

Rebuilding The 6.6L Duramax Diesel

By Roy Berndt

It was really no surprise, since GM had single-handedly alienated the American buying public against the diesel engine beginning back in the late '70s and early '80s with the 5.7L V8 and 4.3L V6 diesel engines that were, let's just say, "less than stellar." While there's no point now in rehashing mistakes of the past, the 6.2L and 6.5L diesels had continued on in a similar tradition, even though the 6.5L was used in the HUMVEE for the military.

In order to have a winning truck this time, GM needed to have a winning diesel powertrain. The General already had two strikes and a third may have put GM out of the diesel pick-up market altogether.

A small group of stakeholders led by the Planning Group reviewed proposals from numerous possible diesel engine manufacturers for the all-new truck. The decision was reached to go with a proposal from one of GM's partners – Isuzu Motors LTD, a company founded in 1916 and, with a long history of successful diesel technology, recognized worldwide as a leader in diesel engines. The proposal was developed as a part of a strategic 90-day study conducted by Isuzu and GM, relative to Isuzu's role in the GM Global enterprise.

While Isuzu's plan called for a "Clean Sheet" brand new engine design that would not be ready until 2003, GM's new HD pickup truck was going into production in late 2000. After high-level executive meetings, Isuzu found a way to pull ahead the timing to meet GM's needs. In May 1997, the project team was established under the leadership of Jim Hogan, GM Truck Group; Yoshihiro Tadaki, Isuzu; and Jim Kerekes, representing GM Powertrain.

The project was codenamed "B908" (bridge between U.S. and Isuzu, 90-day study and 8-cylinders). This would be the first V8 diesel engine Isuzu ever designed for the U.S. HD pickup market. Isuzu was responsible for the base engine design and GM was responsible for the integration of the engine into the vehicle. The GM Powertrain – Romulus Engineering Lab became the center of activity in the U.S.

The first running B908 engines were available in early 1998 in Japan and soon were installed in mule vehicles in the U.S. to begin the final development. The B908 Team used the 13-hour time difference to their advantage. They would videoconference late in the day U.S. time while Japan would work on the issue during their day and when the U.S. team came in the next morning, have another videoconference to review and the US would work during their day while it was Japan's night. It was truly 24/7 development.

The GM-Isuzu 90-day study established the plan to manufacture the new engine: a joint venture company named DMAX Ltd. (signifying the diesel engine and maximum power, cleanliness and fuel economy) was established in September, 1998 in Moraine, OH. A new 650,000 sq. ft. engine plant was built near the former 6.5L diesel engine plant, and many of the employees were able to transfer to the new joint venture.

The totally new engine design was a 6.6L, 90-degree, direct-injection, overhead valve, four-valve-per-cylinder, turbo-charged 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 provided operating quietness and smoothness typical of similarly sized gasoline engines.

When it came time to decide upon the marketing name for the new B908 engine, GM was already handicapped by its poor diesel reputation. The name itself was critical, as it would compete against Ford's established "Powerstroke" Diesel engine. Dodge was using the Cummins engine and needed no other name, so after many meetings the engine was named Duramax Diesel 6600. Like the joint venture name, "Duramax" was meant to highlight the durability and reliability of the new engine.

In late 2000 the Duramax Diesel 6600 debuted in the new 2001 HD pickup trucks. Brought to market in only 37 months, it was the fastest new engine developed by GM Powertrain – at that time. The engine was an immediate success, making Ward's Magazine "10 Best Engines" both in 2001 and 2002, and bringing up GM's market share from 3 percent to 30 percent in the HD Diesel pick-up truck market.

So now that we know how it got here, let's take a look at the basic specs of this engine, the RPO designations and how the proliferation of the major engine components has taken place. In addition, we'll highlight some of what you need to know and watch out for as you go through the remanufacturing of these engines.

Timeline:

2001 Duramax

The RPO LB7 (engine code "1") was first introduced in 2001 and continued until 2004. This is a 32-valve design with high-pressure common-rail direct injection and aluminum cylinder heads. The most problematic issue with the LB7 is injector failure. Since the injectors are under the valve cover in the engine, lubricating oil fuel dilution occurred and often ended in a catastrophic engine failure. A class action lawsuit against GM resulted in an extended warranty for this situation for 7 year/200,000 mile coverage.

