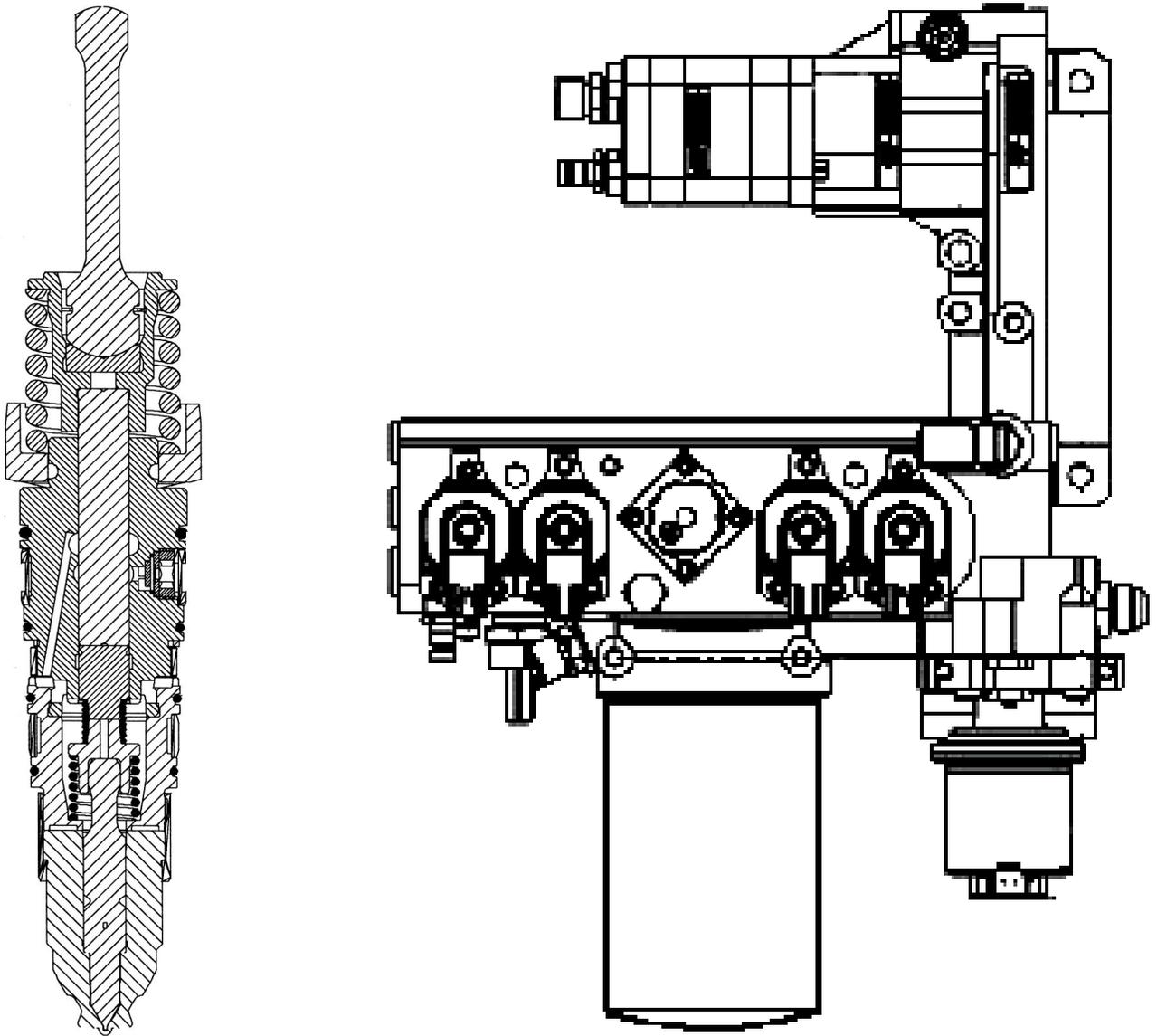


# Signature and ISX CM870 Fuel System



# HPI-TP Fuel System

## Heavy Duty High Pressure Injection - Time Pressure Fuel System

The fuel system developed for the Signature and ISX engine was constructed to deliver precise injected fuel quantities with precise injection timing at high injection pressures. The system consists of six high-pressure unit injectors and an integrated fuel system module (IFSM) containing actuators that provide various fuel pressure pulse widths to individually control injection quantity and injection timing, a pump and regulator for fuel supply pressure, a 10 micron pressure side filter, and various sensors for system monitoring. The system is controlled by an advanced electronic control module (ECM), which makes fueling and timing decisions based on temperature, barometric air pressure, boost pressure, exhaust gas pressure and throttle position.

### **Control Features:**

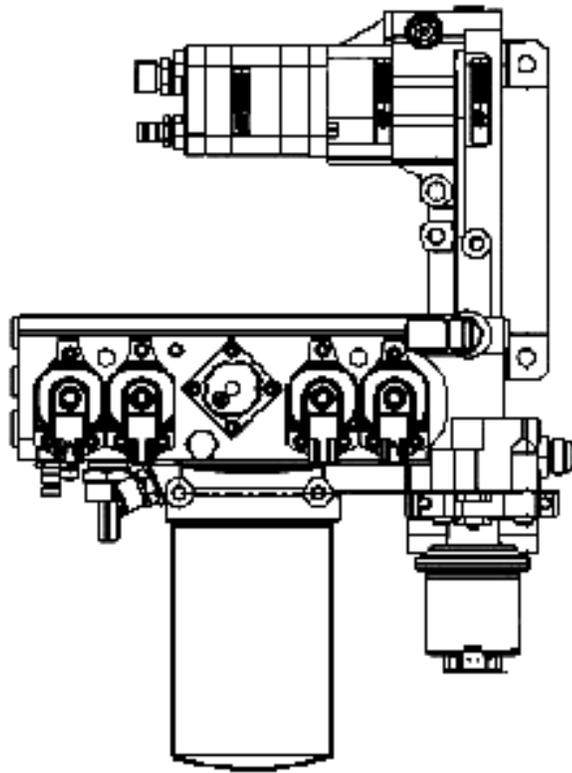
- Full authority electronic controls.
- Modular ECM and software for maximum flexibility when upgrading or adding features.
- Individual cylinder control capability of fueling and/or timing.

