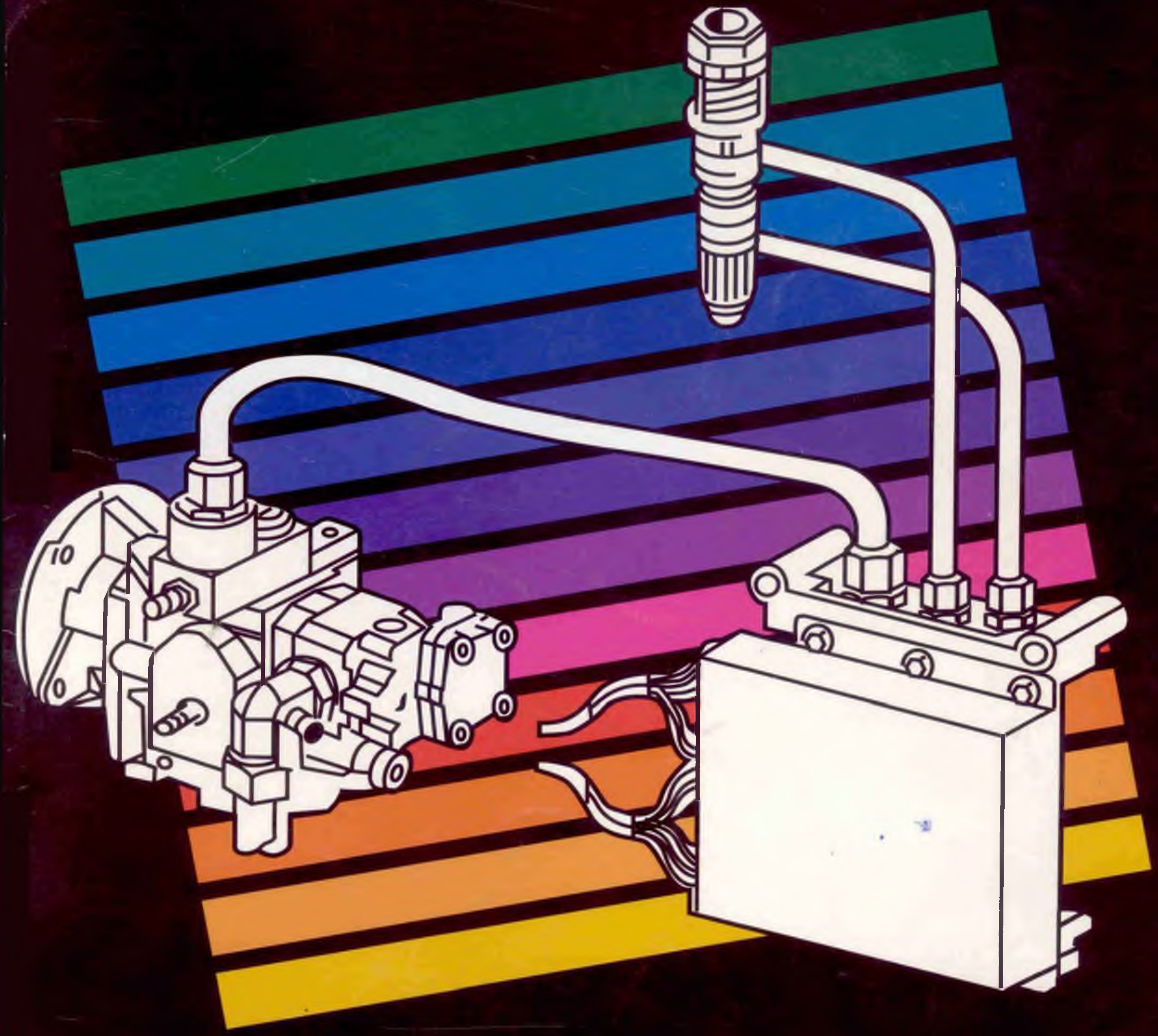
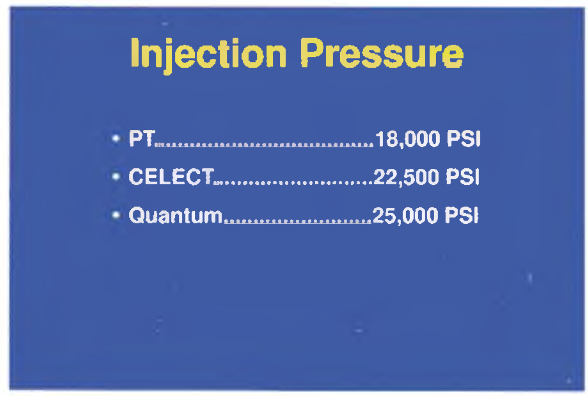
QSK19 Fuel System Familiarization



The QSK19 Fuel System

1.

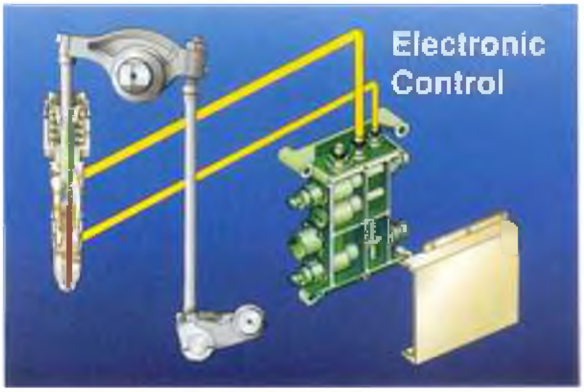
2. The QSK19 fuel system is the newest in fuel technology from Cummins. The QSK19 fuel system offers infinitely variable injection timing using a simple, efficient design, with injection pressures beyond any current Cummins fuel system.



Applications

3. Currently, the QSK19 fuel system is being used on the New QUANTUM System K19 (QSK19) engine which is intended for heavy-duty industrial applications. In the future, Cummins will bring the efficiency of the QSK19 fuel system to other engine platforms as well.

4. The QSK19 fuel system features a mechanically actuated, open nozzle type injector...



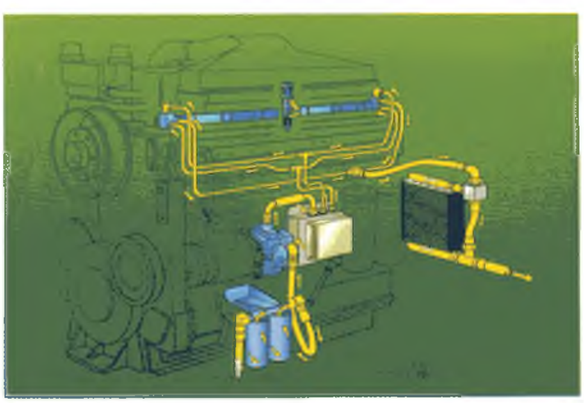
5. ...and using the latest generation of Cummins electronic controls, provides precise fuel management and infinitely variable injection timing.

The QSK19 Fuel System Components

6. The QSK19 fuel system can be divided into:
   - Hydro-mechanical components
   - Electronic control system components

Hydro-Mechanical Components

7. Let's start by looking at the hydro-mechanical components.



8. This schematic provides an overview of the hydro-mechanical system of the QSK19 fuel system.
   1. Fuel filter head and fuel filter element
   2. Fuel pump
   3. Fuel control valve assembly
   4. Fuel manifolds
   5. QSK19 injector
   6. Fuel cooler

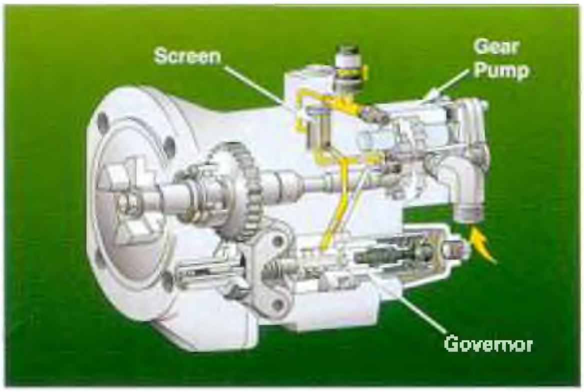
Fuel filters

9. Fuel flow from the supply tank is directed to the dual fuel filter head. The fuel filters have water separators and elements that filter down to 10 microns. Water separator elements are mandatory as the actuators in the control valve body are sensitive to water. The maximum inlet restriction at the filters is 4 inHg with a clean filter and 8 inHg with a dirty filter.

Fuel Pump components

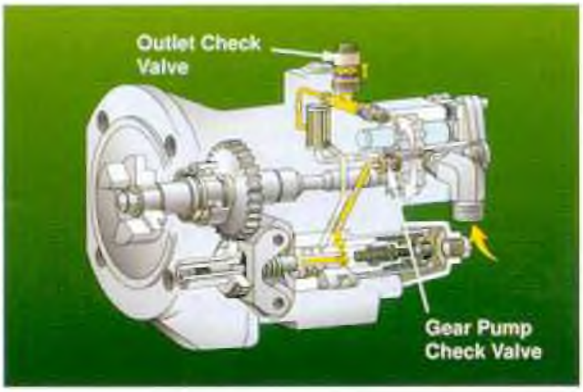
10. From the filters, fuel flow is directed to the inlet of the gear pump. The fuel pump is a version of the current PT fuel pump family.The gear pump generates the system flow and pressure. The fuel inlet is on the side of the gear pump housing.

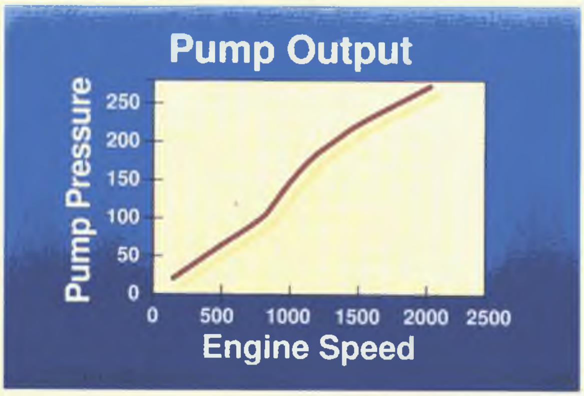
11. From the gear pump outlet, the fuel flows through the filter screen and then to either the pump outlet or the governor assembly. The filter screen is utilized to prevent any pump debris from reaching the fuel actuators. The governor assembly regulates the gear pump output, providing variable flow and pressure to match engine RPM.



