DURAMAX DIESEL ENGINE

Courtesy of GM

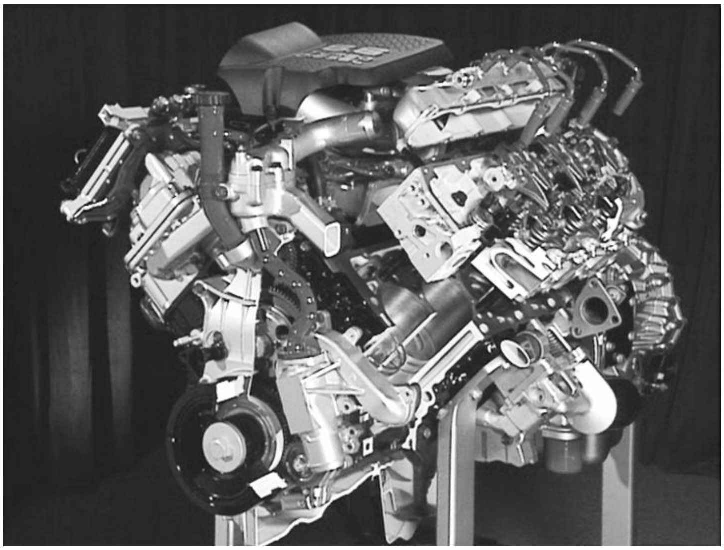


Figure 1 LB7 Engine (Courtesy of Jim Halderman)

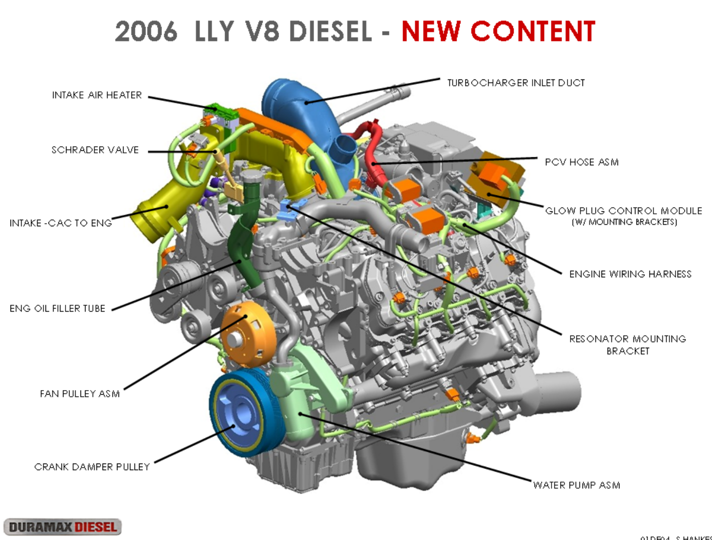


Figure 2 LLY Engine (Courtesy of GM)

TABLE OF CONTENTS

ENGINE OVERVIEW

LB7 Engine

The GM Duramax diesel engine (Figure 1) was introduced in the 2001 model year. It was an all-new engine developed by Isuzu, of which GM owns 37%. The 6.6L V8 engine has a cast-iron block with an aluminum alloy crankcase and cylinder head, 4-valves per cylinder (32 valves total), wastegate controlled turbocharger, gear driven water pump, and an electronically controlled Bosch common-rail (CR) direct injection (DI) fuel system. The 2001-2004 RPO (regular production option code) LB7 developed 300 hp @ 3000 rpm and 520 lb-ft of torque @ 1600 rpm. The fuel injectors were located under the valve cover on the LB7.

LLY Engine

The 2005 "LLY" model (Figure 2) was introduced in January of 2004. The horsepower and torque were increased to 310 bhp and 545 lb-ft while simultaneously reducing NOx and particulates by 90%. Further LLY and the addition of the LBZ model revisions for the 2006 model bumped output figures again to 310 bhp and 590 lb-ft of torque for automatic transmission equipped models.

Figure 3 LLY EGR Cooler (Courtesy of J. Halderman)

All LLY engines were equipped with an EGR (exhaust gas recirculation) valve used to lower NOx emissions. This EGR used an EGR cooler (Figure 3) to cool the exhaust gases using engine coolant to increase gas density, which increases flow. The EGR valve used a position sensor so the ECM (engine control module) could monitor its position. The GM Tech 2 scan tool can be used to bi-directionally operate the EGR valve for diagnostic purposes.

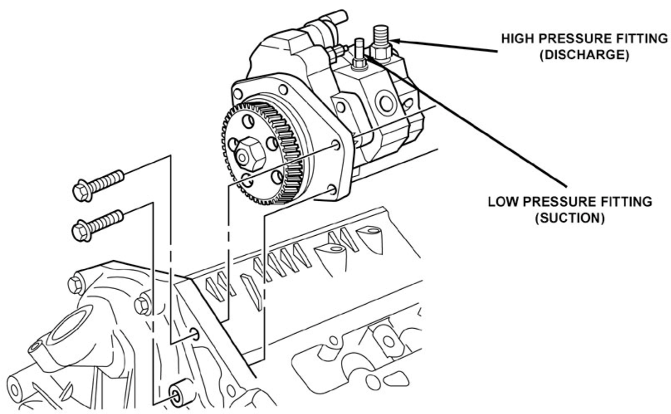


Figure 4 Fuel Injection Pump (video disc 1)

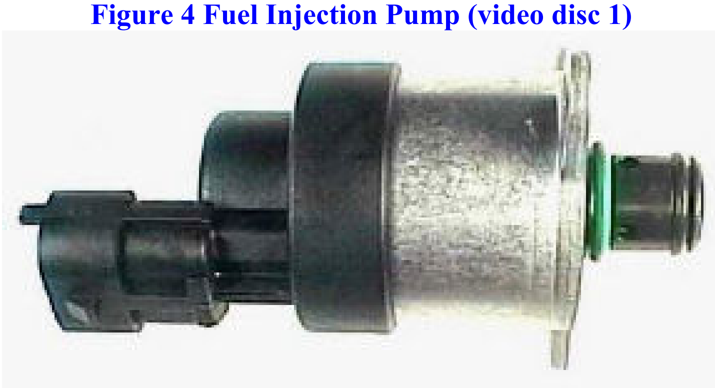


Figure 5 LB7 Fuel Rail Pressure Regulator (FRPR) valve (Courtesy of Jim Halderman)

Fuel Injection Pump

The Duramax fuel injection pump (Figure 4) is located in the “V” of the engine and contains the ECM controlled Fuel Rail Pressure Regulator (FRPR) valve located at the back top of the HP pump (Figure 5).

CAUTION: the DURAMAX uses fuel pressures up to 23,000 PSI. To avoid personal injury NEVER crack open a fuel pressure line and ALWAYS follow the precautions and procedures identified in the GM service information.

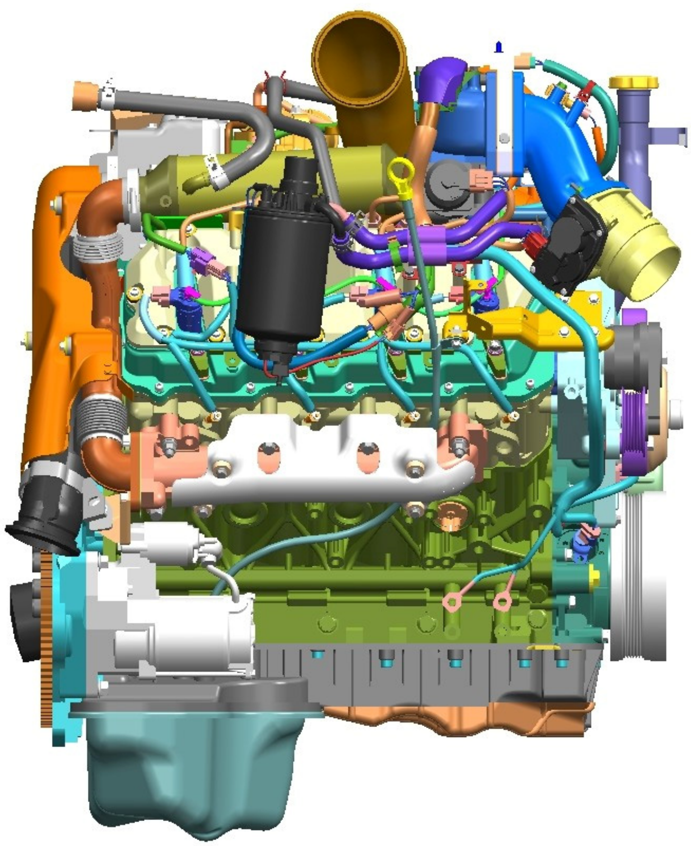


Figure 6 LMM Engine (Courtesy of GM)

LMM Engine

The LMM version introduced in 2007 develops 365 bhp @ 3200 rpm and 660 lb-ft of torque at 1600 rpm. This engine is primarily used in class 4 and 5 medium duty trucks. It was first used in the first quarter of 2007 and has the following additions:

- Particulate trap system
- Intake air valve
- Increased capacity EGR cooler
- with revised gas and coolant side plumbing
- More efficient turbocharger (compressor and turbine)
- Jet pump for the Particulate Trap Filter
- New ECM software calibrations
- Balance rates out to 2500 RPM
- Uses capability of 5 injection pulses per injection event
- Revised injector nozzle flow, and angle
- Hole quantity decreased from 7 to 6 for emissions
- Improved atomization
- Increased peak cylinder pressure
- Strengthen block & connecting rods
- Enhanced cylinder head cooling
- Updated head gaskets

DURAMAX DIESEL ENGINE

	LMM	LLY/LBZ	LLY	LB7
Availability	2007-2008	2006-2008	2004-2005	2001-2004
Engine Controller	32U ECM: New ECM software calibrations for new functionality Balance rates out to 2500 RPM Uses capability of 5 injection pulses per injection event	Bosch E35 ECM	E60 ECM	32U ECM
Emission	Intake air valve Particulate Trap Jet Pump	Catalytic Converter	Catalytic Converter	Catalytic Converter
Emission	Digital EGR Increased capacity EGR cooler with revised gas and coolant side plumbing	Digital EGR	Digital EGR	Vacuum EGR
Emission	Closed PCV	Closed PCV	Closed PCV	PCV with oil Separator
Turbocharger	Variable Nozzle Adjustable Vanes with more efficient turbocharger (compressor & turbine)	Variable Nozzle Adjustable Vanes	Variable Nozzle Adjustable Vanes	Fixed Nozzle Wastegate
Glow Plugs	Individually controlled Silver Glow plugs bursting LLY and newer Caused by voltage fluctuations Bulletin to come directing replacement of all glow plugs if no issue is discovered during diagnosis Programming fix for GPCM	Individually controlled Silver	Individually controlled Silver	Individually Calf controlled Gold
Fuel System	Revised injector nozzle flow, and angle. Hole quantity decreased from 7 to 6 for emissions Improved atomization. External Return Lines No Junction Block.	Larger Injector External Return Lines No Junction Block No FICM	Larger Injector External Return Lines No Junction Block	Smaller Injector Internal Return Lines Junction Block
Intake System	Intake Air Heater	No Intake Air Heater, except on LBZ	No Intake Air Heater	Intake Air Heater

Table 1 Duramax Engine Comparison

DURAMAX Versions:

There are four (4) variations of the Duramax diesel engine (Table 1):

1. 2001-2004 LB7: 2001 LB7s are not equipped with EGR or a catalytic converter. Some 2002-2004 vehicles are EGR and catalyst equipped; some are not.
2. 2005-2006 RPO code LLY: The LLYs is equipped with EGR, catalyst, and a variable geometry turbocharger.
3. 2006.5 RPO code LLY and LBZ: The 2006.5 LLY and LBZ initially had 310 bhp and 590 lb-ft of torque for automatic transmission. This was increased to 360 bhp and 650 lb-ft of torque in 2007. The LLY was an early introduction of some external hardware that was to be used in the mid-year introduction of the LMM.
4. 2006-2007: RPO code LMM: The LMM has higher horsepower ratings and lower emissions, partially due to lower compression rations. The LMM introduces more aggressive EGR operation facilitated by the introduction of an intake throttle and particulate trap technology. The LMM develops 365 bhp @ 3200 rpm and 660 lb-ft of torque at 1600 rpm.

Fluid Capacities and Filters

Table 2 shows the Duramax Engine fluid capacities and filters used.

APPLICATION	METRIC	ENGLISH	FLUID	PART NO.
Engine Crankcase (w/ filter)	9.5 L	10.0 qts.	SAE 15W-40	97214983* or ACDelco PF2232**
Air Filter	—	—	—	A1618C**
Fuel Tank				
– Standard Side Tank	102.2 L	27.0 gal.	—	—
– Optional Rear Tank	87.0 L	23.0 gal.	—	—
Fuel Filter	—	—	—	97256734*
Cooling				
– w/ Auto Trans	20.7 L	21.8 qts.	Dex-Cool	—
– w/ Manual Trans	20.3 L	21.4 qts.	Dex-Cool	—
Transmission				
– 6-speed ZP RPO ML6 manual	6.0 L	6.3 qts.	TransSynd auto trans fluid	12378515*
– 5-speed Allison 1000 Series automatic	7.0 L	7.4 qts.	Dexron III auto trans fluid	

* GM part number. ** ACDelco part number.

Table 1 Duramax Fluid Capacities

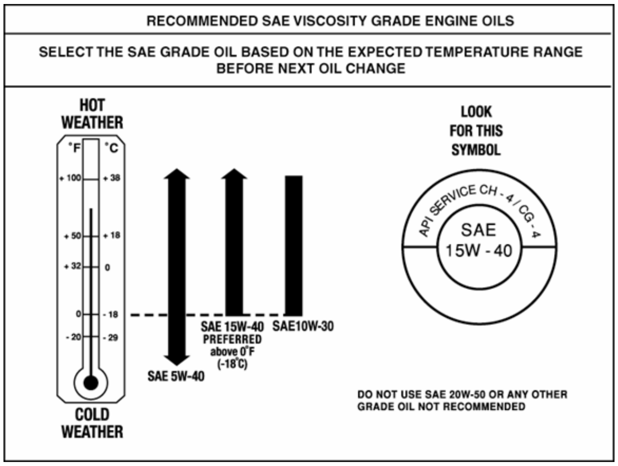


Figure 7 Oil Temperature Chart

Oil Temperature Chart

Figure 7 shows the required oil grade based upon ambient temperature.

Engine Components

ENGINE COMPONENTS

Engine Block

Front Cover

Upper & Lower Oil pans

Piston Assembly

Rear Mains Cross-Bolted 4-Bolt

Rear Cover

Oil Cooler

Oil Filter

Cylinder Heads

Head Gaskets: 3 Head Gaskets: A-B-C

Fuel Injection System (Fuel Injectors)

Thermostats

Piston Cooling Jets

Turbo Bypass Valve

Coolant (DEXCOOL)

Water Pump

Intake Air System

Turbocharger: Wastegate LB7

Glow Plug System

Crankcase Ventilation System

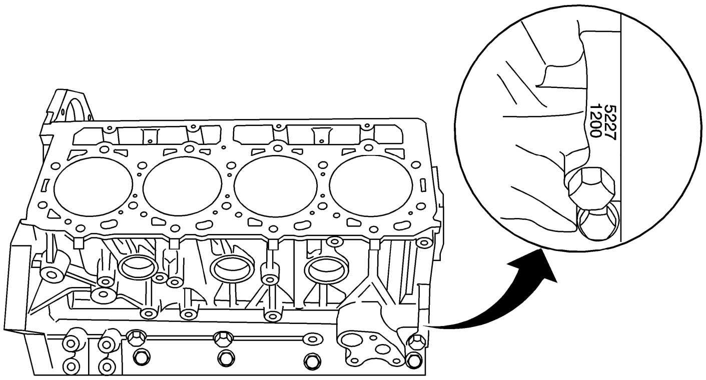


Figure 8 Engine Block (Courtesy of GM)

Engine Block

The cast iron engine block is a 90 degree "V" deep-skirted design using induction hardened cylinder tops for durability. The Date code is stamped on the block. "5227" stands for 227 day of 2005 (August 15, 2005). "1200" stands for the time the block was built.

- Engines built after this date use longer head bolts.
- Engines built before this date use shorter head bolts.

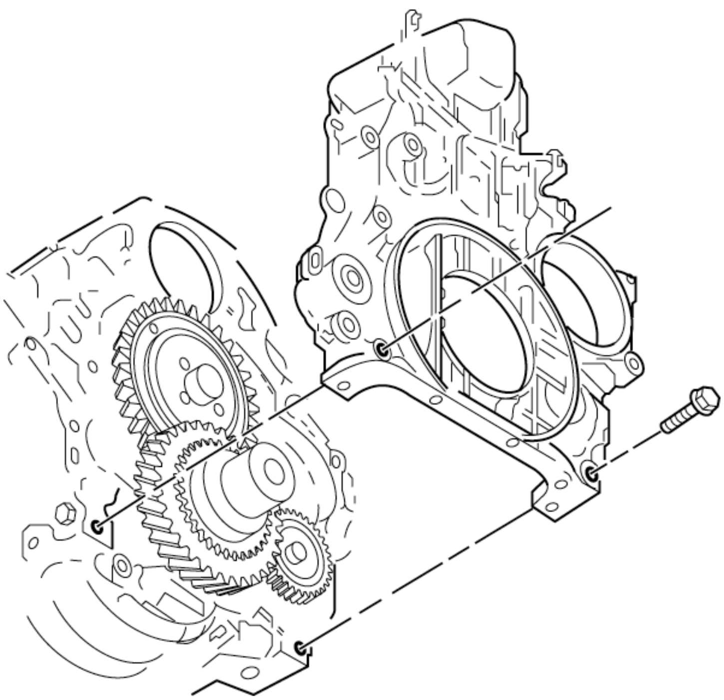


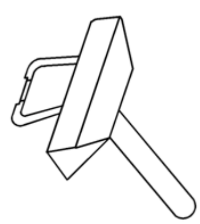
Figure 8 Front Cover (Courtesy of GM)

Front Cover

The front cover (Figure 8) contains the following:

- Camshaft Sensor (CMP)
- Crankshaft Sensor (CKP)
- Gear Driven Oil Pump

The front cover is held in place with bolts and uses a special seal that requires an OEM special tool J37228 to separate the front cover from the cylinder block.



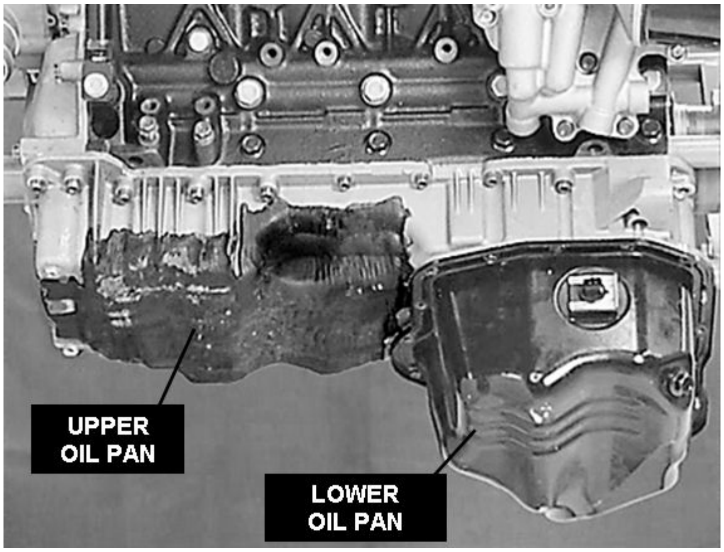


Figure 9 upper and lower oil pans (video disc 1)

Upper & Lower Oil pans

The lower extension on the engine block is referred to as the upper oil pan (Figure 9). It's made from Aluminum and rigidity to the block. The lower oil pan is stamped steel and contains the Oil Level Switch. You need to remove the lower oil pan to replace the Oil Level Switch on the LB7. This is not necessary on any other Duramax engine (LLY, LBZ, and LMM).

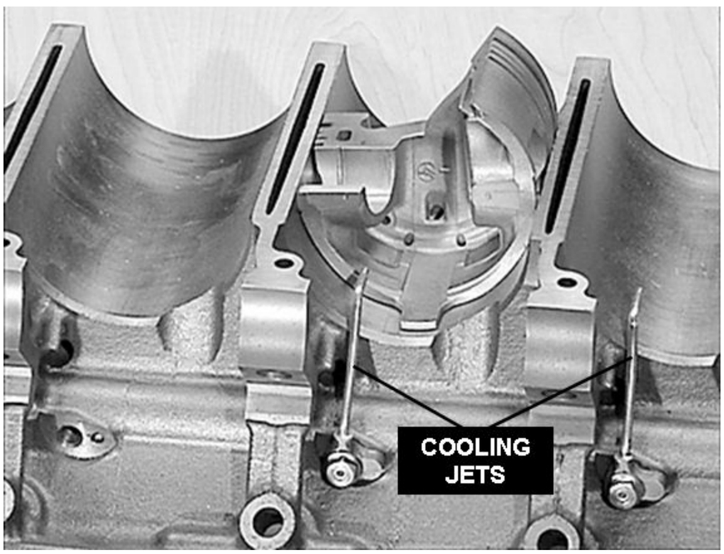


Figure 10 Piston Cooling Jets (video disc 1)

Piston Cooling Jets

Each forged Aluminum piston has an individual cooling jet for each cylinder that is connected to the main oil gallery.

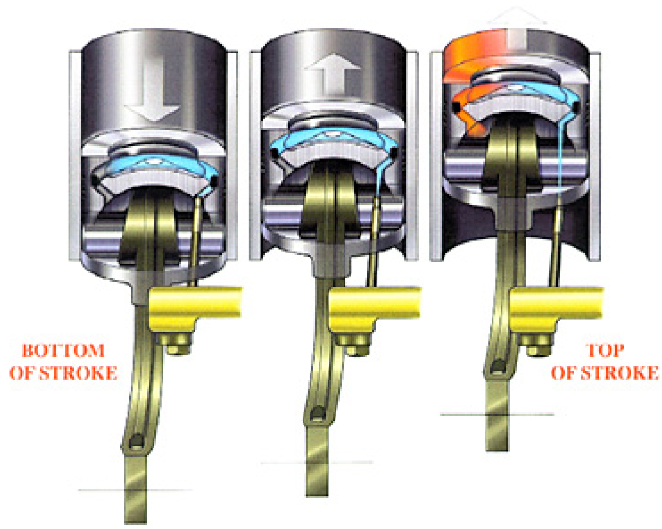


Figure 11 internal cooling passage in piston (video disc 1)

Internal Passage inside Piston Crown:

Oil from each jet sprays into a channel on the underside of the piston, where it circulates in the piston crown and lubricates and removes heat before exiting into the crankcase. This cooling jet system allows the use of a forged Aluminum piston in the Duramax.

A space between the top piston ring and the second piston ring allows for combustion pressure expansion and reduced blowby into the crankcase. This reduces dilution of the oil and also improves piston cooling.

The connecting rods are manufactured using a fractured split technique. The connecting rod is forged as one part before it is split, requiring no connecting rod-to-cap alignment inserts.

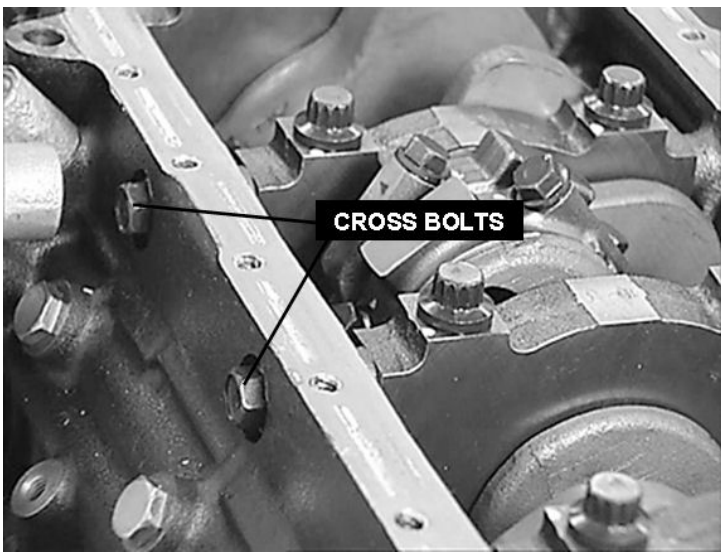


Figure 12 Main Bearings (video disc 1)

Rear Main Bearings

The dynamically balanced crankshaft is made of forged steel with nitrite heat treatment. The front balancer and the flywheel are counterweighted. Crankshaft end play is controlled at the #5 thrust bearing. Cross-bolted bearing caps enhance the structural rigidity of the block and help reduce noise associated with the stress of combustion (Figure 12).

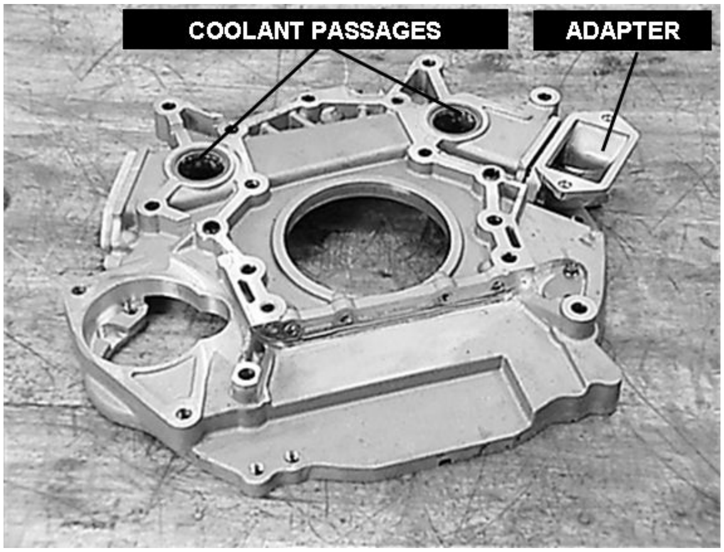


Figure 13 rear cover (Courtesy of GM)

Rear Cover

Coolant goes from gear driven water pump to a tube going to the oil cooler and then to the rear cover. There are coolant passages in the rear cover that go into the two cylinder heads and then to the rest of the engine. Cooling takes place from the REAR to the FRONT.

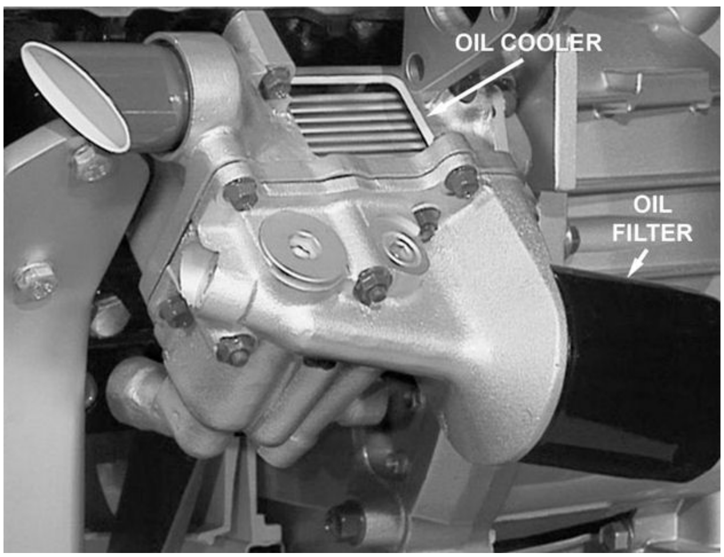


Figure 14 oil cooler and oil filter (Courtesy of Jim Halderman)

Oil Cooler

The spin-on oil filter and oil cooler are on the left side of the engine (Figure 14). The plate type oil cooler can be removed for easy service. The oil cooler connections use O-ring seals. Integrating the oil cooler into the engine enhances cooling and lowers the engine operating temperature. Engine oil circulates within the plates of the oil cooler, which are cooled by the flow of coolant during engine operation. A thermostat inside the oil cooler allows the flow of oil to bypass the cooler when the engine runs under cold temperature conditions. The AC Delco PF2232 (GM p/n 97214983) oil filter (or equivalent) is required for the Duramax 6600 diesel engine. This filter incorporates improved filtering and an integral pressure relief valve but no bypass valve because it is part of the filter housing.

Using a filter that does not meet the standards of the GM p/n 97214983 filter may cause engine damage.