### **Actuator Features:**

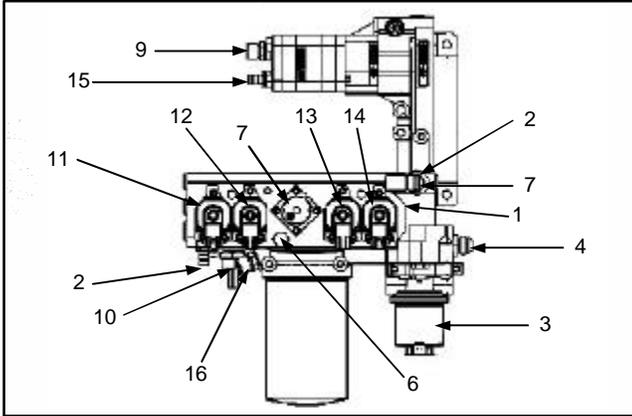
- Low pressure actuators on a common rail to minimize injector envelop and reduce cost.
- Actuators are external to the engine crankcase.

### **Pump Features:**

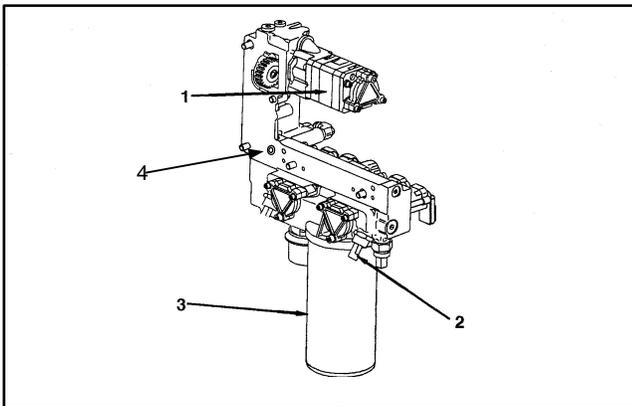
- Regulates supply pressure for timing and metering quantity.



# IFSM Components



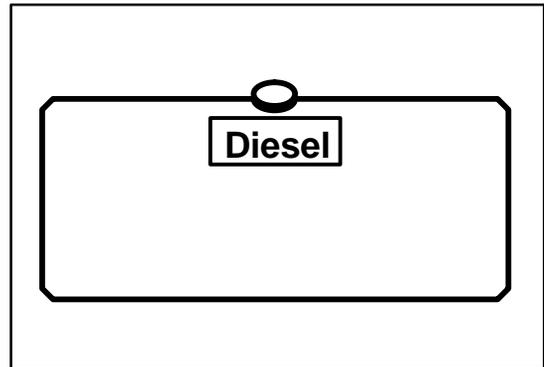
- 1 - Priming Bypass Valve (internal)
- 2 - 380 PSI Regulator
- 3 - Fuel Lift Pump
- 4 - Fuel Inlet
- 5 - Quick Disconnect Pressure Tap - Pressure Side
- 6 - 250 PSI Regulator
- 7 - Fuel Return to Fuel Tank
- 8 - Fuel Shutoff Valve
- 9 - Fuel Return From Cooling Plate
- 10 - Fuel Pressure Sensor
- 11 - Front Bank Rail Actuator
- 12 - Front Bank Timing Actuator
- 13 - Rear Bank Timing Actuator
- 14 - Rear Bank Rail Actuator
- 15 - Quick Disconnect Pressure Tap - Suction Side
- 16 - Fuel Outlet to Cooling Plate



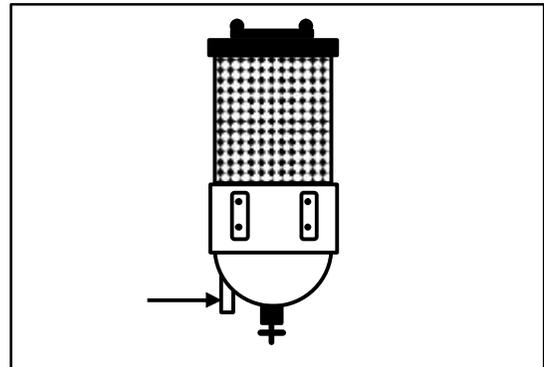
- 1 - Fuel Gear Pump Assembly
- 2 - Fuel Temperature Sensor
- 3 - Fuel Filter
- 4 - Priming Bypass Valve

## Fuel Flow

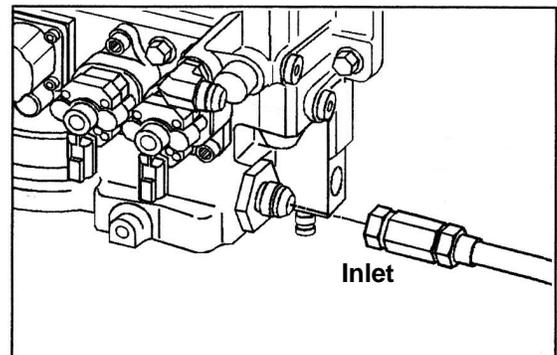
The fuel flows out of the fuel tank and into a prefilter.



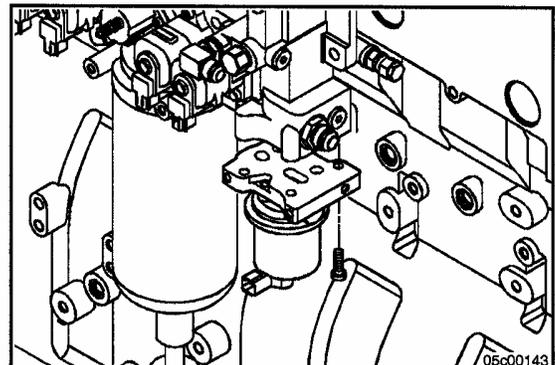
The prefilter is rated at 150 micron and it contains a water-in-fuel sensor and a water drain.

