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GM Duramax Diesel Operation and Diagnostics

In 1996 General Motors was finalizing plans for the next generation of full-size trucks, code named GMT800, and at that time, GM had only 3% market-share for the Diesel Powered HD pick-up truck segment. In order to have a winning truck, GM had to have a winning Diesel powertrain.

At the same time, a small group of stakeholders led by the Planning Group, reviewed proposals from all the possible Diesel engine manufactures for the all new truck. The decision was reached to go with a proposal from one of GM's partners – ISUZU Motors LTD, recognized worldwide as a leader in Diesel engines.

The GM-ISUZU established the plan to manufacture the new engine; a joint venture company, 60% owned by ISUZU and 40% by GM. The company was established in September 1998, in Moraine, Ohio. A new 650,000 square foot engine plant was built near the former 6.5 L Diesel Engine plant, and many of the employees were able to transfer to the new joint venture named, **DMAX Ltd**., signifying the Diesel engine and maximum power, cleanliness and fuel economy.

The totally new engine design was a 6.6L, 90 degree, direct-injection, overhead valve, four-valve-per-cylinder turbocharged Diesel V8 with aluminum high swirl cylinder heads. The electrically controlled common-rail fuel system provided maximum power for each pulse of fuel used and allowed full authority in injection timing and quantity. This combination along with pilot injection resulted in Best-in-Class operating quietness and smoothness typical with similar sized gasoline engines.

The new engine was targeted to meet Best-in-Class-Performance for power and torque. In order to transfer the 300 hp and 520 ft. lbs. of torque to the truck's wheels, a new 5-speed automatic transmission was developed. The Allison Transmission 1000 series was chosen to complete the winning Powertrain. The B908 Team worked very closely with Allison Transmission Engineering Team to match the performance characteristics of the engine with the transmission.

The name itself was critical as it would compete against Ford's established "Powerstroke" Diesel engine. So after many meetings and discussions with Chevrolet Truck and GMC's marketing, the name: **Duramax Diesel 6600** was agreed upon. "**Duramax**" was meant to highlight the durability and reliability of the new engine.

In late 2000 the **Duramax Diesel 6600** debuted for the new 2001HD pick-up trucks.

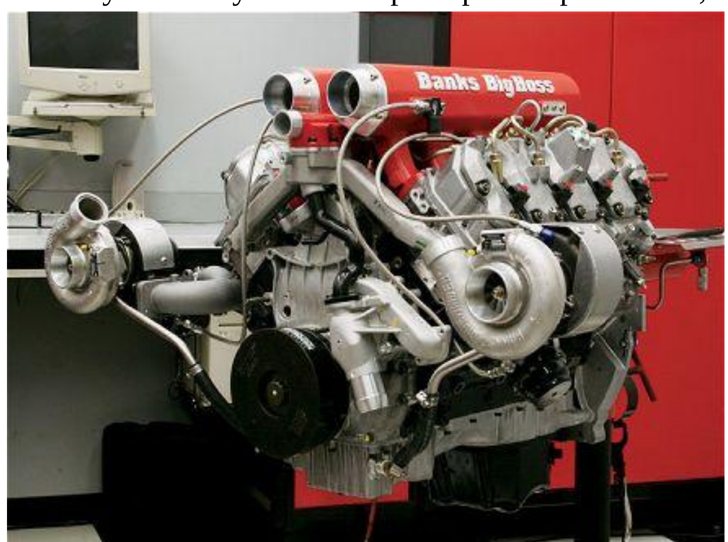
The **Duramax Diesel 6600** has continued to evolve and improve, meeting the ever tightening U.S. emission standards, and leading in the extremely competitive power and torque race. Over one million **Duramax Diesel 6600's** have been produced for the strong customer base.

Today's Duramax is a 6.6-liter V-8 is a four-valve high pressure common rail direct injection diesel currently equipped with a diesel particulate filter to meet the stringent 2010 emissions requirements.

GM Diesel history Note!!

The GM light-truck 6.2L and 6.5L diesel engines were optional in the 1982-2000 C/K series pickup trucks, and in the Suburban, Chevy Tahoe & Blazer, GMC Yukon & Jimmy, vans, and motor homes (RV) - in both turbo diesel (TD) and naturally aspirated (NA) versions. In addition, low cost and ready availability have made these engines extremely popular the world over for diesel conversion projects; powering Land Rovers, Land Cruisers, and a host of other foreign and domestic production vehicles.

Designed as a diesel engine from the ground up by the Detroit Diesel Division of General Motors, the original 6.2L diesel engine was introduced in the 1982 model year GMC and Chevy C/K pickup truck and full-size SUV lines. Taking this engine design to the next level in the 1992 model year, the new 6.5L diesel engine used advanced technology designed for the application of a turbocharger. The 6.2L saw its final year of production in 1993. While the 6.5 was replaced by the Duramax 6600 beginning in the 2001 model-year Chevy and GMC pickup truck production, the 6.5L diesel engine continues to be manufactured and sold by AM General. AM General was the manufacturer of the civilian H1 Hummer and the current military HMMWV.



No aftermarket modifications covered in this class.

There are many aftermarket companies that supply components for the Duramax. If you need any information about their products please contact them

Follow all Safety Rules

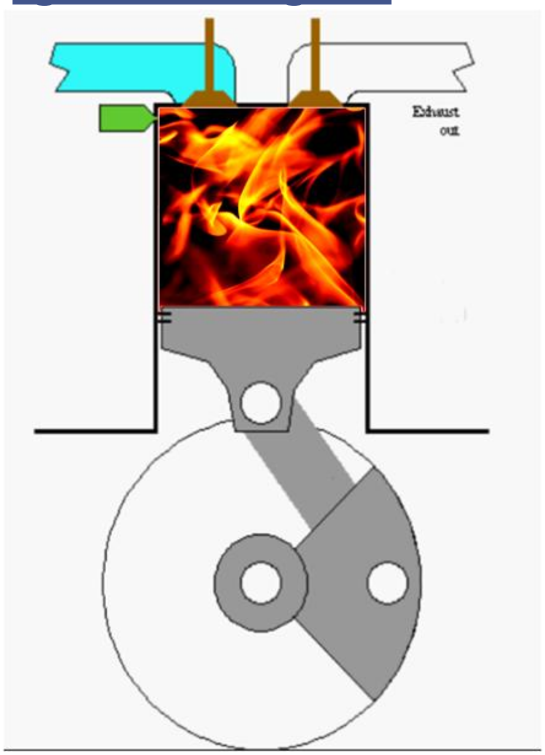
Anything that can go wrong; does at some point in time.

Follow all shop safety rules.

Warning!

High-pressure fuel lines deliver diesel fuel under extreme pressure
It can exceed 30,000 psi.
Use extreme caution when inspecting for high-pressure fuel leaks
High fuel injection pressure can cause personal injury if contact is made with the skin and be forced in the blood stream!

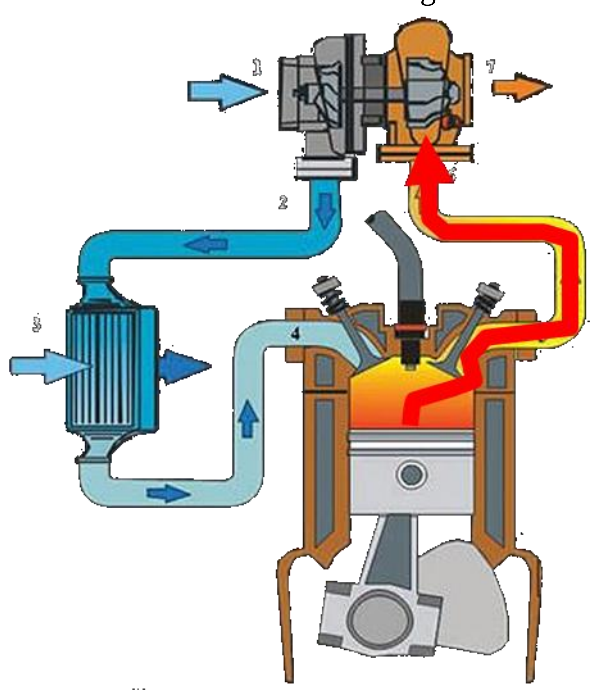
Compression Ignition Engine



Diesels are classified as compression ignition engines.
They don’t require a spark to ignite the fuel.
High compression (400-450 psi) in the cylinder superheats the air that is drawn into the cylinder.
Through correct timing, fuel is injected into the cylinder and mixes with the air and ignites.

Power is created by combustion expanding gasses.

Some of the hot exhaust gas is directed to the turbocharger.
We will discuss turbo operation in detail later.



Fuel Quality and Condition

Before covering the engine itself it is an important consideration to discuss fuel. Diesel fuel accumulates water in the system because hot fuel is returned to the relative cooler tank and condensation is formed. The fuel forms an organic contamination called slime mode which must be removed. At lower temperatures the fuel may Gel, this is sometimes called fuel waxing. All of this can cause problems because fuel system itself is designed and built with very close tolerances. The system controls the fuel with high pressure and the close tolerances re required.

Cloud Point - The cloud point is the temperature at which a cloud of wax crystals first appears in a fuel sample that is cooled under conditions described by ASTM D2500. The cloud point is determined by visually inspecting for a haze in the normally clear fuel.

Pour Point - The pour point is the lowest temperature at which movement of the fuel sample can be determined when the sample container is tilted. The apparatus used is the same as for the Cloud Point and is shown in Figure 1. The sample must be cooled following the procedure described in ASTM D97. At every 3^{o}C of cooling, the sample is inspected and when no movement is detected after 5 seconds, the test is stopped. 3^{o}C is added to the temperature where no movement was observed and this is the pour point. Pour points are always expressed in multiples of 3^{o}C.

Low Temperature Flow Test (LTFT) - The LTFT is designed to evaluate whether a fuel can be expected to pass through an engine fuel filtration system. The test determines the lowest temperature at which 180 ml of fuel can be drawn through a 17 micron screen in 60 seconds or less with 20 kPa of vacuum. The procedure is defined in ASTM D4539.

Cold Filter Plugging Point (CFPP) - The cold filter plugging point, as defined by International Petroleum Standard IP-309 and ASTM D 6371-99, is similar to the LTFT test. It determines the lowest temperature where 20 ml of fuel can be drawn through a 45 micron screen in 60 seconds with 200 mm of water (1.96 kPa) of vacuum.

Additives can lower a diesel fuel's gel point or cloud point and improve its cold flow properties. Most these are typically polymers that diminish the effect of wax crystals on fuel flow by modifying their size and shape.

Biodiesel fuel which is required to be mixed with diesel fuel in many states also adds to gelling. Biodiesel gels at higher temperatures than conventional diesel.

Cetane

Because a diesel engine ignites the fuel without a spark, proper Cetane levels are very important.

Cetane number is a measure of the ignition quality of the fuel.

Cetane number affects combustion roughness.

Results of Wrong Cetane Number:

Poor Ignition Quality

Long Ignition Delay

Abnormal Combustion

Abnormally High Combustion Pressure

Potential Uneven Thrust on Piston / Cylinder

Louder Engine Knock

Excessive Engine Knock & Smoke at Cold Start

Black smoke

Cetane Booster:

Cetane Booster improves the Cetane rating when using marginal to poor quality fuel. Many owners and fleet operators report that using a good Cetane booster lowers maintenance cost.

Results of Low Cetane

Poor Ignition Quality
Long Ignition Delay
Abnormal Combustion
Abnormally High Combustion Pressure
Potential Uneven Thrust on Piston / Cylinder
Louder Engine Knock
Excessive Engine Knock & Smoke at Cold Start
Black smoke

Fuel Quality and Condition

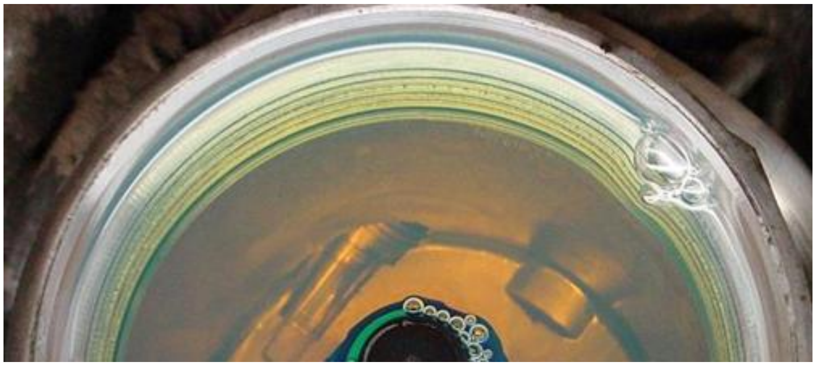
Diesel accumulates water in the fuel system because hot fuel is returned to the fuel tank and causes condensation. Organic contamination (slime)
Diesel fuel gels at lower temperature (Fuel Waxing). Because of the close tolerances in the fuel system fuel problems can and will cause many different problems up to a no start.

Lubricity:

Diesel fuel lubricity is an important property, since the diesel fuel injection system relies on the fuel to lubricate moving parts.

All diesel fuel contains wax:

Normally the wax is a liquid in the fuel, however when diesel fuel gets cold enough the wax starts to crystallize (solidify) if the temperature is sufficiently low enough. Crystals will form to block the fuel filter. The engine can stop running because it is starving for fuel.
Waxing can be severe at very low temperatures.



Cloud Point

The cloud point is the temperature at which a cloud of wax crystals first appears in a fuel sample that is cooled under conditions described by ASTM D2500 (American Society for Testing and Materials). The cloud point is determined by visually inspecting for a haze in the normally clear fuel.

Gel Point

Diesel is a mix of hydrocarbons, and other components having different freezing points. Number-2 diesel begins to cloud at 32° F (0° C) due to the paraffin in the fuel solidifying. At temperatures below 32° F, the molecules combine into solids, large enough to interrupt fuel flow. This is known as the gel point, and generally occurs about 15° degrees F (-9.5° C) below the cloud point. The wax then forms a coating on the filter which results in a loss of engine power. The waxing also affects engine starting performance when the temperature is below freezing. The filter can become very quickly coated with wax. The wax forms a coating on the filter which results in a loss of engine power.

The waxing also affects engine starting performance when the temperature is below freezing. Enough fuel might get through to allow the engine to idle, but not accelerate. There are two common ways to overcome this: one is a diesel additive, the other is a fuel heater.

Diesel Fuel Samples

#1

A sample of good clean fuel;

It has a clear light golden color with no contamination settling to the bottom. Other good samples might be even clearer or a little darker. Becoming familiar with the look, feel and odor of good diesel fuel may be valuable in identifying fuel related concerns. For example, gasoline in diesel will still look normal but one sniff will tell the real story! Don't be fooled by appearances alone.

#2

Water;

The most common contamination we find. The amber fuel appears slightly cloudy and the water which is heavier than the fuel, settles to the bottom. This is what you want water in your fuel system to do! This allows water to separate and collect in the lowest point in the system for removal. Adding chemicals or additives intended to disperse the water into the fuel will cause damage to the fuel system including pumps, lines and injectors. Keep in mind that the fuel water separator has a limited capacity and ignoring the warning light on the dash may result in water making its way to the injectors.

#3
Dirt;
This contamination is very fine silt that managed to plug two filters and destroy a fuel pump. The vehicle this sample came from was a tow-in which required a new pump, flushing of all fuel lines and the tank was removed and washed. This is an extreme example but it shows how dirt can cause big problems. A vehicle that is operated in very dirty or dusty environments should have its filters changed more frequently than the recommended 15,000 mile interval.

#4
Off road use;
This is a sample of fuel that has been dyed red to indicate that it is for off road use only. There are two concerns with red fuel. Since dyed or marked off-road diesel fuel may contain regular sulfur levels or low sulfur levels it is not approved for highway use as high sulfur levels can damage exhaust emissions components. High levels of sulfur in fuel will also create higher levels of acid in the engine oil which can lead to engine wear and damage. The second reason is that off road fuel is frequently stored in *less than ideal* conditions or containers and is more likely to pick up contamination. The color can range from a light rosy red to a dark almost blackish red depending on the fuel quality and the amount of dye used to color it.
#5
Suspect.
The contamination in this test tube did not settle and the dark color is worthy of concern. Since we can rule out dirt there are two possibilities. The first is that this fuel has had chemicals or

waste oil dumped into it. Not good. If the fuel sample were black, oil contamination from the fuel system is possible. Another viable contaminant is algae also known as sludge. This alga is the result of fuel breakdown caused by age or microbial activity. This is another good reason to keep fuel systems water free because bacteria can live in diesel fuel using the water for an oxygen supply. If someone tells you that you have bugs in your fuel take them seriously! If the filters are clogged with a dark slimy film accompanied by a foul odor, its likely cause by algae. This is a common problem with some biodiesel.

Summary of Fuel Specifications

Summary of ASTM Specifications	
Property	**Importance**
Cetane Number	Measure of ignitability (ignition quality), reduce knock and smoke
Cetane Index/Aromatics Limit	Limits aromatic content of fuel to prevent adverse emissions impact, reduce knock and smoke
Volatility	Deposits, wear, exhaust smoke
Viscosity	Injector wear & spray pattern, pump wear, filter damage
Sulfur Content	To protect emissions control equipment
Low Temperature Operability	Flow properties, filter plugging
Water & Sediment Content	Filter plugging, injector wear, increased corrosion
Lubricity	Injector & pump wear
Ash Content	Injector & fuel pump wear, piston & ring wear, engine deposits
Corrosion	Protect copper, brass, bronze fuel system parts
Flash Point	Safety during fuel handling & storage
Carbon Residue	Fuel system deposits, combustion chamber deposits

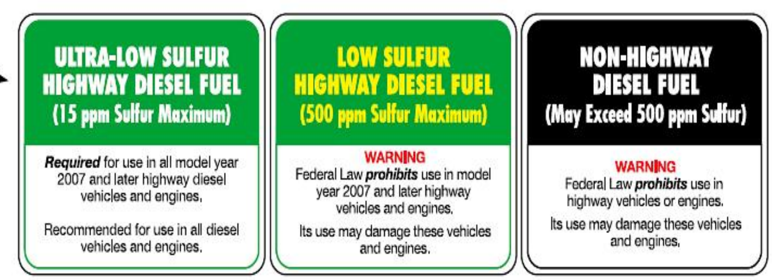
Fuel Additives

Type and Function of Diesel Fuel Additives	
Type of Additive	**Function**
Cetane Number Improver	Improves ignition quality by raising cetane number, better starts, reduces white smoke
Lubricity Improvers	Improve lubricity, better injector & pump lubrication
Detergents / Dispersants	Clean injectors, better spray patterns
Antioxidants	Extend storage life, inhibit oxidation, reduce gum and precipitate formation
Stabilizers	Inhibit oxidation & extend storage life
Metal Deactivators	Deactivate copper compounds in fuel, thereby promoting longer storage life
Biocides	Inhibit bacterial & fungi growth, help prevent fuel filter plugging
Pour Point Depressants	Low temperature operability, improve cold-flow properties
Cloud Point Depressants (Suppressants)	Reduce temperature at which paraffins solubilize
De-Icers	Prevent fuel line freezing
Anti-Foam Agents	Reduce foaming when filling tanks
Smoke Suppressants	Promote more complete combustion, reduce exhaust smoke
Rust Preventors	Reduce formation of rust in fuel systems & storage tanks
Demulsifiers / Dehazers	Used to increase the rate of water separation from the fuel
Dyes	To identify types of diesel for regulatory compliance

Attached are reference documents for additives.

Federal Law requires Specific Labeling

Diesel Dispenser Labeling Requirements



Normally, the diesel fuel sold at the primary vehicle island is ULSD. Low sulfur diesel grades with up to 500 ppm sulfur may be available at some locations through December 2010. It is illegal to use anything other than ULSD in the case of 2007 model year and newer vehicles because using higher sulfur level fuels will render exhaust after-treatment devices ineffective or, at minimum, less effective.

Diesel fuel doesn’t mix with water

Because Diesel fuel doesn’t mix with water it must be separated before entering the fuel system.

Low Sulfur / Ultra Low Sulfur Fuel

Sulfur in fuel

It is impossible to clean the air, or in particular to reduce air pollution from the transportation sector, without getting sulfur out of fuels. Sulfur is a pollutant directly, but more importantly, sulfur prevents the adoption of all major pollution control technologies. No significant air pollution reduction strategy can work without reducing sulfur to near-zero levels. Sulfur is a naturally occurring component of crude oil and is found in both gasoline and diesel. When those fuels are burned, sulfur is emitted as sulfur dioxide (SO2) or sulfate particulate matter. Any reduction in fuel sulfur immediately reduces these sulfur compounds and, as sulfur levels decline past a certain point, the benefits increase to include total pollutant emissions.

Ultra-Low Sulfur Diesel Fuel

Ultra-low sulfur diesel (ULSD) is diesel fuel with 15 parts per million or lower sulfur content. The EPA requires 80% of the highway diesel fuel refined in or imported into the United States (100% in California) to be ultra-low sulfur diesel. One hundred percent must be ULSD nationwide by 2010.

Currently, the vast majority of ultra-low sulfur diesel is produced from petroleum. However, biodiesel (along with some emerging advanced fuels) is inherently ultra-low sulfur and could help meet ULSD requirements in the future.

Ultra-low sulfur content in diesel fuel is beneficial because it enables use of advanced emission control technologies on light- and heavy-duty diesel vehicles. The combination of ULSD with advanced emission control technologies is sometimes called "clean diesel."

- 2003 – 2007 MY may use low or ultra-low sulfur fuels are acceptable
- 2008 MY and later Requires ultra-low sulfur fuel

Duramax Diesel Versions

RPO is an acronym used by General Motors to denote a Regular Production Option

Duramax uses the following RPO’s;

- LB7 8th VIN Number is a **1**
- LLY 8th VIN Number is a **2**
- LLY Van 8th VIN Number is a **W**
- LBZ 8th VIN Number is a **D**
- LMM 8th VIN Number is a **6**
- LML 8th VIN Number is a **8**

Different Mid-Year Changes

Using the 8TH VIN number is important because of the Mid-Year changes

The LLY was introduced in mid- 2004 replacing the LB7

2007 started with the LBZ and was replaced by the LMM in January

Using only the Model year for information will get you the wrong part and bad information

LB7

RPO LB7 (engine VIN code "1") was first introduced in 2001 and continued until mid-2004. It is a 32-valve design with high pressure common rail direst injection and an experimental composite design cylinder head. There were issues with the LB7 injector failure. Fuel leaked and entered the crankcase, causing oil dilution. Customers complained of overheating, and in some cases, blown head gaskets. GM denied there was a problem, but after being sued, GM included overheating and blown head gaskets as a warranted item. GM extended the warranty for the injectors, which now have 7 year/200,000 mile coverage which is expired. The following trucks use the LB7: Chevrolet Silverado, Kodiak, GMC Sierra, and TopKick:

<u>Specifications</u>

- Engine type: 6,599 cc (402.7 cu in) V8 turbo
- Bore x Stroke: 4.06 in (103 mm) x 3.90 in (99 mm)
- Block / Head: Cast gray iron / Cast aluminum
- Aspiration: Turbocharged & Intercooled
- Valve train: OHV 4-V
- Compression: 17.5:1
- Injection: Direct; Robert Bosch GmbH high pressure common-rail
- Power / Torque: 300 bhp (220 kW) @ 3100 rpm / 520 lb·ft (705 N·m) @1800 rpm

LLY

The LLY (GM use 8GF1 internally as the engine’s description) (engine VIN code "2"). Debuted in mid-2004 and continued until the end of 2005. The LLY was GM's first attempt to implement emissions requirements on their diesel trucks. To meet this goal they turned to a newly developed Garret turbocharger with a variable geometry vane system and installed a Exhaust Gas Recirculation valve (EGR). Because of the problems with injectors in the LB7 valve covers were changed to allow access to the injectors without having to remove the valve covers, saving labor costs.

The following trucks used the LLY engine: 2006 Hummer, Chevrolet Silverado, and the GMC Sierra.

Specifications

- Engine type: 6,599 cc (402.7 cu in) V8 turbo
- Bore x Stroke: 4.06 in (103 mm) x 3.90 in (99 mm)
- Block / Head: Cast gray iron / Cast aluminum
- Aspiration: Turbocharged & Intercooled
- Valve train: OHV 4-V (32 Valves)
- Compression: 17.5:1
- Injection: Bosch High Pressure Common-rail
- Power / Torque: 305 bhp (227 kW) @3000 rpm / 605 lb·ft (820 N·m) @1600 rpm
- Head casting is 8gf1
- Block casting is #22351021213

Source:

LBZ

The LBZ (engine VIN code "D") debuted in late 2006 and continued into 2007. It has a more powerful tune loaded into the computer that allows it to produce more power and torque. Changes include:

- Cylinder block casting and machining changes strengthen the bottom of the cylinder bores to support increased power and torque

- Upgraded main bearing material increases durability
- Revised piston design helps lower compression ratio to 16.8:1 from 17.5:1
- Piston pin bore diameter increased for increased strength
- Connecting rod " I " section is thicker for increased strength
- Cylinder heads revised to accommodate lower compression and reduced cylinder firing pressure
- Maximum injection pressure increased from 23,000 psi (1,585.8 bar) to more than 26,000 psi (1,792.6 bar)
- Fuel delivered via higher-pressure pump, fuel rails, distribution lines and all-new, seven-hole fuel injectors
- Fuel injectors spray directly onto glow plugs, providing faster, better-quality starts and more complete cold-start combustion for reduced emissions
- Improved glow plugs heat up faster through an independent controller
- Revised variable-geometry turbocharger is aerodynamically more efficient to help deliver smooth and immediate response and lower emissions
- Air induction system re-tuned to enhance quietness
- EGR has larger cooler to bring more exhaust into the system
- First application of new, 32-bit E35 controller, which adjusts and compensates for the fuel flow to bolster efficiency and reduce emissions"

The following trucks used the LBZ Chevrolet Silverado, Kodiak, Express, GMC Sierra, Savanna, and the TopKick.

Specifications

- Engine type: 6,599 cc (402.7 cu in) V8 turbo
- Bore x Stroke: 4.06 in (103 mm) x 3.90 in (99 mm)
- Block / Head: Cast gray iron / Cast aluminum
- Aspiration: Turbocharged & Intercooled
- Valve train: OHV 4-V
- Compression: 16.8:1
- Injection: Bosch High Pressure Common-rail

LMM

The LML Duramax is released for 2011 model General Motors & Chevrolet HD trucks. The latest version of the 6.6L Duramax, the LML uses advanced emissions equipment, including the use of diesel exhaust fluid injection, to reduce nitrogen oxide emission levels by 63 percent over LMM powered trucks. This allows the LML to exceed currently mandated federal emissions requirements & meet future requirements as well. Not only is the LML the cleanest Duramax in history; it is also the most powerful, being released with 397 horsepower & 765 lb-ft of torque. A version was used in the Chevrolet Silverado, Kodiak, Express, GMC Sierra, Savana, and the TopKick. It is also in the Chevrolet Express and the Trident Iceni.

Specifications

- Engine type: 6,599 cc (402.7 cu in) V8 turbo
- Bore x Stroke: 4.06 in (103 mm) x 3.90 in (99 mm)
- Block / Head: Cast gray iron / Cast aluminum
- Aspiration: Turbocharged & Intercooled
- Valve train: OHV 4-V
- Compression: 16.8:1
- Injection: Bosch High Pressure Common Rail with CP3.3 Injection Pump

- Power / Torque: 365 bhp (272 kW) @3200 rpm / 660 lb·ft (895 N·m) @1600 rpm
- New engine control software

LMK

This engine is not yet commercially launched although it was touted in the automobile press as one of the most important new engine concepts for small trucks and SUVs by finally delivering a capable diesel engine in a compact enough package. As of March 2009, a GM spokesperson stated the engine project has been put on an "indefinite hold" due to current economic conditions.

LML

The 6.6L RPO LML (VIN code "8") is the latest version (2011–present) of the Isuzu/GM Duramax V8 diesel engine and actually a further advanced version of the LMM engine with the majority of the changes addressing a required drastic reduction in engine emissions. The LML engine was significantly updated for 2011 to provide improved exhaust emissions that comply with the new federal emission standards for diesel engines, provide better engine rigidity and further noise reduction. New 29,000 PSI piezo injectors, a complete fuel system design to tolerate up to B-20 Biodiesel mixtures and Urea injection (to reduce Nitrogen oxides) with a 5.3 gallon urea tank are updating the fuel and emissions systems.

Specifications

Configuration:

90 degree V8

Displacement:

403 cubic inches, 6.6 liters

Block/Head material:

- Cast iron block
- Aluminum cylinder heads

Compression Ratio:

16.8:1

Bore:

4.06 inches

Stroke:

3.90 inches

Aspiration:

Variable geometry turbocharger w/air-to-air intercooler

Valve train:

OHV, 4 valves per cylinder

Injection:

- Direct injection
- Bosch high pressure common rail
- 30,000 psi piezo actuated injectors.

Horsepower:

397 hp @ 3,000 RPM

Torque:

765 lb-ft @ 1,600 RPM

LML Duramax Features:

• B20 biodiesel compatible (20% biodiesel, 80% petroleum diesel mixture).
• Fuel mileage increased by 11% over 2010 models.
• Factory engine brake with Allison 1000 transmission.

• GM states: "The engine has been developed to operate for at least 200,000 miles on a rough-duty cycle without the need for a major overhaul."

LML Duramax Emissions:

• Diesel particulate filter (DPF) nearly eliminates emissions of diesel soot. Active regeneration programming cleans the DPF periodically (estimated regeneration period every 700 miles, 300 miles less than previous systems, under normal operating conditions) by injecting diesel fuel into the exhaust stream via a "downstream injector", completely burning off soot captured in the DPF.

• Exhaust gas recirculation (EGR) with EGR cooler.

• Selective catalyst reduction (SCR) utilizing diesel exhaust fluid injection (DEF). DEF is a urea based fluid injected into the SCR to further reduce nitrogen oxide emissions. A DEF tank will need to be filled approx. every 5,000 miles (under normal operating conditions). Engine will enter into a limp-mode if DEF tank is empty.

• EGR cooler bypass to help eliminate soot deposits in the EGR cooler/system, which could potentially cause engine problems.

• Engine block upgraded for increased strength & engine noise reduction.

• Upgraded oil pump increases flow at low rpm.

• Higher strength pistons and connecting rod pins.

• Upgraded main bearing design.

• Oil circuit changed to increase oil flow/pressure to the turbocharger.

• EGR cooler bypass is introduced to reduce soot build up in the EGR system.

Related Topics:

LGH

The 6.6L Duramax diesel engine (VIN code "L") is used on 2010 interim and 2011 Chevrolet Express and GMC Savana vans and 2011 Chevrolet Silverado and GMC Sierra trucks with RPO ZW9 (chassis cabs or trucks with pickup box delete). The LGH engine is rated at 335 bhp (250 kW) at 3100 rpm and 685 lb·ft (929 N·m) at 1600 rpm. Similar to the LML this engine also uses a DPF and DEF system to meet emission standards.

	6.6L Duramax LB7	6.6L Duramax LLY	6.6L Duramax LBZ	6.6L Duramax LMM	6.6L Duramax LML
Years Produced	2001 - 2004	2004 - 2006	2006 - 2007	2007.5 - 2010	2011
Compression Ratio	17.5:1	17.5:1	16.8:1	16.8:1	16.8:1
Aspiration	Turbocharger	VGT Turbocharger	VGT Turbocharger	VGT Turbocharger	VGT Turbocharger
Fuel System	23,000 psi	23,000 psi	26,000 psi	26,000 psi	30,000 psi
	Bosch Common Rail, CP3 Injection Pump				
Peak Horsepower	300 hp @ 3,100 RPM	310 hp @ 3,000 RPM	360 hp @ 3,200 RPM	365 hp @ 3,100 RPM	397 hp @ 3,000 RPM
Peak Torque	520 lb-ft @ 1,800 RPM	605 lb-ft @ 1,600 RPM	650 lb-ft @ 1,600 RPM	660 lb-ft @ 1,800 RPM	765 lb-ft @ 1,600 RPM
Emissions	None	EGR, Catalytic Converter	EGR, Catalytic Converter	EGR, Catalytic Converter, DPF	EGR, SCR, DPF

While the LB7 almost never had an overheating problem while towing heavy in the hot summer temperatures, the 2004.5 through early 2006 model-year LLY did. Running at or near the maximum gross combined weight of 22,000-lbs, up a steep grade, and during the peak of summer temperatures could cause the LLY to exceed a safe engine temperature. Otherwise, from a durability and reliability standpoint, the LLY was/is as good as any other generation. For those LLY owners who have experienced an engine temperature problem, there is a fix. As it turns out, you can easily (though it's not necessarily cheap) replace the truck's radiator, fan-shroud, fan, fan-clutch and related components with those items produced for the 2006/7 model-year LBZ Duramax. A larger radiator and fan will solve the problem. The cause of the temperature problem some experience is due to the use of a larger EGR cooler, which is cooled by engine coolant, and the LLY's incorporation of a smaller engine-driven fan than that used on the LB7. Some feel the use of the new-for-the-LLY Garrett Variable Nozzle Turbine (VNT) turbocharger was partly responsible for the heat issue. Where the LB7 used a stone reliable mechanical-waste gate turbocharger, the LLY's computer-controlled VNT is believed to be a little more restrictive to exhaust flow. If so, it's simply a minor point, though the added complication of computer control does add to potential turbo maintenance issues in a well-used truck.

Duramax LB7

The LB7 will be the first vehicle discussed

It allows a strong base for understanding Duramax

High-pressure common-rail injection technology has revolutionized the diesel industry. Over the last decade, it has allowed engine builders to run higher injection pressures (as much as 29,000 psi in the new LML Duramax and 6.7 L Power Stroke) in order to increase efficiency, while greatly reducing emissions. Use of the common-rail system has also facilitated multiple injection events (making diesels quieter). The icing on the cake is that these cleaner-burning engines make much more power than their predecessors.

Fuel System

Fuel is stored in the fuel tank. The fuel is drawn from the tank, through the Fuel Injection Control Module (FICU) then through the fuel filter, into the low pressure side of the high pressure fuel pump.

The high pressure pump has two functions;

1. Draw in fuel from the tank (Low pressure side). There are some Vans that use a lift pump, but the trucks do not. The low pressure side of the High Pressure Pump draws fuel without the need for a lift pump.

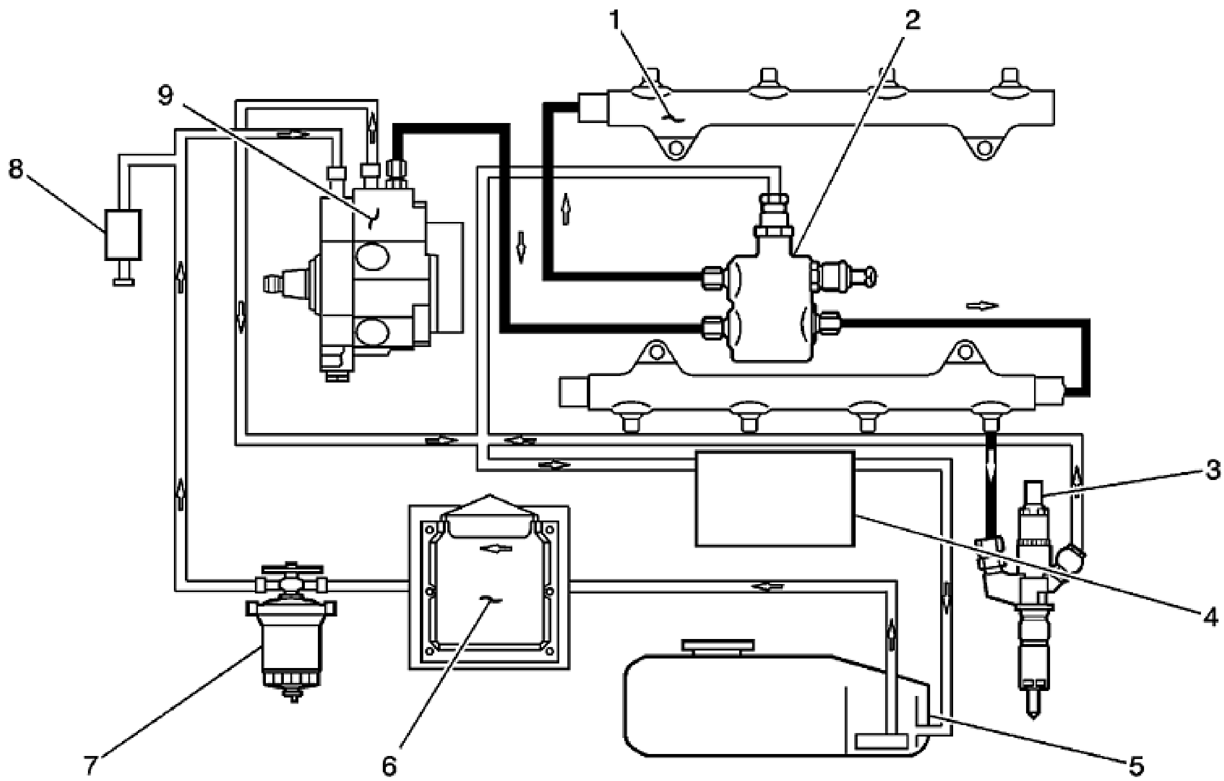
2. Supply high pressure to the fuel rails where the injectors are connected. The High Pressure Pump is supplied fuel by its low pressure side.

3 Fuel System Categories

The fuel system may be divided into 3 categories.

1. The Low Pressure Supply Circuit
2. The High Pressure System Circuit
3. The Low Pressure System Return Circuit

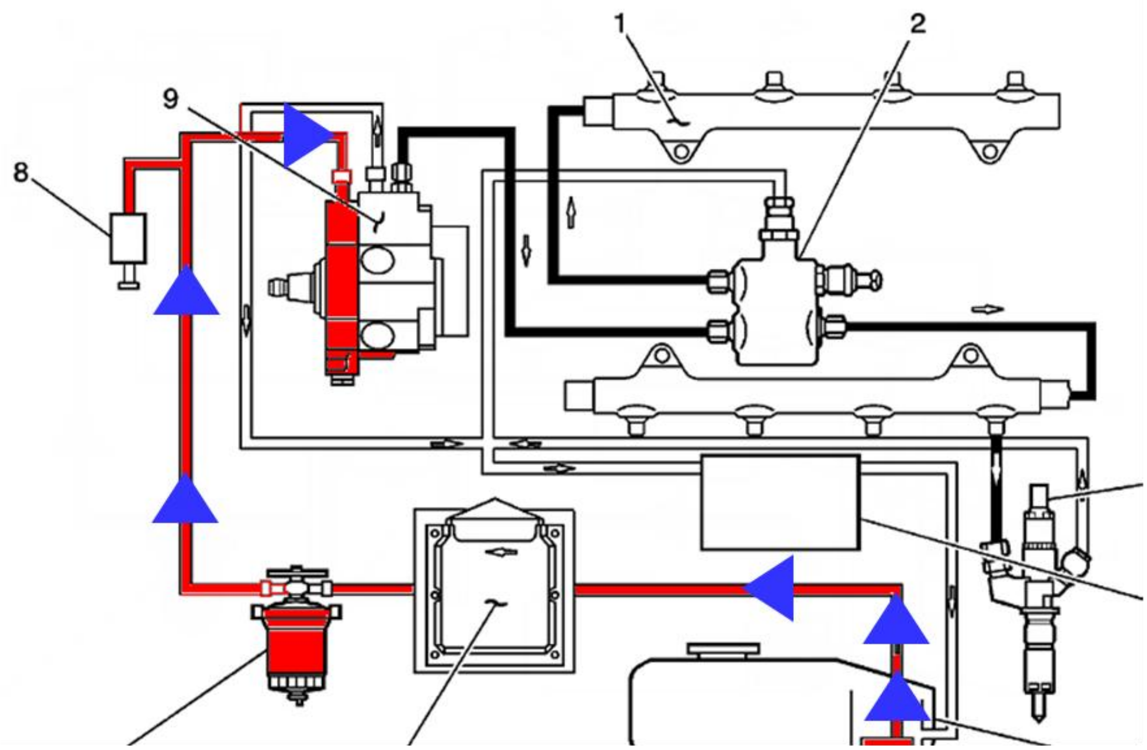
The Low Pressure Supply system starts at the fuel tank and ends at the high pressure fuel pump. The High Pressure System starts at the high pressure pump and ends at the injectors.



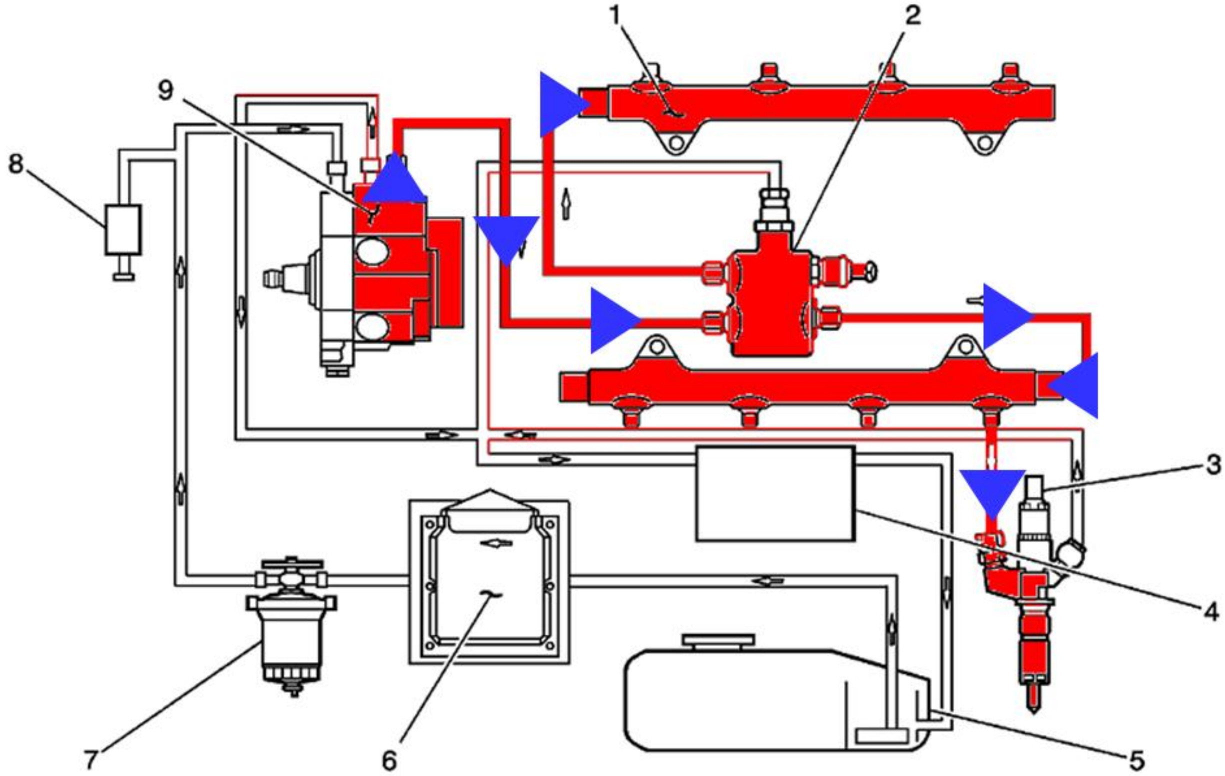
Fuel system components:

1. **Common fuel rail**
2. **Fuel junction block**
3. **Injector**
4. **Fuel cooler**
5. **Fuel Tank**
6. **FICM**
7. **Fuel Filter**
8. **Bleeder Valve**
9. **High Pressure Fuel Pump**

Low Pressure Fuel Path



High Pressure Fuel Path



CP3 High Pressure Pump

The CP3 Diesel Injection Pump is the third generation of the Common Rail High Pressure Fuel Pump developed by Bosch. The CP3 diesel injection pump replaces the VP44 pump in many applications. What makes the CP3 and VP44 pump design revolutionary over the first generation common rail fuel systems is the extremely high pressure levels in which it delivers fuel to the combustion chamber. These pressure levels are between 4,351-29,206 psi. The Bosch VP44 and CP3 fuel systems can operate at approximately four times the level of the prior generation P7100 diesel injection pumps that had psi levels ranging in the 4,000 to 5,000 psi range. This added pressure gives the fuel injectors the ability to spray a finer mist

into the combustion chamber or a more “atomized” fuel creating greater power while using less fuel.
The CP3 fuel pump is said to be an improvement upon the VP44 fuel pump in terms of reliability but they are still very similar in appearance. There are two potential issues with the CP3 pump that can be fixed with minimal expense and routine effort.

Problem 1 –Because the CP3 pump operates at such high psi levels it is important that all debris be removed from fuel. The fuel filter placed in most diesel vehicles in which the CP3 operates is 10 micron. Bosch recommends a 7 micro fuel filter with the CP3 pump. This should increase CP3 pump life.

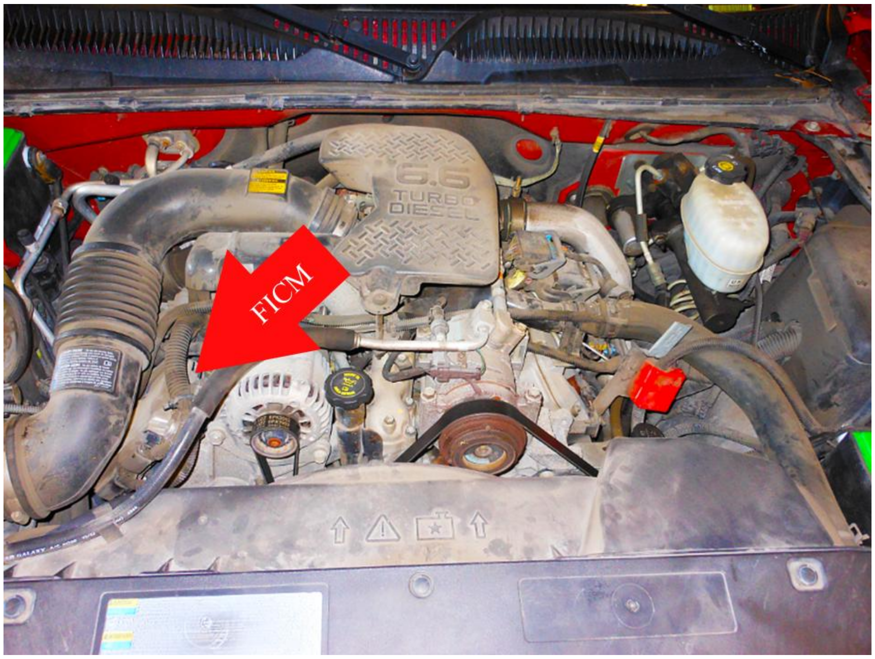
Problem 2 –Modern low sulfur fuel has a High Frequency Reciprocating Rig Test of greater than 520 HFRR. This is too dry to adequately lubricate the CP3 Pump. The CP3 Pump was designed for fuel mixtures that are less than 400 HFRR. **In order to fully protect your CP3 pump we recommend you use a fuel additive, available through companies such as Stanadyne.**

The Low Pressure Supply Circuit

Fuel is moved through the Low Pressure Side of the system by the Low side of the High Pressure pump (a two-stage fuel pump). The fuel moves through the fuel lines to the Fuel Injection Control Module FICM. Then on to the Fuel Filter assembly. It then enters the Low Side of the High Pressure Pump.

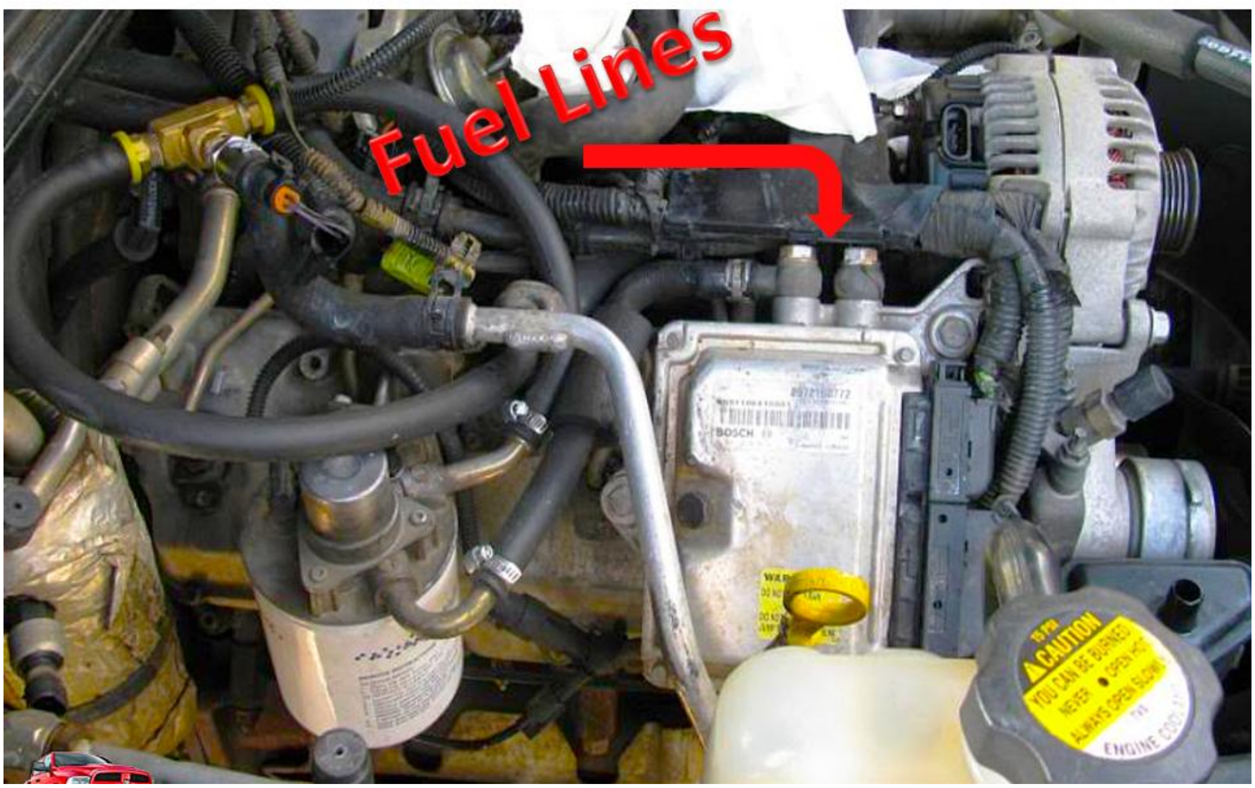
The fuel cooler

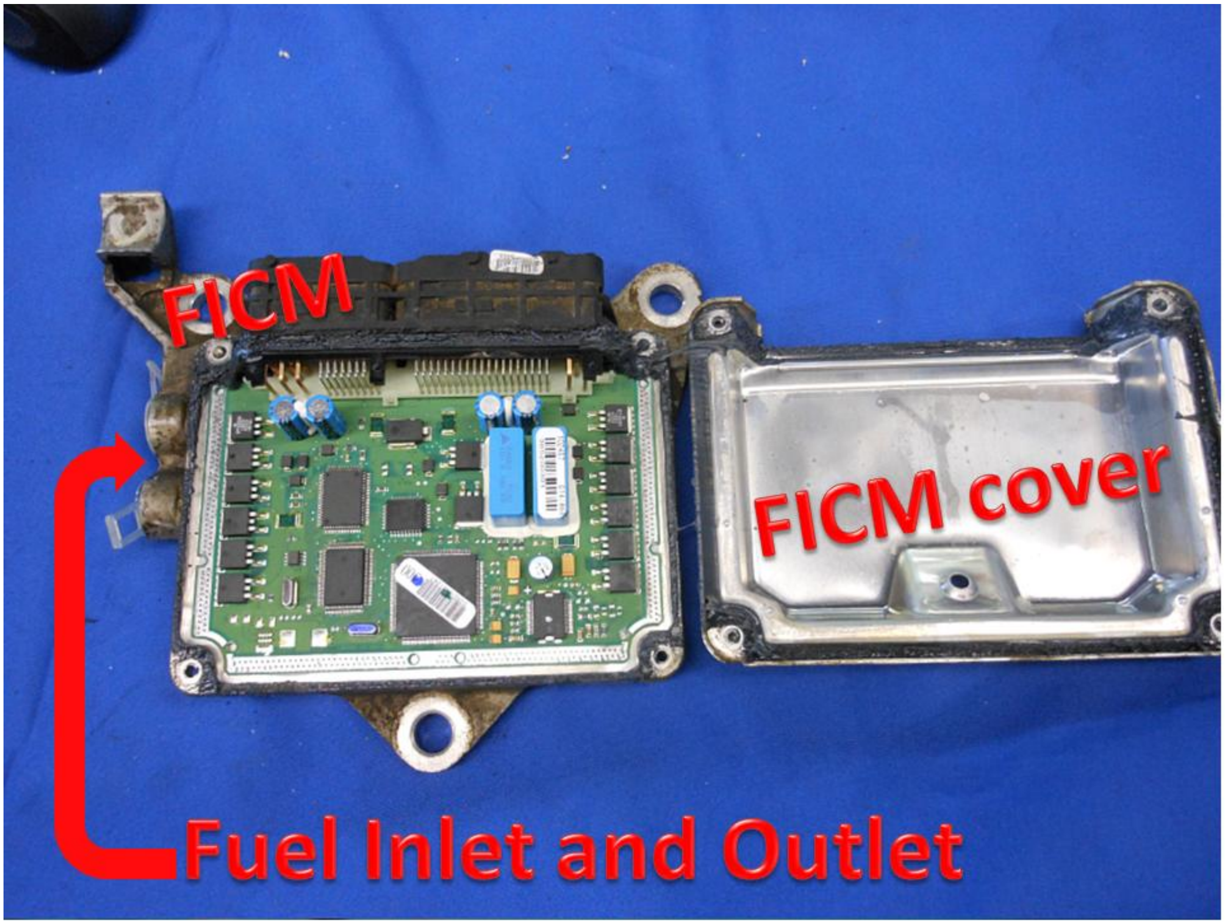
The fuel cooler is mounted near the fuel tank. Fuel returning from the system enters the cooler lowering its temperature before entering the fuel tank.

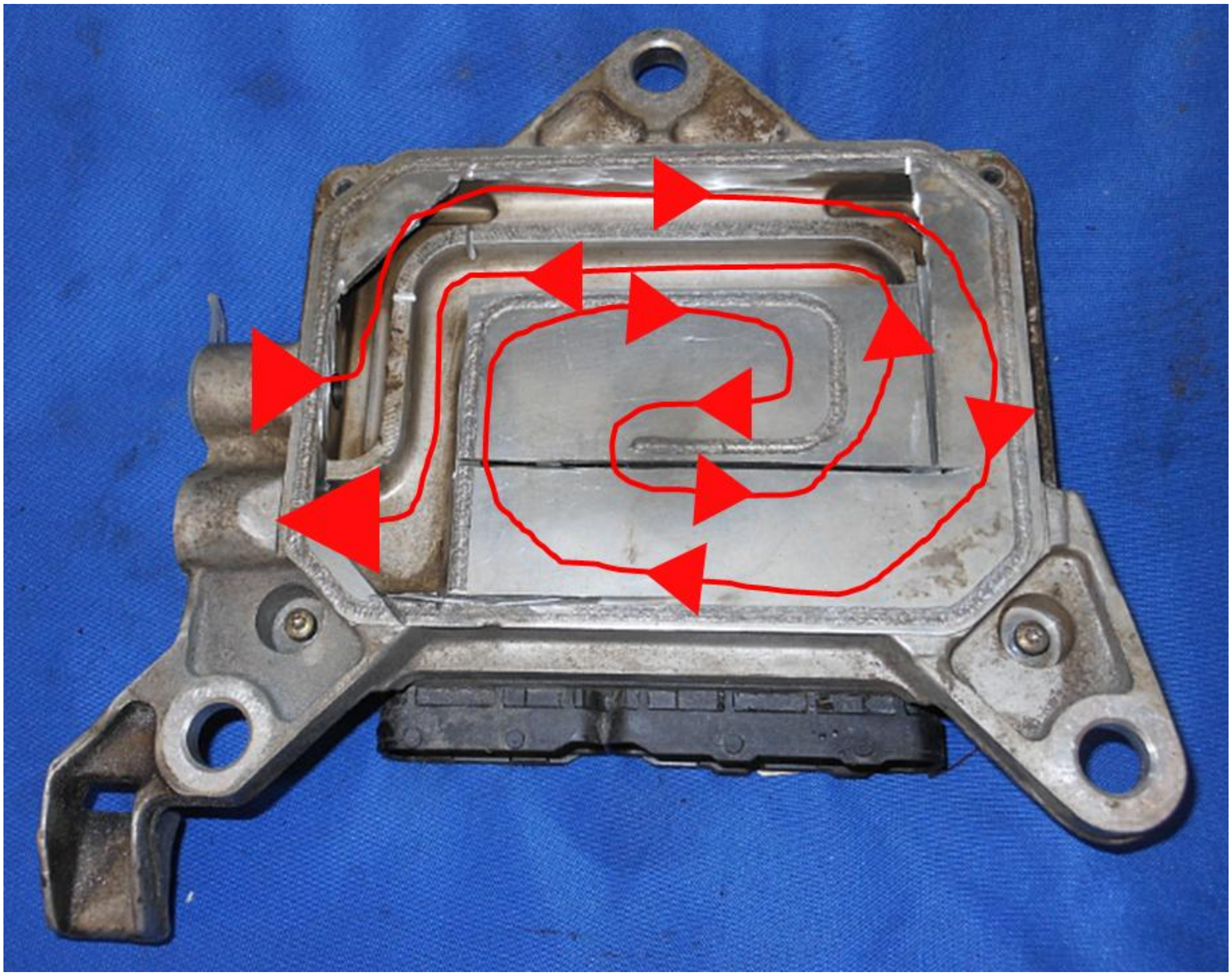


Fuel Injection Control Module (FICM)

The Fuel Injection Control Module (FICM) is mounted on the engine. It has the drivers for the injectors. It is cooled with fuel flowing through it. The PCM commands the FICM to turn on the injectors, and it is responsible for controlling the injectors..




FICM
FICM cover
Fuel Inlet and Outlet



Fuel Filter and water separator assembly

The fuel filter/water separator assembly is located on right side of engine for the pickup trucks and the left side of the engine for larger trucks. The assembly includes the fuel heater, Water-In-Fuel (WIF) sensor, and Filter.

The fuel filter/water separator protects the fuel injection pump by removing water and contaminants from the fuel.

The construction of the filter/separator allows fuel to pass through it, but helps prevent moisture (water) from doing so.

Moisture condenses out of the fuel and collects at the bottom of the canister.

A Water-In-Fuel (WIF) sensor is attached to the lower side of fuel filter housing.
A fuel heater is installed into the top of the filter/separator housing.