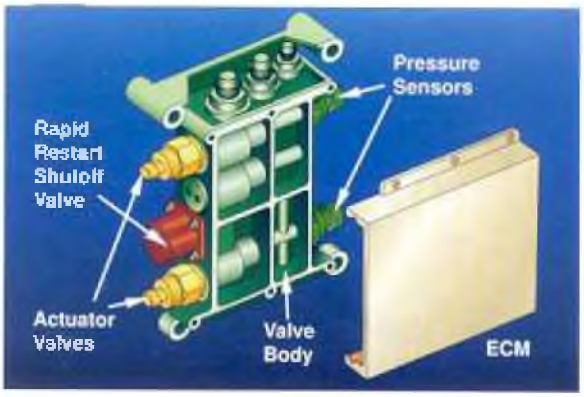
12. The governor assembly vents or spills all excess fuel back through a check valve to the gear pump inlet. The check valve maintains fuel pump housing pressure. The regulated flow output from the gear pump is directed to the PT pump outlet. A check valve in the outlet port controls back flow when the engine is not running.

    The PT pump does not contain throttling or AFC capabilities.



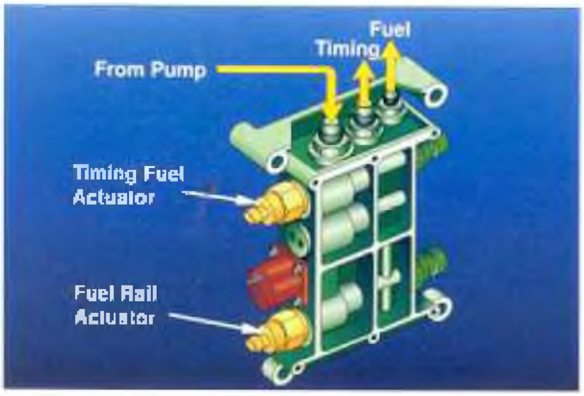


13. The PT pump was selected because it provides excellent pressure characteristics over the complete RPM range.

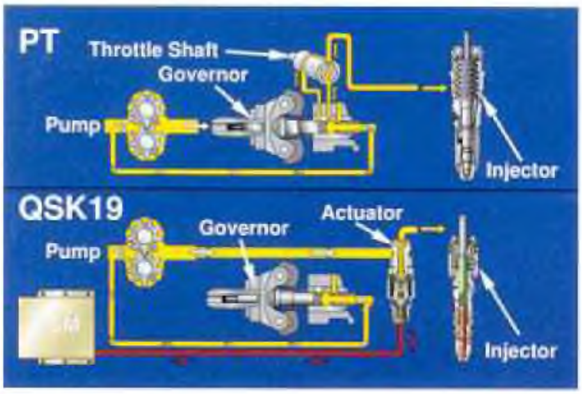


Control valve assembly

14. The core of the QSK19 fuel system is the control valve assembly. Fuel flow produced by the pump is delivered to the control valve assembly. The assembly consists of a shut down solenoid valve, two fuel actuator valves, and two fuel pressure sensors. The ECM mounts on the front of the assembly housing.



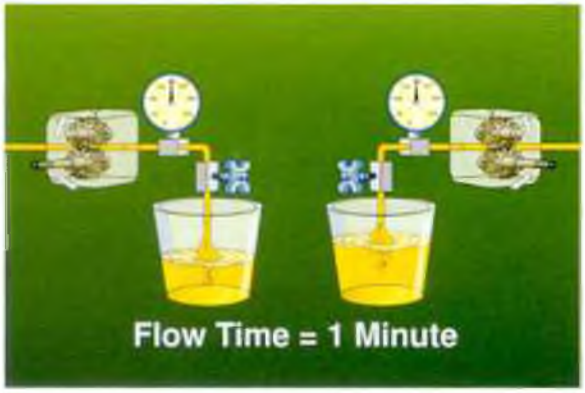
15. The control valve assembly has one fuel inlet port and two outlet ports. Each outlet port is controlled by a separate actuator.
    - The fuel rail actuator controls the fuel required for combustion.
    - The timing fuel actuators controls the fuel necessary to control injector timing.



16. The QSK19 fuel system utilizes the Pressure/Time concept like the PT fuel system. The PT is completely mechanical and relies on mechanically adjusted flow areas to regulate fuel pressure. The QSK19 fuel system, however, controls fuel pressure by electronically adjusting flow areas of the actuators.

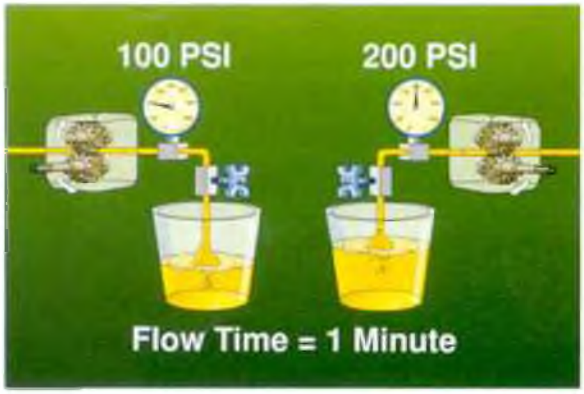
17. For an example of the Pressure/Time concept, let's consider the following: With equal sources of pressure connected to passages of different flow areas, if both systems are allowed to flow for the same amount of time, more fluid will be collected in the container of the system with the larger flow area.

    Therefore, with fluid pressure and flow time held constant, the flow area determines the quantity of fluid collected.



18. If passages of equal flow area are now connected to unequal sources of pressure and the time the fluid is allowed to flow is held constant, more fluid will be collected in the container of the system that has a greater source of pressure.

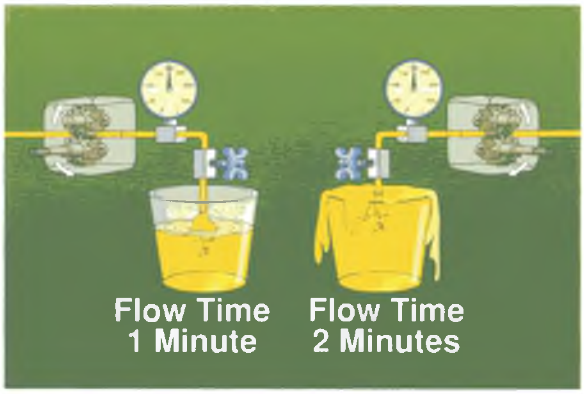
    Thus, if the flow area and flow time are held constant the pressure determines the amount of fluid collected.



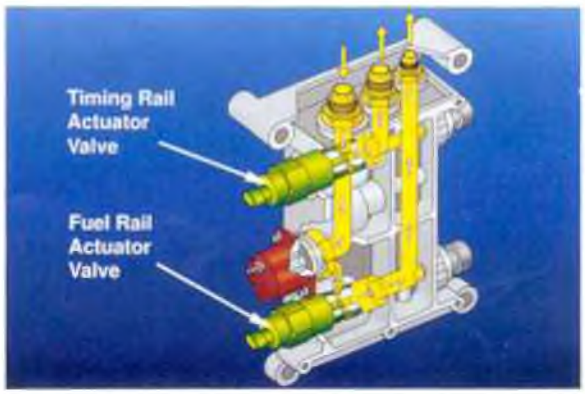
19. Finally, if passages of equal flow area are connected to equal sources of pressure, the time the fluid is allowed to flow will determine the amount of fluid collected.

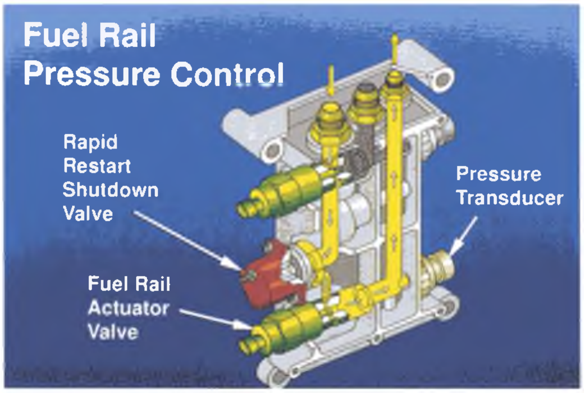
    Thus, if the flow area and fluid pressure are held constant, the time determines the amount of fluid collected.

    These three illustrations provide an excellent example of the Pressure/Time concept used in the QSK19 fuel system rail and timing systems.

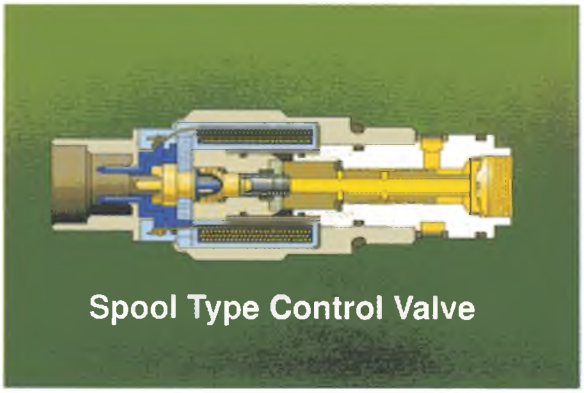


20. The control valve assembly receives fuel flow from the fuel pump. Inside the control valve assembly, the fuel flow divides to supply both control systems.



