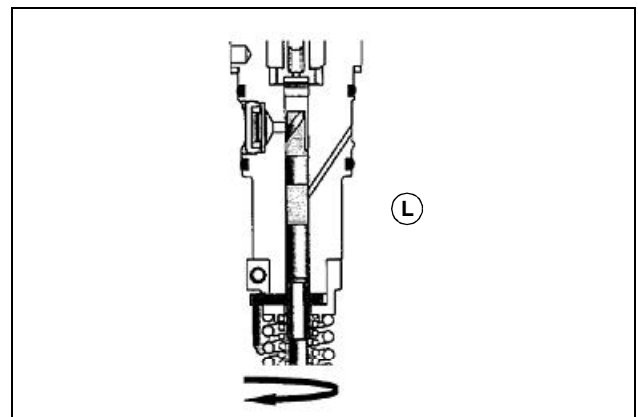
During the charging cycle (D), the camshaft follower follows the back side of the cam lobe, allowing the spring loaded plunger to move downward. As the plunger moves downward, the top edge of the helix uncovers the inlet port, filling the pumping chamber.

As the cam follower is forced to rise, due to the rotation of the engine, it forces the plunger upward and into the pump body (E). The helix on the plunger closes off the inlet port (F). The fuel trapped in the pumping chamber will be highly pressurized and pumped to the nozzle for injection.



MX33031

Picture Note: End of Pumping Event



MX33032

Picture Note: Plunger Rotation

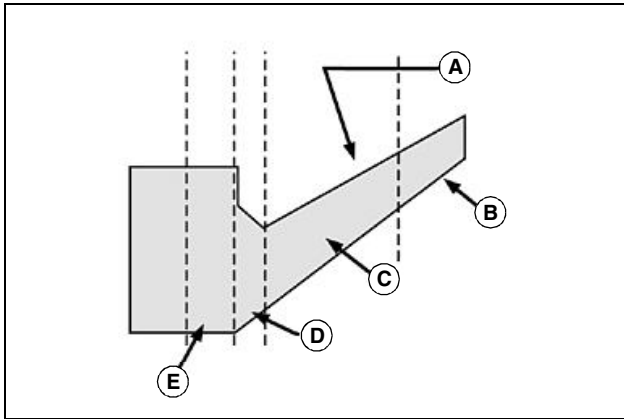
The plunger continues to be lifted by the cam lobe and follower (J). The bottom edge of the helix uncovers the inlet port (K). As the port is uncovered, pressurized fuel from injection, plus any excess fuel in the pumping chamber spills back to the supply gallery. The lowering of pressure in the pumping chamber ends the injection cycle.

A 100 kpa (15 psi) fuel outlet check valve, located at the rear of the cylinder block, maintains fuel pressure within the supply gallery. Excess fuel flows back to the fuel tank through the return line.

An engine driven governor in the camshaft assembly, through linkage to the unit pumps, controls the rotational position of the pumping plunger (L) (see "Governor Operation" on page 42). Varying the helix in relation to the inlet port achieves injection quantity and timing.

ENGINE - DIESEL THEORY OF OPERATION (AIR AND FUEL)

Light Load and Speed Advance Operation



MX33033

Picture Note: Plunger Helix

- A - Upper Ramp
- B - Lower Ramp
- C - Starting (Cranking) Zone
- D - Full Load Zone
- E - Light Load Zone

The upper edge of the helix (A) controls start of pumping (timing). The lower ramp (B) controls fuel quantity delivered. The starting, or cranking zone (C) of the helix produces an advance in timing and a delivery of a large quantity of fuel, both of which aid starting.

The full load zone (D) provides less advance timing (lower upper ramp location), and less fuel, than the starting zone of the helix.

When the engine is run at no, to light load conditions, the governor rotates the plunger so that the light load zone of the helix (E) controls the covering and uncovering of the charging port as follows: With a decrease in load, engine speed increases, causing the governor to turn the plunger which in turn will cause a decrease in fuel with a corresponding increase in timing. As load increases, engine speed drops. The governor moves the plunger in the opposite direction, increasing fuel and decreasing timing advance.

IMPORTANT: Avoid damage! The helix is specially designed to advance fuel timing under light engine loads to improve combustion efficiency, especially during warm-up.

