CATERPILLAR®

SENR1033-07

Systems Operation Testing and Adjusting

3408E and 3412E Industrial Engines

S/N: 4CR1-UP

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Systems Operation
3408E and 3412E Industrial Engines

Media Number -SENR1033-07 **Publication Date -01/12/2006** **Date Updated -15/12/2006**

i01885543

General Information

SMCS - 1000

The 3408E engine is a 65 degree V-8 arrangement. This engine has a bore of 137.2 mm (5.40 inch). The engine has a stroke of 152.4 mm (6.00 inch). The bore and the stroke provide a total displacement of 18.0 L (1099 in^3).

The 3412E engine is a 65 degree V-12 arrangement. This engine has a bore of 137.2 mm (5.40 inch). The engine has a stroke of 152.4 mm (6.00 inch). The bore and the stroke provide a total displacement of 27.0 L (1648 in^3).

The hydraulic electronic unit injector fuel system (HEUI) eliminates many of the mechanical components that are used in a pump-and-line system. The electronic control and hydraulic actuation also provide increased control of the timing and increased control of the fuel injection pressure. The timing advance is achieved by precise control of the unit injector timing. Engine speed is controlled by adjusting the injection duration. A special speed-timing wheel provides information to the Electronic Control Module (ECM) for detection of cylinder position and engine speed.

The engine has built-in diagnostics in order to ensure that all of the components are operating properly. In the event of a system component failure, the operator will be alerted to the condition by the "Check Engine" light. An electronic service tool can be used to read the numerical code of the faulty component or condition. Intermittent faults are also logged and stored in memory.

Starting The Engine

The engine's ECM will automatically provide the correct amount of fuel in order to start the engine. Do not hold the throttle down while the engine is cranking. If the engine fails to start in twenty seconds, release the starting switch. Allow the starting motor to cool for two minutes before using the starting motor again.

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Electronic Control System Components