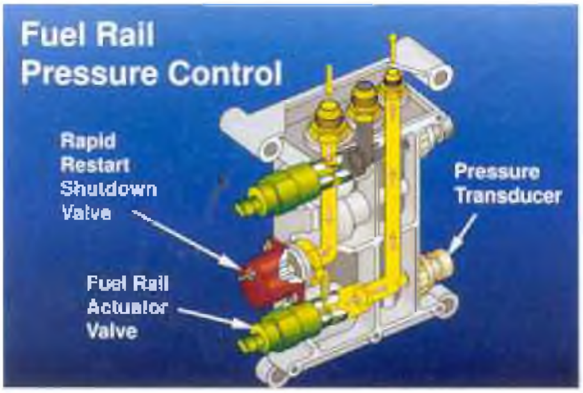


21. The control system that maintains fuel rail pressure consists of a rapid restart fuel shut-off valve, fuel rail actuator and fuel rail pressure sensor. Fuel flows through the rapid restart fuel shut-off valve first and then to the fuel rail actuator.

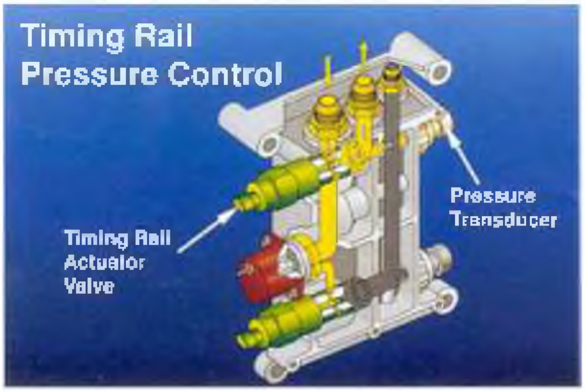


Rail pressure control

22. The actuator is an electronically controlled spool type control valve. The coil receives a PWM signal from the ECM. Depending on the signal from the ECM, the spool will move to the left uncovering the inlet port and allowing fuel flow.



23. The fuel rail pressure sensor monitors this pressure and sends this information to the ECM. The fuel rail actuator valve has a maximum flow rate of 1000 pounds per hour.



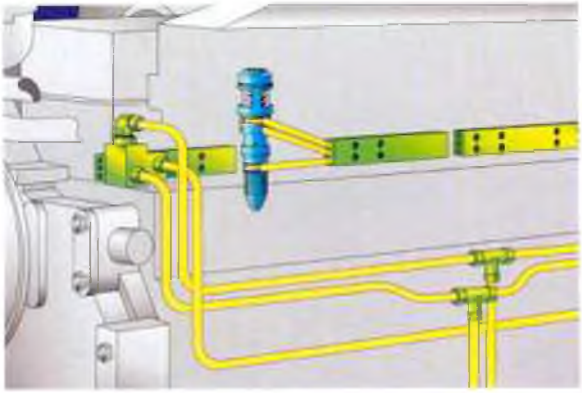
Timing control system

24. The control system that maintains the timing rail pressure consists of a timing rail actuator and timing rail pressure sensor. Fuel pressure in the timing rail is controlled by the timing rail actuator which is also controlled by the ECM. The timing rail pressure sensor monitors the pressure, and sends this information back to the ECM. The timing rail actuator has a maximum flow rate of 1500 pounds per hour.

25. Fuel flows from the control valve body through the fuel transfer tubes to the fuel manifold.

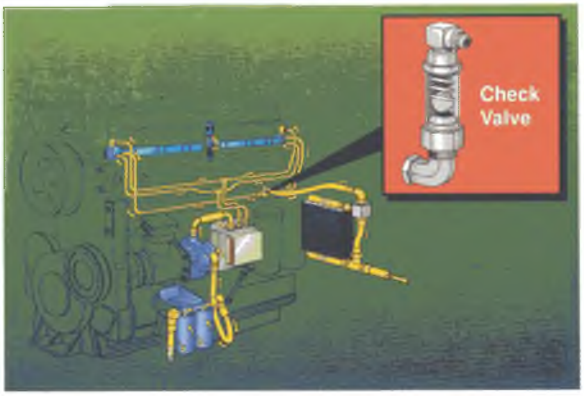
    There are two manifolds, the front manifold serving cylinders 1 through 3 and the rear manifold 4 through 6. Each manifold has three passages: timing rail, fuel rail, and drain.

    Drillings in the cylinder head intersect with the fuel manifold. Timing fuel and rail fuel pass through the cylinder head to the injector. Drain fuel from the injectors passes through the cylinder head to the fuel manifold. We will talk about the QSK19 fuel system injectors later in the program.



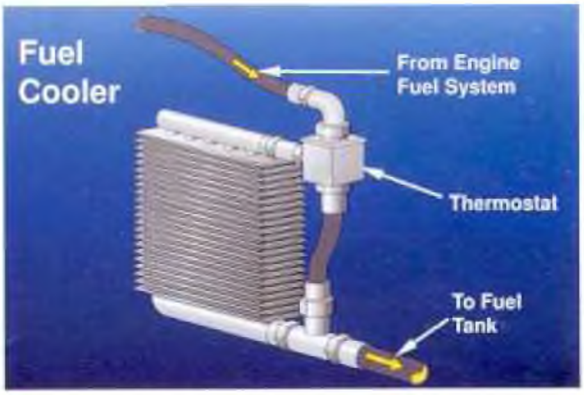
Rail and Timing pressure

26. In applications where the fuel supply tank is higher than the engine, a check valve prevents drain fuel from flowing back into the system when the engine is not in operation.



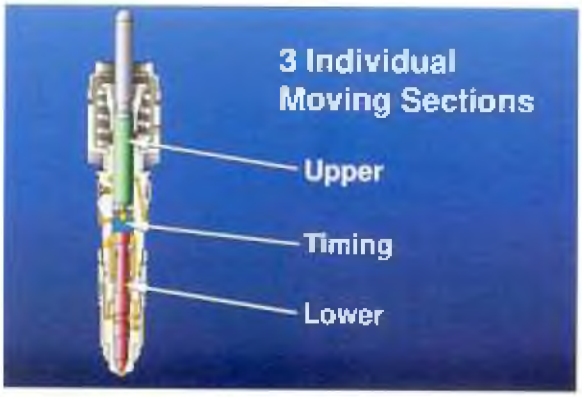
Fuel cooler

27. The correct fuel temperature is critical to the proper operation of the QSK19 fuel system. Thus, a fuel cooling radiator is mandatory. Drain fuel from the fuel manifold is directed to a thermostat at the cooler. At 89˚F the thermostat is closed and no fuel flows through the cooler. At 90˚F the thermostat starts to open and is fully opened at 104˚F. This causes all drain fuel to flow through the cooler. Although heat is dissipated from the fuel by the supply tank, the use of the fuel cooler insures positive temperature control. The typical drain fuel flow rate is 2 GPM. Also, the cooling radiator can have no more than a 5 PSI restriction.



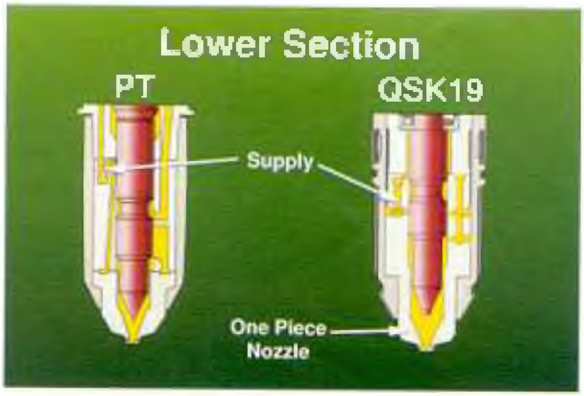
The QSK19 Fuel System Injector

28. The QSK19 fuel system injector shares many design features with PT and CELECT. It represents, however, the next generation in technology. The new QSK19 fuel system injector will be capable of up to 35,000 psi of fuel injection pressure in the future. Currently pressures are in the 25,000 psi range.



29. The new injector has three individual moving sections:
    - The lower plunger,
    - The timing plunger
    - The upper plunger

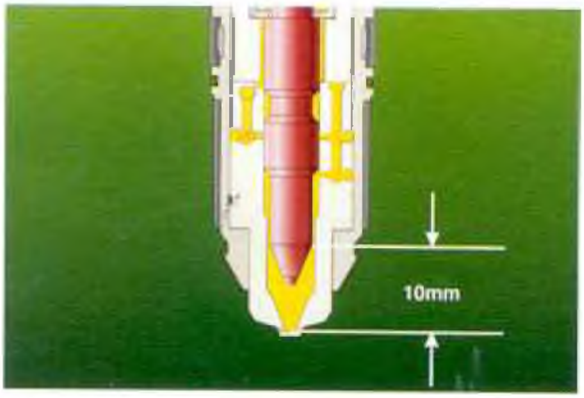
    All of the plungers are coated with Titanium Nitride to resist scuffing wear and provide maximum service life.



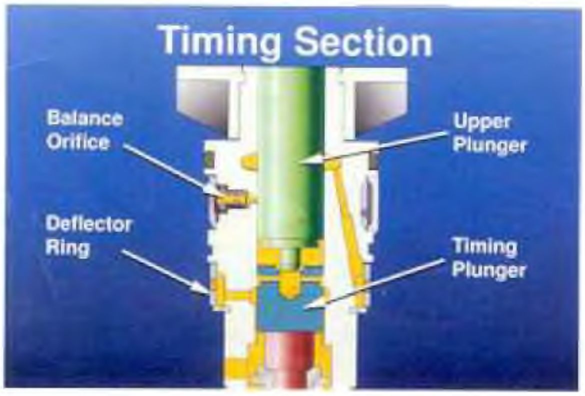
Lower section

30. The lower part of the injector is very similar to the PT injector. The plunger and nozzle are shaped like the PT. The fuel supply, metering, drain and check valves are also similar to the PT system.

    One important difference is that the lower barrel and nozzle are one piece. This design eliminates high pressure joints.



31. The open nozzle design of the injector provides the ideal rate and shape of injection. A slow start of injection allows a slower burn at the beginning of combustion for reduced combustion noise. The sharp end of injection, eliminating secondary injection, provides reduced hydro-carbon emission. For every injection cycle, the stroke of the lower plunger is 10 mm.