Water in fuel sensor

Possible Air Leaks

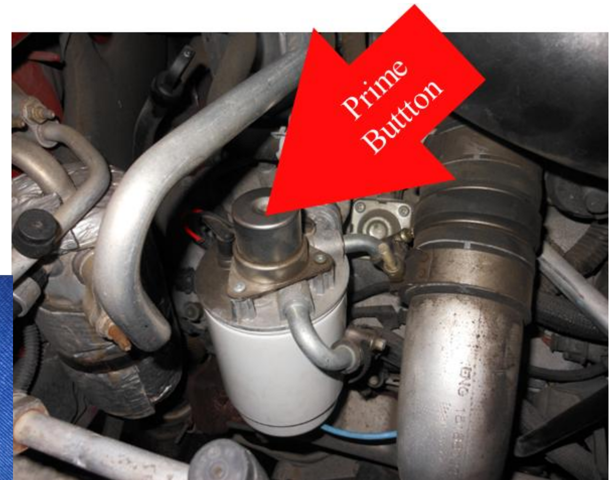
The fuel filter assembly can draw air in which cause aeration of the fuel lowing pressure causing; an extended crank before starting. Other problems a leak can cause is the engine Starts and dies, or Cranks but will not start. All the above go away for a short period of time when the system is primed manually by the pump on top of the filter assemble.

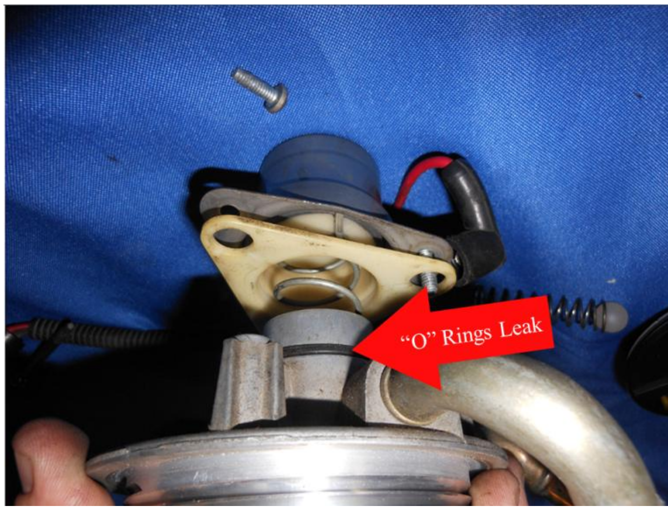
Low pressure leak detection

When one of the symptoms of a leak are present:
Pump the prime button on top of the filter until it is (very) hard to push down. If the symptom goes away it isn't the high pressure pump causing the concern. If the symptom doesn't go away the low fuel pressure side is sucking air into the system. If the prime button doesn't get hard there is a large leak.
If the prime button never gets hard to push, the problem could be the "O" Ring in the button is leaking.
Another procedure for looking for air (bubbles) in the low pressure system is to replace the low side hoses with clear hoses and pump the prime button while looking for bubbles.

Prime button Never get hard

If the prime button never gets hard to push, the problem could be the "O" Ring in the button is leaking.



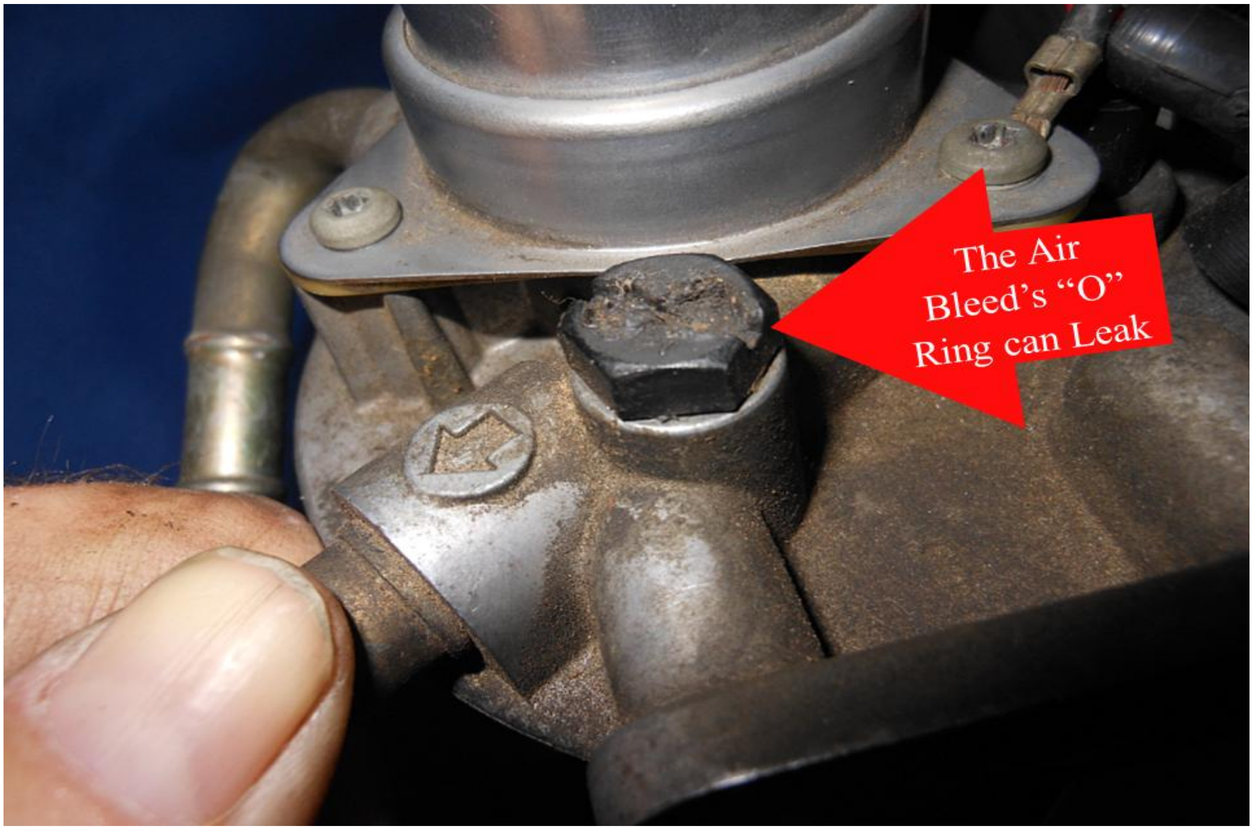


Quick Check for air leaks before the filter.

Rep[lace the filter input hoses with clear tubing so any bubbles will be visible.

O-ring on air Bleed

The O-ring on the air bleed is another place for p[possible air leaks.



Low pressure side test port

Connect a vacuum gauge and Prime the fuel system with the hand primer up to 10 PSI. Check for external leaks and repair. This is a quick test and if you don't see fuel leaking, it doesn't mean the low side isn't drawing in air.

Technicians who work on the Duramax often, like those who have a fleet of them, report that it can be difficult to pin point the leak. They separate each section of the low pressure side and use a hand held vacuum pump to test for leaks.

Technicians who have a fleet of Duramax, report that it can be difficult to pin point leaks They separate each section of the low pressure side and use a hand held vacuum pump to test for leaks.

Bleed the System

Anytime the system is opened like for replacing an “O” Ring or fuel filter; crack open the bleeder screw. Pump the plunger until air stops coming out. Use the test port to connect the vacuum gsuige.

Common Problems

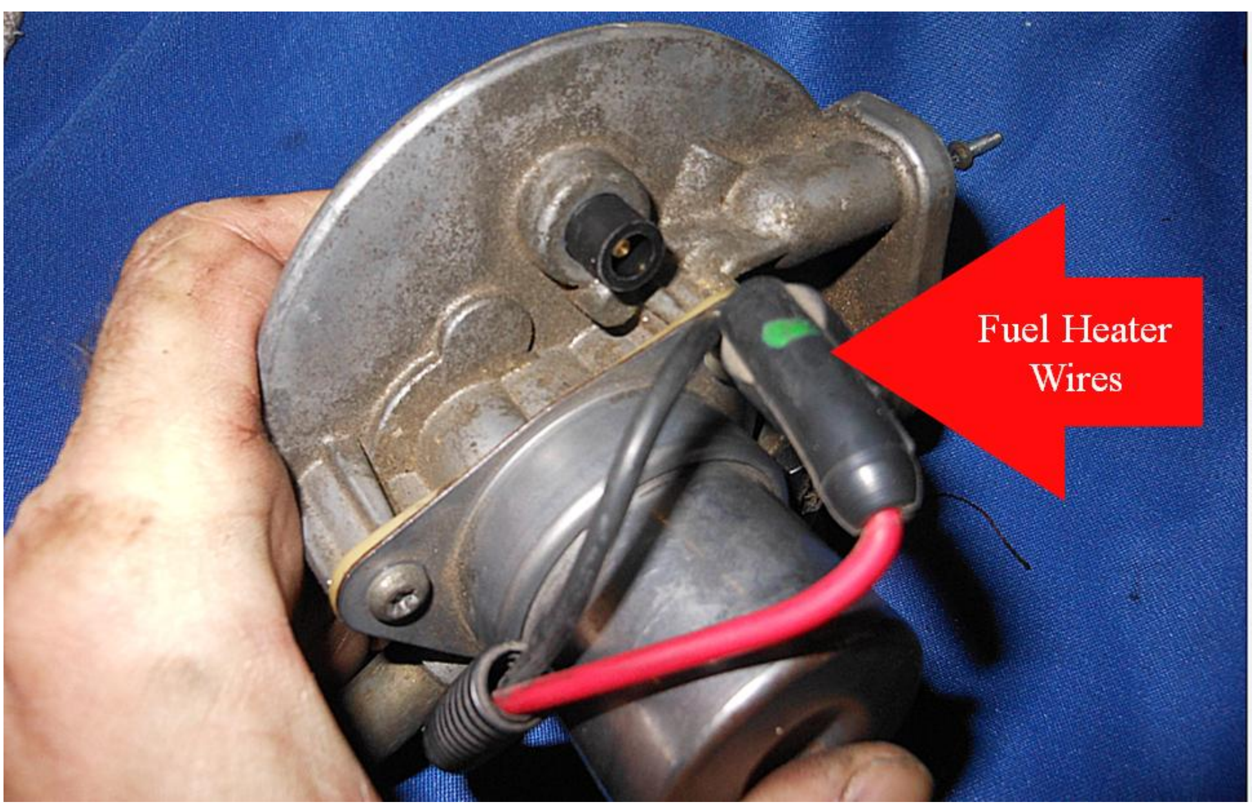
Diagnostic Trouble Code P0087, Low fuel pressure is a common DTC. Owners and technicians have been fighting this code for a long time. Since we are discussing the low pressure side we will only diagnose the low side. We will discuss the high side when we get to it.

Connect a vacuum gauge to the test port. While cranking the engine there should be 3” to 4” HG of vacuum. At WOT (Wide Open Throttle) in park or neutral there should be 4” to 5” HG of vacuum. During a hard acceleration while driving there should be 8” to 12” HG of vacuum.

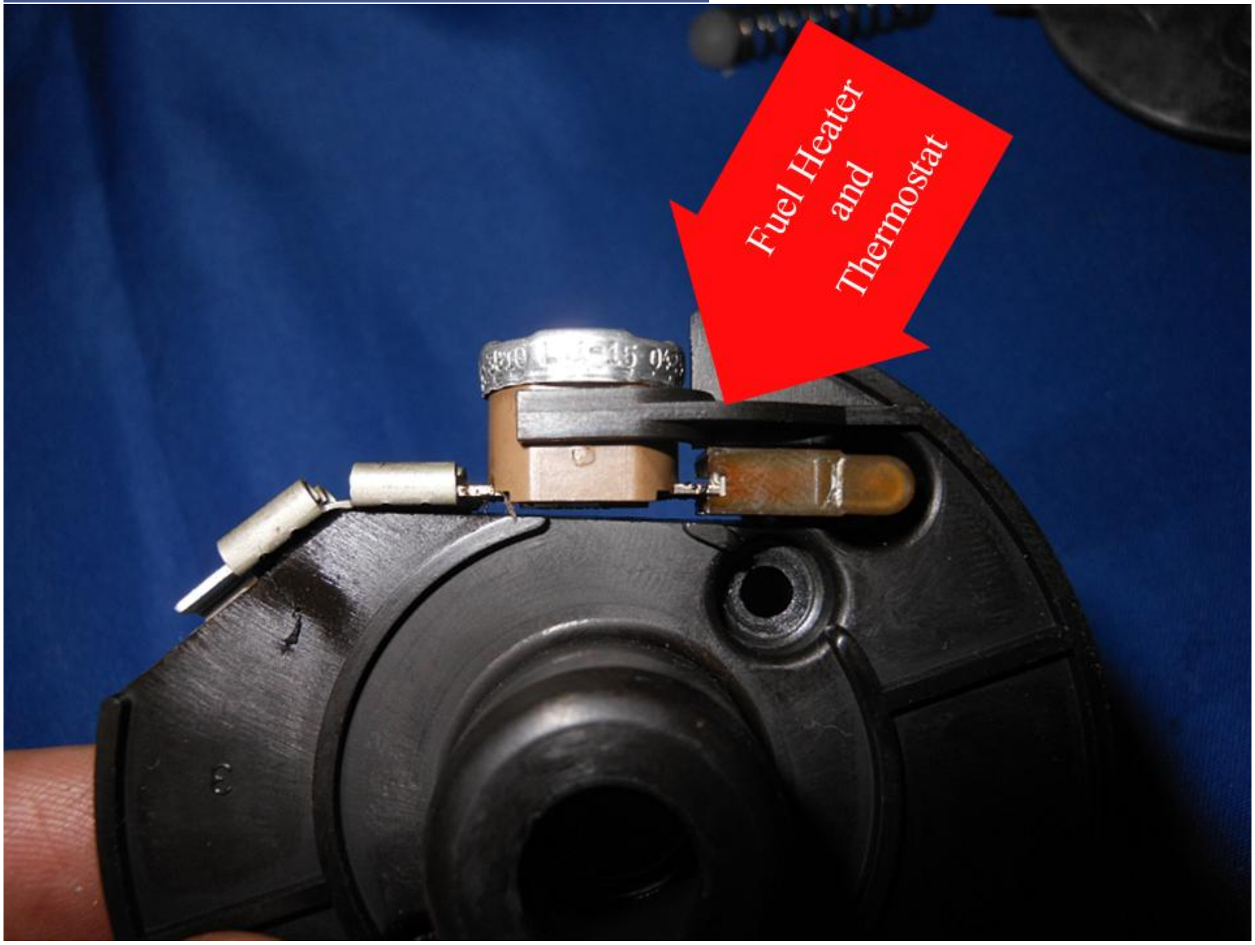
1. Too little vacuum could indicate that the system is drawing in air into the system.
2. Too much vacuum indicates a restriction in the system.

Filter Assemble Details

Fuel Heater Wires

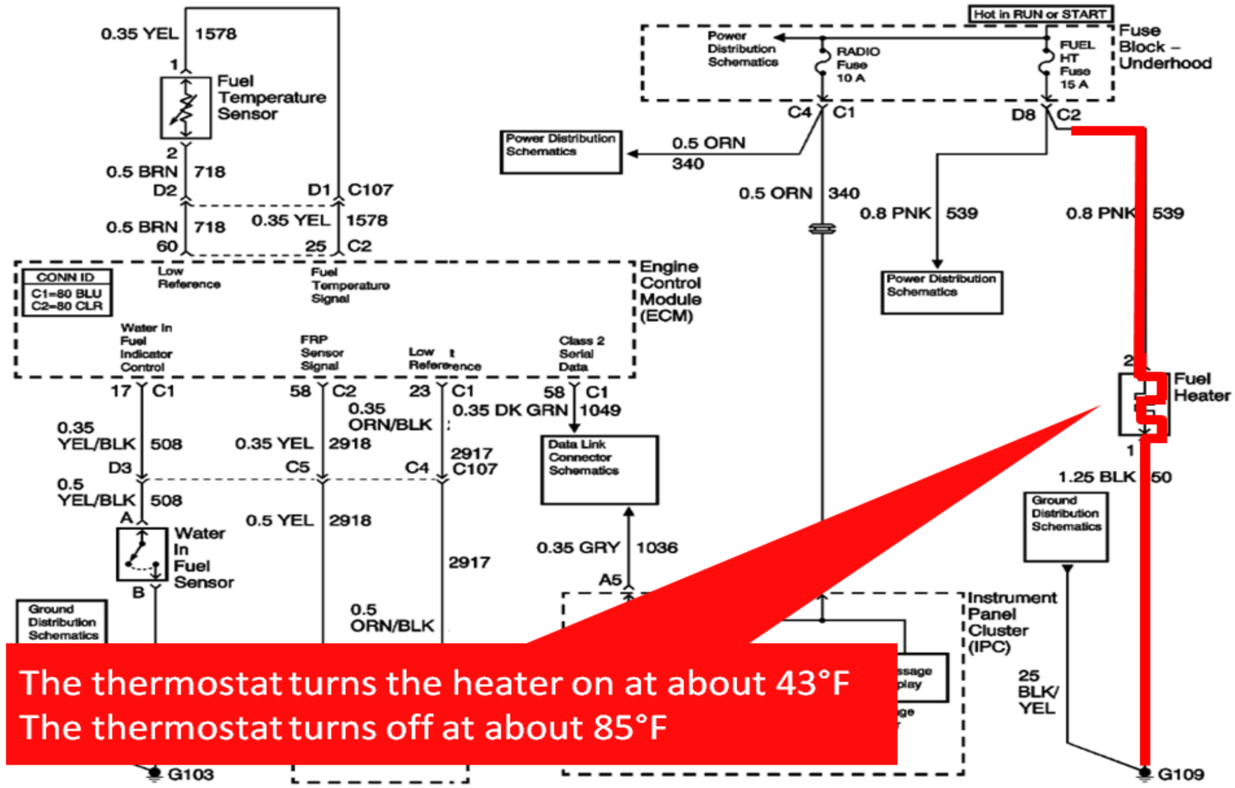


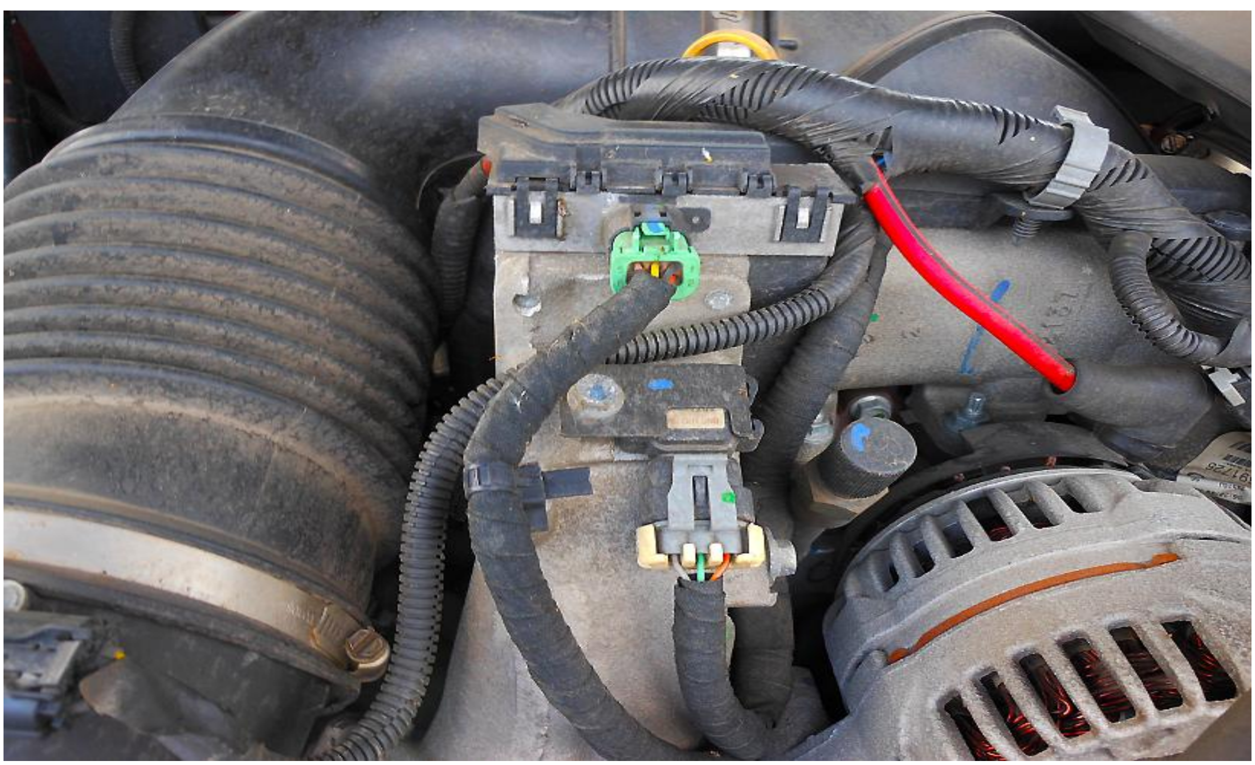
Fuel Heater and Thermostat



The element inside the heater assembly is made of a Positive Temperature Coefficient (PTC) material, and has power applied to anytime the ignition is in the On position. PTC material has a high resistance to current flow when its temperature is high, which means that it will not generate heat when the temperature is above a certain value. When the temperature is below 45° F, the resistance of the PTC element is lowered, and allows current to flow through the fuel heater element warming the fuel. As the temperature reaches 85° F, the thermostat element's resistance rises, and current flow through the heater element stops. Fused voltage to operate the fuel heater is supplied from the Ignition switch when the ECM senses the Ignition is in on position.

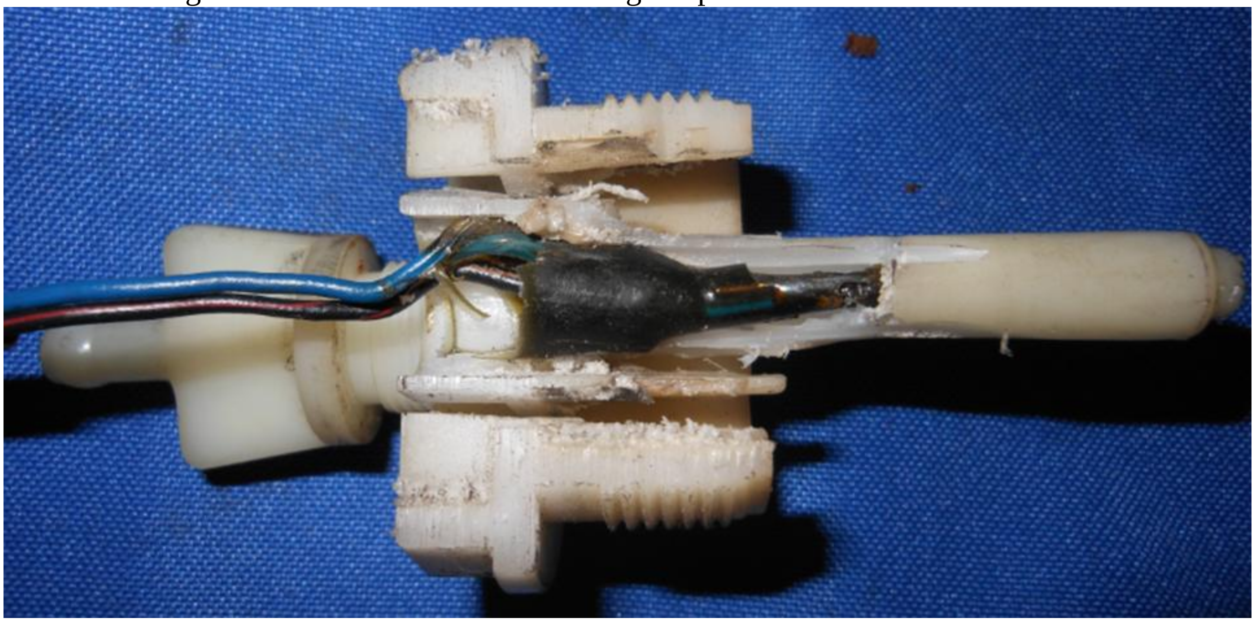
Thermostat Diagram



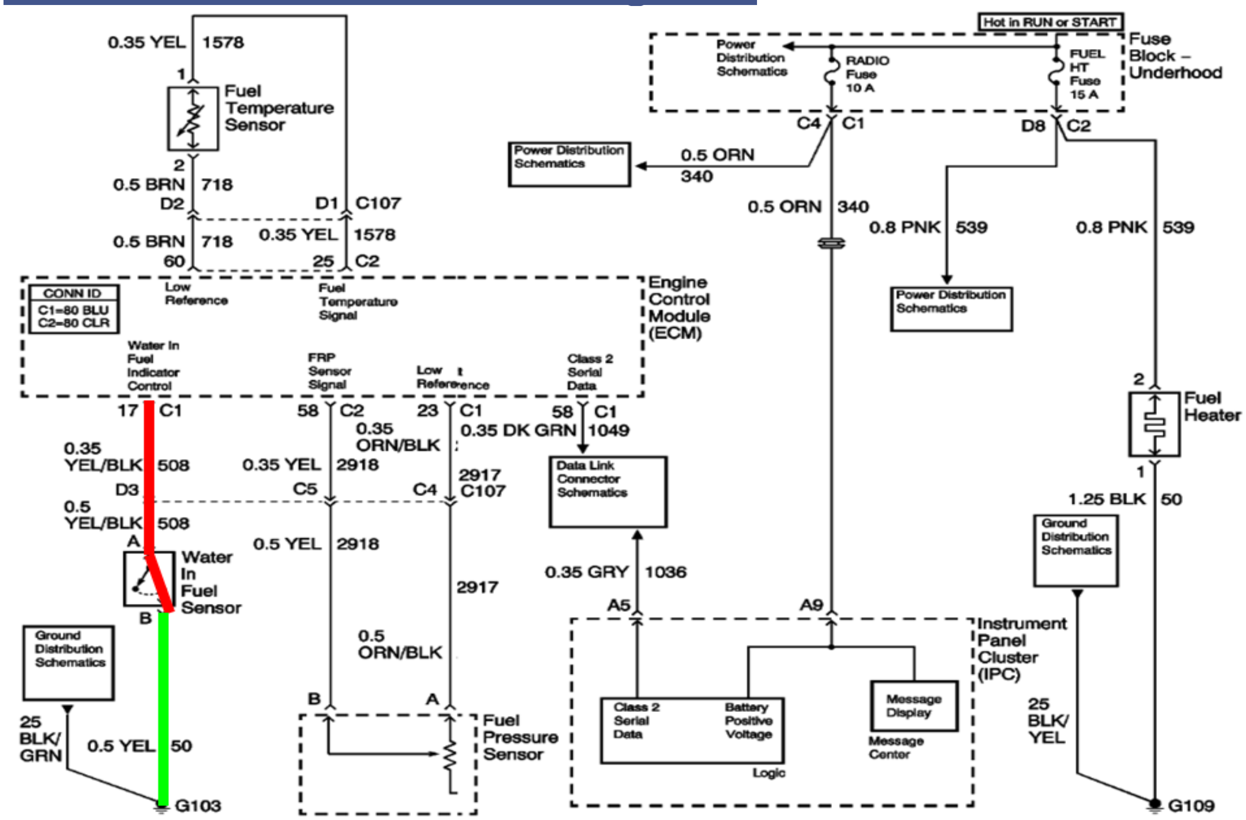


Water In Fuel Sensor

The water in fuel sensor uses a float to measure the amount of water. When the water reaches a specific level the WIF sensor completes the ground circuit for the WIF switch. When the ECM receives the signal it illuminates the WIF warning lamp on the dash.



Water In Fuel Sensor Diagram



Fuel Rail Pressure Regulator

The fuel pressure regulator is located between the Fuel Filter assembly and the High Pressure Fuel Pump. It doesn't regulate fuel pressure but rather fuel volume available to the High Pressure Fuel Pump. Normally open (A fault results in high pressure).

High Pressure Fuel Injection Pump

The Duramax 6.6L V8 CRD, Cummins 5.9 L CRD, and the Jeep 2.8 L CRD uses the Bosch CP3 injection pump.

A radial, 3-piston pump, with a gearotor pump attached to the back, is used as the high-pressure pump for common-rail fuel pressure generation - in this system it is capable of pressures between 4351-23206 psi. A spring-loaded Cascade Overflow Valve regulates internal housing pressure. Regulated internal housing pressure is OEM-specific. The pump shaft is driven by the timing belt at 1:1 ratio to the crankshaft. Fuel pressure is generated independently of the injection process. A Fuel Control Actuator solenoid valve regulates injection pressure. The pump is lubricated by the pumped Diesel fuel and is not responsible for fuel injection timing.

The gearotor pump has two functions

Draws fuel from the fuel supply.

Increases fuel pressure for regulation to housing pressure required for internal lubrication and supplying the high-pressure injection pump.

This fuel system uses a gearotor supply-pump attached to the rear of the high-pressure pump. This medium-pressure fuel pump is driven by the end of the high-pressure pump shaft, and can generate 20" vacuum at the fuel inlet at high rpm. The gearotor pump is supplied fuel from the lift pump in the fuel tank through the fuel FICM and fuel filter assembly.

The outlet of the gearotor pump provides pressurized fuel to a branched circuit internal to the high-pressure pump flange, which supplies both the Fuel Control Actuator solenoid valve and the **Cascade Overflow Valve** (COV)\regulator. Because the gearotor pump increases fuel flow and pressure as engine rpm increases, the pressure and flow is regulated by the COV.

The COV and gearotor supply-pump are not serviced independently of the high-pressure pump.

The COV is located on the front cover of the high pressure pump.

The Cascade Overflow Valve has three functions:

Regulation of lubrication fuel to the internal moving parts of the high-pressure pump.

Regulation of the fuel pressure is accomplished by regulating the fuel supplied to the Fuel Control Actuator solenoid valve.

excess fuel returns to the fuel tank.

This regulated internal pressure, known as housing pressure, is determined by engine displacement and power requirements; the 6.6L CRD requires 80-180 psi.

For comparison, the 2.8 L 4cyl Jeep CRD requires 73 psi.

The COV has a spring-loaded center spool-piece that has a drilled channel with three passages: one for initial low-pressure lubrication, one for lubrication at housing-pressure , and one for overflow. The valve is operated in three stages based on the level of pressure at the inlet.

Stage 1

When the fuel pressure entering the tip of the COV is between 0 and 3 bar (43 psi), pressure is too low to overcome regulator spring tension and fuel flows through the center channel, only . This passage always allows fuel flow through to the pump center-ring and lubricates the pump bearings and internal moving parts. This circuit also allows air to bleed during initial cranking and returns the air to the fuel tank.

The COV is in Stage 1 during cranking, only.

Stage 2

When the fuel entering the COV exceeds 5 bar (73 psi), but is less than 12.4 bar (180 psi), the spool-piece moves against spring tension aligning a second passage for lubrication purposes.

Stage 2 can be reached during cranking and initial startup.

Stage 3

When fuel pressure exceeds 12.4 bar (180 psi), the spool-piece aligns with the overflow passage. This stage relieves the pressure into an overflow circuit that sends the fuel back to the inlet side of the gearotor pump, thus limiting maximum fuel pressure to 12.4 bar (180 psi).

Lubrication fuel continues to flow through all channeled passages during this stage.

Excess fuel is sent back to the fuel tank through the fuel-return circuit

Stage 3 is reached at over-pressure

FUEL CONTROL ACTUATOR

DESCRIPTION

The Fuel Control Actuator solenoid valve is located on the back of the front cover of the high-pressure pump. The solenoid is pulse-width modulated by the ECM and meters the amount of fuel that flows into the high-pressure elements inside the high-pressure pump.

The solenoid is inactive up to 30 seconds after Ignition switch is initially keyed to ON position to allow maximum fuel pressure to the fuel rail during cranking and start up. ECM assumes FCA valve control when CPS signal and rail pressure are within acceptable limits

OPERATION

The Fuel Control Actuator solenoid valve is a pulse-width modulated valve that controls the amount of fuel sent or delayed to the high-pressure pump elements inside the high-pressure pump. The ECM determines the fuel pressure set point based on engine sensor and rail-pressure inputs. If the actual fuel-rail pressure is too low, the ECM commands the solenoid to allow more fuel to flow to the high-pressure pump. This minimizes the difference between the actual fuel-rail pressure reading and the set point. The ECM will also operate the solenoid to delay fuel, reducing flow-rate, if the fuel-rail pressure becomes too high.

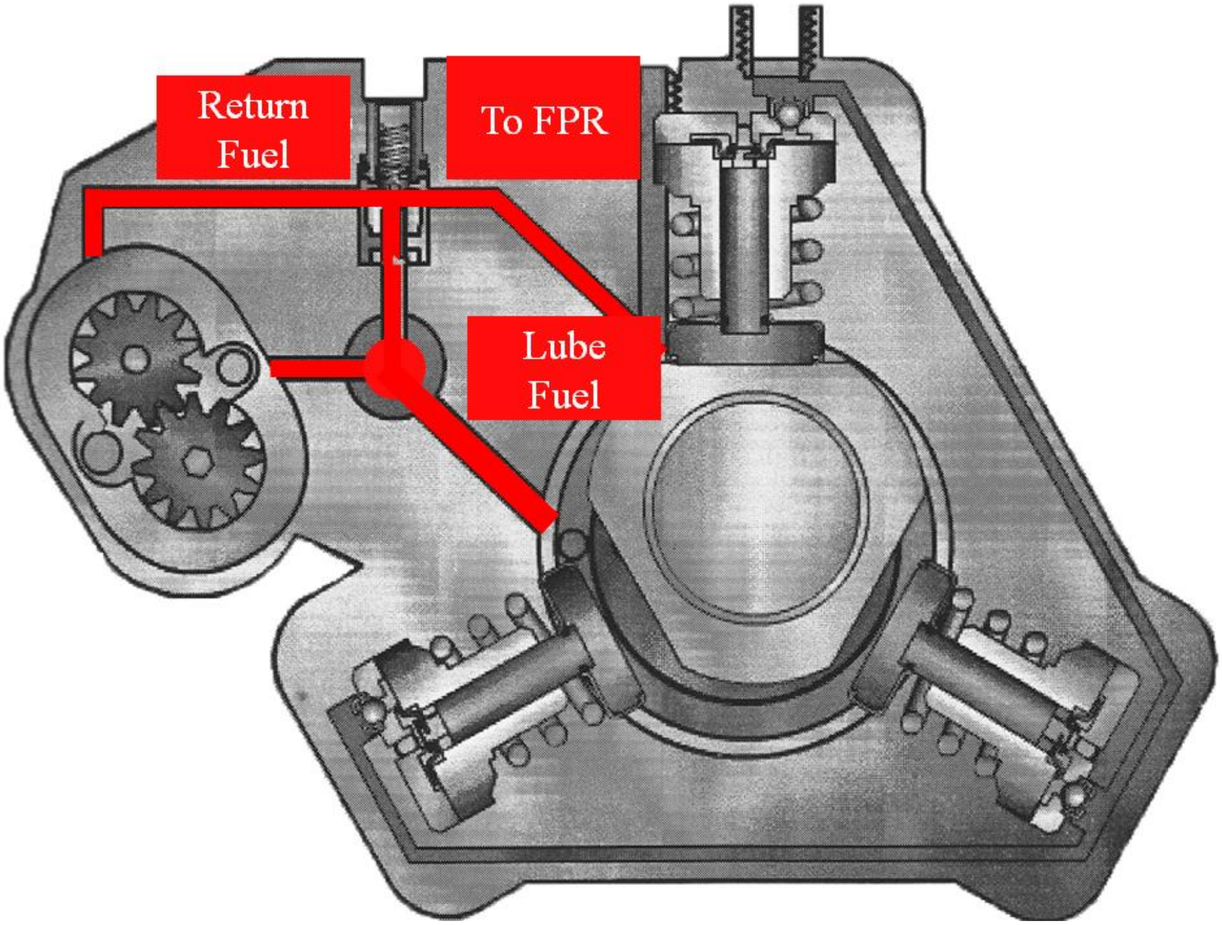
The FCA valve is commanded open by the ECM to allow the high-pressure pump to build maximum pressure (1600 bar, 23,206 psi), or closed to reduce rail pressure. Typical pressures at idle are between 5000 psi and 6000 psi

Thus, rail fuel-pressure can be increased or decreased independent of engine speed

High Pressure Pumping Plungers:

A valve supplies three high pressure pumping chambers with fuel. The pumping chambers have a one-way inlet valves that allow fuel to flow into the chambers. The valves close as the fuel is compressed, causing the high pressure fuel to overcome a spring-loaded ball-and-seat outlet valve. All three pumping chambers are connected together in one circuit, internal to the pump and provide high pressure fuel between 4351 psi and 23,206 psi through a steel line to the fuel rail. The pump’s function is to provide fuel at high-pressure, while the ECM controls injection pressure and timing.

High Pressure Pump Internals



A Fuel Pressure Regulator mounts between the low and high pressure sides of the pump.
It controls the amount of fuel available for the high pressure side of the pump which sets the output pressure
The medium-pressure fuel pump is driven by the high-pressure pump shaft.
It can generate greater than 20" vacuum at the fuel inlet to draw fuel from the fuel tank.

Cascade Overflow Valve

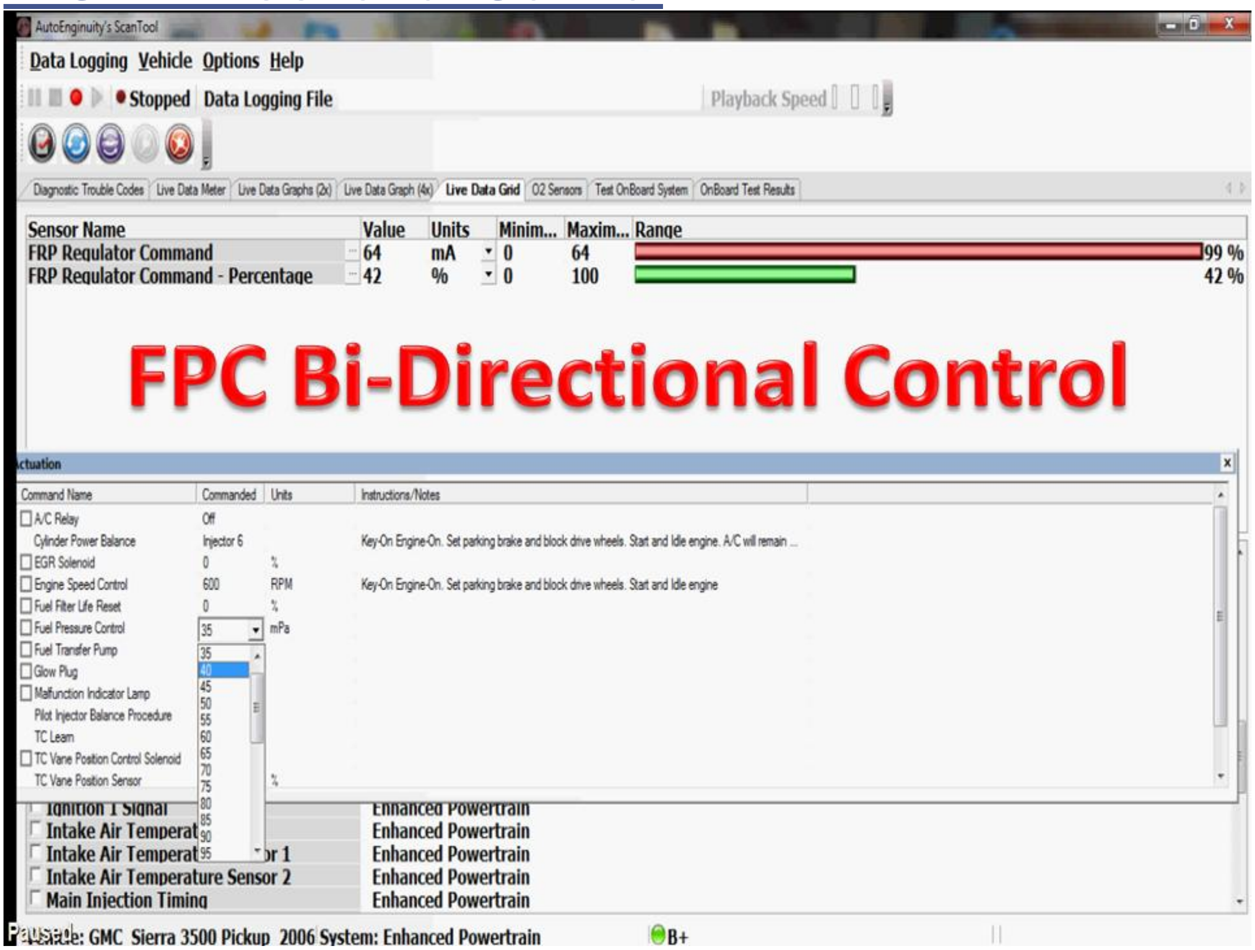
The Cascade Overflow Valve isn't serviceable.
The Cascade Overflow Valve has a spring-loaded center spool-piece that has a drilled channel with three passages: one for initial low-pressure lubrication, one for lubrication at housing-pressure , and one for overflow. The valve is operated in three stages based on the level of pressure at the inlet.
Stage 1 (During engine cranking only)
Pressure is too low to overcome regulator spring tension when the fuel enters the tip of the Cascade Overflow Valve is about 43 psi, and fuel flows through the center channel only. This passage always allows fuel flow through to the pump center-ring and lubricates the pump bushings and internal moving parts. This circuit also allows air to bleed during initial cranking.
Stage 2 (Can be reached during cranking and initial startup)

When the fuel entering the Cascade Overflow Valve exceeds 80 psi, but is less than 180 psi, the spool-piece moves against spring tension aligning a second passage for lubrication purposes.
Stage 3 (Reached at over-pressure)
When fuel pressure exceeds 180 psi, the spool-piece aligns with the overflow passage. This stage relieves the pressure into an overflow circuit that sends the fuel back to the inlet side of the pump, limiting maximum fuel pressure to 180 psi.
Fuel for lubrication continues to flow through all channeled passages during this stage. Excess fuel is sent back to the fuel tank through the fuel-return circuit.

Fuel Rail Pressure Regulator

The fuel pressure is electronically controlled by the Fuel Rail Pressure Regulator (FRPR). The FRPR is a duty-cycle solenoid mounted in the pump and controlled by the Electronic Control Module (ECM) based on feedback from an electronic sensor in the junction block that provides fuel to the supply rails. The FRPR duty-cycle operates in a 5% to 95% percent window, and unplugging the solenoid drives the fuel pressure to the maximum level instead of vice versa, as we might expect. The ECM increases pulse width to lower pressure, so if the solenoid receives a 100% percent duty cycle for some reason, pressure will be at its lowest, and performance will obviously degrade. A 5% percent duty-cycle will produce a fuel pressure of 23,200 psi, and a 95% percent duty-cycle feed will produce a 5,000 psi reading. The scan tool provides target and actual fuel pressure readings for diagnostic purposes. The solenoid is inactive up to 30 seconds after Ignition switch is initially turned to the on position to allow maximum fuel pressure to the fuel rail during cranking and start up. The PCM assumes the FRPR valve control when rail pressures are within acceptable Limits. The PCM determines the fuel pressure set point based on engine sensor and rail-pressure inputs. If the actual fuel-rail pressure is too low, the PCM commands the solenoid to allow more fuel to flow into the high pressure pumping chambers.

FPC Bi-Directional Control



High Pressure Pump

The system uses a medium pressure gear-type supply-pump attached to the rear of the high-pressure injection pump (to supply fuel to the high pressure pump

The supply side of the pump draws fuel from the fuel tank through the Fuel Injector Control Module (FICM), through the fuel filter assembly into the high pressure pump.

This medium-pressure fuel pump is driven by the high-pressure pump shaft.

It can generate greater than 20" vacuum at the fuel inlet.

A Fuel Pressure Regulator mounts between the low and high pressure sides of the pump.

It controls the amount of fuel available for the high pressure side of the pump which sets the output pressure.

High Pressure Common Rail

The fuel rail is mounted to the cylinder-head cover\intake manifold. The rail distributes regulated high-pressure fuel equally to the fuel injectors. A pressure sensor is screwed into the rail so ECM can read and regulate system pressure. A pressure valve is screwed into the fuel rail to allow regulated overflow return to the fuel tank. The fuel rail stores the fuel for the injectors at high pressure. At the same time, the pressure oscillations which are generated due to the high-pressure pump delivery and the injection of fuel are dampened by rail volume. The fuel rail is common to all cylinders, hence its name "common rail". Even when large quantities of fuel are injected, the fuel rail maintains a constant pressure. This ensures that injection pressure remains constant from the instant the injector opens to the end of the injection event. The common rail acts as an accumulator so that each injector has the same fuel volume and pressure available (About 16cc of Fuel).

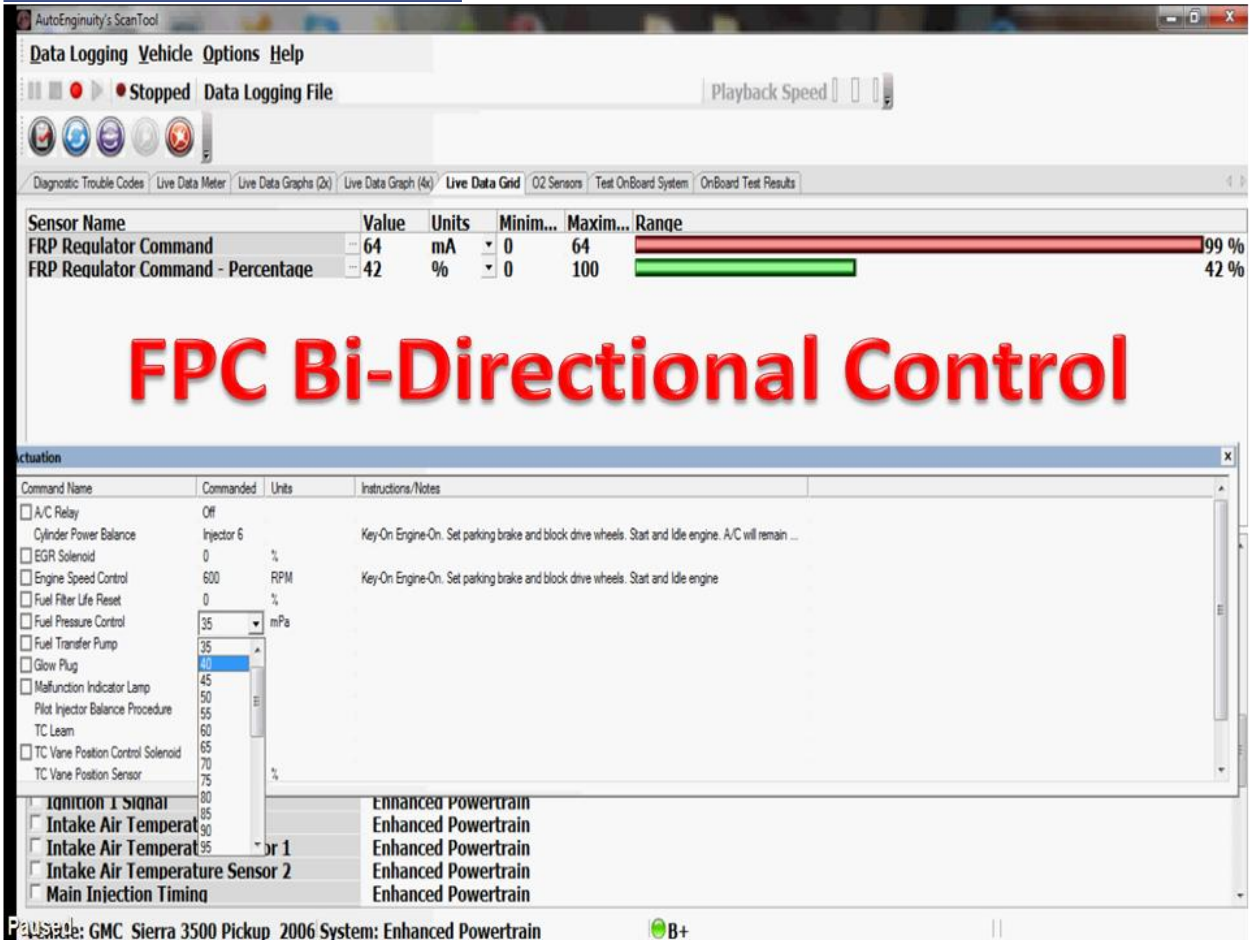
Fuel Rail Pressure Sensor (FRP)

The Fuel Rail Pressure Sensor is mounted in the fuel junction block. The PCM uses the sensor to control fuel pressure. It is a typical 3 wire pressure sensor.

Typical FRP Values

- KOEO the value should be above 174 psi and below 275 psi
- Idle the value should be above 4300 psi and below 5800 psi
- WOT the value should be above 20,000 psi and below 23,000 psi

Scan Data Values



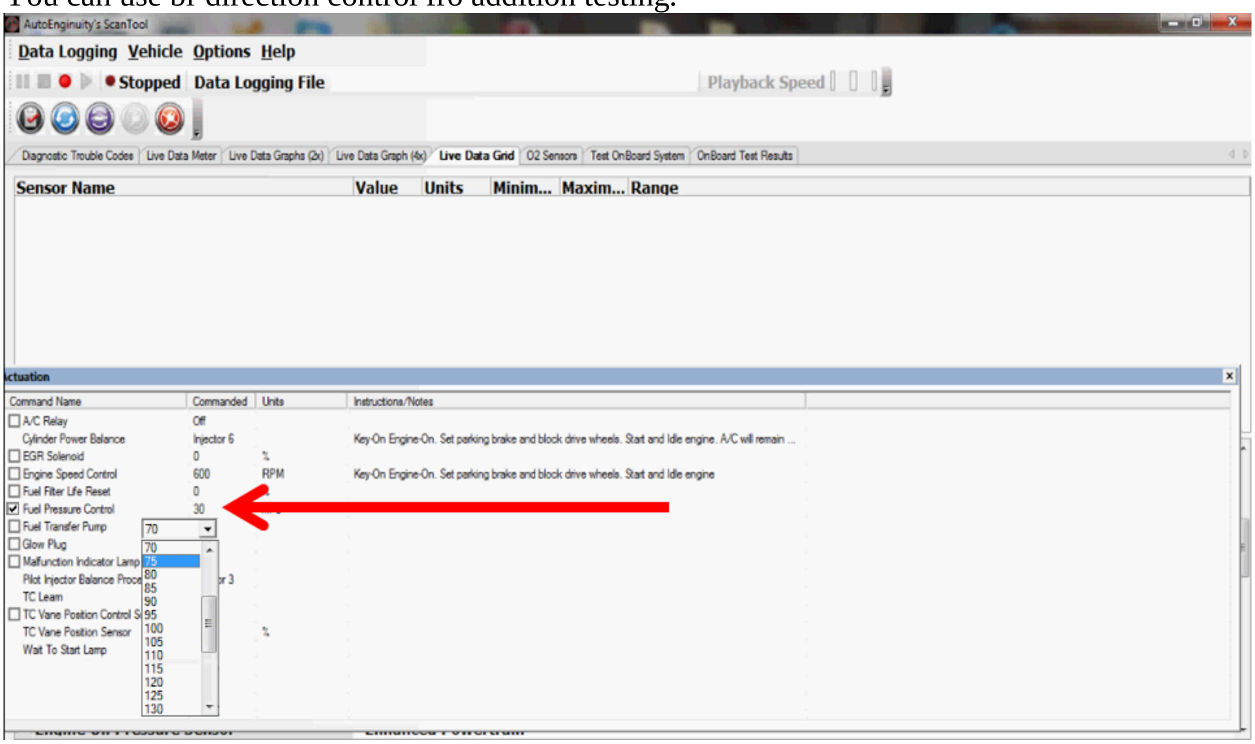
Study differences during normal vehicle operation.

The lower the Duty %
The higher the pressure

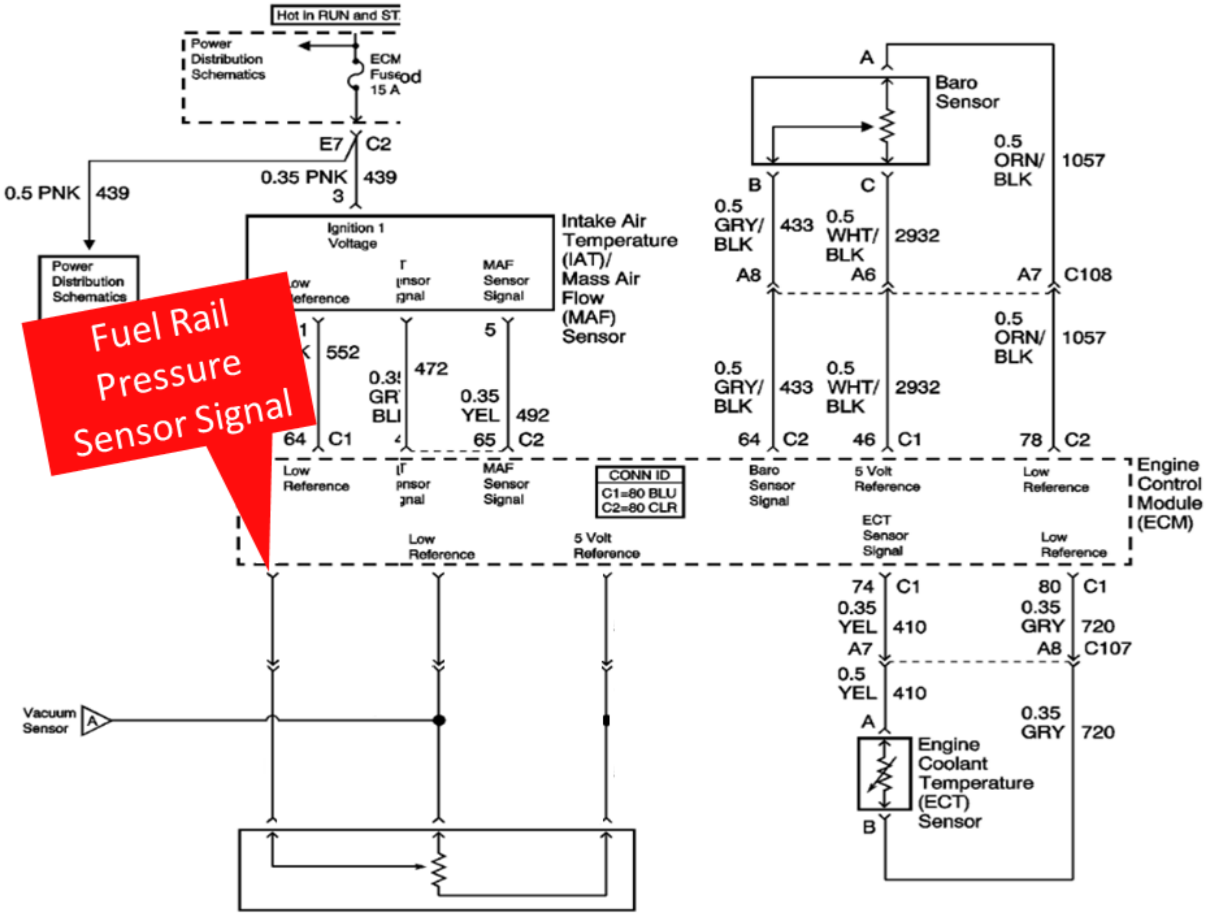
Sensor Name	Value	Units	Minimum	Maxim...	Range
Desired FRP Regulator	1415	mA	0	16384	8 %
FRP Regulator Command	1412	mA	0	16384	8 %
FRP Regulator Command - Percentage	35	%	[illegible]	100	35 %
FRP Regulator Fuel Flow Command	1674.000	mm3	0.000	131070.	1 %
Engine Speed	680	RPM	0	9000	7 %
Engine Oil Pressure Sensor	27	PSI	0	148	18 %
Fuel Rail Pressure - Actual	4514	PSI	[illegible]	[illegible]	12 %
Fuel Rail Pressure - Desired	4496	PSI	[illegible]	[illegible]	12 %
Injector 1 Command	1	ms	0	1000	0 %

Sensor Name	Value	Units	Minimum	Maxim...	Range
Desired FRP Regulator	1366	mA	0	16384	8 %
FRP Regulator Command	1354	mA	0	16384	8 %
FRP Regulator Command - Percentage	33	%	[illegible]	100	33 %
FRP Regulator Fuel Flow Command	3346.000	mm3	0.000	131070.	2 %
Engine Speed	1069	RPM	0	9000	11 %
Engine Oil Pressure Sensor	41	PSI	0	148	27 %
Fuel Rail Pressure - Actual	7175	PSI	[illegible]	[illegible]	19 %
Fuel Rail Pressure - Desired	7107	PSI	[illegible]	[illegible]	19 %
Injector 1 Command	1	ms	0	1000	0 %
Injector 2 Command	1	ms	0	1000	0 %

You can use bi-direction control fro addition testing.

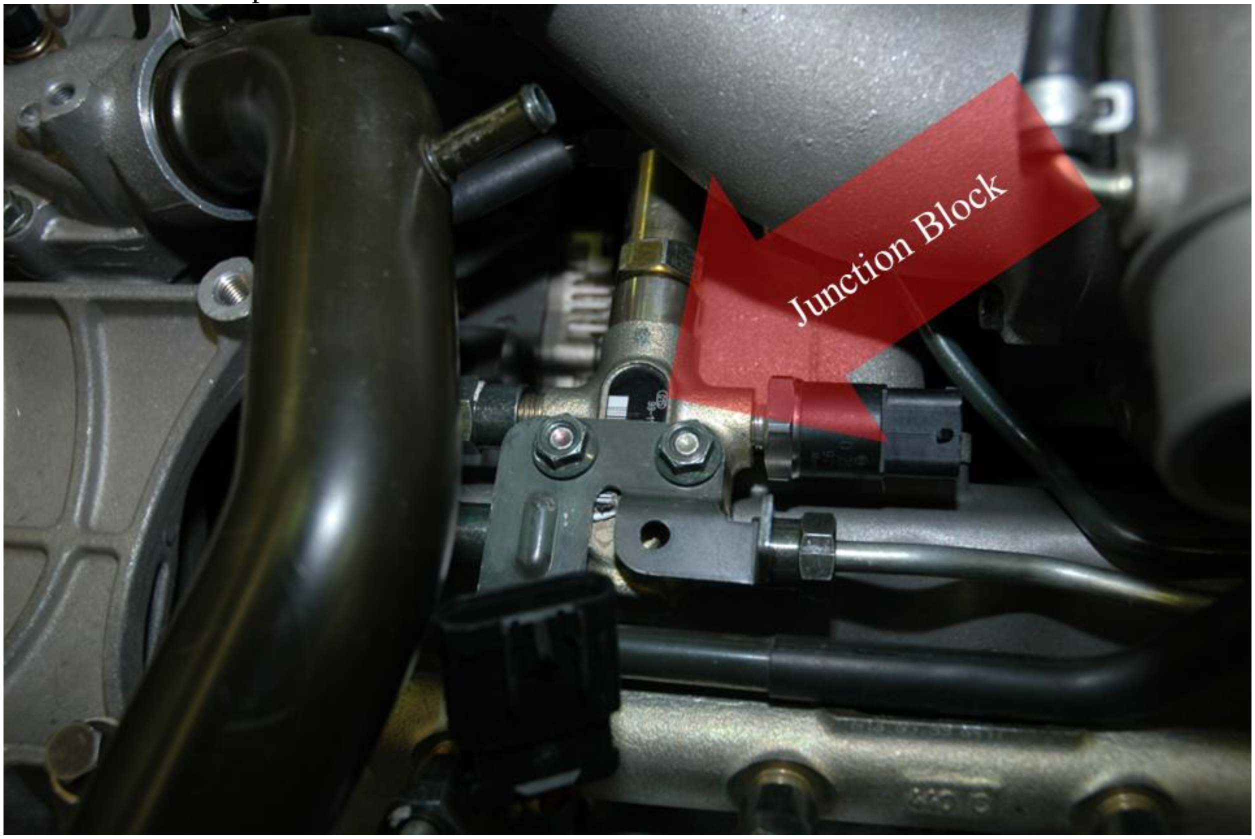


Fule rail pressure sensor diagram



Fuel Junction Block

The block is used to receive fuel from the high pressure pump and direct it to each cylinder head. It is located on the intake manifold's left side. The fuel pressure relief valve is mounted on the block as is the fuel pressure sensor.