Cold Start Advance Operation

IMPORTANT: Avoid damage! By slightly advancing the injection event (pump timing), the injected fuel is provided more time to heat during the compression stroke and burn more cleanly in the combustion chamber when ignited. Without cold start advance (CSA), fuel injected into a cool or cold combustion chamber at cold startup takes longer to heat up and ignite. If this delay in ignition is too great, it results in unburned fuel (white smoke and “slobber”) and rough running or misfire until the combustion chamber warms.

The cold start advance is controlled by oil pressure in the hydraulic roller cam followers, or lifters, for the unit pumps. During cold starting, engine oil is sent by the cold advance thermostat to the cold advance piston in the cam follower via the cold advance oil gallery. The oil pressure lifts the piston 1.5 mm, thus increasing the overall travel length, or stroke, of the unit pump plunger. This advances the pump timing. The increase in stroke of the plunger causes the cam to raise the plunger sooner. This change results in the injection timing to be advanced approximately ten degrees. The oil pressure needed to provide full cold start advance is about 35 psi. A ball check at the base of the piston prevents pumping forces from collapsing the advance.

The cold start advance thermostat begins to block the oil flow when oil temperatures reach approximately 80°C (176°F). When the oil supply port to the roller cam followers is fully blocked, residual oil in the piston cup bleeds out through a drain orifice located in the cup end of the follower. At approximately 15 psi oil pressure, the cold start advance is fully disabled. The follower piston returns to the lower position, returning timing advance to the optimum performance level for an engine at normal operating temperatures.

Glow Plug Cold Start Aid Operation

Glow plugs aid cold weather starting when the ambient temperature falls below 0°C (32°F). When the ignition switch is pushed in to the “AID” position, the indicator light will illuminate and the glow plugs will be activated. See “Glow Plug and Indicator Light Circuit Operation” on page 265 in the Electrical section.

The combustion chamber may be preheated by pushing in the key, with the switch in the run position, for up to 3 seconds before turning the key to the start position.

The engine preheat indicator light in the display panel provides a visual indication that the key is in the AID position and the glow plugs are being energized.

ENGINE - DIESEL DIAGNOSTICS

Diagnostics

About This Group of the Manual

This Group of the manual contains necessary information to diagnose some base engine, all lubrication system and all cooling system problems. The diagnosing malfunction areas are divided into the following headings, containing the following symptoms:

(L) Diagnosing Lubrication System Malfunctions:

- L1 - Excessive Oil Consumption
- L2 - Engine Oil Pressure Low
- L3 - Engine Oil Pressure High

(C) Diagnosing Cooling System Malfunctions:

- C1 - Coolant Temperature Above Normal
- C2 - Coolant Temperature Below Normal
- C3 - Coolant in Oil or Oil in Coolant

(E) Diagnosing General Engine Malfunctions:

- E1 - Engine Cranks/Won't Start
- E2 - Engine Misfires/Runs Irregularly
- E3 - Engine Does Not Develop Full Power
- E4 - Engine Emits Excessive White Exhaust Smoke
- E5 - Engine Emits Excessive Black or Gray Exhaust Smoke
- E6 - Engine Will Not Crank
- E7 - Engine Idles Poorly
- E8 - Abnormal Engine Noise

(F) Diagnosing Fuel System Malfunctions

- F1 - Fuel Supply System Check
- F2 - Excessive Fuel Consumption
- F3 - Fuel in Oil

Procedures for diagnosing some of the above symptoms are formatted such that a test or repair is recommended, then, based on the results, another test or repair is recommended. Other symptoms are formatted in a symptom - problem - solution format. In these symptoms, the problems are arranged in the most likely or easiest to check first. Symptoms arranged in both formats refer to testing procedures in the Tests and Adjustments section of this chapter. The Tests and Adjustments section contains the following testing procedures:

1. Base Engine Testing Procedures:

- a. Test Engine Compression Pressure
- b. Test Engine Cranking Speed

2. Lubrications System Testing Procedures:

- a. Engine Oil Consumption
- b. Check Engine Oil Pressure
- c. Check for Excessive Crankcase Pressure (Blow-By)
- d. Check for Turbocharger Oil Seal Leak