Timing section

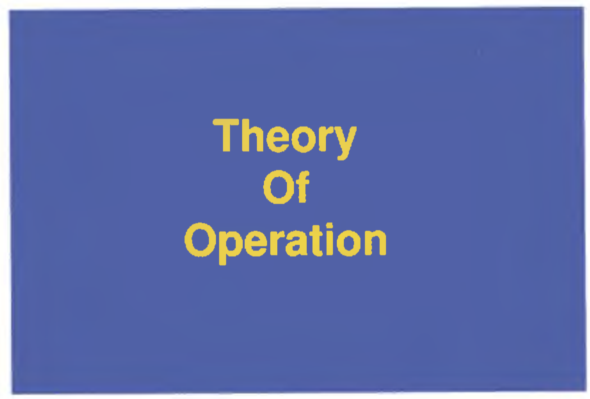
32. The QSK19 fuel system provides infinitely variable injection timing. The timing is varied by controlling fuel pressure to the injector timing section. The timing section consists of a balance orifice, timing plunger, and deflector ring. The timing plunger is positioned in the barrel bore below the upper plunger.

Upper section

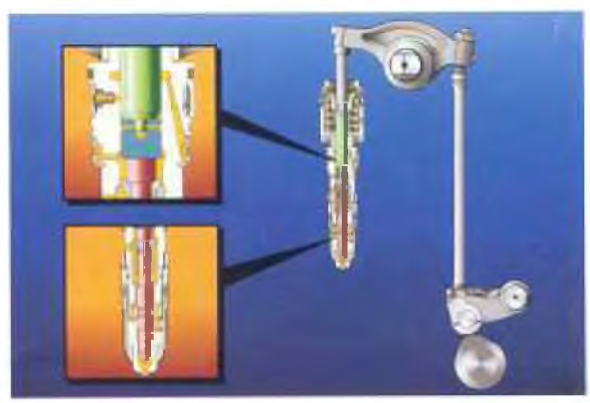
33. The upper section of the injector consists of the barrel, spring housing, return spring, upper plunger, top stop cap and plunger link.

Theory of operation

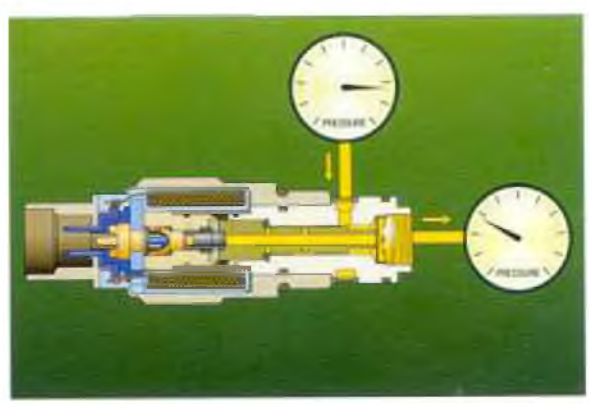
34.



35. We will start the injection cycle with the cam follower on the outer base circle. All three plungers are in contact with each other, as the camshaft rotates, the follower rolls toward the inner base circle which causes all three plungers to retract. When the lower plunger retracts far enough, the rail feed port is uncovered and fuel is PT (Pressure-Time) metered through an orifice into the cup.



36. Remember from PT theory, the "P" is rail pressure and "T" is the time that the feed port is uncovered. The time will depend on engine speed.



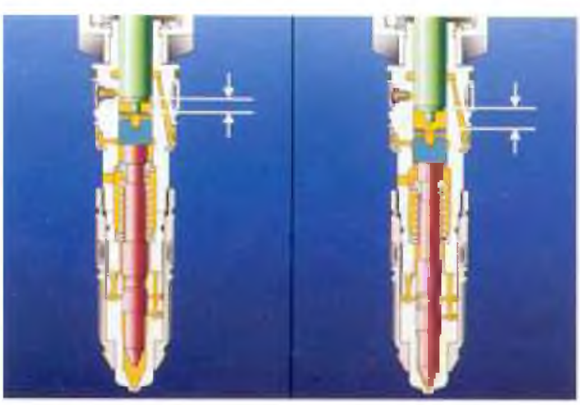
Timing and rail metering

37. The Rail pressure will be controlled electronically and can be as high as 290 psi or as low as 2 psi. The lower plunger is in its fully retracted position when the spring retainer contacts the ledge.

38. The cam follower continues to roll toward the inner base circle, allowing the timing and upper plungers to continue moving upward. When the upper plunger retracts far enough, it uncovers the timing feed port and fuel is also PT metered through an orifice into the timing chamber.

End of timing metering

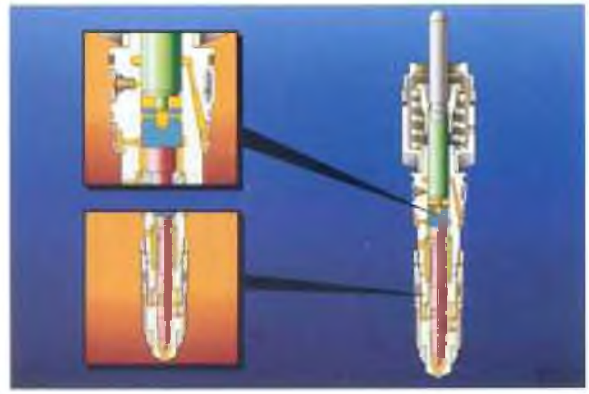
39. As the cam follower starts up the injection ramp of the camshaft, the upper plunger will move down and close the timing feed port to end Timing Metering. The fuel that metered into the timing chamber is now trapped between the upper plunger and the timing plunger.



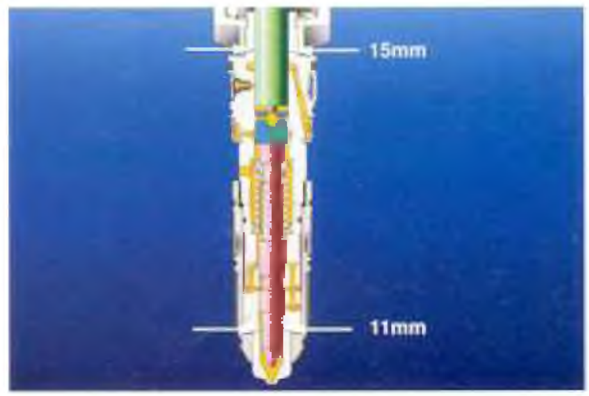
40. The amount (volume) of fuel metered into the timing chamber determines the separation between the upper and timing plungers. The amount of separation determines the effective length of the injector plunger. This length determines when injection will start. Changing the overall plunger length changes the start of injection.

The separation between the plungers varies from a minimum of 2 mm to around 9 mm. This separation is sometimes referred to as “overtravel”.

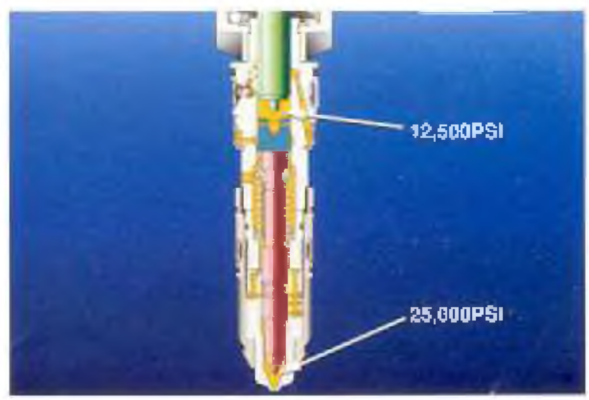
41. The trapped fuel becomes a solid link and all three plungers move down together. As the lower plunger moves, the rail feed port is also closed.



42. The timing and upper plungers have a diameter of 15 mm, compared to the 11 mm diameter of the lower plunger. This difference in diameter reduces the pressures in the timing chamber to approximately 50 percent of the injection pressures.

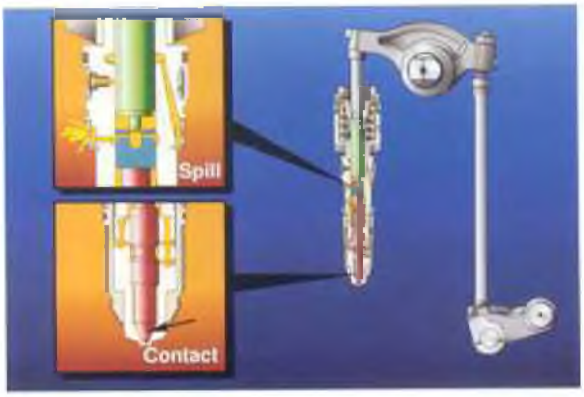


43. Therefore, if the pressure in the timing chamber is 12,500 PSI, pressure in the cup can be as high as 25,000 PSI. This reduction ratio allows the injector train to operate with minimum stress and wear yet still produce extremely high injection pressures.



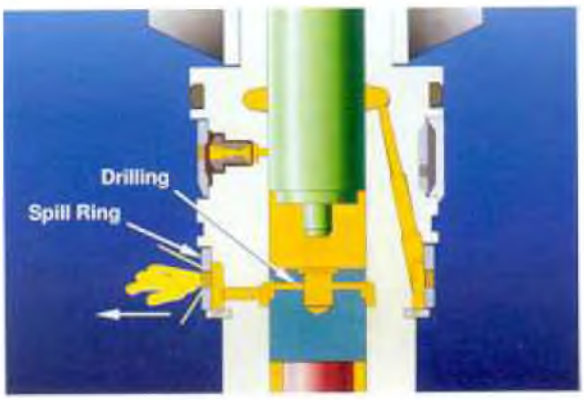
Injection begins

44. The downward velocity of the plungers will increase as the follower continues up the injection ramp of the camshaft. When the pressure in the cup exceeds the pressure in the cylinder, injection begins.