SMCS - 1900

Component Locations

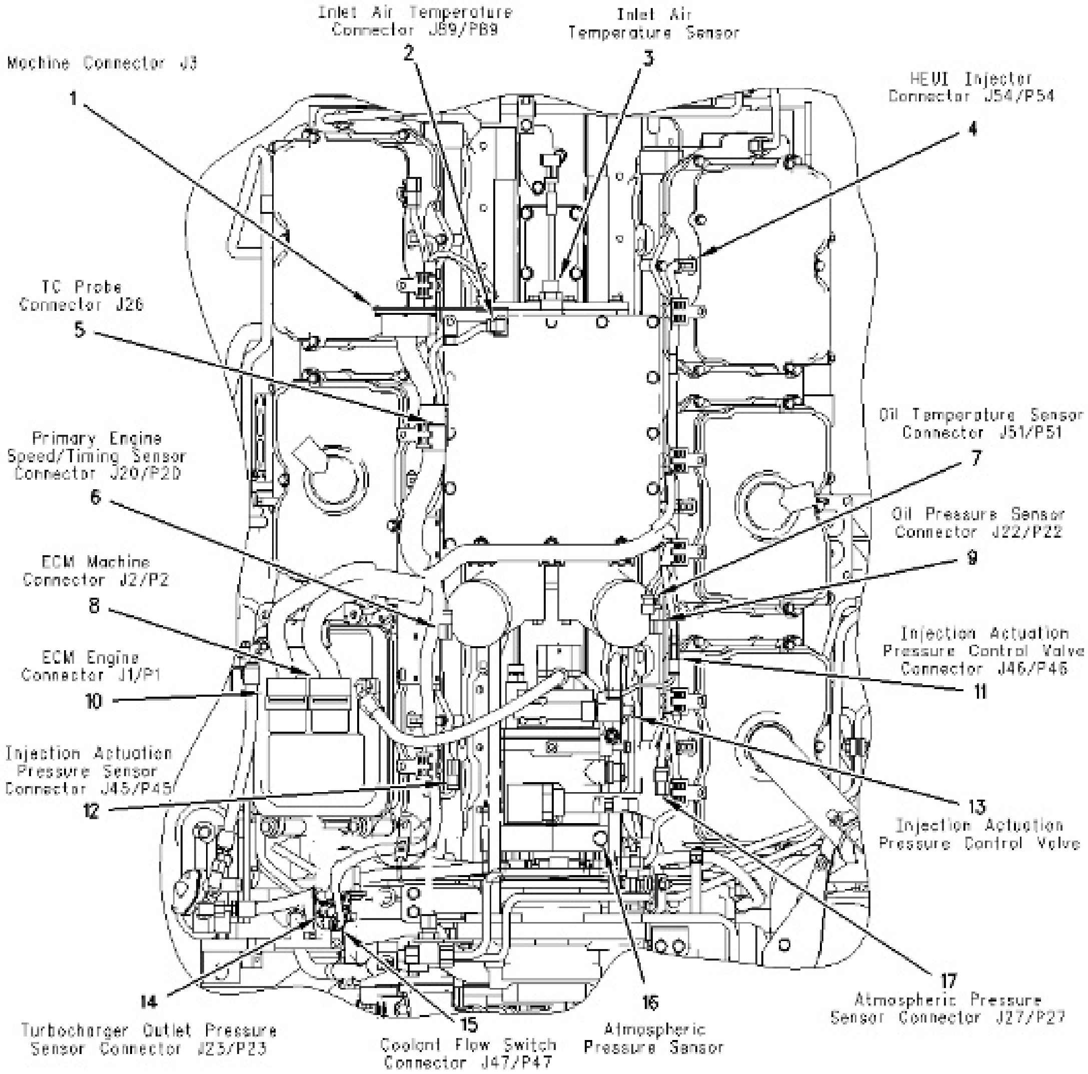

Illustration 1 g00841929

Sensor locations

(1) Machine connector J3

(2) Inlet air temperature sensor connector J89/P89

(3) Inlet air temperature sensor

(4) HEUI injector connector J54/P54

(5) Timing calibration connector J26/P26

(6) Primary engine speed/timing sensor connector J20/P20

(7) Oil temperature sensor connector J51/P51

(8) ECM connector J2/P2

(9) Oil pressure sensor connector J22/P22

(10) ECM connector J1/P1

(11) Injection actuation pressure control valve connector J46/P46

(12) Injection actuation pressure sensor connector J45/P45

(13) Injection actuation pressure control valve

(14) Turbocharger outlet pressure sensor connector J23/P23

(15) Coolant flow switch connector J47/P47

(16) Atmospheric pressure sensor

(17) Atmospheric pressure sensor connector J27/P27

Electronic Control Module (ECM)

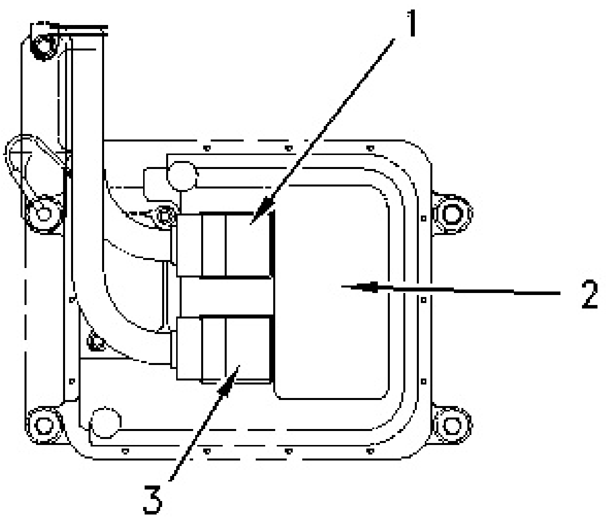

Illustration 2 g00554256

Electronic Control Module for an ADEM II engine

(1) ECM connector ("P2")

(2) Electronic Control Module (ECM)

(3) ECM connector ("P1")

The engine uses an Electronic Control Module (ECM) that is based on a microprocessor. The ECM is mounted on the left rear side of the cylinder block.

The inputs and the outputs to the control module are designed to withstand the short circuits to the battery voltage without damage to the control. The electronic engine control system has the following features that are designed into the system.

- Resistance to radio frequency
- Resistance to electromagnetic interference

The ECM power supply provides electrical power to all engine mounted sensors and actuators. Reverse voltage polarity protection and resistance to vehicle power system voltage swings or surges have been designed into the ECM. The ECM also monitors all input from the sensors. The ECM also provides the correct outputs in order to ensure desired engine operation.

The wiring harness provides communication or signal paths to the various sensors. The ECM performs many functions. The ECM contains all of the engine performance information. The ECM contains all of the information for the emission certification. Several examples are listed: engine timing, air/fuel ratio and rated fuel position control maps.

The ECM is programmed to run diagnostic tests in order to separate a fault to a specific circuit. Once a fault is detected, the fault can be displayed on a diagnostic lamp. A multimeter can be used to check most problems. The ECM will log most of the diagnostic codes that are generated during engine operation. The logged codes or the active codes can be read by an electronic service tool. Refer to the Troubleshooting manual for your engine.