The following trucks use the LB7:

- Chevrolet Kodiak/GMC Topkick
- Chevrolet Silverado/GMC Sierra HD

Engine Specs:

- Engine type: 6,599 cc (6.599 L; 402.7 cu in) V8 turbo
- Bore x Stroke: 4.06" (103.1 mm) x 3.90" (99.1 mm)
- Block/Head: Cast gray iron/cast aluminum

- Aspiration: Turbocharged & Intercooled
- Valvetrain: OHV 4-V
- Compression: 17.5:1
- Injection: Direct; Bosch High Pressure Common-rail
- Power/Torque: 300 bhp (220 kW) @ 3100 rpm / 520 lb-ft (705 N·m) @ 1800 rpm.

2004 Duramax

The RPO LLY (internally called the 8GF1 – engine 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 its diesel trucks. To meet this goal GM turned to a newly developed Garrett turbocharger with a variable geometry vane system and installed an Exhaust Gas Recirculation valve. Learning from problems with injectors in the previous LB7, GM changed the valve covers to not only remove them from the engine oiling system but allow access to the injectors without having to remove the valve covers.

Early on, problems came forward from customers complaining of severe overheating, and, in some situations, blown head gaskets. Although initially GM denied that it was a problem, after it was sued by a consumer group it relented and included overheating and blown head gaskets as a warranted item.

The following trucks used the LLY engine:

- 2006 Hummer H1 Alpha
- Chevrolet Silverado/GMC Sierra HD

Engine Spec changes:

- Power / Torque: 310 bhp (230 kW) @ 3000rpm / 590 lb·ft (800 N·m) @ 1600 rpm
- Head casting is c/n 8gf1
- Block casting is c/n 22351021213

2006 Duramax

RPO 2006 LLY (engine code “2”) debuted in the beginning of 2006 and ended production with the start of the 2007 calendar year. While it retained the LLY designation, mechanically it is identical to the LBZ and is mated to the new 6-speed Allison transmission.

RPO LBZ (engine code “D”) debuted in late 2006 and continued into 2007, sold only in the “classic” body style. 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 length was 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.

LBZ applications:

- Chevrolet Silverado HD
- Chevrolet Kodiak
- GMC Sierra HD
- GMC TopKick

LLY applications:

- Chevrolet Silverado HD
- Chevrolet Kodiak
- GMC Sierra HD
- Chevy Express full-size (reduced power output mated to a 4l85E transmission)
- GMC Savanna full-size (reduced power output mated to a 4l85E transmission)

Engine Specification changes:

- Compression: 16.8:1
- Injection: Bosch High Pressure Common-rail
- For a chart explaining the Power/Torque relationships in this model year, see the enhanced version online. Details at the end of this article.

2007 Duramax

RPO LMM engines (engine code “6”) are based on the LBZ engines, but were designed for U.S. EPA’s 2007 emission standards, and uses ultra-low sulfur diesel fuel, which went on sale in the US and Canada in the fall of 2006.

New emission reduction features include a Diesel Particulate Filter (DPF), which traps particulate matter. When the computer senses a pressure differential between two sensors (one located upstream and another downstream of the DPF) the truck enters a “regeneration” cycle.

During this time the computer commands the fuel injectors to inject fuel after the cylinder has fired, forcing raw fuel into the DOC (Diesel Oxidizing Catalyst) where it is burned to elevate the temperature of the exhaust. This hot exhaust then flows into the DPF and burns the trapped soot.

- Compression: 15.8:1
- Injection: Bosch High Pressure Common Rail with CP3.3 Injection Pump
- Power / Torque: 365 bhp (272 kW) @ 3200rpm / 660 lb·ft (895 N·m) @1600 rpm

Emission controls:

- Additional combustion control, including an even more efficient variable-geometry turbocharging system, cooled (enhanced) exhaust gas recirculation (EGR) and closed crankcase ventilation to reduce nitrogen oxides (NOx)
- Additional exhaust control, including oxidizing catalyst and new diesel particulate filter (DPF) to reduce soot and particulate matter
- Increased-capacity cooling system
- New engine control software
- Use of low-ash engine oil (CJ-4)

LMM Applications:

- 2007- Chevrolet Silverado HD[8]
- 2007- GMC Sierra HD
- Chevrolet Kodiak
- GMC Topkick
- Chevrolet Express/GMC Savanna

Current Duramax Versions

RPO LML (VIN code “8”) is the latest version (2011 - present) of the Isuzu/GM Duramax V8 diesel engine and is actually a more advanced version of the LMM engine. The majority of the changes addressing a required drastic reduction in engine emissions. Some mechanical aspects of the engine, such as piston oil flow design for improved temperature control and oil pump design, were also improved to enhance durability even further.