3. Cooling System Testing Procedures:

- a. Inspect Thermostat and Test Opening Temperature
- b. Pressure Test Cooling System and Radiator Cap
- c. Check for Head Gasket Failures
- d. Check and Service Cooling System

4. Air Supply and Exhaust Systems Testing Procedures:

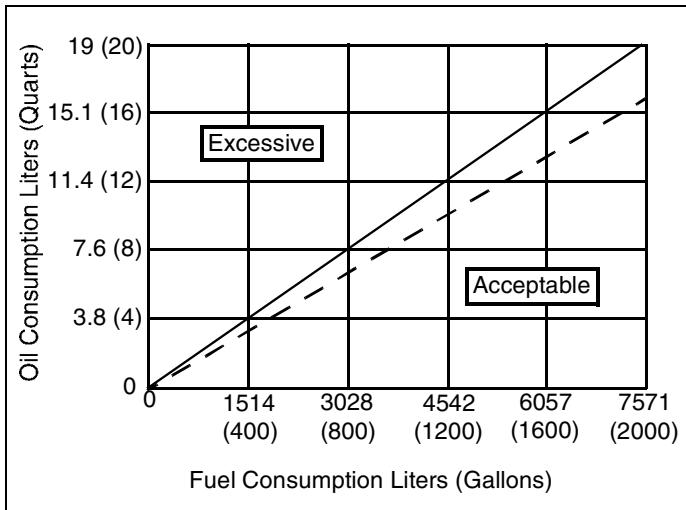
- a. Check Air Intake System
- b. Measure Intake Manifold Pressure (Turbo Boost)
- c. Check for Intake and Exhaust Restrictions
- d. Test for Intake Air Leaks
- e. Check for Exhaust Leaks
- f. Test Air Filter Restriction Indicator Switch

5. Fuel System Testing Procedures:

- a. Check Fuel Supply Quality
- b. Test Air in Fuel
- c. Check for Restricted Fuel Return Line
- d. Measure Fuel Transfer Pump Pressure
- e. Bench Test Fuel Transfer Pump
- f. Check Cold Start Switch Operation
- g. Check Cold Start Advance System Operation
- h. Test Fuel Shut-Off Solenoid Resistance
- i. Bleed the Fuel System
- j. Cylinder Misfire Test (Engine Running)
- k. Check and Adjust Fast Idle Speed
- l. Check and Adjust Slow Idle Speed
- m. Change Engine Rated Speed and Adjust Droop
- n. Test Fuel Injection Nozzles (Engine Running)
- o. Test Fuel Drain Back

ENGINE - DIESEL DIAGNOSTICS

Guideline for Acceptable Oil Consumption



Picture Note: Engine Oil/Fuel Consumption Ratio

Oil consumption complaints are usually reported as how many liters (quarts) are used per day. This information is not very specific. Two questions to consider are:

1. How long is a day?
2. How hard did the engine work in this day?

A much better method of checking oil consumption is based on oil usage compared to the amount of fuel burned (see chart). Long-term oil consumption (three oil drain intervals after engine break-in) should not exceed 0.95 L (1 qt) of oil for every 379 L (100 gal) of fuel burned.

IMPORTANT: Avoid damage! If the engine fuel/oil consumption ratio falls below the dashed line, oil consumption is acceptable. If the ratio is between the solid and dashed line, oil consumption is still acceptable but the oil level and usage should be monitored closely. If the ratio is above the solid line, oil consumption is excessive and action should be taken to determine the cause.

For example, if an engine uses less than 0.95 L (1 qt) of oil for every 379 L (100 gal) of fuel burned, it is within acceptable operating parameters. If the engine begins to use 0.95 L (1 qt) of oil or more for every 379 L (100 gal) of fuel burned, you should investigate to determine the cause of the excess oil consumption.

L1 - Excessive Oil Consumption

Symptom: Excessive Oil Consumption

(1) Check engine oil level. Is level too high or low?

Yes - Adjust oil level.

No - Go to next step.

(2) Check oil for too low viscosity, or coolant-or-fuel-diluted engine oil. Is oil incorrect?

Yes - Change engine oil.

No - Go to next step.

(3) Are there external oil leaks?

Yes - Repair as necessary.

No - Go to next step.

(4) Check coolant for signs of oil. Is there oil in coolant?