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Fuel System

SMCS - 1250

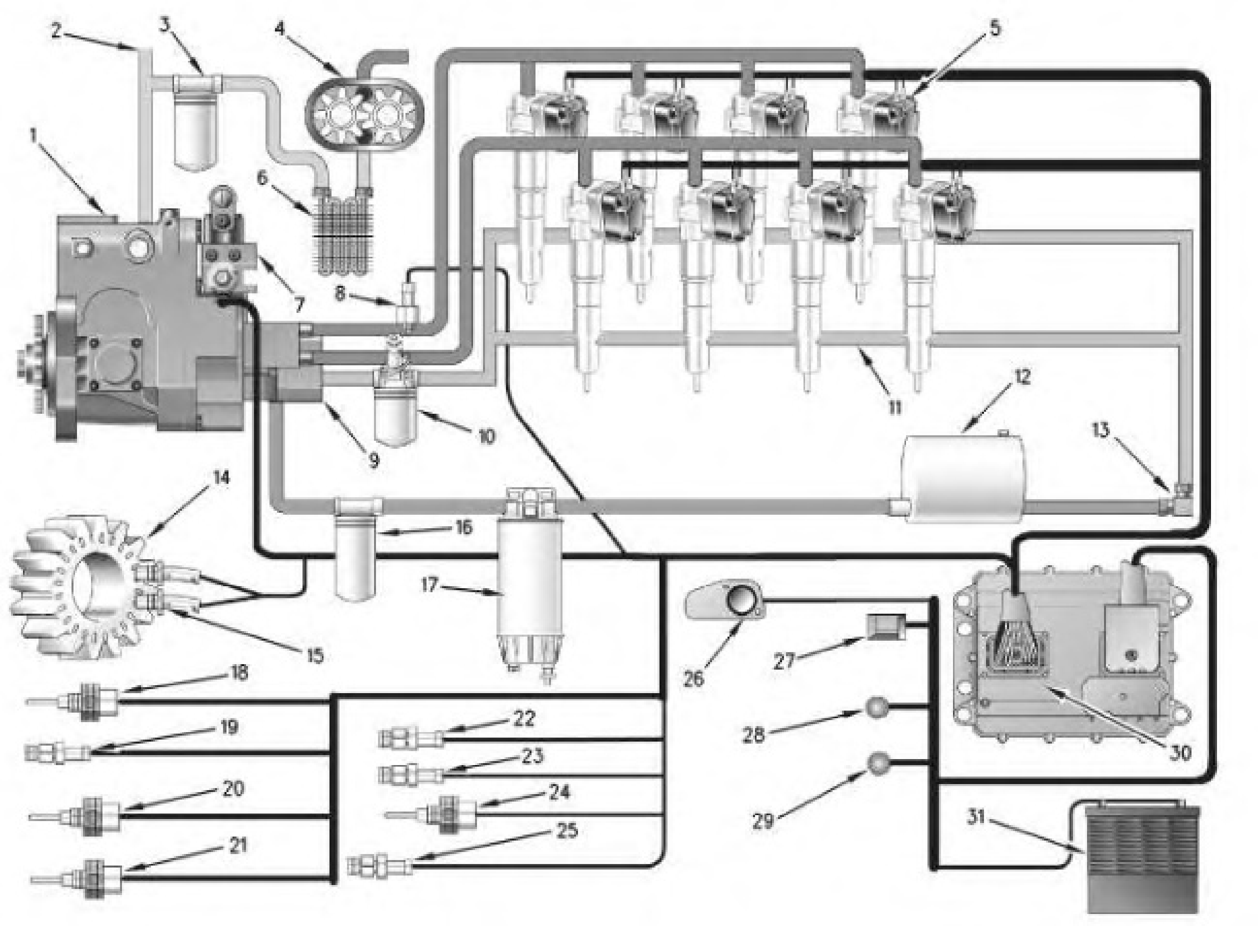

Illustration 1 g00990048

HEUI fuel system (typical example)