Use the Rail Pressure Sensor for testing

Graph the Fuel Pressure Sensor PID on a scan tool. Look for large fluctuations in the graph. If there are large fluctuations, replace the fuel pressure regulator.
You can also compare the fuel rail pressure Desired to the Actual. They should be close together. If they aren't look for the root cause of the low fuel pressure or the root cause of the restriction in the return.
Look for 5000 psi or higher on the scan data PID when cranking. If low disconnect the fuel pressure regulator on the pump.
If low:
Check the FPR electrical circuit.
Check for the low pressure side sucking air.
If there isn't a problem with the FPR or the low pressure side, always look for a restriction in the return before condemning the pump. Also before replacing the pump look at the inputs for fuel control are normal.

Complete the fuel volume test to confirm the pump is not putting out enough pressure/volume.

Fuel Rail Pressure - Actual	7175	PSI	0	37130	19 %
Fuel Rail Pressure - Desired	7107	PSI	0	37130	19 %

Fuel Rail Pressure – Actual

Fuel Rail Pressure – Desired

Fuel Pressure Relief (limiting) Valve

The fuel pressure limiting valve is located on the fuel junction block. Fuel pressure at the fuel rail is monitored by the fuel rail pressure sensor. If fuel pressure becomes excessive, the high pressure fuel overcomes a spring-loaded plunger with tapered-seat outlet valve, causing the pressure limiting valve to open and vent excess pressure into the fuel drain circuit, and back to the fuel tank.

Fuel Injectors

The fuel injection control module (FICM) supplies high voltage to each fuel injector on the ignition voltage circuits. The FICM energizes each fuel injector by grounding the command circuit between the FICM and the fuel injector. The FICM monitors the status of the ignition voltage circuits and the fuel injector command circuits. When a fuel injector circuit condition is detected by the FICM, all of the fuel injectors on the affected ignition voltage circuit will be disabled. If a circuit condition is detected on a fuel injector circuit for cylinders 1, 4, 6, or 7, DTCs P0201, P0204, P0206, P0207 will set, along with DTC P1261. If a circuit condition is detected on a fuel injector circuit for cylinders 2, 3, 5, or 8, DTCs P0202, P0203, P0205, P0208 will set, along with DTC P1262.

CONDITIONS FOR RUNNING THE DTC

DTCs U1800, and U2104 are not set.
The engine is running.
The charging system voltage is between **6-18 volts**.

CONDITIONS FOR SETTING THE DTC;

The FICM detects an incorrect current on a fuel injector circuit.
The condition exists for less than **1 second**.

ACTION TAKEN WHEN THE DTC SETS;

The control module illuminates the malfunction indicator lamp (MIL) when the diagnostic runs and fails.
The control module records the operating conditions at the time the diagnostic fails. The control module stores this information in the Freeze Frame/Failure Records.

CONDITIONS FOR CLEARING THE MIL/DTC;

The control module turns OFF the malfunction indicator lamp (MIL) after 3 consecutive ignition cycles that the diagnostic runs and does not fail.
A history DTC clears after 40 consecutive warm-up cycles, if no additional failures are reported by this or any other emission related diagnostic.
Clear the MIL and the DTC with a scan tool.

2001 through 2003 model year

GM Document ID #1866141 & #04039-B explains that additional injector warranty coverage is now available for a period of 7 years from the date the vehicle was placed into service or 200,000 miles, whichever occurs first. This has expired but some injector failures are p[possible for those injector that did not fail under warranty.

Corporate Bulletin Number 04-06-04-007A

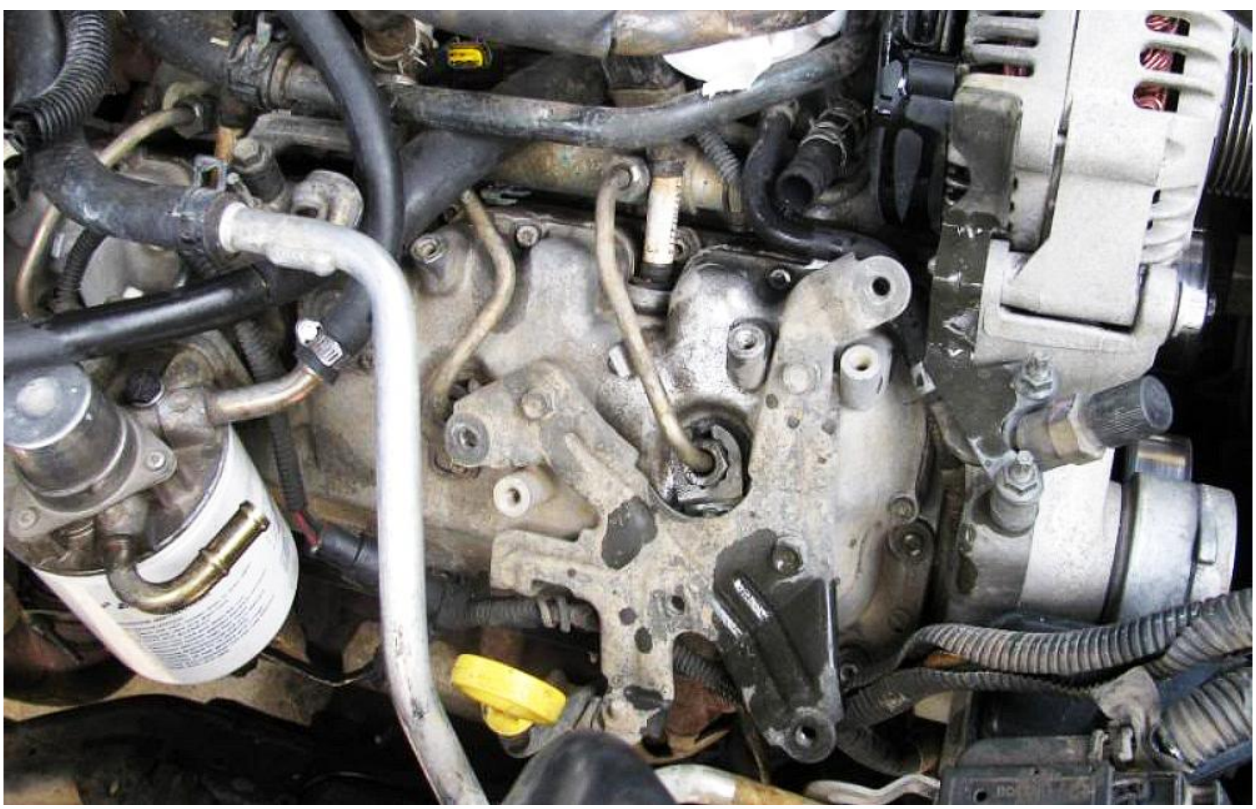
GM recommends following Corporate Bulletin Number 04-06-04-007A for injectors diagnosed with high fuel return rates.
GM specifically directs its dealerships not to replace all 8 injectors for any complaint other than High Fuel Return Rates.
Other types of injector failures are "fix as failed", meaning the individual faulty injector will be replaced, not all eight.
The 6.6L Duramax, as well as the Isuzu 5.2 L and 6.8 L engines are a Common-Rail Diesel injection system, and all utilize similar Bosch and Denso fuel injectors. These injectors are prone to failure under certain situations, all of which are reasonably easy to avoid. These failures include conditions such as leaking fuel into the combustion chamber, leaking excess fuel to the fuel return line, and sticking, or misfiring, injectors.
The primary cause of fuel injector failure in a Duramax or Isuzu Common-Rail is a lack of fuel. Fuel in a diesel injection system provides lubrication to the injection pump and injectors. The fuel injectors on a Common-Rail system rely on high-precision components which can be easily damaged when they lack this lubrication. If the fuel injectors are damaged and leak fuel into the combustion chamber or the return line, this may cause an engine misfire and possibly a low fuel pressure condition, which can lead to damage to other fuel injectors.
Fuel shortages can be caused by clogged fuel filters, leaking fuel supply lines, or worn or malfunctioning fuel injection pumps. The Fuel injection pump draws fuel from the tank, on most models, without the assistance of a lift pump. This suction causes the fuel in the supply line to be under a slight vacuum under normal conditions. This vacuum may cause leaking connections on

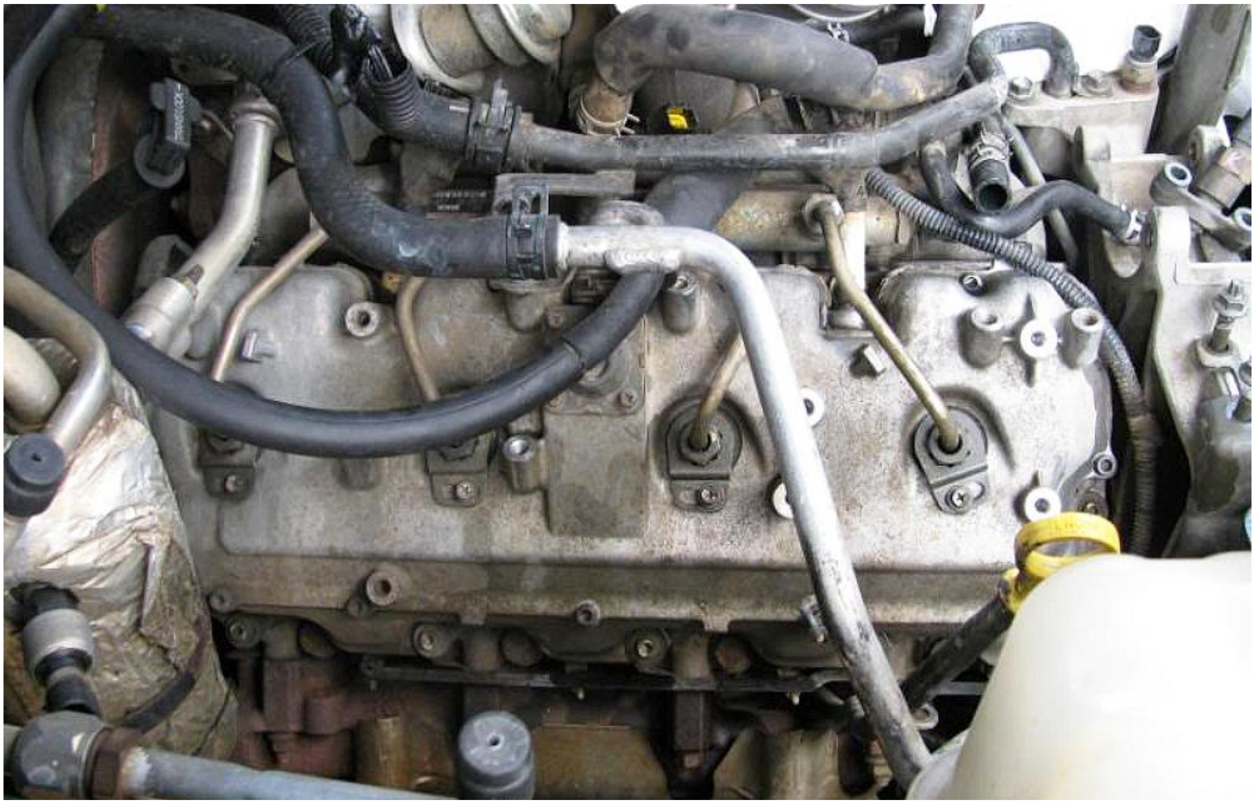
the fuel supply lines to draw air in, and may not show signs of leaking fuel to the outside. This suction-method of drawing fuel from the tank also makes the fuel system more prone to problems related to clog fuel filters. A less common cause of fuel shortages can be clogged fuel tank vents. As fuel is drawn from the tank, air must be allowed to enter the fuel tank through the vent. Partially clogged vents can cause excessive vacuum in the fuel supply system, just as a clogged fuel filter will.

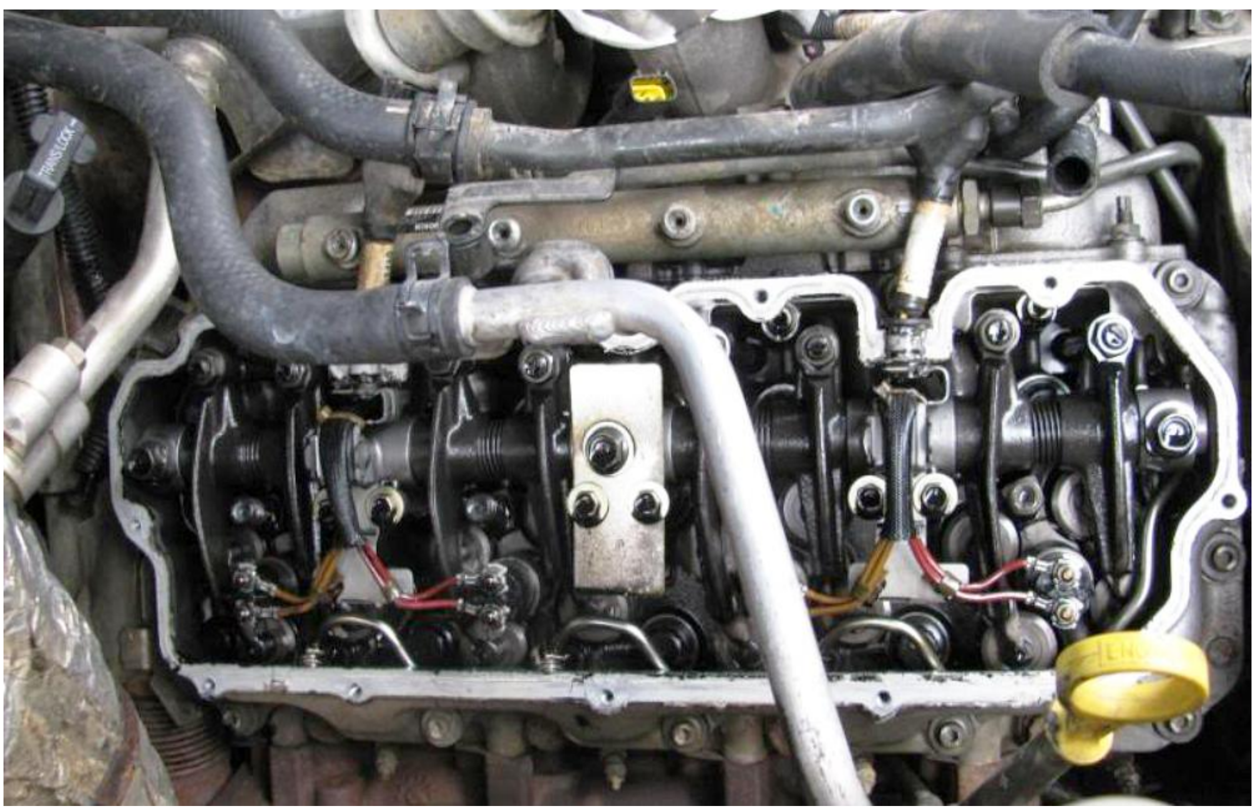
Fuel filters typically clog up over an extended period of time due to normal amounts of contamination in the fuel. However, poor fuel quality, the presence of water in the fuel, or contamination entering through damaged fuel caps or vents can cause these filters to clog very quickly. Contamination is particularly a problem on landscape and construction vehicles which are exposed to large amounts of dust and debris. Any time the water-in-fuel light comes on, the vehicle should be stopped immediately and the fuel filter drained. If the problem recurs, the fuel tank and supply lines should be examined for the presence of water or leaks which may be allowing water to enter. If there is water in the fuel tank, it may be time to reconsider where you are buying fuel.

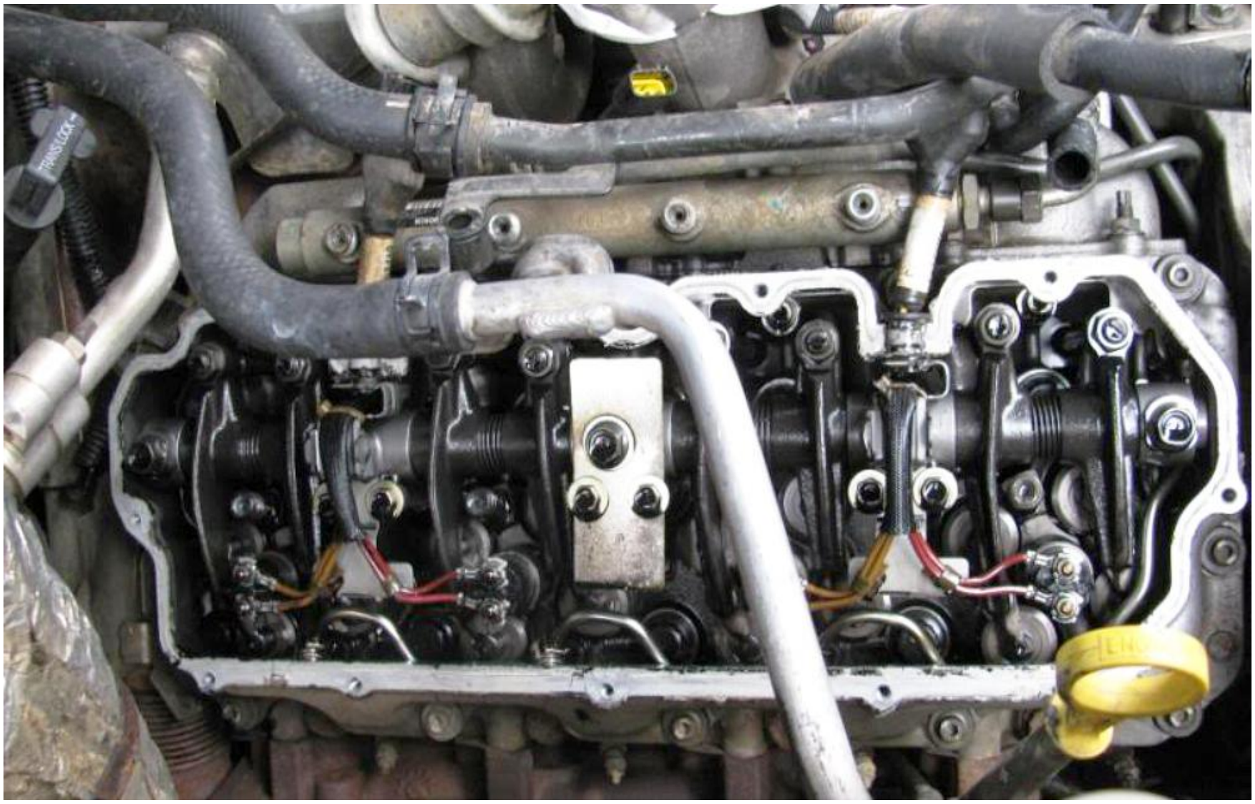
Preventing Bosch and Denso fuel injector failures is actually very easy. Frequent fuel filter replacement is essential, and Fleet Service Northwest recommends the fuel filter on a Duramax be replaced every 6,000 mi, or more frequently if the vehicle is used for towing or hauling loads. For an Isuzu Common-Rail, we recommend replacing the fuel filter when performing each Lube, Oil and Filter service, which we recommend doing at 4,000 mi intervals. Using quality fuels, and avoiding stations that may sell low volumes of diesel, which can cause contamination buildup in the station's storage tank, is another important way to avoid injector damage. Care should be taken when deciding to use biodiesel and the use of homemade biofuels is not a good idea for any modern diesel engine. Use special additives if biofuel problems occur.

LB7 Injectors are under the Valve covers



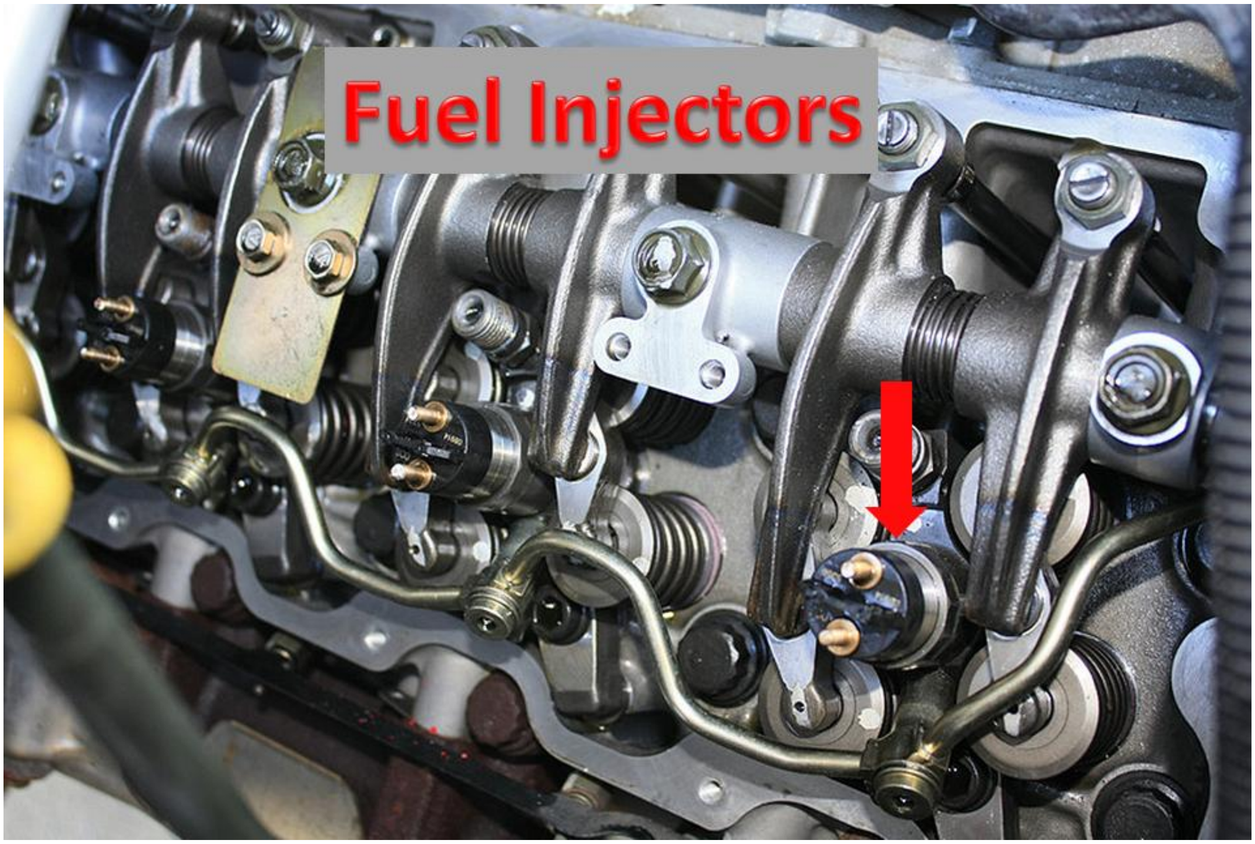







High
Pressure
Line


Sever
Don’t overlook corrosion



Fuel Injector Controlled Module

The injectors are controlled by the Fuel Injector Controlled Module (FICM). They are solenoid style injectors that operate at 93 volts drawing 18-20 amps control circuits. There are two injection events for each ignition cycle, the Pilot injection event and the main injection event.

The Pilot injection event

The pilot event is used only used under 2500 RPM. This is a pre-combustion injection event that reduces noise by injecting only a small amount of fuel.
The ignition of this small amount doesn't create that much noise.

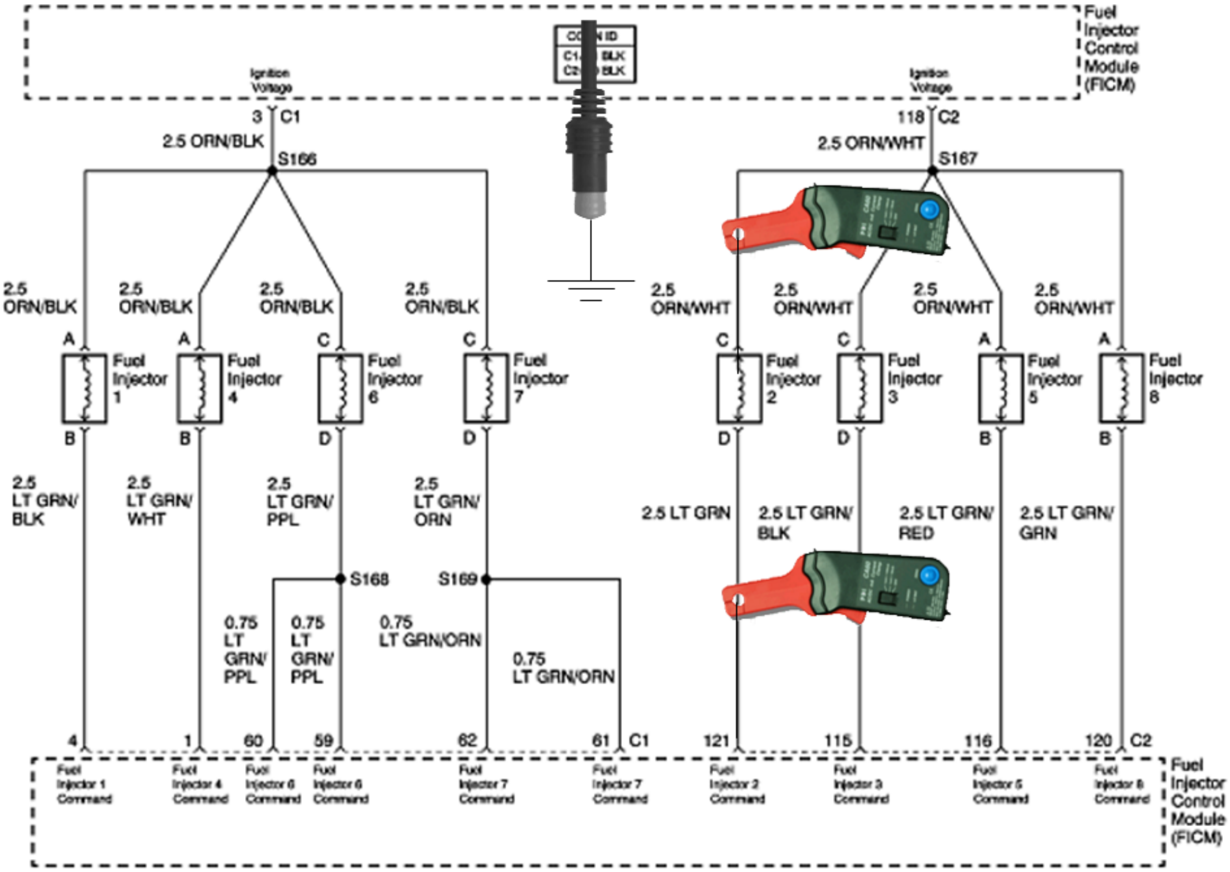
The Main injection event

The main injection event is used to develop engine torque. It starts just as the pilot injection event is ending. The second injection event enters the chamber with a flame front already burning which reduces the diesel ignition noise.

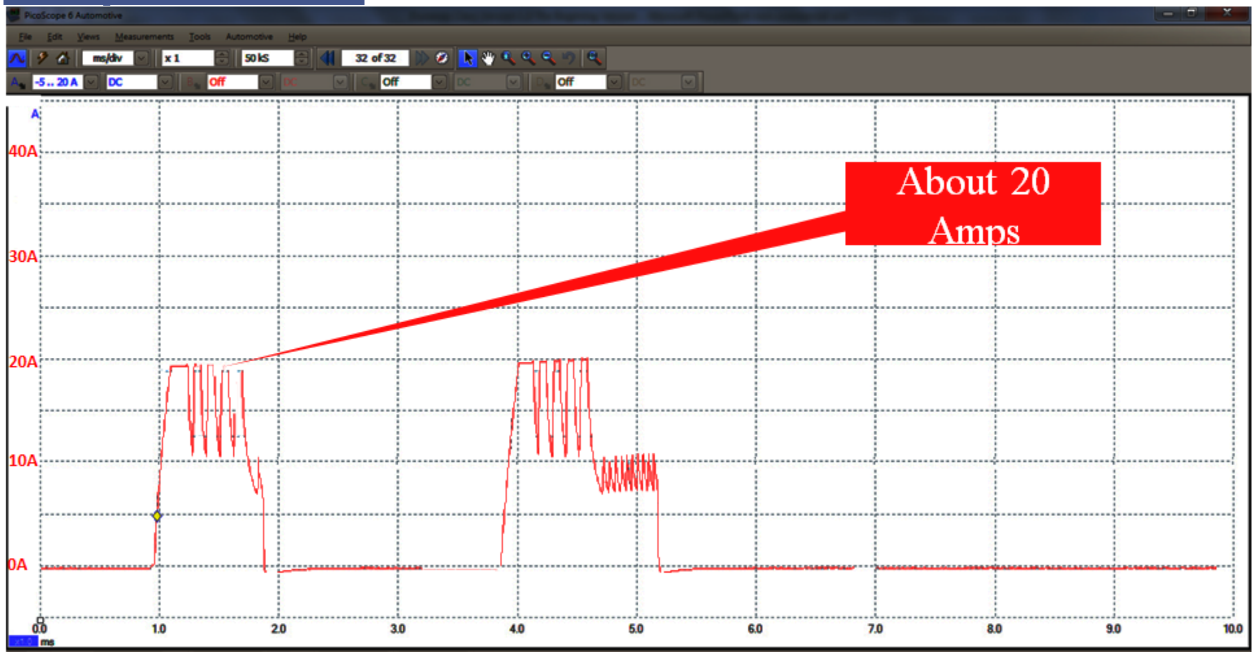
Injector Control

The Fuel Injection Control Module (FICM) supplies high voltage (93 Volts) to each fuel injector on the **ignition voltage circuits**

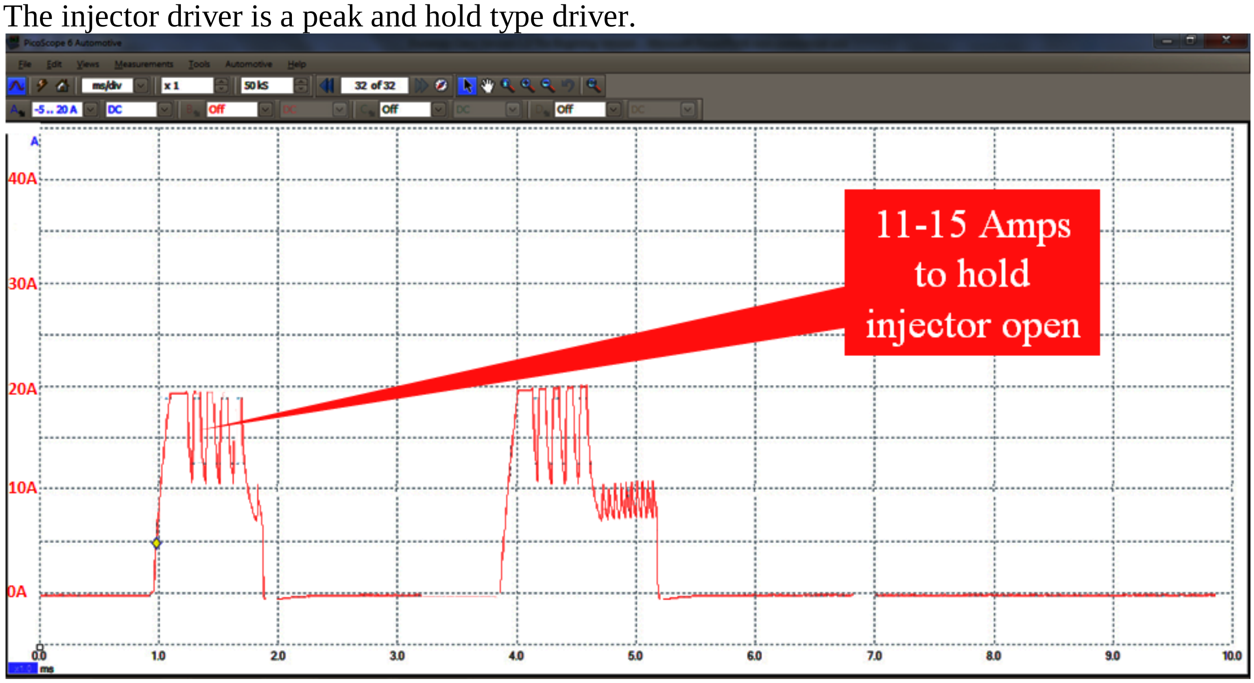
The FICM energizes each fuel injector by **grounding** the command circuit between the FICM and the fuel injector.



Scope Pattern



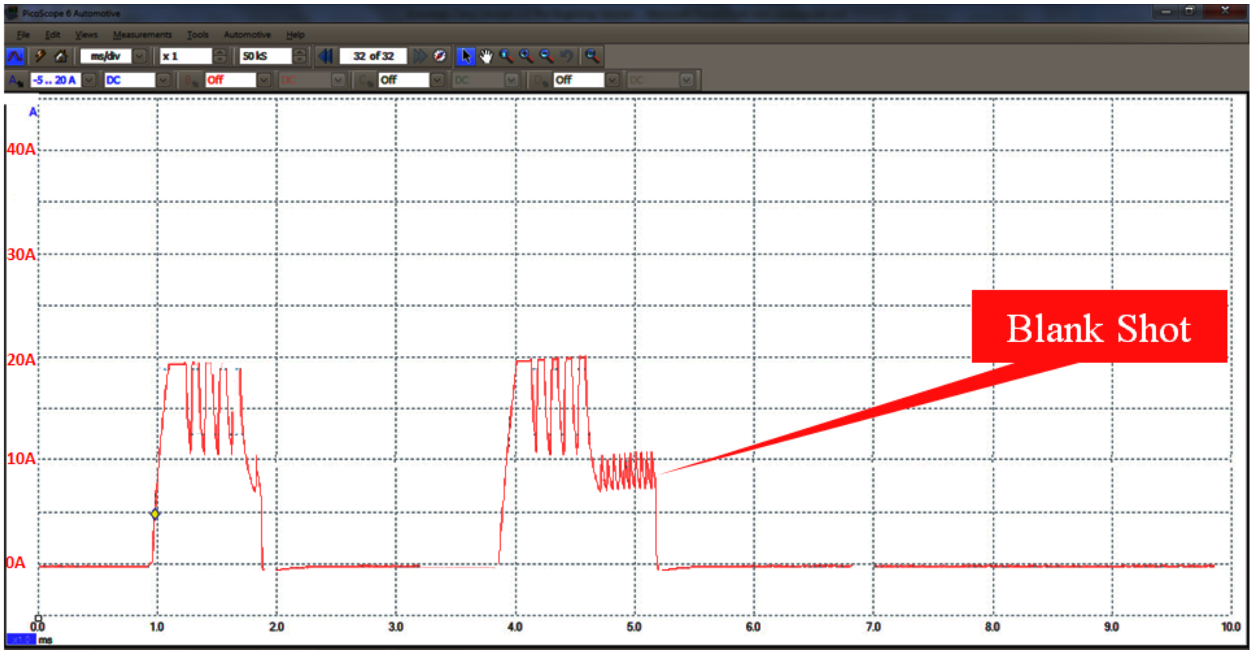
The injector driver is a peak and hold type driver.



Blank Shot

The blank shot produces several inductive "kicks."

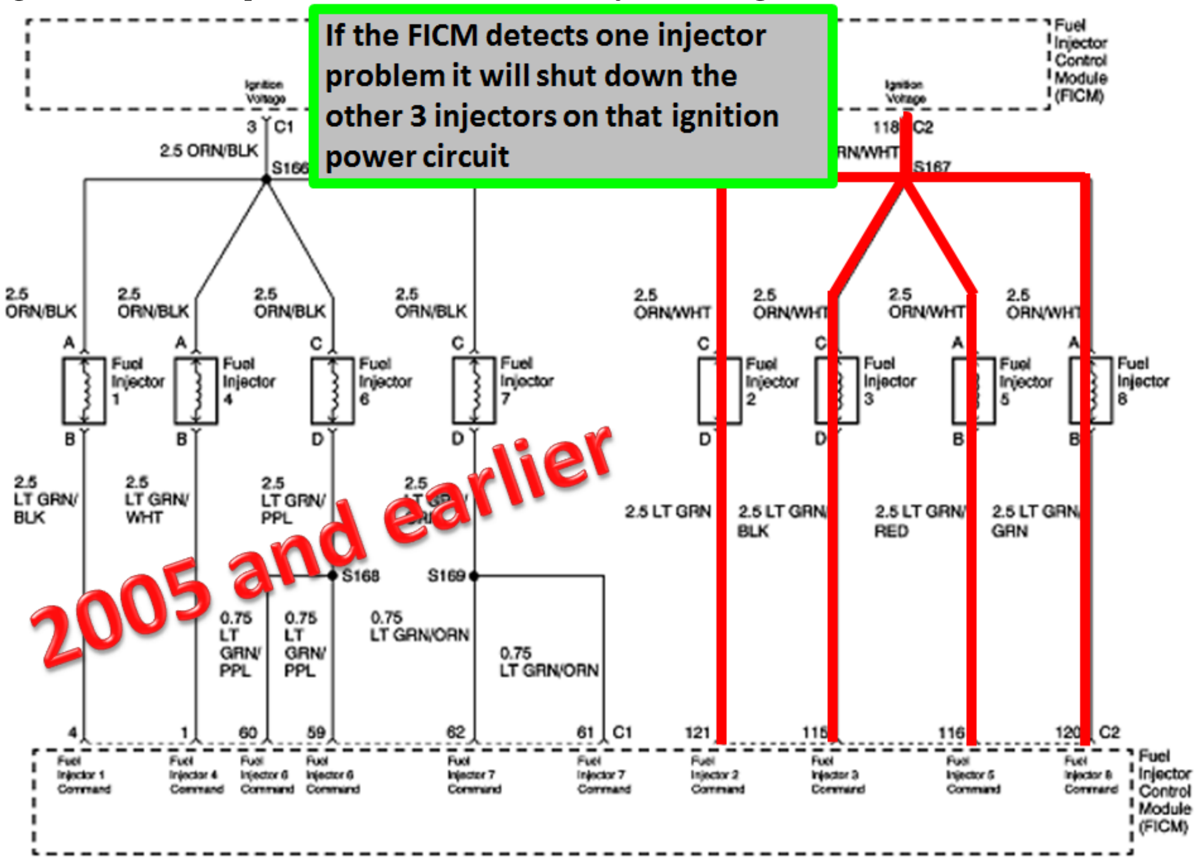
The voltage from the inductive "kicks" produces voltage that is stored in capacitors to help the 93 volts for the next injector firing.



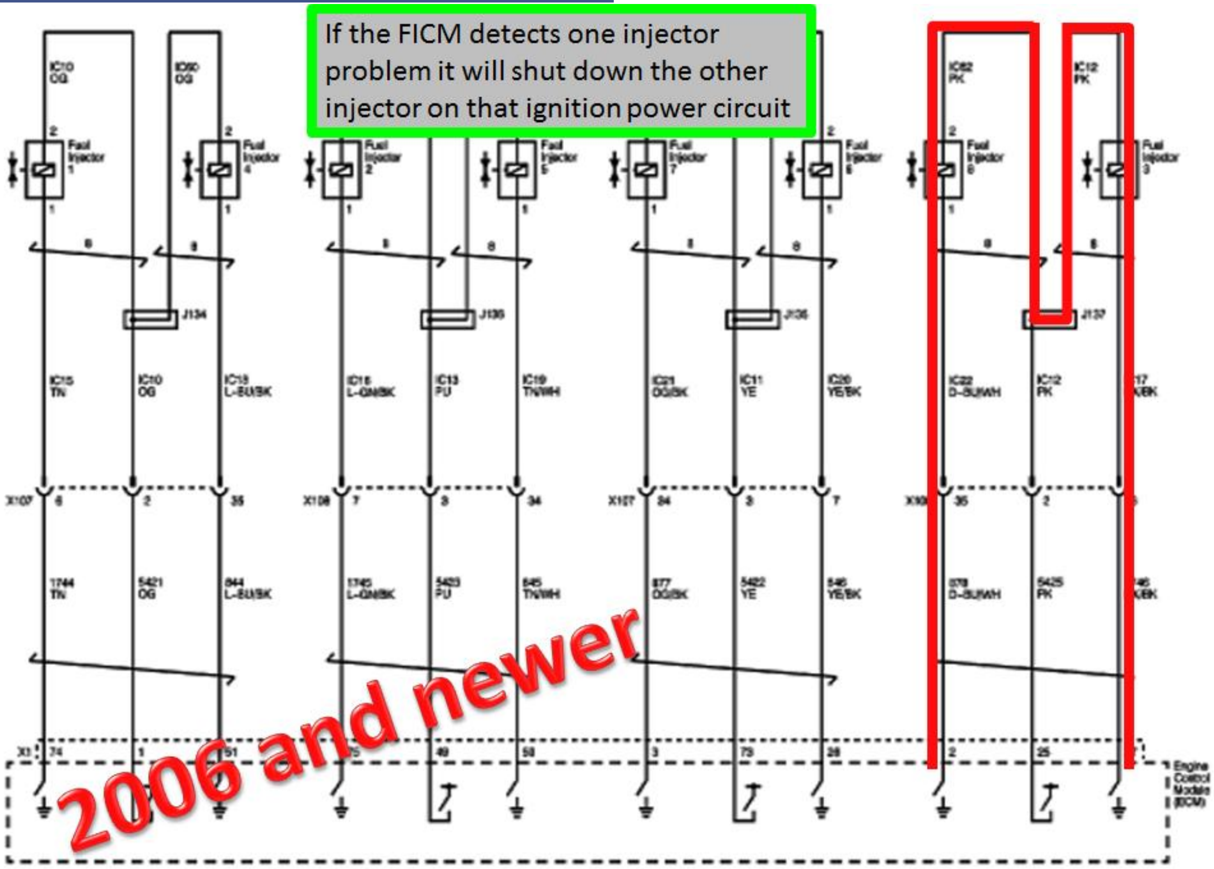
93 Volt Injectors

The injectors are powered up at ignition "on" by the PCM. There are two power circuits with four injectors on each circuit. If the FICM detects one injector problem it will shut down the other injectors on that ignition power circuit. On 2006 and later models there is one power circuit for each pair (2) of injectors. If the FICM detects one injector problem on this system it will shut down the other injector on that ignition power circuit.

The PCM supplies a ground to turn the injector on with a low side driver. After the injector is turned off the PCM toggles the ground on and off several times (called a blank shot) (150 µs to 200 µs). The inductive voltage from the blank shot is recovered and stored in a capacitor. The voltage stored in the capacitor is used for the next injector firing event.



2006 and newer vehicles



Fuel Balance Rates

Balance rates are the individual adjustments to fuel delivery based on engine RPM. If a injector is leaking, too much fuel gets into the cylinder so the piston speeds up faster than the other cylinders. If there is too little fuel, the weak combustion event will cause the piston to be slower than the others.

The ECM monitors the crankshaft revolutions from the crankshaft position sensor.

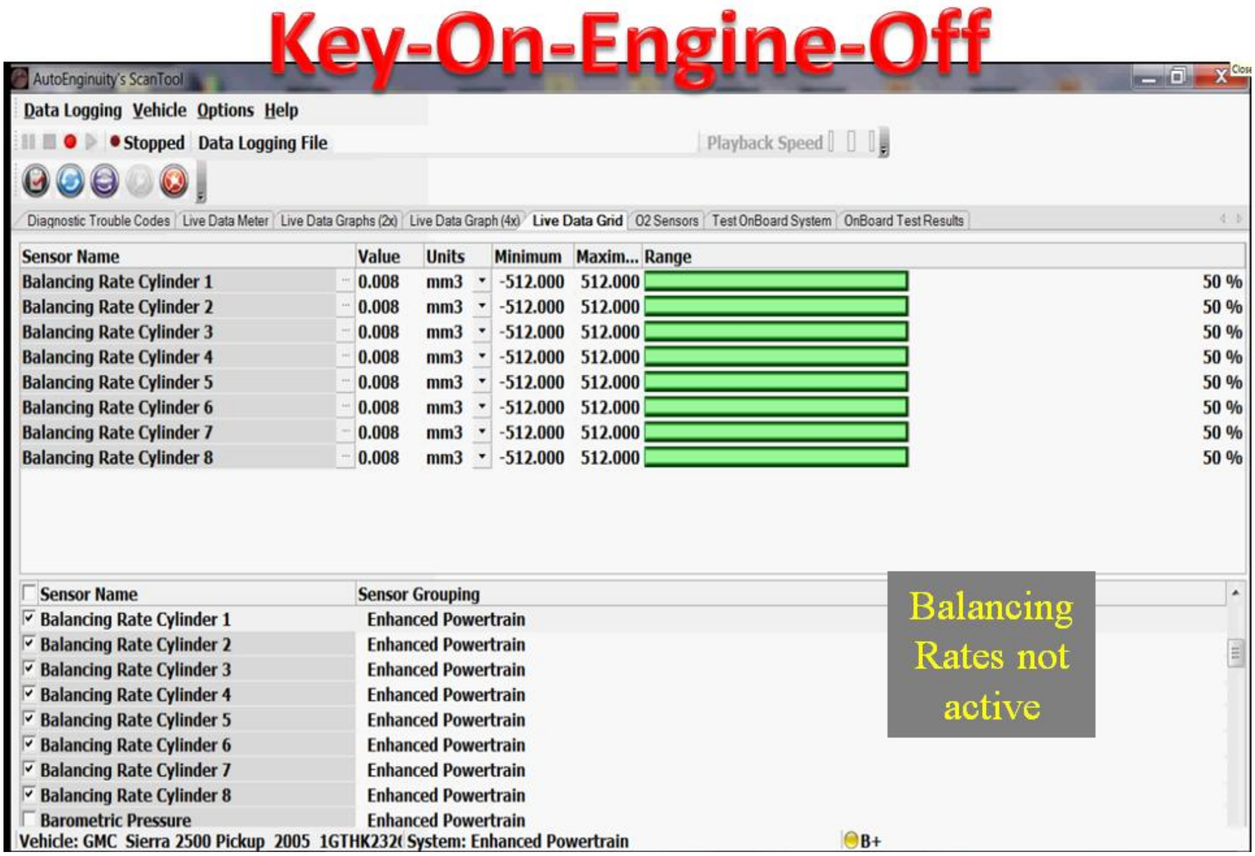
When it sees the unusual increase in speed, it reduces fuel and a negative fuel trim number appears. If an unusual decrease in speed is detected, the fuel is increased and a positive fuel trim number appears.

The ECM will also adjust the cylinder before and the cylinder after the problem cylinder all in an effort to keep the RPM balanced. The normal ranges for automatic transmissions are +/- 4 in park or neutral, and it can go as high as +/- 6 in gear.

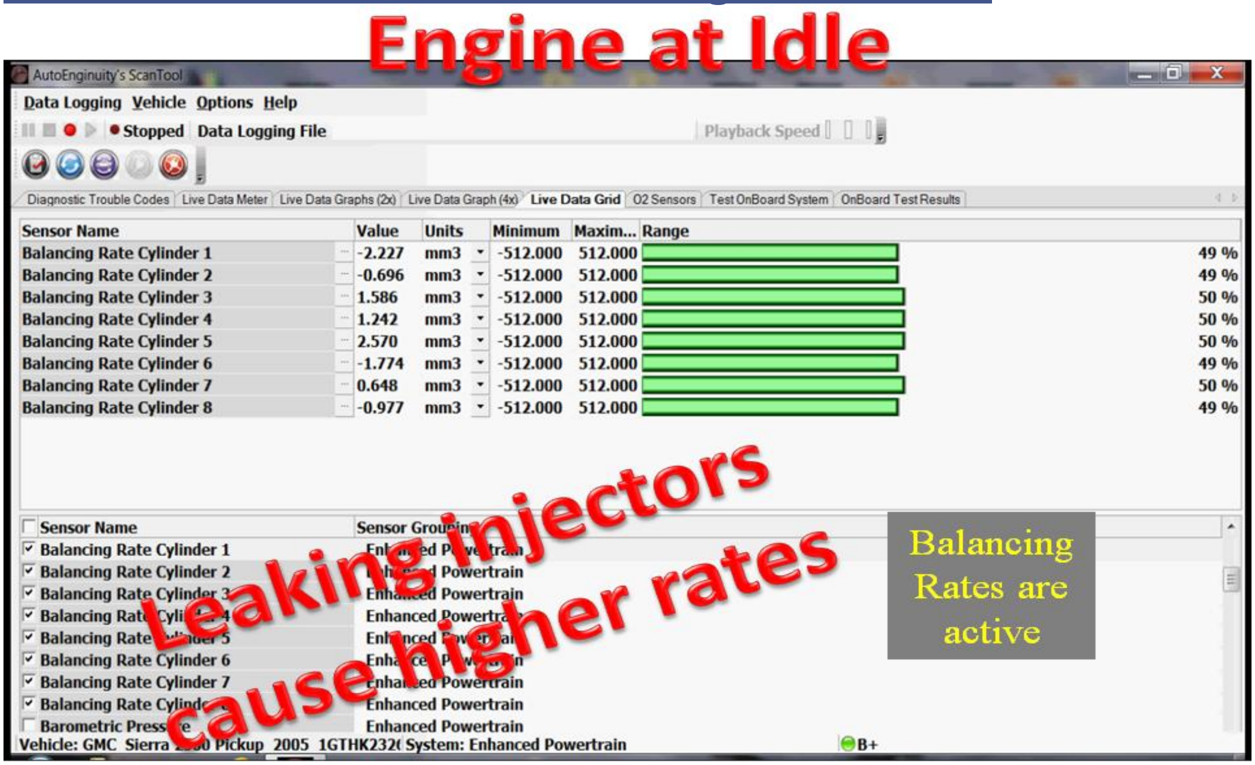
This number is stored in the PCM and the PCM uses it to further fine tune fuel delivery. Balance rates are found in scan data. Balance rates are only active at idle (off idle, they are turned off)

If you work with gas engines, fuel balance rates are long term fuel trims with a narrow specification.

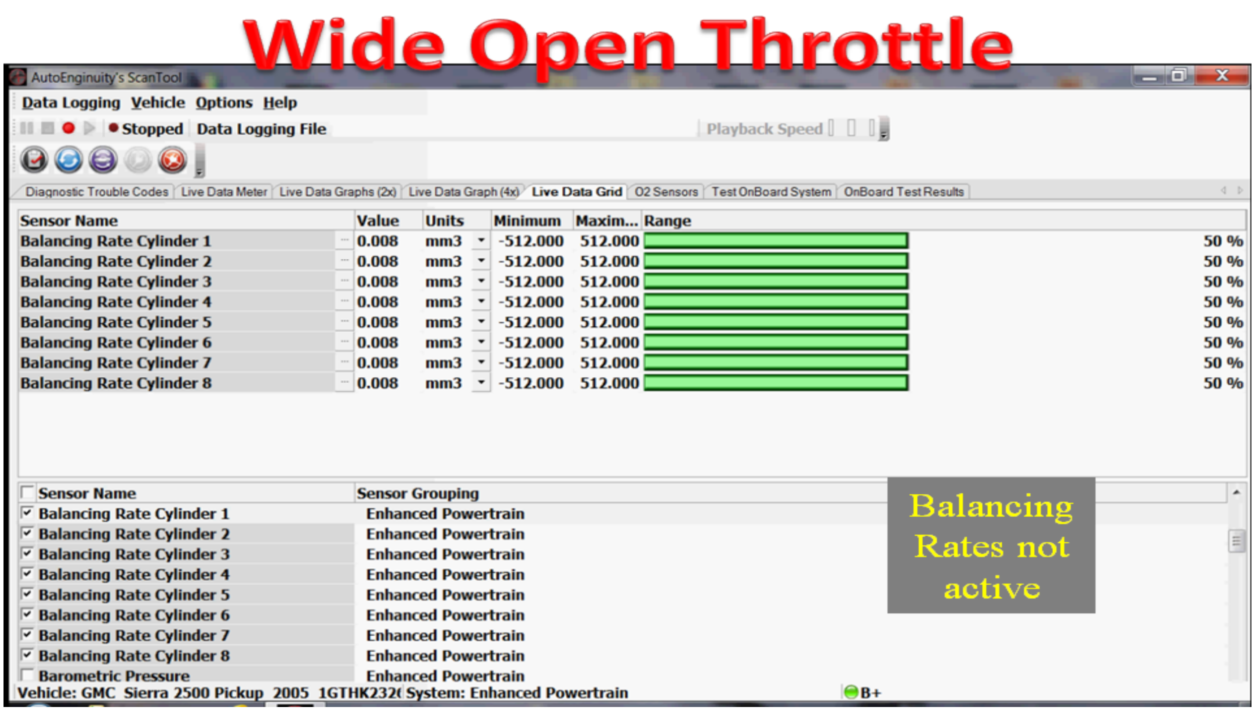
Fuel Balance Scan Data engine off



Fuel Balance Scan Data engine at idle



Fuel Balance Scan Data engine at WOT

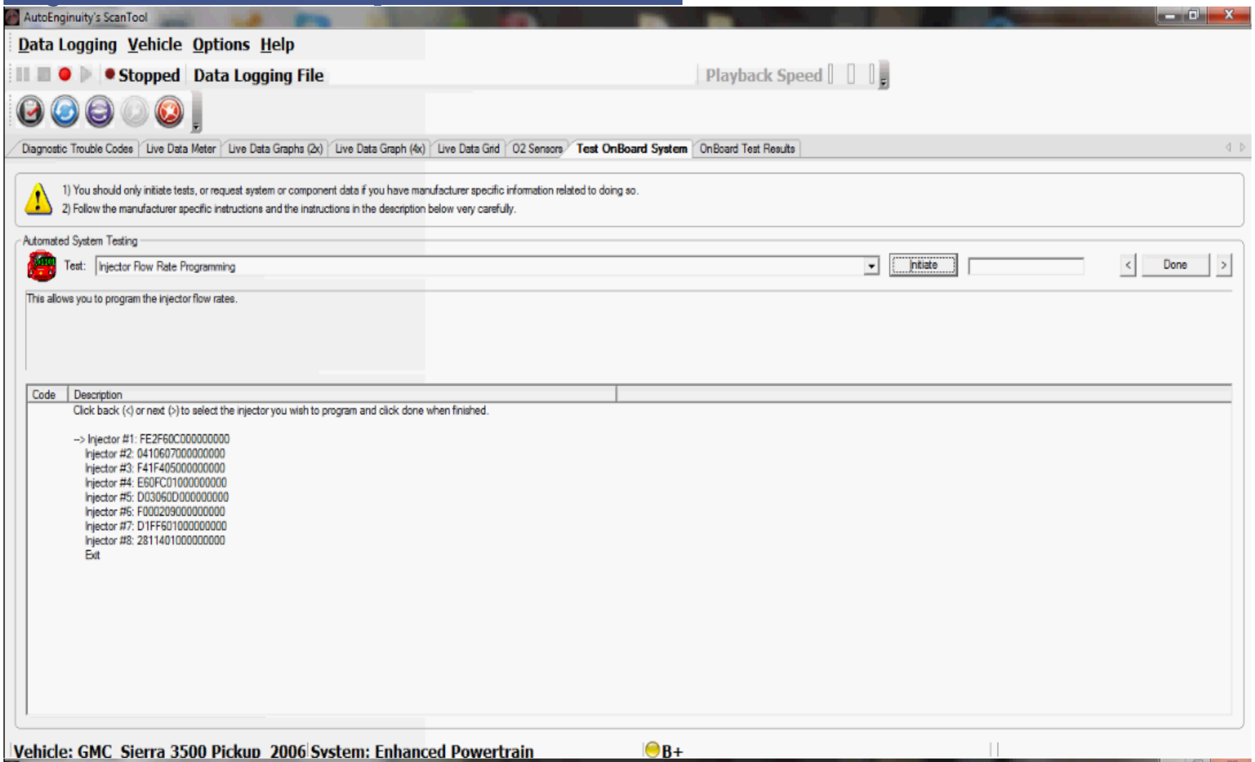


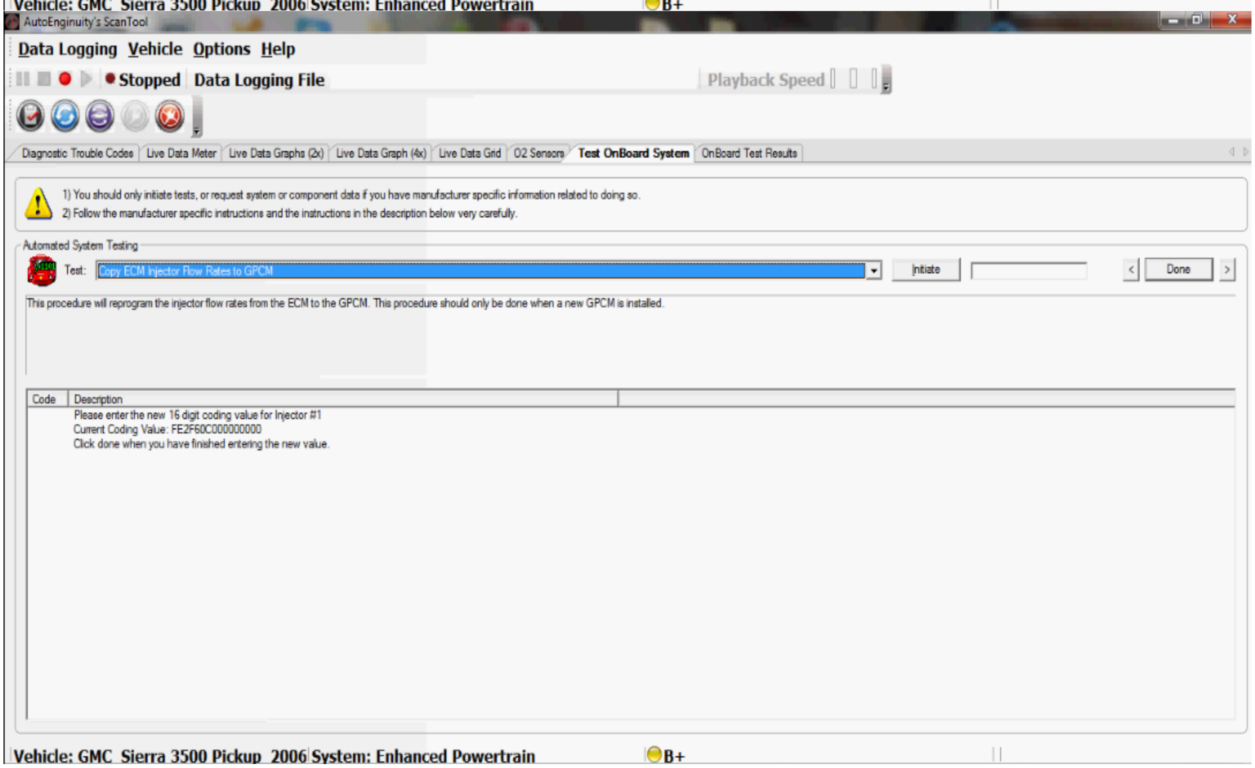
Injector Quantity Rating

New Duramax injectors are graded during manufacturing and matched as sets for uniform delivery. Starting in 2006 all injectors use an injection quantity rating number marked on top of the injector. Injectors cannot be made exactly alike every time. Each one will flow fuel slightly differently. After production the injectors are tested for flow rate under the same pressure and pulse width. Each one is marked to represent the different flow from the benchmark.