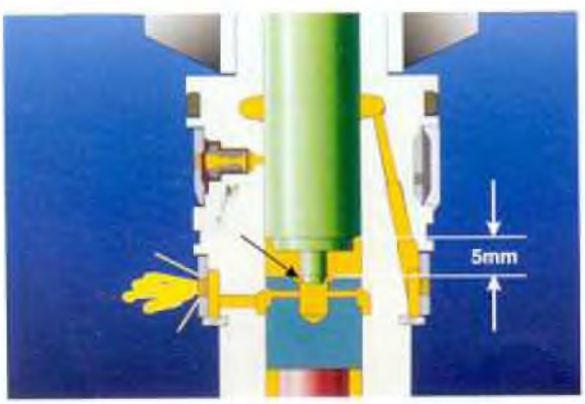
End of injection

45. Injection ends as the lower plunger makes contact with the nozzle seat. At approximately the same time, the groove in the timing plunger aligns with the groove in the barrel, opening the spill port. The timing fuel then spills as the upper plunger continues its stroke.



46. During this spill process, the drilling in the timing plunger regulates the fuel pressure in the timing chamber to keep a load on the lower plunger. This pressure is necessary to prevent the lower plunger from lifting before mechanical contact occurs between the upper and timing plungers.

    A spill ring is positioned over the spill port because the timing fuel spilling from the chamber is under pressure, . The spill ring acts as a pressure deflector to prevent damage to the injector bore in the cylinder head from the continual release of high pressure fuel.

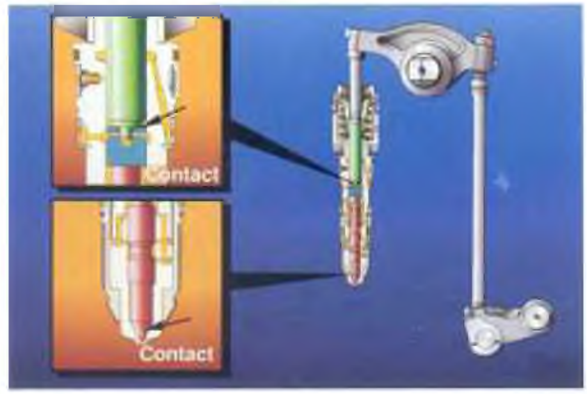


47. During the last 5 mm of upper plunger travel, the nose on the bottom of the upper plunger engages with the port in the timing plunger. The clearance between the two parts acts as an additional flow restriction on the fuel in the port. This additional restriction keeps pressure on the lower plunger while the rest of the timing fuel is spilling.

48. This feature is needed to ensure that the lower plunger does not unseat during the transition from the ramp to the nose of the camshaft lobe.

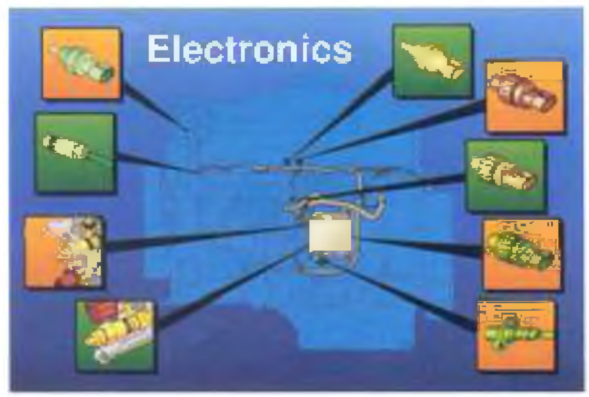
Mechanical crush

49. As all of the timing fuel spills from the chamber, the plungers will make mechanical contact. The downward travel of the injector train will continue creating a mechanical crush condition on the lower plunger. This ensures that the plunger remains sealed in the nozzle during combustion.

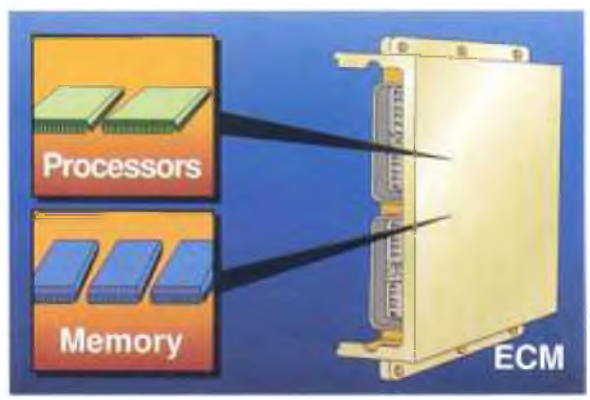


System operation overview

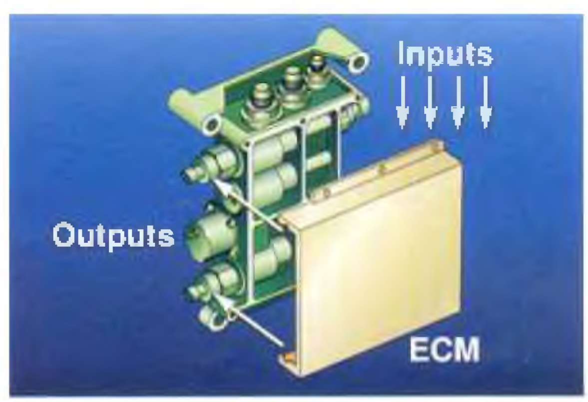
50. By now we should have a good grasp of the fueling and timing concepts involved with QSK19 fuel system. So, let's take a close look at how electronics control the engine fueling.

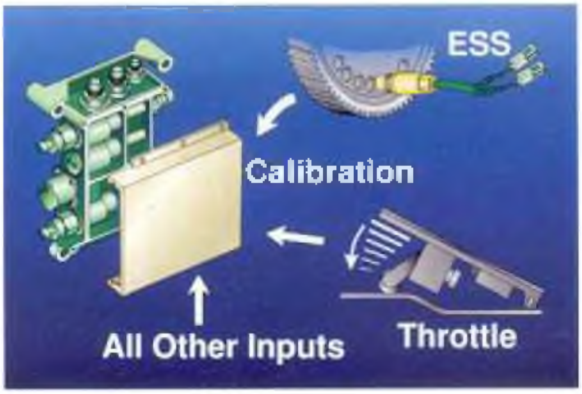


51. The QSK19, like the other Cummins electronic engines, is commanded by an Electronic Control Module (ECM). The QSK19 fuel system ECM contains the latest technology from Cummins Electronics. It has two micro processors to process and manage the data necessary to operate the engine and systems. It also contains 2MB of memory to store calibration and fault data.

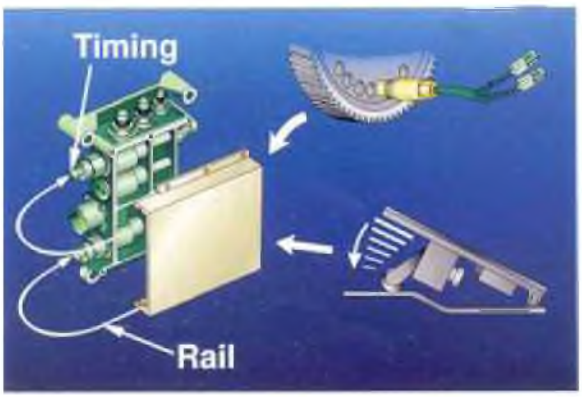


52. The ECM's main task is to manage the fuel control system that operates the engine. The ECM samples all inputs, processes the data, and outputs signals to the rail and timing control actuators many times each second. The ECM can make changes to rail and timing pressures very quickly, responding instantly to the slightest variations in operating and environmental conditions.

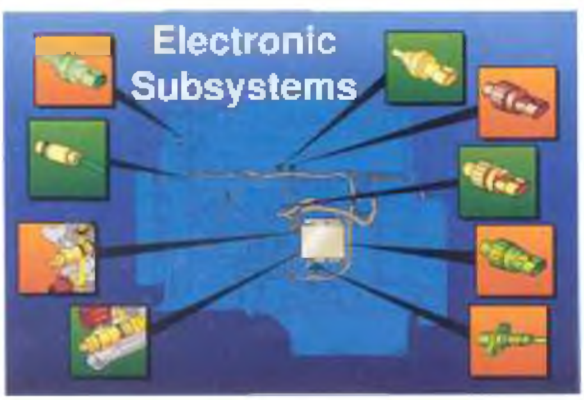




53. For example, look at when the operator opens the throttle to increase engine speed. The ECM will consider the request for increased engine speed, the actual engine speed, an all other inputs. It will then compare this data to its calibrated data to determine the appropriate signal changes.

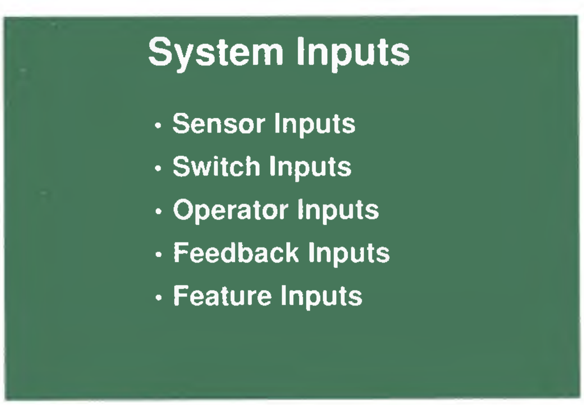


54. If additional engine speed is allowed, the ECM then outputs the appropriate signals to the fuel rail control actuator to increase engine RPM. If this increase in engine speed requires a change in injection timing, the ECM will output the appropriate signals to the timing control actuator as well.



Electronic subsystems

55. From the previous overview, we should have a good idea of the basic system operation. Let's now look at each subsystem and the components that make up these systems. We'll start with the inputs.