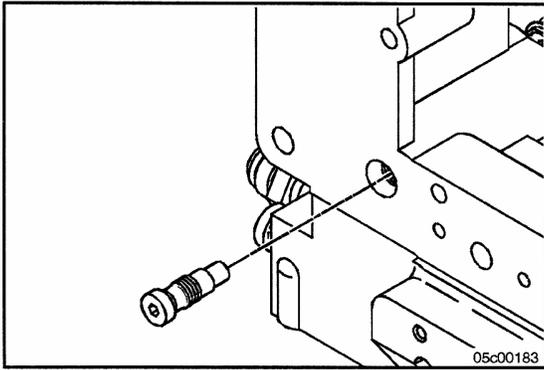


Fuel then flows into the inlet fitting of the IFSM.

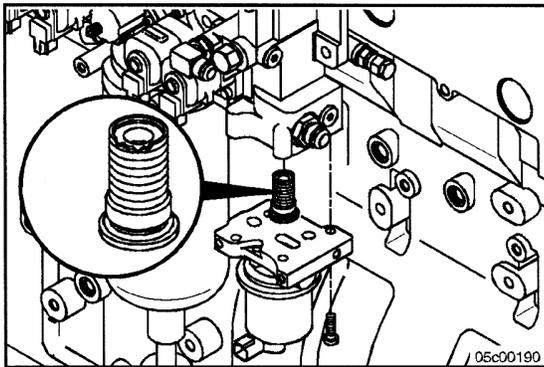


Fuel continues into the fuel lift pump. This pump runs for the first two minutes after the key is turned on to insure that fuel gets up to the gear pump quickly for easier starting.

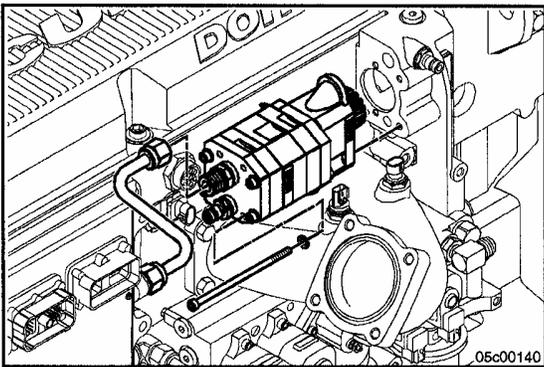




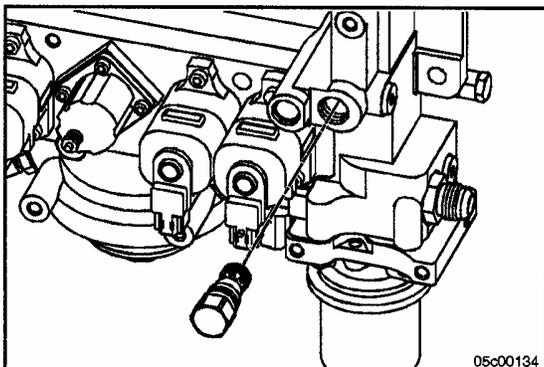
At one psi of pressure a valve in the IFSM housing opens to allow some lift pump output to flow to the drain line. This bypassing of fuel helps to bleed any air from the supply passages.



When the engine starts, the gear pump then draws the fuel directly from the inlet fitting past the anti-drainback valve.

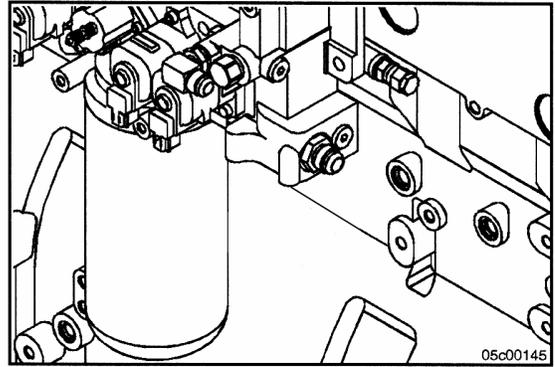


The gear pump provides the high volume and constant pressure needed by the system for correct metering and timing.



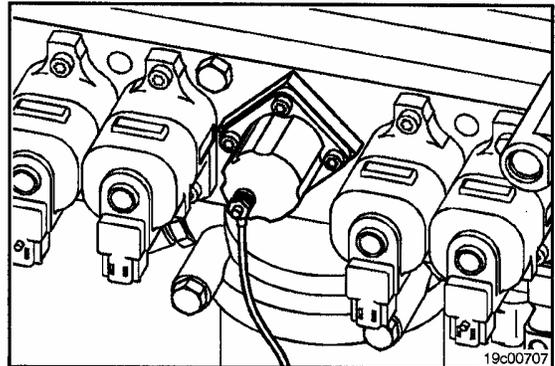
The 380 psi high pressure regulator, installed in the IFSM between the gear pump and the filter, is a safety valve to prevent damage in case of a stuck fuel shutoff valve or other blockage in the fuel lines after the gear pump. Any fuel flowing through the high pressure regulator is dumped back to the drain line in the IFSM and then returned to the fuel tank.

Fuel under pressure flows to the fuel filter. This filter is a 98% efficient 15 micron filter.

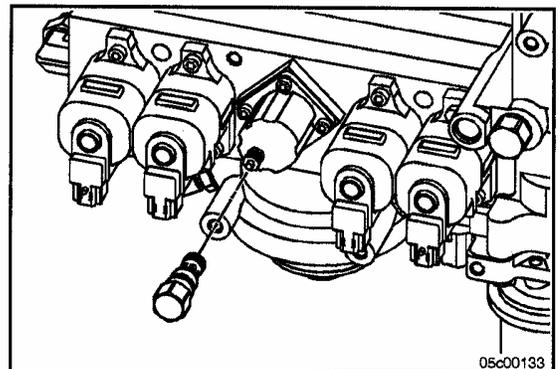


After contaminants are removed, the filtered fuel flows to the rapid restart style shut off valve.

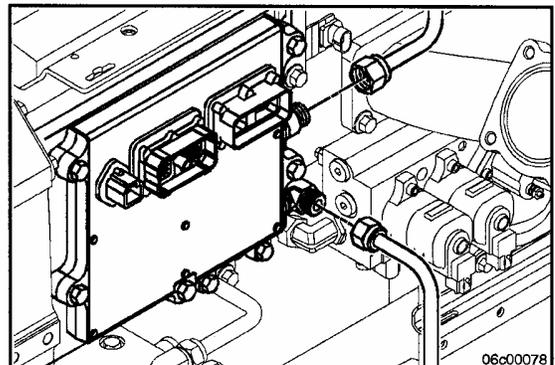
This fuel shut-off valve is capable of stopping fuel flow in case of engine overspeed, or other system problems sensed by the ECM.