Yes - Oil found in coolant: See "C3 - Coolant in Oil or Oil in Coolant" on page 48.

No - Go to next step.

(5) Check for excessive crankcase pressure (blow-by). Is pressure excessive or excessive fumes or dripping oil observed? See "Check for Excessive Engine Crankcase Pressure (Blow-By)" on page 57.

Yes - Excessive fumes or dripping oil observed; appears to be caused by turbocharger boost pressure. Check the turbocharger, repair/replace as needed. See "Turbocharger Failure Analysis" on page 145.

No - Go to next step.

(6) Excessive fumes or dripping oil observed; does not appear to be caused by turbocharger boost pressure?

Yes - Excessive blow-by, not caused by boost pressure is most likely caused by faulty piston rings/cylinder bores not providing an adequate combustion seal. Perform a compression test to verify this is the case. See "Test Engine Compression Pressure" on page 54.

No - Go to next step.

(7) Check for turbocharger oil seal leaks. Are signs of oil leakage present?

Yes - Investigate problems associated with oil leakage as outlined in the test procedure, perform necessary repairs, and retest. See "Check for Turbocharger Oil Seal Leak" on page 57.



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ENGINE - DIESEL DIAGNOSTICS

Symptom: Excessive Oil Consumption

No - See "Pistons, Rings, Cylinder Bore Check" below.

Pistons, Rings, Cylinder Bore Check

At this point, the most likely cause of excessive oil consumption is one of the following failures in the pistons, rings, and/or cylinder bores or in the valve guides. Check the most likely items as needed.

1. Oil control rings worn or broken
2. Scored cylinder bores or pistons
3. Piston ring grooves excessively worn
4. Insufficient piston ring tension
5. Piston ring gaps not staggered
6. Cylinder bores glazed (insufficient load during engine break-in)
7. Worn valve guides or stems

Problem found with pistons, rings, and/or bores or valve guides. Repair problem as necessary.

L2 - Engine Oil Pressure Low

Symptom: Engine Oil Pressure Low

(1) Is oil level low?

Yes - Fill crankcase to proper oil level.

No - Go to next step.

(2) Is oil filter (or cooler) clogged?

Yes - Replace oil filter. Remove and inspect oil cooler. See "Remove Oil Cooler" on page 131.

No - Go to next step.

(3) Is incorrect oil type or weight being used?

Yes - Drain crankcase and refill with correct oil.

No - Go to next step.

(4) Is oil pump defective?

Yes - Remove and inspect oil pump. See "Remove, Inspect and Install Oil Pump" on page 133.

No - Go to next step.

(5) Has oil pressure regulating valve failed?

Yes - Inspect oil pressure regulating valve. See "Remove and Install Oil Pressure Regulating Valve" on page 132.

No - Go to next step.

(6) Is/are there broken piston spray jet(s)?

Symptom: Engine Oil Pressure Low

Yes - Replace piston spray jet(s). See "Remove, Inspect, and Install Piston Cooling Orifices" on page 104.

No - Go to next step.

(7) Is the oil pump screen clogged or pick-up tube cracked?

Yes - Remove oil pan and clean screen. Replace pick-up tube. See "Remove, Inspect, and Install Oil Pick-up Tube Assembly" on page 133.

No - Go to next step.

(8) Is there excessive main or connecting rod bearing clearance?

Yes - Determine bearing clearance. See "Cylinder Block, Pistons, and Rods Specifications" on page 26, or "Crankshaft, Main Bearings, and Flywheel Specifications" on page 26.

L3 - Engine Oil Pressure High

Symptom: Engine Oil Pressure High

(1) Is incorrect oil type or weight being used?

Yes - Drain crankcase and refill with correct oil.

No - Go to next step.

(2) Is the oil pressure regulating valve body loose (wanders)?

Yes - Remove and inspect oil pressure regulating valve. See "Remove and Install Oil Pressure Regulating Valve" on page 132.

No - Go to next step.

(3) Is the regulating valve operating improperly?

Yes - Remove and inspect oil pressure regulating valve. See "Remove and Install Oil Pressure Regulating Valve" on page 132.

No - Go to next step.

(4) Is/are there plugged piston spray jet(s)?

Yes - Replace piston spray jet(s). See "Remove, Inspect, and Install Piston Cooling Orifices" on page 104.

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