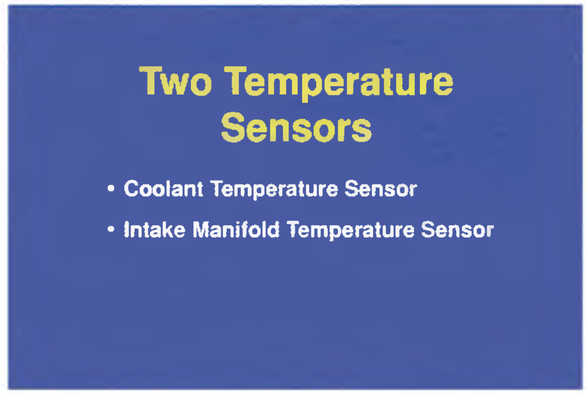


System Inputs

56. The ECM utilizes input information to determine engine fuel and timing pressures, or, more simply, to operate the engine. The inputs are divided into the following:
   - Sensor inputs
   - Switch inputs
   - Operator inputs
   - Feedback inputs
   - Possible feature inputs

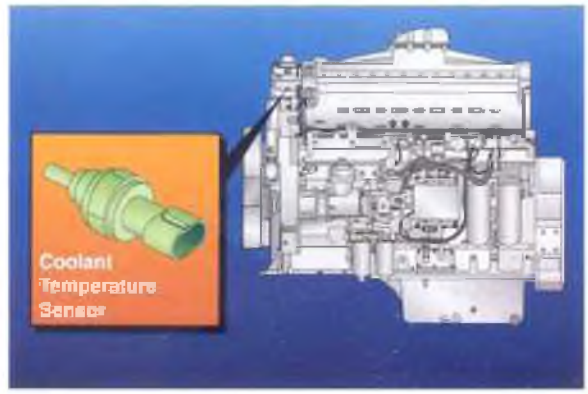
Temperature sensors

57. There are two temperature sensors. The temperature sensors provide critical temperature information to the ECM. The temperature sensors are:
    - Coolant temperature sensor
    - Intake manifold temperature sensor



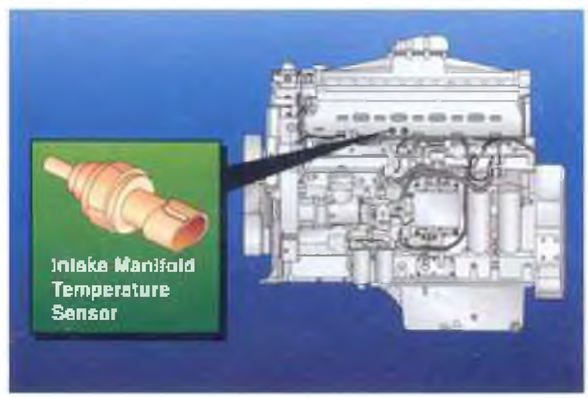
Coolant temperature sensor

58. The coolant temperature sensor is mounted in the thermostat housing. The information this sensor obtains is utilized by the ECM to help make decisions for timing and engine protection.



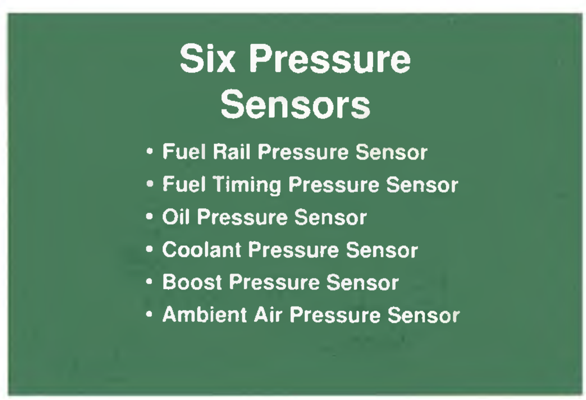
Intake manifold temperature sensor

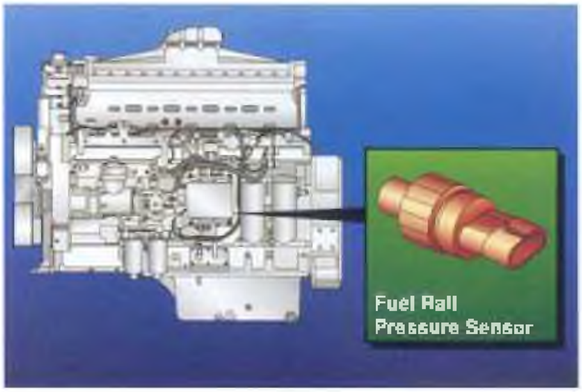
59. The intake manifold air temperature sensor is mounted in the aftercooler housing and measures air temperature after the cooler core. The information this sensor obtains is utilized by the ECM to help make decisions for timing and engine protection.



Pressure sensors

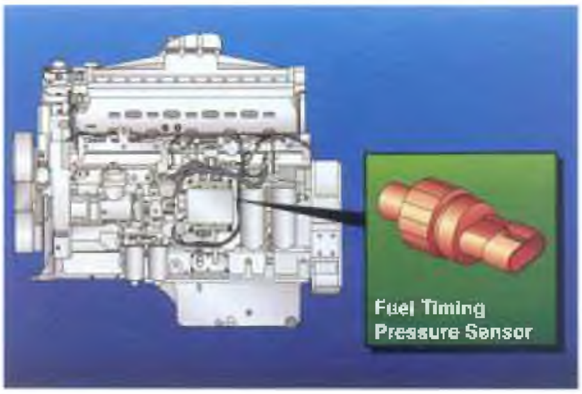
60. There are six pressure sensors that provide critical information to the ECM. The pressure sensors are:
    - Fuel rail pressure sensor
    - Fuel timing pressure sensor
    - Oil pressure sensor
    - Coolant pressure sensor
    - Boost pressure sensor
    - Ambient air pressure sensor





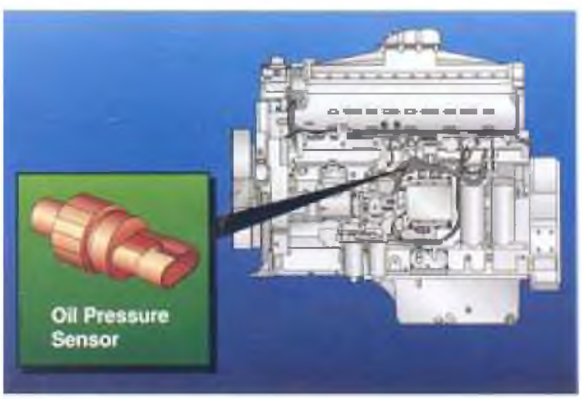
Fuel rail pressure sensor

61. The fuel rail pressure sensor is mounted in the fuel control valve assembly and measures actual fuel pressure in the rail supplying the injectors.



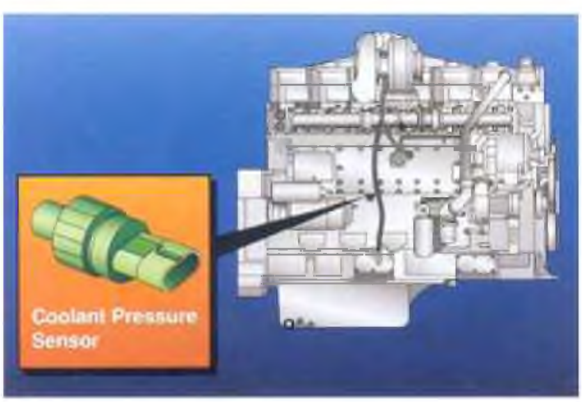
Fuel timing pressure sensor

62. The fuel timing pressure sensor is also mounted in the fuel control valve assembly. It measures actual fuel pressure in the rail supplying the timing chambers.



Oil pressure sensor

63. The oil pressure sensor is mounted in a main rifle port above the ECM. It measures main system oil pressure. The information this sensor obtains is utilized by the ECM to makde decisions for engine protection.

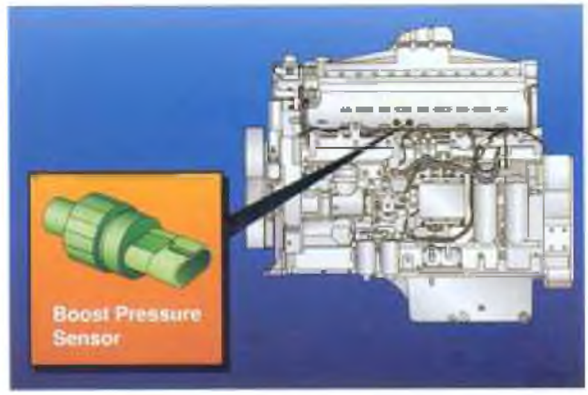


Coolant pressure sensor

64. The coolant pressure sensor is located in the oil cooler housing. It measures coolant system pressure. The information this sensor obtains is utilized by the ECM to make decisions for engine protection.

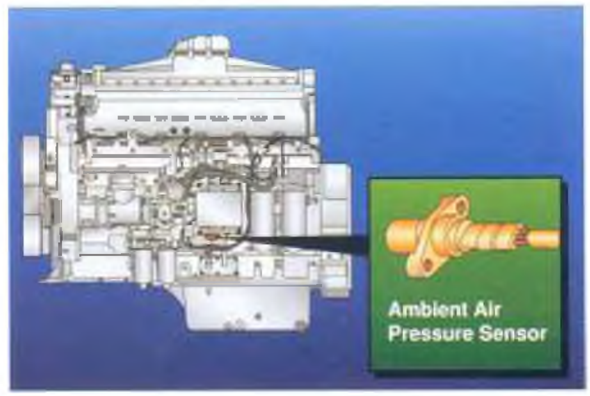
Boost pressure sensor

65. The boost pressure sensor is mounted in the aftercooler housing and measures air inlet pressure after the turbocharger. The information this sensor obtains is utilized by the ECM to determine accurate engine fueling.



Ambient air pressure sensor

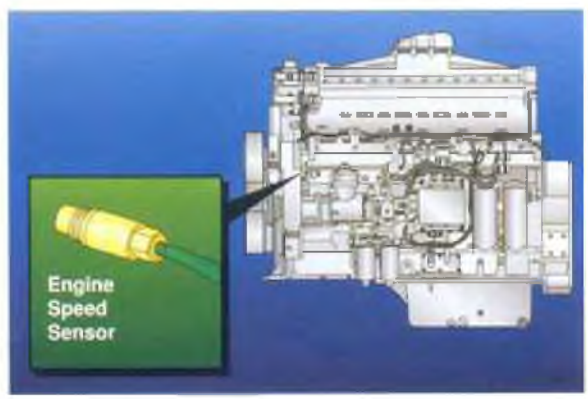
66. The ambient air pressure sensor is mounted on the fuel control valve assembly below the ECM. The ECM utilizes the information received from the sensor to make decisions for engine protection. In high altitude operation, the engine is derated to prevent turbocharger overspeed.