The data is stored in the ECM and must be updated when an injector is changed.

Injector Quality Scan Data



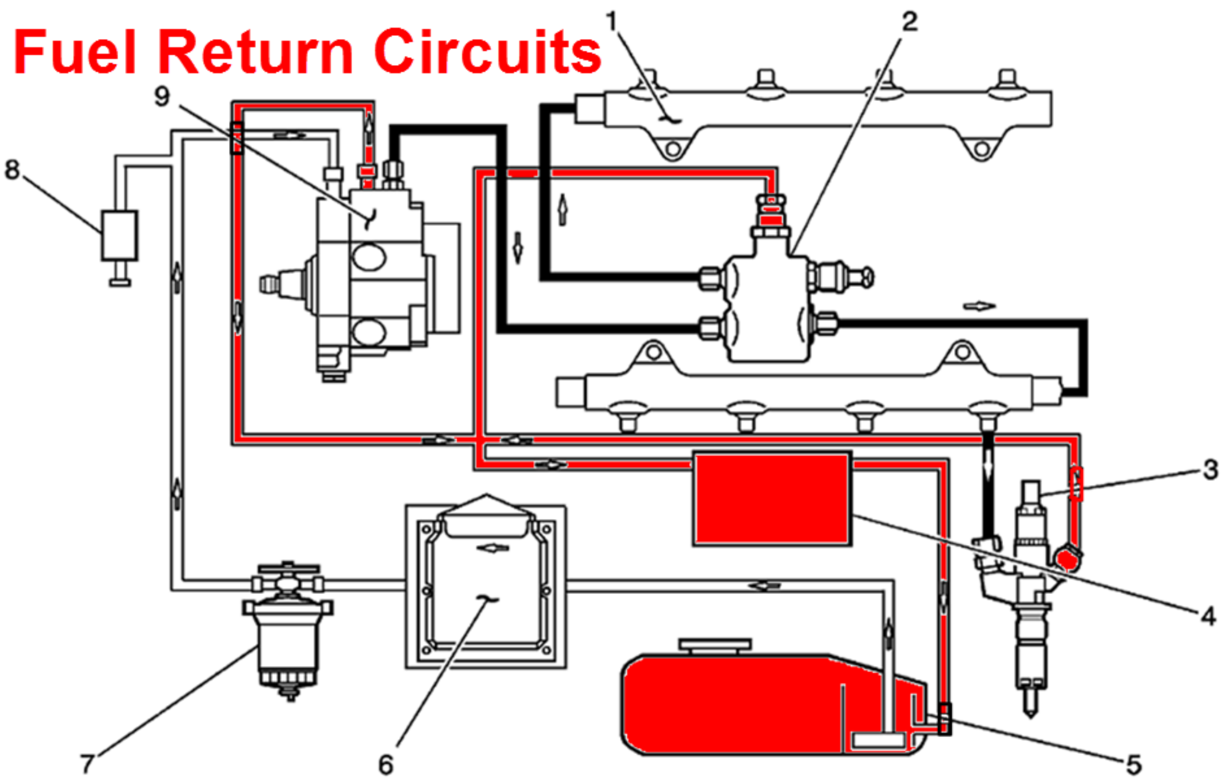


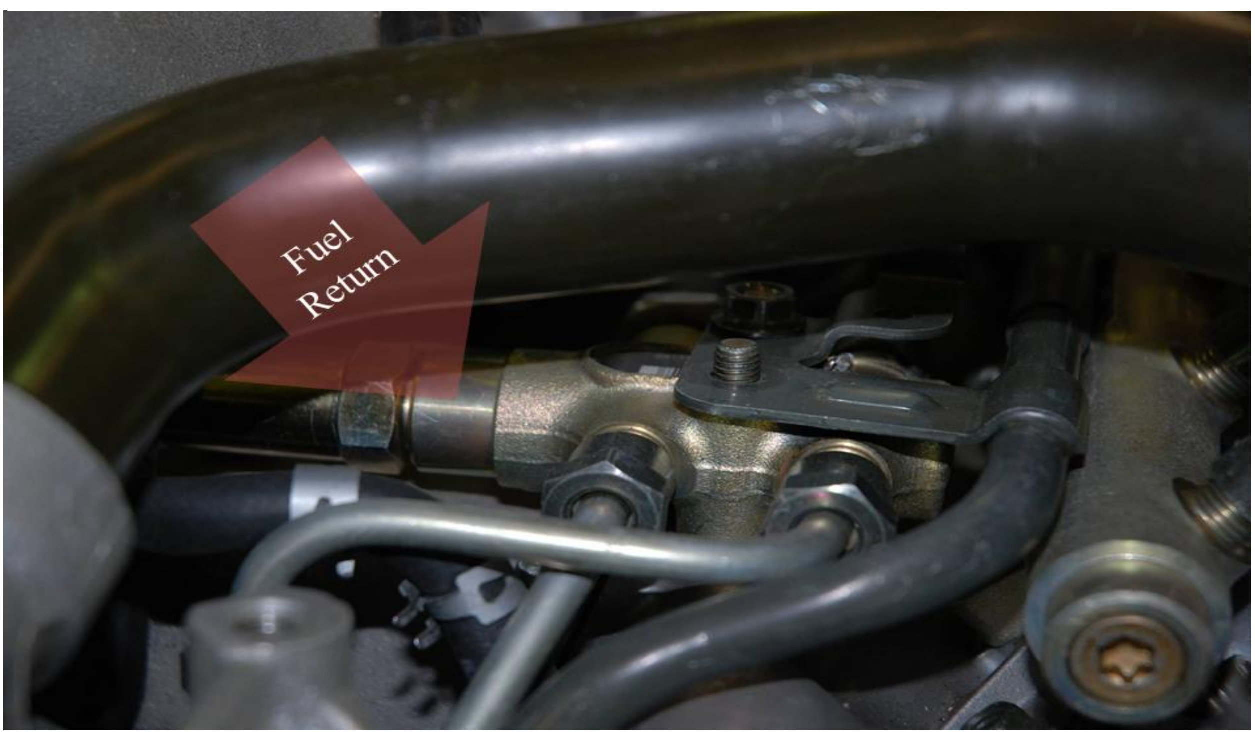
Fuel Return Circuits

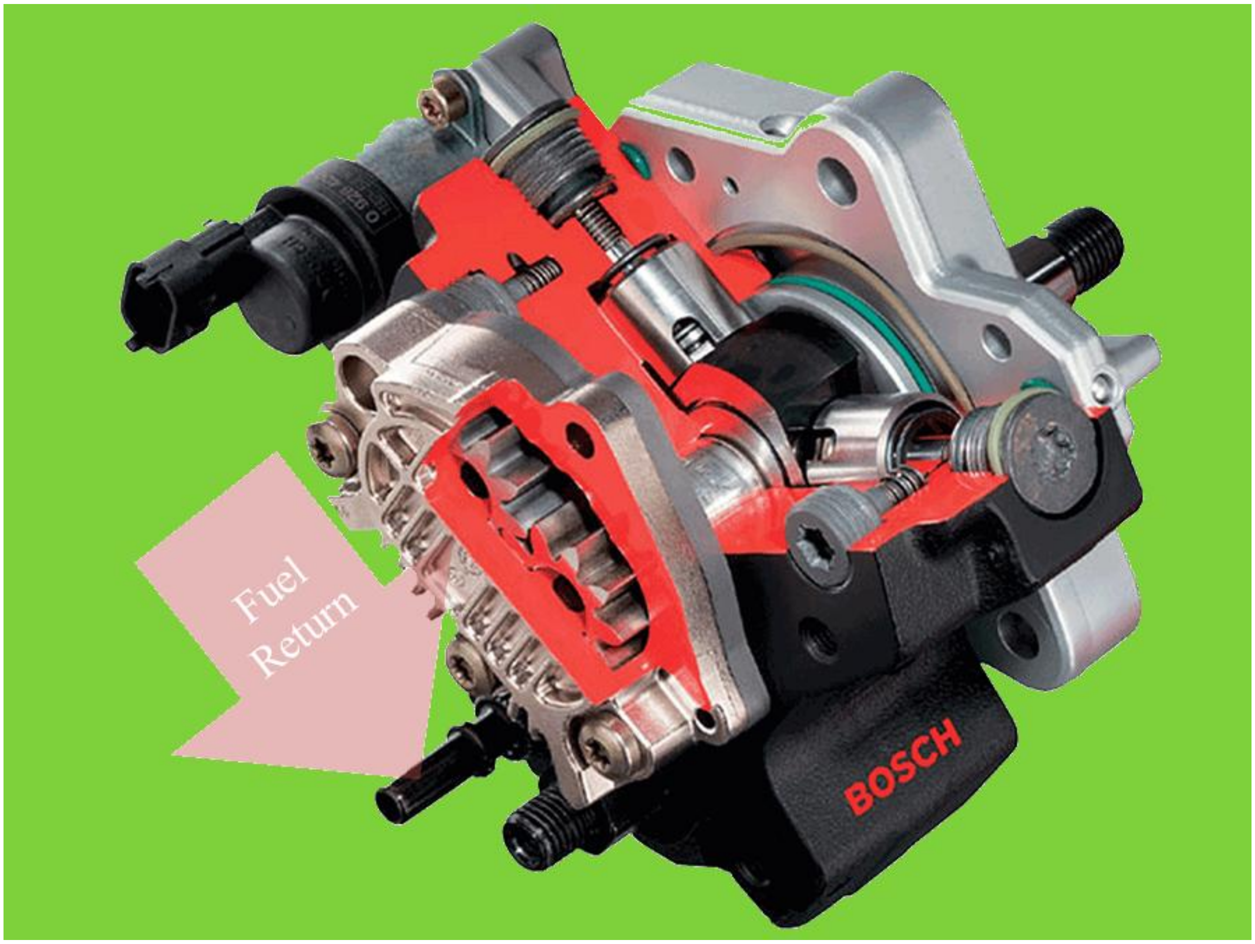
Excess fuel is returned to the fuel tank

There are 10 different points in the fuel system where the fuel is returned;

- Each of the 8 injectors
- The High Pressure Fuel Pump
- The fuel Junction block

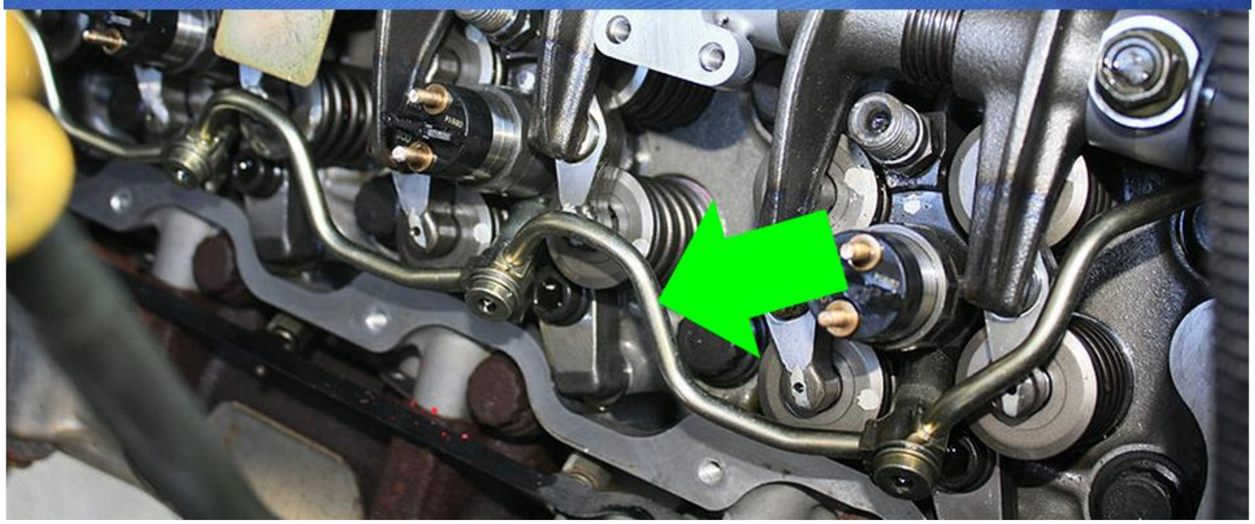






Fuel
Return
BOSCH


Fuel Return
Fuel Return

Fuel Injector Return Flow Testing

Fuel Specific Gravity Testing

Balance rate specifications are based off of# 2 Diesel fuel only.
Use a J 38641-B Diesel Fuel Quality Tester to measure the fuel specific gravity (API Rating). Follow the instructions on the tool to obtain the proper temperature-adjusted value. This information must be accurate for the proper diagnosis of the fuel system.

Fuel Injector Return Flow and Fuel Pressures

the fuel return from the fuel injectors to the tank will vary based on the API value of the fuel. For this reason the Fuel System Diagnosis-High Pressure Side values will vary for identifying a fuel injector or fuel pump concern. Use the following tables when referred to by the diagnostic. The first table is to be used during the initial diagnosis to identify the worst fuel injectors. After the any fuel injectors are replaced, the return flow from each fuel injector must be measured again. This is because the fuel system is returning less fuel to the tank, and thus the fuel pressure is higher during the retest. Failure to use the correct table may result in the replacement of good fuel injectors.

API Rating = Maximum Single Fuel Injector Return Flow

- 30-34 = 3 ml -12 ml
- 35-39 = 4 ml -16 ml
- 40-44 = 5 ml -20 ml

Test Procedure

The Fuel Return System routes fuel from the fuel injectors, the junction block, 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.
Perform this test when there is a DTC P1094, or if there is a Surging, Rough, Unstable, or Incorrect Idle. If a problem is found when performing the Fuel Injector Balance Test with wit a scan tool.

Perform this test when the fuel is more than 65° F.
Note! The fuel return volumes vary based on the API rating of the diesel fuel.
Note! A fuel injector may have high fuel return flow only at higher engine temperatures.

Return Flow Test Kit

Injector Problems

When too much fuel is being returned it is an indication that one or more of the injectors are bad. Injectors can wear out internally, and the bodies may crack. When there is a lot of fuel returning look at the engine oil level. An injector that has a cracked body will dilute the engine oil and increase its level. Cracked bodies are from too much heat and/or a defect in the metal. In this case replacing only the bad injector may be an option. In the case of an injector wearing out you must explain to the owner that all the injector may have the same mileage on them and all of them should be replaced.

It is important to look at the balance rates and add them into your decision.

Does the vehicle have a loss of power?

When looking at the balance rates remember that when they are out of normal specifications it usually isn’t associated with a loss of power. Diagnose fuel control concerns which might cause a slight shift in fuel trims.

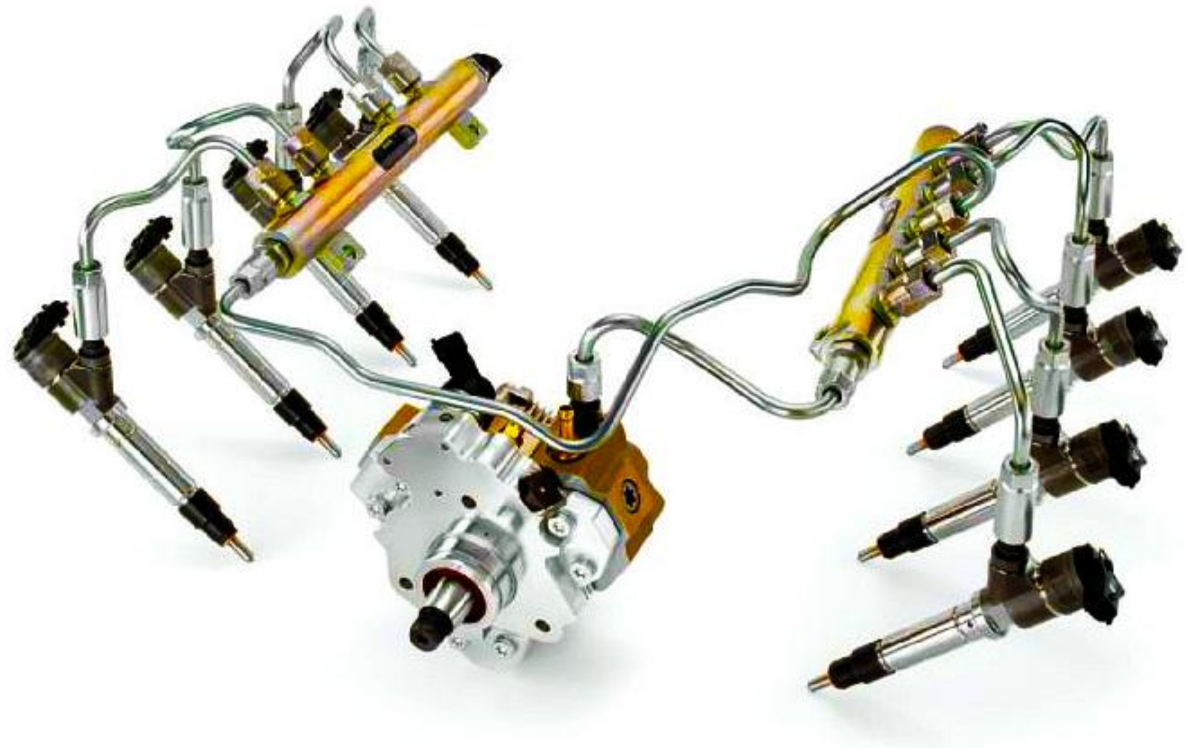
When too much fuel is being returned it is there will be a loss of power issue, diagnose why too much fuel is being returned;

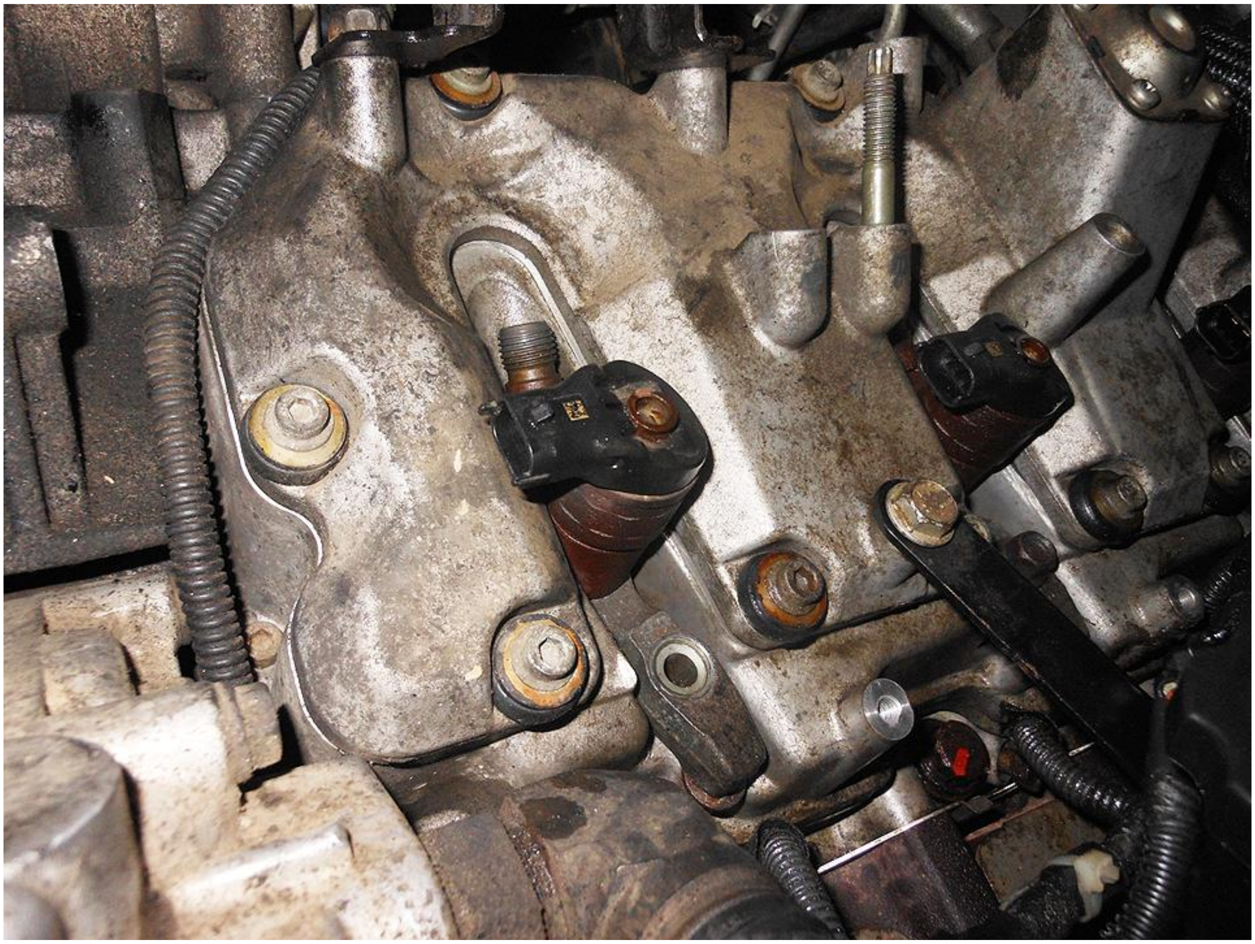
- Does the vehicle have a loss of power?
- When looking at the balance rates remember, when they are outside normal specifications, it usually isn’t as associated with a loss of power.
- When too much fuel is being returned it is.

LLY Fuel System Changes

2004 – 2006 LLY Fuel System

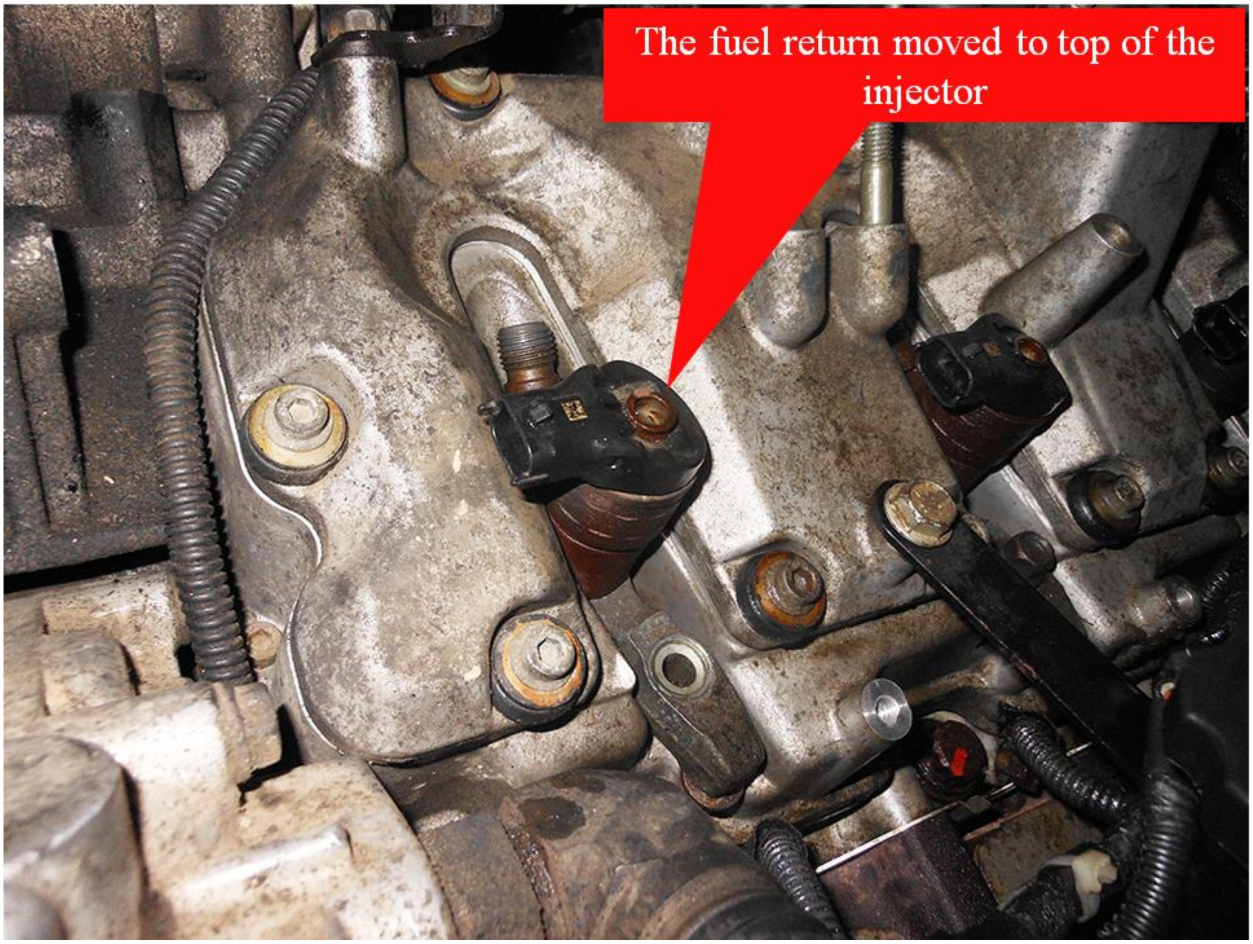
The valve covers are re-designed to allow access to the injector without removing them. There isn't a fuel junction block. It is replaced with a cross over fuel line from one common rail to the other. The High Pressure Fuel Pump supplies fuel to the left rail and the crossover fuel line supplies the right rail.

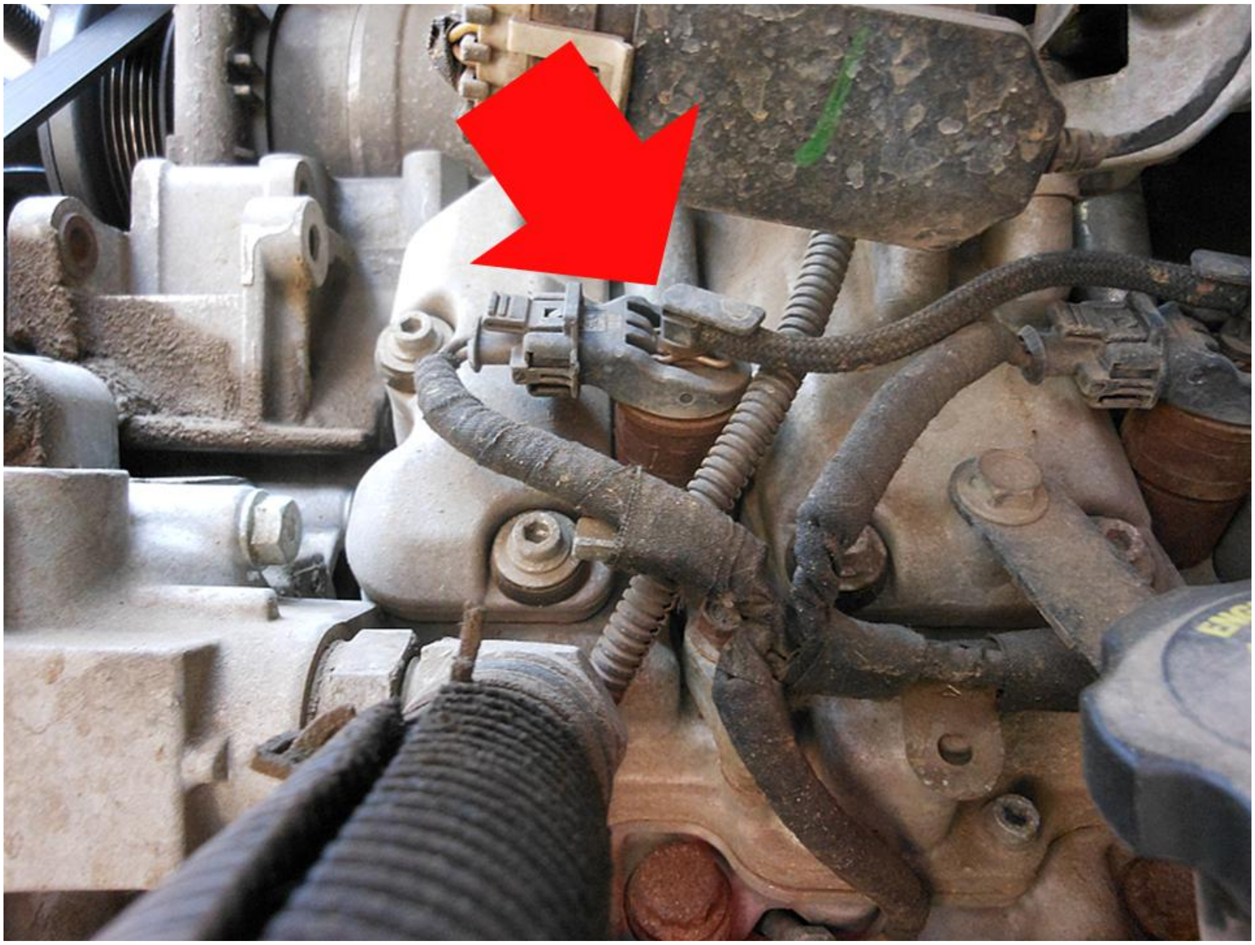




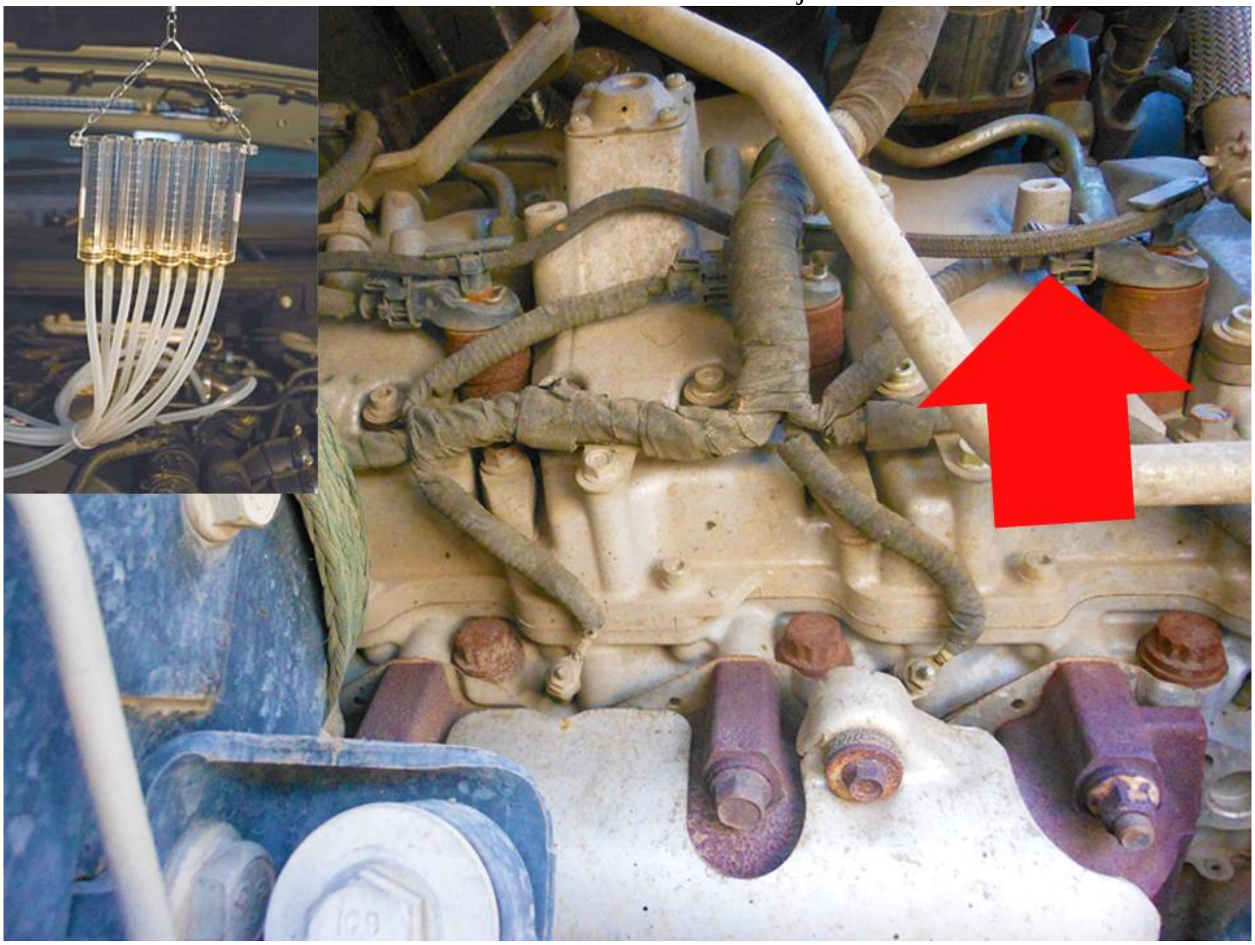
The fuel return line is moved to the top of the injector. It isn’t a steel line like on the LB7, but rather a flexible line. There is a new fuel return test kit available that snaps into the return ports on the injector.

The fuel rail pressure sensor is on the right rail and the fuel pressure relief valve is on the left rail.

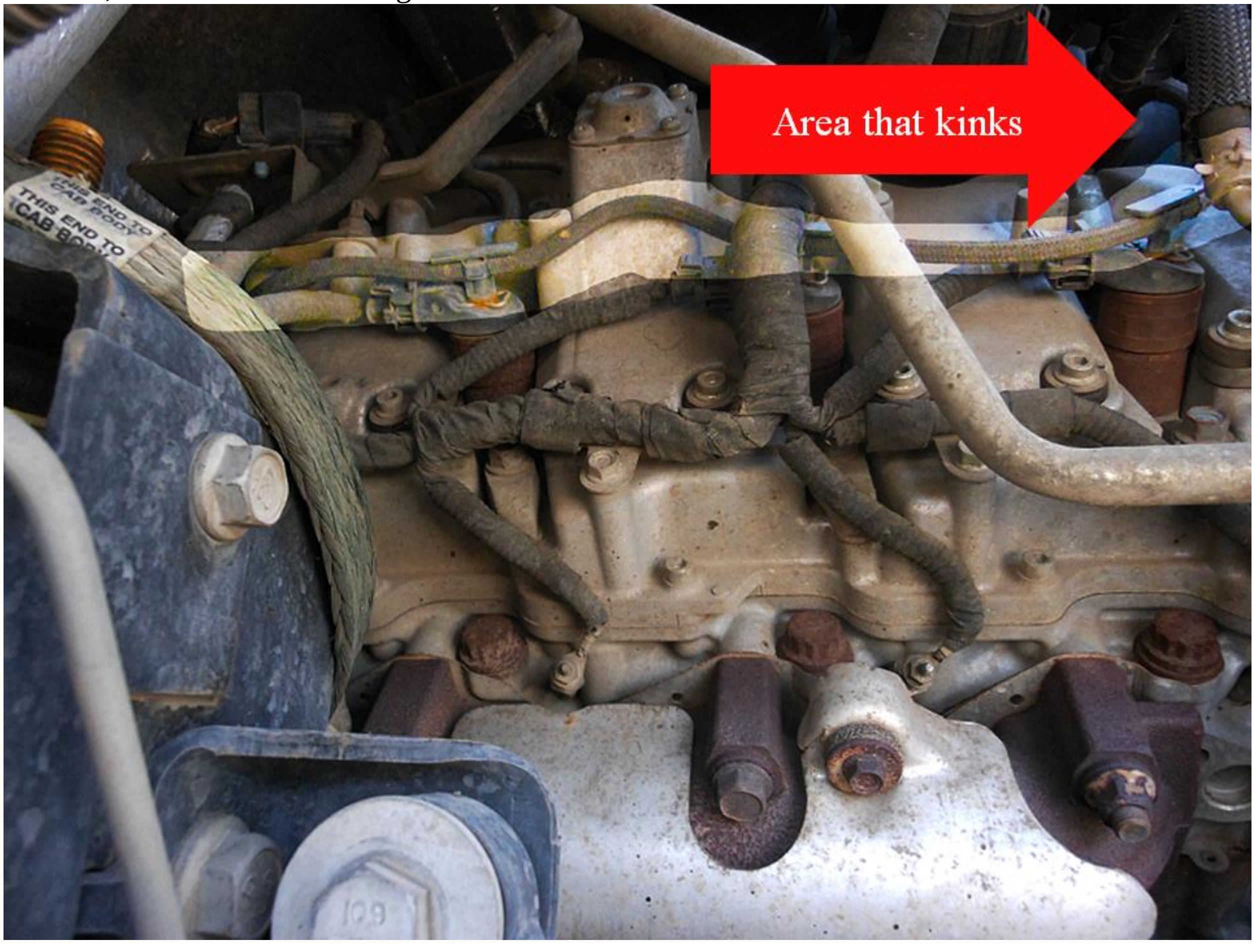




There are testers available to measure the return rate from individual injectors. They require a little more time to connect but offer information about each injector.



The flexible return lines can and will kink setting diagnostic trouble codes. They kink at the end near the firewall/transmission. The codes relate to a plugged fuel filter. If the fuel return is blocked, flow is reduced setting the fault.



LLY Fuel System Changes:

On module years 2004 – 2006 there have been a few changes to the fuel system. The fuel rail pressure sensor is on the right rail. The fuel pressure relief valve is on the left rail.

LMM Fuel System Changes:

The fuel system remains the same for the LMM. The LMM must meet 2010 Fuel requirements. LLM requires Ultra low Sulfur Fuel because it has a diesel particulate filter.

Injector Changes

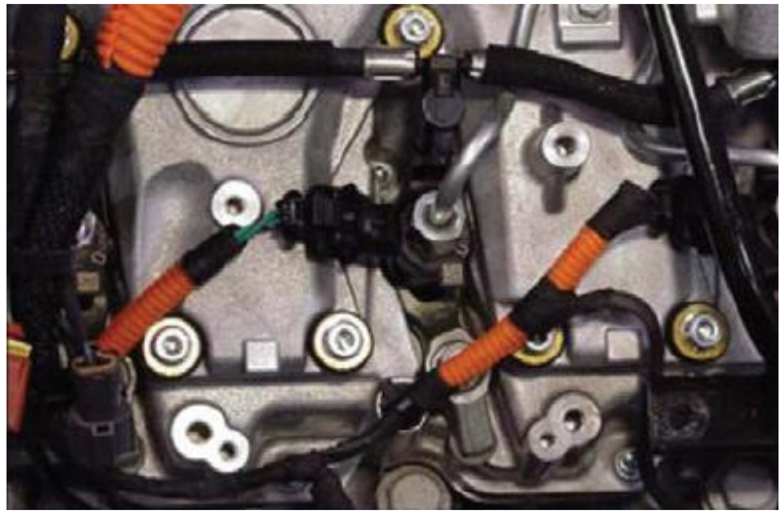
The injectors are larger, that means they flow more fuel than the ones on the LB7. The Fuel Injection Control Module (FICM) has some changes in the way the injectors are controlled, but nothing that affects diagnostics. The injectors operate on 48 volts not 93 volts. 2005 – 2005 25 amp peak with 15 amp hold. 2006 – 15 amp peak with 10 amps hold.
The injectors are designed to closer tolerances than earlier models in an attempt to reduce the number of failed injectors.

LBZ Fuel System Changes

The injectors are designed to closer tolerances than earlier models

LML Fuel System Changes

The LML can use B20 biodiesel compatible (20% biodiesel, 80% petroleum diesel mixture). Fuel pressure changes because of the up-dated Bosch high pressure common rail using piezo actuated injectors at 30,000 psi.



These injectors operate at high voltage, indicated by the orange color of the injector harness. Use certified, insulated Class 0 gloves (expiration date.) The PCM supplies high voltage and provides a ground through high and low side drivers. 160 volts is supplied at 20 amps with peak voltage up to 240 volts to open the injector. A capacitor discharges through an injector for initial opening and holds the injector open with 12 volts. Injectors are grouped into four pairs: 1-4, 6-7, 2-5, and 3-8. If a fault is detected in a pair, that pair is disabled and a DTC is set.

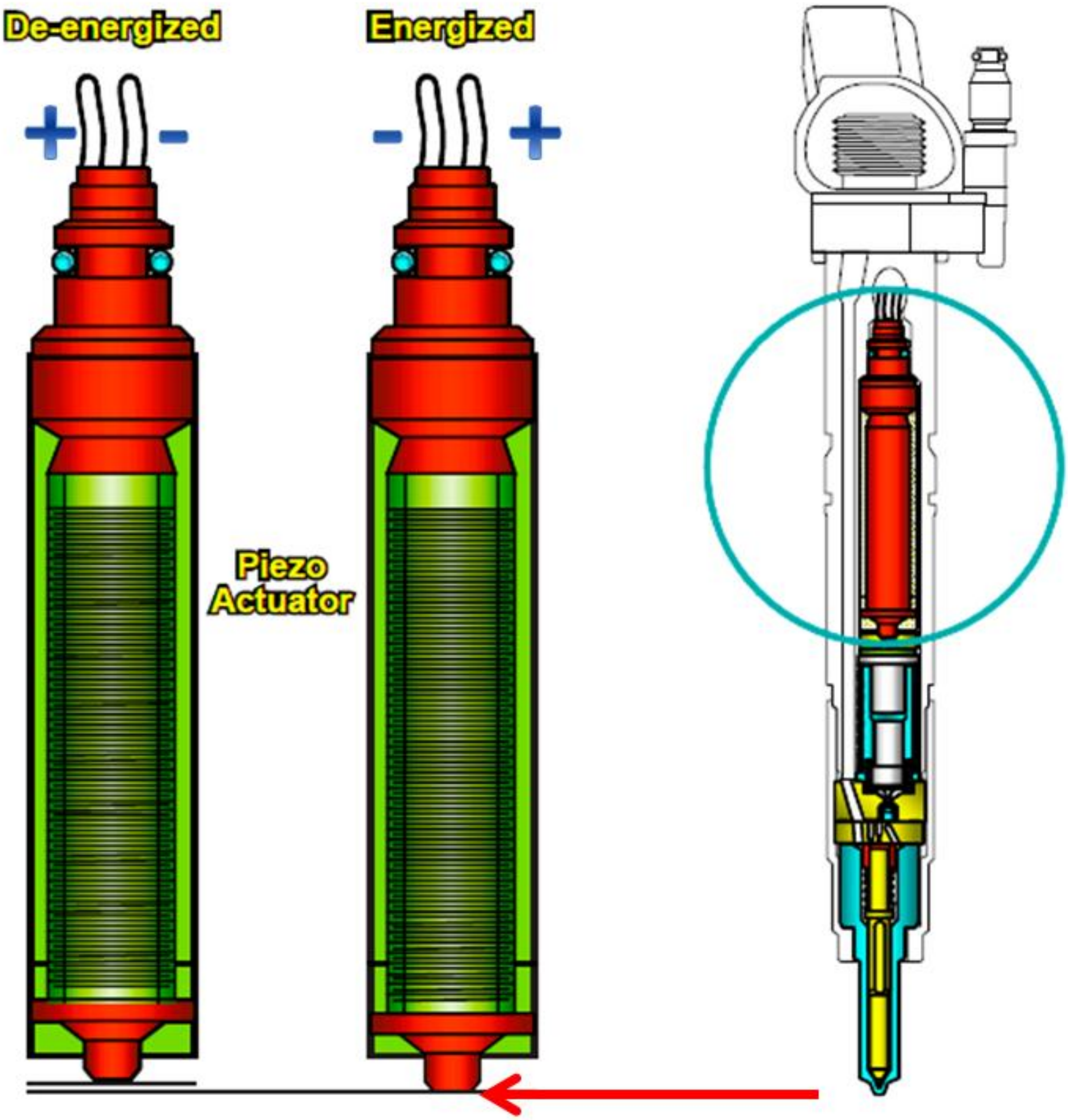
LML Injectors (Piezo Stack)

The injector has hundreds of little piezo slices stacked on top of each other so that the combined expansion increases the total motion. The stack produces 0.004 inch of movement—enough to move the pintle far enough to inject fuel. But because this motion is in the wrong direction—down, not up—the addition of two tiny levers allows the expansion of the piezo stack to cause the pintle to be lifted and the fuel spray to begin. When the injection is complete, the voltage cuts off, the piezo stack shrinks, and a spring closes the pintle.

Piezo injectors have a few key benefits that justify all of this bother. For one thing, they open and close much faster than conventional injectors. That makes for more precise control of the injection interval, which determines how much fuel is sprayed into the engine. Piezo units also provide feedback by producing minute fluctuations in the electricity used to activate them. For example, if the engine-control computer calls for an injector-opening time of 0.5 second, and the injector response shows that it opened for only 0.496 second, the computer can add a tiny bit of time to the next injection cycle to compensate. Such precise fuel metering makes for improved combustion, which leads to better fuel economy and reduced emissions.

Not only are piezo injectors more accurate than conventional solid injectors, they also can perform some tricks that are completely beyond the capabilities of their predecessors. For one thing, by applying a little less electricity, the piezo crystals expand less so the injectors can open partway. A smaller opening means a longer injection time, which is beneficial when trying to accurately inject a tiny amount of fuel, such as when a car is nearly coasting. Because they act so quickly, piezo injectors also can inject several times (as many as seven in some diesels) during a single combustion cycle. This flexibility can reduce emissions in all engines as well as limit soot in diesels.

These benefits have secured a home for piezo injectors in many of the latest diesel and direct-injection gasoline engines. And Continental, for one, says that its piezo units don’t cost more than the less capable conventional equivalents. Piezo injectors are one of the key devices that will keep internal combustions competitive against these pesky electric upstarts for years to come.



Multiple Injection Technology

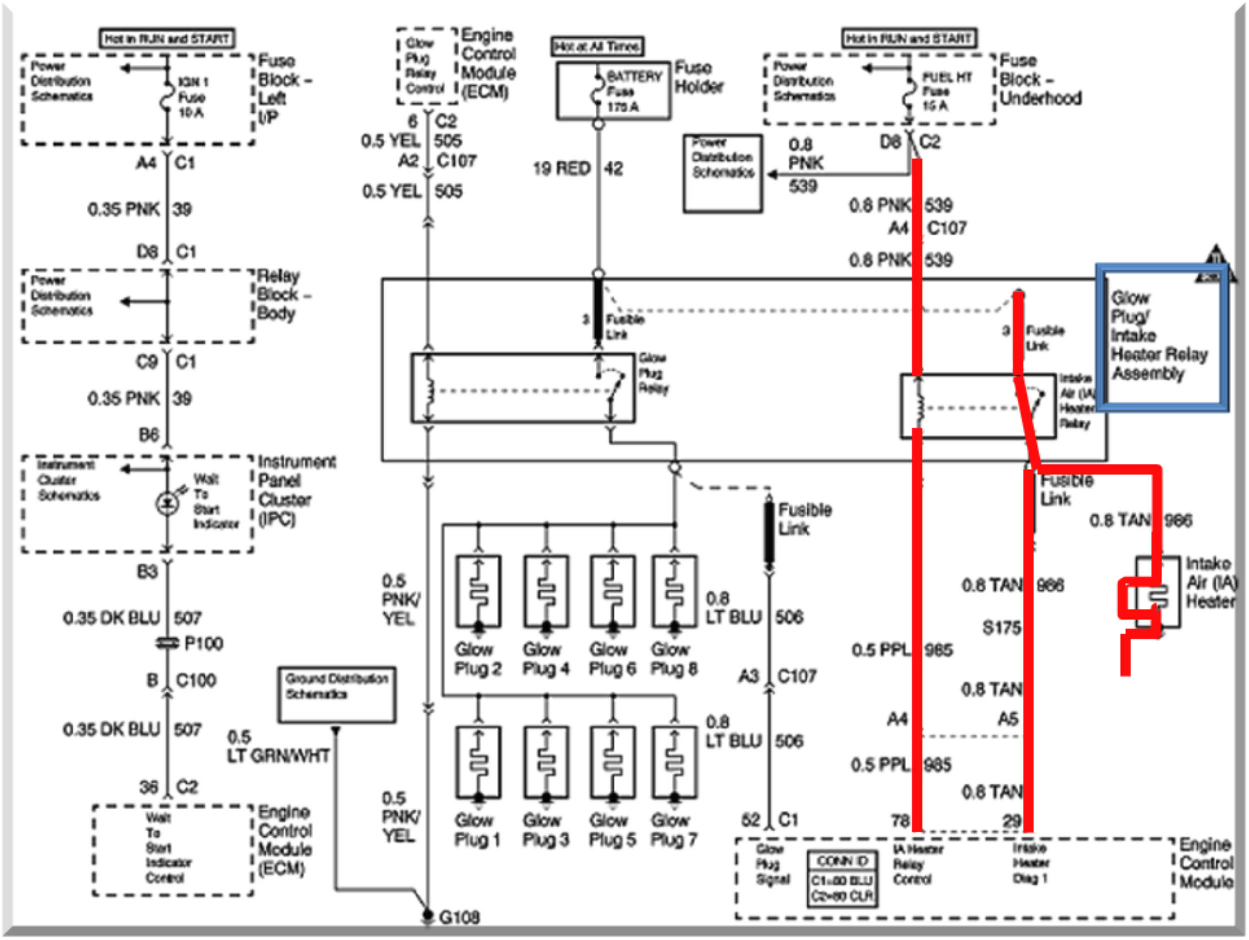
There may be up to 5 injection cycles per cylinder power stroke. The pilot cycle is used to reduce combustion noise by allowing cylinder pressure to rise slightly before the main injection cycle. Pre-injection cycle helps to distribute fuel to start the ignition combustion cycle. During the main injection cycle most of the fuel is supplied for power and torque. After-injection cycle also helps the distribution of fuel for ignition. Post injection cycle is used to raise exhaust temperature for regeneration and for NO_x reduction.

Air Management System

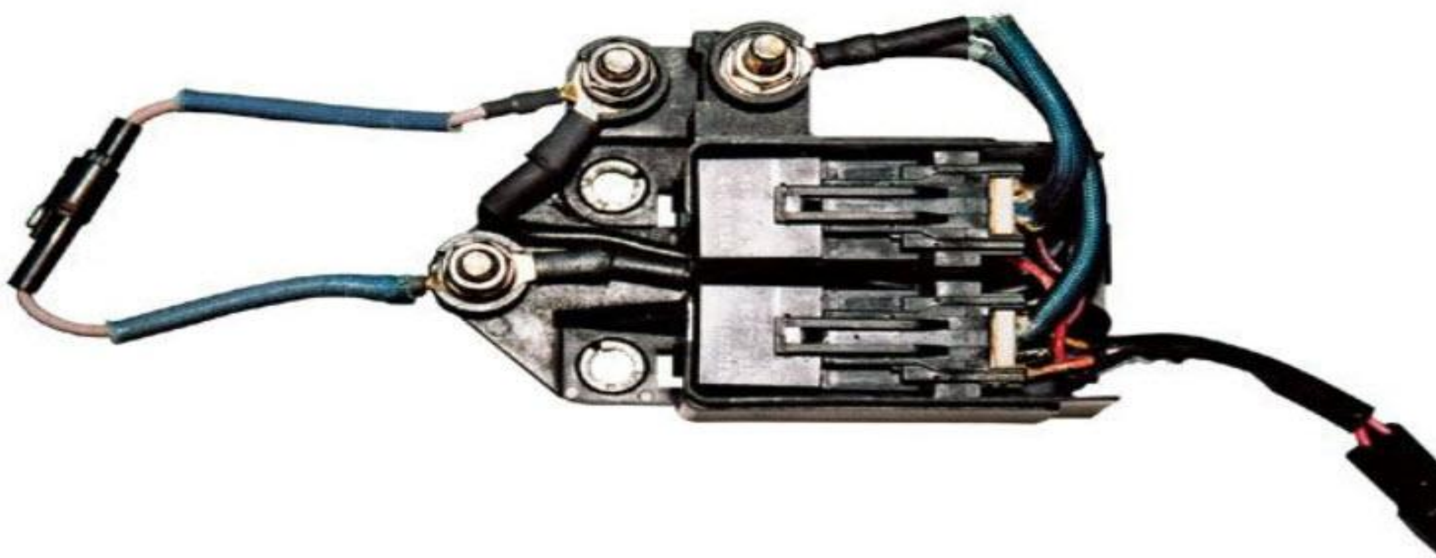
An air filter supplies filtered air for the engine. There is air restriction indicator on the air filter housing, when the filter minder is in the red the filter, it should be inspected and replaced if necessary. Don’t forget to reset the minder.

Intake Air Heater

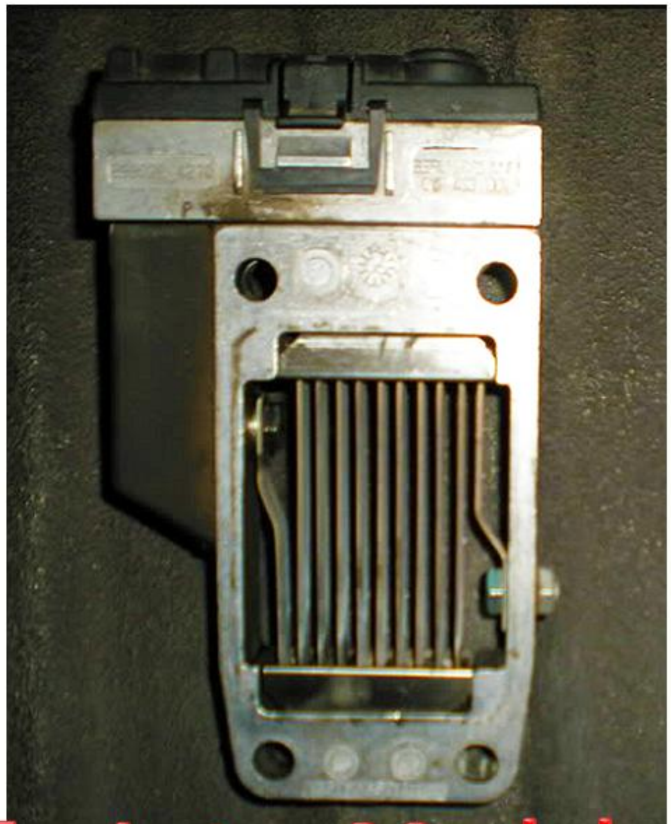
During cold weather operation the incoming air is heated. Heating the air reduces the white smoke during engine warm up and long decelerations. The heater draws, 110 amps @ 12 volts. The PCM turns the heater on when ambient temperature is below 70° F. The glow plug control module and intake air heater shares a relay. Throughout the different models two different heaters have been used. The LB7 used a hot wire and everything else used a grid type. The 2004 and 2005 model year Duramax did not use the intake air heater. The heater returned in model year 2006.