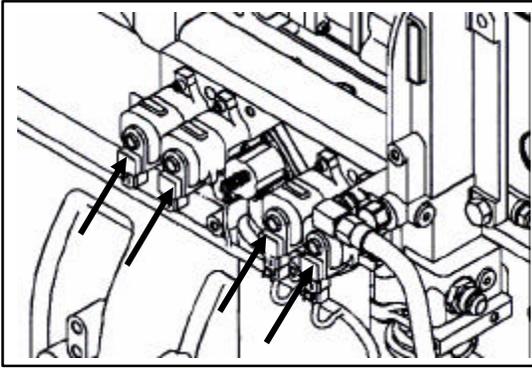


The 250 psi fuel system regulator allows excess fuel to flow out of the rail to limit and maintain the pressure within the IFSM fuel rail.



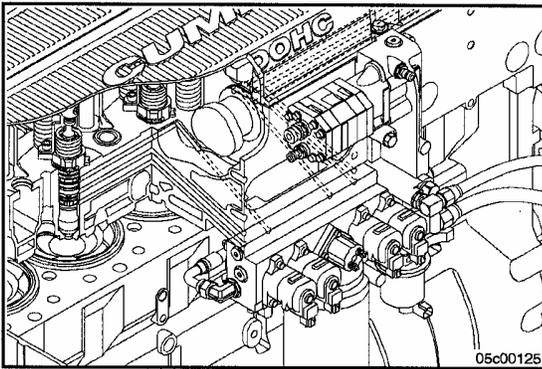
The excess fuel from 250 psi regulator flows through external tubing to a passage in the ECM cooling plate before going through return tubing to the inlet side of the fuel pump.





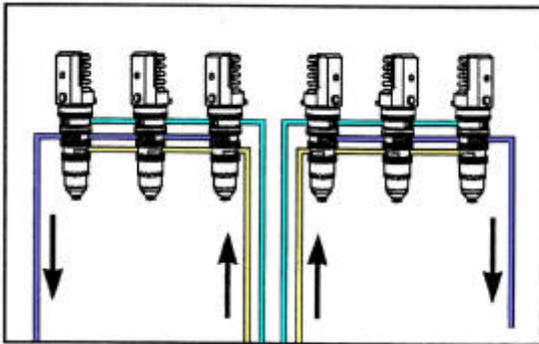
With a constant pressure at the actuators the ECM sends signals to the actuators to control the fuel flow to the injectors.

Each of the actuators is a normally closed ON/OFF device. The actuators open when they receive a signal from the ECM. Opening the actuator allows fuel to flow to its connected timing or metering rail.

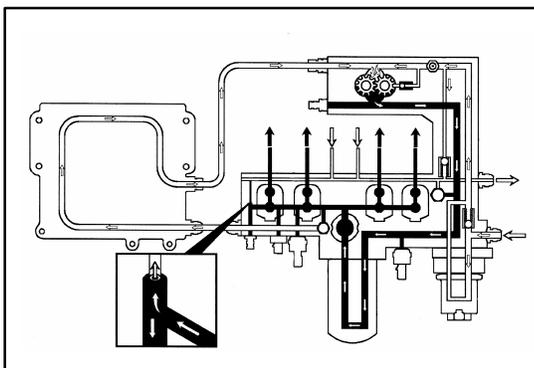


Fuel then enters the common supply passage for the front and rear bank metering and timing actuators.

One set of the actuators controls the amount of fuel injected and the other set controls the timing



The ECM determines the fueling and timing quantities within a given bank and commands the corresponding fuel pulse widths from the actuators. The actuators meter exact fuel quantities to the unit injectors through fueling and timing manifolds in the engine cylinder head.



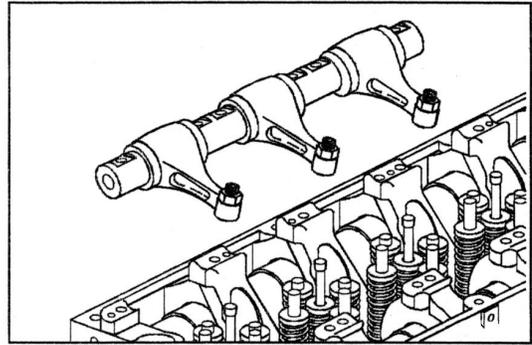
The opening of each actuator sends a pulse down a passage connected to each injector within its bank.

Due to the firing order (1-5-3-6-2-4) and following cam position for each cylinder, only one injector within a bank is in position to receive metering and timing fuel.

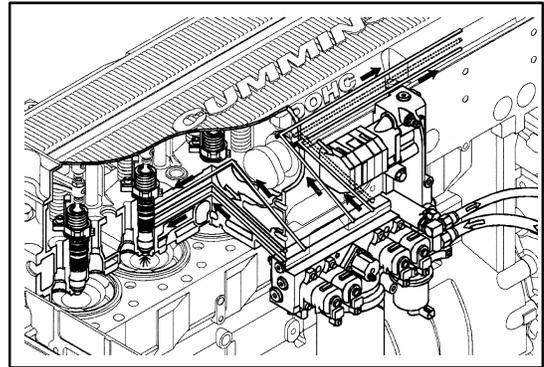
With metering and timing complete, the cam drives the plungers downward. Within the descending stroke a solid hydro-mechanical link is formed and injection begins (start of injection). The timing of the linkage formation is based on metered and timing fuel quantify.

The high injection pressure is only generated within the nozzle of the cam-actuated injector.

