Diesel Futures

Forget the black soot and smoke. Modern diesel-powered cars are quiet, clean and fast.

BY PAUL WEISSLER

Photo by Thorsten Weigl

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You would expect the 6-cylinder engine in the Mercedes E-Class and the V8 in the BMW 7 Series to be so smooth and quiet from the driver's seat that you'd have to look at their tachometers to be sure that they were running. You would not expect that of a diesel, however. Yet these are diesel engines.

The world has been looking to gas/electric hybrids and fuel cells for future fuel efficiency. However, studies show that the diesel can equal or beat what the fuel cell might possibly deliver, and be within a gnat's whisker of a gasoline hybrid like the Prius. The studies of total energy consumption--so-called well-to-wheel studies--were conducted by General Motors, the Massachusetts Institute of Technology (MIT) and the University of Alberta in Canada. The MIT researchers, looking ahead to 2020, found the diesel well ahead of most hydrogen fuel cell possibilities and even ahead of the gas/electric hybrid. To demonstrate the diesel's acceptability, the Chrysler Group and Mercedes-Benz plan to join the only current diesel passenger-car importer, Volkswagen, with new models of their own. As of now, only the VW Jetta/Golf/Beetle 1.9-liter 4-cylinder turbocharged direct injection (TDI) is sold in the States. VW also will bring a more advanced 2.0-liter for the Passat, and probably a 5.0 V10 that develops 308 hp and 550 ft.-lb. of torque for its new Touareg SUV.

Shows the fallacy of hydrogen vehicles - but I already told you that

These new diesels will be sold next year in test quantities. That means just a few thousand each of the Jeep Liberty 2.8 Four and the Mercedes E-Class with a 3.2-liter inline Six. As we go to press, there has been no decision by Ford about its diesel Focus. BMW's 4.0-liter V8 is not coming here soon.

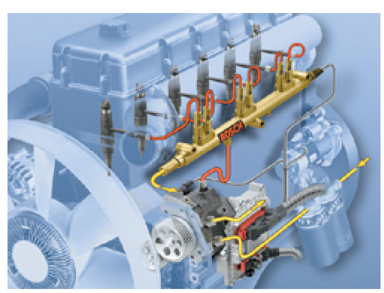
A Primer

A diesel has no spark plugs. It has a very high compression ratio--about twice that of a gasoline engine. So the compression stroke builds up tremendous heat and pressure. A readily combustible fuel is injected and the heat of compression instantly ignites it. Unlike a gasoline engine with a throttle plate to regulate airflow, the diesel is unthrottled. It draws in all the air it can, all the time, without wasting energy pulling air past a partly closed throttle. Performance is determined (within combustion limits) by the amount of fuel injected, so the diesel can produce a great deal of torque at low rpm. Step on the accelerator and a variable turbocharger adds still more air, the injectors spray more fuel, and the diesel develops tree-stump-pulling torque before the tach hits two grand. A gasoline engine needs an air-fuel mixture of about 15:1. The diesel can run on mixtures as lean as 100:1.

Diesels: no throttling losses!

Actually Diesels have less torque for a given RPM and intake pressure (i.e. lower BMEP) since they operate lean

No lean limit for diesels!



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Bosch's "common rail" system has a pressurized fuel reservoir supplying individual injectors.

Still Stumbling

Despite current diesel technology, the engine's future is cloudy. California emissions regulations prevent the sale of diesels there. In 2004, the federal emissions standards for diesels get appreciably tougher. The limits on particulates (soot particles) and oxides of nitrogen (NO_x) between 2004 and 2010 are very stringent, with the standard due to begin taking hard effect in 2007.

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A critical problem is that the diesel's high-temperature

I mentioned the 2010 regulations for soot and NOx - may be impossible to meet with Diesels combustion produces a high level of NO_x. Effectively reducing both particulates and NO_x requires aftertreatment in the exhaust. However, much of the hardware necessary for diesel aftertreatment is still in the early stages of development.

Another problem facing the diesel car is the quality of diesel fuel. Refiners concentrate on high-octane gasoline, and diesel fuel is produced from what crude oil is left. "We have the worst diesel fuel in the world," says Chrysler Vice President Bernard Robertson. Diesel engines need fuel with a high cetane rating, the opposite of octane, for quick starts and continuing combustion. European cetane is in the low 50s, while U.S. cetane is barely over 40. This affects every aspect of the way a diesel engine is tuned and makes for slower starts--and increases emissions.

Sulfur in fuel helps lubricate a fuel system's moving parts, but it produces malodorous exhaust. And at current levels it's totally incompatible with the needed exhaust aftertreatment technology. The stand-ards require a huge drop in sulfur content--from an average of over 300 parts per million (ppm) to 15 ppm in 2006-2007.

A modern fuel injector delivers carefully timed and metered pulses of fuel for high efficiency.

High T means high NOx - a lean NOx catalyst would work against thermodynamics (oxidizing something when you already have excess oxygen) - a lean NOx catalyst is the holy grail of emission control system designers!

I didn't know about the problems with cetane rating and sulfur content in US diesel fuels.