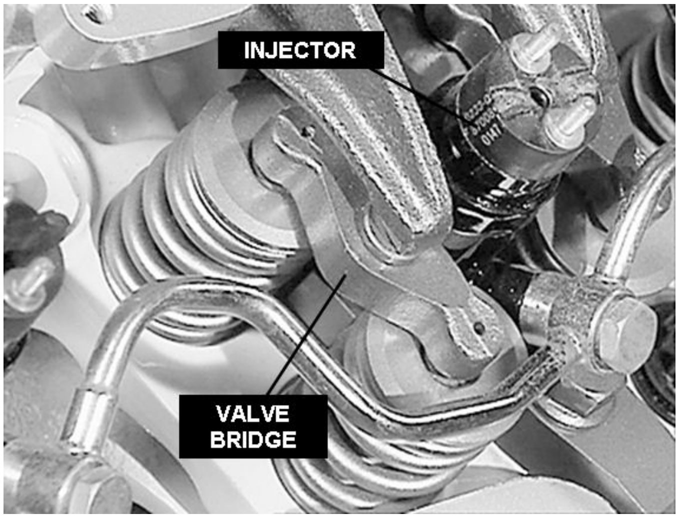


Figure 15 LB7 Valves and injector under valve cover (Courtesy of AC Delco)

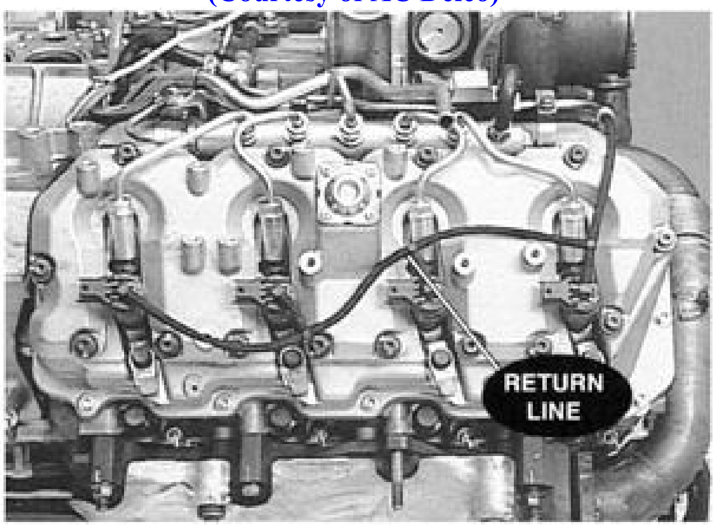


Figure 16 LLY with External Injector Location (Courtesy of AC Delco)

Cylinder Head

The valve train uses an overhead valve design that uses a single hollow camshaft operating 32 valves or four valves per cylinder. The location and arrangement of valves in the cylinder heads promotes the swirl of intake air.

Rocker arms for each cylinder head are mounted on a shaft. Each rocker arm opens a pair of valves through a valve bridge (Figure 15). Each valve is closed by the force of a coil spring. Valve clearance is set during engine manufacture and requires no routine maintenance. The LB7 fuel injector is under the valve cover. This location has caused internal fuel leaks from the return lines leading to oil dilution. The metal return lines shown in Figure 15 are channeled together. The LLY, LBZ, and LMM engines have the injectors located outside of the valve cover (Figure 16). The LLY and later engines use rubber return lines instead of metal lines.

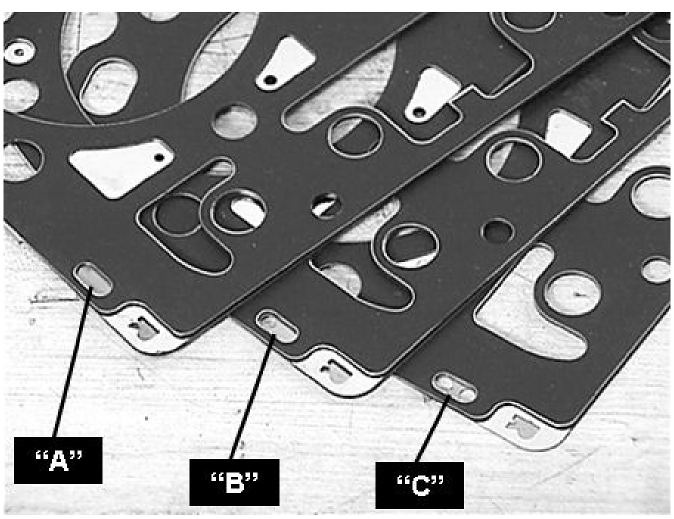


Figure 17 Head Gasket Sizes (video disc 1)

Head Gaskets

The sizes (A-B-C) of head gasket (Figure 17) are used to control deck height. The head gaskets are also identified as right or left as shown in Figure 18.

Figure 18 2006 Riveted Head Gasket Design

New Head Gasket Design

A new stronger design head gasket was introduced for the 2006 Duramax engines. It is a riveted design as shown in Figure 18. The first generation was a crimped design. A technical service bulletin (TSB) was released advising of the new head gasket as a replacement design for all engines.

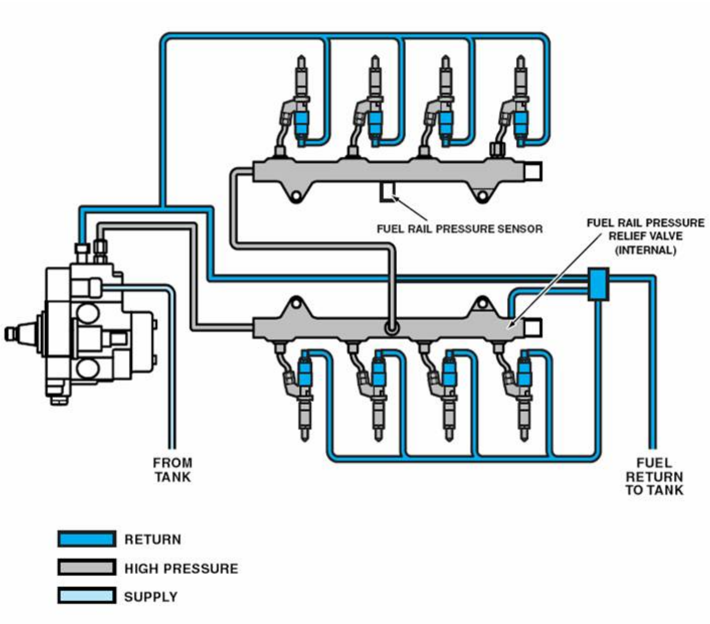


Figure 19 LLY Fuel Injection System (Courtesy of Jim Halderman)

Fuel Injection System

The Duramax diesel uses a common rail fuel system (Figure 19), which has four main advantages over more traditional fuel systems:

- Fuel injection pressure is independent of engine speed and load
- Pilot fuel injection pressure results in lower noise and less emissions
- CR system can fit many different engine applications, regardless of size and cylinder layout
- Combustion force balance between cylinders provides better emission control and smoother operation.

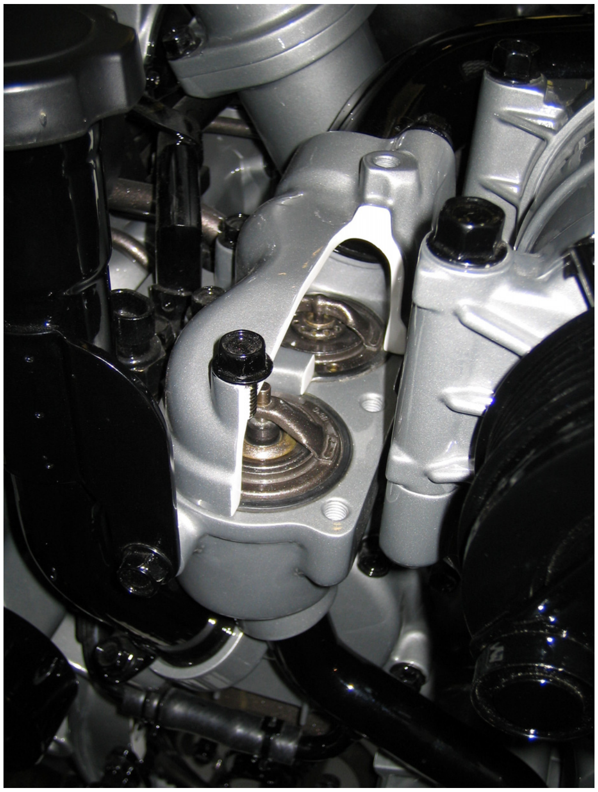
The common rail fuel system uses the following components:

- Fuel tank, hoses and lines
- Fuel Injector Control Module (FICM)
- Fuel filter assembly
- Pump assembly (feed section, Fuel Rail Pressure Regulator (FRPR) and high pressure section)
- High pressure junction block LB7 only (with pressure limiting valve and fuel pressure sensor)
- Common fuel rails (2)
- Fuel injectors (8)
- Fuel cooler

Thermostats

Two thermostats provide improved temperature control (Figure 20). The rear or primary thermostat is a non-blocking, two-stage design. The first stage begins to open at 82 degrees C (180 degrees F). With the opening of the first stage, a small passage is open in which coolant may flow to the water outlet and begin to circulate to the radiator. The secondary or second stage begins to open at 85 degrees C (185 degrees F) and more coolant is allowed to pass through to the radiator. The rear thermostat is fully open at 95 degrees C (203 degrees F).

The front or secondary thermostat has a single-stage design with a bypass flapper valve. It begins to open at 85 degrees C (185 degrees F). As it begins to open, it also begins to close the bypass flapper valve and close the bypass passage. The front thermostat is fully open at 100 degrees C (212 degrees F). DEXCOOL coolant is used up to 100,000 miles. To reduce gelling or biological growths, it is very important that the cooling system be purged of air.



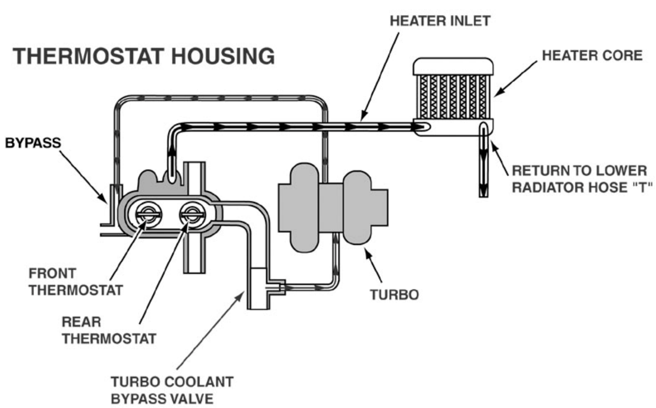


Figure 20 Thermostats (Courtesy of Jim Halderman)

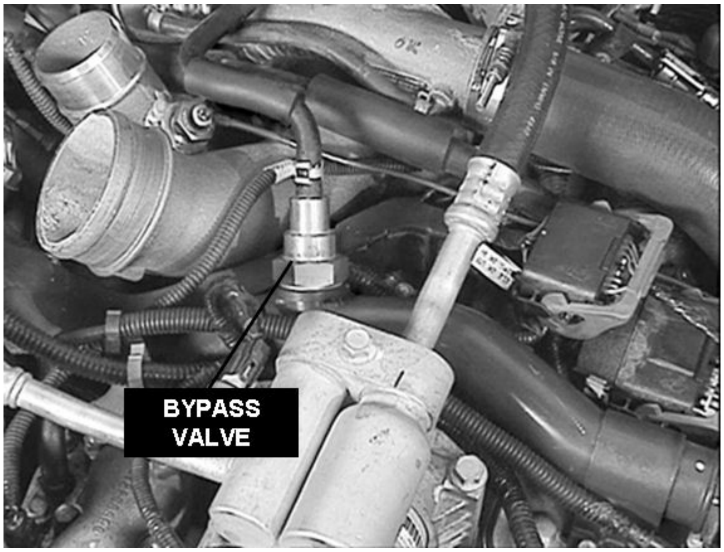


Figure 21 Turbo Coolant Bypass Valve (Courtesy of GM)

Turbocharger Coolant Bypass Valve

This turbocharger coolant bypass valve shown in Figure 21 is used to prevent turbocharger overcooling (reducing turbine speed) by closing off coolant flow through the turbocharger. It opens when the coolant temperature is at 60º C (140 º F).

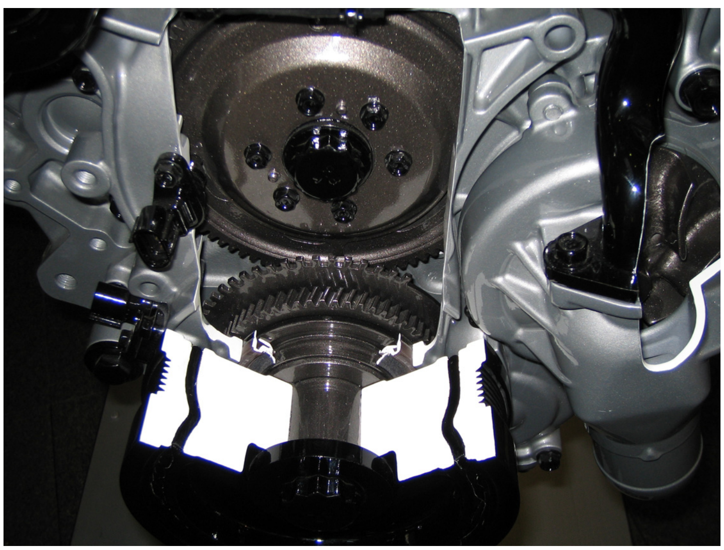


Figure 22 Gear Driven Water Pump (Courtesy of Jim Halderman)

Water Pump

The Duramax diesel engine uses a gear-driven water pump mounted on the front of the cylinder block near the left cylinder bank as shown in Figure 22. This pump connects to the engine gearing at the front of the engine and therefore enters the lubrication system. For this reason it is very important not to pinch the O-Ring during installation to prevent oil in the coolant.

Figure 23 LB7 Intake Air Heater (Courtesy of Jim Halderman)

Figure 24 Air Cleaner Restriction Gauge (Courtesy of Jim Halderman)

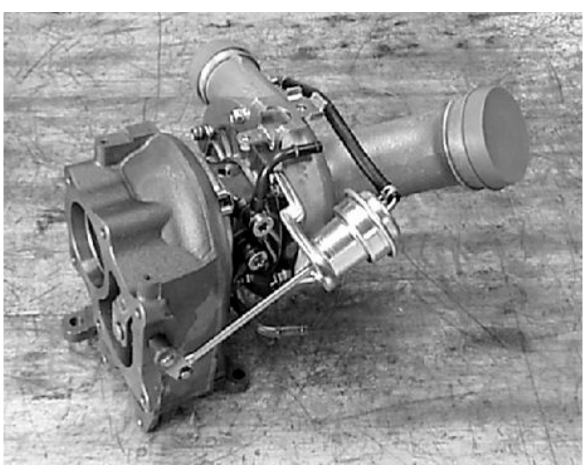


Figure 25 LB7 Wastegate style turbocharger (Courtesy of Jim Halderman)

Intake Air Heater (LB7)

The Duramax uses an Intake Air Heater (IAH) on the LB7 to warm the air entering the engine for proper cylinder combustion (Figure 23). The ECM operates the IAH to reduce white smoke during warm-up and after long decelerations. The IAH should be checked when the engine has a condition of white exhaust smoke upon a cold start.

CAUTION: Do not put ether or any flammable starting aid into the engine air intake during a cold start or hard-to-start situation.

The ECM grounds the control coil of the IAH relay to energize the Intake Air Heater during cold operation. For Federal emissions applications, the IAH relay is housed together with the glow plug relay. California emissions applications have an IAH relay that is separate from the glow plug relay.

The IAH relay can be checked using the Intake Air Heater output control function of a scan tool. The scan tool will request the ECM to activate the IAH relay ON or OFF. The device control will not change unless changed or cancelled by the scan tool. The IAH was discontinued on the LLY but returned on the 2007 and later LBZ and LMM engines.

Figure 24 shows the indicator gauge used to determine air filter condition.

Turbocharger

The Duramax uses a turbocharger mounted in the "V" of the engine. It uses a water-cooled center housing to extend overall durability. Engine oil under lubrication system pressure cools the turbocharger bearings. Exhaust travels through a short straight manifold into a split turbocharger housing in order to conserve energy for turbocharger operation (Figure 25). The split housing prevents exhaust gas pulses from interfering with each other and allows the pulses to cancel out each other as they enter the turbocharger. This results in a more efficient, easier breathing exhaust system.

On the LB7 only, the turbocharger uses a diaphragm-type actuator to operate the wastegate and limit intake manifold boost pressure to 20 psi. Manifold pressure pushes the diaphragm in the actuator, which operates the wastegate through a rod and linkage. There is no ECM control of the turbocharger in the LB7.

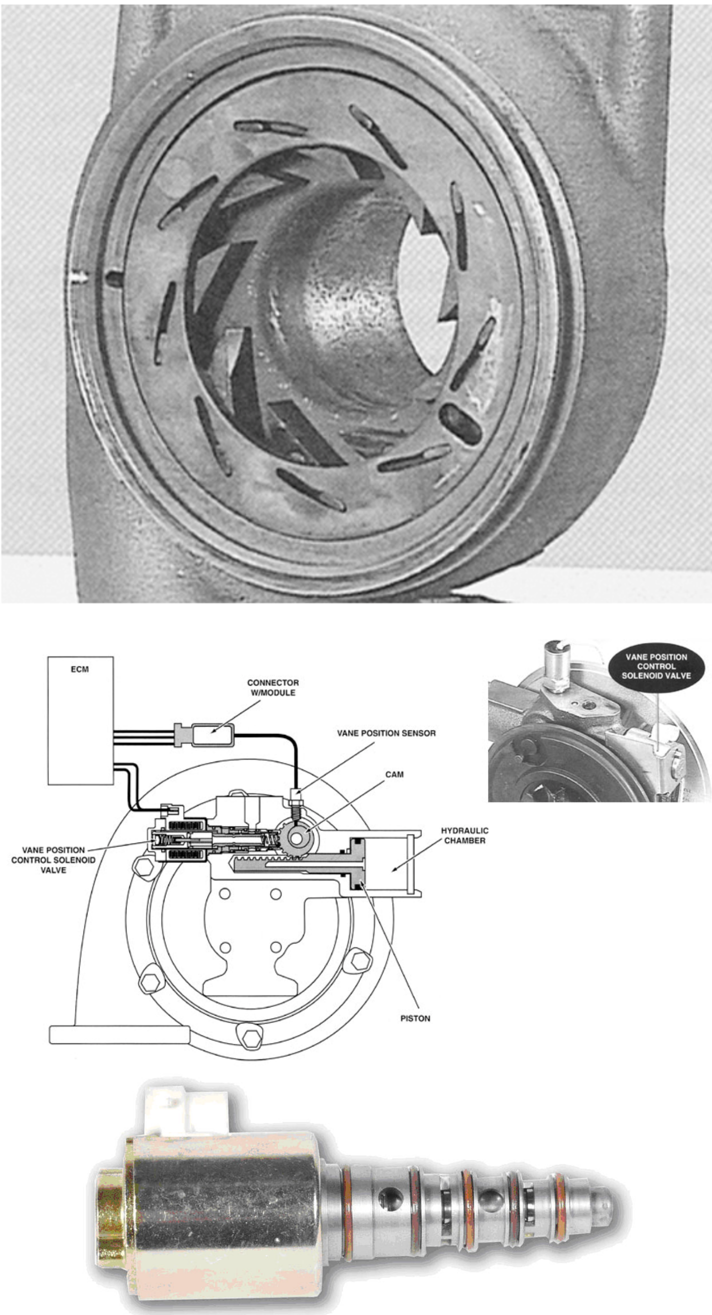


Figure 26 LLY Variable Nozzle Turbo (video disc 1)

LLY Variable Nozzle Turbo

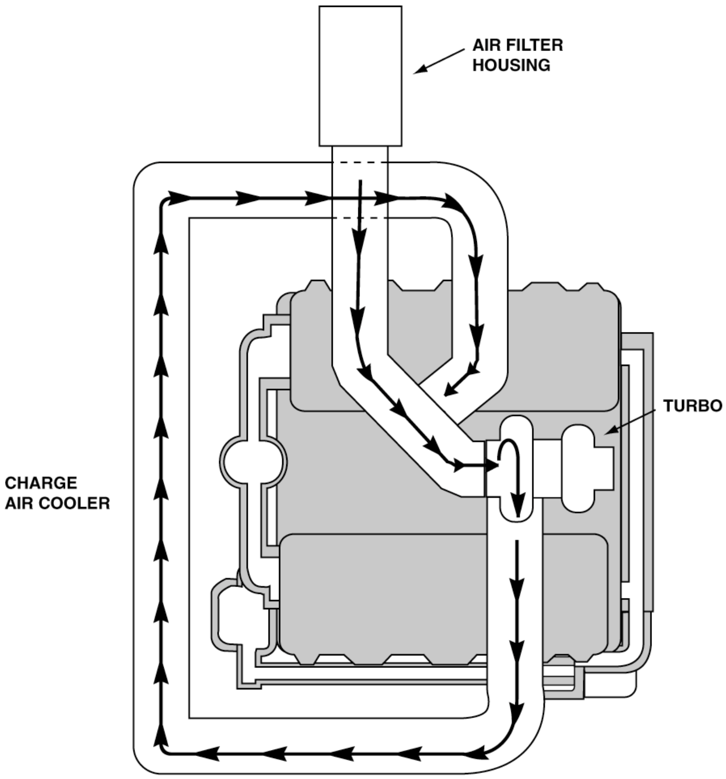
The LLY engine uses a turbocharger with a variable nozzle feature that replaces the wastegate used on the LB7. The variable nozzle feature uses a group of nine vanes located in the turbocharger turbine housing (Figure 27).

The adjustable vanes mount to a unison ring that allows the vanes to articulate. As the position of the unison ring rotates, the vanes change angle like a carburetor Venturi. The vanes are opened to minimize flow at the turbine and exhaust back pressure at low engine speeds. To increase turbine speed, the vanes are closed. Exhaust gas velocity increases, as well as the turbine speed.

The ECM operates a vane position control solenoid valve (Bottom of Figure 26), which controls the pressure and direction of engine oil acting on either side of a hydraulic piston. The piston has a rack of teeth that engage the pinion teeth of a cam. As piston movement causes the cam to rotate, it rotates the unison ring in order to pivot the vanes. The ECM monitors its control of the piston with a vane position sensor.

The vane position control solenoid valve is located in the turbo center housing and connects to the ECM through two wires. The ECM provides the vane position control solenoid valve with variable current through Pulse-Width Modulation (PWM) control using:

- 0 amps: engine oil pushes a hydraulic piston to fully open the vanes/fail safe mode
- Maximum amps: engine oil pushes the hydraulic piston to fully close the vanes
- Variable amps: engine oil on both sides of the hydraulic piston holds the vanes in a



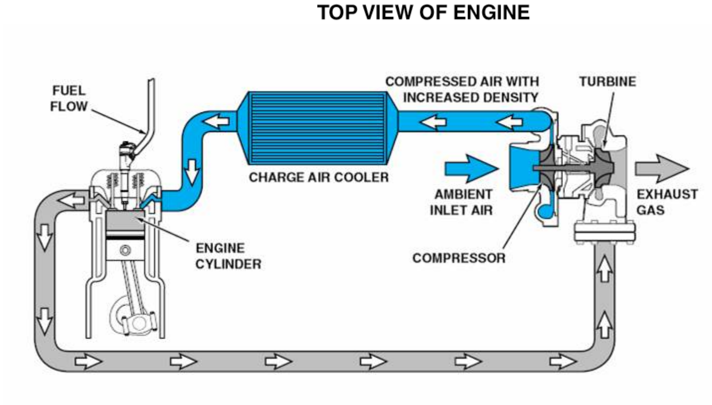


Figure 27 TOP: Air intake system (video disc 1), BOTTOM: LLY Air intake system (Courtesy of Jim Halderman)

position between fully open and fully closed

The ECM strategy for vane position control solenoid valve operation results in variable turbocharger boost based on several inputs, including the boost pressure sensor.

Air Intake System

In the turbocharger of a Duramax engine, air moves through a filter and ducting to the compressor inlet. From the turbocharger compressor outlet, the compressed air moves through an air-to-air heat exchanger to lower its temperature and increase its density before it enters the engine intake manifold (Figure 28).

This heat exchanger is called a charge air cooler, and it is located between the A/C condenser and the cooling system radiator.

The charge air cooler has construction similar to a cooling system radiator. Heat travels from the compressed air moving through inside the finned tubes of the charge air cooler to the air flowing around the tubes. The air movement around the charge air cooler tubes is caused by the operation of the cooling fan.

The result of charge air cooler operation is that air with higher density can move into the cylinder combustion chambers, which increases engine power and decreases Oxides of Nitrogen (NOx) emissions in the exhaust gas stream. If there is a loss of boost pressure or engine power, check for road debris in the charge air cooler.

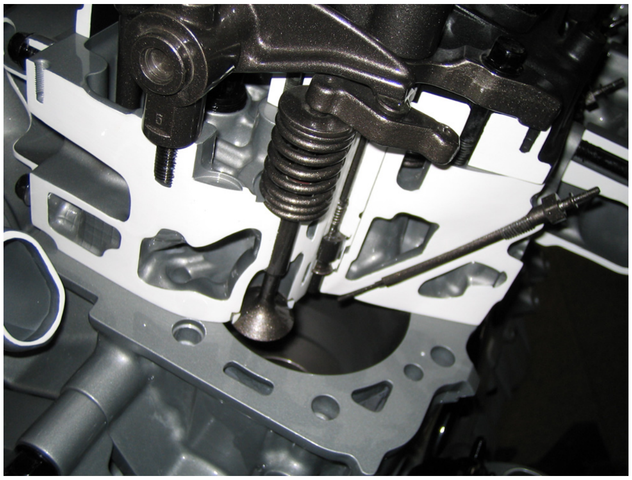


Figure 28 Glow Plugs (Courtesy of Jim Halderman)

Glow Plug System

The Duramax uses 8 glow plugs (one per cylinder) to provide combustion chamber heating (Figure 28). The glows plugs are 12-volt heaters that are energized prior to starting the engine and they may also be energized for a short time after the engine has started.

The instrument cluster uses a “Wait To Start” lamp that illuminates to tell you that glow plug operation is occurring prior to starting the engine. Once the engine has started, the “Wait To Start” lamp does not illuminate during glow plug operation. However, the glow plugs may be energized for up to 30 seconds after the engine has started. The LB7 used two types of control modules or controllers: Federal and California. The Federal system glow plugs are wired in parallel and are not monitored individually. The Federal system module was housed along with the Intake Air Heater Relay as one component. The Federal system also used the glow plug relay portion as a feedback to the ECM showing operation as shown in the schematic in Figure 29. The CA system glow plug amperage draw is monitored individually by the Glow Plug Controller and relayed to the ECM through GMLAN connections and if there is a malfunction, A DTC is set (Figure 30). The LLY and later engines use the CA system.

The 2006 and later LLY engines and all LBZ, and LMM engines use a glow plug system with a glow plug control module that has evolved into a system operated by the ECM that also stores Fuel Injector flow rates along with the ECM.