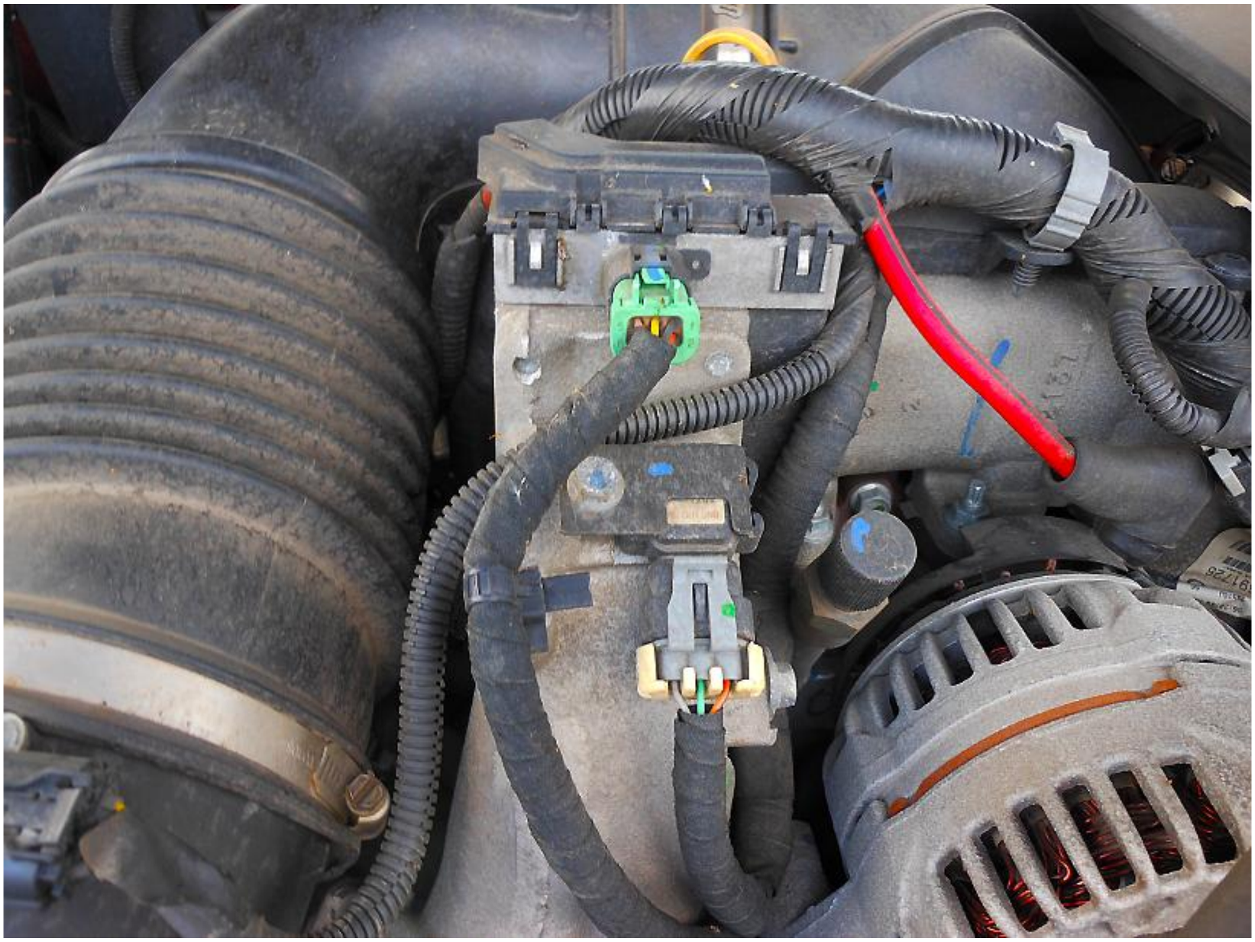
Hot in RUN and START
Power Distribution Schematics
IGN 1 Fuse 10 A
Fuse Block – Left I/P
A4 C1
0.35 PNK 39
D8 C1
Relay Block – Body
C9 C1
0.35 PNK 39
B6
Instrument Panel Cluster Schematics
Wait To Start Indicator
Instrument Panel Cluster (IPC)
B3
0.35 DK BLU 507
P100
B C100
0.35 DK BLU 507
36 C2
Wait To Start Indicator Control
Engine Control Module (ECM)
Glow Plug Relay Control
Engine Control Module (ECM)
6 C2
0.5 YEL 505
A2 C107
0.5 YEL 505
0.5 PNK/YEL
Ground Distribution Schematics
0.5 LT GRN/WHT
G108
Hot at All Times
BATTERY Fuse 175 A
Fuse Holder
19 RED 42
Fusible Link
Glow Plug Relay
Glow Plug 2
Glow Plug 4
Glow Plug 6
Glow Plug 8
Glow Plug 1
Glow Plug 3
Glow Plug 5
Glow Plug 7
0.8 LT BLU 506
A3 C107
52 C1
Glow Plug Signal
CONN ID
C1=80 BLU
C2=80 CLR
Hot in RUN and START
FUEL HT Fuse 15 A
Fuse Block – Underhood
D8 C2
0.8 PNK 539
0.8 PNK 539
A4 C107
0.8 PNK 539
Glow Plug/ Intake Heater Relay Assembly
Intake Air (IA) Heater Relay
0.8 TAN 966
Intake Air (IA) Heater
S175
0.5 PPL 985
0.8 TAN
A4
A5
78
29
IA Heater Relay Control
Intake Heater Diag 1
Engine Control Module



Early LB7



Later Models

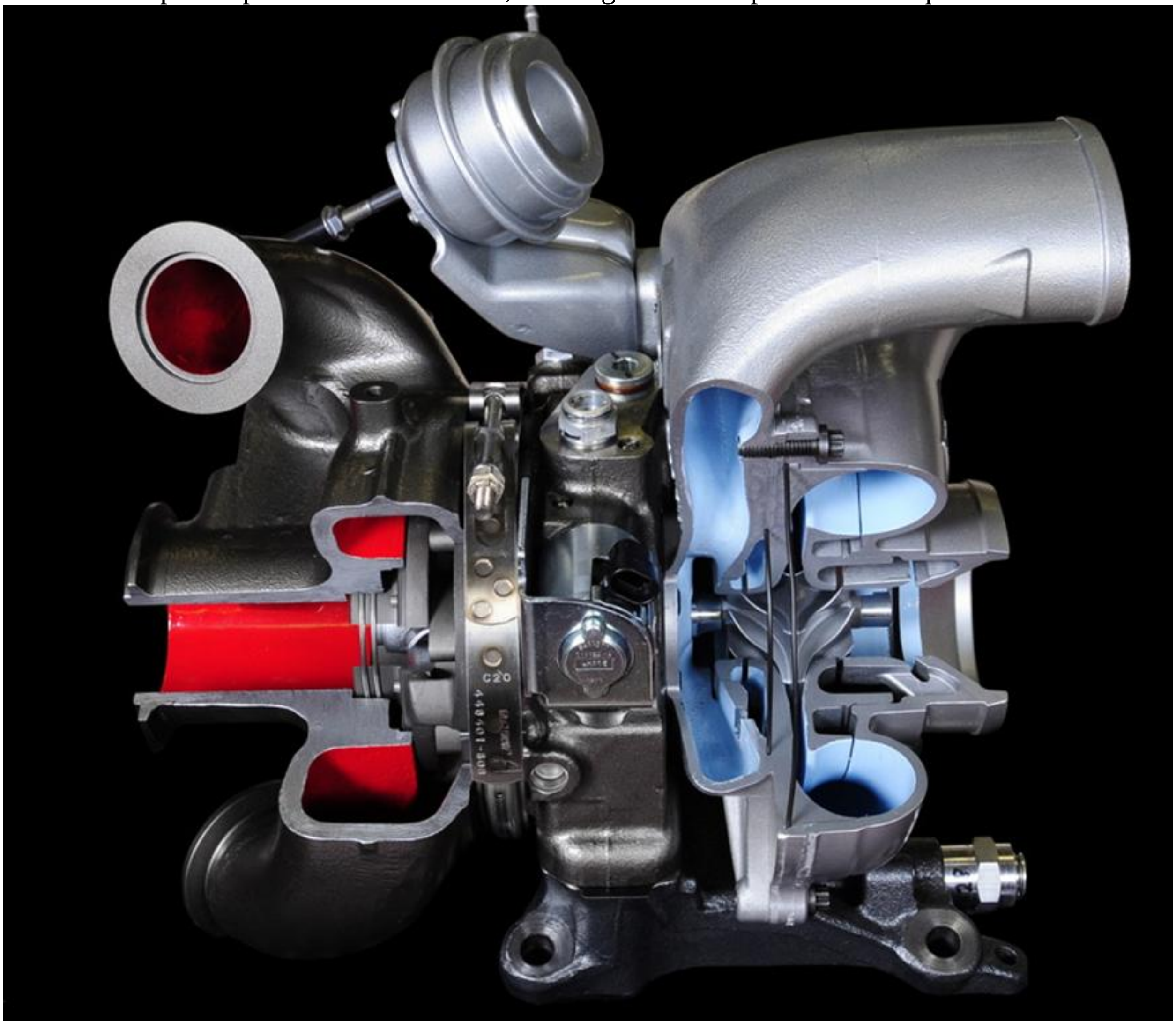


2004 and 2005 Model Years

Did not use an Intake Air Heater
The heater was used again in 2006 model year

Turbocharger

A turbocharger is a forced induction device used to allow more power to be produced from an engine of a given size. A turbocharged engine can be more powerful and efficient than a naturally aspirated engine because the turbine inside the unit compress the air and force it into intake, with proportionately more fuel. This puts more air and fuel into the combustion chamber than if atmospheric pressure alone is used, creating additional power and torque.



Generally, 1/3 of the heat energy obtained from burning the fuel in the cylinder is transferred to the crankshaft in a diesel engine
Another 1/3 of heat energy is dumped into the cooling system.
And the last 1/3 escapes through the engine exhaust.
This means that an engine producing 100 hp at the flywheel.
Also dumps the equivalent of 100 hp into the cooling system.
And another 100 hp into the exhaust system.

Boost

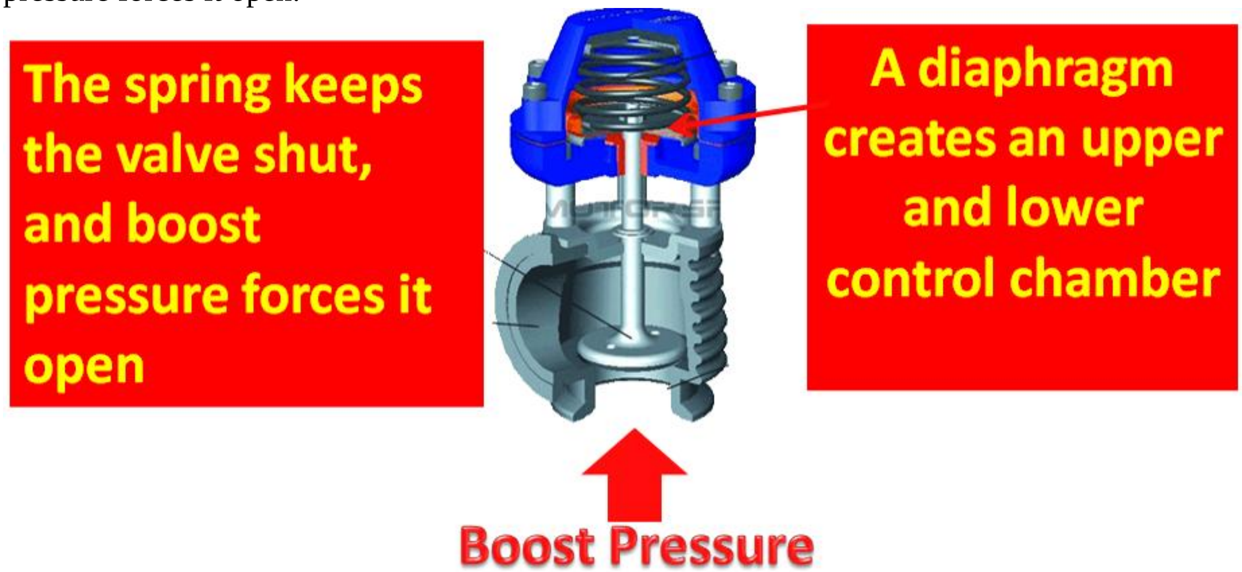
Boost is the pressure above atmospheric pressure (in psi) that the turbocharger generates. Boost pressures are slightly less at the manifold than they are at the turbocharger outlet due to cooling and expansion of the air charge as it passes through the intercooler.

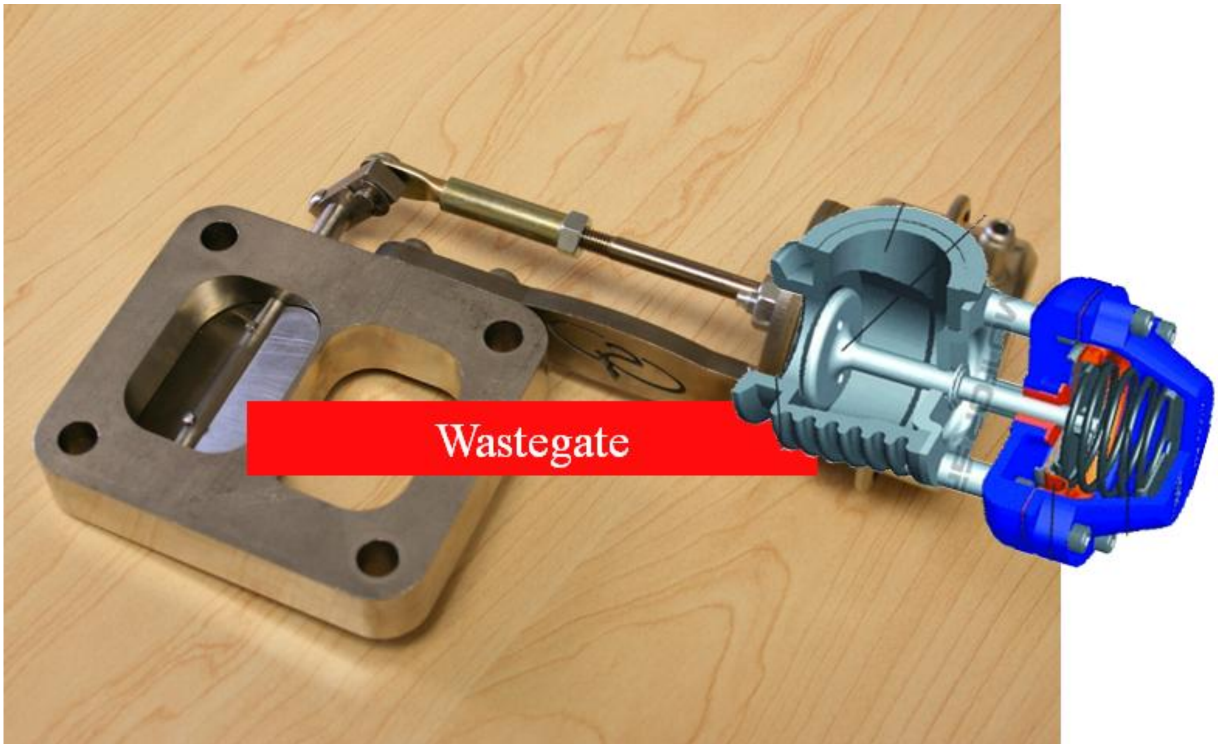
LB7 Turbocharger

The turbocharger on the LB7 uses a wastegate with a maximum boost pressure of 20 psi.

Wastegate

The basic task of the wastegate is to vent exhaust gas away from the turbo inlet, the less exhaust gas that flows through the turbo, the less boost pressure the turbo can produce. Thus the wastegate "wastes" exhaust gas and lowers boost.
Wastegates are simply valves controlled by a spring and boost pressure. A diaphragm mounted between the spring chamber and the boost chamber creates an upper and lower control chambers. Both the boost pressure and spring acts on this diaphragm. The valve is held shut by a spring inside the diaphragm chamber to keep the valve shut. The spring keeps the valve shut, and boost pressure forces it open.



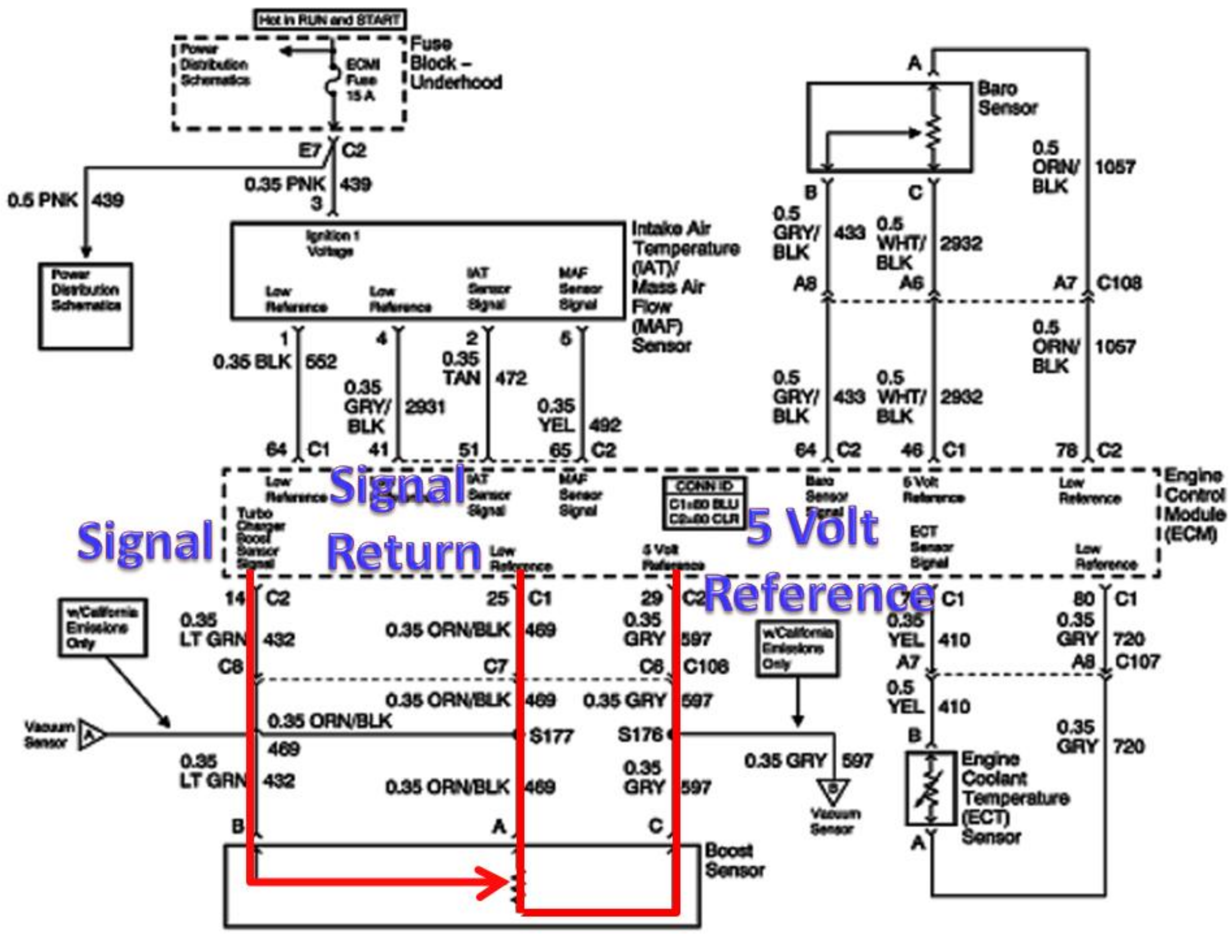

Wastegate

Turbocharger Diagnostics

Any diagnostics should begin with a visual inspection. Look for leaks in the oil supply tubes. Spin the turbine by hand and listen for any noise and watch for any out-of-round movement of the turbine or compressor wheel. Test drive the truck and watch Boost Pressure on the scan tool, looking for an increase in boost as RPM increases to the maximum boost pressure.

Boost Pressure Analysis

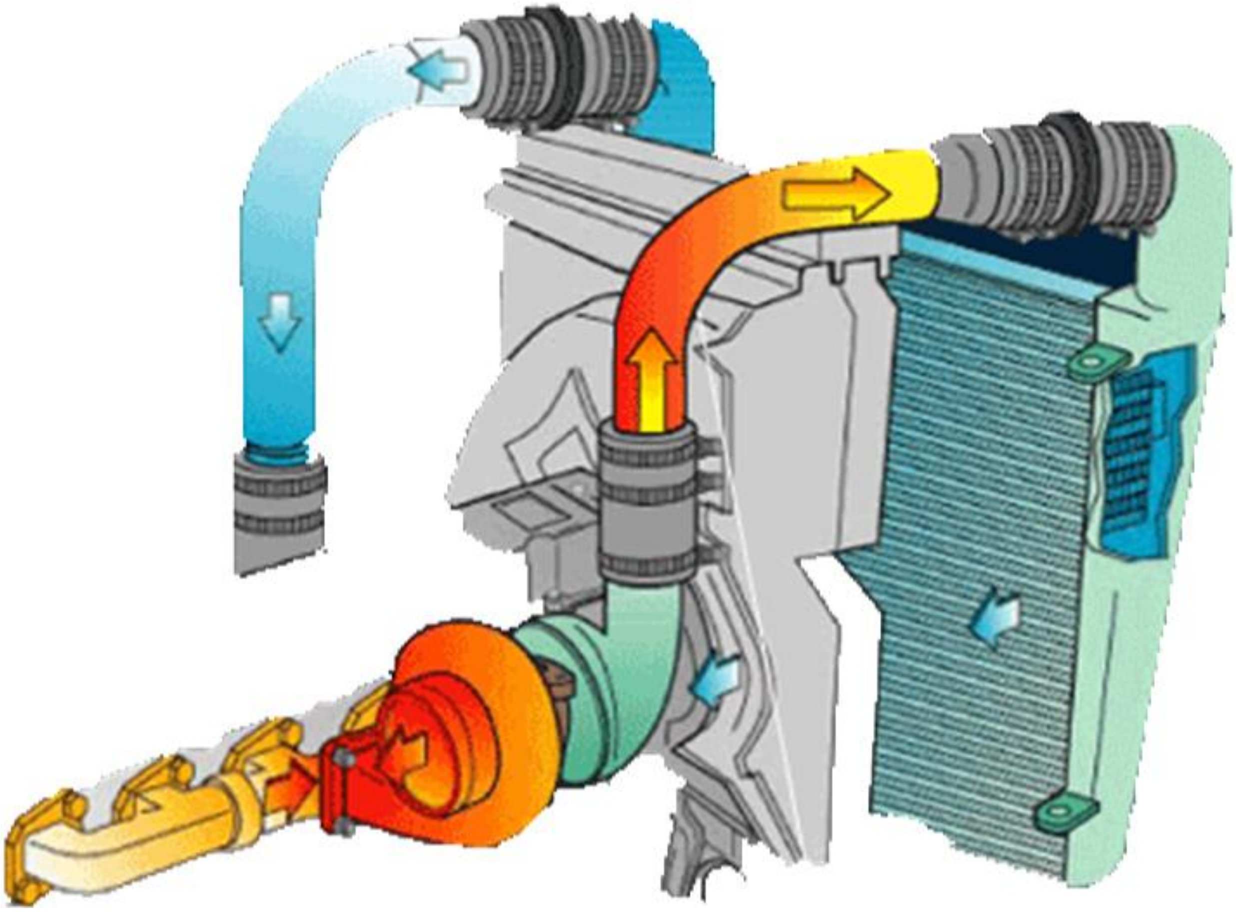
Boost Pressure PID
Key on engine off = Barometric pressure
Engine running = Subtract the K-O-E-O, barometric pressure reading form the value to get boost
Example; PID shows 22.7 Hg.
  22.8 Value - 14.8 Baro = 8 Hg Boost



Charge Air Cooler

The air coming out of the compressor side of the turbo is hot. It must be cooled before it enters the intake manifold. The air is cooled by the charge air cooler.
The charge air cooler is located in the front of the radiator. It is an air to air cooler designed to lower the temperature of the air coming out of the turbocharger outlet before entering the intake

manifold.



In diesel engines, charge air coolers are located between the turbocharger which provides a greater supply of combustion air by air compression and the air inlet manifolds. The temperature of the air compressed by the turbocharger increases during this process. The density of the air whose temperature increases due to compression, friction etc. decreases. Increasing the density of the combustion air will increase combustion efficiency. Hence, the temperature of the air should be lowered prior to channeling within the cylinder. The increase in density of the cooling air will lead to an increase in weight of the charge air of the system, which in turn leads to an increase in engine efficiency and in power production capacity. The basic function of charge air coolers is to facilitate the specified cooling function.

The growing emphasis placed on the environmental approach in our day has a substantial impact on legislations addressing control of emissions. This has a bearing particularly on diesel engine applications and the lowering of NOx levels is becoming ever more crucial.

Charge air coolers, as well as increasing engine efficiency and power also enable lower NOx levels. Many methods have been developed for reducing NOx levels and increasing the efficiency of combustion. Placing a cooler for charge air is one method. Lower charge air temperatures lead to lower temperatures for combustion gases and in turn lower NOx emissions.

The Charge-Air cooler (CAC) is an important part of the engine intake system. Filtered turbo-compressed air flows through the CAC and is then fed directly into the intake manifold. If the CAC is cracked and leaks, unfiltered air can be ingested by the engine, causing accelerated wear and potential engine failure.

Some symptoms of a leaking CAC are:

- Increased fuel consumption
- Exhaust manifold failures
- Elevated Coolant Temperatures
- Loss of engine power
- Premature piston, ring & valve failure
- Turbocharger failures

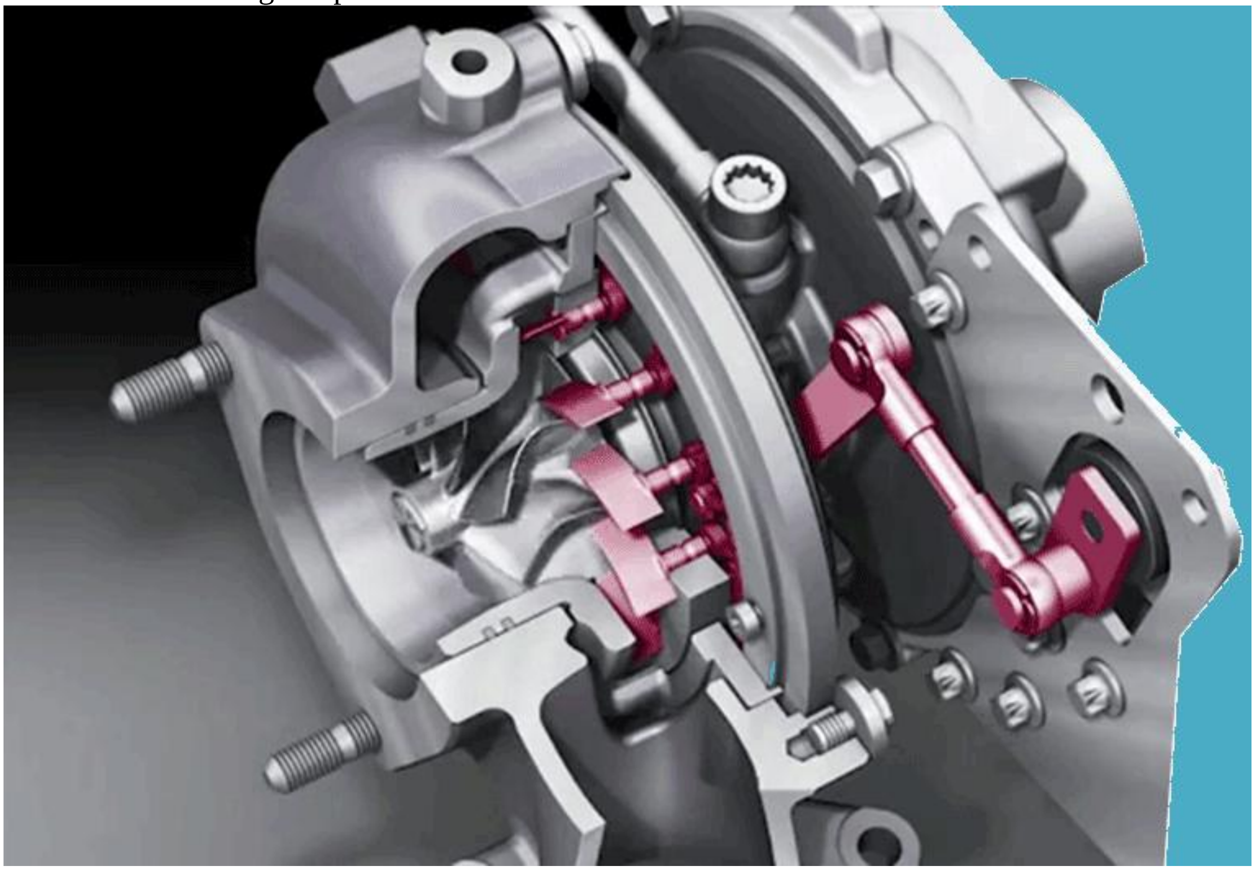
The charge air cooler is located in the front
of the radiator.
It is an air to air cooler designed to lower the temperature of the air coming out of the turbocharger outlet before entering the intake manifold.

LLY/LBZ/LMM/LML Turbocharger

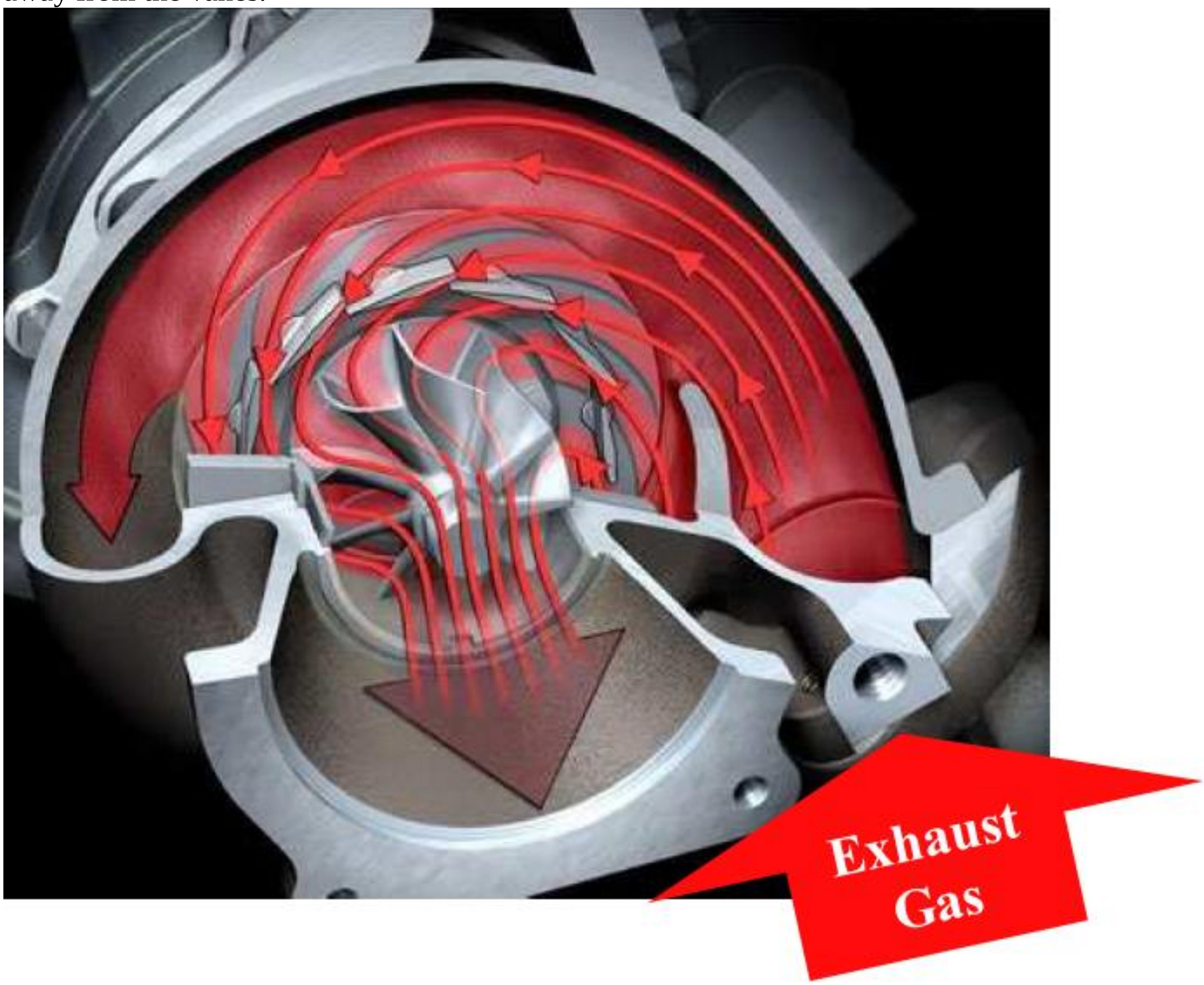
Use Variable Geometry Turbocharger (VGT) and no wastegate.

Variable Turbine Geometry

The next generation in turbocharger technology uses variable vanes to control exhaust flow against the turbine blades. The problem with the wastegate turbocharger is that big Turbo's do not work well at slow engine speeds, while small turbot's are fast to spool but run out of steam pretty quick. A Variable Turbine Geometry turbocharger is also known as a variable geometry turbocharger (VGT) or a Variable Nozzle Turbine (VNT). A turbocharger equipped with Variable Turbine Geometry has movable vanes which can direct exhaust flow onto the turbine blades. The vane angles are adjusted with an actuator. The angle of the vanes vary throughout the engine RPM range to optimize turbine behavior. This allows a turbo to produce a large amount of boost at lower engine speeds.

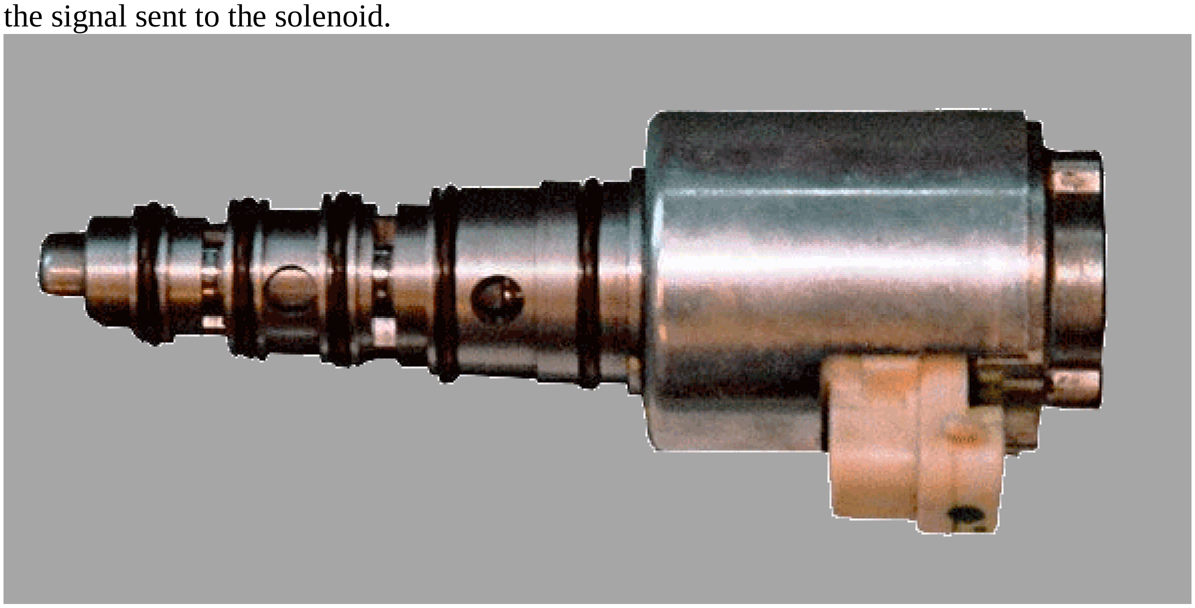


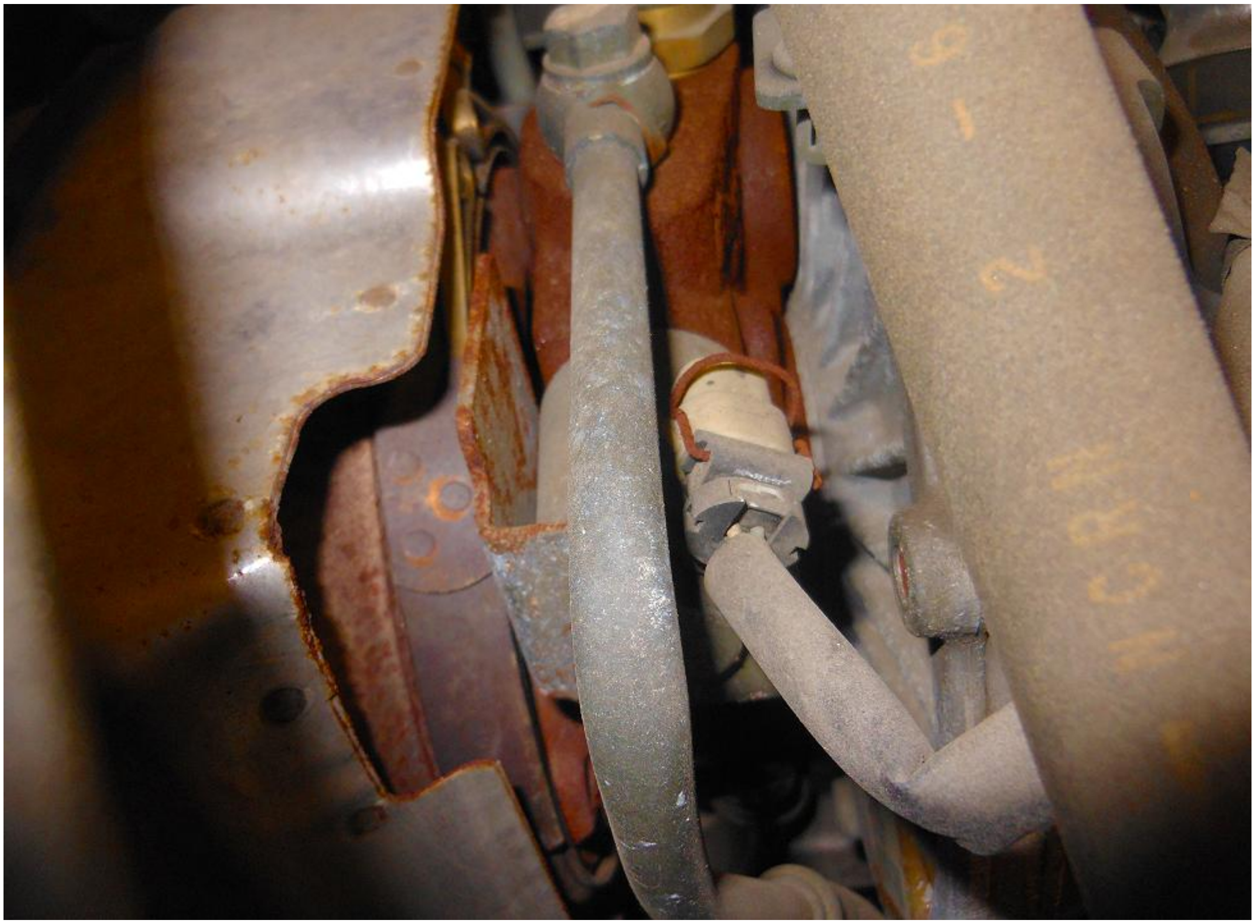
When the variable vanes are almost closed, the narrow passage between the vanes accelerates the exhaust gas towards the turbine vanes at the proper angle making them spin faster creating large amounts of boost. When the variable vanes almost fully open the passages between each vane becomes wider. This slows the exhaust gas which slows the turbine by directing exhaust gas flow away from the vanes.

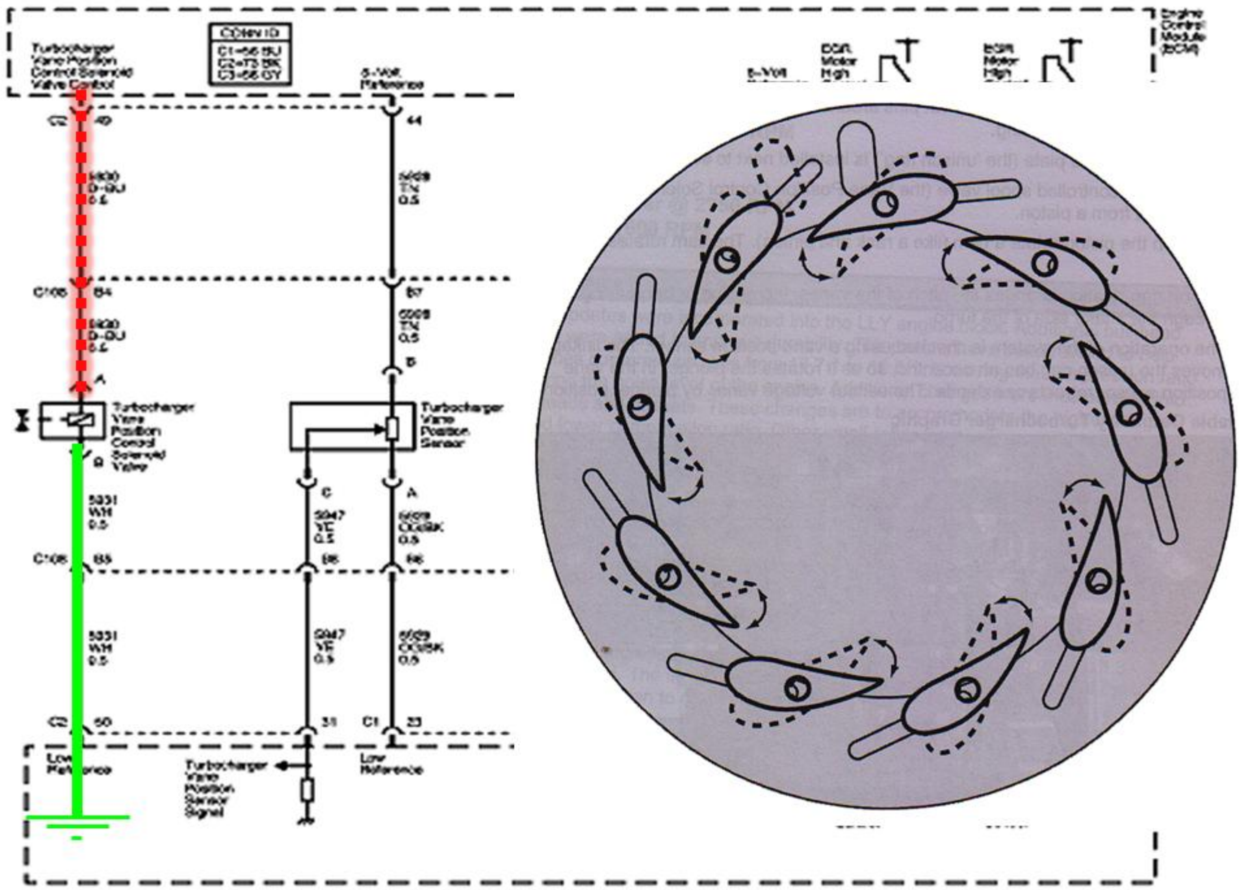


Vane Position Control Solenoid

The Vane Position Control Solenoid is a simple two wire solenoid that is controlled by the PCM with a pulse width signal. The PCM can position the VGT vanes in any position by controlling the signal sent to the solenoid.

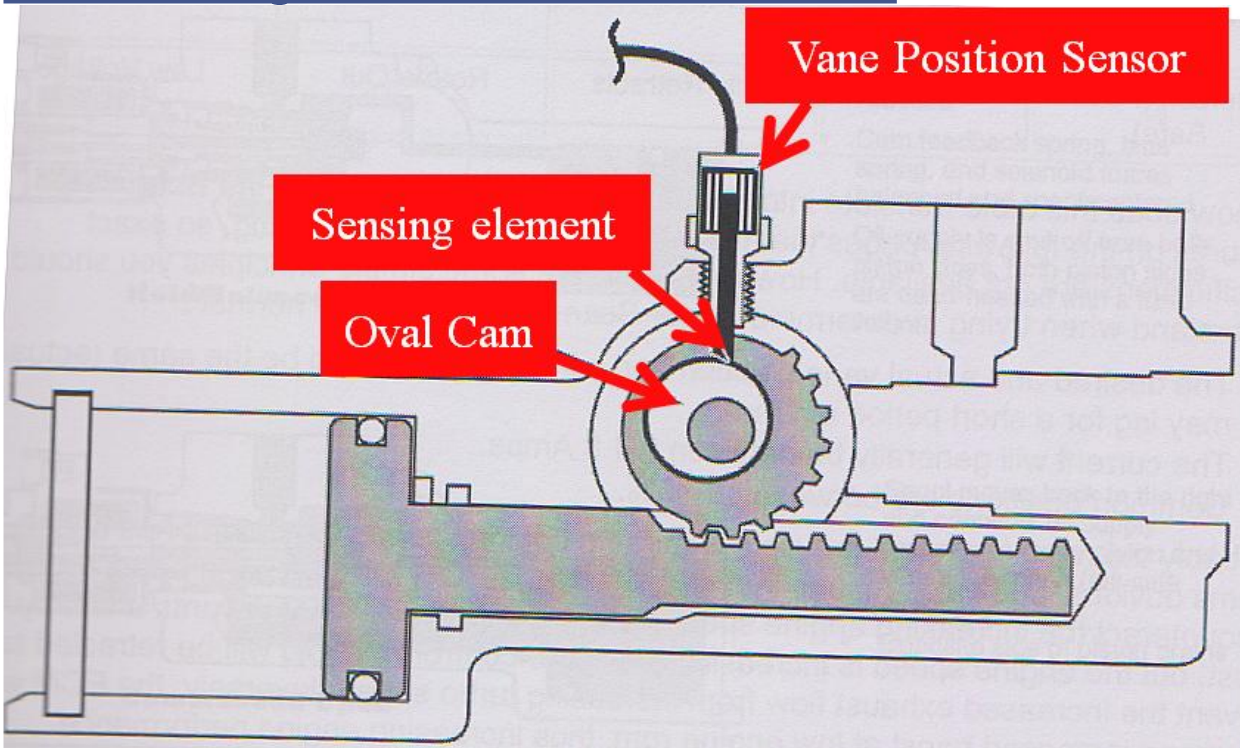






Turbocharger Vane Position Control Solenoid Valve Control
CONN ID
C1=56 BU
C2=73 BK
C3=56 GY
5-Volt Reference
Engine Control Module (ECM)
Turbocharger Vane Position Control Solenoid Valve
Turbocharger Vane Position Sensor
Low Reference
Turbocharger Vane Position Sensor Signal
Low Reference

Turbocharger Vane Position Sensor



Typical vane position is between 10% and 90% with a current draw between zero and 1.9 amps. It is difficult to read the position sensor when accelerating or decelerating so it is important to hold a steady throttle to get an accurate value. The PCM is programmed to control boost while both accelerating and decelerating so that there isn't a steady value to read. The control keeps engine performance high while protecting Turbo overspeed. It is common to think the higher the engine RPM the greater the control signal. However, at higher engine RPM the PCM stops moving the vanes to protect against the turbocharger from an over speed condition.

Solenoid operation

Mode	Current	Piston Movement	Vanes Rotation	Sensor Voltage
Boost Increases	Increases	Extends	Inward	Higher
Boost Decreases	Decreases	Retracts	Outward	Lower
Boost Held Steady	Will Very	None	None	Doesn't move
Default	0 Amps	Fully Retracts	Outward	Low

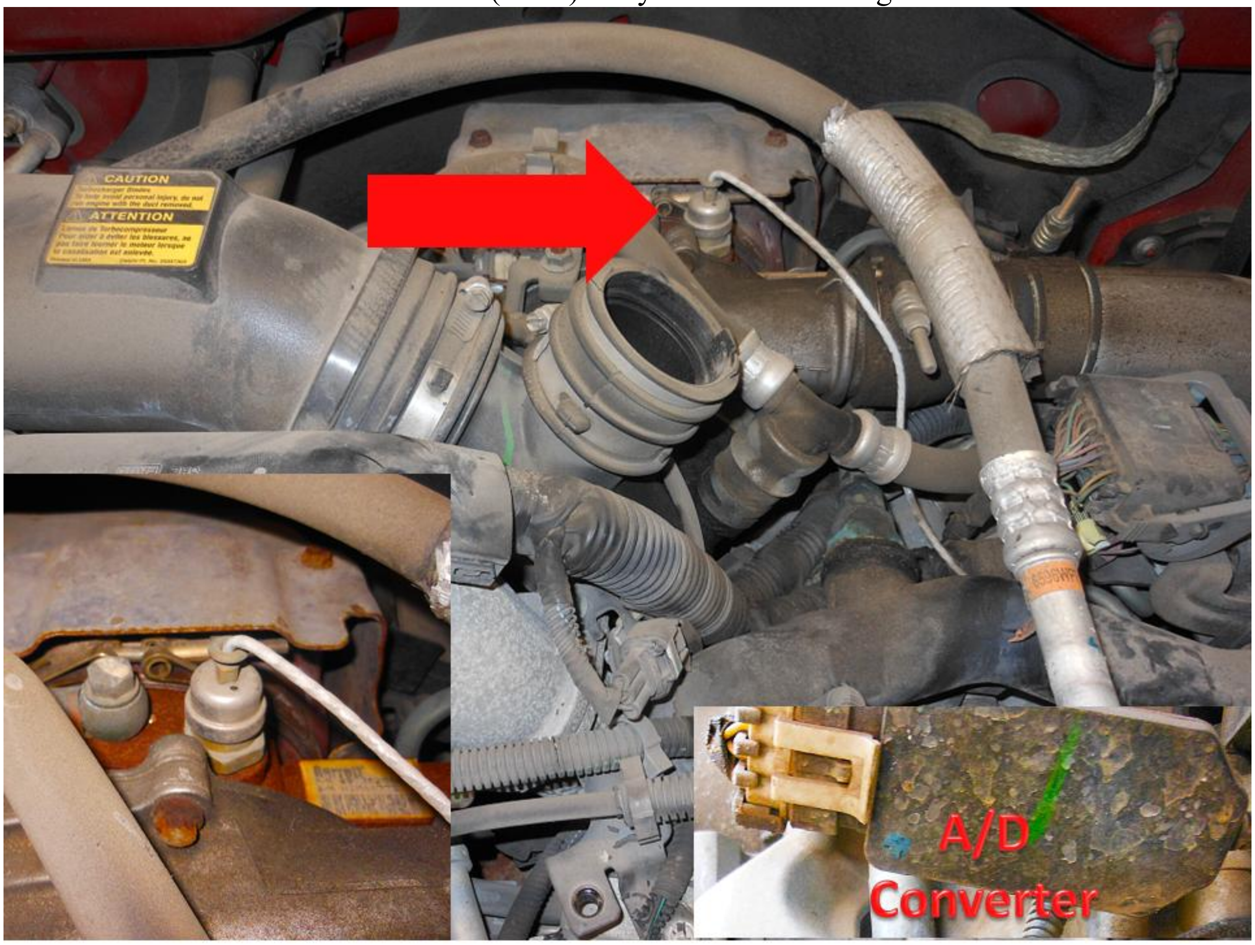
Current between zero and 1.9 amps
Normal position between 10% and 90%

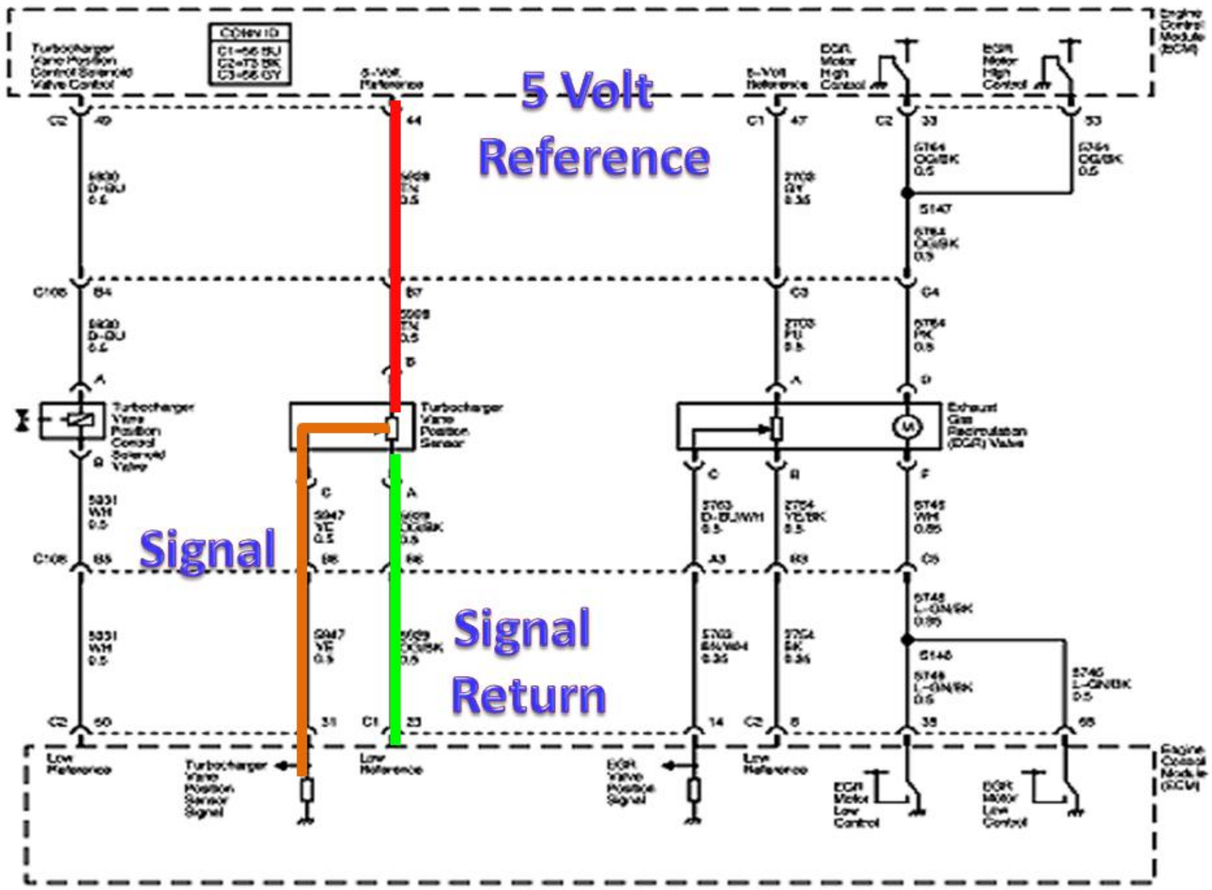
It is difficult to read the position sensor when accelerating or decelerating.
The ECM is programmed to control boost during both.
The control keeps engine performance high while protecting Turbo overspeed.

Turbocharger Vane Position Sensor

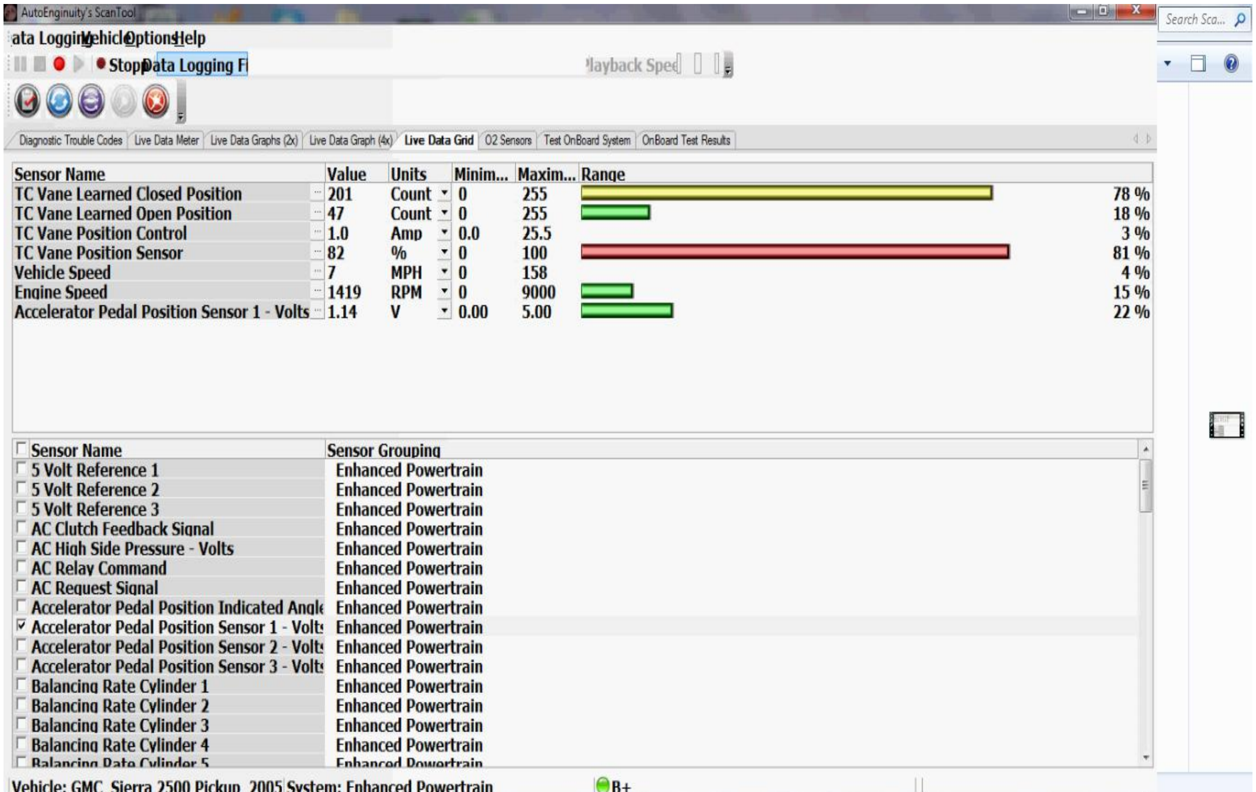
The sensor is a potentiometer that receives a 5 volt reference and uses the signal return to complete the circuit. The third circuit is the variable signal.

There are two sensors for different applications, one sensor covers the 2500HD/3500HD (T800) and another covers 4500HD/5500HD (T560)' they are not interchangeable between the two.