(1) Unit injector hydraulic pump

(2) Oil flow to the engine

(3) Oil filter

(4) Engine oil pump

(5) Injectors

(6) Oil cooler

(7) IAP control valve

(8) IAP sensor

(9) Fuel transfer pump

(10) Secondary fuel filter

(11) Fluid manifolds

(12) Fuel tank

(13) Fuel pressure regulator

(14) Speed-timing wheel

(15) Engine speed/timing sensors

(16) Primary fuel filter

(17) Water separator

(18) Oil temperature sensor

(19) Engine boost pressure sensor

(20) Coolant temperature sensor

(21) Coolant level sensor

(22) Oil pressure sensor

(23) Fuel pressure sensor

(24) Fuel temperature sensor

(25) Atmospheric pressure sensor

(26) Throttle position sensor

(27) Data link

(28) Alarm warning lamp

(29) Diagnostic lamp

(30) Electronic Control Module (ECM)

(31) Batteries

The operation of the Hydraulic Electronic Unit Injector (HEUI) fuel system utilizes the concepts of hydraulics and the multiplication of force to deliver fuel to the engine. The HEUI fuel system is completely free of adjustment. Adjustments cannot be made to the mechanical components of the system. Changes in performance are made by installing different software in Electronic Control Module (ECM) (30) .

This fuel system consists of six basic components:

- Hydraulic Electronic Unit Injector (HEUI) (5)
- Electronic Control Module (ECM) (30)
- Unit injector hydraulic pump (1)
- Injection actuation pressure control valve (7)
- Fuel transfer pump (9)
- Injection actuation pressure sensor (8)

Note: The components of the HEUI fuel system are not serviceable components. These fuel system components must not be disassembled. Disassembly will damage the components. If the components have been disassembled, Caterpillar may not allow a warranty claim or Caterpillar may reduce the warranty claim.

Component Description

Hydraulic Electronic Unit Injector

The HEUI fuel system utilizes a hydraulically actuated electronically controlled unit injector (5) .

The precise delivery of the fuel controls the engine's performance. All fuel systems for diesel engines use a plunger and barrel in order to pump high pressure fuel into the combustion chamber. A fuel injection pump camshaft lobe is typically used to provide a mechanical force to the plunger. The plunger then pumps the precise amount of fuel into the combustion chamber. The HEUI fuel system uses engine oil that has been pressurized by the system's hydraulic pump in order to apply force to the plunger. Control for the exact timing of the fuel delivery is provided electronically by the engine's ECM. Due to the differences in the HEUI fuel system, a technician must use different troubleshooting methods in order to diagnose fuel system problems.

The HEUI fuel system's hydraulic pump pressurizes the engine lubrication oil from 10 MPa (1450 psi) to 23 MPa (3350 psi) in order to transfer force from the engine's rotational energy to hydraulic energy that is used by the injector. The HEUI fuel system operates in the same manner as a hydraulic cylinder. A piston in the injector is used to receive the hydraulic energy that is supplied by the pump. The piston converts the hydraulic energy to a mechanical force that is applied directly to the injector's plunger assembly. The plunger assembly multiplies the mechanical force that is provided by the piston. The plunger converts the force into a hydraulic pressure that is placed on the fuel that is in the injector barrel. By multiplying the force of the high pressure oil that is supplied by the HEUI fuel system's hydraulic pump, the HEUI can produce the injection pressures that are essential for the complete fuel atomization that provides combustion efficiency.

Engine oil is used by the unit injector hydraulic pump in order to supply hydraulic pressure to the injectors. This hydraulic pressure is called injector actuation pressure. The actuation pressure of the oil generates the high injection pressures that are delivered by the unit injector. This injection pressure is greater than actuation pressure by approximately six times. The pressure in the system is multiplied by the intensifier piston that is located in the injector.

Low actuation pressure results in low injection pressures. During conditions of low engine speed such as idle and start, the low injection pressure is due to the low actuation pressure that is being produced by the unit injector hydraulic pump.

High actuation pressure results in high injection pressures. During conditions of high speed such as high idle and acceleration, high injection pressures can be produced because of the high actuation pressures that are produced by the hydraulic pump.

There are many other operating conditions when the injection pressure fluctuates between the minimum and the maximum. Regardless of the speed of the engine, the HEUI fuel system provides infinite control in order to provide the optimum fuel injection pressure.

Electronic Control Module (ECM)

The Electronic Control Module (ECM) (30) is mounted directly on the engine. The ECM is a powerful computer that provides total electronic control of engine performance. The ECM gathers performance data from the engine through a series of engine sensors. This data is used by the ECM in order to modify the engine's fuel delivery, injection pressure, and injection timing. The ECM also contains performance maps in the form of software that define engine's horsepower, torque curves, and rpm.

Most of today's engines are equipped with an ECM that can be reprogrammed in the field. There are electronic service tools that can be used to program the ECM. These electronic service tools use flash programming in order to load new software into the ECM.