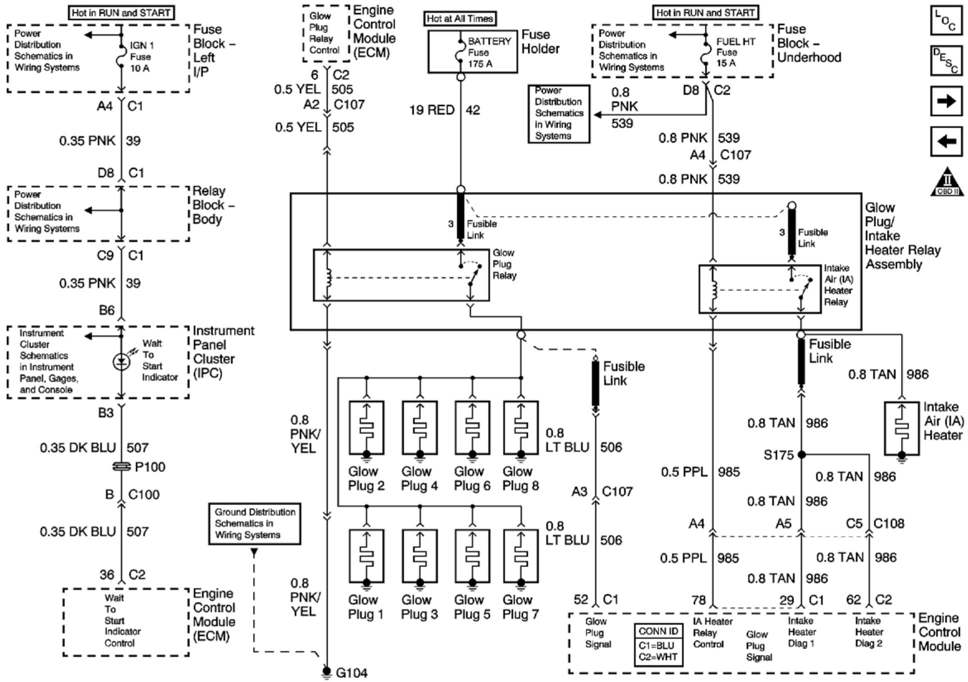


Figure 29 LB7 Federal Glow Plug System Schematic (Disc 1 Slide)

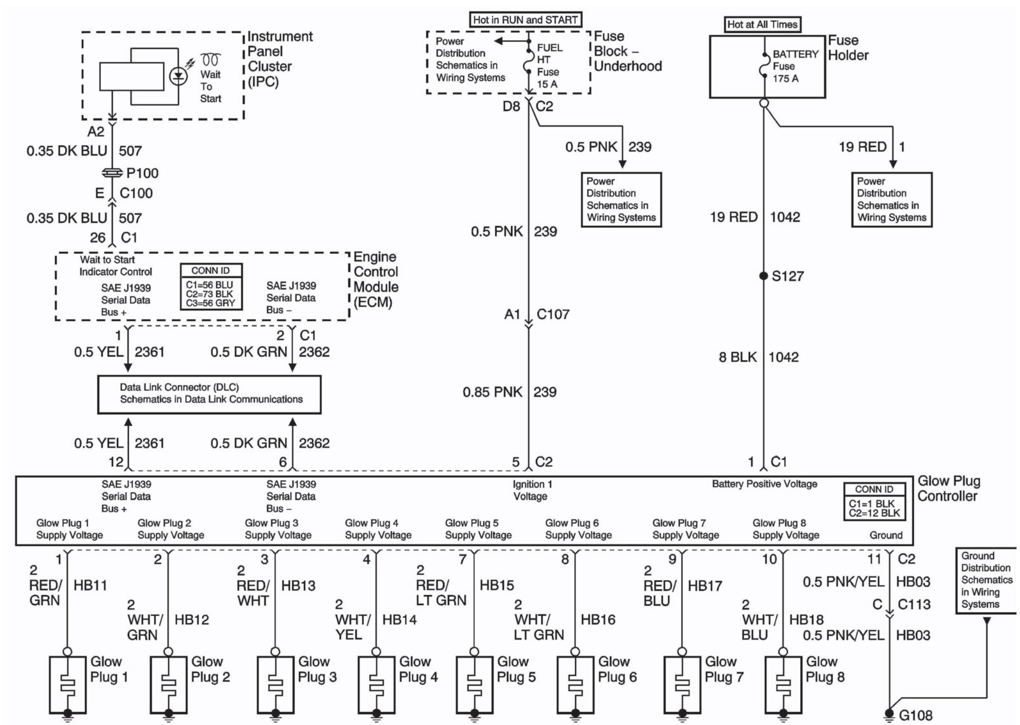


Figure 30 LB7 California & LLY Glow Plug System Schematic (Disc 1 Slide)

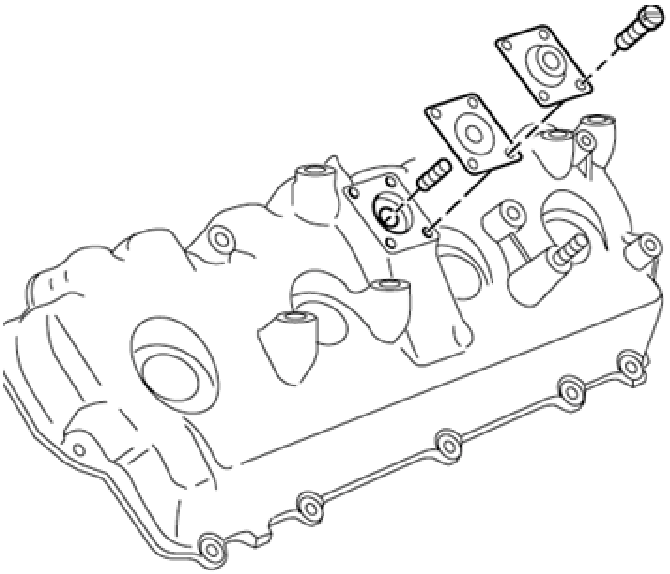


Figure 31 LB7 Crankcase depression valve (Courtesy of AC Delco)

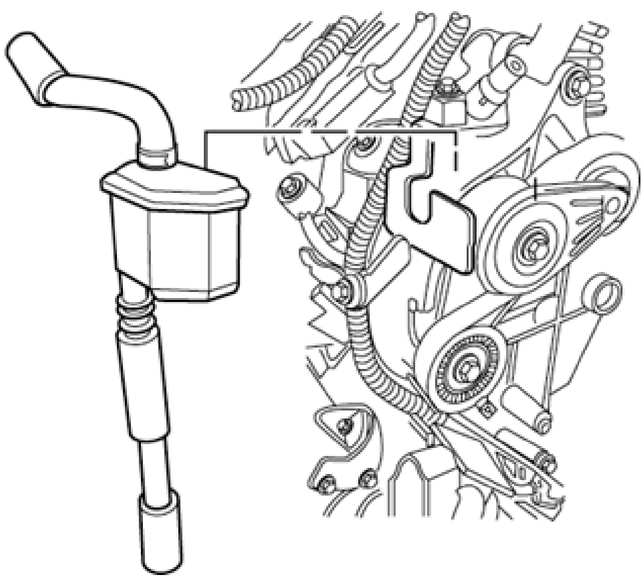


Figure 32 LB7 NON-integral oil separator (Courtesy of AC Delco)

Crankcase Ventilation System

The LB7 uses an open crankcase ventilation system much like old road draft tube of past big block diesel engines like the Detroit Diesel 92 series (Figure 31). The LB7 crankcase ventilating system vents crankcase gases to the atmosphere. Each valve cover uses a crankcase depression valve with a diaphragm type valve to control movement of vented gases to an oil separator (Figure 31). As crankcase pressure increases, gases escape past the diaphragm valves and flow through hoses to the oil separator (Figure 32). If the crankcase gases are under a vacuum, each diaphragm valve closes to prevent unfiltered air from entering the crankcase.

The oil separator collects oil vapor from the crankcase gases, which condenses to liquid and flows back into the engine through a drain hose. The crankcase gases without oil vapor then flow into the atmosphere in the engine compartment.

The LLY and later engines use a closed system oil separator design that is an integral part of the engine. This system contains a check valve in the oil drain hole in the hose from the separator containing condensed liquid oil to the crankcase. The road draft type vapor tube containing oil vapor from the separator that went to the ground on the LB7 is now routed back into the turbocharger intake.

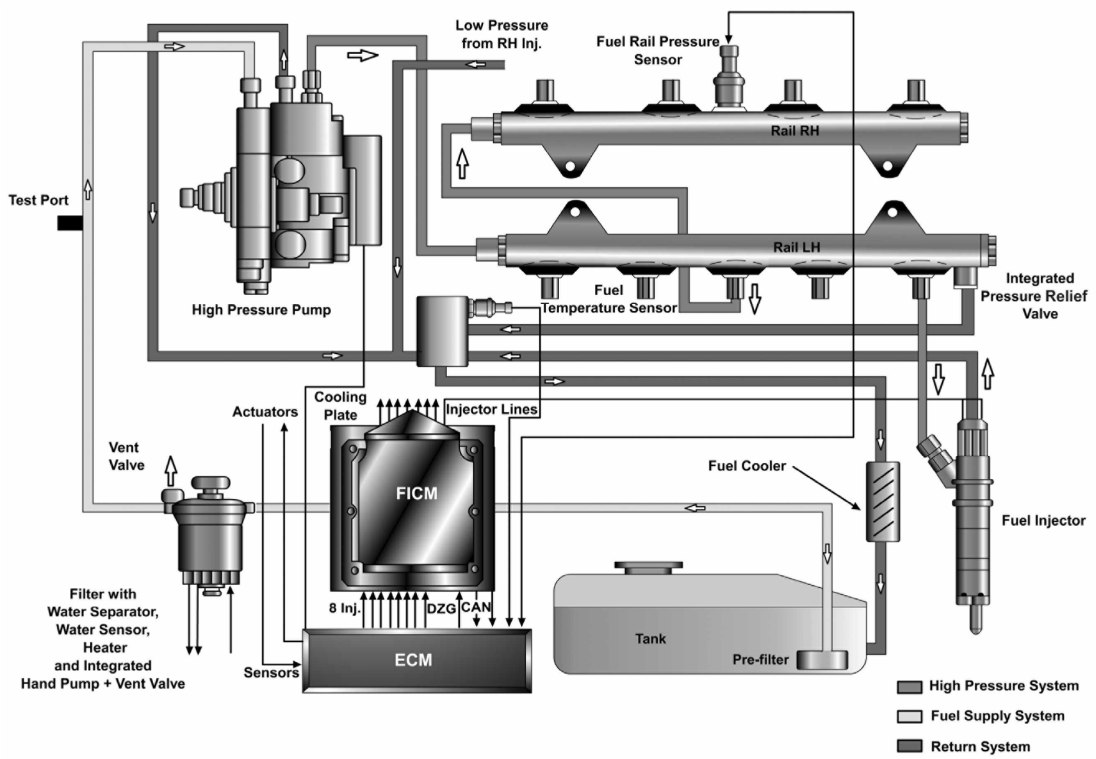


Figure 33 LLY Fuel System (Courtesy of Jim Halderman)

FUEL SYSTEM

The Duramax diesel uses a common rail fuel system (Figure 33), which has four main advantages over more traditional fuel systems:

- Fuel injection pressure is independent of engine speed and load
- Pilot fuel injection pressure results in lower noise and less emissions
- CR system can fit many different engine applications, regardless of size and cylinder layout
- Combustion force balance between cylinders provides better emission control and smoother operation.

The common rail fuel system uses the following components:

- Fuel tank, hoses and lines
- Fuel Injector Control Module (FICM)
- Fuel filter assembly
- Pump assembly (feed section, Fuel Rail Pressure Regulator (FRPR) and high

pressure section)
- High pressure junction block (with pressure limiting valve and fuel pressure sensor)
- Common fuel rails (2)
- Fuel injectors (8)

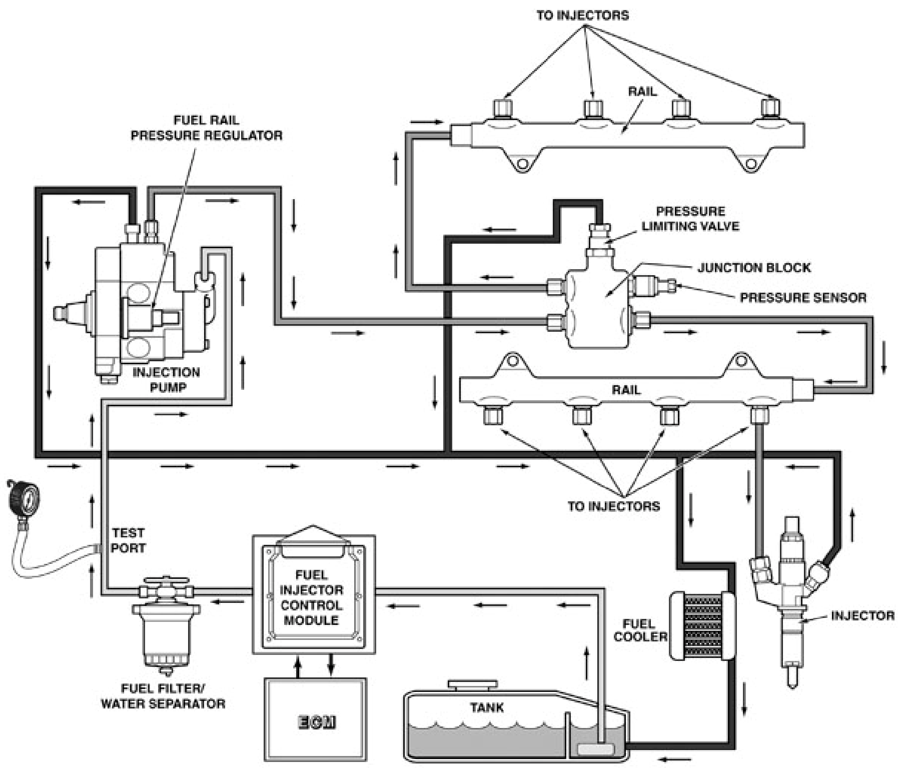


Figure 34 Fuel System Suction Side (Disc 1 Slide)

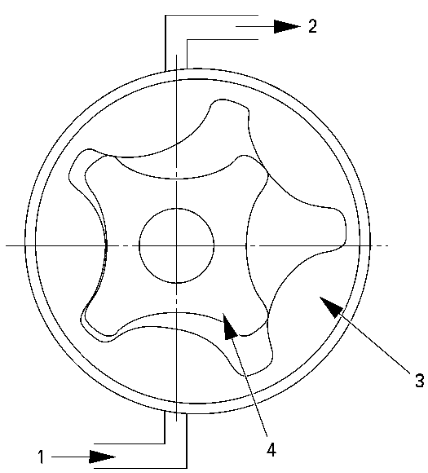


Figure 35 Fuel Supply Pump (Courtesy of Robert Bosch Corporation)

Suction Side

Fuel flows from the tank through the FICM (Fuel Injection Control Module) and then the fuel filter to the injection pump. The fuel supply pump is built into the high-pressure pump to pump fuel up and supply fuel through fuel filter into the high-pressure pump unit. No separate lift pump is used on the Duramax. The supply pump inside rotor (4) is driven by supply pump camshaft. When the inside rotor starts to rotate, the outside rotor also rotates together with inside rotor. The outside rotor (3) has one more tooth than the inside rotor, therefore, the inside rotor tooth slides on the face of the inside tooth in the outside rotor during rotation (Figure 35). The fuel hold clearance between the outside rotor and inside rotor tooth causes fuel to be pushed out of the discharge port (2).

The fuel supply pump's delivery quantity is proportional to engine speed. This is why the gear pump's delivery quantity is reduced by a suction throttle at the inlet (suction) end, or limited by an overflow valve at the outlet (pressure) end. To bleed the fuel system before the first start, or when the tank has been driven "dry", a hand priming pump is fitted to the fuel filter assembly.

Fuel Injection Control Module (FICM)

Fuel being pumped from the fuel tank (s) passes through the fuel injection control module (FICM) to cool it then on to the filter. The FICM is mounted on the engine and contains step-up transformers and high speed switching drivers that use high voltage and current up to 96 volts and 20 amps. The generation of this energy creates considerable heat that must be removed, so the fuel removes this heat. On the Topkick and Kodiak Class 6 and 7 medium duty trucks, the position of the FICM and Fuel filter are revered where fuel flows through the Filter first then the FICM.

NOTE: The fuel junction block was only used on 2001 to 2004 LB7 engine.

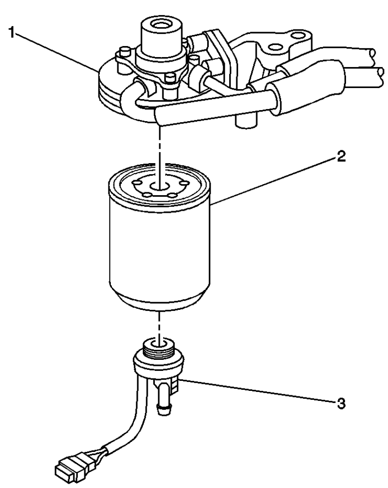
Fuel Filter

The fuel filter assembly is located on the right rear (passenger) side of the engine and it prevents contaminated fuel from entering the fuel injection pump (Figure 36). The fuel filter assembly has the following parts:

- Fuel filter/water separator
- Hand primer pump
- Heater element
- Water-in-fuel sensor (replaced with filter)

The fuel filter removes contaminants (water and dirt) and heats fuel when outside temperatures are low. The filter assembly has a primer pump that is used when the fuel system loses its prime or when the fuel filter has been replaced. The primer and heater are part of the fuel filter/heater element housing.

The primary filter also has an optional fuel-



(1) Fuel Filter/Heater Element Housing
(2) Filter
(3) Water In Fuel Sensor

Figure 36 Fuel Filter (Courtesy of GM SI2000) heater because where fuel is flowed through the injection system circuitry at a rate much higher than that required for fueling the engine, constant filtering of fuel removes some of the wax and therefore some of its lubricity even when the appropriate seasonal pour point depressants are present.

Pour point depressants tend not to have too much effect on the cloud point of a fuel, which is its first stage of waxing. This is a condition to which Number 2D fuels are more prone than Number 1D. Fuel heaters allow the use of fuels at temperatures substantially below their fuel cloud point.   The heater is an electric heating element that uses battery current to heat fuel in the sub-system.

You can also test the filter suction side for AIR and the amount of suction at 4-5 inches. Suspect the filter if the suction is greater.

If the truck runs out of fuel, you will first refill the truck and then prim and bleed the fuel filter. You crack open the bleeder valve (vent screw) and use the hand priming pump until fuel flows out. The filter is a major source of drivability issues. Although the filter change interval is 30,000 miles, it is a good idea to change the fuel filter during every oil and filter change.

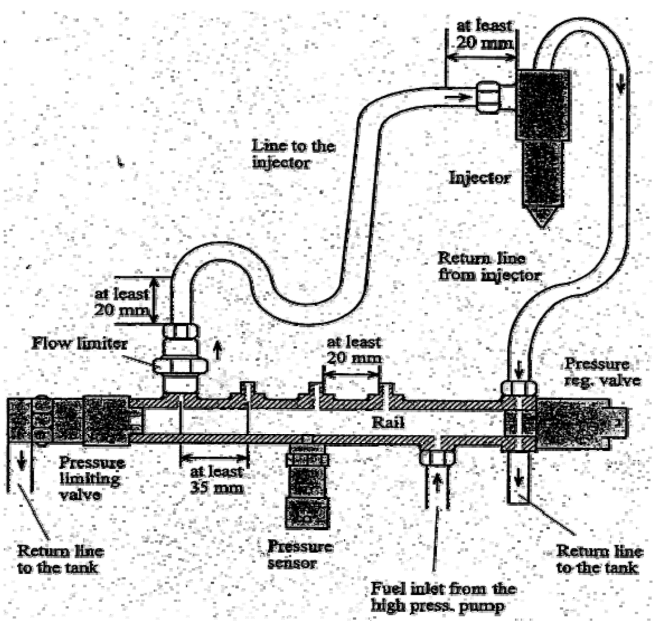


Figure 37 Fuel Lines (Courtesy of Robert Bosch Corporation)

Fuel Lines

The Duramax uses a combination of metal, rubber, and steel braided low-pressure fuel supply lines (Figure 37) in the fuel suction or supply side from the tank to the high-pressure fuel injection pump. These fuel lines and the components connected to them are on the suction side of the gear fuel supply pump. If there are any leaks in the lines they will not show because the fuel is under suction and air can enter the line and get into the high-pressure pump. The high-pressure pump is unlike the DS pump or DB2 pumps used on the 6.5L diesel, in the sense that this is not a radial piston distributor-type pump that must maintain a balance between high and low-pressure in the pump. When air was introduced into a DS pump it causes an imbalance between the pumping plungers. This can still occur in the CR-system and cause engine **misfire** with DTCs stored. AIR-IN-FUEL is still a big problem in CR Fuel Systems. Check all fuel supply hose clamps for tightness. O-rings seal the connections in the fuel system. Fuel system O-ring seals are made of special material. Service the O-ring seals with the correct service part.

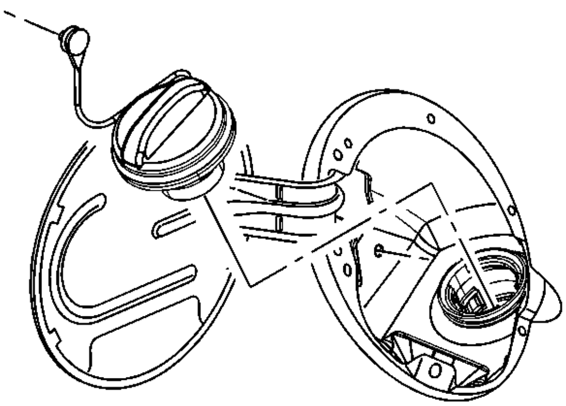


Figure 38 Fuel Filler Cap (Courtesy of GM SI 2000)

Fuel Cap

Duramax diesels use a fuel filler cap (Figure 38) with a two-way check valve (vacuum and pressure). The pressure portion allows air to escape during the day when the tank heats up. In the event of a rollover this valve prevents spillage. Under pressure no more than 2 psi will be in the fuel tank. The vacuum portion of the valve must allow air to enter the tank to push the fuel to the fuel supply pump and replace the fuel used by the engine. A vacuum or pressure differential of no more than 1 inch of Hg opens the vacuum valve.

A slight hissing sound will occur when a fuel cap of this type is removed. Diesel fuel caps are unique to Diesel fuel systems, so never use a fuel cap designed and calibrated for gasoline, because the pressures are higher and can cause Diesel driveability problems. The fuel filler cap has a torque-limiting device that prevents the cap from being over tightened. To install turn the cap clockwise until you hear audible clicks. This indicates that the cap is fully seated

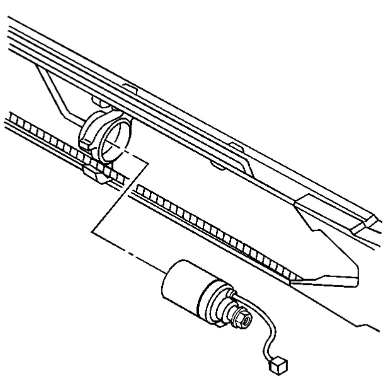


Figure 39 Dual Tank Fuel Pump (Courtesy of GM)

Electric Fuel Pump

On class 2 and 3 trucks equipped with dual fuel tanks, an electric fuel pump (Figure 39) is located on the left frame rail. This fuel pump is powered by the fuel pump relay that is controlled by the ECM. Fuel is transferred from the auxiliary fuel tank to the primary fuel tank in order to ensure all of the usable fuel volume is available to the high pressure fuel injection pump.

CAUTION: the DURAMAX uses fuel pressures up to 23,000 PSI. To avoid personal injury NEVER crack open a fuel pressure line and ALWAYS follow the precautions and procedures identified in the GM service information.

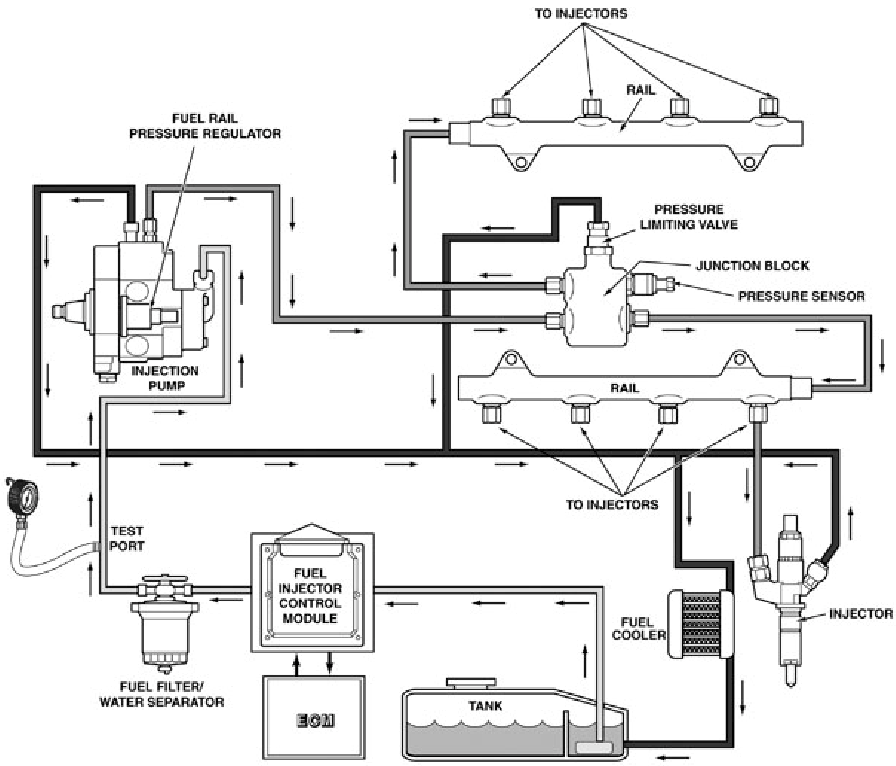


Figure 40 Fuel System High Pressure Side (Disc 1 Slide)

High Pressure Side

The high-pressure pump (Figure 40) is the connection between the low- pressure and the high-pressure stages. Under all operating conditions, it is responsible for providing adequate high-pressure fuel throughout the truck's service life. This also includes the provision of extra fuel as needed for rapid starting and for rapid build-up of pressure in the rail. The high-pressure pump continually generates the system pressure as needed in the high-pressure accumulator (rail). This means therefore, that in contrast to conventional systems, the fuel does not have to be specially compressed for each individual injection process.

The high-pressure pump is installed preferably at the same point on the diesel engine as a conventional distributor pump. It is driven by the engine (at half engine speed to a maximum of 3000 RPM through a coupling, gearwheel, chain, or toothed belt, and lubricated by the diesel fuel, which it pumps. The **fuel rail pressure regulator** is installed directly on the high-pressure pump. Inside the high-pressure pump the fuel is compressed with three radially arranged pump pistons, which are at an angle of 120° to each other.

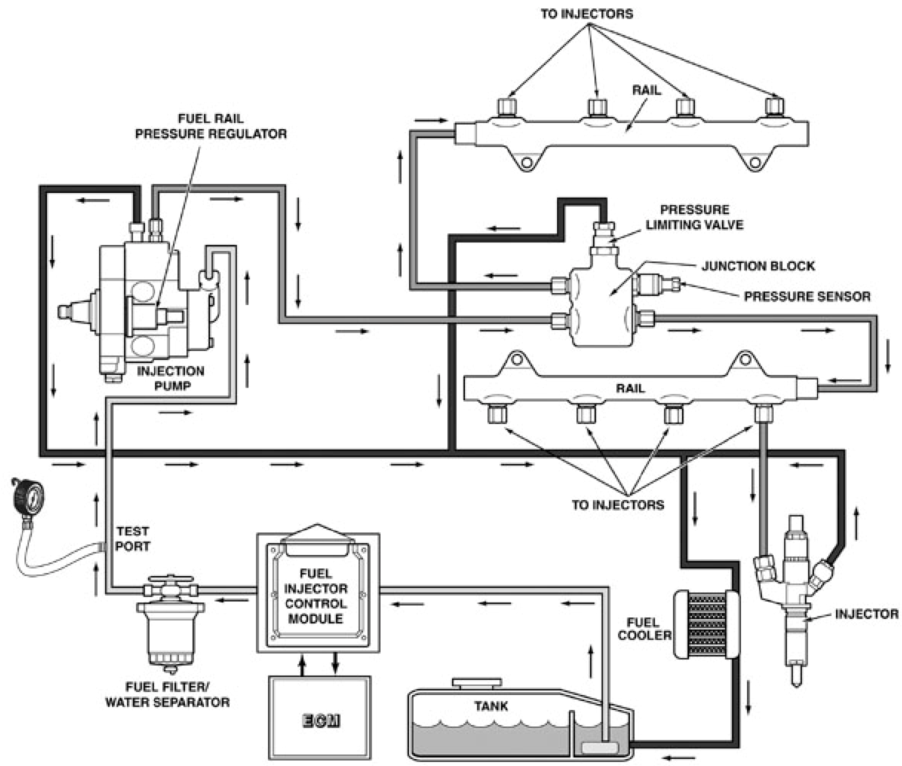


Figure 41 Fuel System Return Side (Disc 1 Slide)

Return Side

The return side (Figure 41) of the Duramax fuel system has fuel returning from the high pressure pump and each of the fuel injectors through the fuel cooler and returning to the tank. Only the LB7 used internal metal return lines on the fuel injectors with banjo fittings under the valve covers. LLY, LBZ, and LMM engines use external rubber return lines on the fuel injectors.

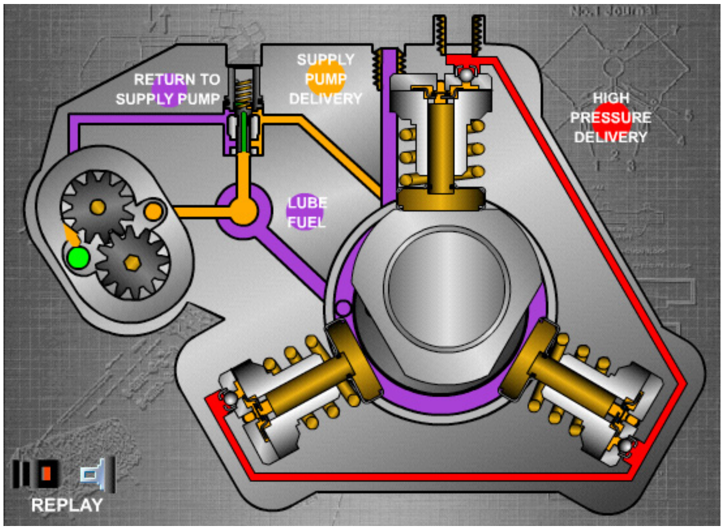


Figure 42 High Pressure Fuel Injection Pump (Disc 1 Slide)

Fuel Injection Pump Operation

The fuel enters the high-pressure pump through the fuel inlet and into the suction side of the gear pump (Figure 42). The gear pump pressurizes the fuel and pumps it into another internal passage to the circular passage feeding the inlet valves to the pumping elements. The driveshaft with its eccentric cams moves the three pump plungers up and down in accordance with the shape of the cam.

As soon as the delivery pressure exceeds the overflow valve's opening pressure the pre-supply gear pump can force fuel into the pump element's inlet valve into the pumping-element chamber when pump piston is moving downward on the suction stroke. The inlet valve closes when the pump piston passes through BDC and, since it is impossible for the fuel in the pumping-element chamber to escape, it can now be compressed beyond the delivery pressure. The increasing pressure opens the outlet valve as soon as the rail pressure is reached, and the compressed fuel enters the high-pressure circuit.

The high-pressure pump's delivery rate is proportional to its rotational speed, which is a function of engine speed. The CR-system is designed so that the amount of excess fuel is not high and the fuel requirements can still be satisfied during WOT operation. The pump piston continues to deliver fuel until it reaches TDC (delivery stroke), after which the pressure collapses so that the outlet valve closes. The fuel remaining in the pumping-element chamber relaxes and the pump piston moves downwards again. As soon as the pressure in the pumping-element chamber drops below the pre-supply pump pressure, the inlet valve opens and the pumping process starts again.

Two major components in the fuel system are the fuel rail pressure regulator (FRPR) and the fuel rail pressure sensor.

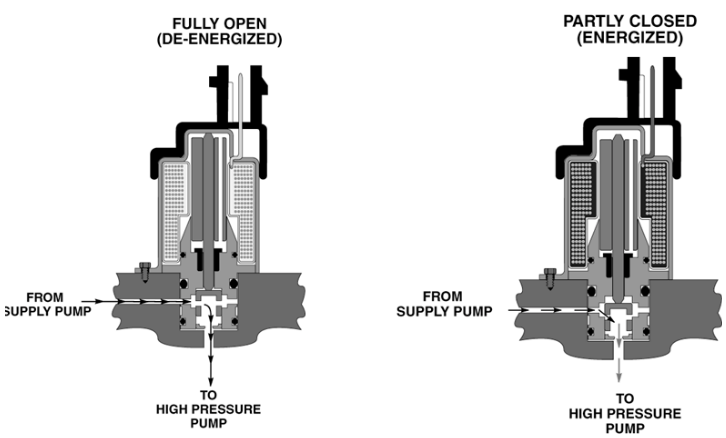


Figure 43 Fuel rail pressure regulator (Disc 1 Slide)

Fuel Rail Pressure Regulator (FRPR)

The fuel rail pressure regulator (FRPR) as shown in Figure 43 is controlled by the ECM to set the required rail pressure as a function of engine loading, and maintains it at this level. The FRPR is an open and closed valve that is normally open (NO).