Engine speed sensor

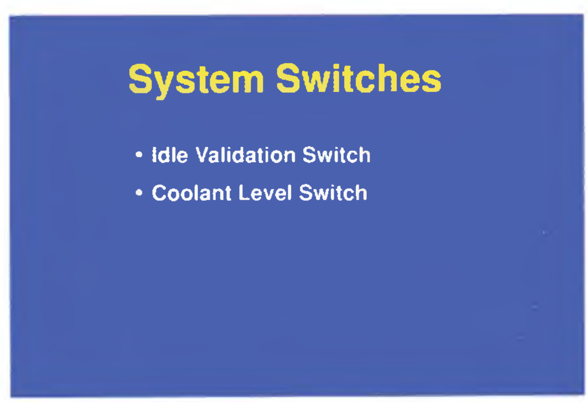
67. The engine speed sensor is located in the back of the front gear housing. It detects 24 raised pads on the back of the camshaft gear and sends signals to the ECM. The ECM processes these signals to determine engine speed.

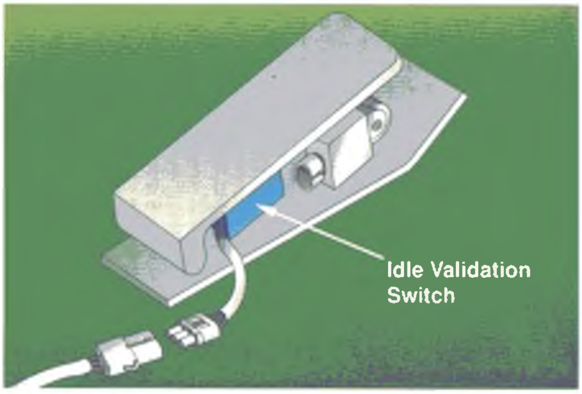
    The sensor has a dual signal output providing two separate signals to the ECM. Even if one signal is lost, the engine will continue to operate.



Switch inputs

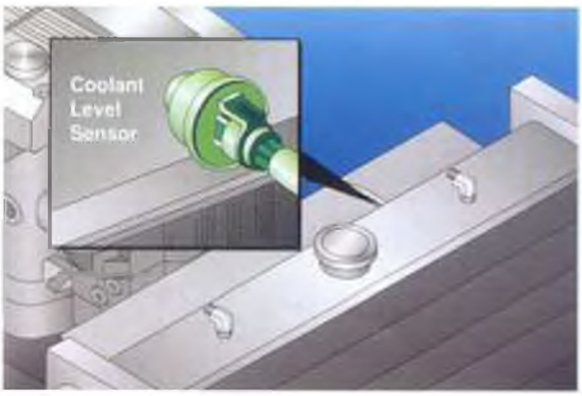
68. There can be two system switches. They are:
    - Idle validation switch
    - Coolant level switch





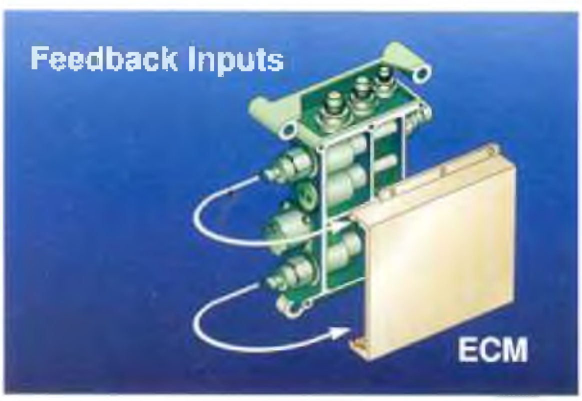
Idle validation switch

69. The idle validation switch is located in the throttle pedal assembly. It provides a confirming signal to the ECM as to the position (released or depressed) of the throttle pedal.



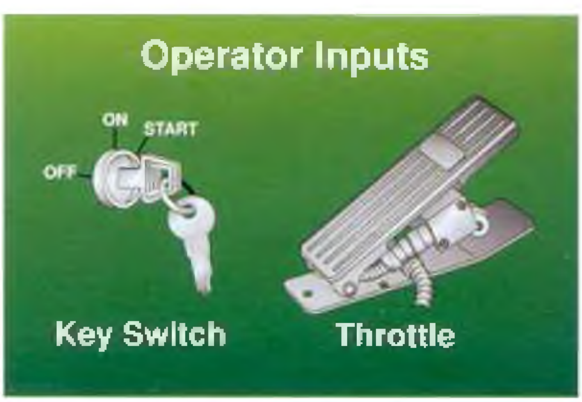
Coolant level switch

70. The coolant switch monitors the coolant level in the radiator top tank. If the fluid level drops below a predetermined point the switch will open, indicating a low fluid level to the ECM. The information this sensor obtains is utilized by the ECM to make decisions for engine protection.



Feedback inputs

71. In addition to monitoring the fuel and timing pressure sensors to determine actual pressures, the ECM also monitors the current returning from the rail and timing control actuator valves. This feedback information provides confirmation of correct valve operation.



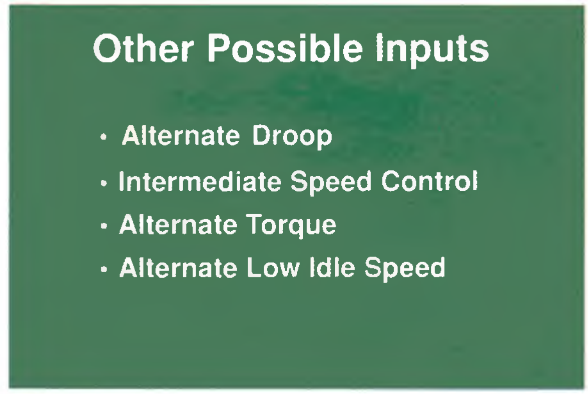
Operator inputs

72. The two main inputs from the operator are the key switch and the throttle. The position of the key switch determines the state of engine operation (on of off), and the position of the throttle determines the desired engine speed.

Possible feature inputs

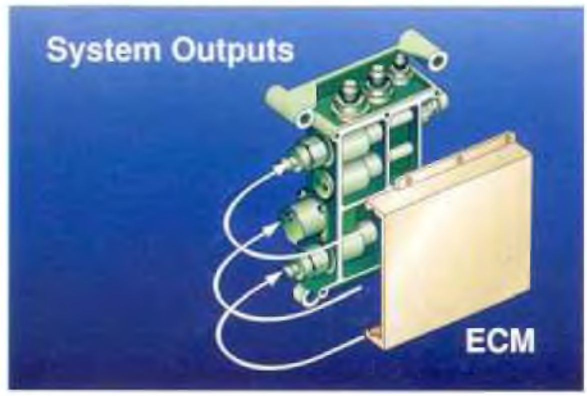
73. The other possible feature inputs modify engine operation and are provided by switches. The intermediate speed control feature will be discussed later. Some of these inputs are:

    Alternate droop
    Intermediate speed control
    Alternate torque
    Alternate low idle speed



System outputs

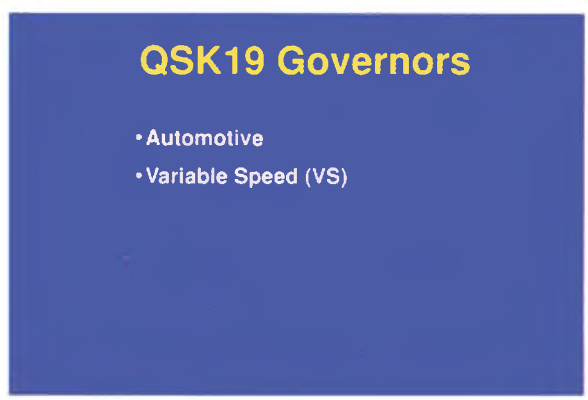
74. There are six system outputs. Three of the outputs control the fuel rail, timing rail , and fuel shutdown functions. The fuel and timing control actuator valves are spool type valves. The spools are controlled by an electromagnetic device which is commanded by the ECM. The ECM produces the following signals:
    - Fuel control actuator valve signal - PWM (Pulse Width Modulation) duty cycle
    - Timing control actuator valve signal - PWM duty cycle
    - Fuel shutoff - power to the shutoff solenoid valve



75. The remaining three outputs are for system information.
    - Diagnostic lamps - fault communications
    - Datalink - system programming
    - Tachometer - output signal for tachometer operation

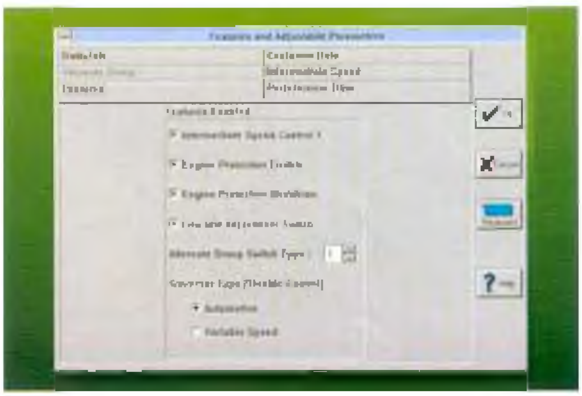
QSK19 Fuel System Governors

76. The QSK19 fuel system is capable of providing two types of engine governing, Automotive type and Variable speed VS type. Both of the governor types are programmable through calibration.



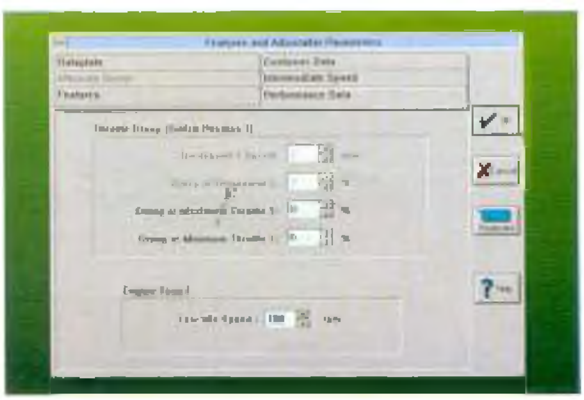
Automotive governor

77. The automotive governor maintains engine speed based on throttle position and engine load. The percent throttle determines the available engine torque. With the throttle in a fixed position, engine speed will drop as the load is increased.