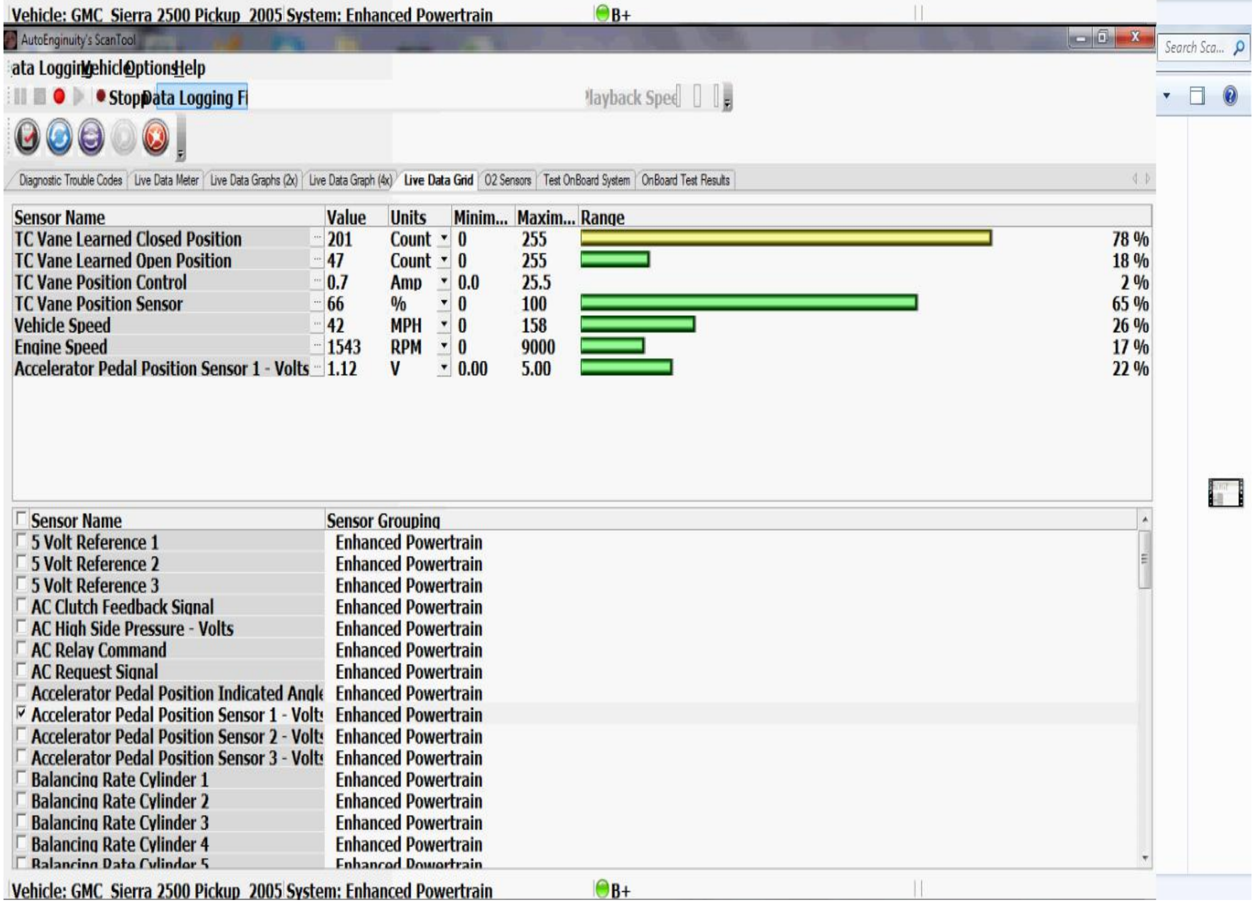


5 Volt
Reference
Signal
Signal
Return
Turbocharger Vane Position Sensor
Exhaust Gas Recirculation (EGR) Valve



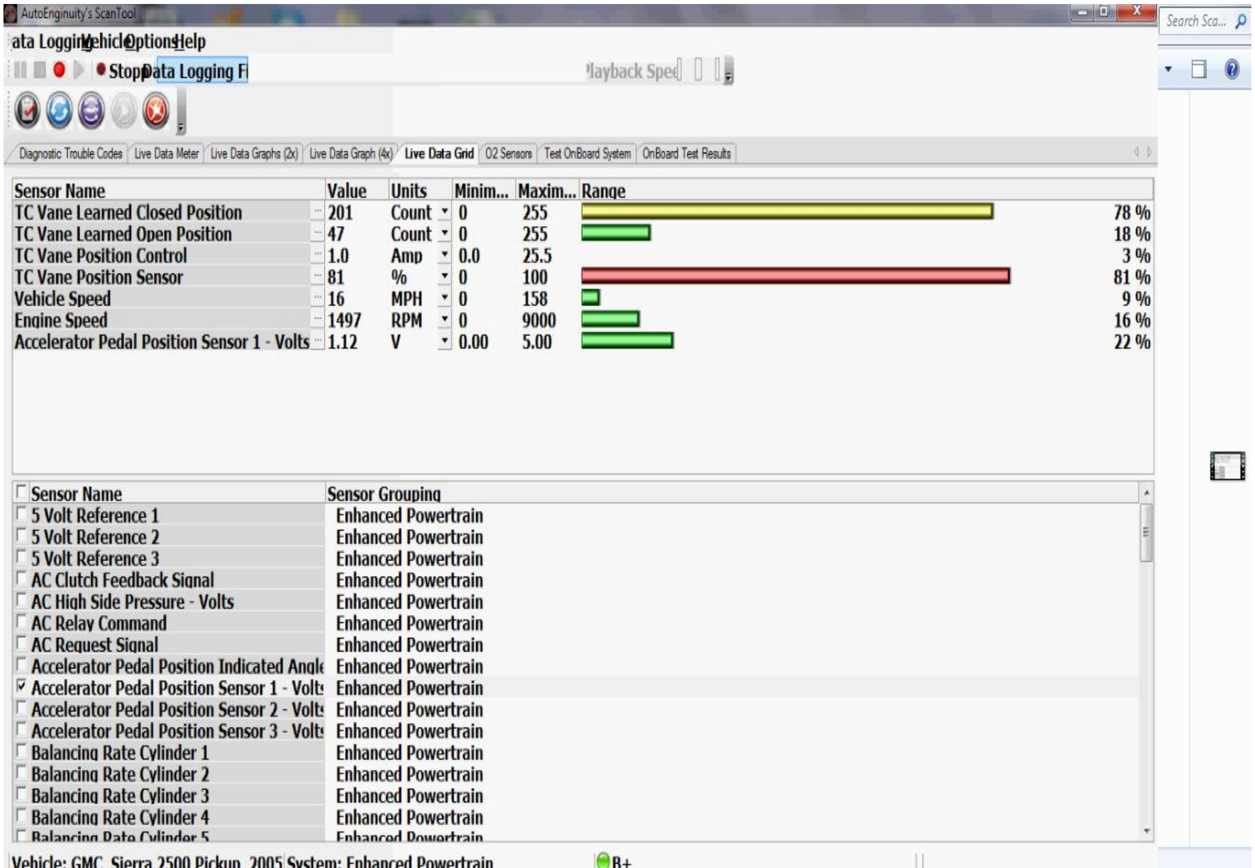
Sensor Name	Value	Units	Minim...	Maxim...	Range
TC Vane Learned Closed Position	201	Count	0	255	78 %
TC Vane Learned Open Position	47	Count	0	255	18 %
TC Vane Position Control	1.0	Amp	0.0	25.5	3 %
TC Vane Position Sensor	82	%	0	100	81 %
Vehicle Speed	7	MPH	0	158	4 %
Engine Speed	1419	RPM	0	9000	15 %
Accelerator Pedal Position Sensor 1 - Volts	1.14	V	0.00	5.00	22 %

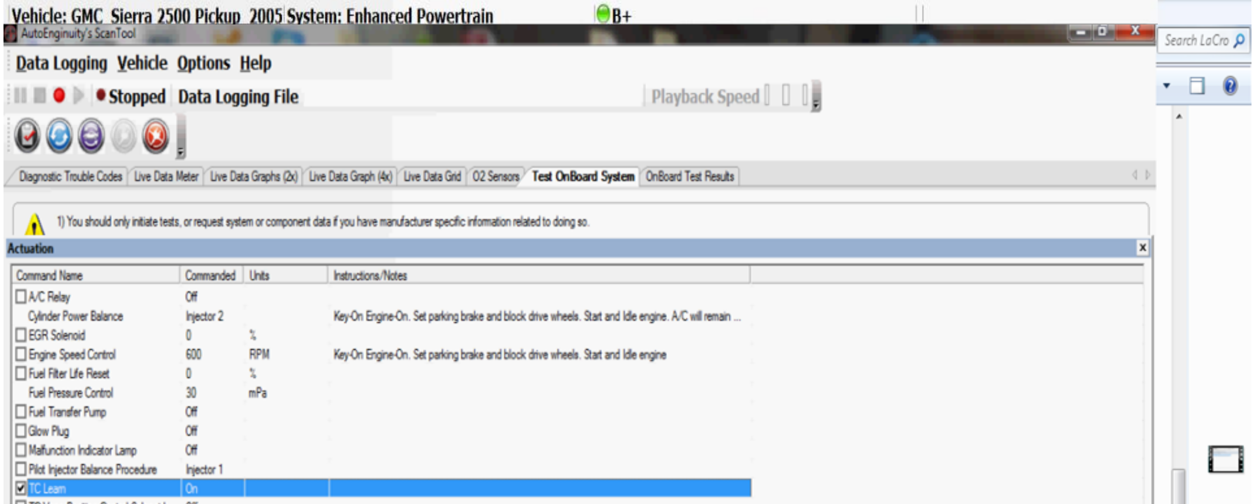
Sensor Name	Sensor Grouping
5 Volt Reference 1	Enhanced Powertrain
5 Volt Reference 2	Enhanced Powertrain
5 Volt Reference 3	Enhanced Powertrain
AC Clutch Feedback Signal	Enhanced Powertrain
AC High Side Pressure - Volts	Enhanced Powertrain
AC Relay Command	Enhanced Powertrain
AC Request Signal	Enhanced Powertrain
Accelerator Pedal Position Indicated Angle	Enhanced Powertrain
☑ Accelerator Pedal Position Sensor 1 - Volts	Enhanced Powertrain
Accelerator Pedal Position Sensor 2 - Volts	Enhanced Powertrain
Accelerator Pedal Position Sensor 3 - Volts	Enhanced Powertrain
Balancing Rate Cylinder 1	Enhanced Powertrain
Balancing Rate Cylinder 2	Enhanced Powertrain
Balancing Rate Cylinder 3	Enhanced Powertrain
Balancing Rate Cylinder 4	Enhanced Powertrain
Balancing Rate Cylinder 5	Enhanced Powertrain



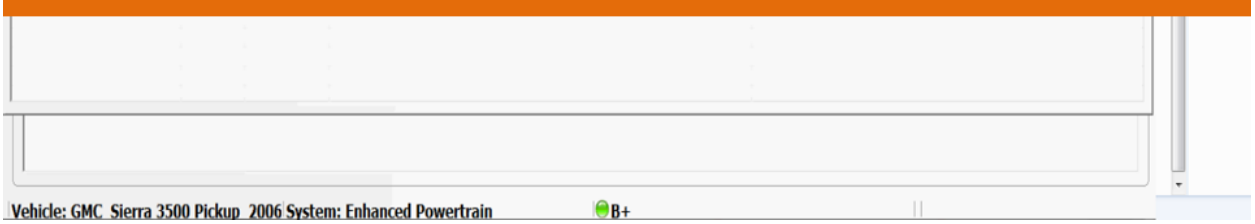
Sensor Name	Value	Units	Minim...	Maxim...	Range
TC Vane Learned Closed Position	201	Count	0	255	78 %
TC Vane Learned Open Position	47	Count	0	255	18 %
TC Vane Position Control	0.7	Amp	0.0	25.5	2 %
TC Vane Position Sensor	66	%	0	100	65 %
Vehicle Speed	42	MPH	0	158	26 %
Engine Speed	1543	RPM	0	9000	17 %
Accelerator Pedal Position Sensor 1 - Volts	1.12	V	0.00	5.00	22 %

Sensor Name	Sensor Grouping
5 Volt Reference 1	Enhanced Powertrain
5 Volt Reference 2	Enhanced Powertrain
5 Volt Reference 3	Enhanced Powertrain
AC Clutch Feedback Signal	Enhanced Powertrain
AC High Side Pressure - Volts	Enhanced Powertrain
AC Relay Command	Enhanced Powertrain
AC Request Signal	Enhanced Powertrain
Accelerator Pedal Position Indicated Angle	Enhanced Powertrain
☑ Accelerator Pedal Position Sensor 1 - Volts	Enhanced Powertrain
Accelerator Pedal Position Sensor 2 - Volts	Enhanced Powertrain
Accelerator Pedal Position Sensor 3 - Volts	Enhanced Powertrain
Balancing Rate Cylinder 1	Enhanced Powertrain
Balancing Rate Cylinder 2	Enhanced Powertrain
Balancing Rate Cylinder 3	Enhanced Powertrain
Balancing Rate Cylinder 4	Enhanced Powertrain
Balancing Rate Cylinder 5	Enhanced Powertrain





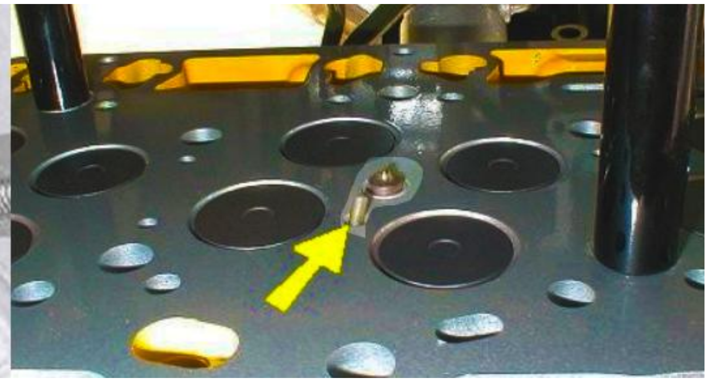
If any turbo work is preformed (including replacement, cleaning) preform the Bi-directional Re-Lean command



Glow Plugs

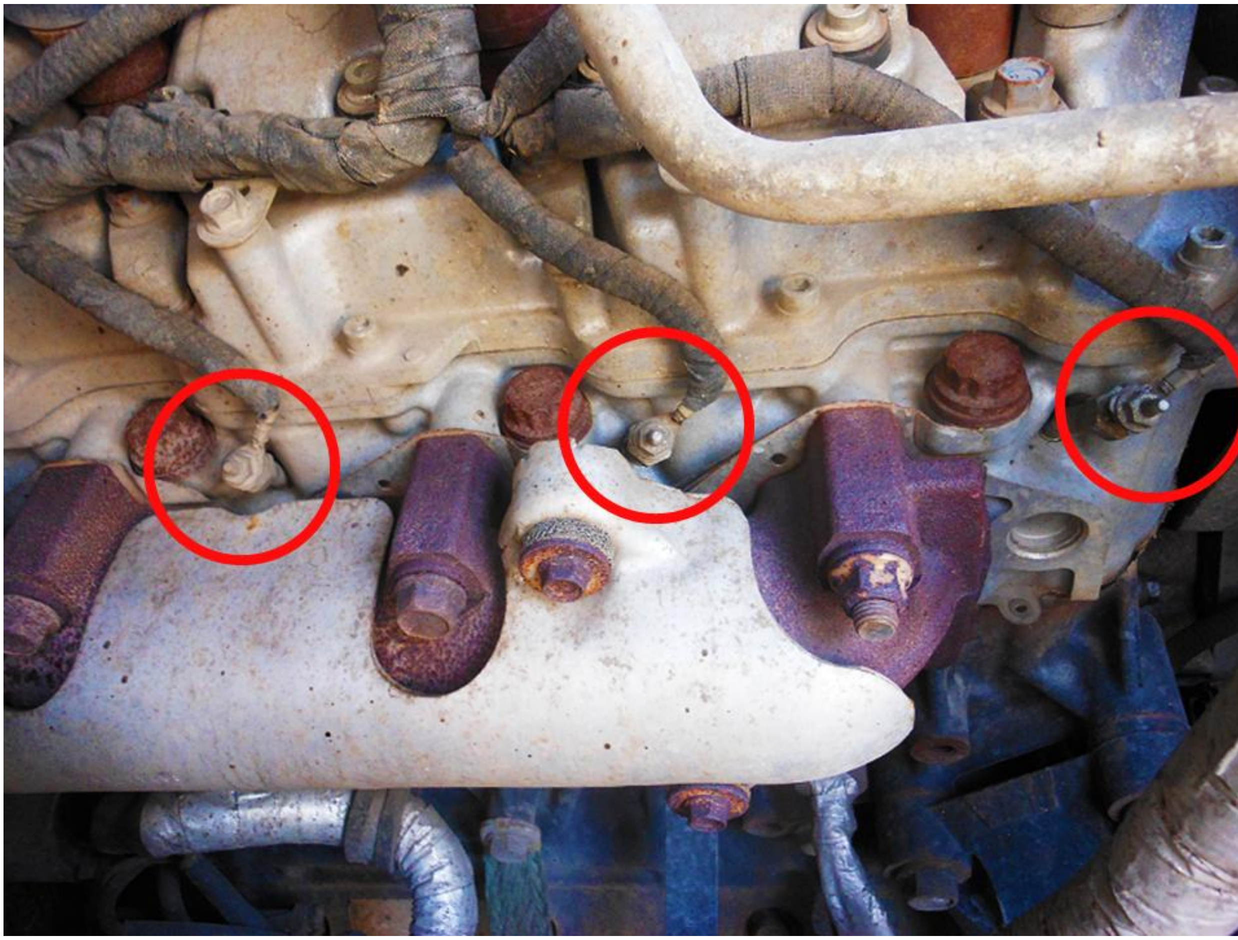
The glow system has been modified to improve cold starting and reduce white smoke when cold. The LLY's glow system "Wait to Start" lamp will illuminate now for just three seconds. The new silver tipped glow plugs (LB7's were gold) are designed to reach 1000° C (1832° F) in just 1.8 seconds, and then PWM (pulse width modulation) is used to maintain that temperature for the remainder of the three seconds. In addition, each new fuel injector has one of its seven spray holes oriented to spray directly onto the heated glow plug tip. Total glow system current draw peaks at 110 amps for the 1.8 second initial heat cycle, and then the current is reduced to 30 amps for the remaining 1.2 seconds to maintain the 1000° temperature. Also new is the individual glow plug control, where the LB7's glow plugs were ganged on a common circuit. This allows glow control for individual cylinders and improved glow plug diagnostic ability using a set of eight new trouble codes. The LLY glow plug system remains in use though the

LML version.



Duramax has two different control circuits.

The Duramax glow plugs are model year specific and some years are not interchangeable. As An Example; the LB& glow plugs have a gold color, the LLY has a silver color. The LBZ has a silver color but the threads are machined in the sleeve further down than the LB& and LLY. The LBZ glow plug was also used on the 2006 LLY. Although the LMM and LML's glow plugs look like the LBZ units they may be different, so order replacements by model year and VIN.



One glow plug per cylinder.
They are 12 volt heaters that are energized prior to starting the engine
The LLY, LBZ, LMM, and LML are 4.7 volt heaters.
They may also be operated for a short time after the engine has started (up to 30 seconds) .

Glow Plug Control Module

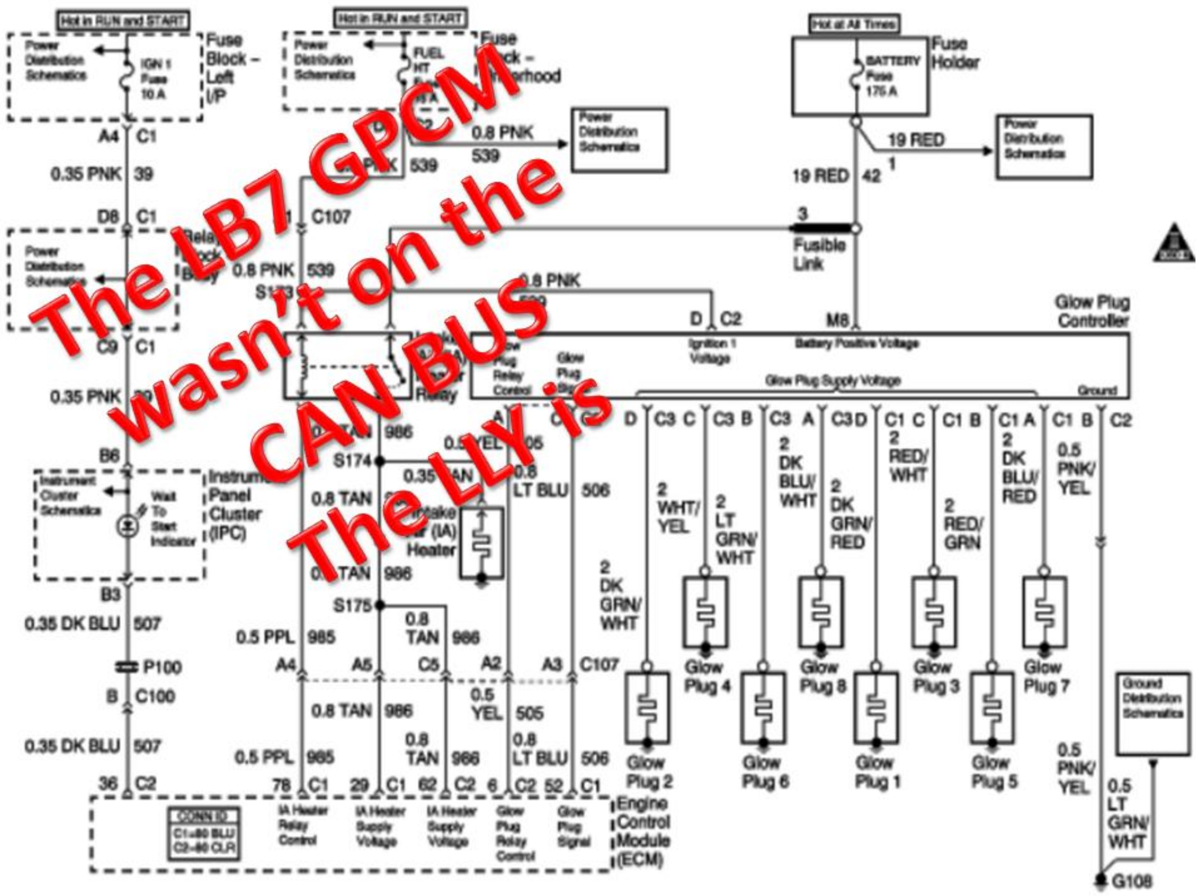
A Glow Plug Control Module (GPCM) turns the glow plugs on and off.
It monitors the voltage drop of the circuit and detecting any faults.
The module is required in California with other states using them also.
The GPCM sends and receives information on the CAN BUS on LLY and later models.

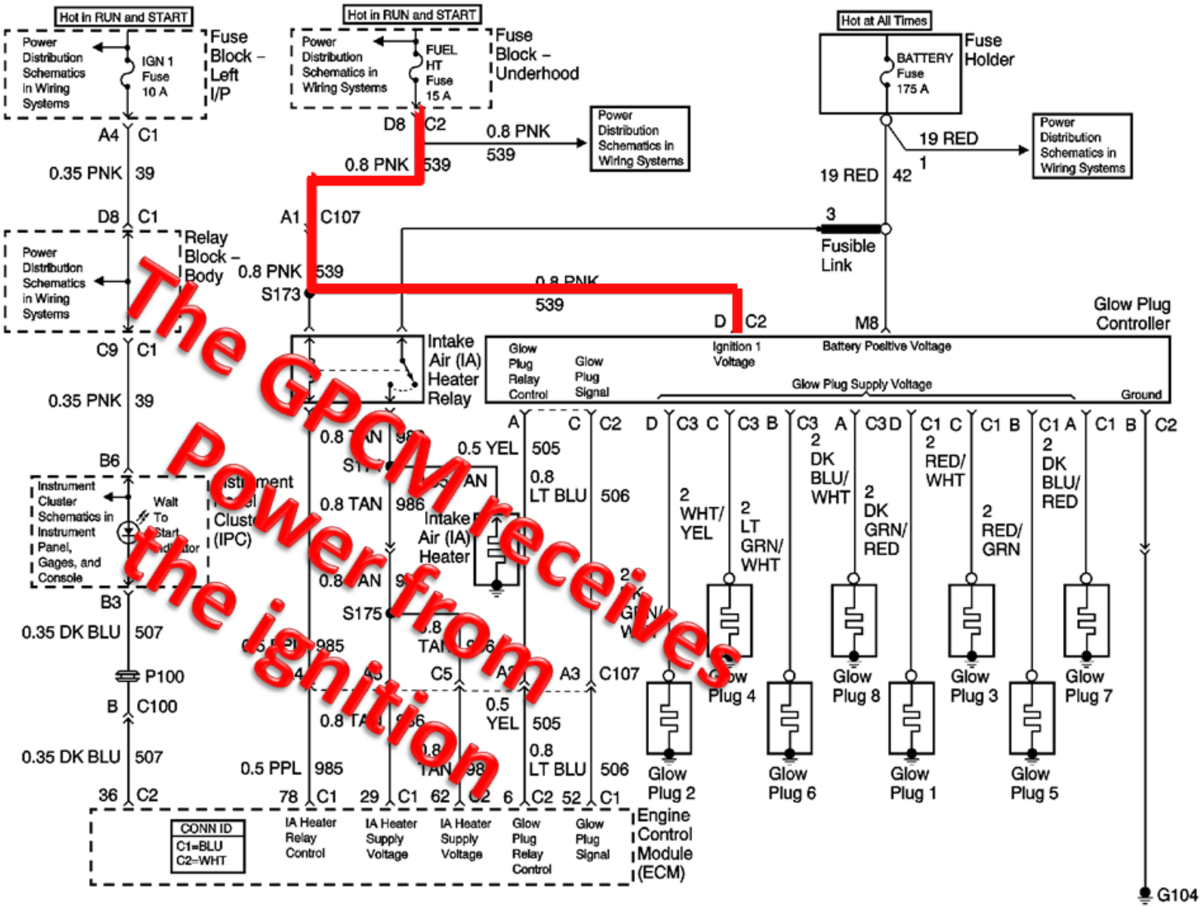
Glow Plugs LMM Engines

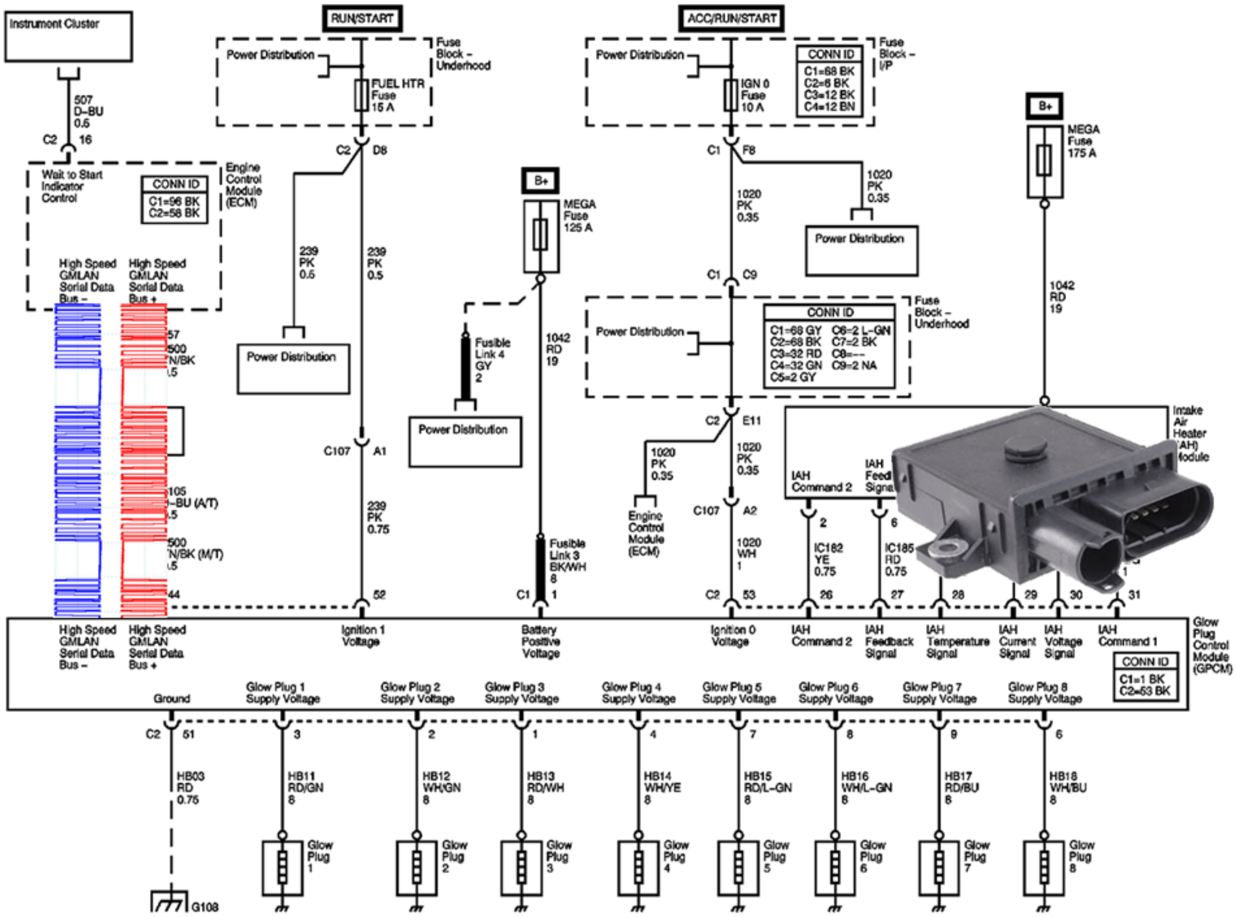
The voltage on the LMM engines has been changed to start at about 10 volts and rise to system voltage as they are cycled.

Controller Area Network (CAN)

There is a training program on the CAN BUS.

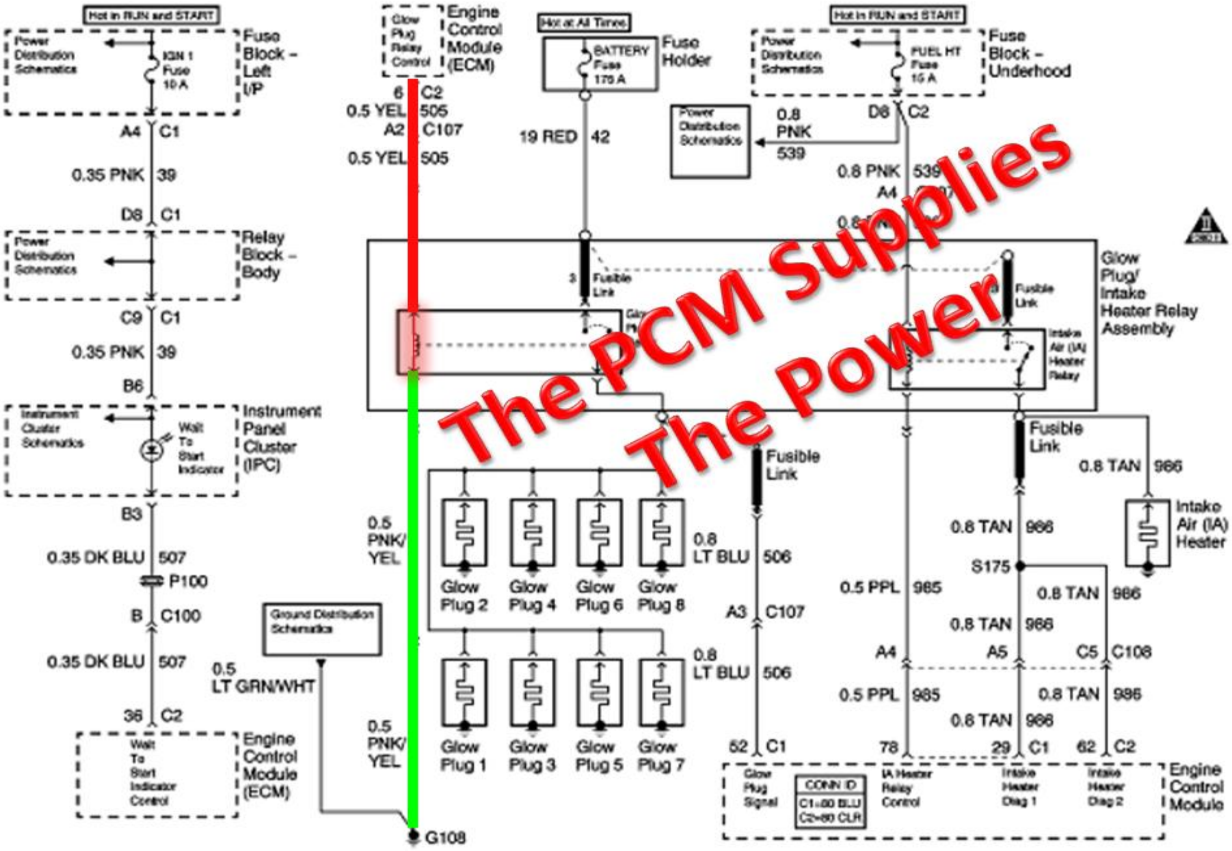



The GPCM receives Power from the ignition
Hot in RUN and START
Fuse Block – Left I/P
IGN 1 Fuse 10 A
Power Distribution Schematics in Wiring Systems
Hot in RUN and START
Fuse Block – Underhood
FUEL HT Fuse 15 A
Hot at All Times
Fuse Holder
BATTERY Fuse 175 A
D8 C2
0.8 PNK
539
19 RED
42
1
A4 C1
0.35 PNK 39
D8 C1
A1 C107
Relay Block – Body
0.8 PNK 539
S173
3
Fusible Link
D C2
M8
Glow Plug Controller
Glow Plug Relay Control
Glow Plug Signal
Ignition 1 Voltage
Battery Positive Voltage
Glow Plug Supply Voltage
Ground
C9 C1
0.35 PNK 39
Intake Air (IA) Heater Relay
0.5 YEL 505
0.8 LT BLU 506
B6
Instrument Cluster Schematics in Instrument Panel, Gages, and Console
Wait To Start Indicator
Instrument Panel Cluster (IPC)
0.8 TAN 986
S175
Intake Air (IA) Heater
B3
0.35 DK BLU 507
P100
B C100
0.35 DK BLU 507
0.5 PPL 985
C5
A3 C107
2 WHT/YEL
2 LT GRN/WHT
2 DK BLU/WHT
2 DK GRN/RED
2 RED/WHT
2 RED/GRN
2 DK BLU/RED
Glow Plug 2
Glow Plug 4
Glow Plug 6
Glow Plug 8
Glow Plug 1
Glow Plug 3
Glow Plug 5
Glow Plug 7
36 C2
78 C1
29 C1
62 C2
6 C2
52 C1
CONN ID
C1=BLU
C2=WHT
IA Heater Relay Control
IA Heater Supply Voltage
Glow Plug Relay Control
Glow Plug Signal
Engine Control Module (ECM)
G104

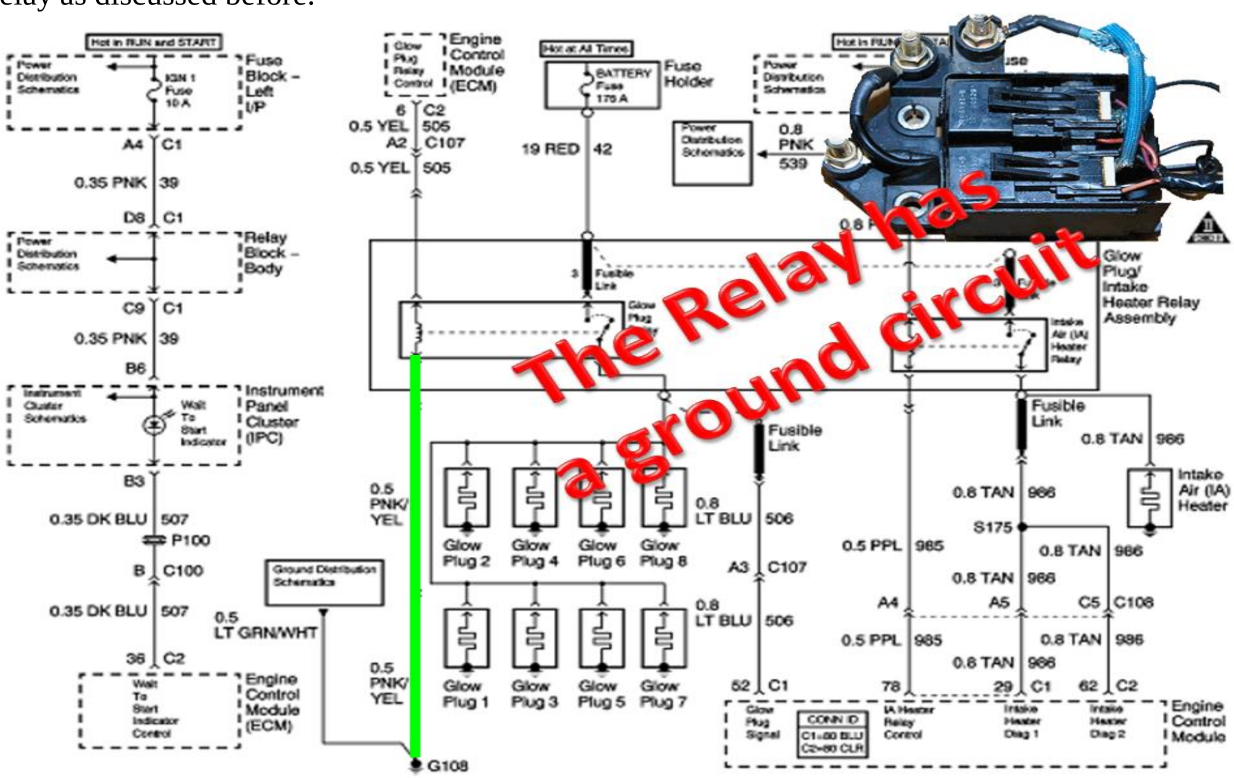


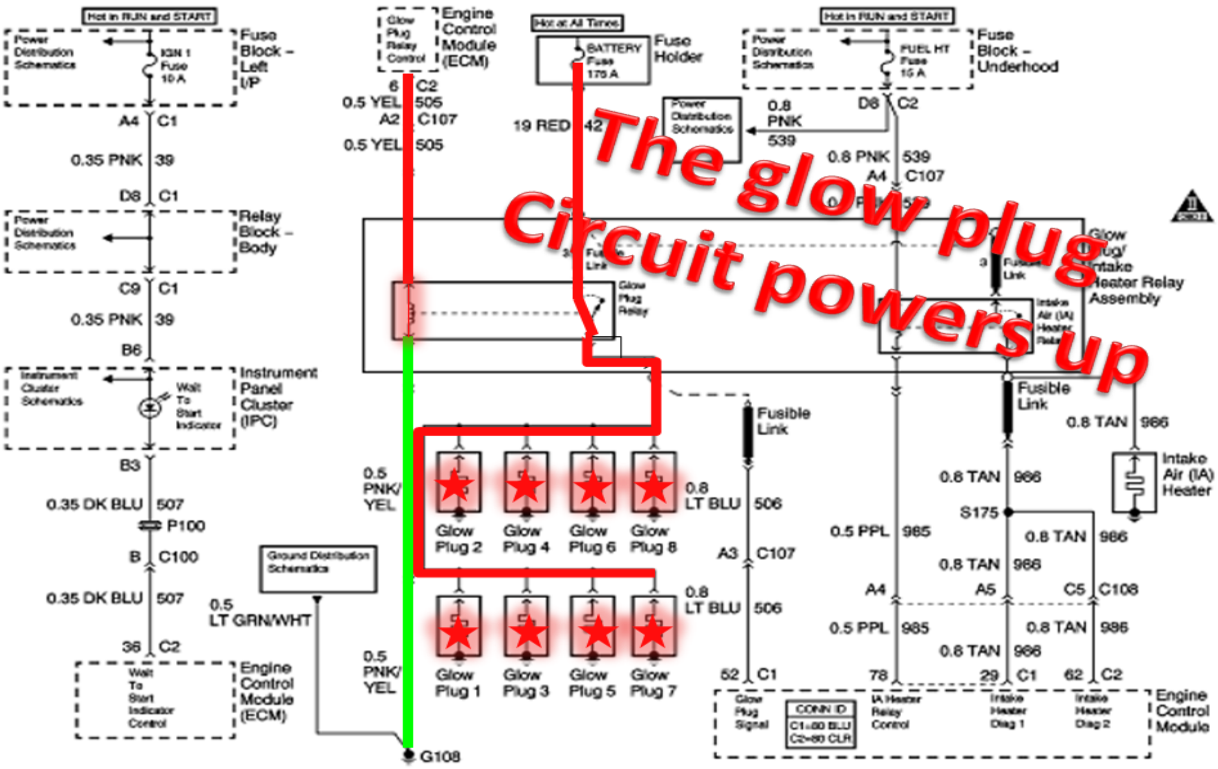
A relay is used on Federal emission vehicles

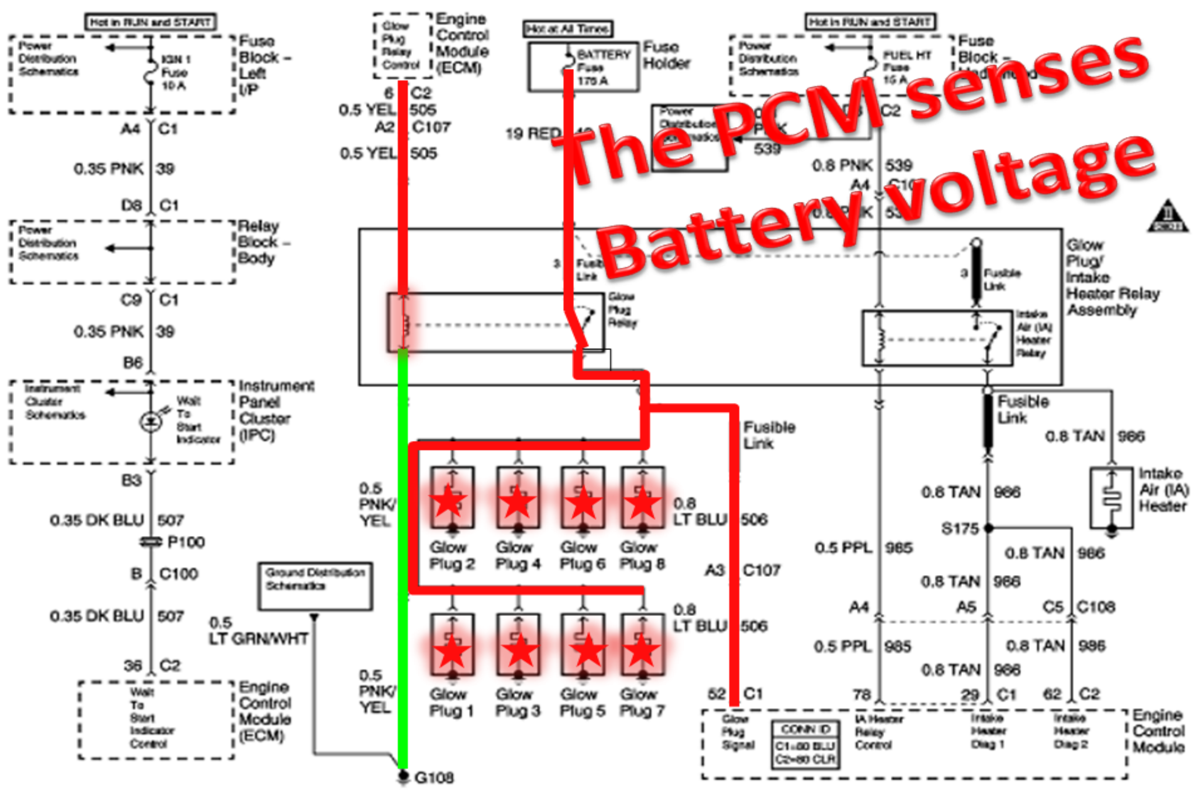
The relay is in combination with the intake air heater



relay as discussed before.




The glow plug circuit powers up
Hot in RUN and START
Fuse Block – Left I/P
IGN 1 Fuse 10 A
Power Distribution Schematics
Relay Block – Body
Instrument Panel Cluster (IPC)
Wait To Start Indicator
Engine Control Module (ECM)
Glow Plug Relay Control
Hot at All Times
BATTERY Fuse 175 A
Fuse Holder
Fuse Block – Underhood
FUEL HT Fuse 15 A
Glow Plug/ Intake Heater Relay Assembly
Glow Plug Relay
Intake Air (IA) Heater Relay
Fusible Link
Intake Air (IA) Heater
Glow Plug 2
Glow Plug 4
Glow Plug 6
Glow Plug 8
Glow Plug 1
Glow Plug 3
Glow Plug 5
Glow Plug 7
Ground Distribution Schematics
G108
Glow Plug Signal
IA Heater Relay Control
Intake Heater Diag 1
Intake Heater Diag 2
CONN ID C1=80 BLU C2=80 CLR


The PCM senses Battery voltage
Hot in RUN and START
Fuse Block – Left I/P
IGN 1 Fuse 10 A
Relay Block – Body
Instrument Panel Cluster (IPC)
Wait To Start Indicator
Engine Control Module (ECM)
Hot at All Times
BATTERY Fuse 175 A
Fuse Holder
Glow Plug/ Intake Heater Relay Assembly
Glow Plug Relay
Fusible Link
Intake Air (IA) Heater
Glow Plug 2
Glow Plug 4
Glow Plug 6
Glow Plug 8
Glow Plug 1
Glow Plug 3
Glow Plug 5
Glow Plug 7
Ground Distribution Schematics
G108
Glow Plug Signal
IA Heater Relay Control
Intake Heater Diag 1
Intake Heater Diag 2
CONN ID C1=80 BLU C2=80 CLR

Glow Plug Module LLY & Later

he glow plugs are turned on 110 amps at 4.7 volts for approximately two seconds. Then the GPCM reduces the current to approximately 30 amps to maintain the glow plug's temperature of 1832°F. The PCM illuminates the Wait to Start lamp for approximately one second when the engine is cold.

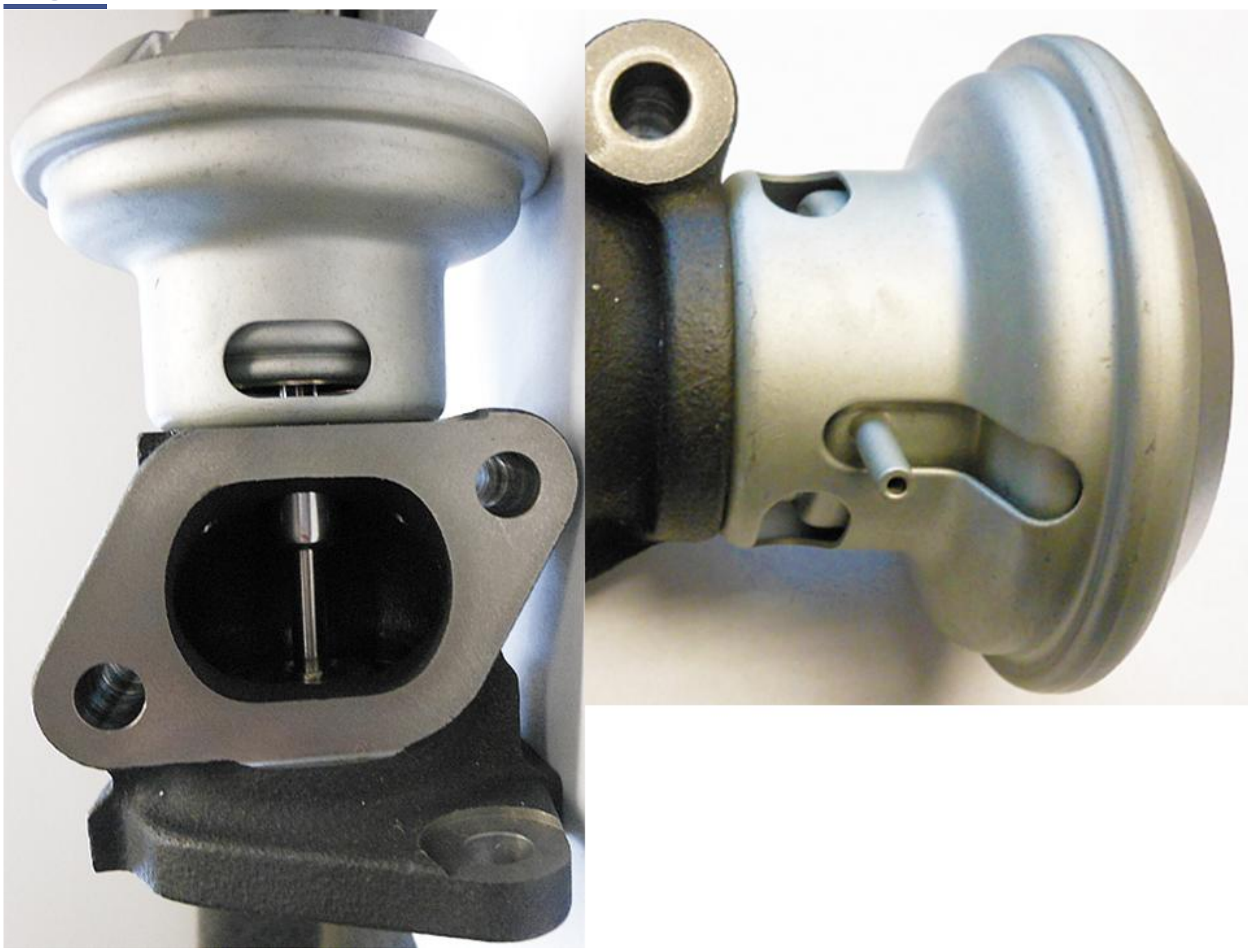
It may or may not illuminate when the engine is warm. On-time varies on engine and ambient temperatures. The PCM and GPCM may keep the glow plug on after engine start up to reduce White Smoke and improve the quality of the idle.

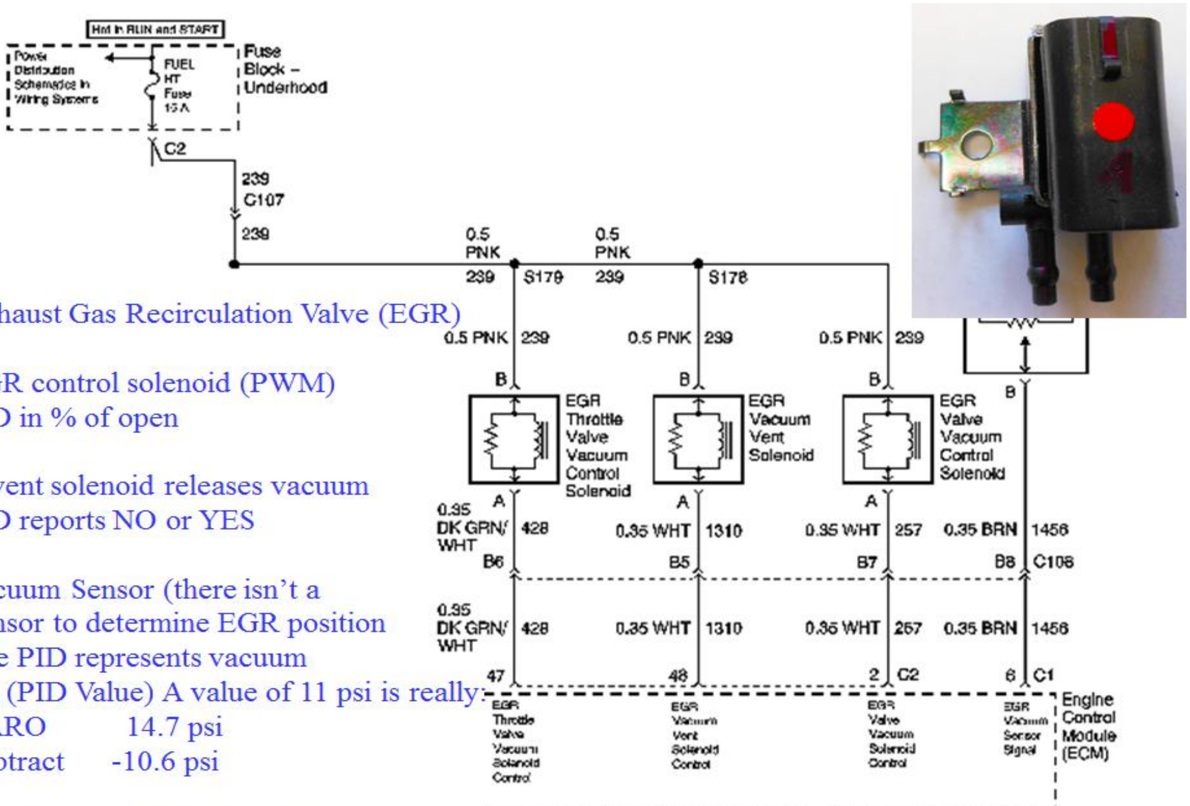
As a note, The GPCM was redesigned along with the glow plugs GPCM now includes the injector Flow Rate Values.

On-time varies on engine and ambient temperature.

The PCM and GPCM may keep the glow plug on after engine start up to reduce White Smoke and improve the quality of the idle.

EGR





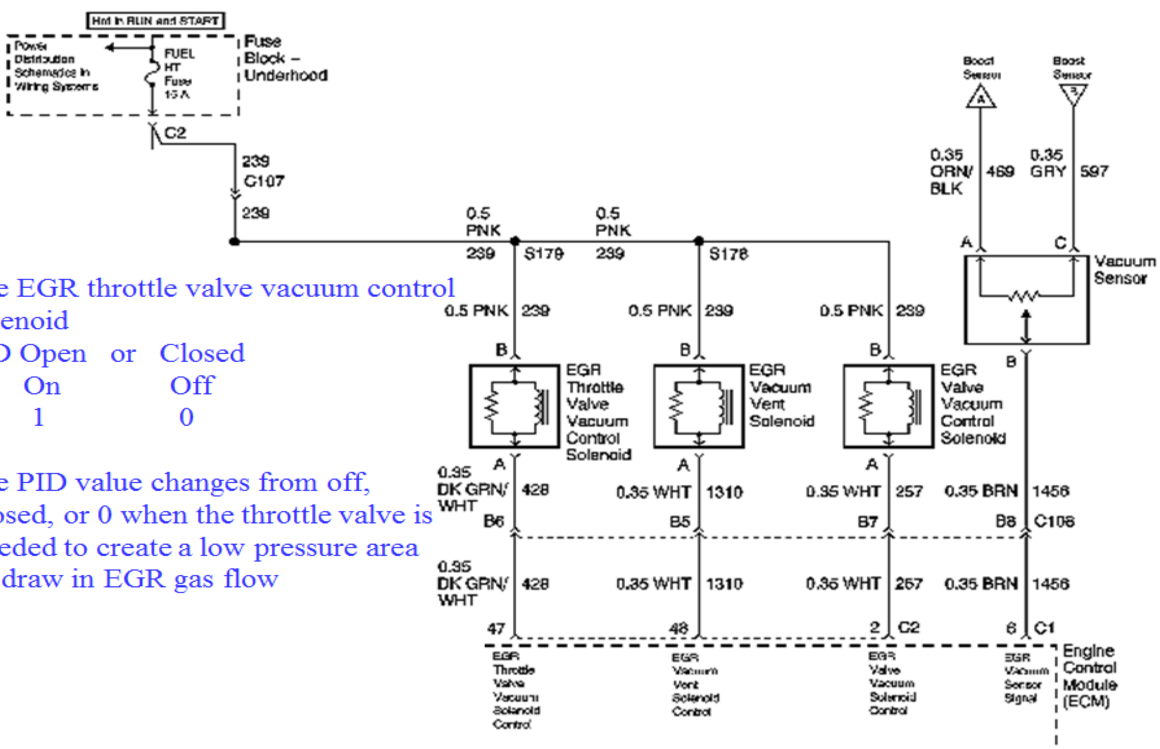
Exhaust Gas Recirculation Valve (EGR)

EGR control solenoid (PWM)
PID in % of open

A vent solenoid releases vacuum
PID reports NO or YES

Vacuum Sensor (there isn't a
Sensor to determine EGR position
The PID represents vacuum
IE; (PID Value) A value of 11 psi is really:
BARO 14.7 psi
Subtract -10.6 psi

Equals 4.1 inches of vacuum



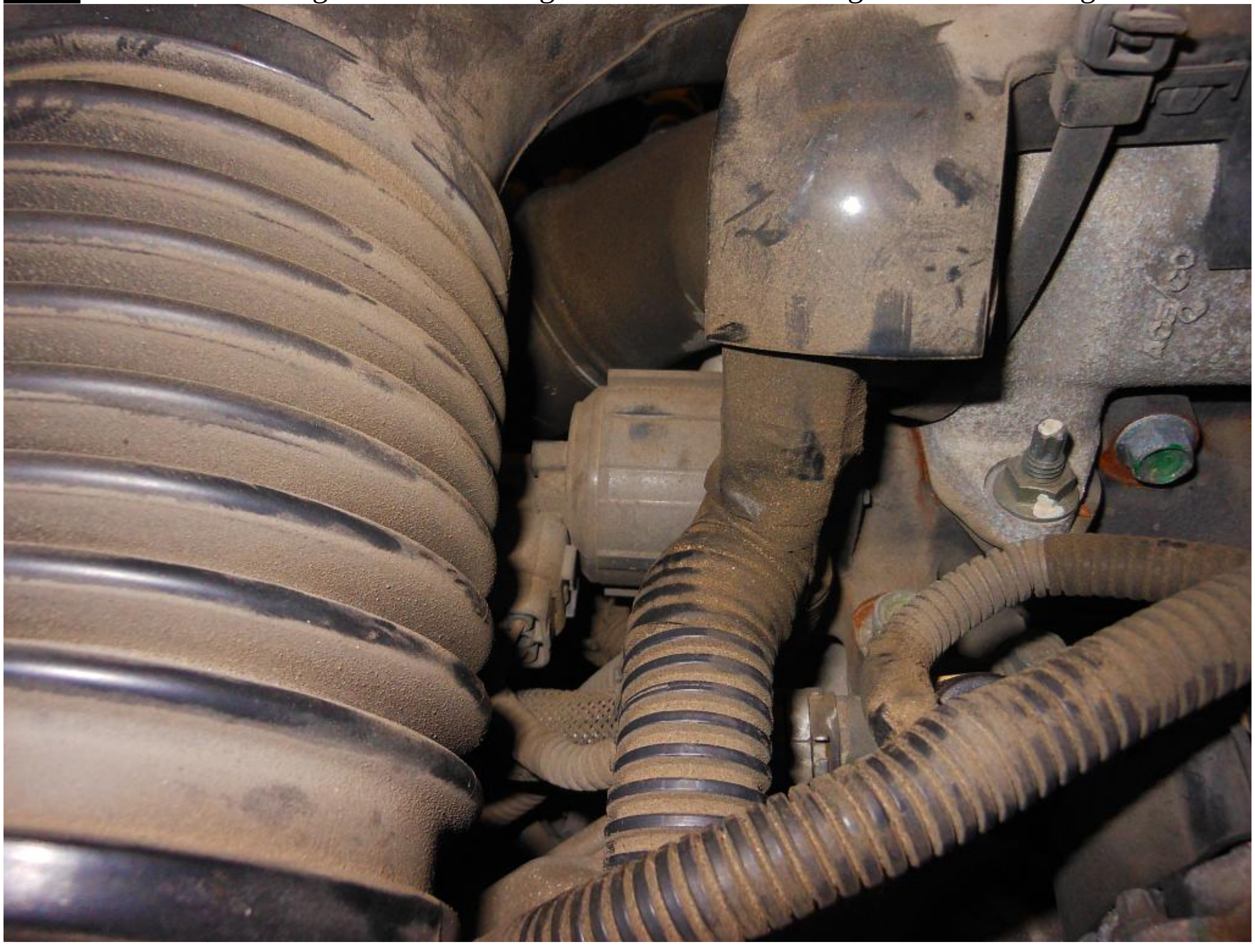
The EGR throttle valve vacuum control
Solenoid
PID Open or Closed
On Off
1 0

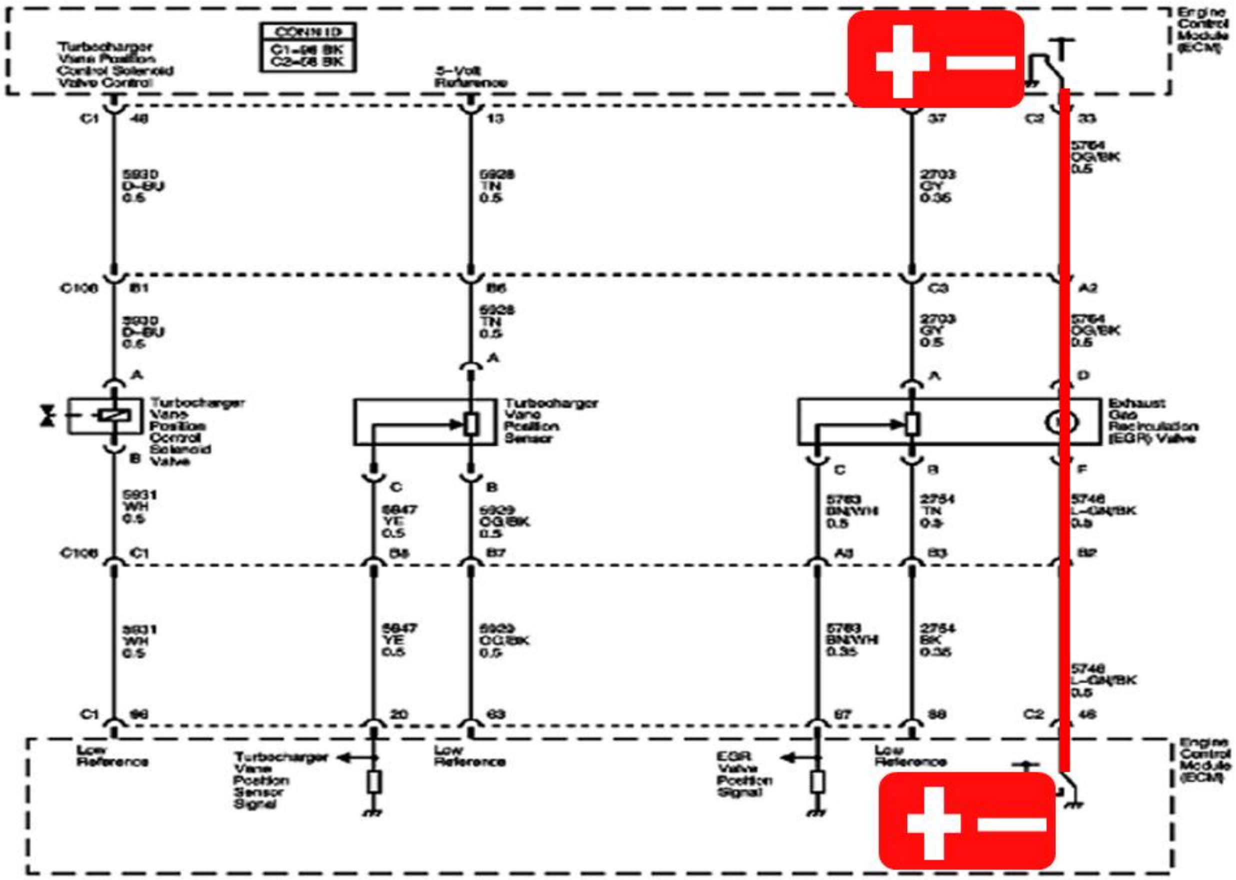
The PID value changes from off,
Closed, or 0 when the throttle valve is
Needed to create a low pressure area
To draw in EGR gas flow

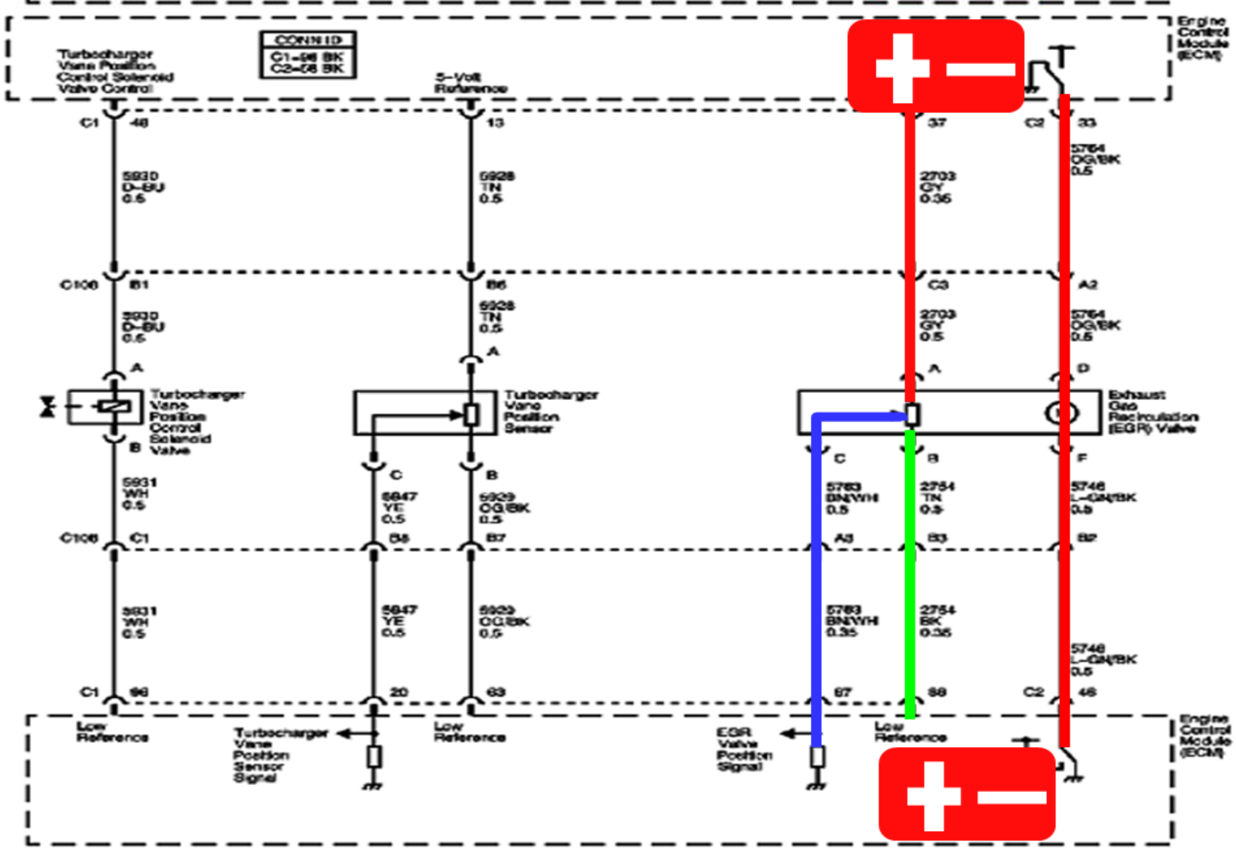
LLY/LBZ/LMM/LML EGR changes

The vacuum controlled system has been replaced with a stepper motor EGR control system. A position sensor is used for feedback control it is a potentiometer. The PCM controls the stepper motor with a PWM signal to move a screw, the screw moves in two directions. The stepper motor does in one direction opening the valve and the other direction closing it. The PCM uses the Mass Air Flow Sensor changes during EGR operation to determine if there is the correct amount of flow.