If the rail pressure is excessive, the pressure-control valve CLOSES and a portion of the fuel returns from the rail is sent to the tank. If the rail pressure is too low, the pressure-control valve OPENS and allows more high-pressure fuel to flow and pressure increases. The fuel rail pressure is constantly fluctuating due to the PWM (pulse width modulation) process of control used by the ECM. The pressure can be from 3,000 to 23,000 PSI. Fuel pressure at idle is about 5,000 PSI with the peak at 23,000 PSI. By turning a circuit ON/OFF rapidly, a highly controllable range of signals is obtained. PWM is a way of controlling voltage. Pulse means turning ON/OFF. Width means the amount of time the voltage is ON compared with the amount of time the voltage is OFF. Modulation refers the circuit is being controlled, or modulated, over different operations. The percentage of ON/OFF is called the Duty Cycle or frequency, which is 5% - 95%. The higher the Duty Cycle the lower the output pressure.

The ECM considers the current operating conditions (rpm, load, temperature, boost and others) when it sets injection timing and pressure. The ECM develops a learned "correction" offset to correlate FRPR actuator position (commanded pressure) and actual fuel rail pressure based on input from the fuel rail pressure sensor. Once the ECM has learned the FRPR offset, it can immediately command the exact desired fuel pressure. On 2001-2006.5 engines, the regulator is on the back of the high-pressure pump. On 2006.5-up engines, the FRPR is on the end of the fuel rail.

- When **open**, the **FRPR** allows maximum fuel flow to the high pressure pump increasing the high pressure fuel pump output
- When **closed**, the **FRPR** limits fuel flow to the high pressure pump, decreasing high pressure fuel pump output.

The fuel rail pressure regulator incorporates two control loops:

- Slow-response electrical control loop for setting a variable mean pressure in the rail, and
- Fast-response mechanical control loop to compensate for the high- frequency pressure fluctuations.

For diagnosis, remove FRPR and check for rust or biological growth that may cause drivability concern. If you crank the engine with the FRPR disconnected the system will deliver maximum fuel pressure. Disconnecting the FRPR and FICM, and cranking the engine will drive the system to max pressure and can check for a leaky injector. Check the FRPR with a scan tool using Output Tests to increment the duty cycle UP or DOWN and look for a corresponding change in fuel pressure. An increase in duty cycle should decrease pressure.

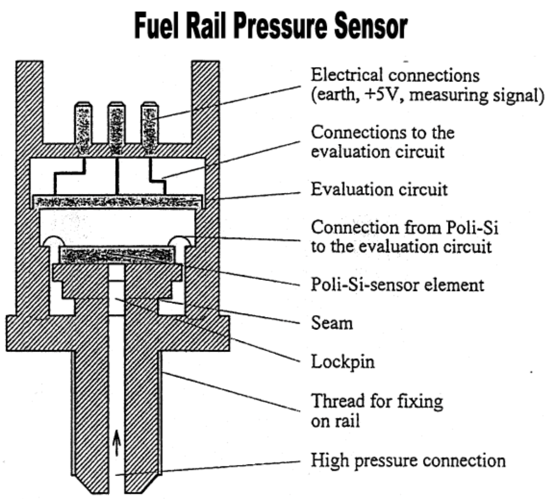


Figure 44 Fuel Rail Pressure Sensor (Courtesy of Robert Bosch Corporation)

Fuel Rail Pressure Sensor

The Fuel Rail Pressure Sensor sends a voltage signal to the ECM that corresponds to the applied pressure (Figure 44). The rail-pressure sensor comprises: sensor element, printed-circuit board and sensor housing with electrical plug- in connection.

Fuel flows to the rail-pressure sensor through an opening, the sensor diaphragm seals off the end. Pressurized fuel reaches the sensor's diaphragm through a blind hole. The sensor element for converting the pressure to an electric signal is mounted on this diaphragm. The signal generated by the sensor is inputted to an evaluation circuit, which amplifies the measuring signal and sends it to the ECM.

When the diaphragms shape changes, the electrical resistance of the layers attached to the diaphragm changes. This change results from a build-up of pressure and changes the electrical resistance causing a voltage change across the 5 Volt resistance bridge. This voltage change is in the range 0...70 mV (depending upon pressure) and is amplified by the evaluation circuit to 0.5 to 4.5 Volts.

Precise measurement of rail pressure is imperative for correct system functioning. This is one of the reasons for the very tight tolerances that apply to the rail-pressure sensor during measurement. In the main operating range, the measuring accuracy is approximately plus or minus 0.2% of full-scale reading. If the rail pressure sensor should fail, the pressure-control valve is triggered "blind" using an emergency (limp-home) function with fixed values.

In the course of **diagnosis**, it's important the ***ECM desired fuel rail pressure meets the actual fuel pressure as measured on the scan tool.***

CAUTION: the DURAMAX uses fuel pressures up to 23,000 PSI. To avoid personal injury NEVER crack open a fuel pressure line and ALWAYS follow the precautions and procedures identified in the GM service information.

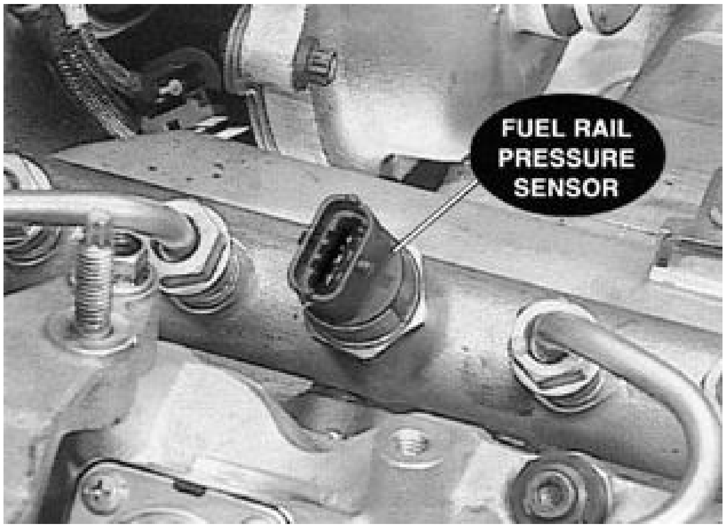


Figure 45 Fuel Rail (Courtesy of GM)

Fuel Rail

The high-pressure accumulator (Figure 45) stores the fuel at high pressure. The rail volume dampens the pressure oscillations, which are generated due to the high-pressure pump delivery and fuel injection. There are 2 high-pressure accumulator fuel rails, one for the left bank cylinders 1-3-5- 7 and one for the right-bank cylinders 2-4-6-8. The fuel rail is common to all cylinders in that bank and the function block, hence the name *common rail*. Even when large quantities of fuel are extracted, the common rail maintains its inner pressure practically constant so the injection pressure remains constant.

The rail volume is permanently filled with pressurized fuel. The compressibility of the fuel resulting from high pressure is utilized to achieve the accumulator effect. When fuel leaves the rail, the pressure in the high-pressure accumulator remains constant. Similarly, the pressure variations resulting from the pulsating fuel supply from the high-pressure pump are compensated. In the inlet port, you will find a pulsation dampener or orifice that thins out the high pressure waves. You can find contamination in this area as well during diagnosis. It is also critical that all metal fuel lines be torques to specifications.

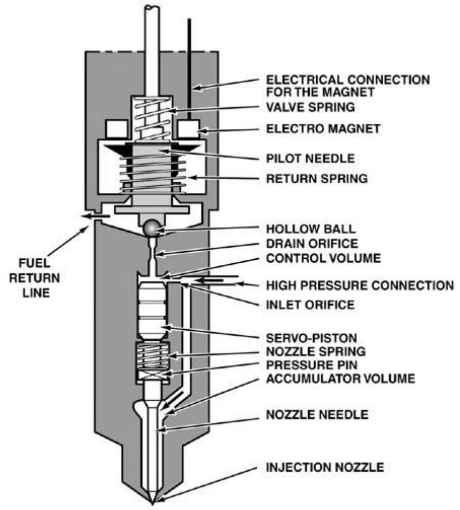


Figure 46 Fuel Injector (Disc 1 Slide)

Fuel Injector

The Duramax uses electronically controlled injectors (Figure 46). The injector's operation is divided into 4 operating states:

1. Injector closed (with high pressure applied),
2. Injector opens (start of injection)
3. Injector opened fully
4. Injector closes (end of injection).

These operating states result from the distribution of the forces applied to the injector's components. With the engine at standstill and no pressure in the rail, the nozzle spring closes the injector.

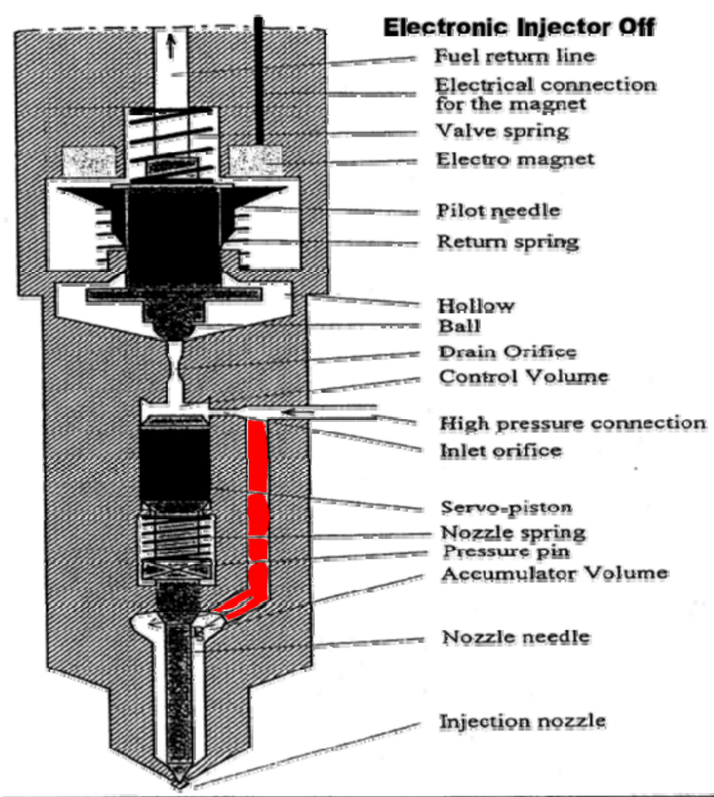


Figure 47 Injector Closed (Courtesy of Robert Bosch Corporation)

Injector Closed (At-Rest Status)

In OFF or "at-rest" state, the solenoid valve is not energized and the drain orifice is closed (Figure 47). With the drain orifice closed, the valve spring forces the armature's check ball onto the drain-orifice seat. The rail's high pressure builds up in the valve control chamber, and the same pressure is also present in the nozzle's chamber volume. The rail pressure applied at the control plunger's end face, together with the force of the nozzle spring maintains the nozzle in the closed position against the opening forces applied to its pressure stage.

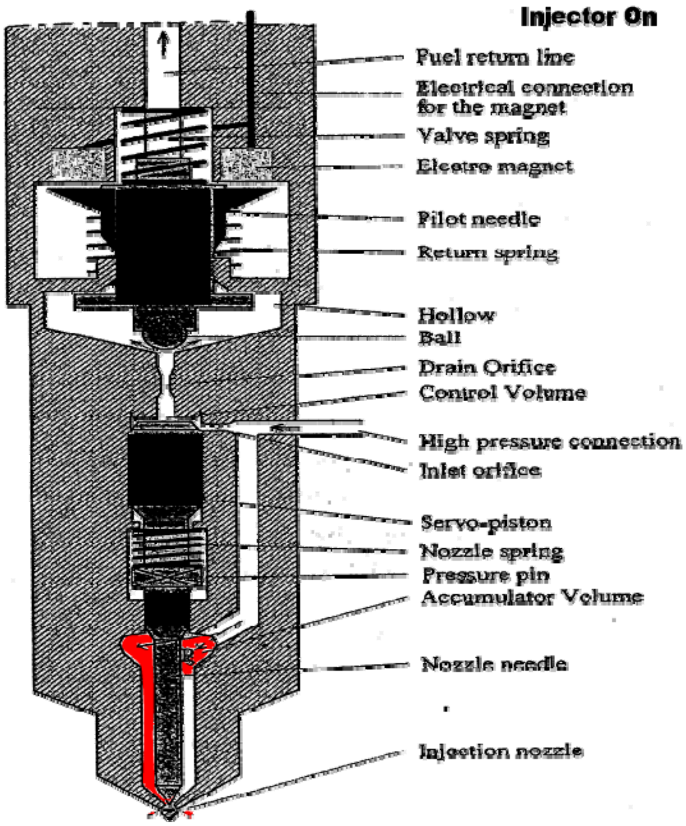


Figure 48 Injector ON (Courtesy of Robert Bosch Corporation)

Injector Opens (Start of Injection):

The injector is in its at-rest position as shown in Figure 48. The solenoid valve is energized with the pick-up current of about 20 amps, which causes the drain orifice to open quickly. The force exerted by the triggered solenoid now exceeds that of the valve spring and the armature opens the drain orifice. The high-level pick-up current is reduced to the lower holding current of approximately 12 amps required for the electromagnet. When the drain-orifice opens, fuel can flow from the valve-control chamber into the cavity situated above it, and from there via the fuel return to the fuel tank. The drain-orifice prevents complete pressure balance, and the pressure in the valve control chamber sinks as a result. This leads to the pressure in the valve-control chamber being lower than that in the nozzle's chamber volume, which is still at the same pressure level as the rail. The reduced pressure in the valve-control chamber causes a reduction in the force exerted on the control plunger, the nozzle needle opens as a result, and injection starts.

The nozzle needle's opening speed is determined by the difference in the flow rate through the bleed and feed orifices. The control plunger reaches its upper stop where it remains supported by a cushion of fuel, which is generated by the flow of fuel between the bleed and feed orifices. The injector nozzle has now opened fully, and fuel is injected into the combustion chamber at a pressure almost equal to that in the fuel rail. Force distribution in the injector is similar to that during the opening phase.

Injector closes (end of injection): As soon as the solenoid valve is no longer triggered, the valve spring forces the armature downwards and the ball closes the drain orifice. Check ball problems can cause drivability issues and injector return flow rate measurement is used for this diagnosis. Balancing rates with scan tool are used to measure injector performance.

Figure 49 Return Flow Rate Tool (Courtesy of Jim Halderman)

Return System

Fuel returns to the tank from the injectors, fuel rail pressure regulator, and the pressure-limiting valve in the junction block (LB7 only). The LLY and later engines This return occurs in parallel at the same time. The armature volume in the injector solenoid valve chamber dampens the oscillation in the armature. The counter pressure in the return line, respectively the total pressure in the armature chamber should be 4 psi to 14.5 psi (0.3 to 1 bar) in order to guarantee reproducible and sufficient damping characteristics of the fuel and air mixture in the armature chamber. Injector return flow rate measurement (Figure 49) is used for this diagnosis. You can measure return flow on each bank as part of diagnosis.

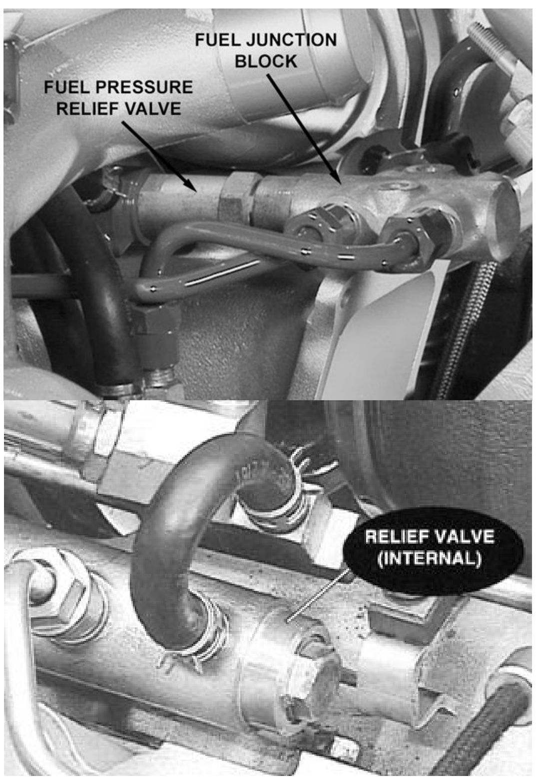


Figure 50 Junction Block & Fuel Pressure Relief Valve (Courtesy of GM)

Function Block W/Limiter Valve & Pressure Sensor

A function block (Figure 50) is located between the right and left banks of the Duramax engine to connect the right and left bank fuel rails. It contains a rail pressure sensor (LB7) and a pressure-limiting valve.

The pressure limiting valve prevents overpressure greater than 27,550 psi (190 Mpa) and is (Figure 50) mounted on the junction block (LB7). On the LLY and later engines it is located in the left fuel rail (Figure 50, bottom). This opens a return if the pressure exceeds the maximum pressure 27,550 psi (190 Mpa); the rail pressure than falls below the low pressure limit.

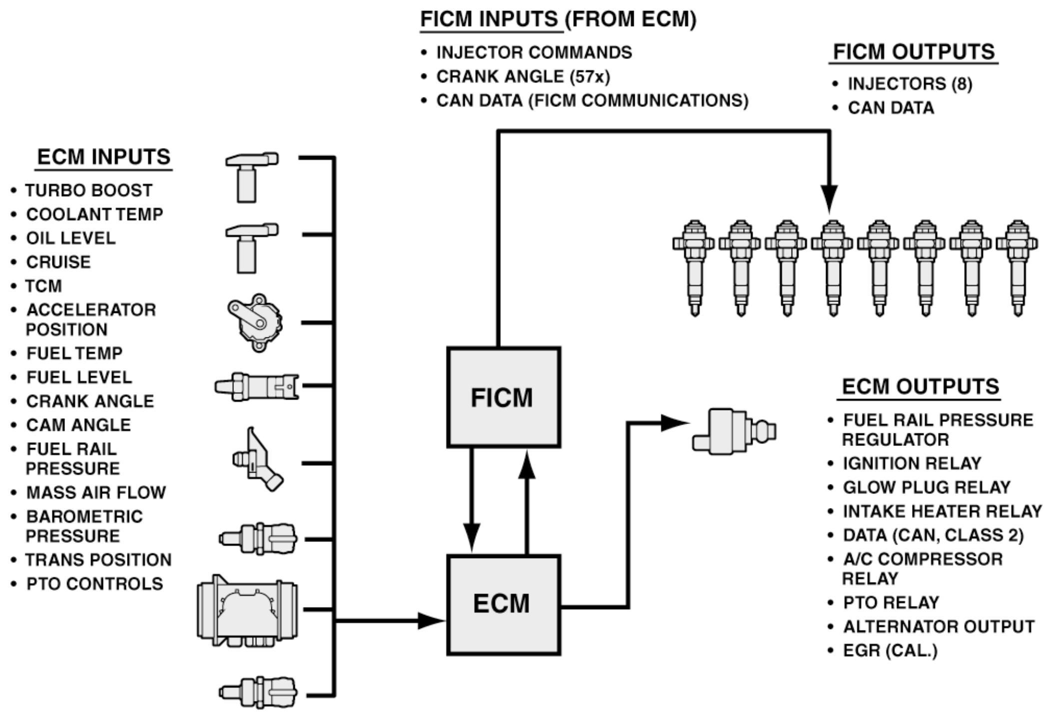


Figure 51 Fuel Management System (Disc 1 Slide)

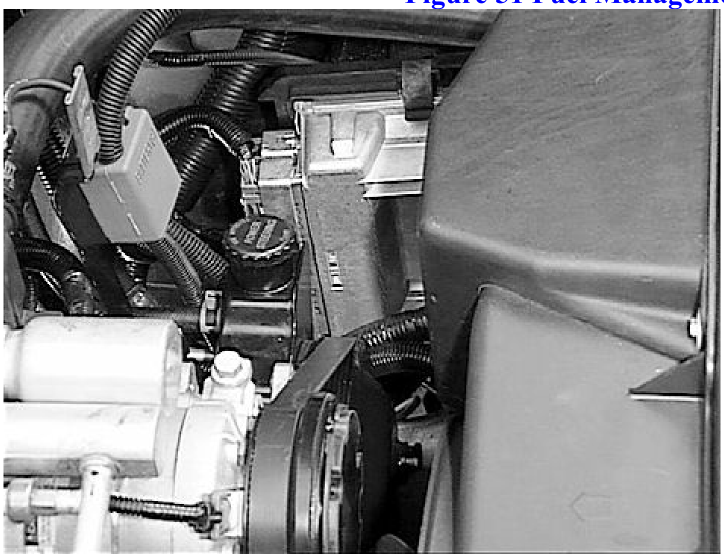


Figure 52 ECM Location (Disc 1 Slide)

ECM OVERVIEW

The Duramax uses engine management with the following groups of components (Figure 51):

- ECM Input sensors to monitor operating conditions of the engine and inputs.
- ECM Outputs or actuators that convert ECM control signals into mechanical or electronic action. ECM Functions:
  - Constant monitoring of sensors
  - Controls the engine systems
  - Performs engine diagnostics
  - Sets and stores DTCs and DTC history
  - Communicates with the instrument panel for MIL, Wait-to-Start and gauge indications
  - Coordinates with the FICM and TCM (Transmission Control Module –A/T models) for fuel and transmission control
  - Determines malfunction strategy (alternate sensor, reduce power, limp-home)
  - Located in the engine compartment on most applications (Figure 52)

The Duramax also uses a TCM (Transmission Control Module) with the Allison 1000 Automatic transmission. The TCM communicates with the ECM through the J1938 Controller Area Network or CAN, which is also called the GMLAN (GM Local Area Network).

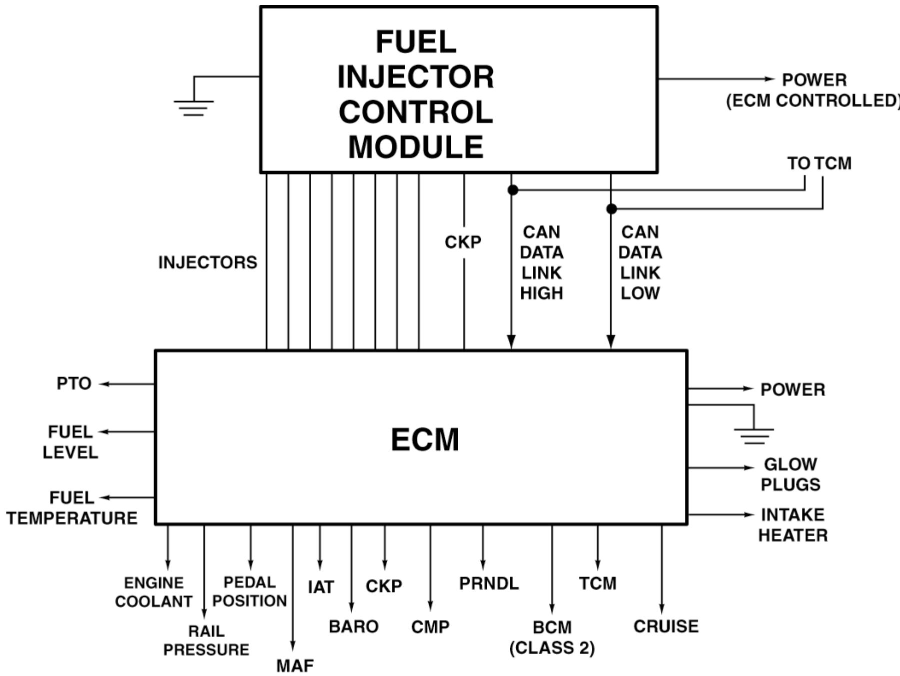


Figure 53 FICM (Disc 1 Slide)

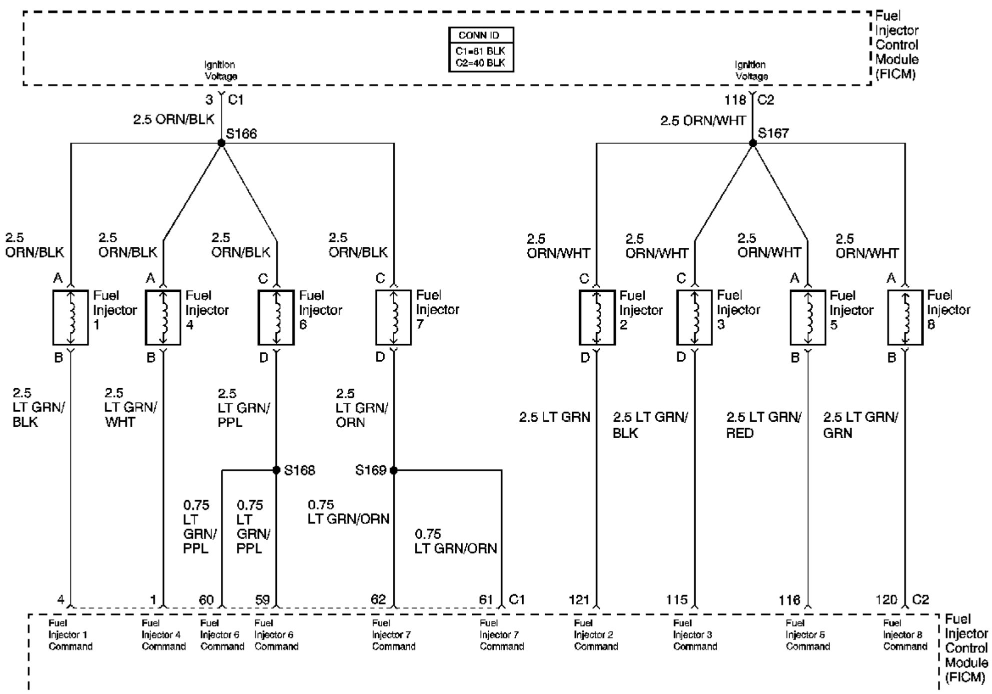


Figure 54 FICM LB7 Schematic (Disc 1 Slide)

Fuel Injection Control Module (FICM)

The ECM can handle only small amount of current, so the current needed to operate the high-speed injector solenoids comes from the Fuel Injection Control Module (FICM) as shown in Figure 53. This is an OBD II system that uses Class 2 data communication on pin 2 of the DLC (data link connector) and requires the use of a CAN Adapter for the scan tool.

The FICM is the injector driver that provides high current to the injector solenoid. The FICM contains step-up transformers and high speed switching drivers that use high voltage and current up to 96 volts and 20 amps (Figure 54). Output signals from the ECM are used to trigger drivers in the FICM to operate the fuel injectors. Diagnosis functions in the injector driver stages of the FICM detect faulty signal characteristics and these are reported to the ECM. The FICM has the diagnostic function internally without diagnostic trouble code storage and sends the error message via a J1939 GMLAN (GN Local Area Network) connection. The ECM monitors this J1939 message from the FICM, determines the DTC and turns on the MIL (Malfunction Indicator Light).

On Mid-2006 engines the fuel-cooled FICM was eliminated. The injector control voltage was reduced from 48 volts DC to 24 volts DC, which also lowered the control current. This change, combined with a more air-cooling on the ECM, allowed Bosch and GM to integrate the FICM into the ECM and eliminate the separate fuel-cooled FICM. The 2006 Bosch-manufactured ECM incorporates the first application of a powerful E35 controller. This 32-bit processor can support up to 5 injection pulses per combustion event.

The ECM monitors its GMLAN connection with the FICM for OBD II related error messages. If it detects a DTC, the ECM: determines DTC, stores a freeze frame, & turns on the MIL.

If a misfire DTC is not set and you suspect insufficient fuel delivery, you can perform a cylinder balance, check using a scan tool. A balancing rate that exceeds: 7mm^3 (cubic millimeters) indicates that the system is trying to compensate for insufficient fuel.

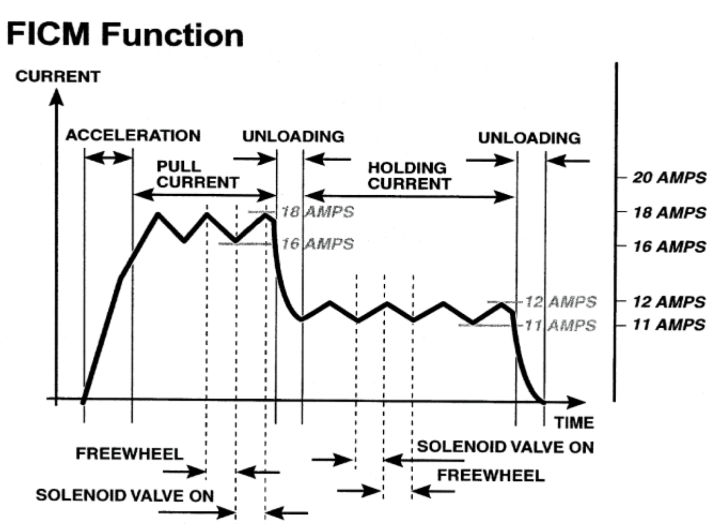


Figure 55 FICM Function (Courtesy of GM)

FICM Function

Current needed to operate the high-speed injector and solenoids comes from FICM that performs the following tasks:

- Creates current based on the Crankshaft Position (CKP) signal and ECM requests provided wiring (Figure 55).
- Capacitors are recharged by capturing voltage spike generated by the collapse of the magnetic field when injector solenoid is turned off.
- Generates heat when operating; fuel passes through it used as a coolant.
- Output signals from ECM used to trigger drivers in the FICM to operate the fuel injectors

The injector driver stage current generates a magnetic force in the triggering element. The coil must be triggered with steep current. This necessitates high voltages being made available in the FICM.