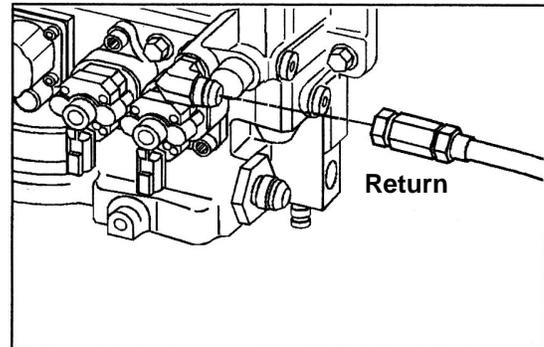
The end of injection occurs when the lower plunger meets the nozzle seat.



The fuel used above the timing plunger, to achieve the injection timing, flows into the drain passage in the cylinder head, then into the drain passage in the IFSM.

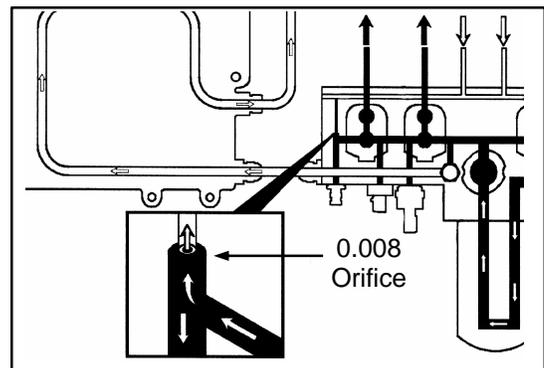


Fuel is returned to the fuel tank through the connection on the IFSM.

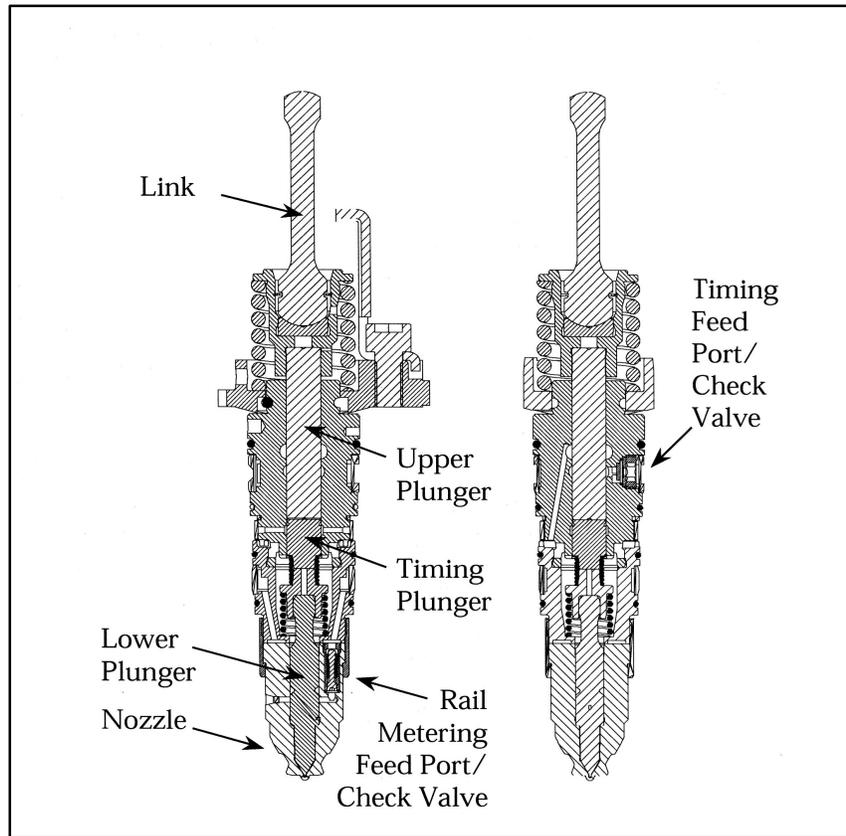


When the engine is shutdown, the fuel trapped between the actuators and the injectors absorbs heat from surrounding engine components. As the temperature of the fuel increases, the fuel expands and increases pressure in the metering supply rails. If allowed to build, this pressure would push fuel through the open injector into the cylinder. This would result in increased cranking resistance and hard starting while the engine is still warm.

A passage drilled between the metering supply rail and the drain passage in the IFSM, along with a check valve mounted in each metering actuator, provides fuel venting to reduce this pressure. An .008 orifice is installed in the drilling to limit fuel flow to the drain passage during normal engine operation.



# Injector



## ***Injector Features:***

Time Pressure (TP) metering for improved timing and fueling accuracy and minimal metering delay.

28,000 psi injection pressure for emissions control and fuel economy.

One piece nozzle assembly to eliminate traditional leak paths.

Fully variable timing for emissions control and fuel economy.

Titanium nitride coated plungers for wear and scuff resistance.

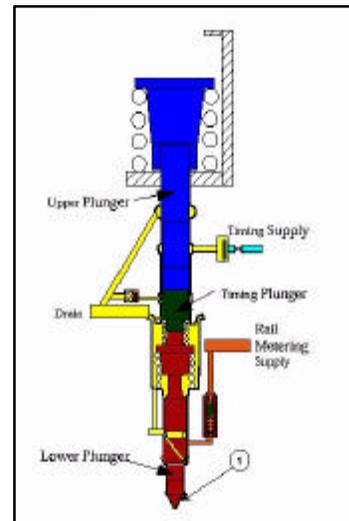
Check valve assemblies are calibrated prior to assembly.

Trapped volume spill and timing spill control for lower unburned hydrocarbons and particulates.

# Injector Operation

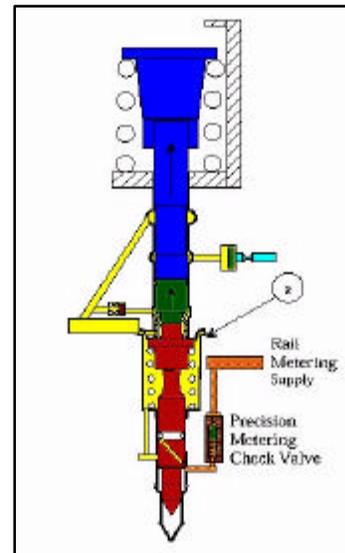
## Event One

The Injector is mechanically loaded by the drive train causing the Lower plunger to be pressed tightly against the nozzle seat. The Lower plunger is held in this position until the end of the Exhaust stroke.