Use Bi-directional controls to command EGR control (Increase or Decrease). Watch the **EGR VAC** PID that increasing shows increasing vacuum and decreasing shows decreasing vacuum.



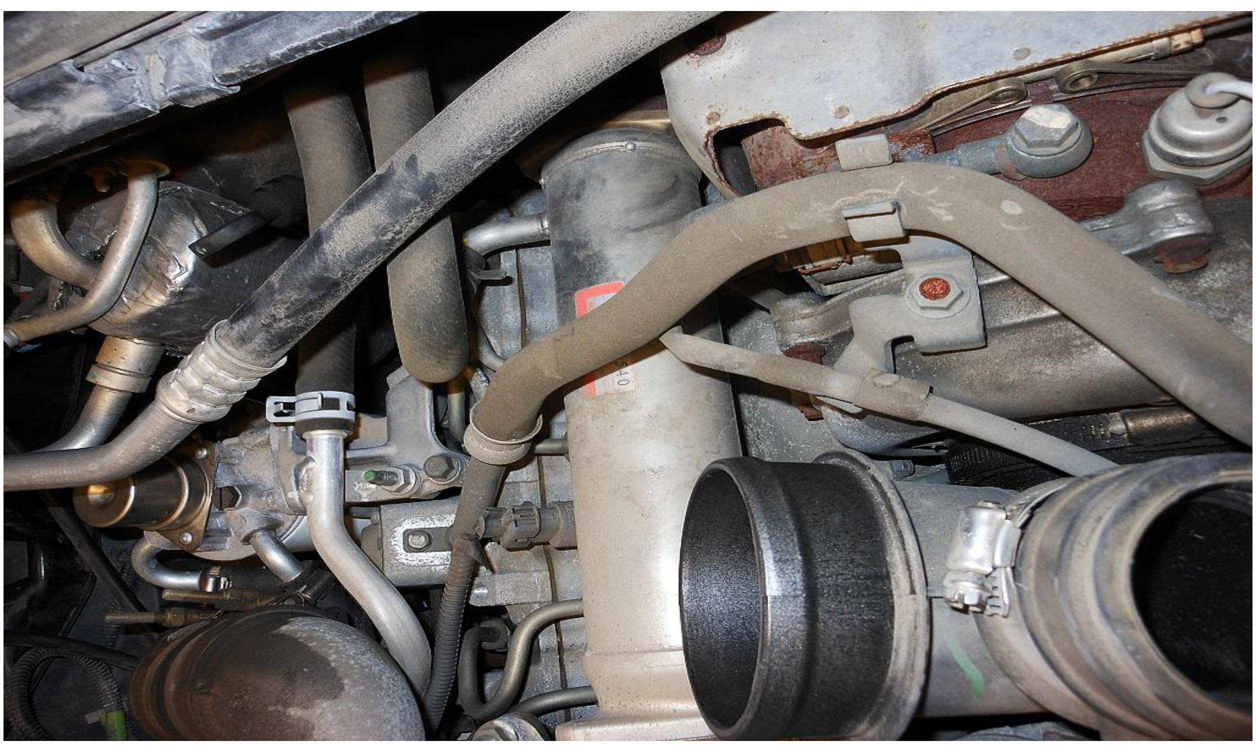

Engine Control Module (ECM)
Turbocharger Vane Position Control Solenoid Valve Control
CONN ID
5-Volt Reference
Turbocharger Vane Position Control Solenoid Valve
Turbocharger Vane Position Sensor
Exhaust Gas Recirculation (EGR) Valve
Low Reference
Turbocharger Vane Position Sensor Signal
EGR Valve Position Signal


Engine Control Module (ECM)
Turbocharger Vane Position Control Solenoid Valve Control
CONN ID
5-Volt Reference
Turbocharger Vane Position Control Solenoid Valve
Turbocharger Vane Position Sensor
Exhaust Gas Recirculation (EGR) Valve
Low Reference
Turbocharger Vane Position Sensor Signal
EGR Valve Position Signal

Digital EGR Valve

The PCM controls the stepper motor with a PWM signal to move a screw .
The screw moves in two directions.
One direction opening the valve and

the other direction closing it.
Leaky EGR Cooler
Cooler have been known to leak coolant into the intake
Symptoms are:



White smoke (Steam)
Low coolant level

Diesel Particulate Filter (DPF filter)

The LLM engine is the first to use a Diesel Particulate Filter (DPF filter). It captures soot in the exhaust stream before it can enter the atmosphere.

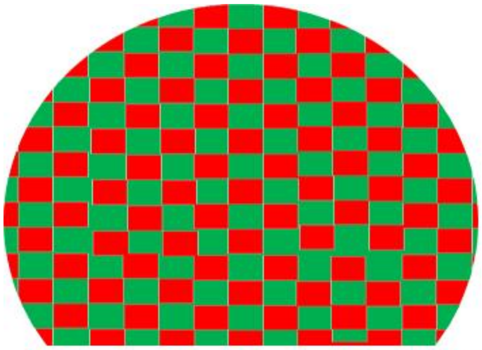
The use of Ultra Low Sulfur fuel decreases the soot content allowing the DPF to do its job efficiently.

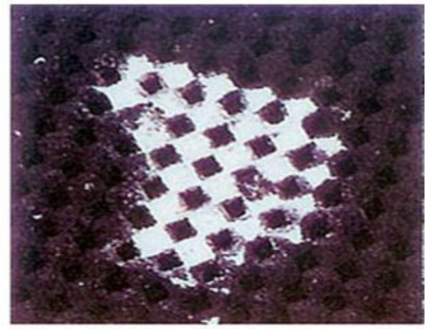
Carbon from incomplete combustion is a component of the particulate matter. There will be incomplete combustion because there is either more fuel to oxygen; too rich a mixture, or more oxygen to fuel; too lean a mixture. To get the mix precisely correct may be theoretically possible but would lead to a very expensive, complex engine management system as the air being introduced for each firing of each cylinder would have to be analyzed for it's number of oxygen molecules and the number of molecules of petrol matched. Air is more dense in colder weather, leading to more oxygen introduced to the cylinder and fuel is not going to be precisely measured either. The aim of engine designers is to get a close as he can which will result in an efficient as possible engine.

Soluble Organic Fraction (SOL): The organic fraction of diesel particulates, including heavy hydrocarbons from both the fuel and engine lubricating oil. The term soluble" originates from the analytical method used to measure SOF which is based on extraction of particulate matter samples using organic solvents. The SOL is often referred to as the "wet" fraction of PM.

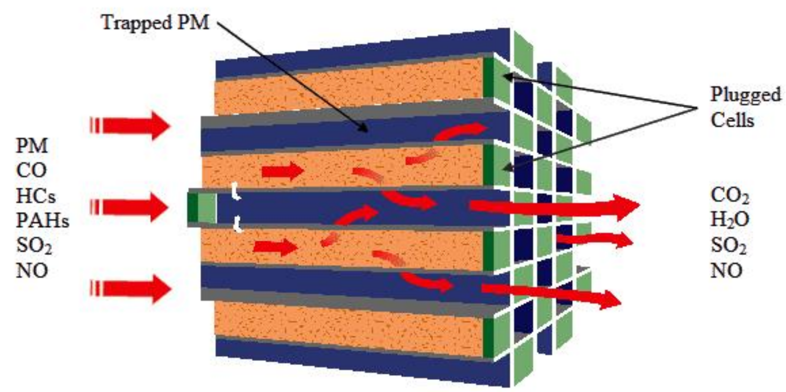
Sulfates formed from the sulfur in the fuel. Sulfur is a naturally occurring component of crude oil and is found in diesel fuel. When those fuels are burned, sulfur is emitted as sulfur dioxide (SO_2) or sulfate particulate matter. Any reduction in fuel sulfur immediately reduces these sulfur compounds and, as sulfur levels decline past a certain point, the benefits increase to include total pollutant emissions.

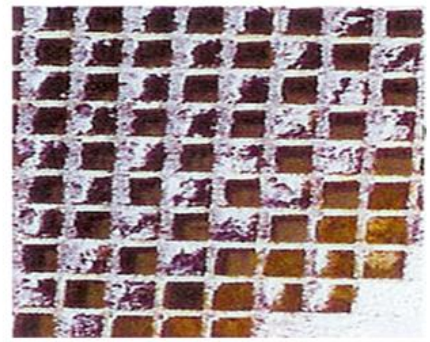
The core is similar to a full flow catalytic converter honeycomb design with half of the channels blocked at the inlet and the other half blocked at the outlet forcing the exhaust gasses to flow though the walls between the channels. As the exhaust gasses flow though the walls, the particulate matter is trapped where it remains until it is burned off during regeneration. After regeneration, the resulting minute amount of ash remains where over time it too will build up and require removal. Ash removal can only be done manually which requires removal of the DPF to be cleaned in a reverse flow machine designed to remove ash and collect it for proper disposal. The substrate cores of both catalytic converters and particulate filters are similar in composition and construction.

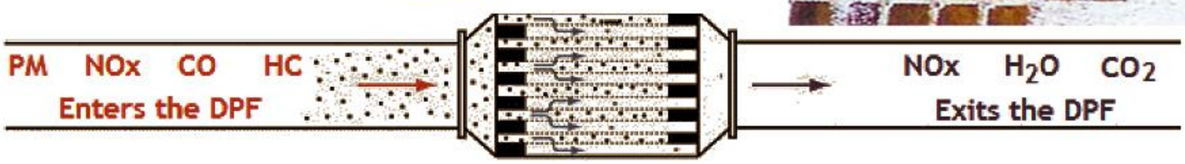


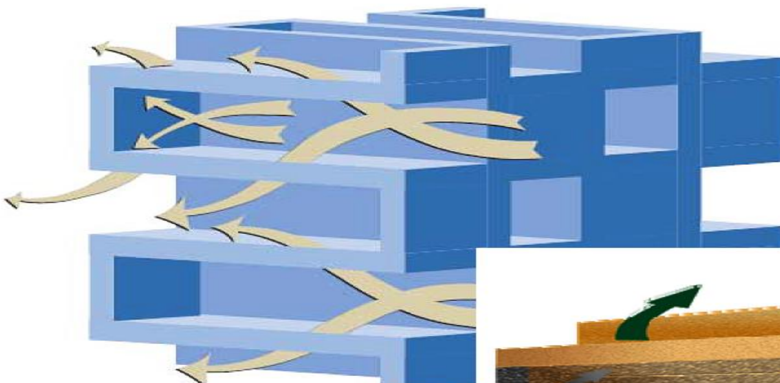


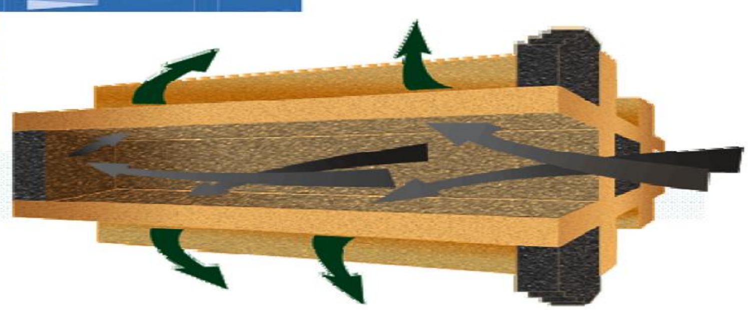
Diesel Particulate Filter

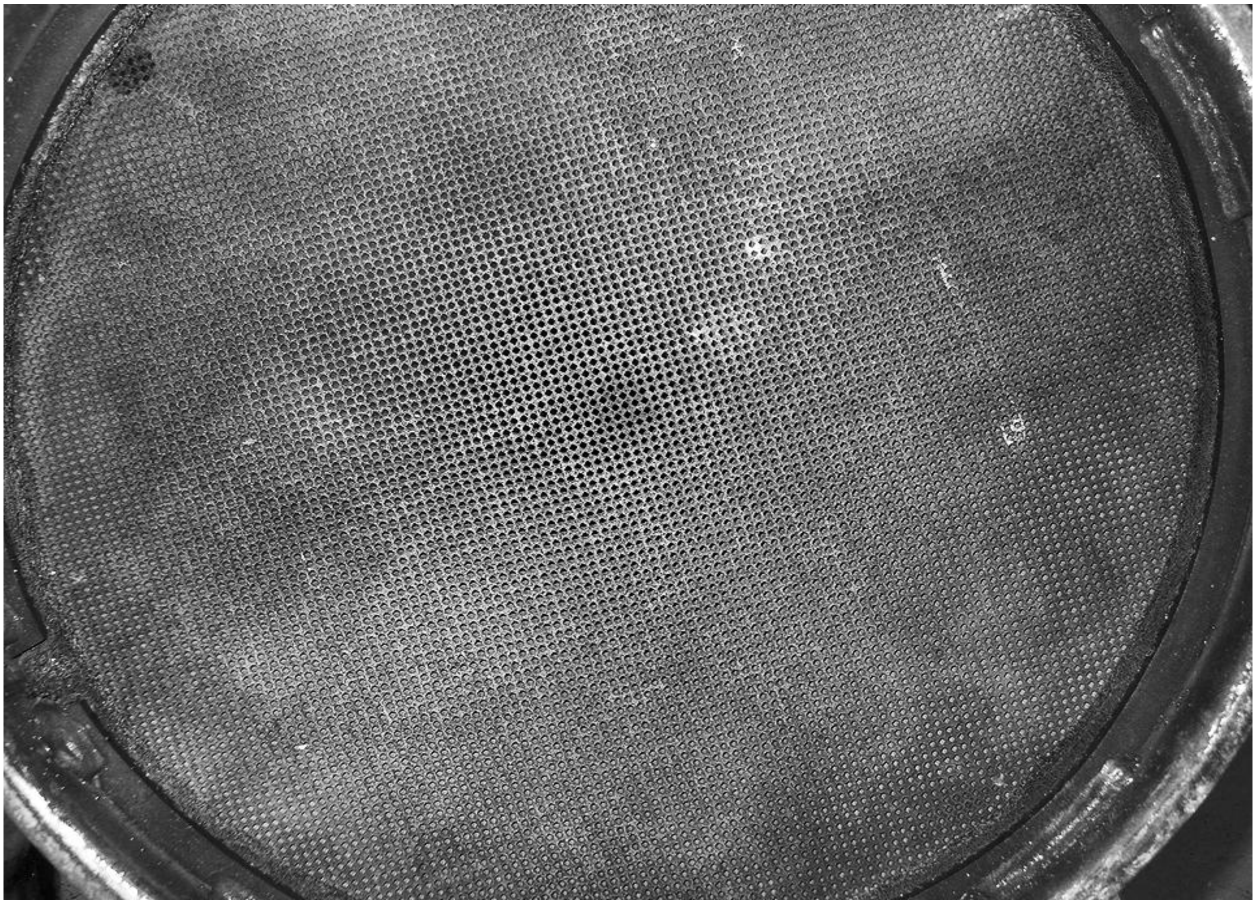










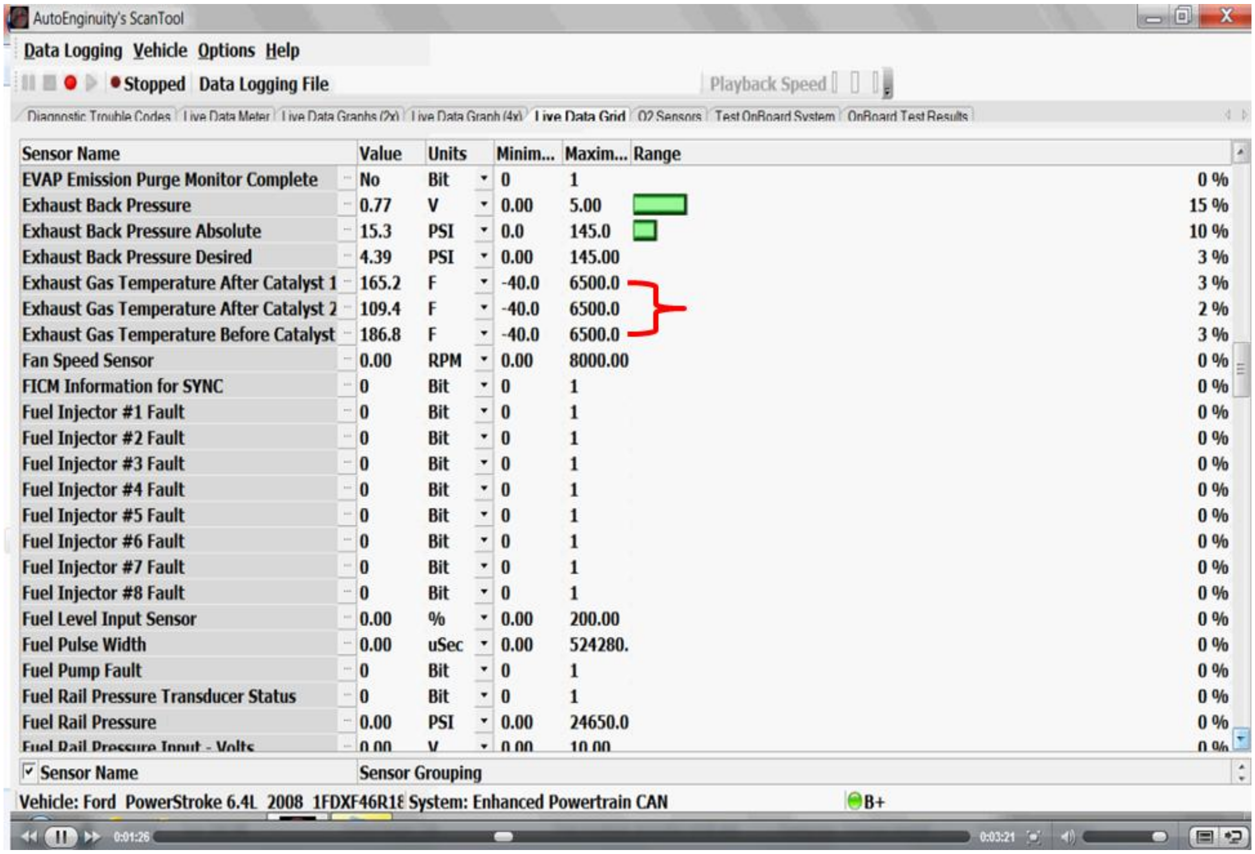


Professional Cleaners Available

OTC 5280	Donaldson DPF Pulse Cleaner	FSX TrapBlaster 7
$20,750 List	Not provided. Estimated street price of $15K. When sold with Thermal Regenerator – $25K	$44,800 plus cost of air dryer and dust collector

The default for the Exhaust gas sensors is 140° F. (P040D)
If the PCM sees an over temperature condition on the sensors (Over 1700° F) it will De-Rate the engine’s power output, and possible shut it down, and keep it from cranking for one hour. That tells the technician that if he is diagnosing a “No Crank” problem to look at the exhaust gas

temperature sensors. The information system may alert the driver with a message to “Please pull to the side of the road immediately”.
There is another condition that Ford’s hotline reports. If an injector is stuck open the engine will not crank.



Sensor Name	Value	Units	Minim...	Maxim...	Range
EVAP Emission Purge Monitor Complete	No	Bit	0	1	0 %
Exhaust Back Pressure	0.77	V	0.00	5.00	15 %
Exhaust Back Pressure Absolute	15.3	PSI	0.0	145.0	10 %
Exhaust Back Pressure Desired	4.39	PSI	0.00	145.00	3 %
Exhaust Gas Temperature After Catalyst 1	165.2	F	-40.0	6500.0	3 %
Exhaust Gas Temperature After Catalyst 2	109.4	F	-40.0	6500.0	2 %
Exhaust Gas Temperature Before Catalyst	186.8	F	-40.0	6500.0	3 %
Fan Speed Sensor	0.00	RPM	0.00	8000.00	0 %
FICM Information for SYNC	0	Bit	0	1	0 %
Fuel Injector #1 Fault	0	Bit	0	1	0 %
Fuel Injector #2 Fault	0	Bit	0	1	0 %
Fuel Injector #3 Fault	0	Bit	0	1	0 %
Fuel Injector #4 Fault	0	Bit	0	1	0 %
Fuel Injector #5 Fault	0	Bit	0	1	0 %
Fuel Injector #6 Fault	0	Bit	0	1	0 %
Fuel Injector #7 Fault	0	Bit	0	1	0 %
Fuel Injector #8 Fault	0	Bit	0	1	0 %
Fuel Level Input Sensor	0.00	%	0.00	200.00	0 %
Fuel Pulse Width	0.00	uSec	0.00	524280.	0 %
Fuel Pump Fault	0	Bit	0	1	0 %
Fuel Rail Pressure Transducer Status	0	Bit	0	1	0 %
Fuel Rail Pressure	0.00	PSI	0.00	24650.0	0 %
Fuel Rail Pressure Input - Volts	0.00	V	0.00	10.00	0 %

Engine Power De-Rate Mode

If the PCM sees an over temperature condition on the sensors (Over 1700° F) it will De-Rate the engine’s power output, and possible shut it down, and keep it from cranking for one hour
Also:

EGT sensors Open circuits
Low Fuel Pressure
Engine Oil Temperature over 275° F

DPF Regeneration

The problem associated with DPF's is that over time, soot collecting in the DPF can clog it, resulting in decreased performance and fuel efficiency. The PCM must detect a clogging filter and burn off the collected soot. To reduce DPF clogging an exhaust Aftertreatment known as regeneration is used. Sensors tell the PCM when excessive particulate matter has built up in the DPF, and the regeneration mode is triggered. During regeneration, the engine idle is increased to help heat the DPF, and diesel fuel is injected during the exhaust stroke (cylinders 5 and 7) allowing fuel to enter the exhaust system and burn in the DPF. The combustion of diesel fuel in the DPF generates the heat necessary to burn off soot cleaning it. The frequency and length of regeneration will fluctuate as both are determined by driving conditions. For most drive

conditions, regeneration frequency will vary from 100 - 600 miles between regenerations and last from 10 to 40 minutes.
To reduce DPF clogging an exhaust aftertreatment known as active regeneration is used.
Pressure sensors tell the PCM when excessive particulate matter has built up in the DPF, and active regeneration mode is triggered.
During regeneration, the engine idle is increased to help heat the DPF, and diesel fuel is injected during the exhaust stroke, allowing fuel to enter the exhaust system and burn in the DPF (The two back cylinders)
The diesel fuel in the DPF generates the heat necessary to burn off soot.
There is a lot of fuel flowing during regeneration, if there isn't enough heat raw fuel by-passes (Blow-By) the piston rings and dilutes the engine oil. It is very important to change the oil on schedule or suffer engine damage. The regeneration process pushes extreme temperatures (1200° F) through the turbocharger causing the seals to fail earlier than they should.
If the system is in active regeneration during a deceleration the driver may hear a light popping through the intake (sort of like a sticking turbo).

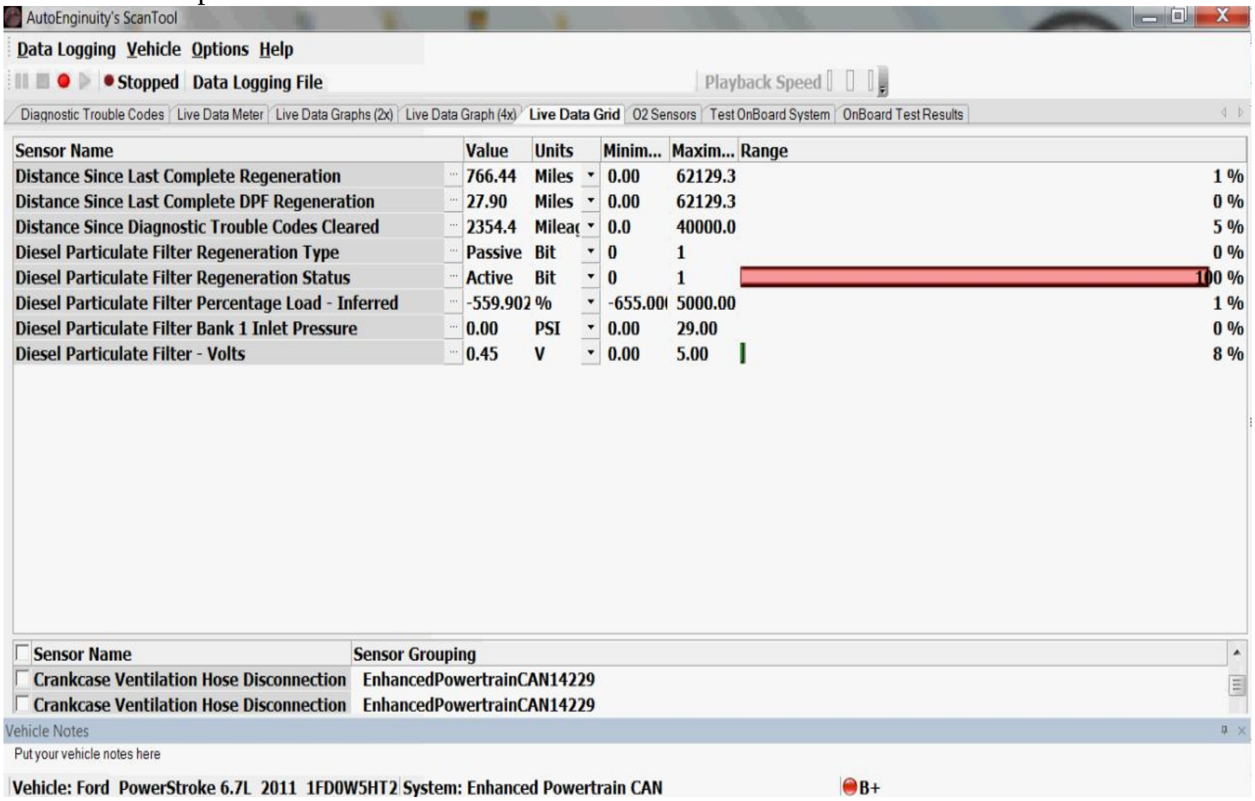
Passive Regeneration

Passive Regeneration begins when the exhaust gas temperature reaches somewhere over 500°F), which can be achieved under medium to heavy load conditions (Running the truck hard keeps it clean)
The system will regenerate on its own if enough heat has been generated normally.
If there isn't enough heat, the system enters active regeneration .
The ECM cycles the fuel injectors post combustion.

Operation during regeneration

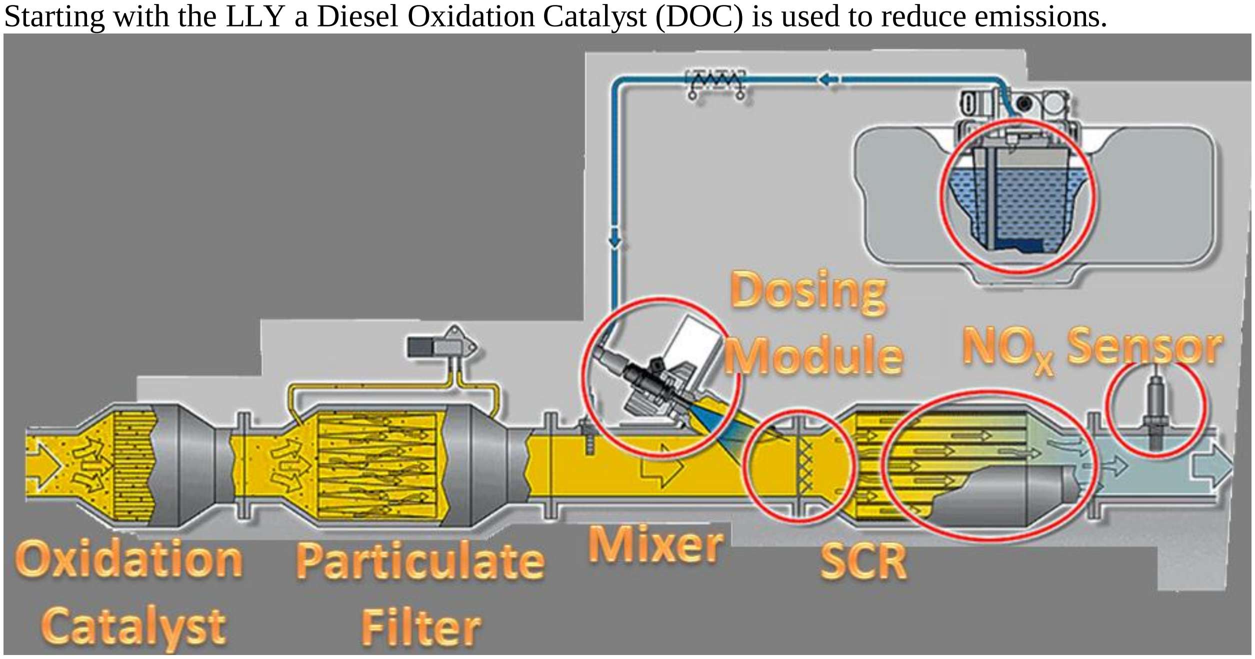
During regeneration engine idle speed may be between 1100 to 1200 RPM in park/neutral with foot off brake.
High idle speed drops to within 50 RPM of normal idle when the brake pedal is touched, PRNDL is actuated, or clutch is actuated
White smoke in cold ambient temperatures is normal .
Powertrain power is limited to 325 horsepower (HP).
Engine responsiveness may be slightly different than normal operation.
During initiation of regeneration, exhaust smell may be noticed - especially on new vehicles.
Powertrain sound will be different including air induction noise (including flutter on deceleration or engine shut down), exhaust noise, and changes in engine radiated noise.
During regeneration, exhaust temperatures are elevated.

If Regeneration occurs at idle the PCM may activate the EGR throttle plate to restrict oxygen to control the temperature.



LMM Emission Controls

Starting with the LLY a Diesel Oxidation Catalyst (DOC) is used to reduce emissions.



Diesel Oxidation Catalysts (DOC)

A Diesel Oxidation Catalyst (DOC) is a device which utilizes a chemical process in order to break down pollutants from diesel engines in the exhaust stream, turning them into less harmful components. They are normally a honeycomb shaped configuration coated in a catalyst designed to trigger a chemical reaction to reduce particulate matter. They use a chemical process to break down pollutants in the exhaust stream turning them into less harmful components. They are normally a monolith honeycomb shaped configuration substrate coated with platinum group metal catalyst designed to trigger a chemical reaction to reduce particulate matter. Oxidation catalysts work by oxidizing CO, HC and the soluble organic fraction of the PM to CO_2 and

H_2O in the oxygen rich exhaust stream of the diesel engine. Diesel exhaust contains sufficient amounts of oxygen, necessary reactions. The concentration of O_2 in the exhaust gases from diesel engine varies between 3 and 17%, depending on the engine load. Conversion of diesel particulate matter is an important function of the diesel oxidation catalyst. The catalyst is very activity in the oxidation of the organic fraction (SOF) of diesel particulates. Conversion of SOF may reach and exceed 80%. The remaining PM will be trapped in the PM filter. The DOC has limited abilities to reduce nitrogen oxides in diesel exhaust. NO_x conversions of 10-20% are usually observed.

Carbon from incomplete combustion is a component of the particulate matter.

There will be incomplete combustion because there is either more fuel to oxygen; too rich a mixture, or more oxygen to fuel; too lean a mixture. To get the mix precisely correct may be theoretically possible but would lead to a very expensive, complex engine management system as the air being introduced for each firing of each cylinder would have to be analyzed for it's number of oxygen molecules and the number of molecules of petrol matched. Air is more dense in colder weather, leading to more oxygen introduced to the cylinder and fuel is not going to be precisely measured either. The aim of engine designers is to get a close as he can which will result in an efficient as possible engine.

Soluble Organic Fraction (SOL):

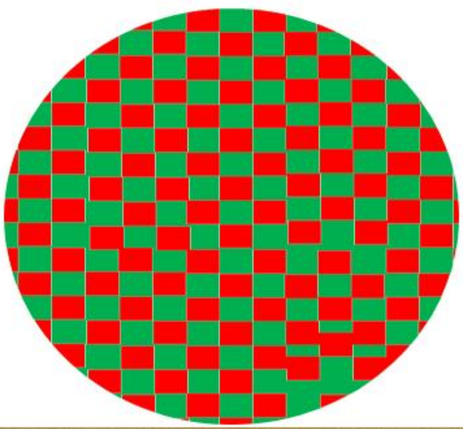
The organic fraction of diesel particulates, including heavy hydrocarbons from both the fuel and engine lubricating oil. The term soluble" originates from the analytical method used to measure SOF which is based on extraction of particulate matter samples using organic solvents. The SOL is often referred to as the "wet" fraction of PM.

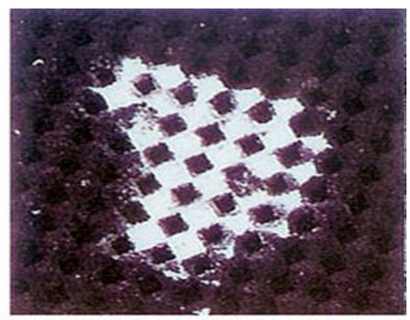
Sulfates formed from the sulfur in the fuel.

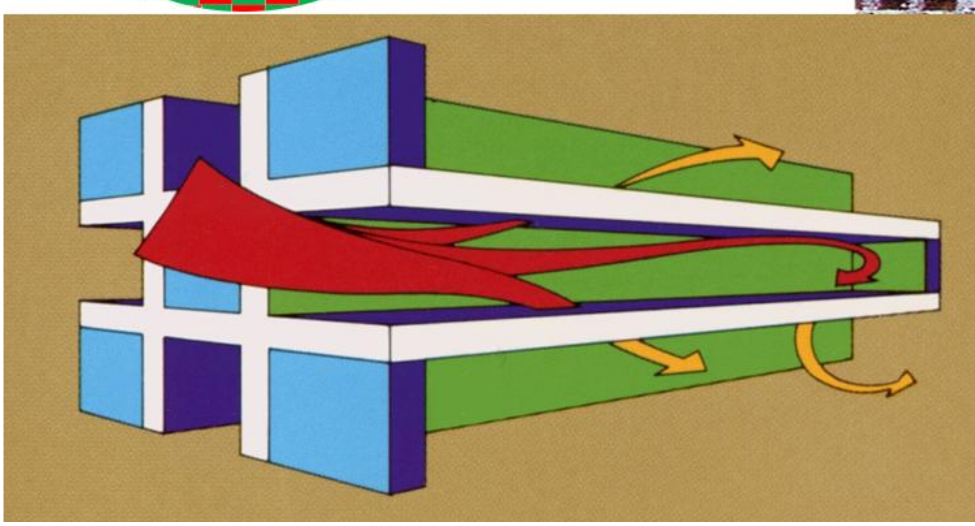
Sulfur is a naturally occurring component of crude oil and is found in diesel fuel. When those fuels are burned, sulfur is emitted as sulfur dioxide (SO2) or sulfate particulate matter. Any reduction in fuel sulfur immediately reduces these sulfur compounds and, as sulfur levels decline past a certain point, the benefits increase to include total pollutant emissions.

Diesel Particulate Filter

This core is similar to a full flow catalytic converter honeycomb design with half of the channels blocked at the inlet and the other half blocked at the outlet forcing the exhaust gasses to flow though the walls between the channels. As the exhaust gasses flow though the walls, the particulate matter is trapped where it remains until it is burned off during regeneration. After regeneration, the resulting minute amount of ash remains where over time it too will build up and require removal. Ash removal can only be done manually which requires removal of the DPF to be cleaned in a reverse flow machine designed to remove ash and collect it for proper disposal. The substrate cores of both catalytic converters and particulate filters are similar in composition and construction.

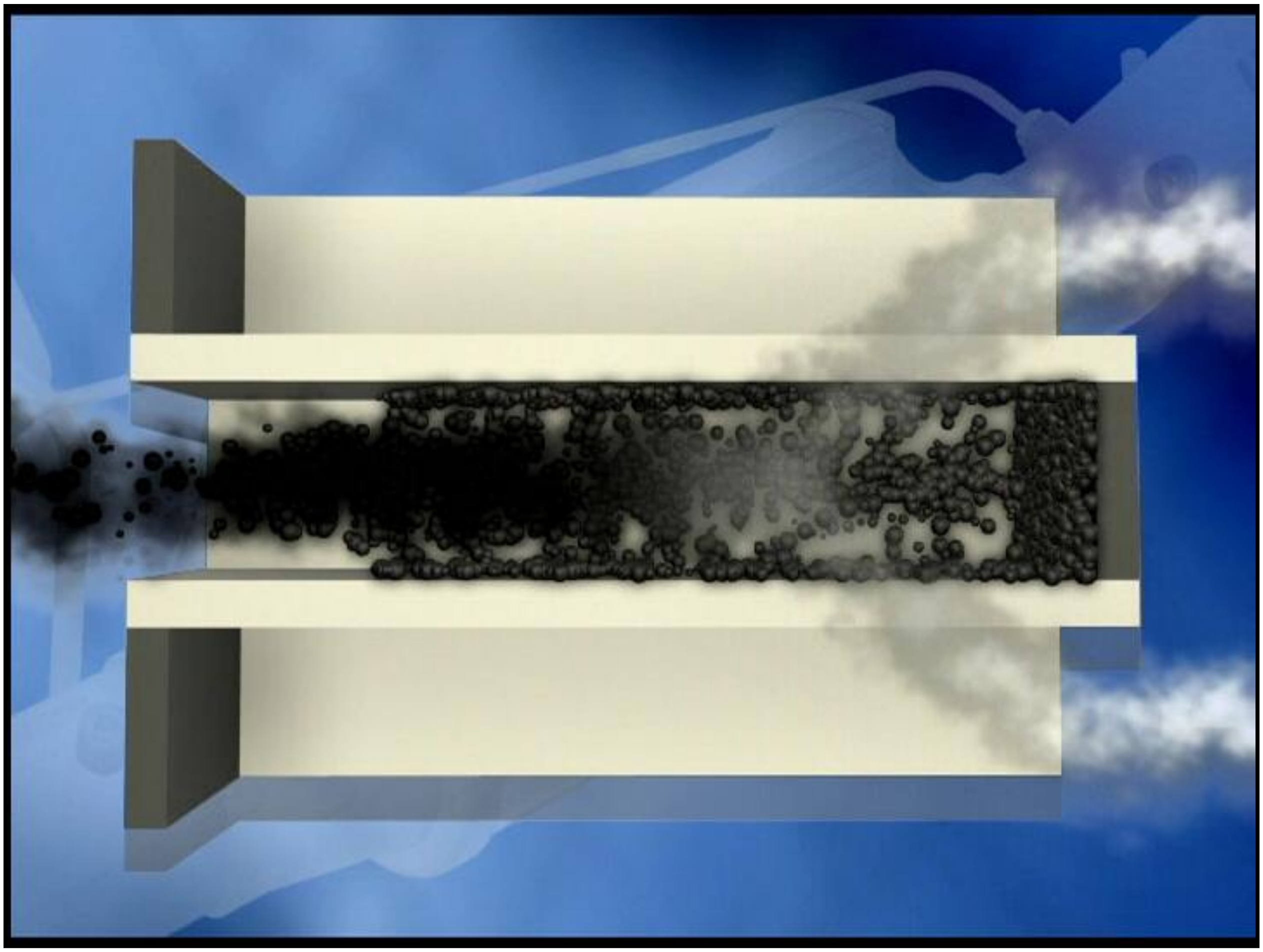






Soot Build Up

Over time the soot will build up and plug the DPF.

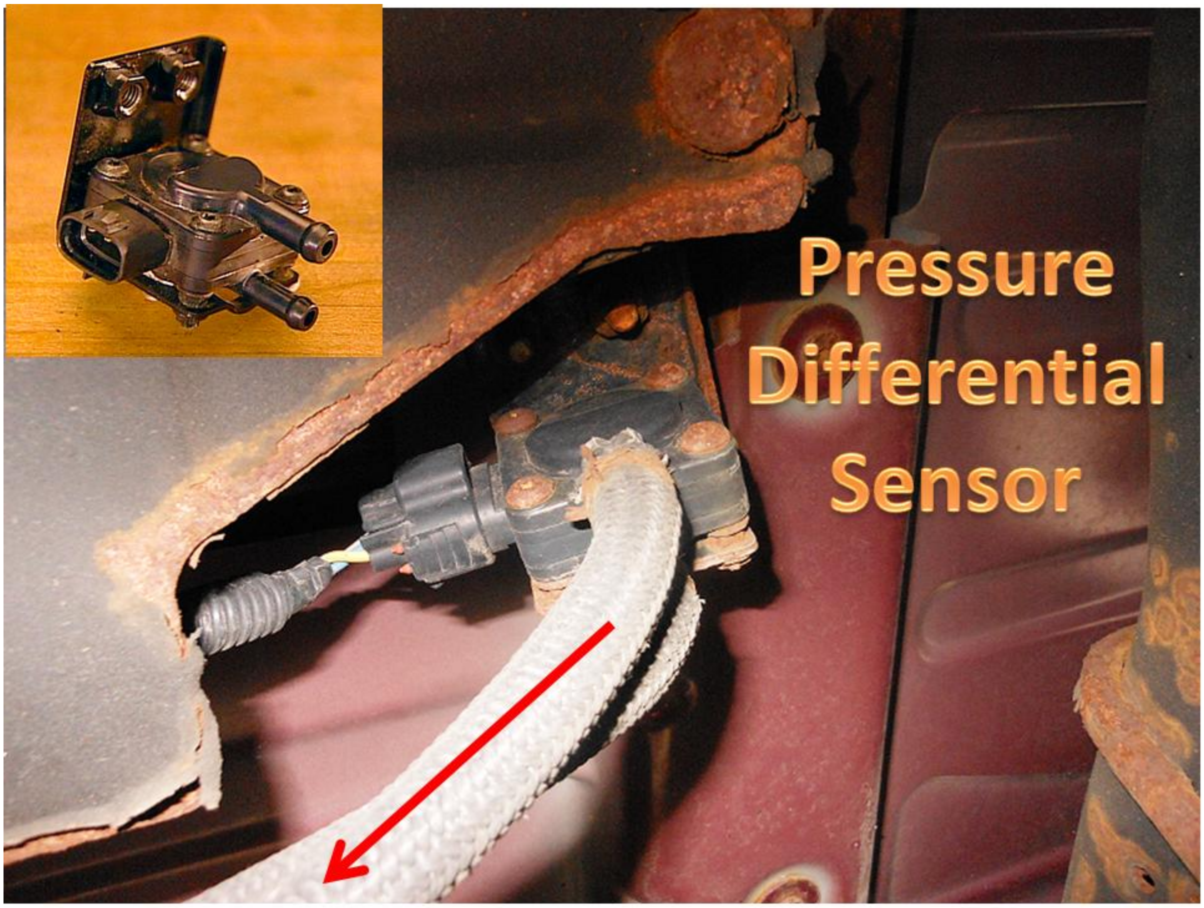


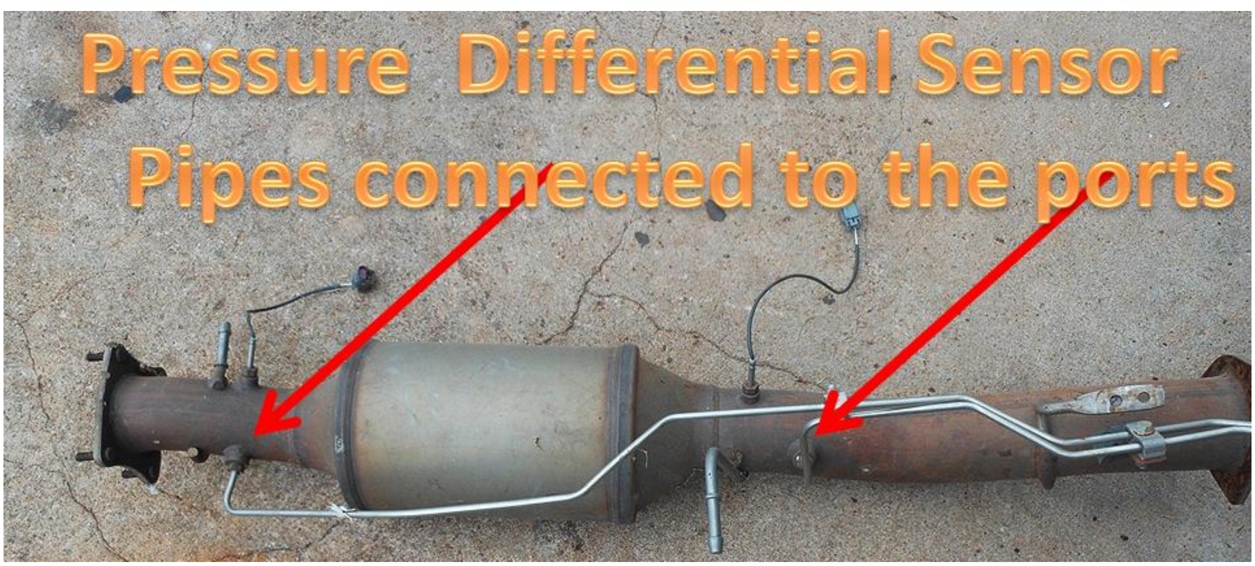
Exhaust Gas Pressure Sensors

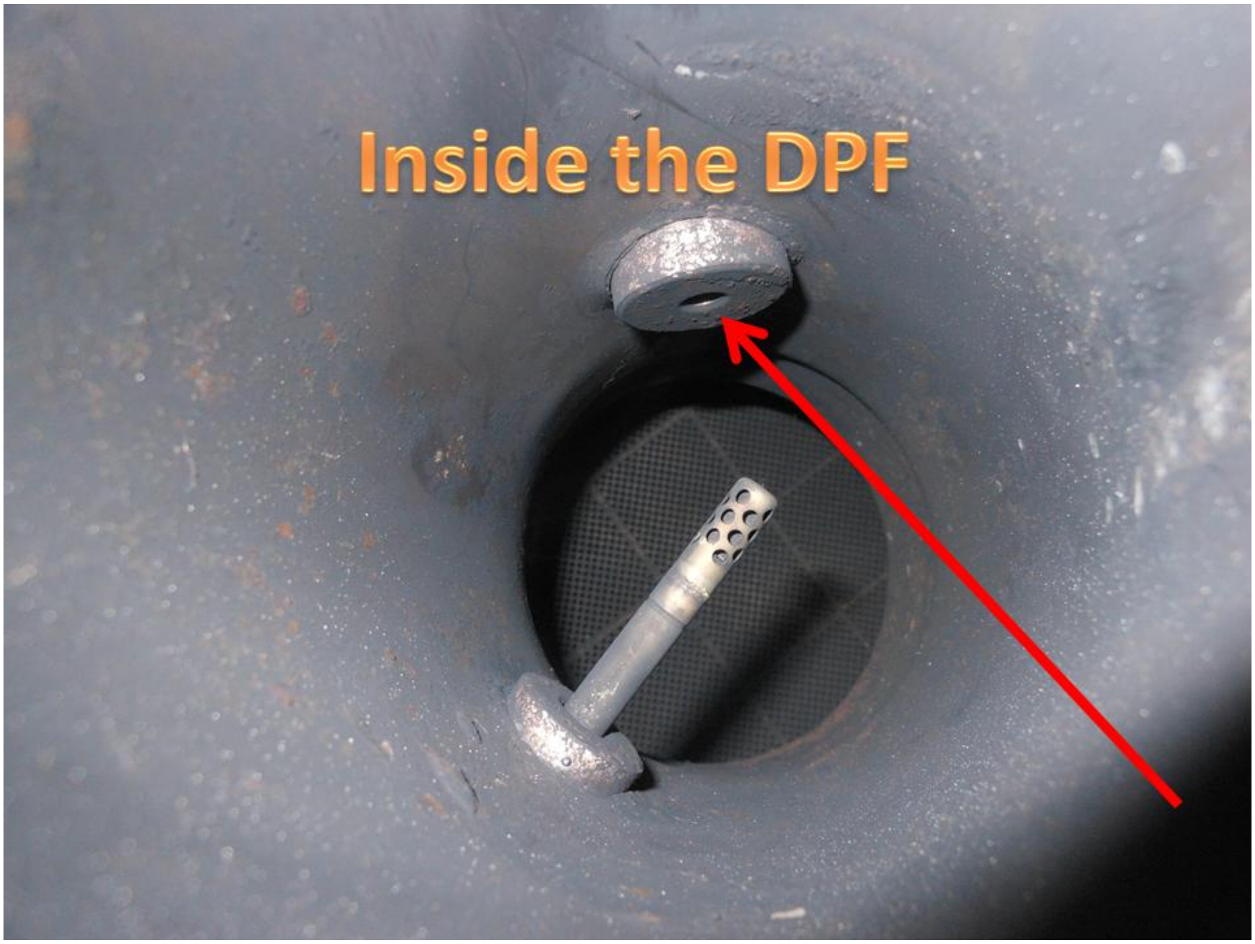
Pressure is measured in front of (inlet) and behind (outlet) the DPF
The PCM monitors the pressure from a Pressure differential Sensor. The PCM uses the values to determine when too much soot has built up in the DPF. The pressure sensor measures the pressure difference between the inlet and outlet of the DPF. The PCM determines that the DPF is restricted if the pressure difference increases above the normal threshold. The PCM uses the information to know when to command regeneration.

Pressure differential Sensor

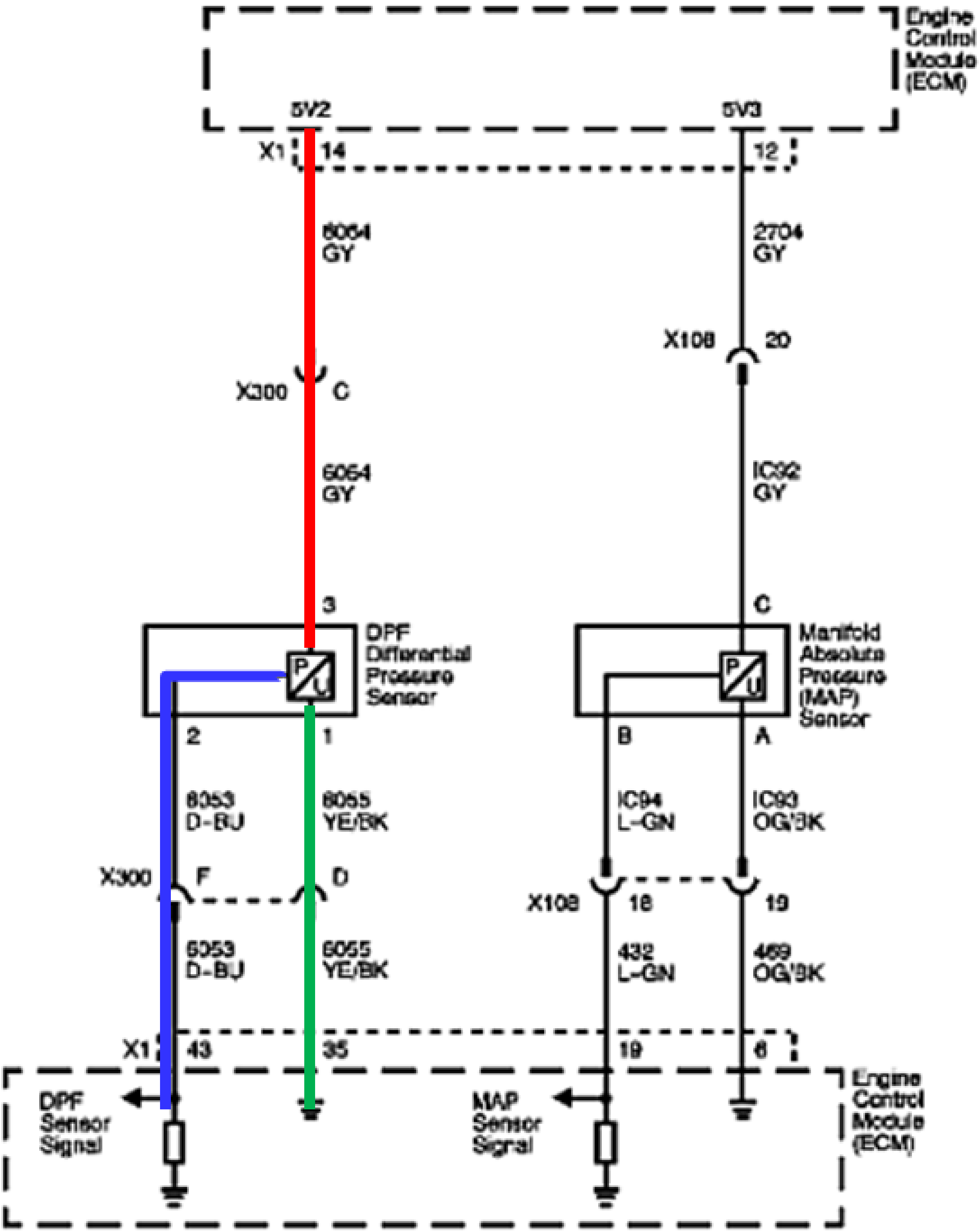
- Measures the pressure difference between the inlet and outlet of the DPF.
- The PCM determines that the DPF is restricted if the pressure difference increases above the calibrated threshold.
- The PCM uses the information to know when to command regeneration.


Pressure
Differential
Sensor


Pressure Differential Sensor
Pipes connected to the ports



The pressure differential sensor is a three wire sensor that receives a 5 volt reference from the PCM. To complete the circuit the sensor's return is also connected to the PCM. The third circuit is the signal reporting the amount of pressure.

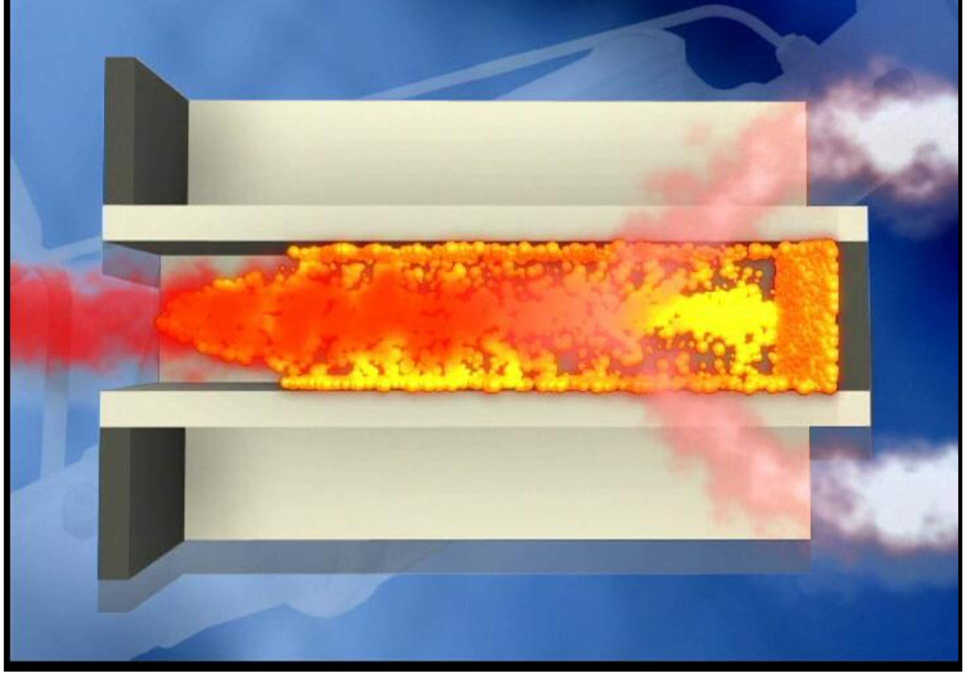


DPF Regeneration Model

GM has programmed the PCM with a predetermined maximum soot loading model. The Delta Exhaust Pressure Differential exceeded overrides all other factors;

- 325 miles
- 46 gallons of fuel consumed
- 8 hours of operation

Delta Exhaust Pressure Differential exceeded.