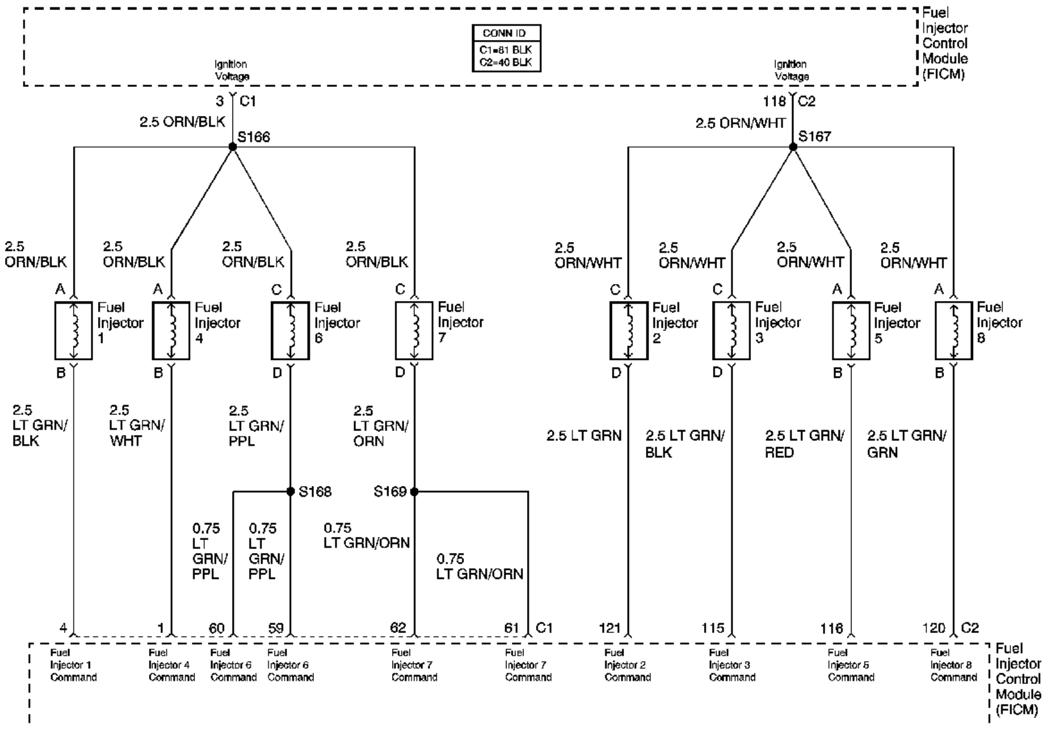


Figure 56 FICM LB7 Schematic (Disc 1 Slide)

When the ECM detects a fault, it monitors the message from the FICM, determines the DTC, stores a freeze frame and turns on the MIL. The FICM monitors injector current and sends the following to the ECM (Figure 56):

- High Side Driver (HSD) Over Current Error
- Load Drop

Low Side Driver (LSD) Over Current Error

- Booster Voltage Low

When the ECM receives one of these errors, it sets the proper injector circuit DTC (P0201-P0208).

The ECM also monitors the output circuits to the FICM for faults and can store the following DTCs:

- Injector Output Circuit Diagnosis-(P1223, P1226, P1229,P1232,P1235,P1238,P1241, PI 244)
- High Resolution Circuit (P0370), High Resolution Circuit Performance (P0374)

Injector "Blank Shot"

In order to generate the high voltage and current to fire the injectors, the FICM acts as a capacitor. It captures current generated from the collapsing magnetic field of each injection and uses it to fire the next injector. The FICM fires each injector so that electrical current can be captured for the next firing. To maintain the high levels of current even in cases where fuel isn't needed during deceleration, the FICM fires ***blank*** shots to the injectors. These short firings allow the FICM to maintain its electrical build up needed to fire the injectors when they require fuel.

The blank shot allows cool fuel to flow into the injector control chamber and cool the check ball. The blank shot occurs if the vehicle is decelerating and the APP (Accelerator Pedal Position) is at 0%. During a blank shot:

- Injector solenoid is energized
- Drain (Bleed) orifice opens
- Small amount of fuel spills out of injector to the return line
- Solenoid turns off (after 150 milliseconds)
- Injector needle valve never lifts from its seat
- Blank shot can be viewed on a scan tool

OBD II Misfire

The ECM monitors the J 1939 CAN connection for OBD II related error messages from FICM. If it detects a DTC (diagnostic trouble code), the ECM does the following:

- Determines the DTC
- Stores freeze frame
- Activates MIL Misfire parameters:
- Misfire code registers after engine is running at idle for more than 90 seconds
- Engine temperature must be > 56°C/132°F

The ECM receives the following injector current problems from the FICM:

- High Side Driver Over Current
- Low Side Driver Over Current Load Drop
- Booster Voltage Low

If a misfire DTC is not set and you suspect insufficient fuel delivery, you can perform a cylinder balance check using a scan tool. A balancing rate that exceeds± 7mm3 indicates that the system is trying lo compensate for insufficient fuel.

The ECM is programmed to handle a single injector failure differently than the failure of a group of cylinders. FICM monitors fuel injector current draw. Under or over value is registered with the FICM that sends an error signal to the ECM. The ECM receives one of these errors and sets a diagnostic trouble code (DTC).

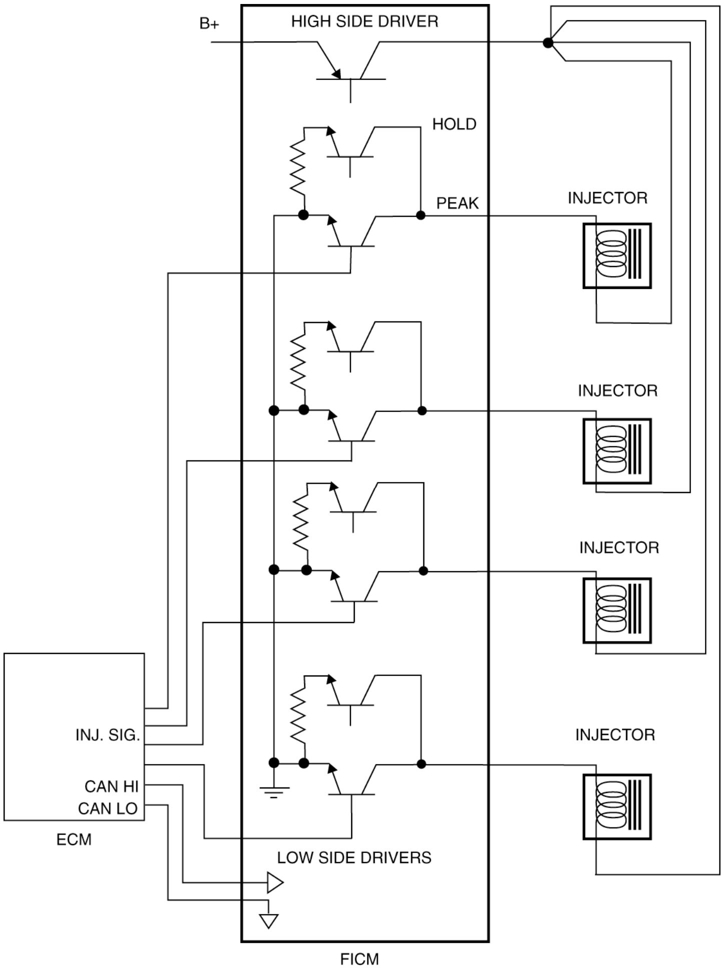


Figure 57 Injector Drivers (Disc 1 Slide)

FICM Drivers

Each injector has two drivers (Figure 57):

- High-side driver (HSD) - delivers high voltage, B+ side of injector solenoid
- Low-side driver (LSD) - provides common ground on the negative side of the injector solenoid There are 10 transistor (5 per bank) drivers for these functions:
- 2 for B+, 8 for grounds

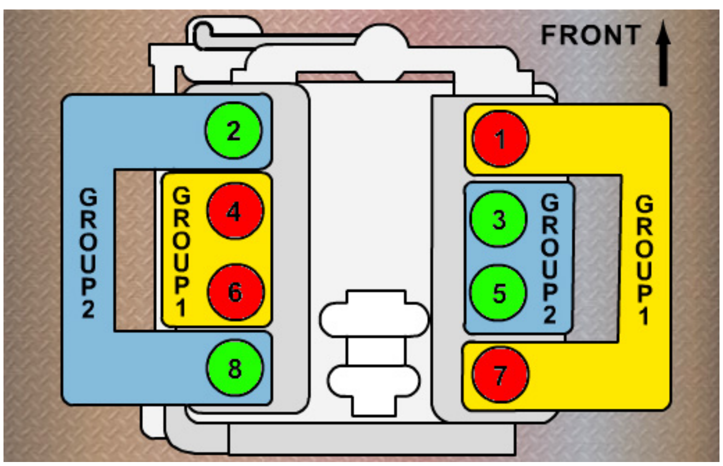


Figure 58 Cylinder Firing Groups (Disc 1 Slide)

Injector Firing Groups

The injectors are fired in groups. Group 1 and group 2 divide the injectors electronically (Figure 58). **Group 1** is cylinder's 1-4-6-7 with 1 and 7 on the right bank and 4 and 6 on the left bank uses DTC 1261. **Group 2** is cylinders 2-3-5-8 with 3 and 5 on the right bank and 2 and 8 on the left bank and uses DTC 1262. DTC 1261sets when the HSD or LSD circuit is open on Group 1 (1-4-6-7) for about 32 ms as detected by the FICM. The ECM commands the FICM to boost the fuel to Group 2 (2-3-5-8) and shut down Group 1 and the engine will limp on just the four cylinders in Group 2. DTC 1262 sets when the HSD or LSD circuit on Group 2 (2-3-5-8) is open for about 32 ms as detected by the FICM. The ECM commands the FICM to boost the fuel to Group 1 and shut down Group 2 and the engine will limp on just the four

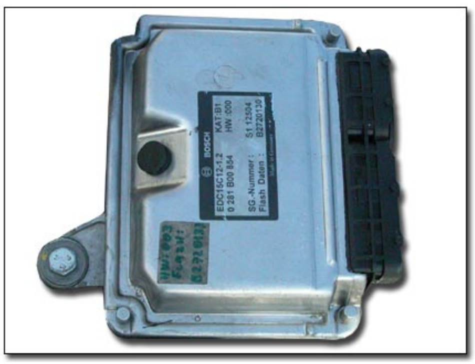


Figure 59 LLY FICM (Courtesy of Jim Halderman)

cylinders in Group 1.

DTC codes P0201 through P0208 are used for individual circuit problems in injectors 1 through 8 and P1261 and 1262 for open or grounded circuits in injector Banks 1 or 2. If codes P0201 through P0208 set and the engine rpm does not stabilize the ECM will command the FICM to shut down the affected injector Group, either 1 or 2. The Reduced Engine Power message indicates one of the Groups has been shut down.

LLY FICM

The 2005 LLY (Figure 59) and later engines have voltage control circuits that are divided into two groups of 4 cylinders each. On the 2005 LLY there are four groups of cylinder voltage circuits. So there are 2 cylinders on each group. The injector drivers have internal diagnostics that detect electrical faults, such as opens, shorts to voltage and shorts to ground. When an error is detected, a 32 bit message enables the ECM to determine the injector number, injector driver group number and the injector driver chip number.

If only the individual injector DTC, P0201-P0208 sets, only the affected injector is shut off. If a DTC is set for the injector driver group, both injectors in the affected group are turned OFF.

E35 Bosch ECM

The added processing power of the Bosch E35 controller eliminated the FICM. During the manufacturing process, the flow quantity of each injector is measured and this data, together with the injector's cylinder position, is stored in the memory of both the Glow Plug Control Module and the ECM. The 32-bit ECM can use injector flow data to precisely meter fuel delivery to individual cylinders and compensate for flow variations among individual injectors.

SENSOR OVERVIEW

The ECM inputs are shown to the left in Figure 60 and the outputs or actuators are shown on the right.

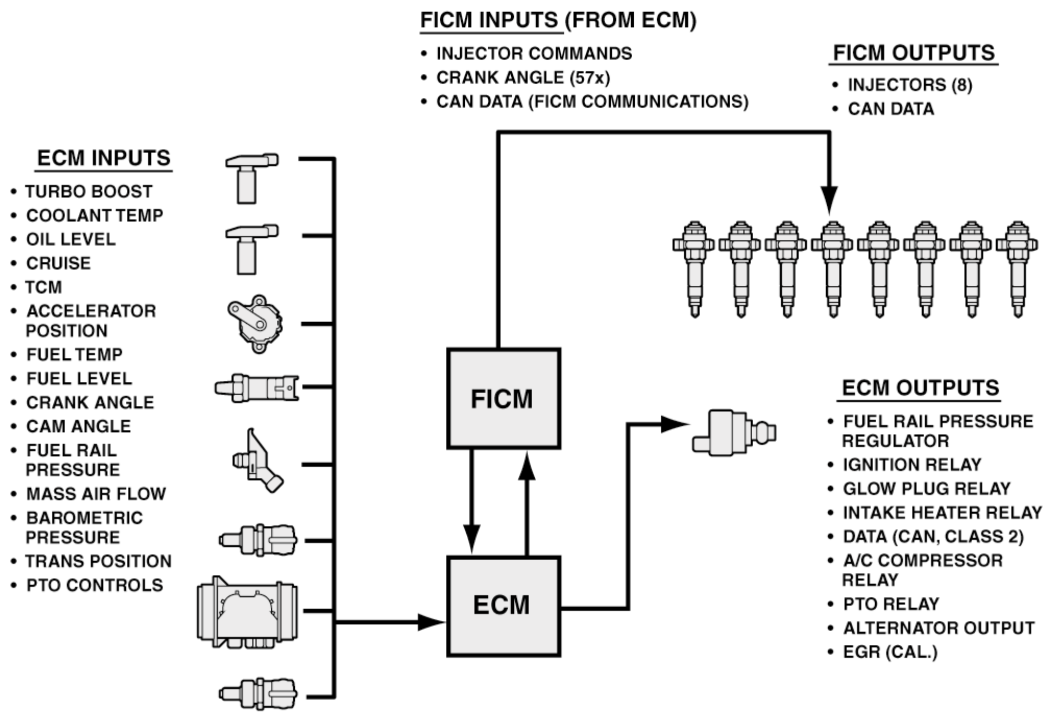


Figure 60 Fuel Management System (Disc 1 Slide)

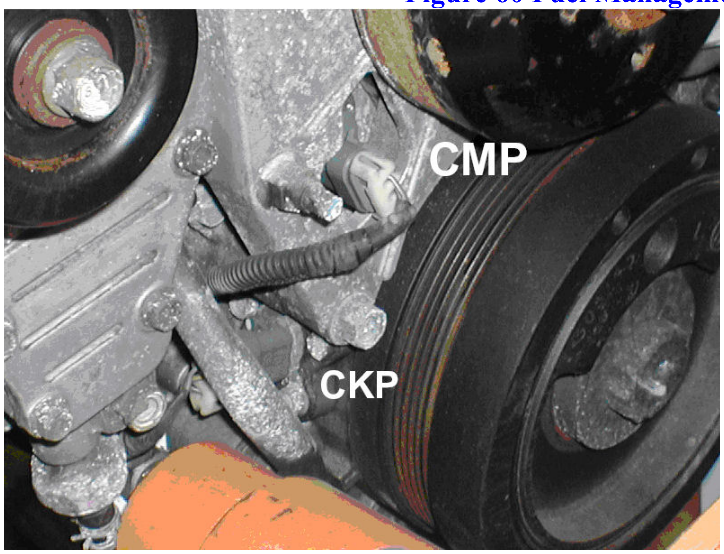


Figure 61 CMP and CKP sensors (Disc 1)

Sensors

Crankshaft Position (CKP) sensor, mounted at the front engine cover, identifies engine speed and generates a 57X signal to the ECM (Figure 61).

Camshaft Position (CMP) sensor, located at the front engine cover, provides a 3X signal to identify piston position (Figure 61).

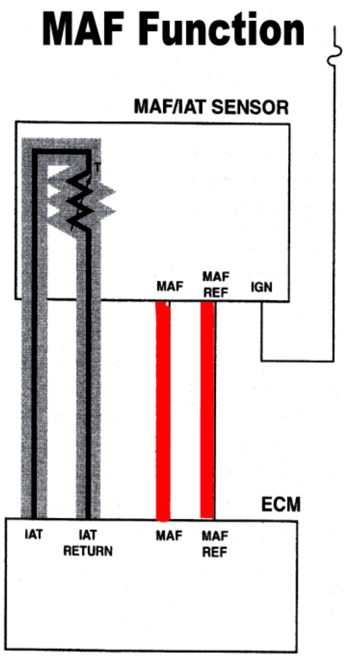


Figure 62 MAF Sensor Function (Courtesy of Robert Bosch Corporation)

Mass Air Flow (MAF) sensor, mounted on the intake air assembly, measures the volume of intake air for fuel management decisions (Figure 62).

Intake Air Temperature (IAT) sensor is integral with the MAF sensor and identifies intake air temperature for the ECM (Figure 62).

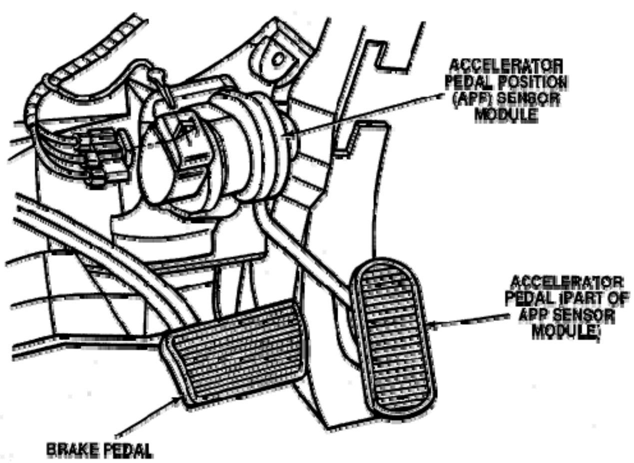


Figure 63 APP Sensor (Courtesy of GM)

Accelerator Pedal Position (APP) sensor, (Figure 63) located on the accelerator pedal assembly, identifies the driver's demand for acceleration to help the ECM accommodate increasing demands for fuel. The APP sensor uses 3 individual sensors inside a housing mounted on the accelerator pedal control assembly. Three separate signal, low reference, and 5-volt reference circuits connect the accelerator pedal sensor with the ECM. Each sensor has a specific function that determines pedal position. APP sensor 1 voltage increases as the accelerator pedal is depressed, from below 1.0 volts at zero pedal travel to above 2.0 volts at 100 percent pedal travel. APP sensor 2 voltage decreases from above 4.0 volts at zero pedal travel to below 3.0 volts at 100 percent pedal travel. APP sensor 3 voltage decreases from above 3.8 volts at zero pedal travel to below 3.3 volts at 100 percent pedal travel.

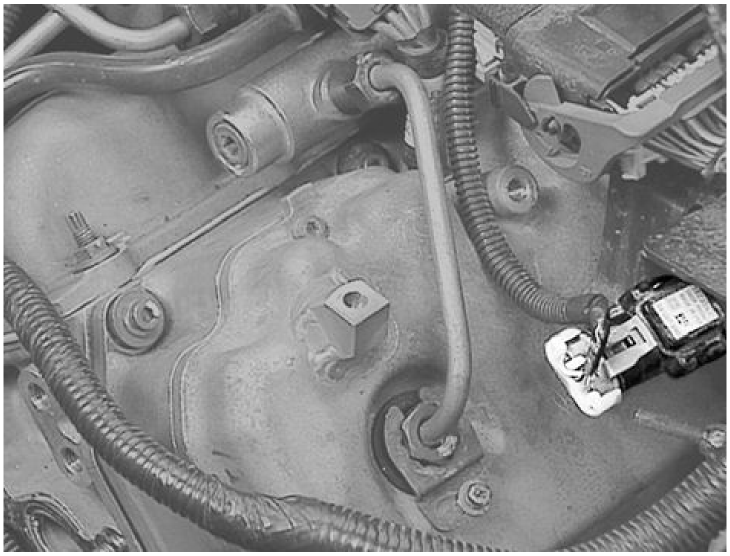


Figure 64 Baro and Turbo Boost Sensor (Courtesy of AC Delco)

Barometric (Baro) Pressure Sensor: located at the left valve cover, identifies barometric pressure for the ECM (Figure 63). This air pressure reading is used to fine tune the fuel supply.

Turbo Boost Sensor: Located in the intake manifold, it measures absolute pressure and functions as a Manifold Air Pressure (MAP) sensor (Figure 64).

Figure 65 Low Oil Level Switch (Disc 1)

Low Oil Level Switch: Mounted on the oil pan to identify when the oil level is low (Figure 65).

Oil Pressure Sensor: Mounted on the side of the block in the main pressure port. Monitors oil pressure for engine shut-down.

Brake Switch: input to the ECM, used for fuel delivery conservation.

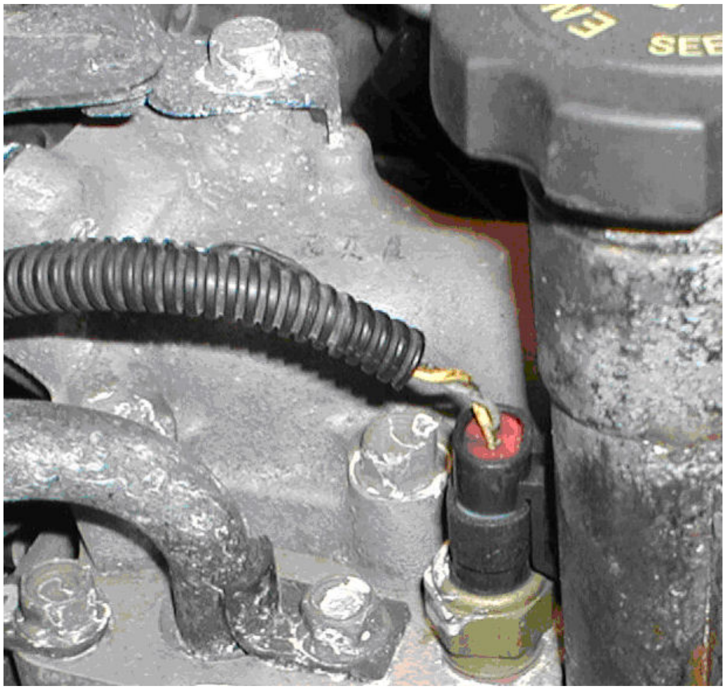


Figure 66 ECT Sensor (Disc 1)

Engine Coolant Temperature (ECT) Sensor:

The ECT is thermistor where the resistance is inversely proportional to temperature of the thermistor. As the temperature increases the resistance decreases so that the voltage input to the ECM changes with the engine temperature. Low coolant temperature produces high resistance and high coolant temperature produces low resistance. It is threaded (Figure 66) into the engine coolant jacket, in direct contact with the engine coolant. The coolant sensor provides the computer with an engine coolant temperature reading.

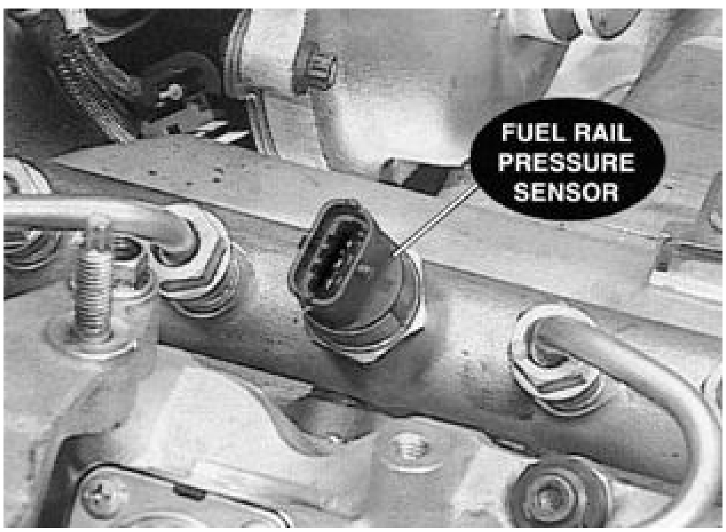


Figure 67 Fuel Rail Pressure sensor (Courtesy of GM)

Fuel Rail Pressure Sensor: input to the ECM to adjust fuel high pressure fuel using the fuel rail pressure regulator (Figure 67).

Fuel Temperature Sensor: located in the return line. It provides a signal to the ECM to fine tune fuel delivery.

EGR Valve Position Sensor: used on California emissions engines. The ECM uses an Exhaust Gas Recirculation (EGR) feedback signal to monitor EGR valve performance.

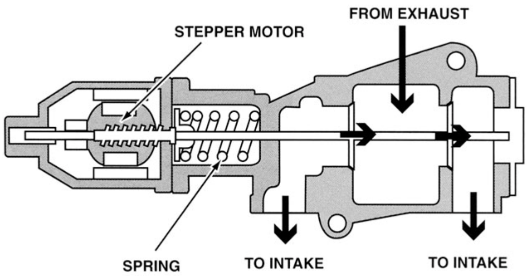


Figure 68 Digital EGR Valve (Disc 1 Screen Capture)

Digital EGR

The RPO LLY version of the Duramax 6600 diesel engine uses an Exhaust Gas Recirculation (EGR) system with digital control. Previously, the RPO LB7 version certified for California emissions was equipped with a vacuum-operated EGR system. The digital EGR valve is shown in Figure 68.

Some of the gas from the engine exhausts stream flow through a cooler, where heat from the gas is transferred to engine coolant. When the ECM operates the EGR valve, a controlled amount of exhaust gas enters the air intake system. The EGR lowers gas temperature during combustion by displacing oxygen, which reduced Oxides of Nitrogen (NOx).

Grounds

The main engine and **ECM grounds** are located on the left side of the engine and are very close to the ground and subject to corrosion. Be sure to check these ground connections in the course of any diagnosis.

Figure 69 Injector Wiring Harness

Injector Wiring

Make sure that you check the injector wiring (Figure 69) for frayed wires and that the terminals are tight on the injectors

FICM Connectors

Check the FICM connectors to be sure they are tight and fully seated into the FICM.

ECM Connectors

There are two ECM connectors located on the Left side of the engine, which connect the FICM and the ECM. The wring from these connectors goes down and under to connect to the FICM. Make sure that these connectors are fully seated and free of corrosion.

FICM Vent

A vent is located on the top of the FICM for venting air. Make sure that it is open and do not allow any fluids to enter the vent.

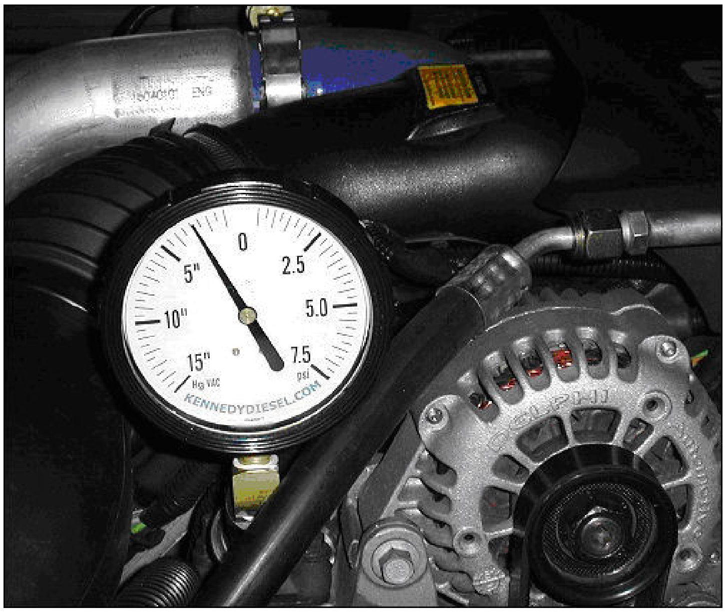


Figure 70 Combination Gauge (Courtesy of Jim Bigley, thediesel.page.com 1)

SUCTION TESTING

Use a combination gauge shown in Figure 70, which is a vacuum and pressure gauge along with clear plastic hose connected by a tee. Install a this transparent hose between the FICM outlet and the fuel filter inlet to check for the following:

- Suction pressure
- Presence of air on the supply side
- Pressure test Key ON, Engine OFF: Pressurize the system to check for leaks

You are looking for no more that 5 inches of mercury of suction as shown in Figure 70. The technician is measuring suction and will not see any positive pressure. Too much suction is a restriction usually caused by the filter or the Seran pickup sock in the fuel tank. BioDiesel fuel can cause a waxy buildup on the pickup sock. Test drive the vehicle with the gauge apparatus connected to find intermittent problems. ***For drivability diagnosis always start with this test.***

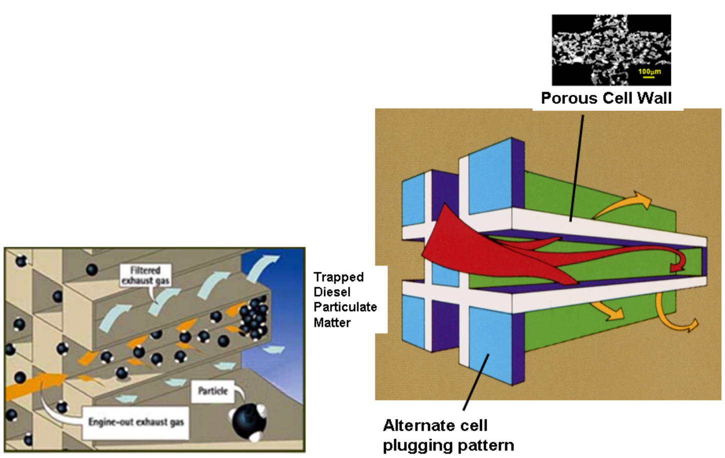


Figure 71 Diesel Particulate Filter (DPF) Courtesy of GM

Diesel Particulate Filter (DPF)

The Diesel Particulate Filter (DPF) used on the LMM engine at this time, collects diesel exhaust gas particulates, preventing their release into the atmosphere (Figure 71). This is done by pushing particulate-laden exhaust through a filter substrate of porous cells (catalytically coated, silicon carbide filter) that removes particulates from the exhaust gas. The exhaust enters the filter and because every other filter cell is capped at the opposite end, the exhaust particulates cannot exit the cell. Rather, the exhaust passes through the porous walls of cell leaving the particulates trapped on the cell wall.