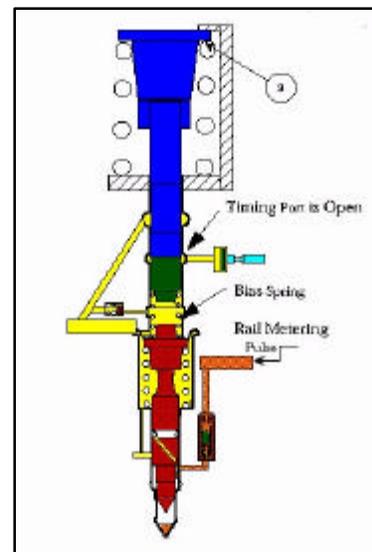
## Event Two

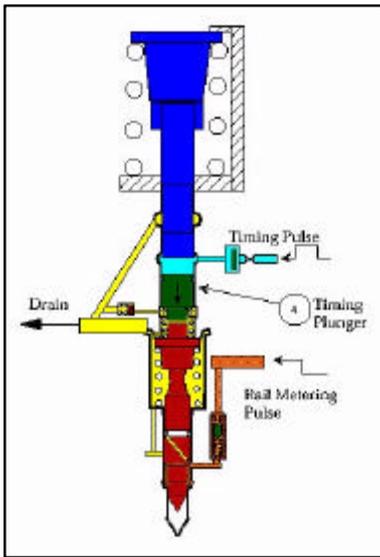
The three injector plungers retract together, following the cam retraction profile, until the Lower Plunger contacts its mechanical stop. The Lower plunger spring holds it there. This is the beginning of the Rail metering window. Rail metering will begin when the Metering check valve is opened by a pressure pulse from the Metering Actuator .



## Event Three

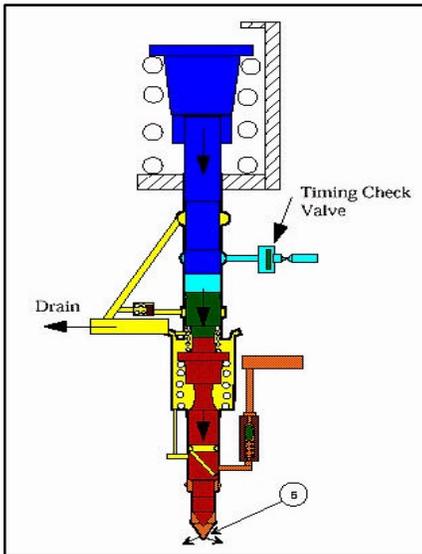
The maximum injector lift is determined by the cam inner base circle or a top stop, as shown. Only one injector is ready for timing and rail fuel along the manifold bank. The rail metering pulse has reached this injector and the rail check valve has opened. Fuel is metered into the nozzle. The constant pressure pulse is sent for a commanded time period.





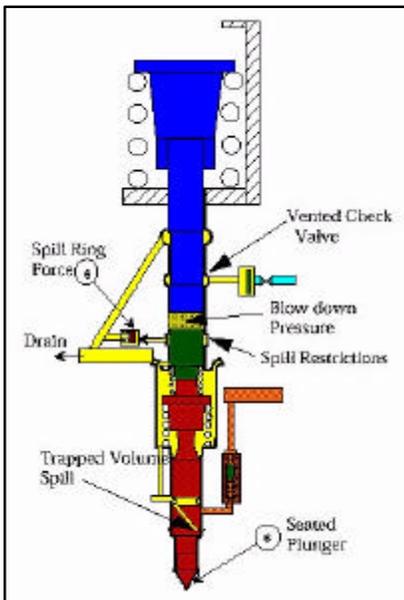
#### Event Four

The Timing Actuator opens and starts the Timing pulse to the injector. The Timing plunger moves down and the timing advances as long as the Timing pulse lasts. The rail Metering pulse must finish before the Timing plunger closes the rail metering window. In these diagrams, the Timing plunger has stopped prior to reaching the Lower plunger.



#### Event Five

The cam pushes the Upper plunger down. This closes the Timing check valve. The Timing Plunger is hydraulically pushed down and it contacts the Lower Plunger. All three plungers move together and injection starts when the Lower plunger reaches solid fuel in the nozzle.

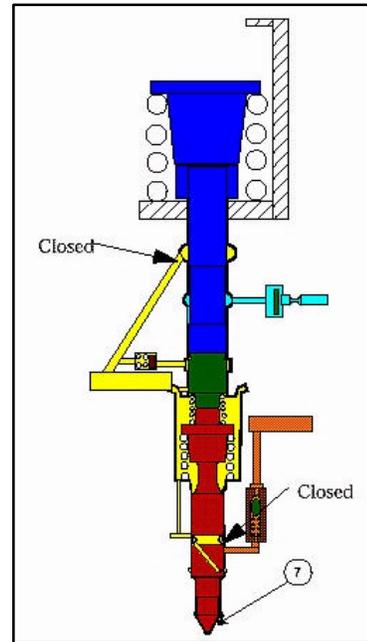


#### Event Six

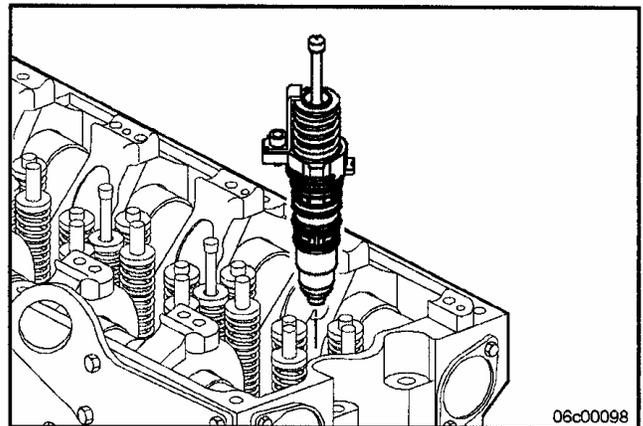
The trapped volume spill (TVS) drilling assists in a crisp end of injection. The Timing check valve is also vented to drain to release any injection pressure. The Lower plunger is held tightly against the nozzle seat by the spill pressure above the timing plunger (blow down). This pressure is controlled by the spill ring spring force, the Timing plunger's annular orifice and the Barrel to Timing plunger spill groove overlap.