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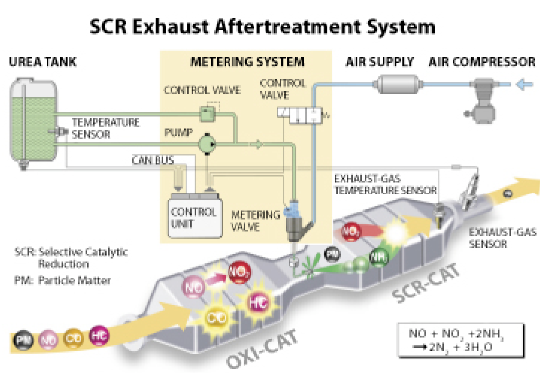
Photo by Thorsten Weigl

No, Really. It's A Diesel

The Lotus Elise-based Opel ECO-Speedster is the poster child for General Motors' diesel possibilities. Thanks to an ultrathin, carbon-fiber body, the ECO-Speedster weighs just 1455 pounds. Its coefficient of drag is a razor-thin 0.20. But unlike most record-breaking test cars from automakers, this one is a diesel. Power comes from the world's smallest mass-produced 4-cylinder diesel engine. Measuring in at 1251cc, and boasting a variable-geometry turbo and a common rail injection system, the Four produces 110 hp and 148 ft.-lb. of torque. The engine is mated to a 5-speed Easytronic shift-by-wire transmission.

Driving on public roads around Opel's Dudenhofen proving grounds, the ECO-Speedster reveals precious little outward visibility, little forward resistance and no wind noise at all. What it showed on the test track was startling performance: 0 to 100 kph (62 mph) was reached in only 8.8 seconds. Top speed was 256.739 kph (159.53 mph). Even more impressive than the car's willingness to go quickly is its unwillingness to drink fuel. We recorded 92.6 mpg. Small wonder that this small wonder of a diesel now owns 17 world records.--*Matt Davis*

Why not apply low-weight carbon fiber bodies with low drag coefficients and varible-geometry turbos to good old fashioned gasoline fueled vehicles???



Remember I mentioned Selective Catalytic Reduction for stationary engines? I didn't realize anyone was seriously thinking of putting this on a vehicle!!!

New Tricks For An Old Dog
The key to diesel performance is the fuel-injection system. VW currently uses a high-pressure mechanical fuel system with two pulses per injection. Future systems will rely on electronically controlled pulsing of high-pressure injectors. The solenoid-type fuel injector can provide up to five pulses per injection. The piezoelectric injector can provide up to 10.

At the heart of most new systems is the Bosch-invented "common rail." It has a high-pressure pump feeding a pipe-shaped accumulator. That means at any engine speed, every injector gets the same maximum pressure. Today that's up to about 26,000 psi, from Bosch,

be regenerated periodically. When the trap is restricted (after intervals as short as 100 miles), a small quantity of fuel is injected to raise the trap temperature to as high as 1100°F, incinerating the soot in about 15 minutes, according to Gary Smith of General Motors Powertrain Division.

PSA Peugeot Citroën injects a cerium solution that reduces incineration temperatures, saving fuel. But, the solution eventually is depleted and must be replenished. GM is testing catalytic coatings that would last the life of the car, Smith says.

However, NO_x remains the bigger problem, as the 3-way catalysts used in gasoline engines won't work in diesels. Exhaust-gas recirculation (EGR),

Two column format here - read down to the next page then back up

Particulate traps may be the only solution for Diesels

Just like I told you!

with 30,000 psi coming. The higher the pressure, the smaller the injector nozzle openings can be, producing smaller pulses that provide better fuel atomization. Combine that with more frequent, strategically timed pulses during each compression-stroke injection, and the result is more complete combustion.

Despite five years of success with the common rail, VW prefers a different Bosch fuel-injection system--the electronically controlled unit pump-injector with one unit for each cylinder. Its tuning capabilities are comparable to the common rail's and it develops slightly higher peak pressure. But a common rail for all cylinders has greater potential for consistency.

High-tech diesels start instantly if warm, and in about 2 seconds at subzero temperatures. New glow plugs from Bosch reach 2200°F in under 2 seconds, so the minute or so of preheating diesels in cold weather is but a memory.

> Diesels operate lean and hot, so have low CO and UHC

On The Way Out

Not only are diesel hydrocarbon and carbon monoxide emissions low, but there's an excess of air in the exhaust that could improve operation of an oxidation-type catalytic converter. Particulate aftertreatments that work best at this time are traps that fill up and have to

with a cooler in its circuit to lower exhaust temperatures, helps a lot by reducing the peak temperatures at which NO_x is formed. Calibration tweaks of the fuel system and turbocharger, and reshaping the intake port and combustion chamber to promote a smoother burn pattern, also are expected to help.

There are two exhaust system aftertreatments in development to handle NO_x. Both have been used successfully for industrial applications. However, the automotive environment is more problematic.

One system is called selective catalytic reduction (SCR) treatment. This uses an injection of a solution containing urea, a readily available ammonia-based compound. In combination with a specific catalyst in the exhaust system, SCR reduces NO_x to nitrogen and water without hurting fuel economy.

Another possibility is a NO_x adsorber, also called the "lean NO_x trap." The gases adhere to the surface of the adsorber as a nitrate. When the trap is "filled," fuel is injected. This promotes a catalytic action, converting the nitrate to nitrogen and water.