Regeneration typically occurs at continuous speeds over 30 mph, for 25 to 30 minutes Normal regeneration is transparent to the driver.

DPF Regeneration: Regeneration typically occurs at continuous speeds over 30 mph, for 25 to 30 minutes. Normal regeneration is transparent to the customer. Exhaust gas temperature can exceed 1000° F, and 1500° F during regeneration.

When soot build up increases past the calibrated threshold the PCM commands regeneration to burn the soot into an ash

There are 4 modes of regeneration:

1. Passive
2. Active
3. Manual
4. Forced

Passive Regeneration:

During normal operation when exhaust temperature reaches near 900° F, enough heat is created to burn off some of the soot.

Active Regeneration

When enabling conditions have been met the PCM will command additional fuel as a post injections so that it will burn in the exhaust and burn off the collected soot.

Active Regeneration Enabling Conditions:

Exhaust gas temperature less than 752° F

Engine RPM between 600 RPM and 1200 RPM

Battery voltage must be above 10 volts

Brake pedal must not be pressed

Ambient temperature must be higher than -22° F

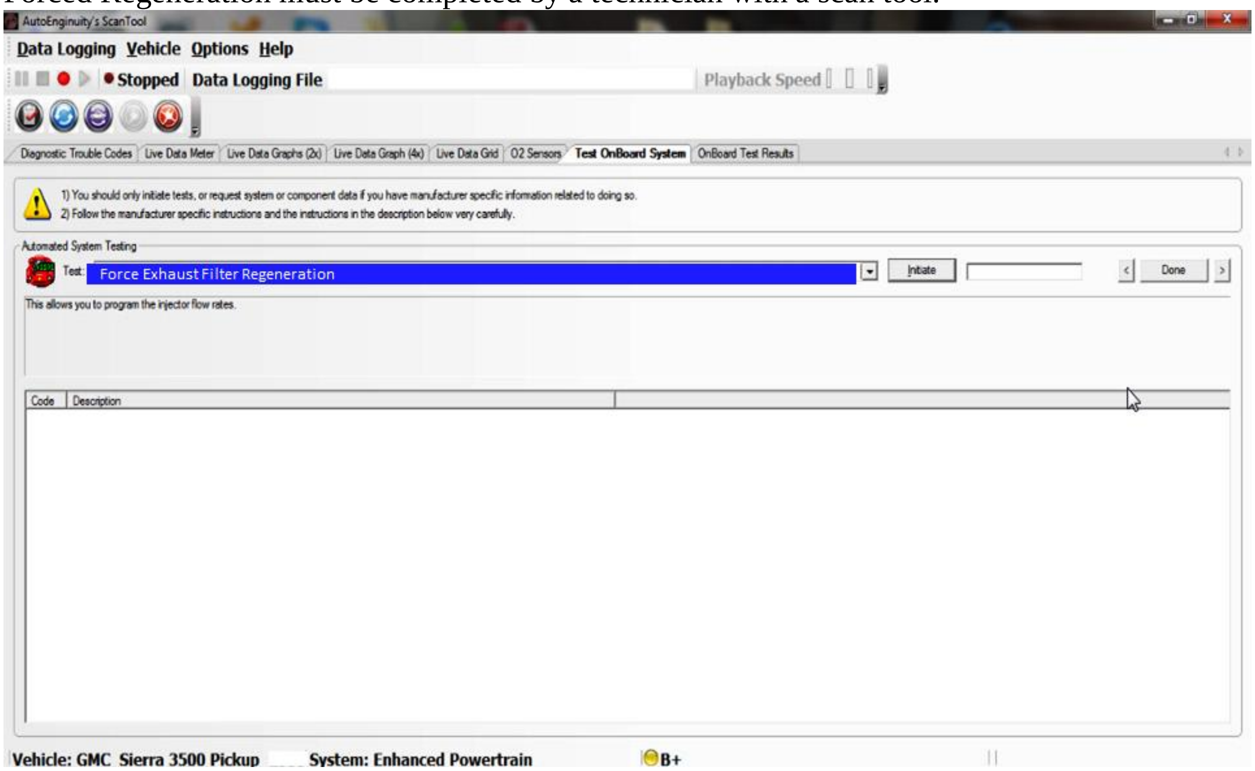
Fuel level in fuel tank must be between 15% and 85% full

Manual Regeneration

If the enabling conditions for passive and active regeneration are never met a warning will appear on the dash.

Forced Regeneration

Forced regeneration can only be done with a Scan Tool.
Access the Bi-Directional menu and activate the forced regeneration function.
Does not use the shops exhaust hoses during forced regeneration.
They may be damaged and start a fire because of the extreme temperature generated.\
If the warnings are ignored by the operator, the PCM will set a fault describing the condition.
If diagnostic Trouble Codes are set or scan data indicates accumulated soot displays 30 grams or more.
Forced Regeneration must be completed by a technician with a scan tool.



Typical Codes

P244B
Diesel Particulate Filter Differential Pressure Too High
P244C
Catalyst Temperature Too Low During Regeneration
P2453
Diesel Particulate Filter Differential Pressure Sensor Performance
P2454
Diesel Particulate Filter Differential Pressure Sensor
Circuit Low Voltage

P2455

Diesel Particulate Filter Differential Pressure Sensor
Circuit High Voltage

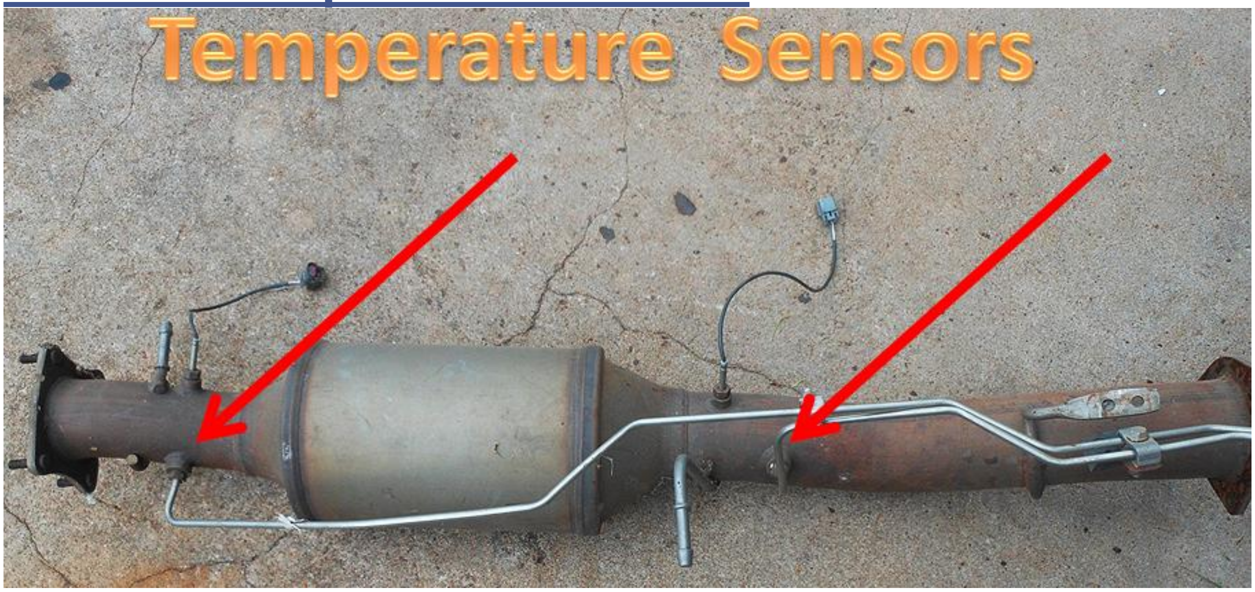
P2459

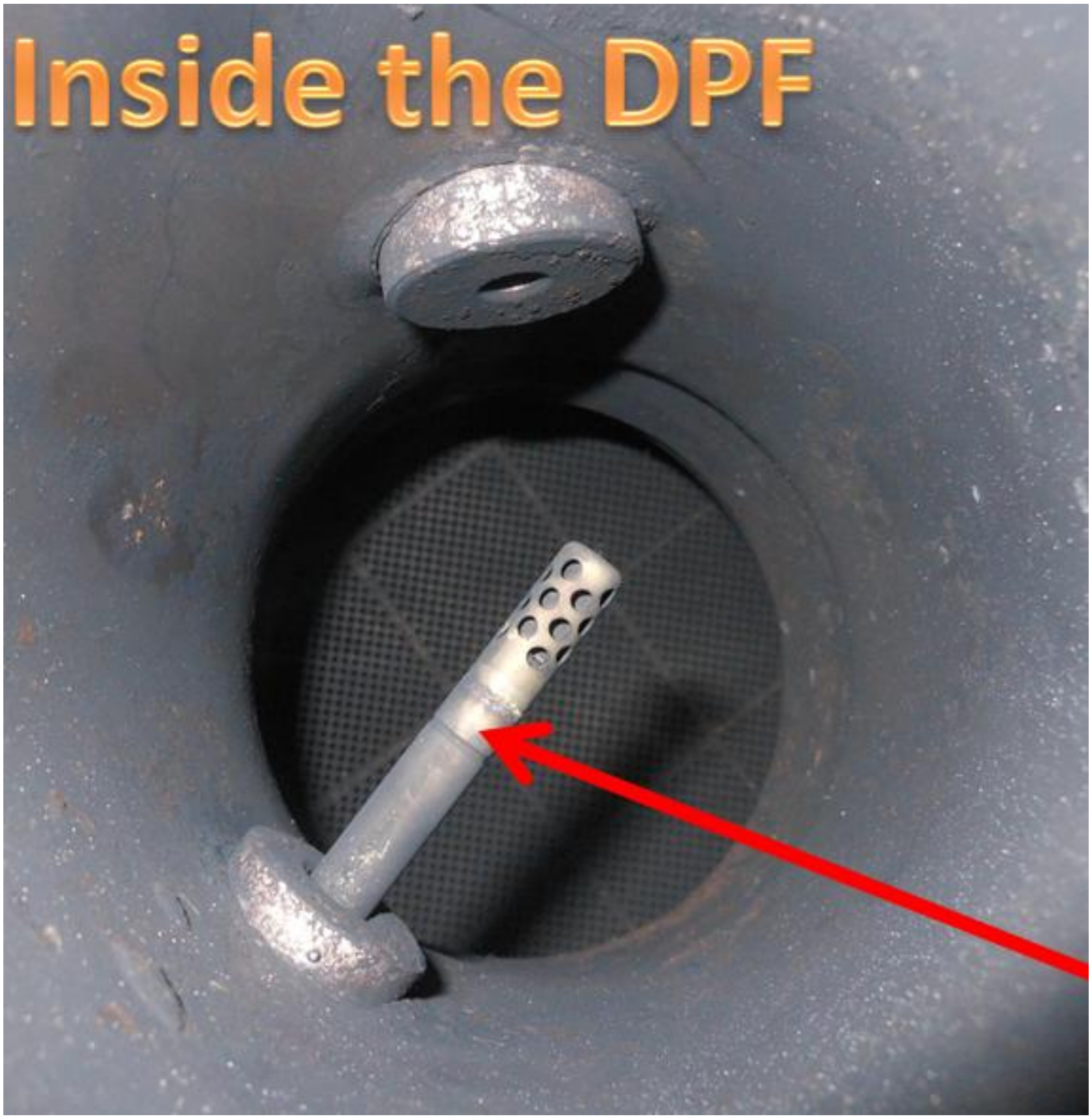
Diesel Particulate Filter Regeneration Frequency (Too High)

P2463

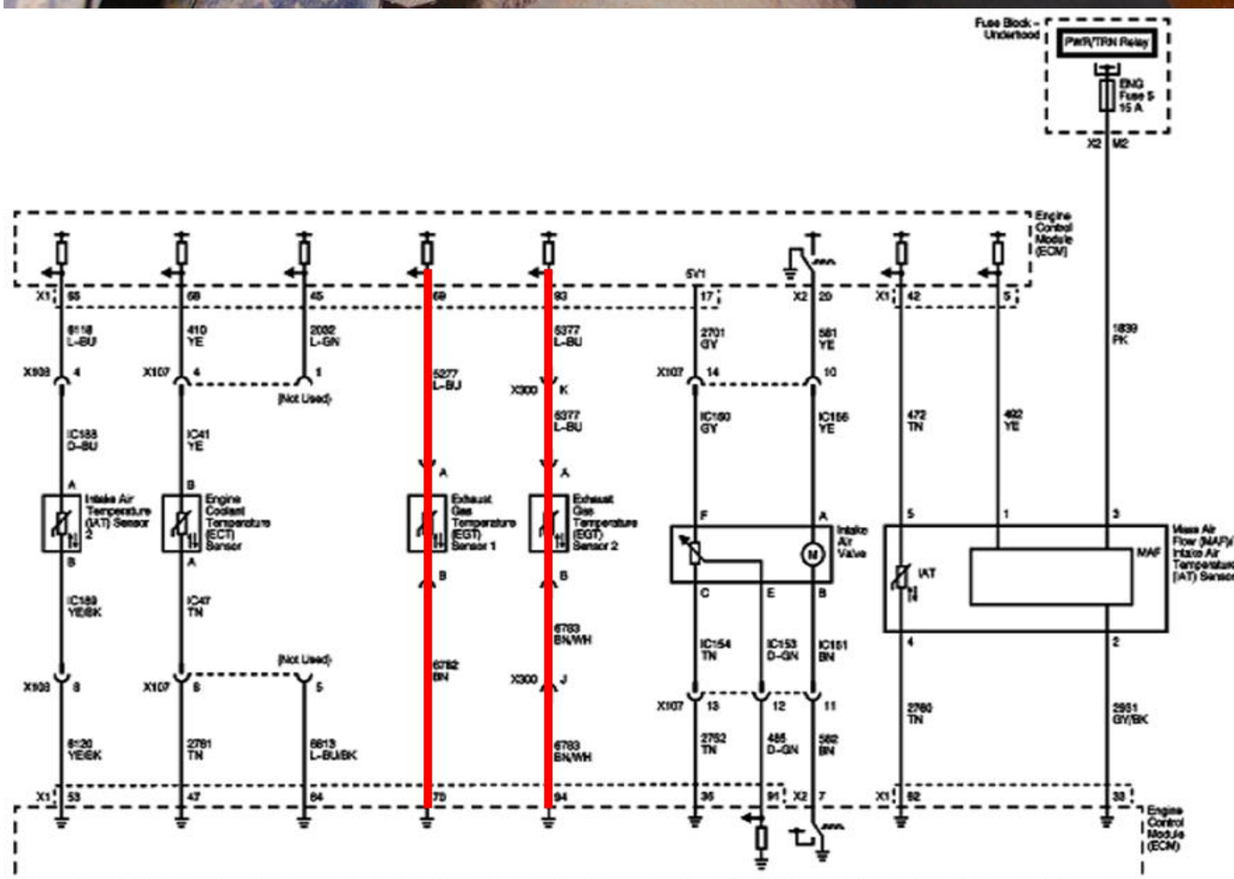
Diesel Particulate Filter - Soot Accumulation

Exhaust Temperature Sensors




Inside the DPF


Diesel Particulate Filter
Temperature Sensors
Pressure Sensors

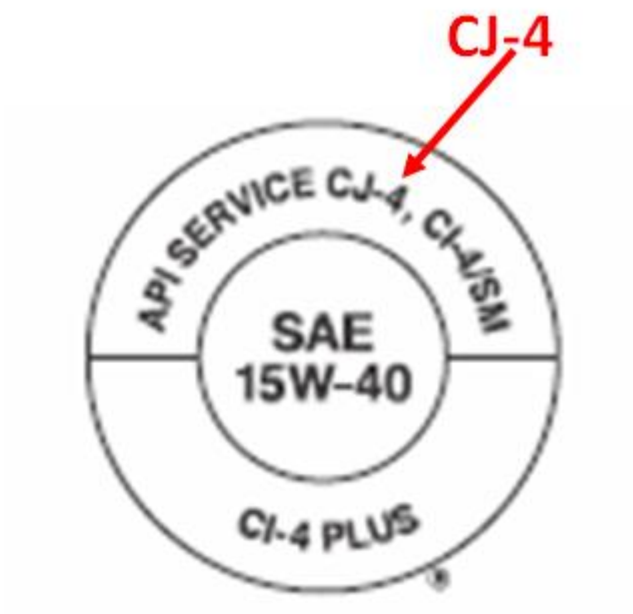

Fuse Block - Underhood
PWR/TRN Relay
Engine Control Module (ECM)
Intake Air Temperature (IAT) Sensor 2
Engine Coolant Temperature (ECT) Sensor
(Not Used)
Exhaust Gas Temperature (EGT) Sensor 1
Exhaust Gas Temperature (EGT) Sensor 2
Intake Air Valve
Mass Air Flow (MAF)/ Intake Air Temperature (IAT) Sensor
IAT
MAF

Professional Cleaners Available

OTC 5280	Donaldson DPF Pulse Cleaner	FSX TrapBlaster 7
$20,750 List	Not provided. Estimated street price of $15K. When sold with Thermal Regenerator – $25K	$44,800 plus cost of air dryer and dust collector

Use the correct engine oil with a DPF

A DPF can become loaded with ash from burning oil from normal engine oil consumption. Engine oil (API CJ-4) has a Low Ash content and is required for vehicles with the DPF system. CI-4 has higher ash content and will result in greater ash accumulation in DPF, shortening service intervals.



CJ-4 – Heavy Duty Diesel Engine Service; Exhaust Aftertreatment – Introduced in 2006. For high-speed, four-stroke engines designed to meet 2007 model year on-highway exhaust emission standards. CJ-4 oils are compounded for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm (0.05% by weight). However, use of these oils with greater than 15 ppm (0.0015% by weight) sulfur fuel may impact exhaust after treatment system durability and/or oil drain interval. CJ-4 oils are effective at sustaining emission control system durability where particulate filters and other advanced after treatment systems are used. Optimum

protection is provided for control of catalyst poisoning, particulate filter blocking, engine wear, piston deposits, low and high temperature stability, soot handling properties, oxidative thickening, foaming, and viscosity loss due to shear. API CJ-4 oils exceed the performance criteria of API
CI-4 with CI-4 PLUS, CI-4, CH-4, CG-4, and CF-4 and can effectively lubricate engines calling for those API Service Categories. When using CJ-4 oil with higher than 15 ppm sulfur fuel, consult the engine manufacturer for service interval. 8800 MONOLEC ULTRA Engine Oils meet the API CJ-4 specification.

Engine Power De-Rate Mode

If the PCM sees an over temperature condition on the sensors (Over 1700° F) it will De-Rate the engine's power output, and possible shut it down, and keep it from cranking for one hour
Also:

- EGT sensors Open circuits
- Low Fuel Pressure
- Engine Oil Temperature over 275° F

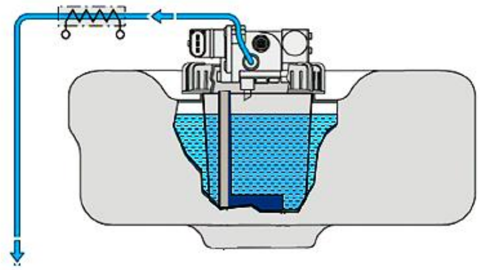
Selective Catalytic Reduction

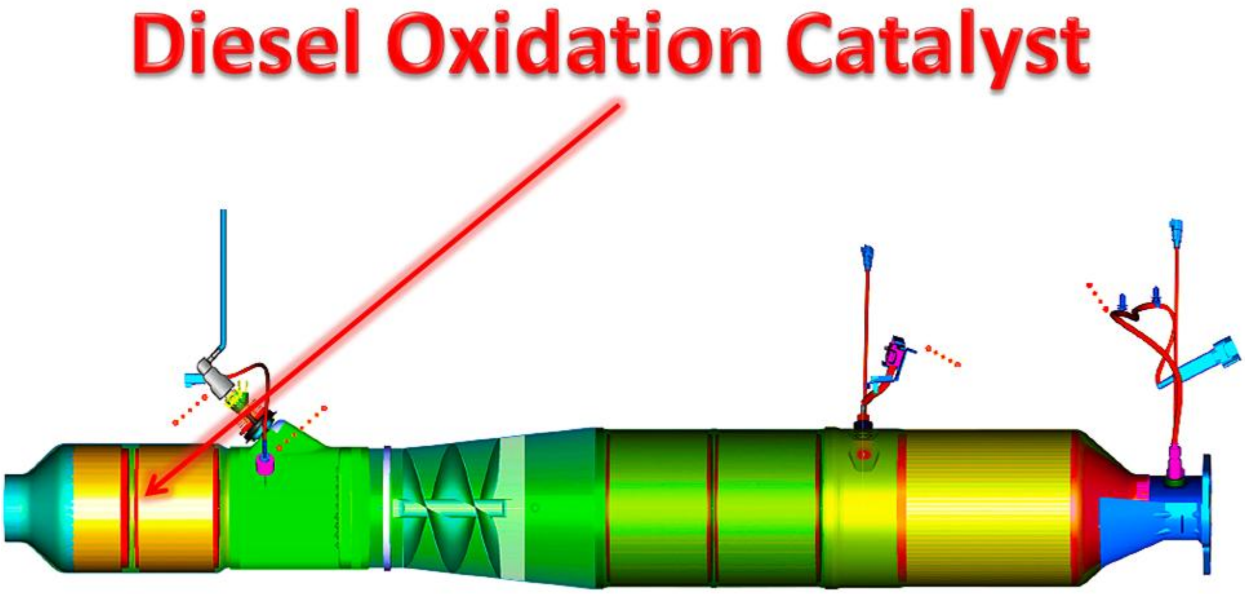
GM Part No. U.S. 88862659 or diesel exhaust fluid that meets ISO 22241-1 and displays the API Diesel Exhaust Fluid certification mark

The filler cap for the diesel exhaust fluid (DEF) is under the hood (pick-up models) on some models and beside the diesel fuel filler cap on others (Van Models). GM Part No. U.S. 88862659 or diesel exhaust fluid that meets ISO 22241-1 and displays the API Diesel Exhaust Fluid certification mark.

Emissions Aftertreatment

Reducing emissions is a multi-step process. The first step is to optimize the turbocharged engine for efficient combustion, which reduce harmful emissions. A more efficient system, which uses less fuel, and does not overly burden the Aftertreatment system. The system is a four step process with each subsystem fully integrated so that The EGR, DOC, DPF, works together with the diesel exhaust fluid.





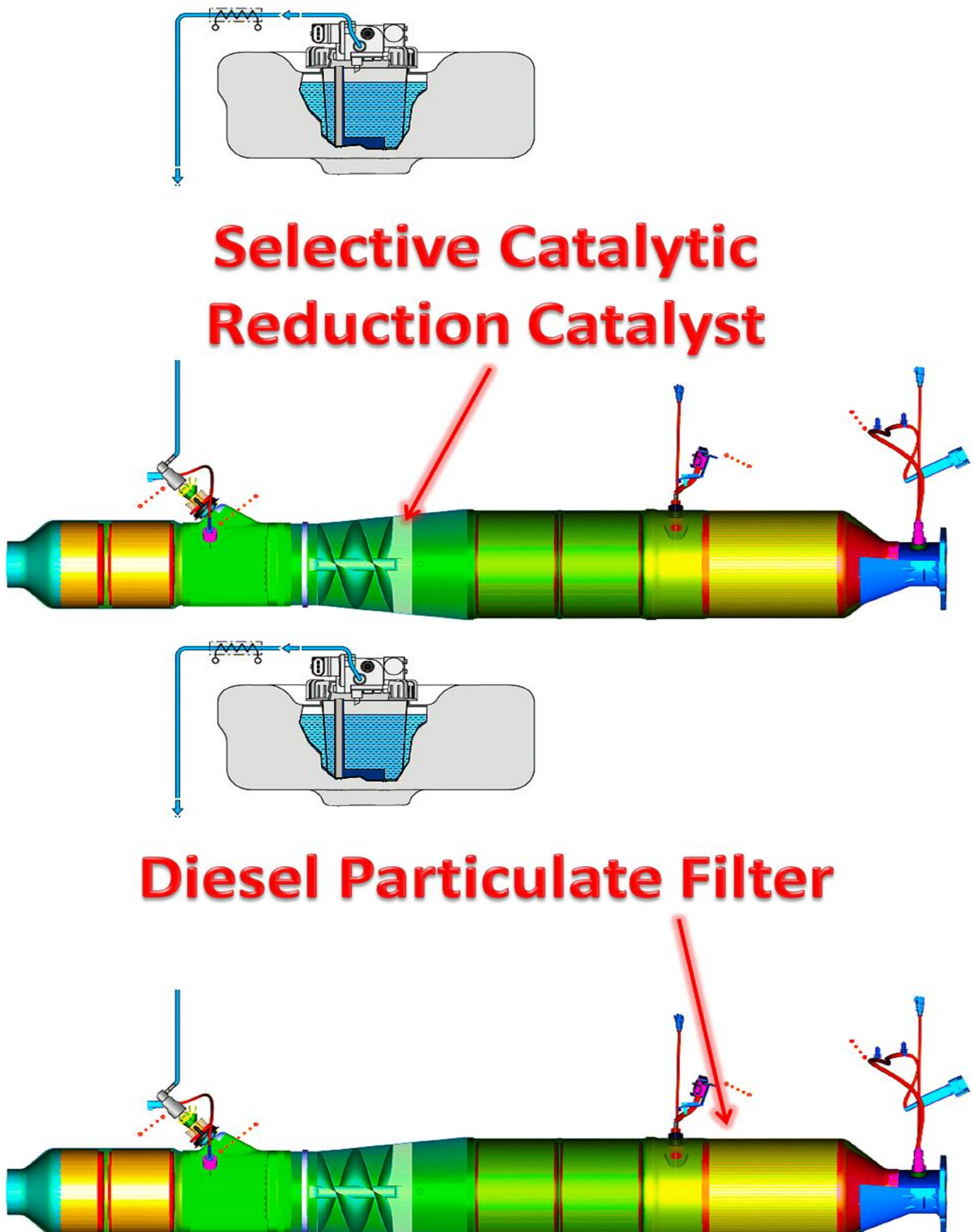
The systems are positioned after the Diesel Oxidation Catalysts (DOC) and before the Diesel Particle Filter (DPF).

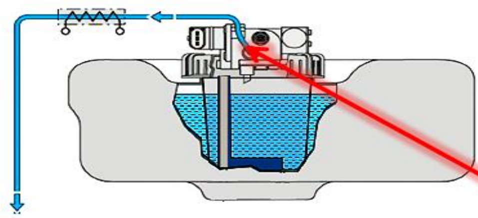
It consists of:

- Selective Catalytic Reduction Catalyst (SCR)
- A slightly over 5.0 gallon tank for holding the DEF
- Heating element
- Pressure pump
- Pressure sensor dosing valve
- Pressure reversing valve

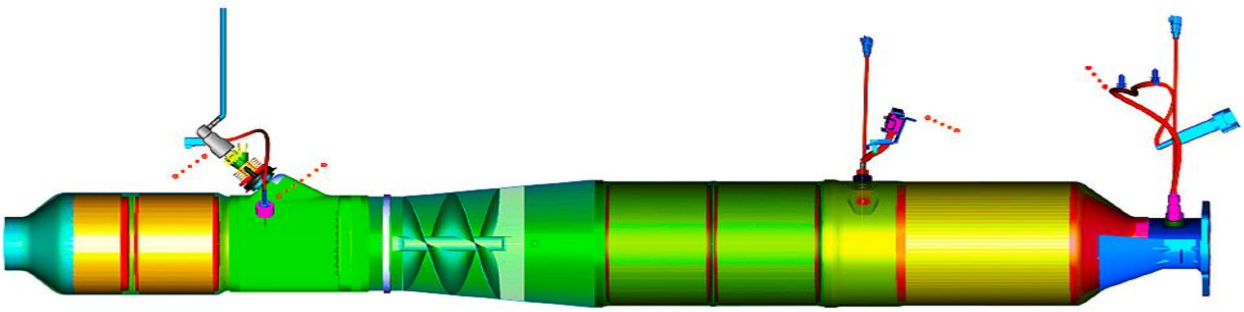
The SCR system injects a solution of 32.5% Urea and 67.5% of water into the exhaust just before the exhaust gas enters the SCR. The solution is called reductant when its mixed together. It is important to note that scan data refers to reductant and not DEF. When heated by exhaust temperature, the reductant is converted into ammonia and carbon dioxide. The molecules are atomized (vaporized) by the dosing valve as its injected. The solution and exhaust gas enters a mixer that resembles a corkscrew to create a turbulence for toughly mixing the reductant and exhaust gas. The turbulence in the mixer evenly distributes the ammonia within the exhaust flow. The NOx and ammonia are converted into harmless inert nitrogen and water. Dosing typically occurs between 400° F and 992° F.

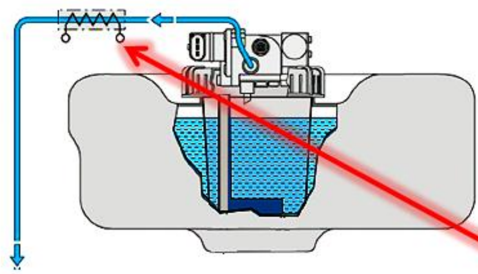
When the ignition is turned off the module will reverse the pump to remove any reductant in the system to avoid freezing in the lines and the dosing valve.


Selective Catalytic Reduction Catalyst
Diesel Particulate Filter

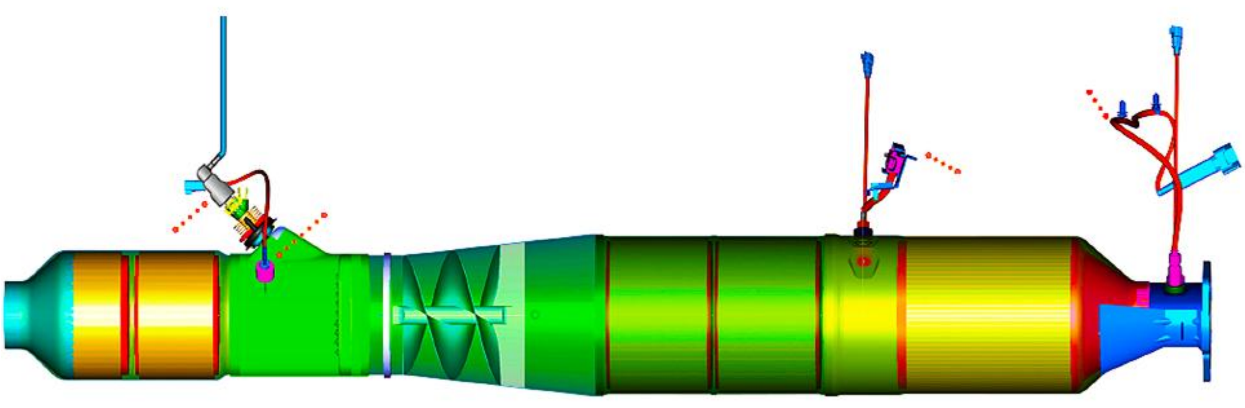


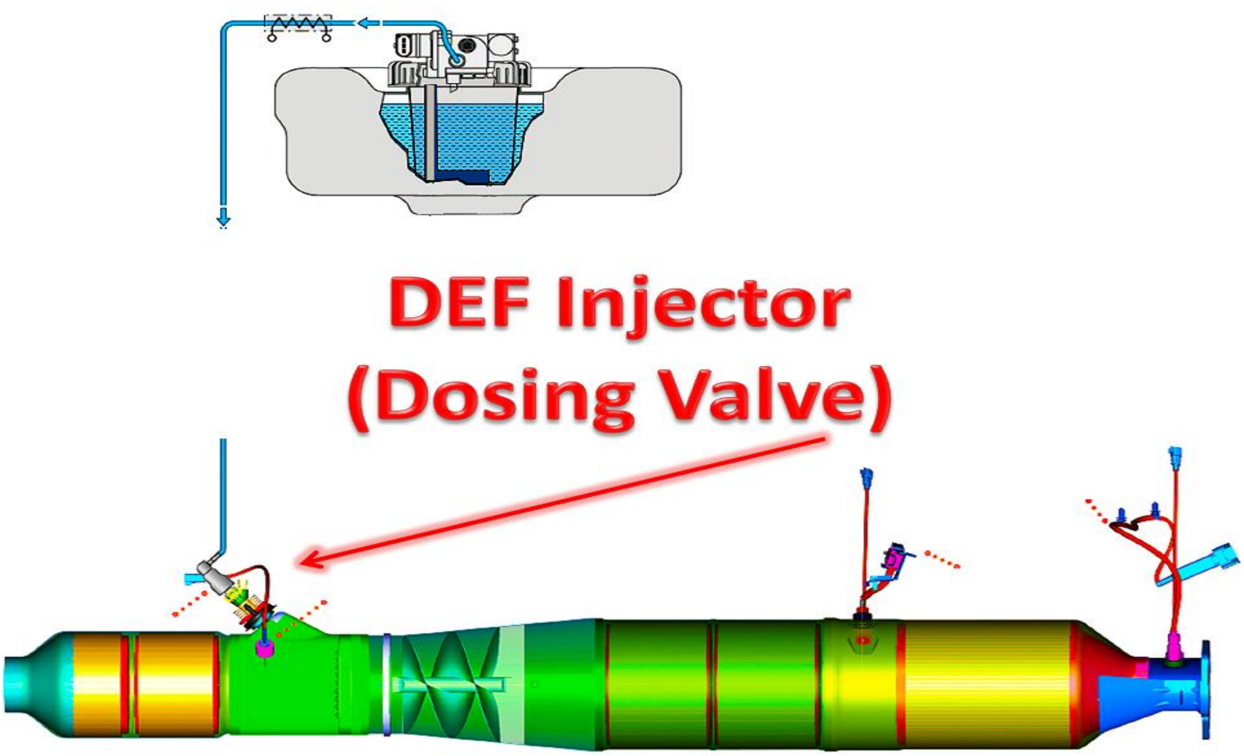
Diesel Exhaust Fluid Pump

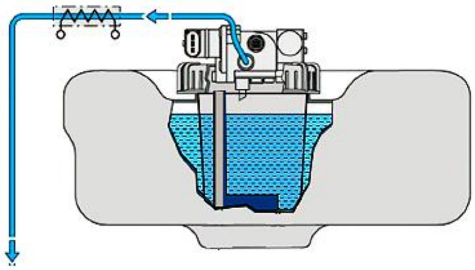


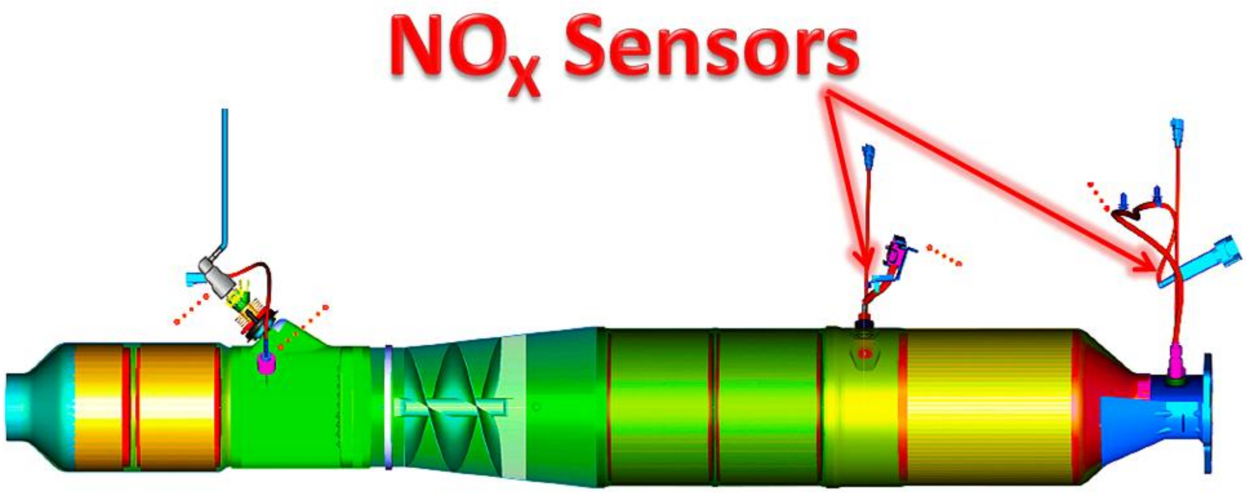


In line DEF Heater




DEF Injector
(Dosing Valve)





SCR

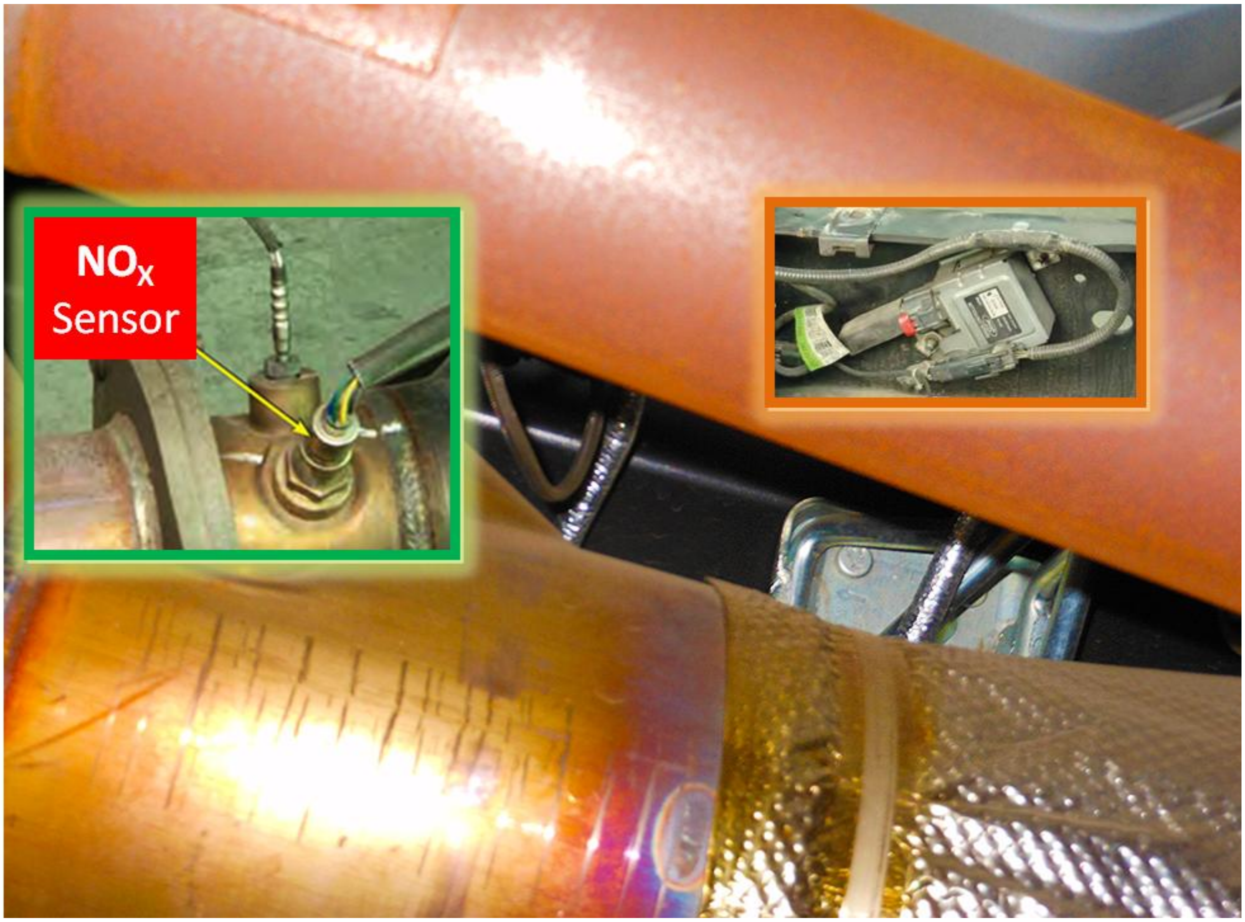
Before the exhaust gas enters the SCR chamber, it is dosed with Diesel Exhaust Fluid (DEF).
Urea is a solution that is approximately 67.5 % water and 32.5 % pure automotive grade urea
When the water and urea is called reductant.
When heated, the DEF is converted into ammonia and carbon dioxide.
The molecules are atomized (vaporized).
The solution enters a mixer that resembles a corkscrew.
The mixer evenly distributes the ammonia within the exhaust flow.
The NOx stored in the SCR and ammonia are converted into harmless inert nitrogen and water.
Dosing typically occurs between 400° F and 992° F

Reductant Pressure Sensor

The PCM monitors the reductant pressure sensor to calculate how much reductant to inject. The reductant pressure sensor is also used to shut the pump off when the lines are being drained after the ignition is shut off.

NO_x Sensor Module

The NO_x sensor module is mounted to the vehicle frame under the body. It monitors the NO_x sensor mounted in the diesel Aftertreatment exhaust system downstream of the SCR and DPF. It communicates to the PCM via the CAN2 to report NO_x concentrations as well as sensor and controller errors.



NO_x Sensor

The NO_x sensor is used primarily to sense NO_x concentrations in diesel exhaust gas. The sensor is mounted in a vehicle's exhaust pipe.

The sensor is mounted downstream of the SCR and DPF. The sensor interfaces with the NO_x sensor module.

DEF Level

The Power Control Module (PCM) monitors the DEF level and consumption rate in order to calculate an estimated range in miles remaining until the DEF reservoir is empty. DEF levels are detected by the 3-position solid-state DEF level sensor. The driver is provided with an elaborate series of prompts and warnings that are initiated when the DEF level falls below a calibrated value.

Fluid (DEF) Warning Strategy

Warning Level 1;

Warning Level 1 is triggered when the DEF level falls below the top-most position of the DEF Level Sensor and the estimated range remaining is greater than 1609 km (1000 mi). No prompts or warnings are presented to the driver.

Warning Level 2;

Warning Level 2 is triggered when the estimated range remaining falls below 1,609 km (1,000 mi) based on current DEF consumption rates. The Driver Information Center (DIC) displays the message Exhaust Fluid Range X MI, where X is the estimated range remaining in miles. This message remains on the DIC until acknowledged by the driver.

Warning Level 3;
Warning Level 2 automatically advances to Warning Level 3 when the ECM detects an ignition ON to ignition OFF event. A level 3 warning remains active as long as the estimated range remaining is greater than 483 km (300 mi) based on current DEF consumption rates. The DIC displays the message Exhaust Fluid Range X Miles, where X is the estimated range remaining in miles.

Warning Level 4;
Warning Level 4 is triggered when the estimated range remaining falls below 483 km (300 mi) based on current DEF consumption rates. The message Exhaust Fluid Range X MI, where X is the estimated range remaining in miles is displayed in the DIC. This message is also displayed at the beginning of each ignition cycle. This message remains on the DIC until acknowledged by the driver.

Warning Level 5;
Warning Level 5 is triggered when the estimated range remaining less than approximately 121 km (75 mi) is based on current DEF consumption rates. The message Exhaust Fluid Low - Speed Limited Soon, is displayed on the DIC. This message is also displayed at the beginning of each ignition cycle or a refill of the DEF reservoir is detected. This message remains in the DIC until acknowledged by the driver.

Warning Level 6;
Warning Level 6 is triggered when the estimated range remaining less than approximately 0 km (0 mi) is based on current DEF consumption rates. The driver will hear 4 chimes on entering Warning Level 6. The DIC displays the following messages:
Exhaust Fluid Empty Refill Now
644 km (400 miles) until 105 km/h (65 mph) Max Speed
The messages are also displayed at the beginning of each ignition cycle. The Exhaust Fluid Empty Refill Now message remains on the DIC until acknowledged by the driver. The 644 km/h (400 mph) until 105 km/h (65 mph) Max Speed mileage countdown until speed limitation will remain displayed in the DIC.
The DEF Indicator in the instrument panel is continuously illuminated. The vehicle remains in Warning Level 6 until the DEF reservoir is refilled or the first mileage countdown expires. After the first mileage countdown expires, the system will advance from Warning Level 6 to Warning Level 7.

Warning Level 7;
Warning Level 7 is active after the first mileage countdown expires or without a refill of the DEF reservoir. The driver will hear 4 chimes on entering Warning Level 7. The DIC displays the following messages:
Exhaust Fluid Empty Refill Now

Transitioning to 105 km/h (65 mph) Max Speed
The messages are alternately displayed every 5 seconds on the DIC. Exhaust Fluid Empty Refill Now remains on the DIC until acknowledged by the driver; however, the Transitioning to 105 km/h (65 mph), remains displayed in the DIC.
The DEF Indicator in the instrument panel is continuously illuminated.
Vehicle speed limit is ramping down from Max Speed limit to the limit of 105 km/h (65 mph).

Warning Level 8;
Warning Level 8 is triggered after the speed limit ramp-down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 8. The DIC displays the following messages:
Exhaust Fluid Empty Refill Now
Speed Limited to 105 km/h (65 mph)
120 km (75 miles) until 89 km/h (55 mph) Max Speed
The messages are alternately displayed every 5 seconds on the DIC. The Exhaust Fluid Empty Refill Now message remains in the DIC until acknowledged by the driver and occurs every ignition cycle or a refill of the DEF reservoir is detected. The speed limited and mileage countdown for speed limitation remains displayed in the DIC
The DEF Indicator in the instrument panel is continuously illuminated. The vehicle remains in Warning Level 8 until the DEF reservoir is refilled or the second mileage countdown expires. Vehicle speed is limited to 105 km/h (65 mph).

Warning Level 9;
Warning Level 9 is triggered after the second mileage countdown expires without a refill of the DEF reservoir. The driver will hear 4 chimes on entering Warning Level 9. The DIC displays the following messages:
Exhaust Fluid Empty Refill Now
Transitioning to 89 km/h (55 mph) Max Speed
The messages are alternately displayed every 5 seconds on the DIC. Exhaust Fluid Empty Refill Now remains in the DIC until acknowledged by the driver; however, the Transitioning to 89 km/h (55 mph) Max Speed message remains displayed in the DIC.
The DEF Indicator in the instrument panel flashes continuously.
Vehicle speed limit is ramping down from 105 km/h (65 mph) Max Speed limit to 89 km/h (55 mph).

Warning Level 10;
Warning Level 10 is triggered after the speed limit ramp-down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 10. The 4 chimes are repeated 3 more times during this ignition cycle. The DIC displays the following messages:
Exhaust Fluid Empty Refill Now
Speed Limited to 89 km/h (55 mph)
120 km (75 miles) to 7 km/h (4 mph) Max Speed
The messages are alternately displayed every 5 seconds in the DIC. Exhaust Fluid Empty Refill Now remains in the DIC until acknowledged by the driver; however, the speed limited and mileage countdown for speed limitation remain displayed in the DIC message remains displayed in the DIC.

The DEF Indicator in the instrument panel flashes continuously. The vehicle remains in Warning Level 10 until the DEF reservoir is refilled or the third mileage countdown expires.
Vehicle speed is limited to 89 km/h (55 mph).

Warning Level 11;
Warning Level 11 is not used.

Warning Level 12;
Warning Level 12 is not used.

Warning Level 13;
Warning Level 13 is triggered after the third mileage countdown expires without a refill of the DEF reservoir. The driver will hear 4 chimes on entering Warning Level 13. The DIC displays the following messages:
Exhaust Fluid Empty Refill Now
Transitioning to 7 km/h (4 mph) Max Speed
The messages are alternately displayed every 5 seconds in the DIC. Exhaust Fluid Empty Refill Now remains in the DIC until acknowledged by the driver; however, the Transitioning to 7 km/h (4 mph) Max Speed message remains displayed in the DIC.
The DEF Indicator in the instrument panel flashes continuously. Vehicle speed limit is ramping down from 89 km/h (55 mph) max speed limit to 7 km/h (4 mph).

Warning Level 14;
Warning Level 14 is triggered after the speed limit ramp-down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 14. The 4 chimes are repeated every 3 minutes. The DIC displays the following messages:
Exhaust Fluid Empty Refill Now
Speed Limited to 7 km/h (4 mph)
The messages are alternately displayed every 5 seconds in the DIC. Exhaust Fluid Empty Refill Now remains in the DIC until acknowledged by the driver; however, the Speed Limited to 7 km/h (4 mph) message remains displayed in the DIC.
The DEF Indicator in the instrument panel flashes continuously. The vehicle remains in Warning Level 14 until the DEF reservoir is refilled.
Vehicle speed is limited to 7 km/h (4 mph).

Fluid (DEF) Warning Strategy (Anti-Tampering)

If a conditions associated with an attempt to disable the reductant system are detected. the PCM activates an anti-tampering feature and presents the driver with a series of prompts and warnings. When the conditions associated with an attempt to disable reductant system operation are detected, the ECM activates the anti-tampering feature and presents the driver with a series of prompts and warnings.
Once initiated, anti-tampering warnings grow increasingly more serious as the vehicle continues to be driven. The vehicle's current warning status is displayed on the scan tool. When tampering is suspected, the normally OFF Reductant System Malfunction Warning Indicator Command will display Warning Level 1 through Warning Level 11 depending on the number of miles driven. The series anti-tampering warnings alert the driver that reductant system service is urgently needed.

Warning Level 1
Warning Level 1 is triggered when the ECM first detects an abnormal value on a reductant system circuit. The Driver Information Center (DIC) displays the following messages:
Service Exhaust Fluid System
See Owner's Manual Now
160 km (99 miles) until 105 km/h (65 mph) Max Speed
The messages alternate every 5 seconds in the DIC until acknowledged by the driver; however, the mileage countdown message remains in the DIC. The DEF Indicator in the instrument panel is illuminated.

Warning Level 2
Warning Level 2 is triggered after the first mileage counter expires. The driver will hear 4 chimes on entering Warning Level 2. The DIC displays the following messages:
Service Exhaust Fluid System
See Owner's Manual Now
Transitioning to 105 km/h (65 mph) Max Speed
The messages alternate every 5 seconds in the DIC until acknowledged by the driver; however, the Transitioning to 105 km/h (65 mph) Max Speed remains in the DIC. The DEF Indicator in the instrument panel is illuminated. Vehicle speed limit is ramping down from max speed limit to the limit of 105 km/h (65 mph).

Warning Level 3
Warning Level 2 automatically advances to Warning Level 3 after the speed limit ramp down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 3. The DIC displays the following messages:
Service Exhaust Fluid System
See Owner's Manual Now
Speed Limited to 105 km/h (65 mph)
120 km (75 miles) Until 89 km/h (55 mph) Max Speed
The messages alternate every 5 seconds in the DIC until acknowledged by the driver; however, the Speed Limited to 105 km/h (65 mph) remains in the DIC. The DEF Indicator in the instrument panel is illuminated.
Vehicle speed is limited to 105 km/h (65 mph).

Warning Level 4
Warning Level 4 is triggered after the second mileage counter expires. The driver will hear 4 chimes on entering Warning Level 4. The DIC displays the following messages:
Service Exhaust Fluid System
See Owner's Manual Now
Transitioning to 89 km/h (55 mph) Max Speed
The messages alternate every 5 seconds until acknowledged by the driver; however, the Transitioning to 89 km/h (55 mph) Max Speed remain displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously. Vehicle speed limit is ramping down from 105 km/h (65 mph) max speed limit to 89 km/h (55 mph).

Warning Level 5

Warning Level 4 automatically advances to Warning Level 5 after speed limit ramp down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 5. The series of 4 chimes will repeat 3 times every 3 minutes during each ignition cycle until the vehicle is serviced. The DIC displays the following messages:
Service Exhaust Fluid System
See Owner's Manual Now
Speed Limited to 89 km/h (55 mph)
120 km (75 miles) Until 7 km/h (4 mph) Max Speed
The messages alternate every 5 seconds until acknowledged by the driver; however, the speed limitation and mileage countdown remains displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously.
Vehicle speed is limited to 89 km/h (55 mph)

Warning Level 6
Warning Level 6 is not used

Warning Level 7
Warning Level 7 is not used

Warning Level 8
Warning Level 8 is not used

Warning Level 9
Warning Level 9 is not used

Warning Level 10
Warning Level 5 automatically advances to Warning Level 10 after third mileage counter expires or a key cycle. The driver will hear 4 chimes on entering Warning Level 10. The DIC displays the following messages:
Service Exhaust Fluid System
See Owner's Manual Now
Transitioning to 7 km/h (4 mph)
The messages alternate every 5 seconds until acknowledged by the driver; however, the Transitioning to 7 km/h (4 mph) remains displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously. Vehicle speed limit is ramping down from 89 km/h (55 mph) max speed limit to 7 km/h (4 mph).

Warning Level 11
Warning Level 10 automatically advances to Warning Level 11 after speed limit ramp down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 11. The series of 4 chimes will repeat every 3 minutes until the vehicle is serviced. The DIC displays the following messages:
Service Exhaust Fluid System
See Owner's Manual Now
Speed Limited to 7 km/h (4 mph)

The messages alternate every 5 seconds until acknowledged by the driver; however, the Speed Limited to 7 km/h (4 mph) remains displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously.
Vehicle speed is limited to 7 km/h (4 mph).
Warning Strategy (Anti-Tampering):

Fluid (DEF) Warning Strategy (DEF Quality)

A supply of clean, fresh Diesel Exhaust Fluid (DEF) is critical for optimum Selective Catalyst Reduction (SCR) efficiency. SCR efficiency is determined by monitoring the Nitrogen Oxide (NOx) sensors located upstream and downstream of the SCR. This vehicle provides the driver with an elaborate series of prompts and warnings that are initiated when the Power Control Module (PCM) detects a drop in the SCR NOx reduction efficiency suggesting a diluted or contaminated DEF supply.
When contaminated or diluted DEF is suspected, the ECM initiates the DEF Quality warning process. Once initiated, DEF quality warnings grow increasingly more serious as the vehicle continues to be driven. The vehicle's current DEF quality warning status is displayed on the scan tool. When a drop in SCR efficiency is detected, the normally OFF Reductant Field Quality Warning Indicator Command will display Warning Level 1 through Warning Level 11 depending on the number of miles driven. The series of DEF Quality Warnings alert the driver that DEF system service is urgently needed.

Warning Level 1
Warning Level 1 is triggered when the ECM first detects the SCR efficiency is below a calibrated value. The Driver Information Center (DIC) displays the following messages:
Exhaust Fluid Quality Poor
See Owner's Manual Now
160 km (99 miles) until 105 km/h (65 mph) Max Speed
The messages alternate every 5 seconds until acknowledged by the driver; however, the mileage countdown remains displayed in the DIC. The DEF Indicator in the instrument panel is illuminated.

Warning Level 2
Warning Level 2 is triggered after the first mileage countdown expires without a DEF fluid service. The driver will hear 4 chimes on entering Warning Level 2. The DIC displays the following messages:
Exhaust Fluid Quality Poor
See Owner's Manual Now
Transitioning to 105 km/h (65 mph) Max Speed
The messages alternate every 5 seconds until acknowledged by the driver; however, the Transitioning to 105 km/h (65 mph) Max Speed remains displayed in the DIC. The DEF Indicator in the instrument panel is illuminated. Vehicle speed limit is ramping down from max speed limit to the limit of 105 km/h (65 mph).

Warning Level 3
Warning Level 2 automatically advances to Warning Level 3 after speed limit ramp down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 3. The DIC displays the following messages:

Exhaust Fluid Quality Poor
See Owner's Manual Now
Speed Limited to 105 km/h (65 mph)
120 km (75 miles) Until 89 km/h (55 mph) Max Speed
The messages alternate every 5 seconds until acknowledged by the driver; however, the speed limitation and mileage countdown remains displayed on the DIC. The DEF Indicator in the instrument panel is illuminated.
Vehicle speed is limited to 105 km/h (65 mph).

Warning Level 4
Warning Level 4 is triggered after the second mileage countdown expires without a DEF fluid service. The driver will hear 4 chimes on entering Warning Level 4. The DIC displays the following messages:
Exhaust Fluid Quality Poor
See Owner's Manual Now
Transitioning to 89 km/h (55 mph)
The messages alternate every 5 seconds until acknowledged by the driver; however, the Transitioning to 89 km/h (55 mph) remains displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously. Vehicle speed limit is ramping down from 105 km/h (65 mph) max speed limit to 89 km/h (55 mph).

Warning Level 5
Warning Level 5 is triggered after the speed limit ramp down is complete or a key cycle. The driver will hear 4 chimes on entering Warning Level 5. The series of 4 chimes will repeat 3 additional times every 3 minutes. The DIC displays the following messages:
Exhaust Fluid Quality Poor
See Owner's Manual Now
Speed Limited to 89 km/h (55 mph)
120 km (75 miles) Until 7 km/h (4 mph) Max Speed
The messages alternate every 5 seconds until acknowledged by the driver; however, the speed limitation and mileage countdown remains displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously.
Vehicle speed is limited to 89 km/h (55 mph).

Warning Level 6
Warning Level 6 is not used.

Warning Level 7
Warning Level 7 is not used.

Warning Level 8
Warning Level 8 is not used.

Warning Level 9
Warning Level 69 is not used.

Warning Level 10

Warning Level 10 is triggered after the third mileage counter expires without a DEF fluid service. The driver will hear 4 chimes on entering Warning Level 10. The DIC displays the following messages:

Exhaust Fluid Quality Poor

See Owner's Manual Now

Transitioning to 7 km (4 mph) Max Speed

The messages alternate every 5 seconds until acknowledged by the driver; however, the Transitioning to 6 km (4 miles) Max Speed remains displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously. Vehicle speed limit is ramping down from 89 km/h (55 mph) max speed limit to 7 km/h (4 mph).

Warning Level 11

Warning Level 11 is triggered after the speed limit ramp down is complete or a key cycle. The driver will hear 4 chimes every 3 minutes on entering Warning Level 11. The series of 4 chimes will repeat every 3 minutes. The DIC displays the following messages:

Exhaust Fluid Quality Poor

See Owner's Manual Now

Speed Limited to 7 km (4 mph) Max Speed

The messages alternate every 5 seconds until acknowledged by the driver; however, the Speed limited to 7 km (4 mph) Max Speed remains displayed in the DIC. The DEF Indicator in the instrument panel flashes continuously.

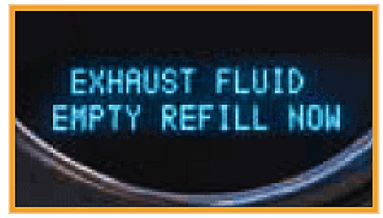
Vehicle speed is limited to 7 km/h (4 mph).

DEF Warning Lamp (ICON)


EXHAUST FLUID
QUALITY POOR


SPEED LIMITED TO
4 MPH


EXHAUST FLUID
RANGE: 1000 MI


EXHAUST FLUID
EMPTY REFILL NOW


SPEED LIMITED TO
55 MPH


4 MPH MAX SPEED
NEXT FUEL FILL


EXHAUST FLUID LOW
SPEED LIMITED SOON


55 MPH MAX SPEED
UPON RESTART

If the driver continues to operate the truck with a dry DEF tank, after a final warning and restart, the truck will operate in a “limp home” mode that limits speed to just 4 mph until the tank is refilled.

Operation during regeneration

If Regeneration occurs at idle the PCM may activate the EGR throttle plate to restrict oxygen to control the temperature.