The cleaned exhaust gas exits the filter through the adjacent cell. The PDF can reduce more than 90% of particulate matter (PM).

To prevent clogging, particulate matter is burned off, leaving ash and yielding carbon dioxide and small amounts of water

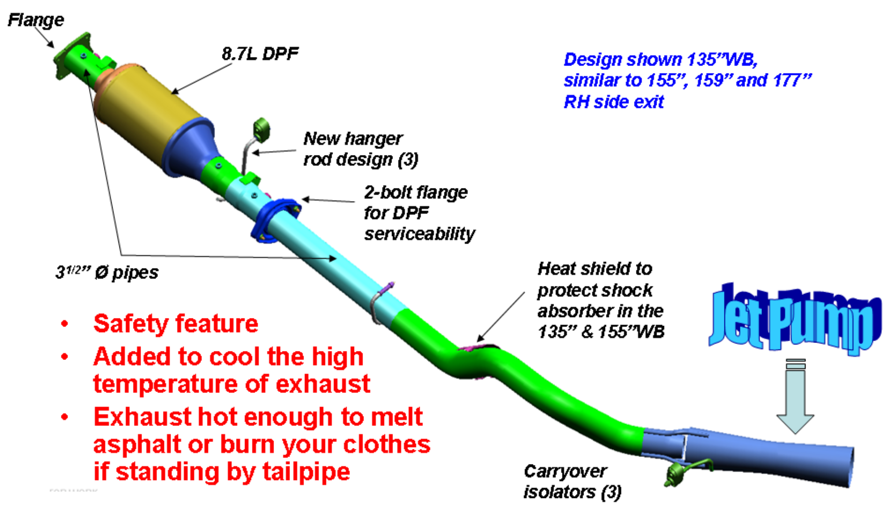


Figure 72 PDF Layout (Courtesy of GM)

PDF System Configuration (Figure 72)

Exhaust Gas Temperature (EGT) Sensor 2

Differential Pressure Sensor (DPS)

Diesel Oxidation Catalyst (DOC)

Exhaust Particulate Filter (EPF)

Differential Pressure Sensor (DPS) Pressure lines

Exhaust Gas Temperature (EGT) Sensor 1

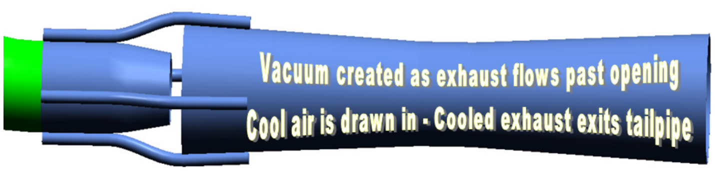


Figure 73 Jet Pump (Courtesy of GM)

Jet Pump

A jet pump (Figure 73) similar to a carburetor Venturi is used at the tailpipe to create a low pressure area or vacuum. It draws in cool air that cools the exhaust as it exits the tailpipe.

DISC 2 DIAGNOSIS

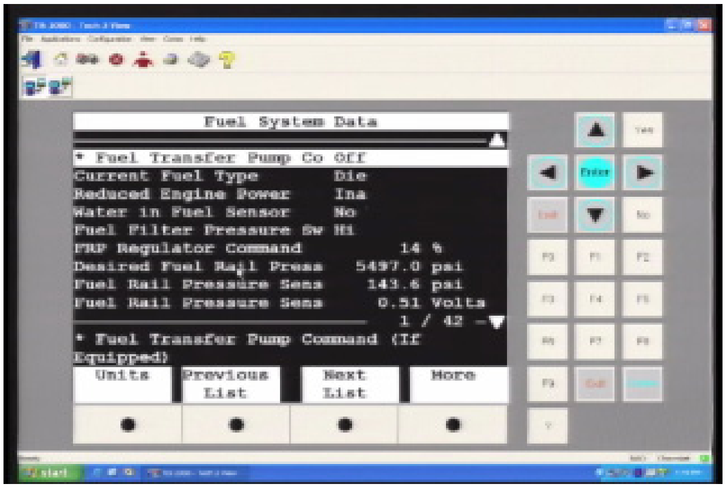


Figure 74 Tech 2 Scan Tool Screen View Showing FUEL SYSTEM DATA (Disc 2)

SCAN TOOL DIAGNOSTICS

The processes covered will require the use of the GM Tech 2 Scan Tool (Figure 74) and a laptop personal computer (PC). We are using an RS232 cable that comes with the Tech 2 connected to one of the PC com ports (9-pin connector). Tech 2 View Software is required.

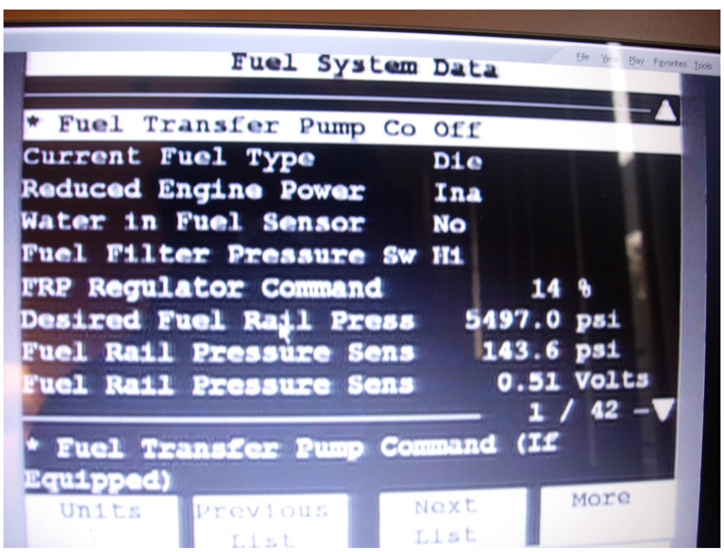


Figure 75 Tech 2 Scan Tool Screen View Close-up showing Desired Fuel Rail Pressure Sensed (Actual) Fuel Rail Pressure (Disc 2)

The two area primarily used for fuel system diagnosis are:

Desired Fuel Rail Pressure

Sensed (Actual) Fuel Rail Pressure

In Figure 75, you see a desired fuel rail pressure of 5,497 psi and a sensed or actual fuel pressure of 143.6 psi. Question to ask: does the sensed or actual fuel rail pressure meet the desired fuel rail pressure. The engine is always varying the pressure, which is unlike a gasoline engine. Sometimes the engine may require 5,000 psi and at other times it may need 10,000 psi. If a problem is found in these values not matching, we would test suction pressure and fuel supply.

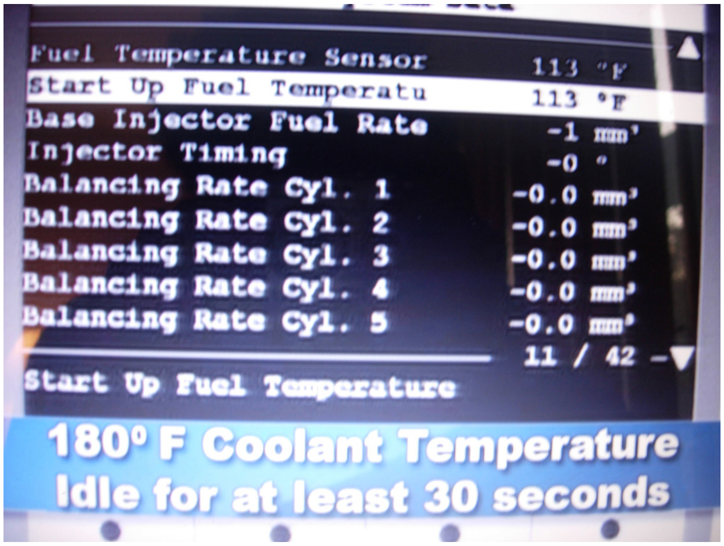


Figure 76 Tech 2 Scan Tool Screen View showing BALANCING RATE under Fuel System Data (Disc 2 Photo)

Scan Tool Parameter	Units	Typical Data Value
Actual Fuel Rail Pressure	Mpa/PSI	37-40 Mpa/5200-5800 PSI
Balancing Rate Cyl. 1-8	mm^3	-2.5 to +2.5

Balancing Rate

Balancing rate (Figure 76) is the Fuel Trim on a gasoline engine. It tells us if the ECM is adding or subtracting more fuel, where the gasoline engine is going rich or lean in terms of fuel air mixture. The display is in cubic millimeters (mm^3). The primary inputs are the CMP (Camshaft position) and CKP (Crankshaft position) sensors.

Rule #1: You need to be at least an operating engine temperature of 180° F at idle for 30 seconds (Figure 82). Truck needs to be in DRIVE with parking brake applied and in neutral at idle.

The ECM is looking at cylinder contribution and calculating how much power contribution each cylinder has.

Important: If any DTCs other than DTC P0300-P0308 are set, refer to Diagnostic Trouble Code (DTC) List - Vehicle.

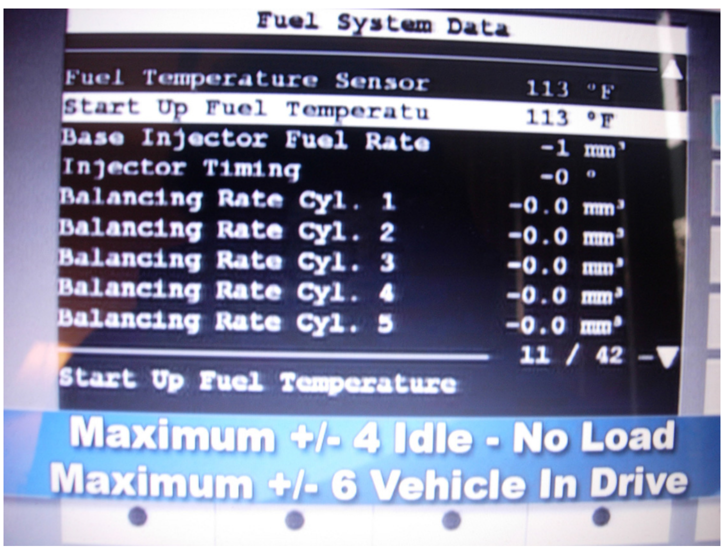


Figure 77 Tech 2 Scan Tool Screen showing BALANCING RATE SHOWING FUEL LIMTS +4 mm^3 and -4 mm^3 in Neutral or Park and between +6 mm^3 and -6 mm^3 in Drive (Disc 2 Photo)

Fuel Injector Balance Test with Tech 2

The fuel injector balance test (Figure 77) is performed when a misfire, knock, excessive smoke, or rough running condition exists with no electrical DTCs. This test uses the Balance Rate and Cylinder Power Balance test to identify cylinders that are not producing the designed power output. The balance rate adjustments are utilized by ECM only at idle. The balance rates are the fuel adjustments for each individual cylinder based on the variations in engine crankshaft speed. The balance rates will change depending on if the transmission is in Neutral or Drive. During the Cylinder Power Balance portion of the test, the ECM turns OFF individual injectors while the engine is running. The ECM adjusts for the drop in engine RPM during cancellation and may not change on the scan tool display. The lack of power at the cancelled cylinder will feel like a misfiring cylinder or vibration. If a fuel injector is turned OFF and there is a no difference felt when compared to the other cylinders, that cylinder is identified with the concern. If the customer concern occurs during idle or during off-idle tip in acceleration, the balance rates are used to identify the cylinder with a fault related to the fuel injector or engine compression.

1. Start and run the engine until the engine coolant temperature (ECT) is more than 82°C (180°F).
2. Turn OFF all accessories.
3. Perform the fuel pressure regulator test
4. If the fuel pressure regulator graph was not normal, replace the fuel pressure regulator.
5. Apply the parking brake and place the transmission in Drive.
6. Hold the brake pedal in the fully applied position. A hiss will be noticeable when the brake is fully applied.
7. Idle the engine for more than 30 seconds.
8. Observe the Balancing Rate parameters with a scan tool and record the values for Cylinders 1-8.
9. Repeat steps 4-7 with the transmission in Neutral.
10. Balance Rates should be between +4 mm^3 and -4 mm^3 in Neutral or Park and between +6 mm^3 and -6 mm^3 in Drive. Perform the Cylinder Power Balance Test in Special Functions if not within the specifications.
11. Record any cylinders that indicate a different cylinder power contribution and compare Balance Rates previously recorded with Cylinder Power Balance results.
12. If the Balance Rates were not high or the **Cylinder Power Balance** test did not indicated a cylinder with a different power contribution, refer to Diagnostic Aids.

Figure 78 Clear plastic hose in the SUCTION side (Courtesy of GM)

Suction Pressure

One of the first rules in fuel system diagnosis is to check the following first:

- Suction pressure (Figure 78)
- Presence of air on the supply side
- Pressure test Key ON, Engine OFF: Pressurize the system to check for leaks

Also utilize the scan tool record feature and drive the truck on the highway for a more accurate diagnosis. Loss of fuel rail pressure can be caused by restrictions and blockages in the fuel supply system.

- Disconnect the fuel return line at the engine. Refer to Metal Collar Quick Connect Fitting Service.
- Remove the fuel filler cap.
- Apply 6.9 kPa (1 psi) of pressure air into the fuel return at the engine. Air flow should be detected at filler tube.
- If air flow was not detected at the filler tube, disconnect the fuel return line at the fuel sender and apply 6.9 kPa (1 psi) of air pressure into the fuel return line at the engine.
- If air flow was present, replace the fuel sender assembly.
- If no air flow was present, inspect for a restricted or a damaged fuel return line. Repair or replace the fuel return line.

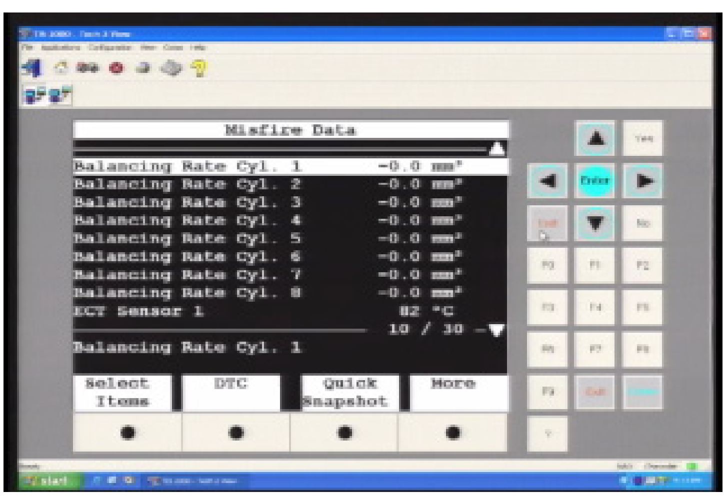


Figure 79 Misfire Data on Scan Tool (Disc 2 Screen Capture)

Analyzing Misfire Data

The engine control module (ECM) monitors changes in crankshaft speed using input from the crankshaft position sensor (Figure 79). The ECM adjusts the fuel delivery to each cylinder in order to minimize crankshaft speed changes. If the ECM identifies a cylinder or cylinders requiring an excessive amount of fuel in order to maintain the correct crankshaft speed, a DTC will set.

Conditions for Setting a Misfire DTC: Cylinder RPM is less than the minimum average cylinder speed after an injection event counted 180 times. Always look at and use RPM data for diagnostic analysis. Be sure to scroll down the data list under Misfire Data to see those sensor inputs that apply to a misfire.

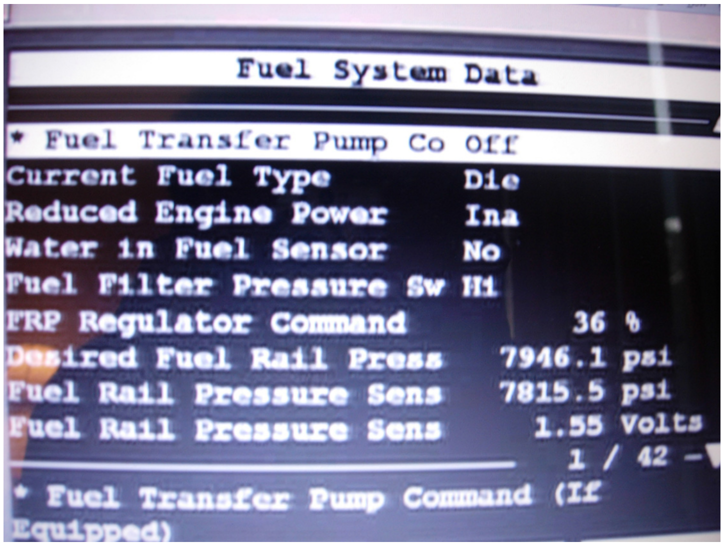


Figure 80Fuel System Data showing a change in the sensed fuel rail pressure (Disc 2 Photo)

Engine Running Measuring Fuel Rail Pressure

The engine is started and you can see in Figure 86 that the Actual or Sens Fuel Rail Pressure has gone from 143.6 psi to 7815.5 psi (Figure 80). Under no load as the RPM was increased the two pressures desired and actual or sensed were even or very close to each other. You are looking for a change in fuel rail pressure. There was a bit of a delay but they did catch up. The actual and the desired fuel rail pressure should always be close to or meet each other.

Figure 81 Live Plot on Scan Tool (Disc 2 Photo)

Live Trace Plot

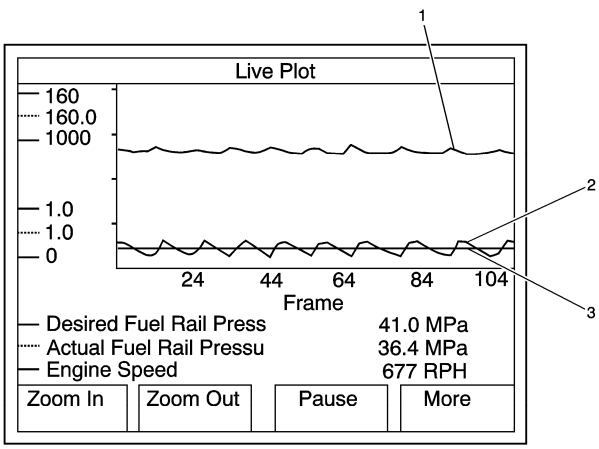
Fuel Rail Pressure Regulator (FRPR) Diagnosis:

Looking for a sticking FRPR. The graph on the screen shows there parameters being plotted:

- Engine Speed
- Fuel Rail Pressure Sens
- Desired Fuel Rail Pressure

Fuel Pressure Regulator Diagnosis

The Fuel Pressure Regulator graphing procedure (Figure 81) offers valuable information on regulator performance by comparing desired and actual fuel rail pressure. An almost perfect comparison between actual rail pressure and desired rail pressure is found on a fairly new, low mileage engine. A minor ripple is acceptable behavior for the fuel rail pressure regulator and is seen on high mileage engines. A "shark tooth" fluctuation in actual fuel rail pressure indicates a sticking pressure regulator. Set up the following Min/Max ranges for graphing the fuel rail pressure on scan tool:



(1) Engine Speed
(2) Actual Fuel Rail Pressure
(3) Desired Fuel Rail Pressure

Figure 82 Live Plot showing a surging FRPR (Courtesy of GM)

- Engine Speed Min/Max range is 0-1,000 RPM.
- Actual Fuel Rail Pressure Min/Max range is 1-160 MPa.
- Desired Fuel Rail Pressure Min/Max is 1-160 MPa.
- Start and idle the engine.
- Observe the live plot for sharp changes or shark tooth pattern in the Actual Fuel Rail Pressure while performing the following actions:
- Idling the engine
- Shifting the transmission from Park to Drive and back to Park
- Turning the steering from left stop position to right stop position
- Turning the air conditioning ON and OFF
- If there is a violent fluctuation in the Actual Fuel Rail Pressure as seen in the surging graph below, replace the fuel pressure regulator. Figure 82 shows a FRPR that has a surge.

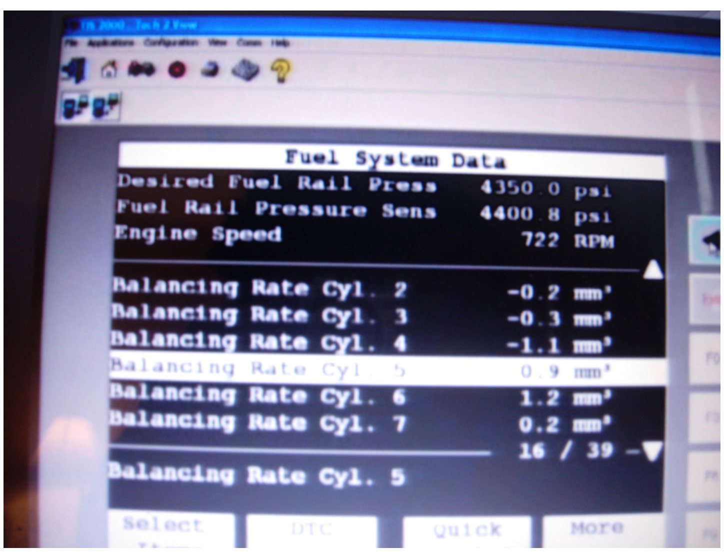


Figure 83 Fuel System Data showing Injector Balancing Rates (Disc 2 Photo)

Checking Fuel Balance Rates

The Balance Rates shown in Figure 83 are all normal. Balance Rates should be between +4 mm^3 and -4 mm^3 in Neutral or Park and between +6 mm^3 and -6 mm^3 in Drive. Perform the Cylinder Power Balance Test in Special Functions if not within the specifications.

If these balance rates are out of specifications and suction pressure was OK and there was no air in the fuel, there may be an injector issue.

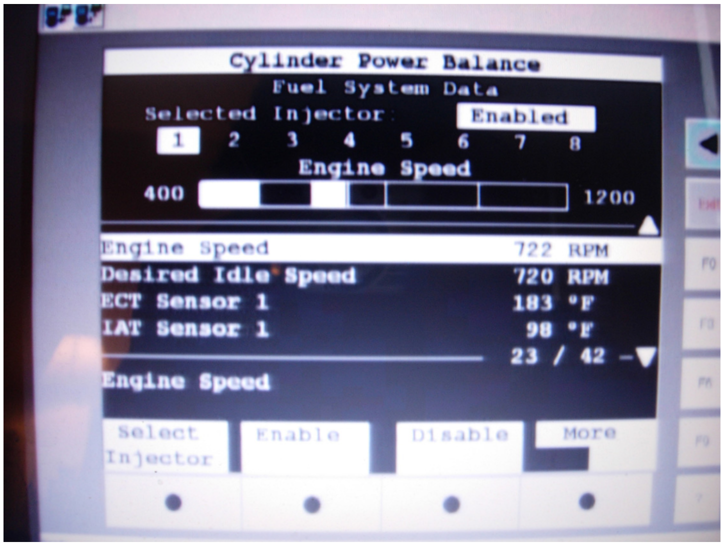


Figure 84 Power Balance Test Screen (Disc 2 Photo)

Cylinder Power Balance Test

- After Tech 2 power-up, choose the 6.6L Duramax engine from the menu selections.
- Select the PowerTrain Option from the menu
- Press F2 for SPECIAL FUNCTIONS.
- Press F2 on the SPECIAL FUNCTIONS menu for FUEL SYSTEM.
- Press F0 for CYLINDER POWER BALANCE TEST and follow the Tech 2 instructions to perform the test (Figure 84).

You short out cylinders looking for a significant difference in the two RPM values in Figure 90 to determine if they are contributing to the engine load. Even if all 8 injectors balance OK, it may be that the ECM has compensated for other problems, such as a bad valve or low compression.

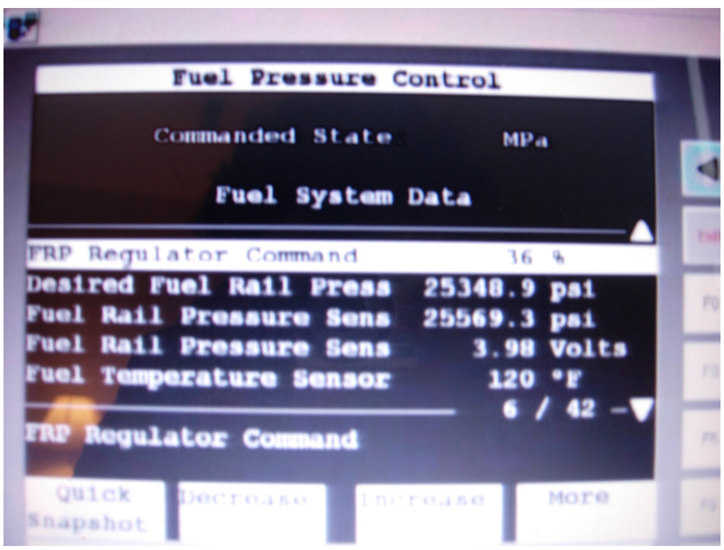


Figure 85 Fuel Pressure Control Screen (Disc 2 Photo)

Fuel Pressure Control

Total Output Test

In Figure 85, we are looking at the FRPR command Duty Cycle or the percent on time of the FRPR. As the Fuel Rail Pressure is increased using the bi-directional scan tool, you can see that the Duty Cycle does not increase significantly demonstrating how the high pressure capacity of this CR system. The Total output goes all the way up to 26,000 psi.

Variable Nozzle Turbo Diagnosis

Vane Position Sensor: Adjusts the turbocharger vane position in 5 percent increments from 0-100 percent. The device control will be aborted if engine speed is above idle or if the coolant temperature is too cold. You see if the desired vane position (Figure 86) is meeting the actual vane position. When the throttle is opened, the two values should move together when they are operating correctly.

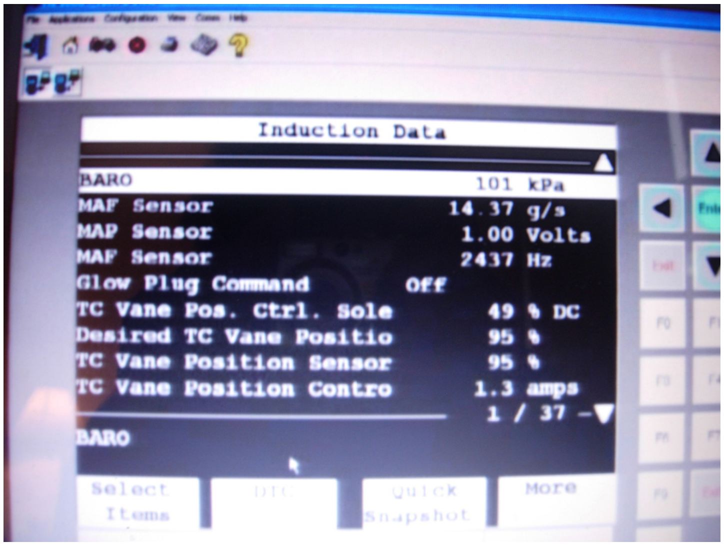


Figure 86 Induction Data Screen (Disc 2 Photo)

Diagnosis Input Sensors

The BARO sensor (Figure 87) is reading in KPa at 101, which is 14.7 psi or atmospheric pressure at sea level. The MAF sensor reads in grams per second and frequency

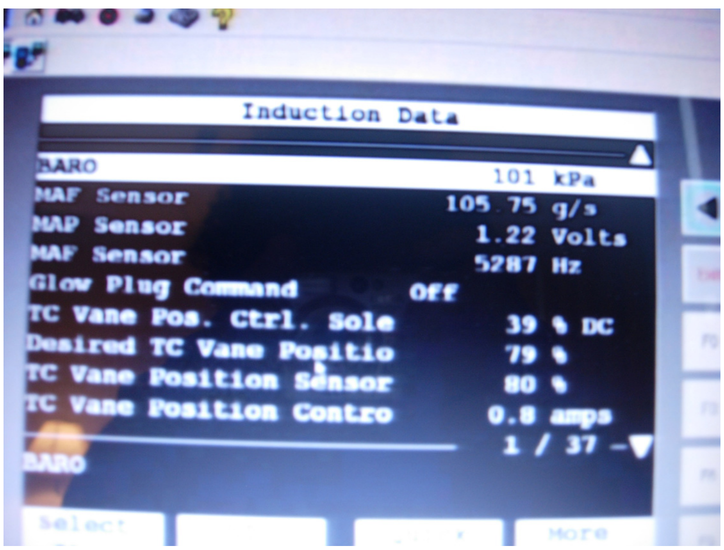


Figure 87 Induction Data Screen showing BARO & MAF sensors (Disc 2 Photo)

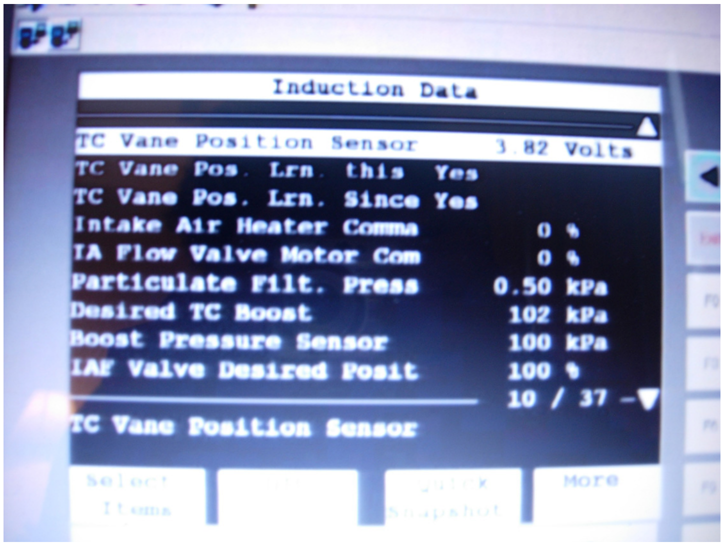


Figure 88 Induction Data Screen showing Desired TC Boost sensor (Disc 2 Photo)

Figure 88 shows the Desired TC Boost Sensor data. At 100 KPa there is no boost. You would have to load the engine to see an increase in boost pressure. If there was a leak in the charge air cooler, the ECM would tighten the vanes and increasing boost. If the vanes become too tight, a DTC will set.