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-hardening to tolerate up to 20% biodiesel mixtures and urea injection (to reduce Nitrogen oxides) with a 5.8 gallon urea tank are updating the fuel and emissions systems. This engine now has fuel injectors, one directly injecting in the exhaust tract, to allow raw fuel injection during the particulate filter recycling routine.

This was previously accomplished by running raw fuel through the engine via the engine fuel injectors without igniting the fuel (valves were kept open), but risks of washing down cylinder walls and causing engine damage are increased with the use of Biodiesel. The RPO LML engine is rated at 397 horsepower at 3000 rpm and 765 lb.-ft. of torque at 1600 rpm. RPO LGH 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.

RPO 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. General Motors planned a 4.5 liter 72-degree V8 for light-duty applications which would be built at GM's powertrain facility in Tonawanda, New York after 2009. Designed to fit in the same space as a Chevrolet Small-Block engine, it is expected to produce over 310 bhp (230 kW) and 520 lb-ft (705 N·m) of torque. It added urea injection, 29,000-psi (2,000 bar) piezo-electric common-rail fuel system over previous Duramax architecture.

It was initially targeted for the Chevy Silverado/GMC Sierra and Hummer H2. Unlike previous Duramax engines, the 4.5 liter is planned to be designed and built entirely by GM, without assistance from Isuzu.

As of March 2009, a GM spokesperson stated the engine project has been put on an "indefinite hold" due to current economic conditions. It is a shame that this engine has not yet materialized since it could have been GM's ace in their sleeve. To date there are no diesels in what used to be classified as the half-ton truck market that would have a diesel available. If the Ford F-150 beats GM to the punch they will have squandered an opportunity of major proportion to take the lead.

CYLINDER BLOCKS

In typical import manufacturing fashion, production casting numbers do not necessarily give you what you would call a definitive identifier. That is why it is so important to know the specific casting identifiers. It is my intent to provide you with that information to correctly understand the proliferation by sight and not casting number.

The Duramax cylinder blocks are pretty simple to identify, since there are only two of them.

The first block casting was used from the original release through the end of 2005 MY of production. It is easily identified by the difference where the water pump bolts to the block and the bolt bosses (or absence thereof). See **Figure 1**.

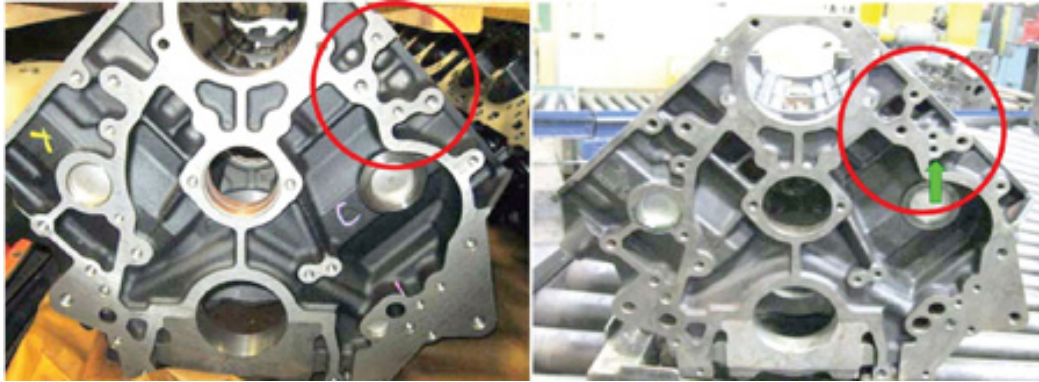
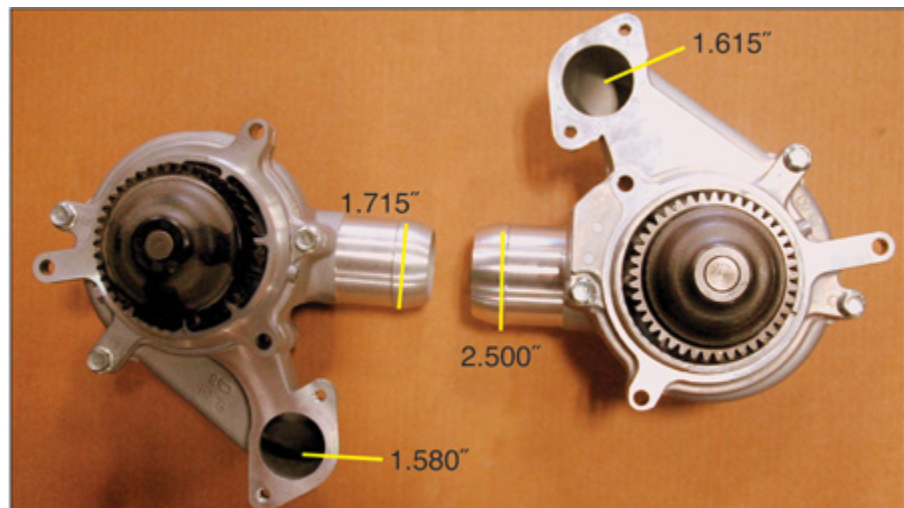