INSITE - Features and Adjustable Parameters

78. The automotive governor would be selected from the **Features** screen in the Features and Adjustable Parameters function of INSITE.

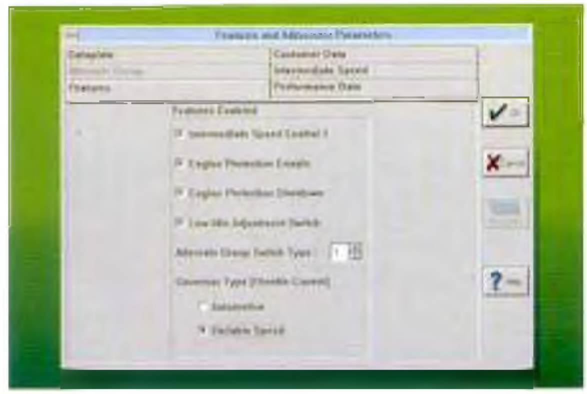


79. In the **Performance Data** screen, the parameters shown can be set for the automotive governor. Breakpoint 1 speed is the RPM at which the fuel curve transitions to high idle droop. Droop at Breakpoint 1, is the percentage droop setting at this RPM. Droop at Maximum Throttle, is the percentage droop setting at maximum high idle RPM. Droop at Minimum Throttle. Is the percentage droop setting at idle RPM. Engine Speed, provides idle speed setting.

Variable speed governor

80. The variable speed governor varies engine speed in direct relationship to throttle position. The governor tries to hold the engine speed constant at a fixed throttle position.

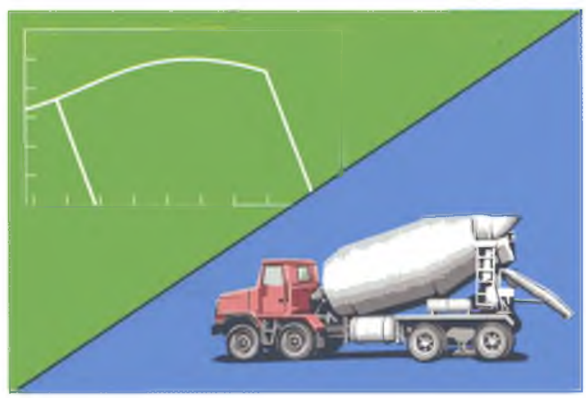
81. The variable speed governor would also be selected from the **Features** screen in the Features and Adjustable Parameters function of INSITE.



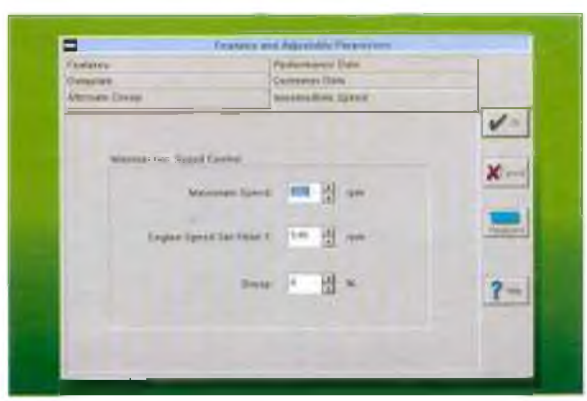
82. In the **Performance Data** folder, the same parameters as were set for the automotive governor can also be set for the variable speed governor.

Intermediate speed control

83. The QSK19 fuel system offers up to two intermediate speed control settings. In an intermediate speed control mode, the engine speed is controlled to a preprogrammed value regardless of throttle position.



84. A separate droop percentage can be set which applies to all switched intermediate speeds and will be in force while the engine is in intermediate speed control.

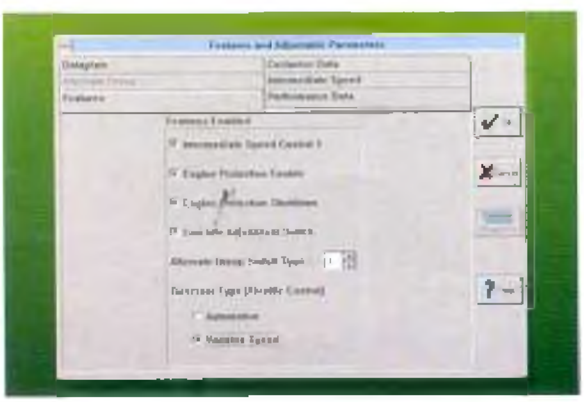


Low idle adjustments

85. The low idle speed setting is set by calibration. It can however be modified by the Increment/Decrement switch. The speed can be increased or decreased by toggling the increment, decrement switch.

Engine Protection Features

86. The QSK19 fuel system features an engine protection system that is designed to prevent engine damage due to prolonged exposure to extreme conditions. The ECM monitors the following systems to provide this protection:
    - Coolant level
    - Coolant temperature
    - Oil pressure
    - Intake manifold temperature



INSITE - Features and Adjustable Parameters

87. Engine Protection can also be enabled or disabled from the Features screen in INSITE's Features and Adjustable Parameters function.

    Engine Protection Shutdown is also enabled or disabled from this screen.
    When the ECM detects a out-of-bounds condition, a series of protective actions are initiated. The action initiated is dependent on the severity and duration of the condition. The protective actions are as follows:
    - Engine protection lamp is lit and a fault is logged
    - Engine torque and [or] speed is derated
    - Engine shutdown is activated

Engine Protection Lamp

88. The first level of protection is the Engine Protection Lamp. When a parameter being monitored goes out-of-bounds, the ECM lights the engine protection lamp and logs a fault. The engine protection lamp is the operator's first indication that a system parameter is out-of-bounds.

Torque and speed derate

89. After turning on the engine protection lamp, the ECM starts recording elapsed time and monitors the severity of the event. If either duration or severity exceed a programmed value, the ECM initiates a torque and/or speed derate.

    After a derate is initiated, the ECM will continue to monitor both duration and severity and will shutdown the engine if the condition is not corrected. The engine shutdown feature can be overridden through OEM calibration options.

Altitude derate

90. The QSK19 fuel system will automatically derate the engine at a predetermined altitude. The ECM determines altitude by monitoring ambient air pressure and, using calibration tables, determines the altitude derate.

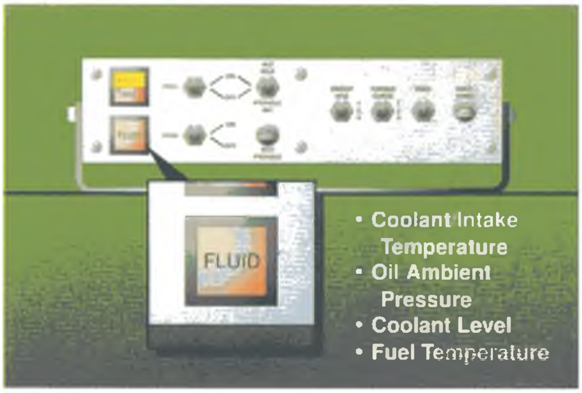
Overspeed protection

91. If the engine speed exceeds a predetermined RPM, the ECM will remove power from the fuel shutdown solenoid valve stopping fuel flow to the system. It will also log a fault and continue recording engine data. When the engine speed drops to a predetermined RPM, the ECM will apply power to the shutdown solenoid to restart the engine.

    The ECM can be programmed to deny engine restart if a predetermined number of shutdowns has occurred. This prevents the use of the engine when an intermittent problem exists.

Diagnostics

92



Engine protection lamp

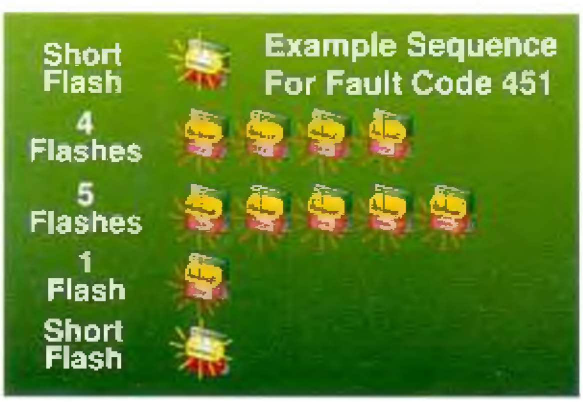
93. The engine protection lamp is used to warn the operator of the following conditions:
    - Coolant/intake temperature out of range.
    - Oil/ambient pressure out of range.
    - Coolant level out of range. The protection lamp will light and stay on as long as any of these conditions exist.
    - Fuel temperature out of range.

Warning/Stop engine lamps

94. The yellow warning lamp is used to warn the operator that a component or system has logged a fault. The vehicle can continue operation, but the conditions must be corrected as soon as possible. The red engine stop lamp is used to warn the operator that a major system problem has occurred. The vehicle should be shutdown as soon as possible.

Diagnostic switch

95. The diagnostic switch is used in conjunction with the yell and red fault lamps to display active fault codes. With t engine not running and the key switch in the "ON" positic move the diagnostic switch to the "ON" position to check active fault codes.



Flash code sequence

96. The fault code flash process sequence begins with the WARNING (yellow) lamp flashing once. There will be a short one to two second pause and then the STOP (red) lamp will flash out the three digit fault code. There will be a short pause between each digit in the code. After the code has been flashed, the yellow lamp will flash and then the red lamp will again flash out the same fault code. The system will continue flashing this same fault code until the diagnostic switch, increment/decrement switch, or key switch is activated.

97. To display the next active fault code, move the increment/ decrement switch to the increment position. If there is another active fault code, it will flash out as before. If there is only one active fault code, that code will flash out again.

98. If there are multiple active fault codes, use the increment/ decrement switch to move through the list. The increment position will move forward through the fault list and the decrement position will move backward through the list. If you move completely through the list of codes, you will come back to the first code again.

Program end

PROFESSIONAL

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