The ECM is also used to record engine faults that may occur. These faults are usually triggered when one of the engine sensors detect a parameter that is operating out of the normal range of operation. An electronic service tool can be used in conjunction with the engine ECM to run several diagnostic tests on engine's electrical systems or electronic systems.

Unit Injector Hydraulic Pump

The unit injector hydraulic pump (1) is a high pressure hydraulic pump that is located at the front of the engine. The unit injector hydraulic pump is a variable displacement axial piston pump that is driven by the front gear train of the engine. The unit injector hydraulic pump uses a portion of the engine lubrication oil to supply the HEUI fuel system. The unit injector hydraulic pump pressurizes the engine lubrication oil to the correct injection actuation pressure in order to power the HEUI injectors.

Injection Actuation Pressure Control Valve (IAP Control Valve)

The Injection Actuation Pressure Control Valve (IAP Control Valve) (7) is located on the side of unit injector hydraulic pump (1). The pressure control valve assembly controls the outlet flow of the hydraulic pump. The pressure control valve assembly also controls the hydraulic pump pressure.

There are three components of the pressure control valve assembly.

- Injection actuation pressure control valve
- Compensator valve assembly
- Valve base

The compensator valve assembly contains three major parts:

- Load sensing spool
- Pressure limiter spool
- Check valve

The load sensing spool controls the oil flow to the control piston. The control piston controls the swashplate angle. The swashplate angle determines the pressure that is produced by the pump.

In the event of a malfunction of the pump, the pressure limiter spool acts as an emergency relief valve. A malfunction of the pump would cause the pressure to rise above the relief setting. The pressure limiter spool is a simple spring loaded relief valve. The valve opens at a preset pressure. When the valve opens, high pressure oil is sent to the control piston. This will destroke the pump and the oil flow that is being produced by the pump will be reduced.

The check valve works in conjunction with the pressure limiter spool. The valve allows high pressure oil to flow to the control piston when the pressure limiter spool has opened. The check valve remains closed at all other times.

The IAP control valve is an electrically controlled solenoid valve. The IAP control valve works with the load sensing spool in order to control the pump outlet pressure. The IAP control valve is actually an electrically operated hydraulic pressure relief valve. The IAP control valve converts an electrical signal from the ECM to the mechanical control of the spool valve in order to control the pump's outlet pressure.

Under most conditions, the pump is producing an excess oil flow. The IAP control valve instructs the load sensing spool to discharge excess pump flow to the control piston in order to control injection actuation pressure at the desired level. The IAP control valve is a solenoid valve of high precision. The IAP control valve is used to control the actuation pressure that provides hydraulic pressure to the injectors. The performance maps that are programmed into the ECM contain a desired actuation pressure for every engine operating condition. The ECM uses a control current in order to control the IAP control valve. This control current is used to vary the action of the solenoid in order to maintain an actual actuation pressure that is very near to the desired actuation pressure that has been determined by the ECM.

Fuel Transfer Pump

Fuel transfer pump (9) is mounted on the back of unit injector hydraulic pump (1). The fuel transfer pump must first draw fuel from fuel tank (12). Then, the fuel transfer pump must be capable of providing enough flow to the low pressure fuel system in order to maintain a continuous system pressure. A normal system pressure for the low pressure fuel system is usually between 310 kPa (45 psi) and 450 kPa (65 psi). This pressurized fuel is continuously supplied to injectors (5) .

The fuel transfer pump is a fixed displacement gear pump. The fuel transfer pump contains an integral pressure relief valve. This relief valve opens at approximately 630 kPa (91 psi). Excess flow from the valve discharges to an internal passage from the outlet side of the pump. The internal passage sends the fuel back to the inlet side of the pump.

Injection Actuation Pressure Sensor (IAP)

IAP sensor (8) monitors the actual injection actuation pressure. The oil manifold supplies the injectors with a continuous flow of actuation oil. This oil is used to power the injectors. The IAP sensor is installed in this high pressure oil manifold. The IAP sensor monitors the oil pressure in the manifold. The ECM is continuously monitoring the IAP sensor for pressure changes. The ECM interprets this signal in order to provide control for the engine's fuel system.