Figure 1. The block on left is 2001-'05 MY production and the block on the right is '06 MY and up production. Note the additional bolt holes for the later, higher-output water pump.

The second block has the additional bosses and also uses longer main bearing bolts. The main bearing bolt used in '05 MY and earlier is approximately 4- $\frac{1}{4}$ " long. The bolts used in '06 MY and later are approximately 4- $\frac{1}{2}$ " long.

The water pump mounting bolts changed but so did the water pump. There is a larger output and higher volume water pump being used (see **Figure 2**) as seen by the difference of the output outlet.

Figure 2. Water pump on the left is used through '05 MY and has a smaller water outlet size. The water pump on the right is for '06 MY and up with a higher volume and flow that eliminated the potential for any overheating and has a larger outlet size.



CRANKSHAFT

Crankshafts for the D-Max are forged steel with a nitride heat treatment. The nitride hard face provides a strong wearresistant bearing face that has a high lubricity quality, an excellent surface. for aluminum alloy shell-type bearings.

The downside is that the affected area is very shallow and ANY undersize grinding will require the crankshaft to be re-nitride treated. This is NOT an option: if the crankshaft is not re-treated it will fail 100% of the time. There are even those of the opinion that too heavy of a polish will give you an issue as well, so the handling of these crankshafts with the utmost care is critical.

There are two crankshafts for the D-Max up through '05 MY and '06 MY and later. There is a difference in their balance and their differences are very subtle. There are a couple of “bumps” in the forging in the area just off the second and fourth main bearing journal area (see **Figure 3**) for the '06 MY and later parts, but dimensionally the two cranks are identical.