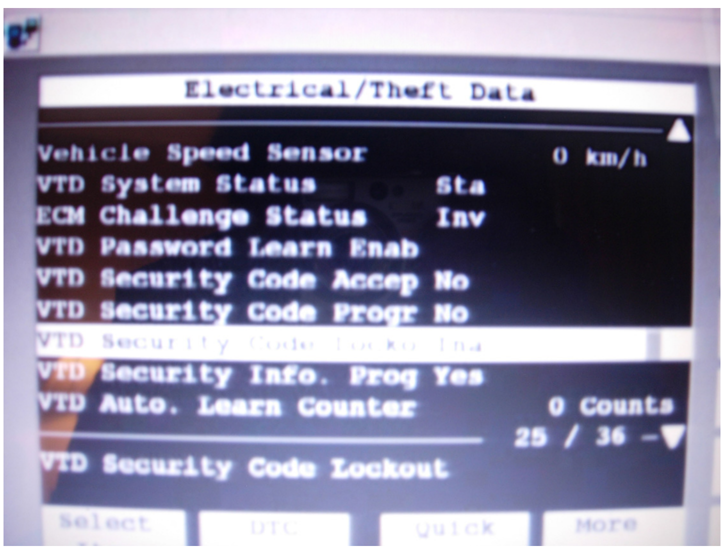


Figure 89 Electrical/Theft Data Security Locko Ina (Disc 2 Photo)

DIAGNOSTIC TROUBLE CODES (DTC)

Diagnostic Trouble Codes (DTC) are tests performed by the ECM or other controllers over and over again until the test is passed.

Technicians often ignore Theft Deterrent DTCs on some Engine Cranks No Start concerns. The key may be the cause of the drivability problem. You may have to perform the Key Learn procedure for a no-start, so the BCM will relay the correct information to the ECM allowing the engine to start.

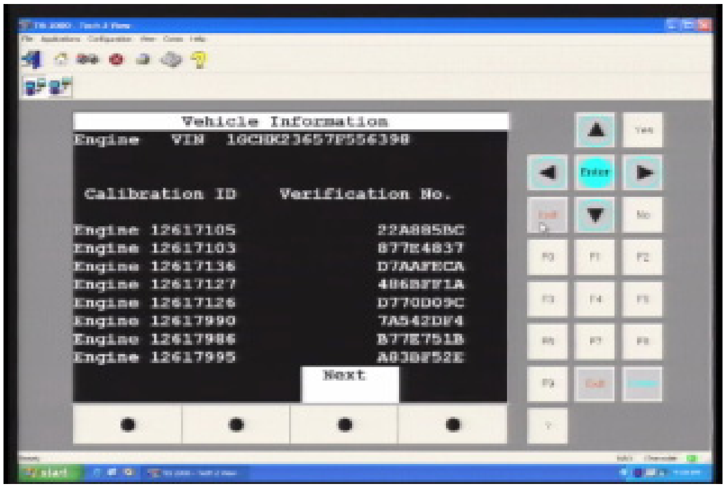


Figure 90 Vehicle Information noting calibration

Engine Calibration Info

Using the Tech 2 scan tool access "Vehicle Information" (Figure 90) by VIN (vehicle identification number). You can go on the GM Web site: http://service.gm.com/index_en-US.html (no www in front of this URL). To check for EPROM or Flash PROM updates.

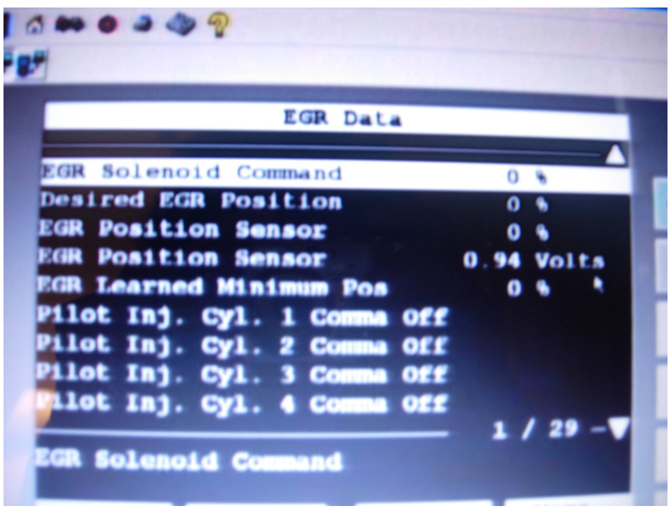


Figure 91 EGR Data (Disc 2 Photo)

EGR Data

On the TECH 2 screen shown in Figure 91 you can view the operation of the Digital EGR used on LLY and later engines. The ECM Desired EGR position is shown and the actual position it is in is shown directly below it. Using the TECH 2, you can also command the EGR on for diagnostic purposes as part of symptom-based diagnosis.

Diagnostic Trouble Codes (DTC) are just tests performed by the ECM or other controllers over and over again until the test is passed.

Figure 92 Additional DTC Information (Disc 2 Photo)

Additional DTC Information

Figure 92 shows a TECH 2 screen that allows the technician to check DTC status, information and to electronically clear all codes, which is required after a repair, has been verified. In this example, the instructor had disconnected the MAF/IAT connector to simulate a P0113 DTC. You press F0 function key on the TECH 2 to go to the screen in Figure 93.

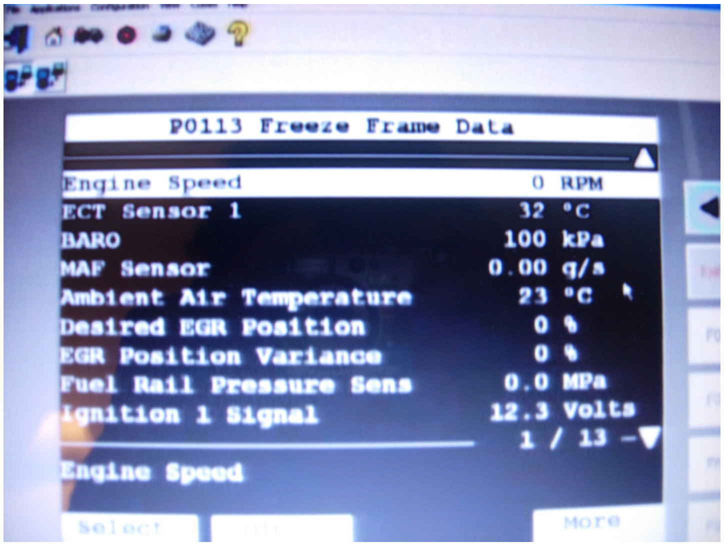


Figure 93 P0113 Freeze Frame Data (Disc 2 Photo)

Freeze Frame Data

Specific Freeze Frame data now comes on the screen for P0113 as shown in Figure 93.

Conditions for Running the DTC are DTCs P0116, P0117, P0118, and P0128 are not set. The engine run time is more than 8 minutes. Conditions for Setting the DTC are that the IAT is less than -39°C (-38°F) for more than 2 seconds.

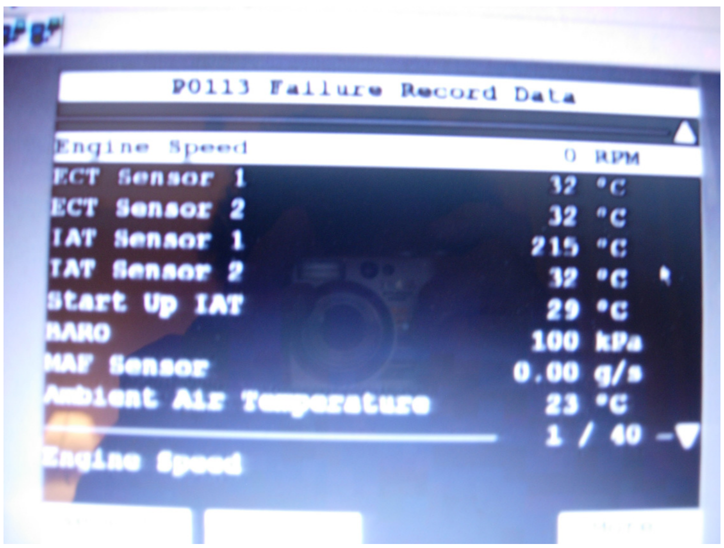
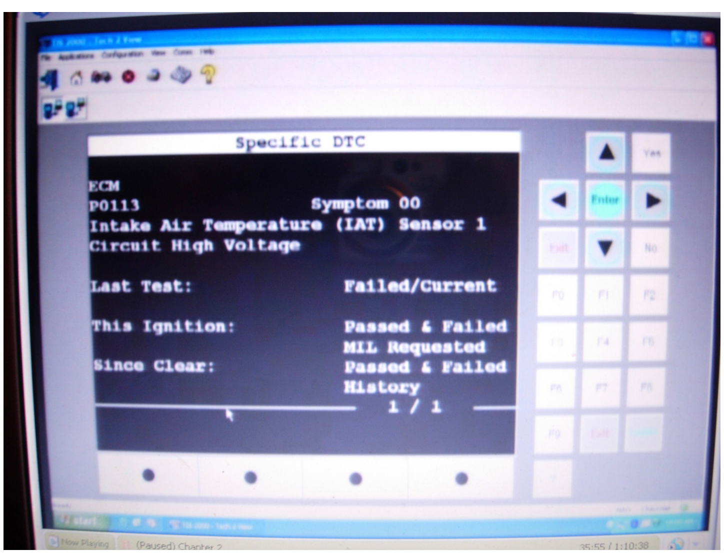


Figure 94 P0113 Failure Record Data (Disc 2 Photo)

P0113 Failure Record Data

Go back to the previous screen and press F1 to obtain the Failure Record Data for P0113 (Figure 94). This screen will show similar failure information for this DTC. The difference between Freeze Frame Data and Failure Records is that Freeze Frame Records are not updatable. Failure Records Data will provide ongoing information about the DTC.



Specific DTC MAF/IAT Disconnected

Pressing F2 on the screen in Figure 92 provides the Diagnostic Test Status for DTC P0113, which shows as failed (Figure 95).

Figure 95 Specific DTC MAF/IAT disconnected (Disc 2)

Figure 96 Specific DTC MAF/IAT Reconnected (Disc 2 Photo)

Specific DTC MAF/IAT Reconnected

Reconnecting the MAF/IAT connector and then pressing F2 again, now shows that the DTC or test is now passed as shown in Figure 96

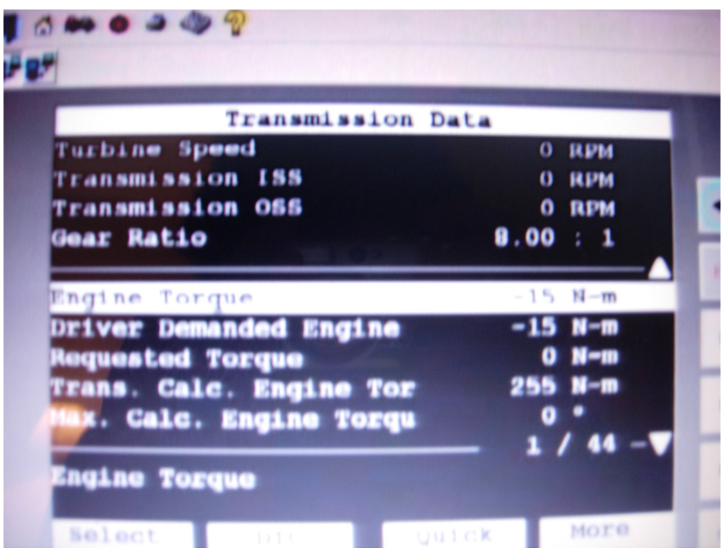


Figure 97 Transmission Data (Disc 2 Photo)

Transmission Data

Figure 97 shows the available transmission date for the Allison 1000 Automatic Transmission. For fuel economy complaints, drive the truck with the TECH 2 attached and check each of the 5 or 6 speed ratios to see if they are correct.

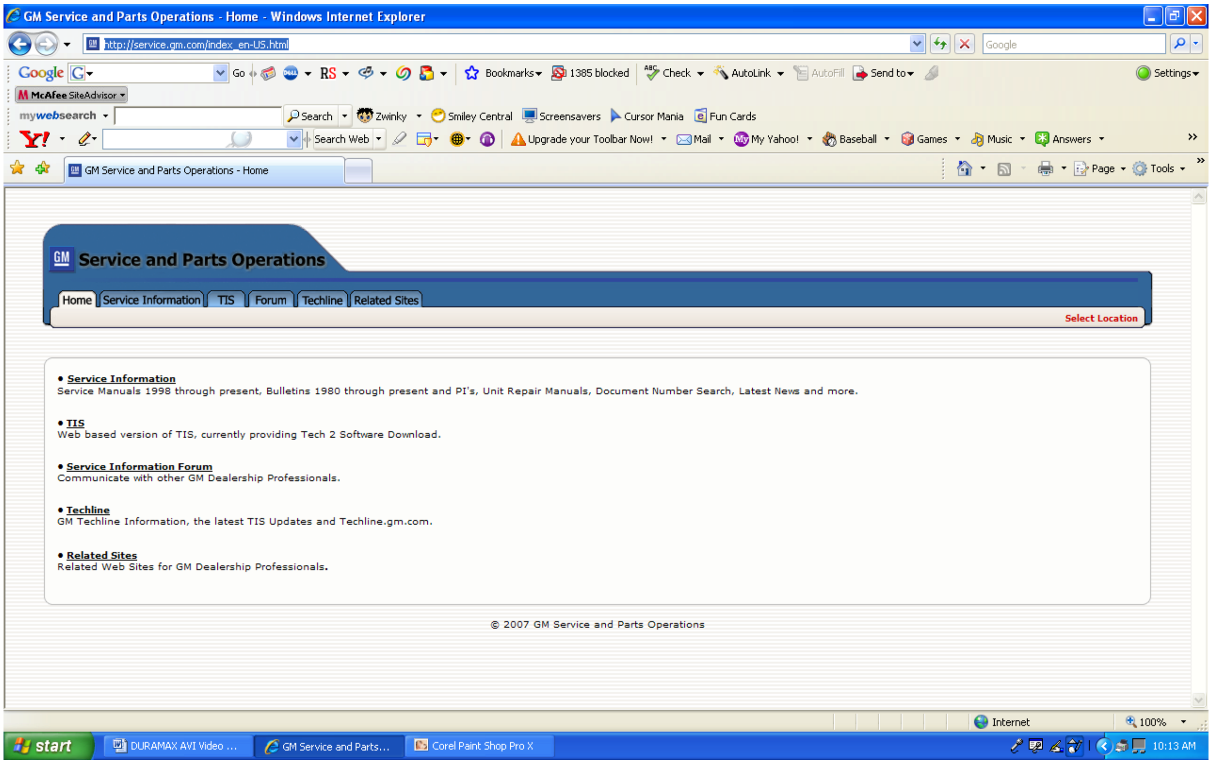


Figure 98 service.gm.com Web Site (Disc 1 Capture)

WEBSITE INFO GM Service Information Web Site

The following web address (Figure 98): http://service.gm.com/index_en-US.html is used to access the GM system to obtain specific EPROM calibration data for the truck you are working on.

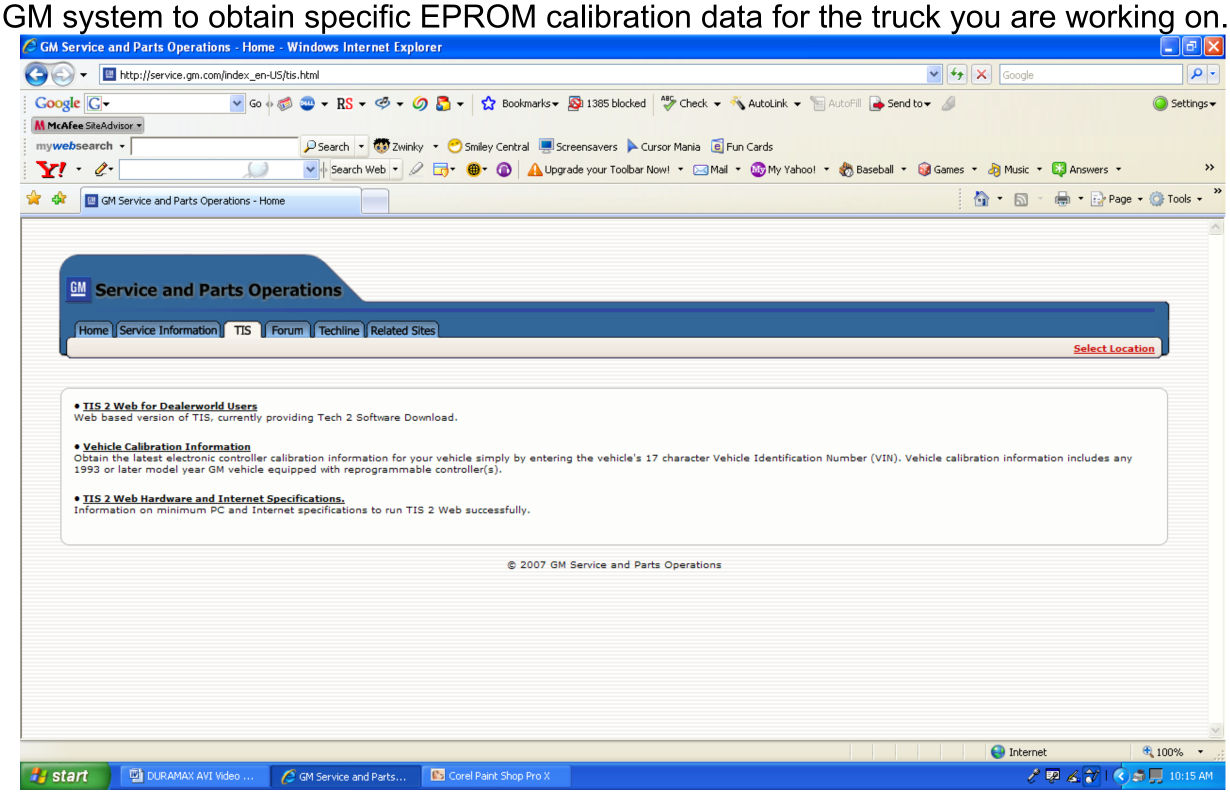


Figure 99 TIS Tab (Disc 1 Capture)

TIS2000 : In Figure 99, you click on the TIS tab that will take you to the screen in Figure 100

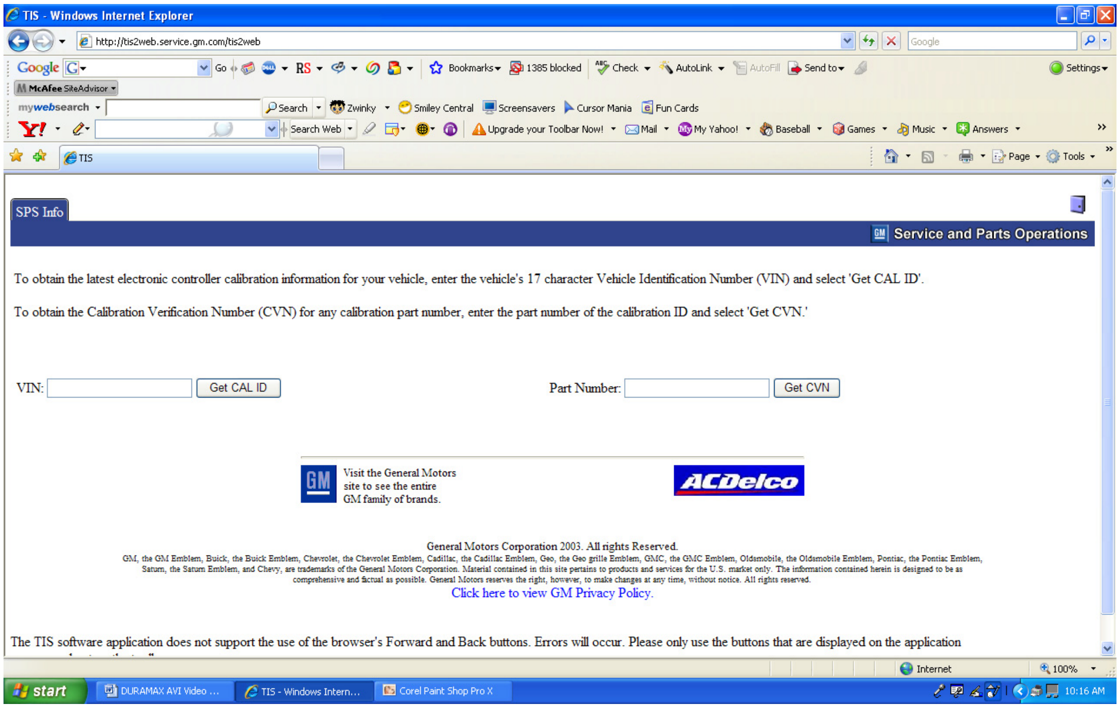


Figure 100 History of Controller Calibrations (Disc 1 Capture)

SPS Info: Figure 100 shows the screen where the technician will input the VIN to obtain the latest calibration and TSB (technical service bulletin) on the specific vehicle that was inputted. The history of this vehicle's controller will be displayed including TSBs.

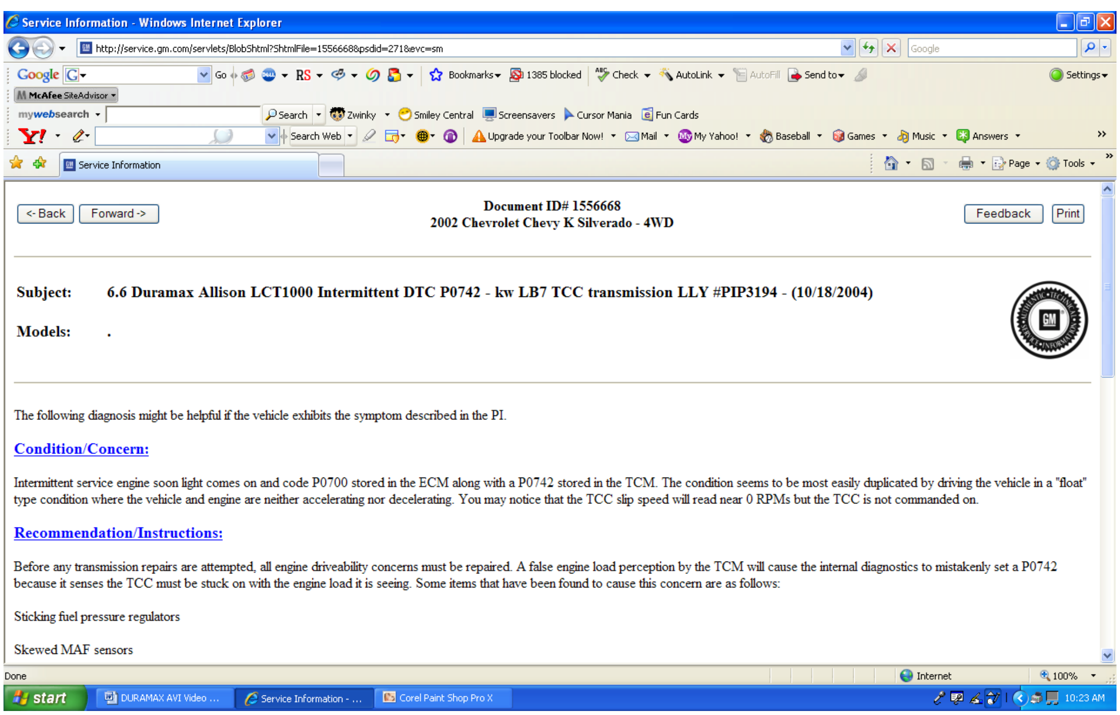


Figure 101 Bulletin Capture

Calibration Change Bulletin: The TSB shown in Figure 101 shows a calibration change.

Figure 102 AC Delco Web Page (Disc 2 Photo)

AC Delco Web Page

Figure 102 shows the AC Delco web page that provides complete service manual information for a subscription price. The lowest price is $20 for 3 days of use. It is available in several different languages. The following Figures will walk you through the access of Duramax service information on a 2002 Chevrolet Silverado truck.

Figure 103 GM SI2000 Service Information Home Page (Disc 2 Capture)

Figure 103 Shows the selection page for what type of GM vehicle you need service information for. You select year, make and model from the drop-down menus.