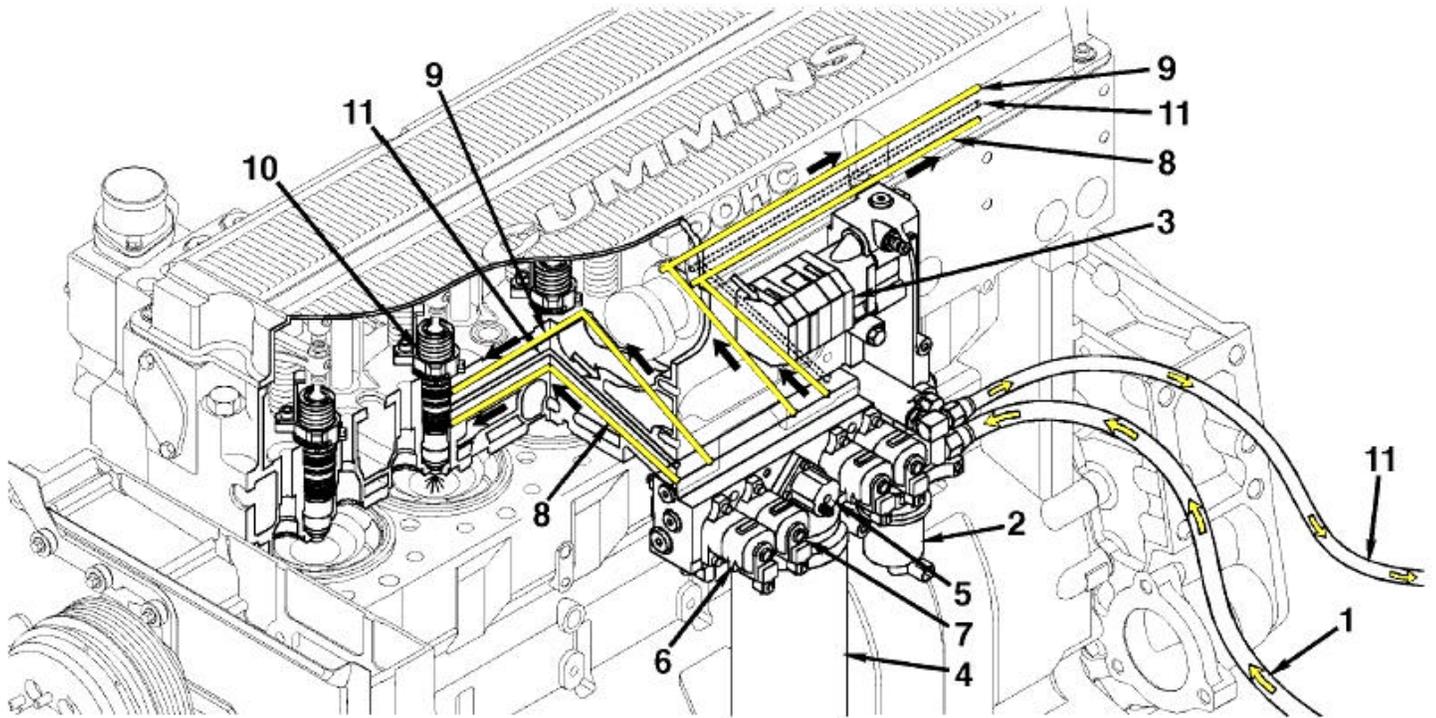
### Event Seven

The Injector is mechanically loaded by the drive train causing the Lower plunger to be pressed tightly against the Nozzle seat. The Timing and Rail Metering windows are closed and will allow the other cylinders in its bank to get their fueling pulses. The Lower plunger is held in this position until the end of its Exhaust stroke .