Operation of the HEUI Fuel System

Low Pressure Fuel System

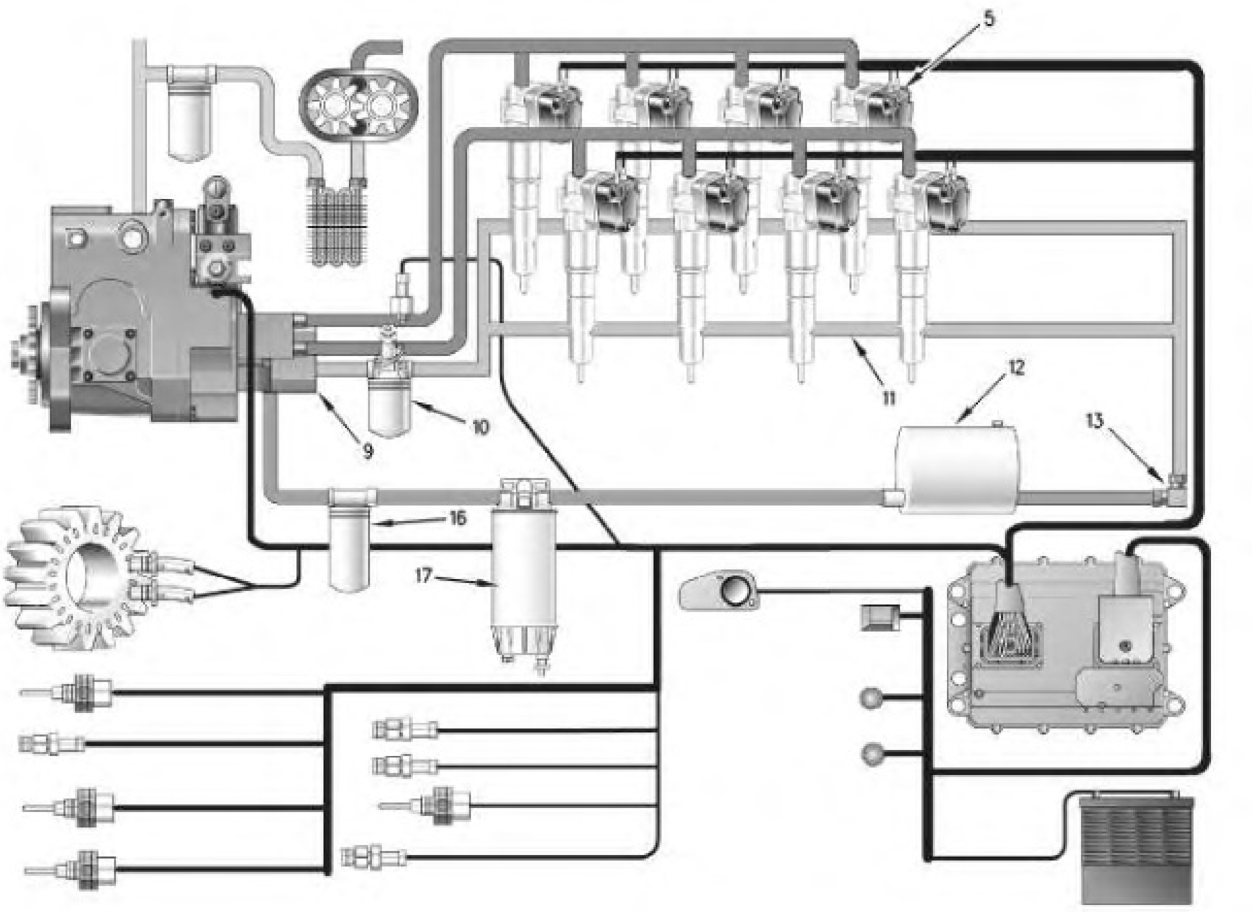

Illustration 2 g00990166

Low pressure fuel system (typical example)

(5) Injectors

(9) Fuel transfer pump

(10) Secondary fuel filter

(11) Fluid manifolds

(12) Fuel tank

(13) Fuel pressure regulator

(16) Primary fuel filter

(17) Water separator

The low pressure fuel system serves four basic functions. The system supplies the injectors (5) with fuel for combustion. Supplies extra fuel flow for cooling of the injectors. This extra fuel flow removes air from the system. The system also supplies the fuel that is used to cool the ECM.

The low pressure fuel system consists of seven basic components:

- Fuel tank (12)
- Water separator (17)
- Primary fuel filter (16)
- Fuel transfer pump (9)
- Secondary fuel filter (10)
- Fluid manifolds (11)
- Fuel pressure regulator (13)

Fuel is drawn from fuel tank (12) and flows through the water separator (17). The water separator is typically a 15 to 30 micron filter. The water separator will filter large debris from the fuel. The water separator also has the capacity that will filter large amounts of water from the fuel. If equipped, the fuel may flow to the primary fuel filter (16). The primary fuel filter is used to filter the fuel before entering the fuel transfer pump.