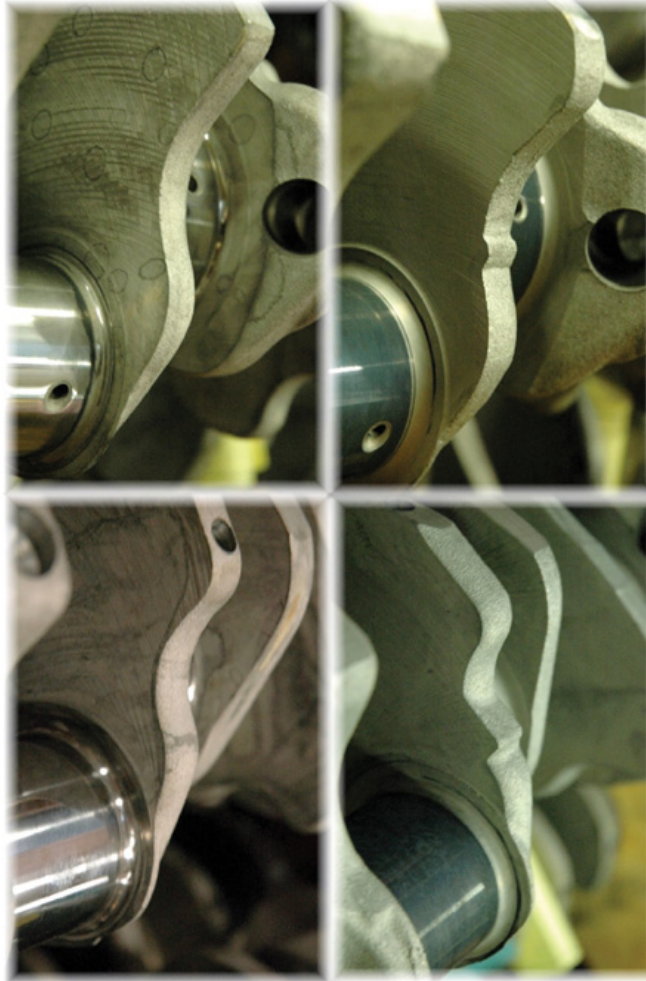


Figure 3. Upper and lower views on the left is the early crankshaft through '05 MY. The views on the right that have the small “bumps” in the forging are of the '06 MY to current production crankshaft. These crankshafts are balanced differently and are reported to be not interchangeable.

CAMSHAFTS

Camshafts are easy to identify: they are all the same, except for the timing gears. As shown in **Figure 4**, the early timing gears (through '05 MY) were solid and '06 MY and later used a split gear that is spring loaded to avoid any type timing gear train noise. These camshafts are rifle

drilled and will, on occasion, break. It's not chronic but it is something to be aware of. They are relatively inexpensive.



Figure 4. Camshaft timing gear on the left is early solid style thru '05 MY and on right the two pieces that are used as the spring loaded assembly to avoid and eliminate potential timing noise '06 MY to current.

ROCKER ARMS, CAM FOLLOWERS AND PUSHRODS

The same '05 MY and '06 MY break for changes applies to the rocker arms, cam followers and pushrods. Through '05 MY the pushrods were solid and did not have oil running through them. Beginning in '06 MY the push rods were hollow and did have oil running through them. Rocker arm oiling holes changed from .110" to .150". The cam followers changed to a larger diameter pin that the roller would rotate on as it followed the cam lobe. This lifter also had provisions to feed oil through the pushrod (see **Figure 5**).



Figure 5. The upper left has the '05 MY on the left and '06 MY on right – note the difference in oil hole size. Pushrods on the lower left are '05 MY and earlier on the left and '06 MY and later on the right. Lastly, on the right side of the picture, the cam follower on the left is through '05 MY and '06 MY to current is on the right.

CONNECTING RODS

Connecting rods are pretty much the same story as the other components. Used through '05 MY, the first generation connecting rod has a lighter beam and shorter wrist pin. The second connecting rod ('06 MY and later) has a dimple on the beam and has a heavier beam and longer wrist pin.

PISTONS

The pistons follow suit with the rods. The different model years obviously had a pin length change and they have different compression ratios. Visually, they are unmistakable (as seen in **Figure 6**). The later piston is scalloped and had bushings for the wrist pin, and has a graphite coating on the skirt.



Figure 6. The piston on left was used up through the '05 MY and the piston on right is '06 MY and later with a longer wrist pin.

CYLINDER HEAD, VALVE COVERS, INJECTORS AND GLOW PLUGS

This is the only area that may get a bit confusing. There are three cylinder heads and they do not follow as clean a break as the rest of the components. However, these guidelines should make it easy for you.

The first cylinder head was used through mid-'04 MY and had the injectors under the valve cover. The problem was, if an injector went bad it contaminated the lubricating oil and often the result would be a catastrophic engine failure. This cylinder head is easily identified by the valve cover rail being around the perimeter of the cylinder head (see **Figure 7**) and the fact that the injectors sit way down in the cylinder head between the four valves.