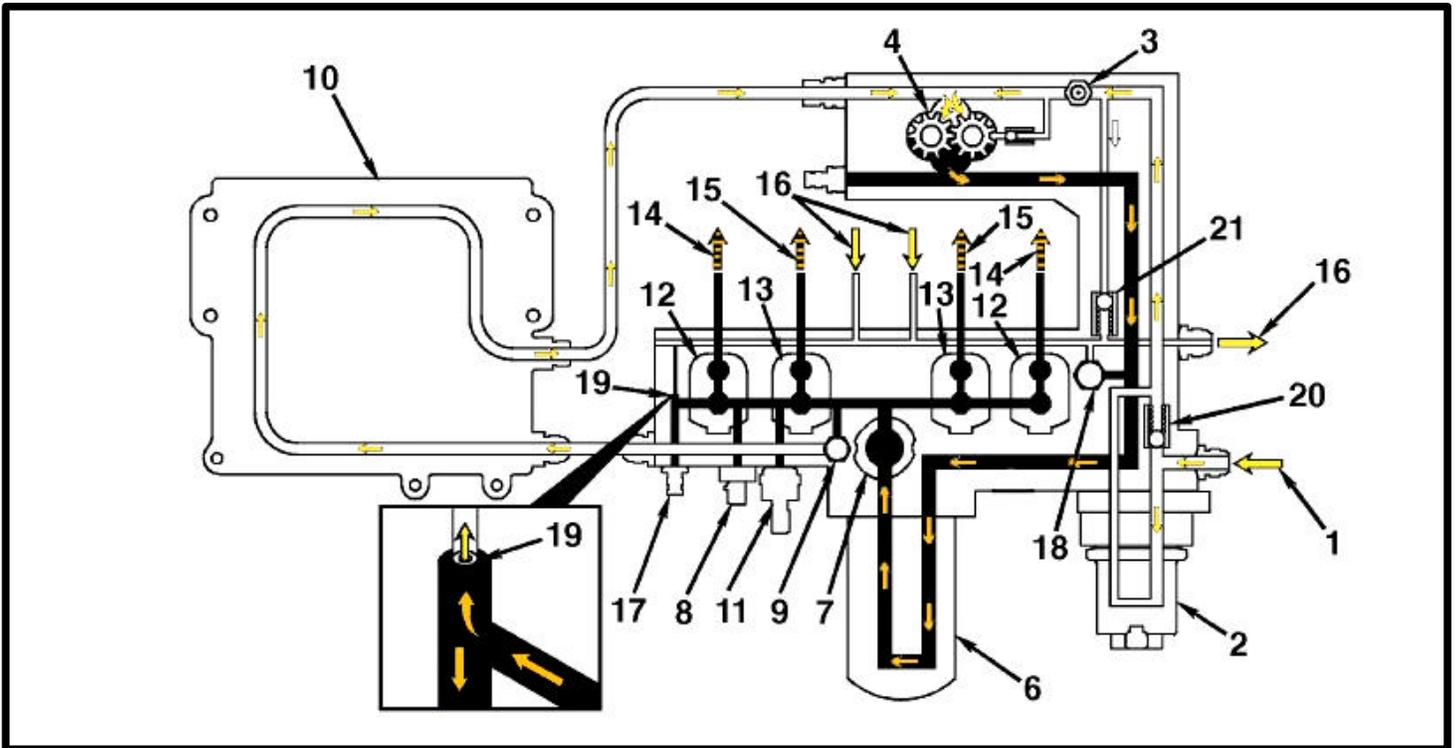


The injector is centrally located in the head for each cylinder and is camshaft actuated.

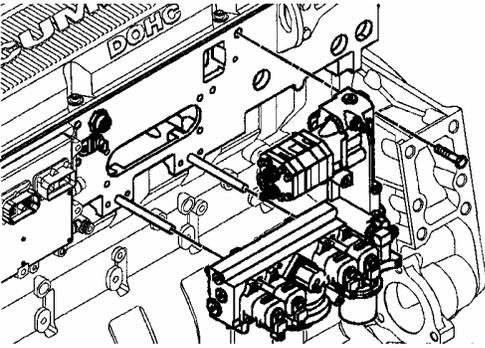




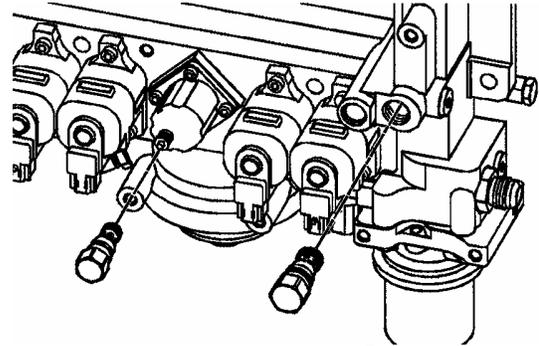
- 1. Fuel Supply from Tank**
- 2. Fuel Lift Pump**
- 3. Fuel Pump**
- 4. Pressure Fuel Filter**
- 5. Fuel Shutoff Valve**
- 6. Fueling Actuator**
- 7. Timing Actuator**
- 8. Fueling Supply to Injector**
- 9. Timing Fuel Supply to Injector**
- 10. Injector**
- 11. Fuel Drain to Tank**



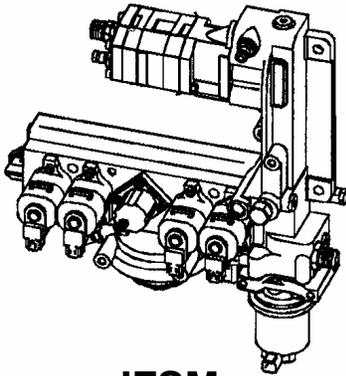
1. Fuel Supply From Tank
2. Fuel Lift Pump
3. Compuchek™ Fitting (Fuel Inlet Restriction)
4. Fuel Pump
6. Pressure Fuel Filter
7. Fuel Shutoff Valve
8. Engine Fuel Temperature Sensor
9. 250 PSI Regulator
10. ECM Cooling Plate
11. Rail Fuel Pressure Sensor
12. Fueling Actuator
13. Timing Actuator
14. Fueling Supply to Injector
15. Timing Fuel supply to Injector
16. Fuel Drain to Tank
17. Compuchek™ Fitting (Rail Fuel Pressure)
18. 380 PSI Regulator
19. Hot Start / Stall Orifice
20. Anti Drainback Valve
21. Fuel Lift Pump Bypass Valve



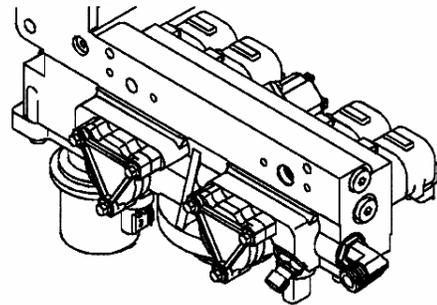
**IFSM**



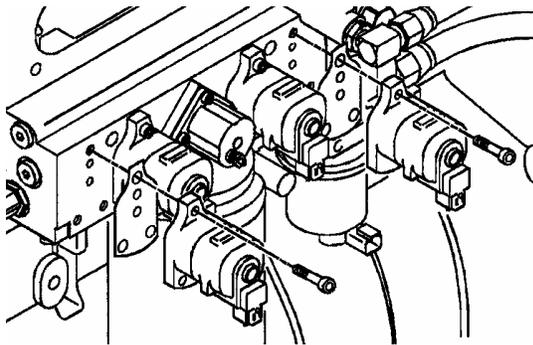
**250 and 380 PSI  
Regulators**



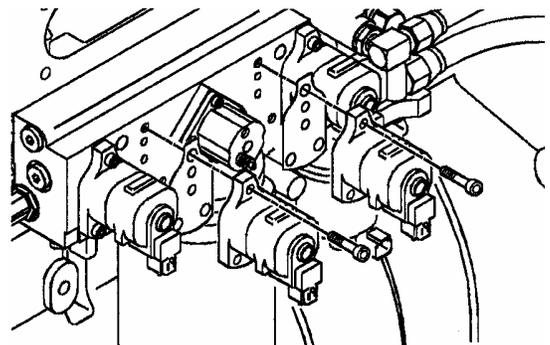
**IFSM**



**Pulsation Dampers**



**Metering Actuators**



**Timing Actuators**



**Cummins Ontario Inc.**  
**7175 Pacific Circle**  
**Mississauga, ON L5T 2A5**