Fuel flows from the primary fuel filter to the inlet side of fuel transfer pump (9). The fuel transfer pump is mounted on the back of unit injector hydraulic pump. Fuel is drawn into the inlet port of the pump. An inlet check valve in the inlet port of the fuel transfer pump prevents fuel from flowing back into the fuel tank while the engine is not running. The fuel flow is increased by a simple gear pump and the fuel is then discharged through the outlet port of the pump. The outlet port also incorporates a check valve that is used to prevent pressurized fuel leakage back through the pump.

The fuel transfer pump is used in order to pressurize the fuel that supplies the low pressure fuel system. The maximum pressure that is generated by the fuel transfer pump is limited to 630 kPa (91 psi) by an internal pressure relief valve.

Fuel flows from the outlet port of the fuel transfer pump to the secondary fuel filter (10). The secondary fuel filter is a two micron fuel filter. The two micron fuel filter removes very small abrasive contaminants in the fuel. Fuel then flows from the secondary fuel filter to the fuel supply passages that are drilled into fluid manifolds (11).

The fluid manifolds are mounted on top of the cylinder heads. A fuel supply passage runs for the length of the fluid manifold. This passage connects with each unit injector bore in order to supply fuel to the unit injectors. Pressurized fuel flows through the fluid manifold to all of the unit injectors. Excess fuel flows out of the fluid manifold, into the fuel return line, and then to the fuel pressure regulator (13) .

The fuel pressure regulator consists of an orifice and a spring loaded check valve. The orifice is a flow restriction that provides a back pressure to the supply fuel. The spring loaded check valve opens at 410 kPa (60 psi) in order to allow the excess fuel to return to the fuel tank. The excess fuel that passes through the orifice is used in order to transfer heat away from the fuel system. A ratio of fuel that is returned to the tank to the amount of fuel that is consumed by the engine is approximately 3 to 1. When the engine is off and no fuel pressure is present, the spring loaded check valve closes. The spring loaded check valve closes in order to prevent the fuel in the cylinder head from draining to the fuel tank.