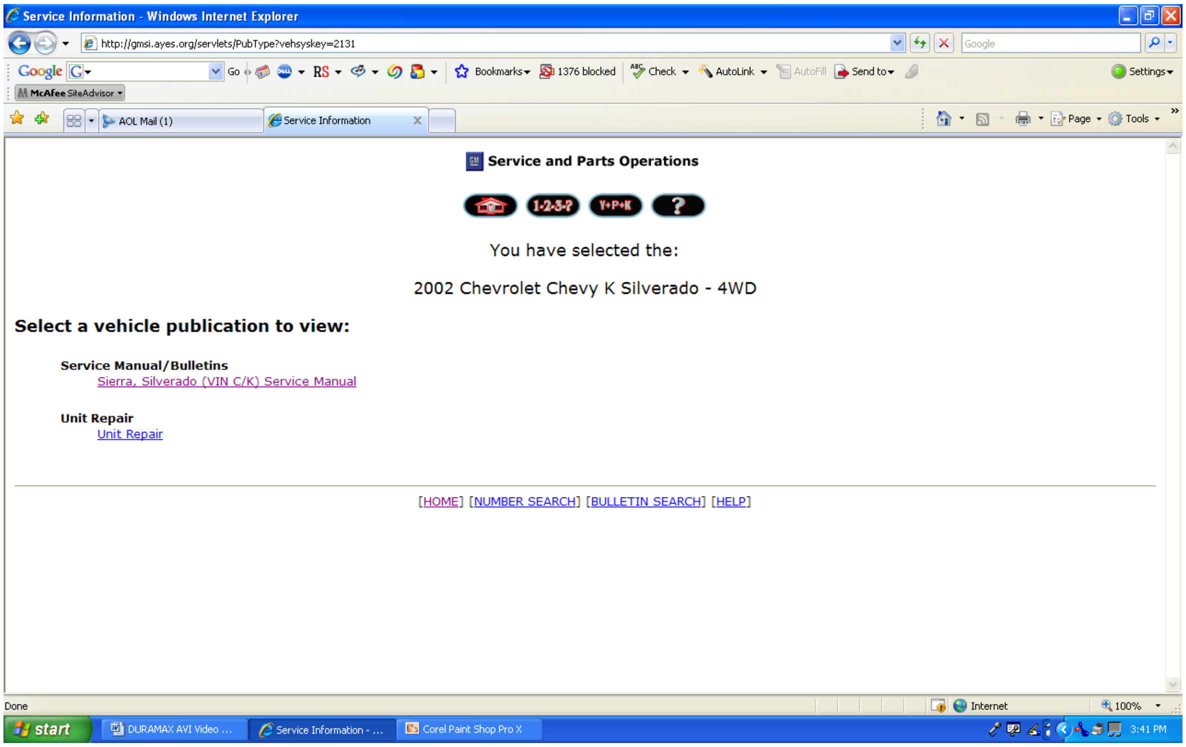


Figure 104 Vehicle Selected Page (Disc 2 Capture)

In Figure 104, after selecting a 2002 Chevrolet K Silverado, you come to the selection of either Service Manual/Bulletins or Unit Repair Manuals. We select **Service Manual/Bulletins**

Figure 105 Vehicle System Selection Page (Disc 2 Capture)

In Figure 105, we select **Engine**

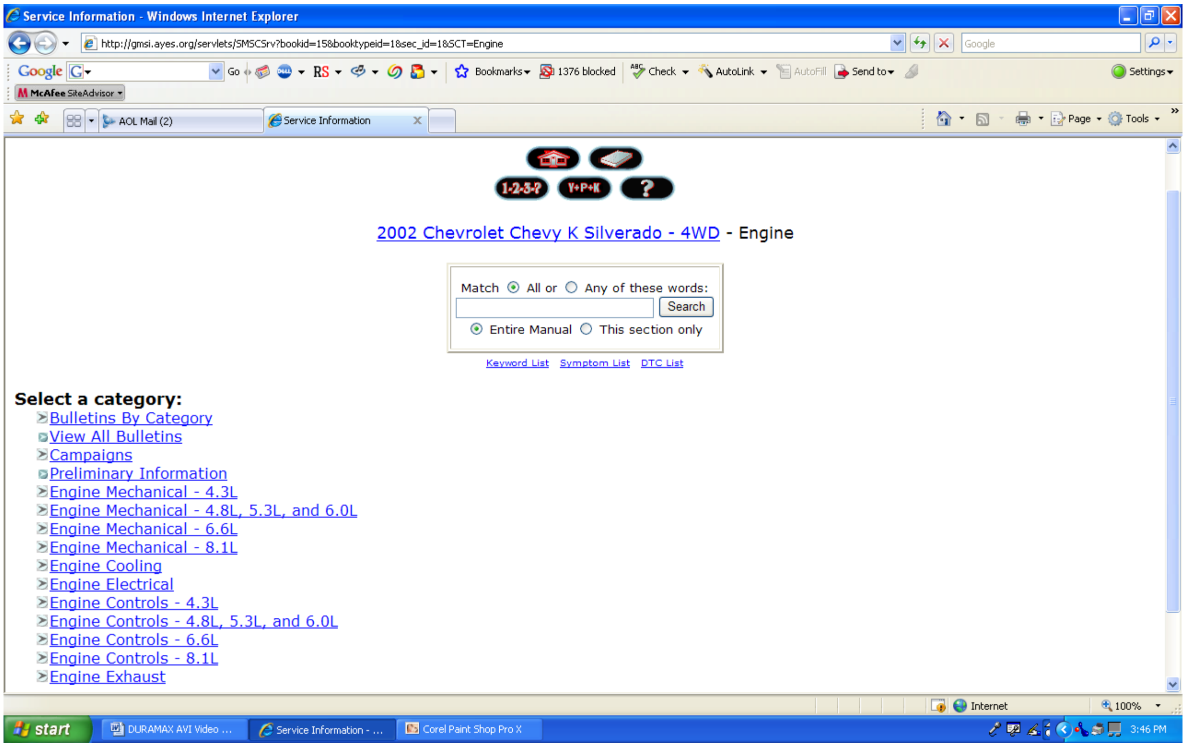


Figure 106 Engine System Selection Page (Disc 2 Capture)

In Figure 106, we select **Engine Controls – 6.6L**

Figure 107 Service Area Selection Page (Disc 2 Capture)

In Figure 107, we select for this text: **Diagnostic Information and Procedures**

Figure 108 Diagnostic Choices (Disc 2 Capture)

In Figure 108, you find the GM Diagnostic Circuit Check that should be done on all engine control related concerns. You further find the listings of Scan Tool information and all Diagnostic Trouble Codes (DTC). We selected **DTC P0113** MAF/IAT

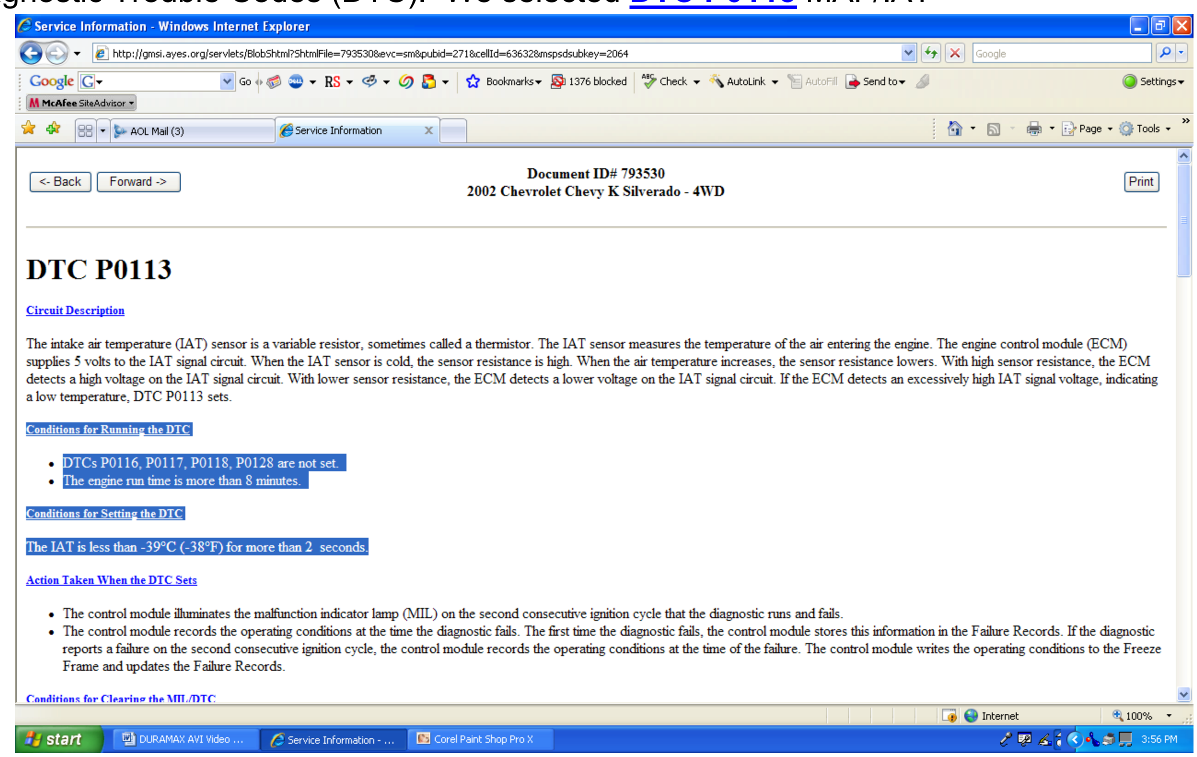


Figure 109 DTC P0113 MAF/IAT (Disc 2 Capture)

Figure 109 shows all of the needed diagnostic information for DTC P0113

Service Information - Windows Internet Explorer

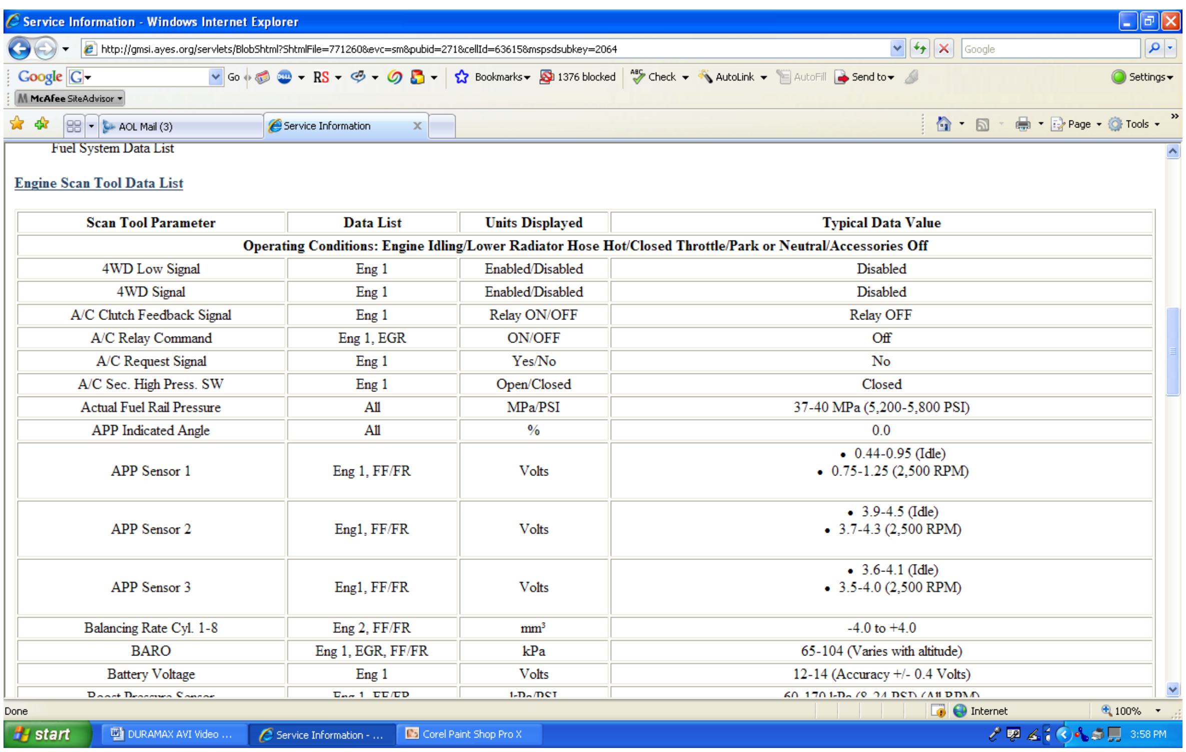
Document ID# 739053
2002 Chevrolet Chevy K Silverado - 4WD

Hard Start

Inspection	Action
DEFINITION: The engine cranks OK, but does not start for a long time. The engine does eventually run, or may start but immediately dies.	
Preliminary Inspection	• Refer to Symptoms - Engine Controls . • Ensure the driver is using the correct starting procedure.
Sensor Inspection	• Inspect the engine coolant temperature (ECT) sensor. Use the scan tool to compare the ECT with the ambient air temperature on a cold engine. If the coolant temperature reading is more than 5 degrees more or less than the ambient air temperature on a cold engine, inspect for a high resistance in the coolant sensor circuit or the sensor itself. • Turn ON the ignition with the engine OFF. Observe the actual fuel rail pressure with a scan tool. The actual fuel rail pressure should be between 1.0-1.8 MPa. If it is not, inspect for high resistance in the fuel rail pressure (FRP) sensor circuits or the FRP sensor. Refer to Circuit Testing and Wiring Repairs in Wiring Systems. • Inspect the crankshaft position (CKP) sensor reluctor wheel. Remove the CKP sensor and attempt to move the reluctor wheel front to back or side to side with a probe. If there is any movement the reluctor wheel retaining bolts are loose.
Fuel System Inspection	• Inspect the fuel pressure regulator 12-volt circuit for an intermittent short to ground. Observe the FRP Command percent while cranking. A range of 85-95 percent indicates a possible short to ground condition. • Start the engine and command the fuel pressure to 160 MPa with a scan tool. If the actual fuel pressure does not reach 160 MPA, perform the Fuel System Diagnosis - High Pressure Side . • Inspect the fuel supply to the fuel injection pump. Refer to Fuel System Diagnosis . • Inspect for a restricted fuel filter. Refer to Fuel System Diagnosis . • Inspect for air in the fuel system. Refer to Fuel System Diagnosis . • Inspect for external fuel leaks. Refer to Fuel Leaks . • Inspect for high engine oil level. Refer to Fuel in Engine Oil in Engine Mechanical - 6.6L.

Figure 110 Hard Start Symptom Diagnosis (Disc 2 Capture)

In Figure 110, we had returned to the screen in Figure 108 Diagnostic Choices and selected a symptom-based diagnosis trouble chart. The technician follows this or other charts to resolve the customer concern. There are computer hyperlinks to other areas on the web site to allow you fine the cause of the concern.



Service Information - Windows Internet Explorer

Fuel System Data List

Engine Scan Tool Data List

Scan Tool Parameter	Data List	Units Displayed	Typical Data Value
Operating Conditions: Engine Idling/Lower Radiator Hose Hot/Closed Throttle/Park or Neutral/Accessories Off			
4WD Low Signal	Eng 1	Enabled/Disabled	Disabled
4WD Signal	Eng 1	Enabled/Disabled	Disabled
A/C Clutch Feedback Signal	Eng 1	Relay ON/OFF	Relay OFF
A/C Relay Command	Eng 1, EGR	ON/OFF	Off
A/C Request Signal	Eng 1	Yes/No	No
A/C Sec. High Press. SW	Eng 1	Open/Closed	Closed
Actual Fuel Rail Pressure	All	MPa/PSI	37-40 MPa (5,200-5,800 PSI)
APP Indicated Angle	All	%	0.0
APP Sensor 1	Eng 1, FF/FR	Volts	• 0.44-0.95 (Idle) • 0.75-1.25 (2,500 RPM)
APP Sensor 2	Eng1, FF/FR	Volts	• 3.9-4.5 (Idle) • 3.7-4.3 (2,500 RPM)
APP Sensor 3	Eng1, FF/FR	Volts	• 3.6-4.1 (Idle) • 3.5-4.0 (2,500 RPM)
Balancing Rate Cyl. 1-8	Eng 2, FF/FR	mm^3	-4.0 to +4.0
BARO	Eng 1, EGR, FF/FR	kPa	65-104 (Varies with altitude)
Battery Voltage	Eng 1	Volts	12-14 (Accuracy +/- 0.4 Volts)

Figure 111 Engine Scan Tool Data List (Disc 2 Capture)

In Figure 111, we had returned to the screen in Figure 108 Diagnostic Choices and selected **Engine Scan Tool Data List**. This list shows all of the various data that can be accessed and manipulated by the GM TECH 2 scan tool

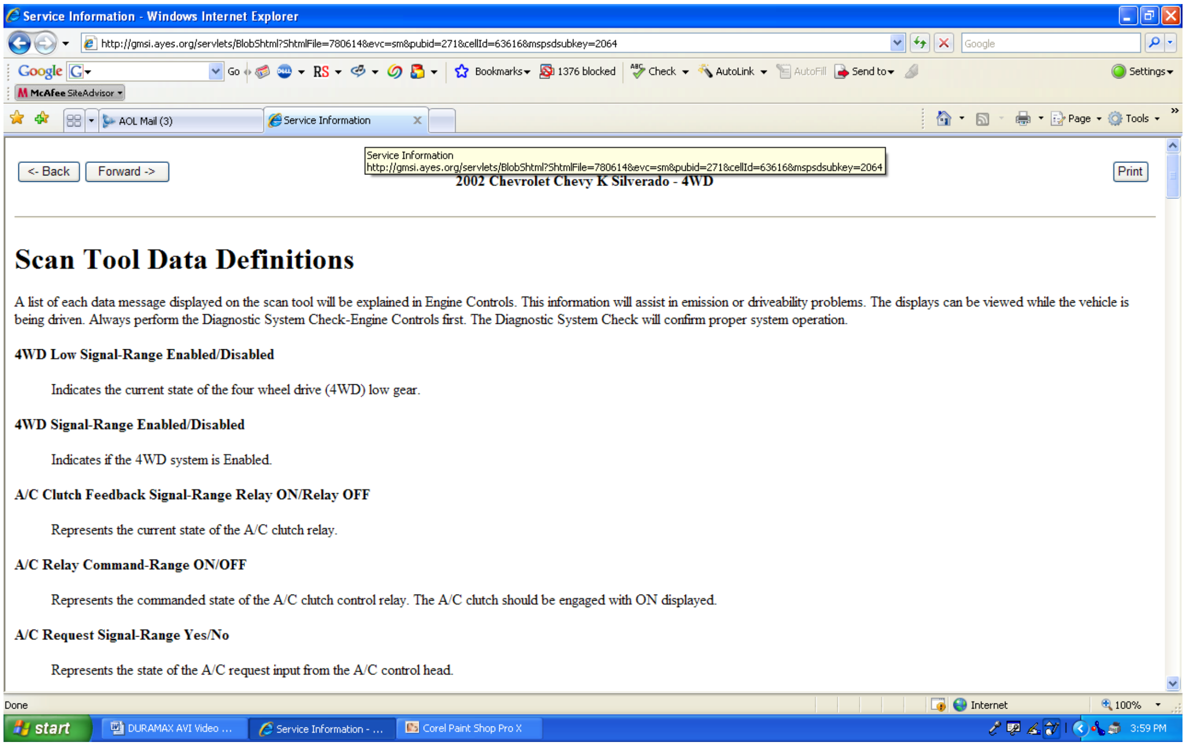


Figure 112 Scan Tool Data Definitions (Disc 2 Capture)

In Figure 112, we had returned to the screen in Figure 108 Diagnostic Choices and selected **Scan Tool Data Definitions.** This page explains all of the data that can be read by the TECH 2 scan tool.

Figure 113 Vehicle System Selection Page (Disc 2 Capture)

We have paged back to Vehicle System Selection Page to find all of the bulletins for the Duramax diesel by typing in the word DURAMAX in the search box shown in Figure 113.

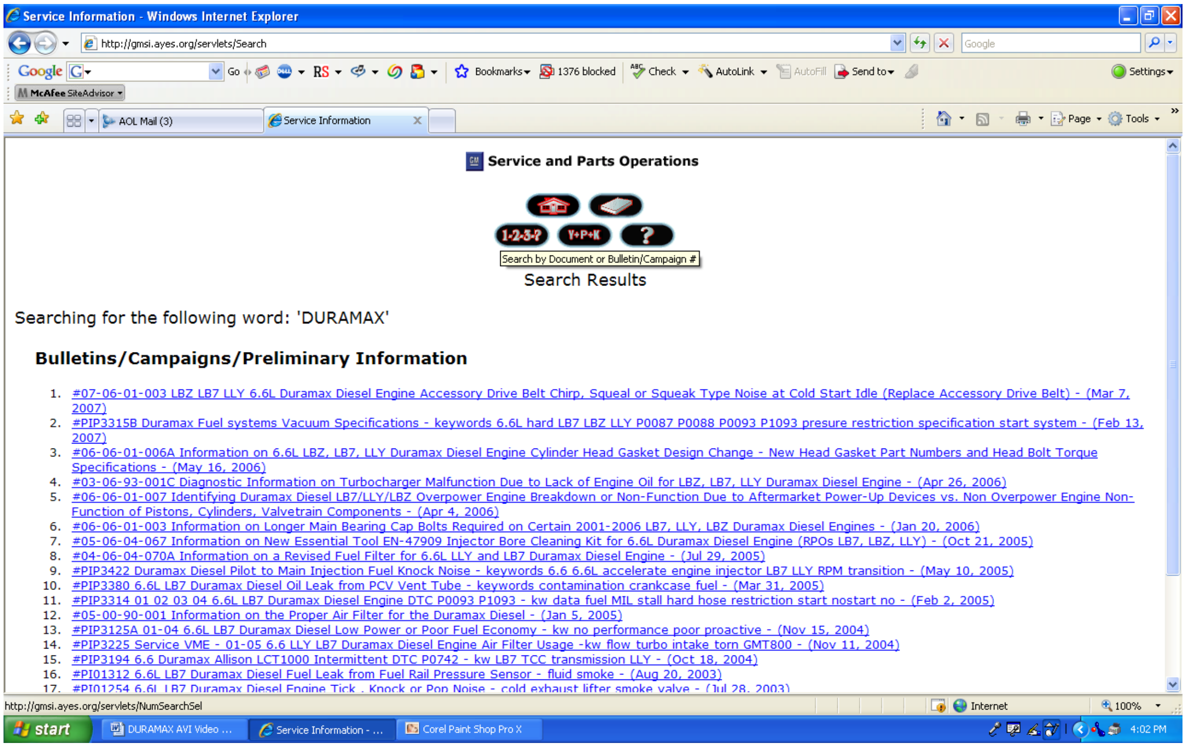


Figure 114 Bulletin Search Results (Disc 2 Capture)

Figure 114 shows the results of the bulletin search.

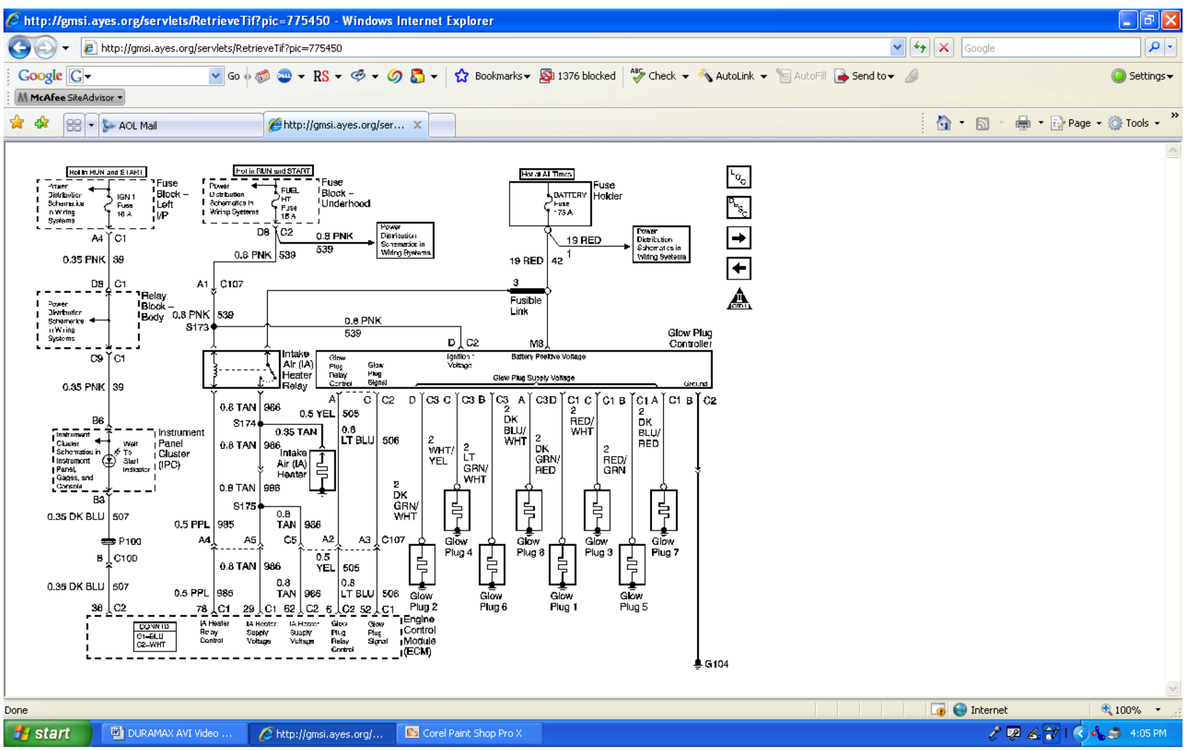


Figure 115 Wiring Schematic (Disc 2 Capture)

We paged back to Diagnostic Information and Procedures page and selected **Schematic and Routing Diagrams** to get to the California Glow Plug schematic in Figure 115.

- **Engine Overview**
- **Engine Components**
- **Fuel Systems**
- **ECM Overview**
- **Sensor Overview**
- **Suction Testing**
- **Diagnosis**
- **Scan Tool Diagnostics**
- **Diagnostic Trouble Codes (DTC)**
- **Website Info**

Diagnostic Approach

- **Verify Complaint**
- **Open the hood**
- **Visual Check**
- **GM Diagnostic Circuit Check**
- **Check Bulletins and Preliminary Info**
- **Check DTC?, Status?, DIC INFO**
- **Fuel System: Air and Suction, Balancing Ratio: 4mm^3 idle and 6 mm^3 in Drive**
- **Oil, check fuel**
- **Check Cylinder Balance, Power Balance Test**
- **Return Volume Test, compare side to side**
- **Check Volume on each cylinder**

Figure 115 Diagnostic Approach

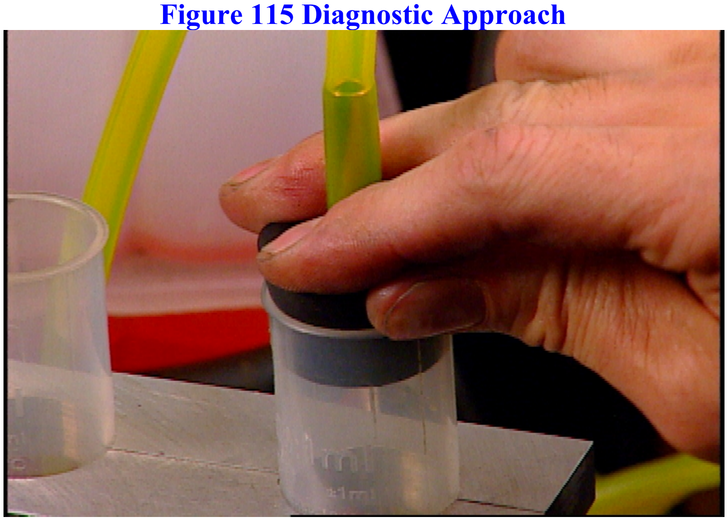


Figure 116 Return Volume Test Kit EN 47589

Diagnostic Aids

- The fuel return volumes vary based on the American Petroleum Institute (API) rating of

DIAGNOSTIC REVIEW PROCESS

The following systems were covered in this video program.

Anyone servicing a vehicle needs a diagnostic approach or strategy as shown in Figure 115. A diagnostic strategy is simply a scientific process of elimination.

High Pressure System Return Volume Test

High Pressure System

The high pressure fuel injection pump includes a fuel supply pump and a high-pressure pump. Fuel is drawn by the supply pump and delivered to the high-pressure pump. The pump is engine-driven by the camshaft. High pressure fuel is regulated by the fuel rail pressure regulator mounted on the fuel injection pump. From the high-pressure pump, the fuel moves to the left and right fuel rails through high pressure metal lines. Each fuel rail distributes high pressure fuel to one bank of 4 fuel injectors. The fuel pressure relief valve is location on the left rail on LLY, LBZ, and LMM engines (on the back of the pump on a LB7), and relieves excessive fuel pressure which the diesel fuel.

- A fuel injector may have high fuel return flow only at higher engine temperatures.

Special Tools Required

- J 45873 Fuel Return Volume Test Kit
- J-45873-30 Injector Flow Test Adapter

Initial Fuel Injector Return Flow Values API Rating	Maximum Single Fuel Injector Return Flow
30-34 ml	3 ml
35-39 ml	4 ml
40-44 ml	5 ml
Retesting Fuel Injector Return Flow Values API Rating	Maximum Single Fuel Injector Return Flow
30-34 ml	4 ml
35-39 ml	5 ml
40-44 ml	5 ml

Figure 116 Injector Return Rates

returns to the fuel tank.

Return System

The fuel return system routes fuel from the fuel injectors, the pressure relief valve, and the fuel injection pump. The return fuel travels to the fuel cooler and then to the fuel tank. This fuel is used to cool and lubricate the injection pump and the injectors.

Return Volume Test (SI2000)

NOTE: If you were not referred to this test from another diagnostic, do not perform this procedure. Only perform this test when the fuel is more than 18°C (65°F). Before replacing the fuel pressure relief valve, ensure that the break-away torque is within specifications. Fuel that is contaminated with gasoline may cause permanent damage to the fuel pressure relief valve

1. Remove fuel pressure relief valve return hose and plug the hose to prevent fuel leakage.
2. Install a section of rubber fuel hose on the fuel pressure relief valve connection and place loose end of hose into a clean fuel container.
3. If engine cranks but does not start, crank engine for 15 seconds. Observe for fuel leaking from fuel pressure relief valve.
4. If fuel leaks from the fuel pressure relief valve, replace the pressure relief valve.
5. If engine starts and runs, idle engine while commanding the fuel rail pressure to 180 MPa with a scan tool. Observe for fuel leaking from fuel pressure relief valve.
6. If fuel leaks from fuel pressure relief valve, replace pressure relief valve.
7. Always replace fuel return hose retaining clips on the fuel injectors with new clips after removing.
8. Remove the fuel return hose from the fuel injectors of the right cylinder bank.

9. Connect yellow hoses from the J 45873 to the J-45873-30.
10. Connect J-45873-30 with yellow hoses to each fuel injector return port of the right cylinder bank, and install the retaining clips.
11. Install 4 yellow hoses in the J 45873 graduated cylinders in numerical order.
12. Connect fuel return hoses to the J-45873-30 to prevent leakage.
13. If engine starts and runs, idle the engine until fuel start dripping into all the graduated cylinders and yellow hoses are full of fuel.
14. The engine cranking speed must be more than 150 RPM during the cranking portion of this test.
15. If engine does not start, crank engine in 15-second intervals, with 1 minute cooling time between intervals, until fuel starts to flow into all of the graduated cylinders.
16. Elevate the 4 yellow hoses to retain the fuel in the hoses, and empty the 4 graduated cylinders into a suitable container.
17. Install the 4 yellow hoses in the J 45873 graduated cylinders in numerical order.
18. If engine starts and runs, idle engine for 15 seconds.
19. If engine does not start, crank the engine for 15 seconds.
20. During replacement of the injectors, inspect the inlet and outlet fittings for corrosion or contamination.
21. Measure quantity of fuel in each of the graduated cylinders.
22. If high return flows (Figure 116) were recorded, replace those fuel injectors that had high return flow and retest the fuel return flow,
23. Replace any additional high return flow

injectors and proceed to the next number step.

24. Install and connect all fuel system components that were previously removed or disconnected.
25. Remove the fuel return pipes from the fuel injectors of the left cylinder bank and repeat the fuel return flow test previously preformed on the right cylinder bank.
26. If high return flows were recorded, replace those fuel injectors that had high return flow and retest the fuel return flow, referring to Fuel System Specifications (Figure 116).
27. Replace any additional high return flow injectors and proceed to the next number step.
28. Install and connect all fuel system components that were previously removed or disconnected.
29. Start and idle engine. You may have to prime fuel system before the engine will start. Command fuel pressure control to 180 MPa with a scan tool. The actual fuel pressure should be the same as the commanded pressure.
30. If engine does not start or the fuel pressure is less than 145 MPa when commanded, replace the fuel injection pump.
31. Command the fuel pressure control to 180 MPa with a scan tool. The fuel pressure should be able to reach 145 MPa when commanded.
32. If fuel pressure is less than the specified value, refer to Fuel System Diagnosis. Verify repair.