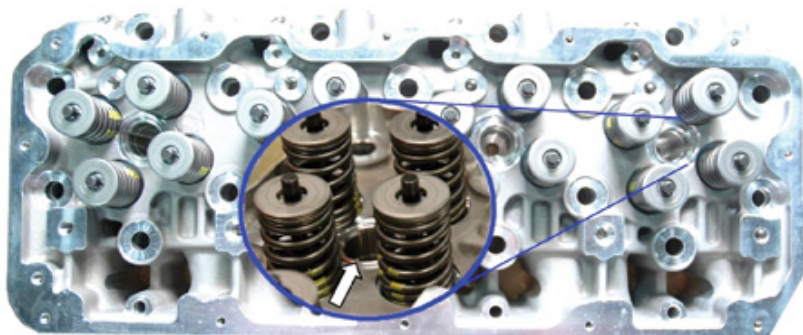
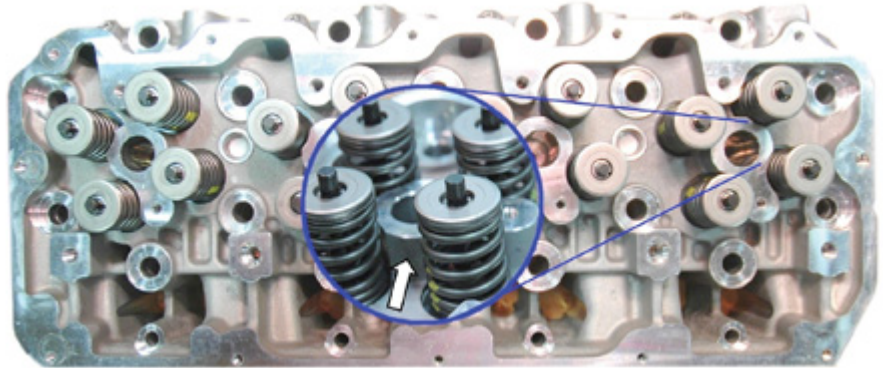


Figure 7. The early cylinder head through mid '04 MY had injectors under the valve cover and the injector sealed deep in the head as seen in the inset with arrow.

The second cylinder head, which came into being mid-'04 MY, had the revised valve cover and the new injector that was now outside of the lubricating oil (see **Figure 8**). This model head is easily recognized not only by the cover but the injector is longer and the mounting surface is a raised boss that you cannot mistake.

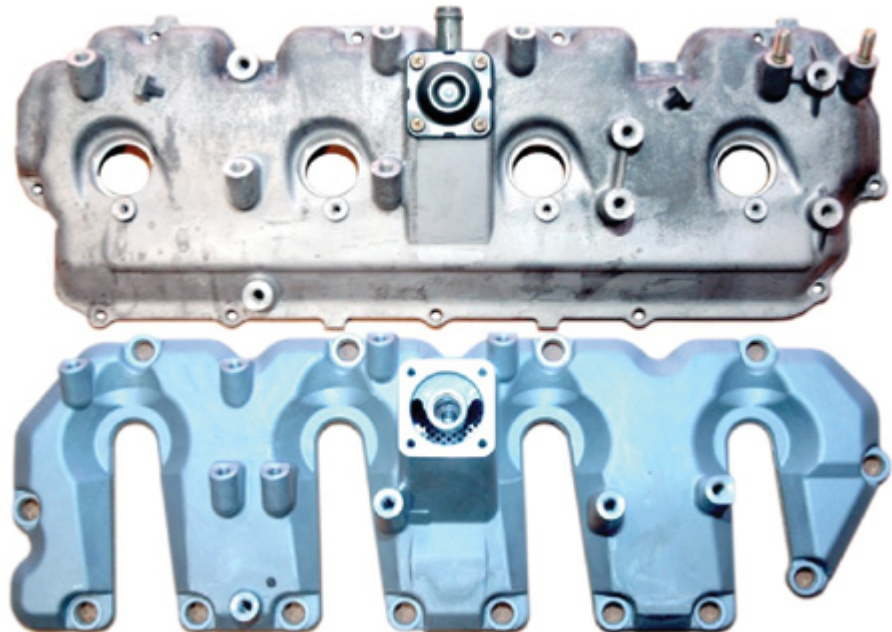
Figure 8. The second design head mid '04 MY through '05 MY with injectors out of the lubricating oil mounted on a raised boss (see inset) allow for a rapid identification.



The third and final cylinder head (used from '06 MY-current) looks very similar to the second design cylinder head. The only distinct identifier is the glow plug hole, which uses a different thread so that it cannot be installed in the previous cylinder head.