Injection Actuation System

Actuation Oil Flow

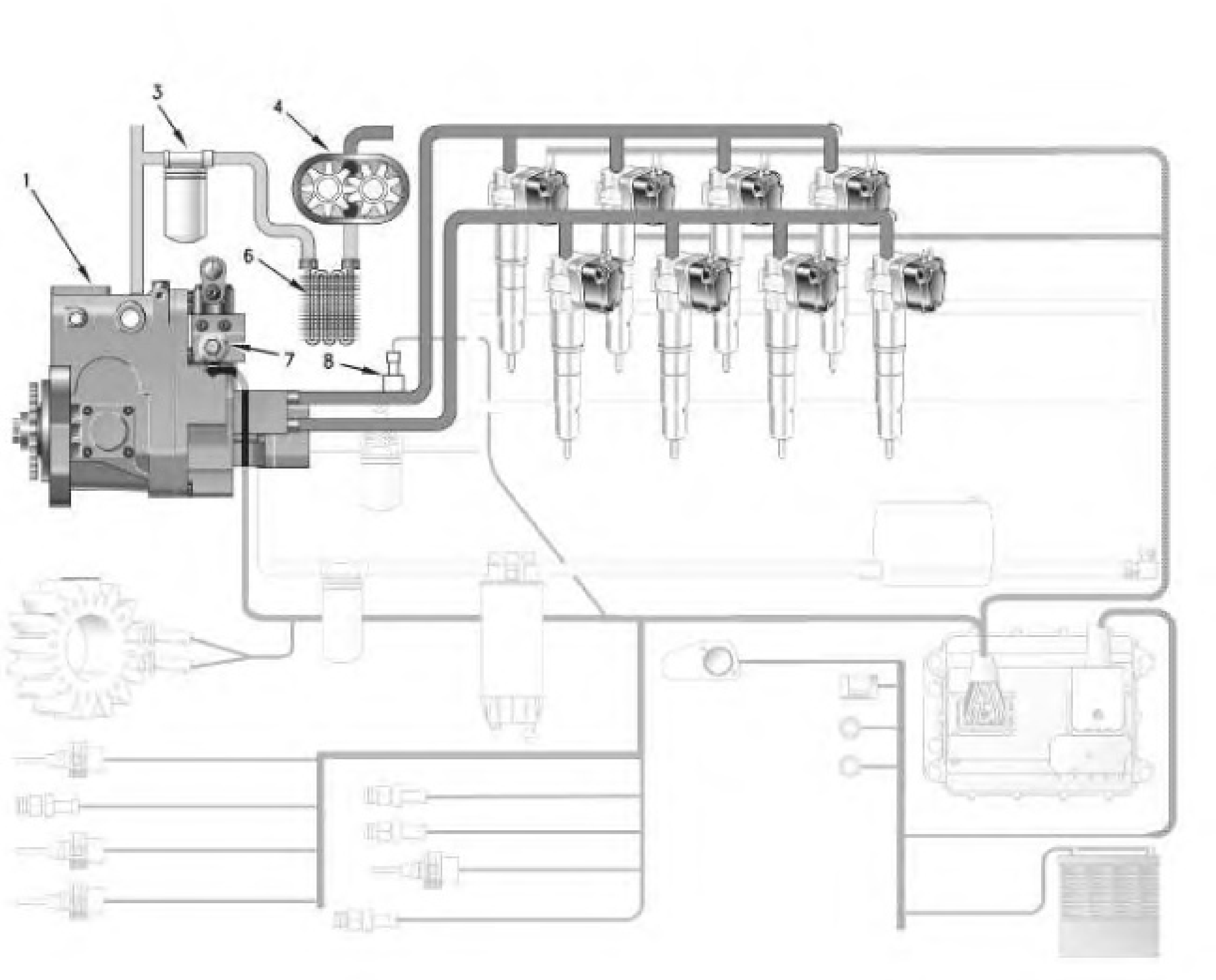

Illustration 3 g00990201

Actuation Oil Flow (typical example)

(1) Unit injector hydraulic pump

(3) Oil filter

(4) Engine oil pump

(6) Oil cooler

(7) IAP control valve

Diesel Engines

ABS	Agco-Sisu
Akasaka	Baudouin
BMW	Bukh
Caterpillar	CHN 25/34
Cummins	Daihatsu
Detroit	Deutz
Doosan-Daewoo	Fiat
Ford	GE
Grenaa	Guascor
Hanshin	Hatz
Hino	Honda
Hyundai	Isotta
Isuzu	Iveco
John-Deere	Kelvin
Kioti	Komatsu
Kubota	Liebherr
Lister	Lombardini
MAK	MAN B&W
Mercedes	Mercruiser
Mirrlees BS	Mitsubishi
MTU	MWM
Niigata	Paxman
Perkins	Pielstick
Rolls / Bergen	Ruggerini
Ruston	Scania
Shibaura	Sisu-Valmet
SKL	Smit-Bolnes
Sole	Stork
VM-Motori	Volvo
Volvo Penta	Westerbeke
Wichmann	Yanmar

Machinery

ABG	Airman
Akerman	Ammann
Astra	Atlas Copco
Atlas Weyha.	Atlet
Bell	Bendi
Bigjoe	Bobcat
Bomag	BT
Carelift	Case
Caterpillar	Cesab
Challenger	Champion
Claas	Clark
Combilift	Crown
Daewoo-Doosan	Demag
Deutz-Fahr	Dressta

Machinery

Drott	Dynapack
Extec	Faun
Fendt	Fiat
Fiatallis	Flexicoil
Furukawa	Gehl
Genie	Grove-gmk
Halla	Hamm
Hangcha	Hanix
Hanomag	Hartl
Haulpack	Hiab
Hidromek	Hino truck
Hitachi	Hyster
Hyundai	IHI
Ingersoll-rand	JCB
JLG	John-Deere
Jungheinrich	Kalmar
Kato	Kioti
Kleeman	Kobelco
Komatsu	Kramer
Kubota	Lamborghini
Landini	Liebherr
Linde	Link-belt
Manitou	Massey-Ferg.
Mccormick	MDI-Yutani
Mitsubishi	Moxy
Mustang	Neusson
New-Holland	Nichiyu
Nissan	OK
OM-Pimespo	others-tech
Pel-Job	PH-mining
Poclain	Powerscreen
Same	Samsung
Sandvik	Scania
Schaefer	Schramm
Sennebogen	Shangli
Shibaura	Steiger
Steinbock	Steyr
Still	Sumitomo
Super-pac	Tadano
Takeuchi	TCM
Terex	Toyota
Valpadana	Venieri
Versatile	Vogele
Volvo	Weidemann
Wirtgen	Yale
YAM	Yanmar