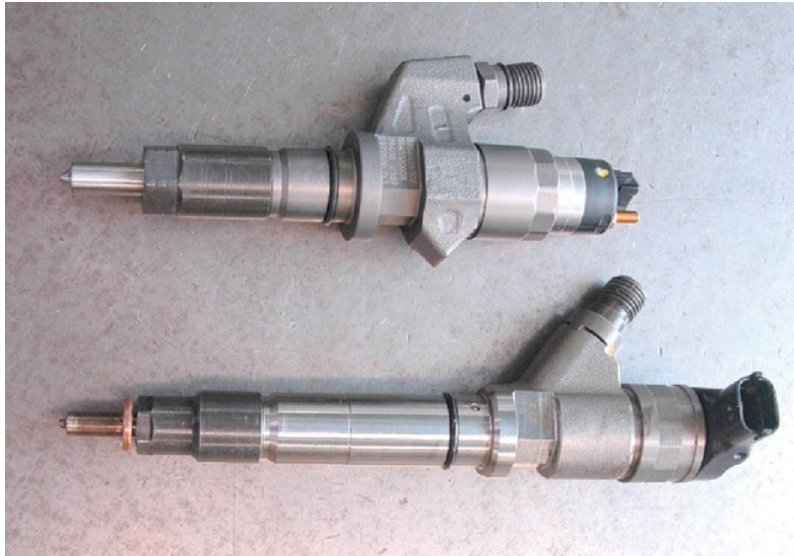
There have been two basic Duramax valve covers used, if you discount the crankcase ventilation differences (see **Figure 9**). A larger, normal looking cover that had the injectors underneath was used through mid-'04 MY. The second looks like a pretzel project gone bad. Injectors are out of the cover with no chance of contaminating the lubricating oil. This second cover also went through various renditions of emissions experimentation, with the orifice sizes for the crankcase ventilation changing from .370" to .465" to, lastly, .560". If you replace a cover, know which hole you have for crankcase ventilation.

Figure 9. The valve cover on the top is the early cover through mid-year '04 MY. The lower cover is redesigned so that injectors are outside of the lubricating oil and they are the later type cover used through current production.



The Duramax had two different fuel injector body types. The one that sat under the valve cover is shorter and in the lubricating oil. The injector that now sits outside the valve cover is quite a bit longer and there is no way to mix them up or put one in the wrong head (see **Figure 10** for proper identification).

Figure 10. The injector on top is the one that was used under the valve cover and inside the engine oiling system. Mid '04 MY the cylinder head and valve cover were changed to have the fuel injectors outside the lubricating oil eliminating any chance of fuel dilution of the oil.



Three different glow plugs were used to correspond with the three different cylinder heads (see **Figure 11**). The first and second series glow plugs (used in the mid-'04 MY through '05 MY engines) look identical but have different voltages. The early production is 11 volt and the mid-'04 MY is 4.7 volt. The barrels have the voltage marked on them so do not inter-mix these glow plugs or there will be problems. Either the engine will not start or you will be burning up your glow plugs. The '04 MY injector and the '06 and later glow plugs are actually the same glow plug but the '06 MY has the threads about midway down the body. As stated earlier, the glow plug hole is the major difference between the two cylinder heads.

Figure 11. The glow plug on the left is for the early production injector under cover cylinder head. The center one came on the scene in mid '04 MY and is used through '05 MY and the last one on the right is '06 MY through current production. They are all different and do not interchange.



Things worth noting:

- The oil pump drive gear went from right hand to left hand thread in '06 MY. The premise behind the decision was that the engine rotation could potentially loosen the nut, although I have found no one to confirm that had ever happened. However, once it was changed so that the engine's natural rotation would keep the nut tight there ARE reports of that happening. This locks up the oil pump, so the rest I leave to your imagination.
- The camshaft has a negative ramp on the lobe.
- D-Max has apparently solved the issue of valve seat inserts falling out of aluminum cylinder heads. The incidence of occurrence is near zero.
- The increased glow plug length design allows for injection to fire directly across the glow plug. Injectors fire off five burst during each combustion cycle.
- The use of a variable vane turbo allows for high torque at low RPM and spools the turbo up quicker.

Reprinted by permission of *Engine Builder* magazine.