ALTERNATE FUEL TECHNOLOGY

Clean Diesel Technology

"Clean Diesels?" You may think we're joking, but diesel engine manufacturers have been working overtime to clean up the "dirty-stinky-noisy" perception of diesels over the last few years; and market acceptance of light duty diesel vehicles is picking up. Fact is, diesel OEs (original equipment manufacturers) in the U.S. and Europe are predicting a diesel "mega-boom." Read on to find out what's been happening, and why.

VW started the light-duty diesel revival with its modern 1.9 liter 4 cylinder turbo-diesel direct injection (TDI) engine, used here in the Golf. Also shown: Dodge Ram with Cummins 24 valve diesel; Ford HEUI Powerstroke; and GMC Duramax 6.6 V8 applications.

Here in the U.S., sporty diesel pickups and SUVs are more and more seen fueling up alongside medium and heavy diesels. Why? Because today's diesel vehicles are quieter, more powerful and less offensive, thanks to the electronics needed to meet stricter EPA standards. While petroleum-diesel fuel is not considered an alternate fuel (as is synthetic or bio-based diesel fuel), it is getting cleaner. Dual-fuel diesels are using alternate fuels like natural gas for even lower overall emissions. In Europe, seven out of 10 luxury cars are now diesel powered, and new diesel passenger car sales are reportedly near 40 percent; by 2010 they'll reach 50 percent.[1]

The growing popularity of light diesel trucks in the U.S. is forecasted to continue with diesel powered vans & SUVs. Diesel automobiles are also making a comeback. Second-generation "refined power" diesel engines with greater efficiency and improved overall performance are part of the reason. Diesel engines for light duty hybrid electric vehicles (HEVs) developed both by Ford and DiamlerChrysler for the ill-fated Partnership for a New Generation of Vehicles (PNGV) have achieved upwards of 70 mpg. No doubt engines like these will find their way into production vehicles.

Market Forces and Technology

The oil embargo of the 1970s awakened Americans to the need for greater fuel economy and manufacturers responded with a new breed of diesel cars ranging from VW's 55 mpg diesel Rabbit to Lincoln's BMW-powered five-cylinder luxury sedan. GM, Olds and Cadillac; Isuzu, Mercedes Peugeot, Toyota and other diesel cars were also marketed. But once gasoline again became plentiful, U.S. motorists tired of the hassles of pre-glowing, ignition "rattle," foul exhaust, and soot on their driveways. Well-known engine failures and under performance hastened the demise of the American flirtation with diesel cars, and sales plummeted.

Despite their shortcomings, however, diesels of all types have remained a staple in our nation's - and the world's – means of getting work done. Globally, drivers opt for the fuel economy of diesels to offset high motorfuel prices. But the stage was set for today's popularity for light-duty diesels here in the U.S. around 1997. Tightening tailpipe emissions standards resulted in advances in on-board clean diesel technology, and the robust economy of the time didn't hurt either.

According to the *Diesel Technology Forum*, new on-road diesel engine PM (Particulate Matter) emissions have been reduced 83 percent and NO_x by 63 percent since 1988. "The emissions reductions achieved from 1990 through 1994 [alone] were massive."[2] Moreover, HC, CO and $C0_2$ emissions, already inherently low with diesel engines, have improved. At this point, continued clean air gains hinge on the availability of cleaner low-sulfur petro-diesel fuel, or the use of synthetic and bio-diesel fuels. Cleaner fuels have been mandated by the federal government[3], but OEs and fuel producers are at odds over the issues of "when and how" EPA standards will be met. (More on this in a future issue). Non-road equipment emissions regulations will likely follow suit.

The medium and heavy on-road diesel market has not been as plagued with jaundiced perceptions or federal regulations as have diesel automobiles. The OEs have been converting existing engine platforms from the use of in-line injection systems to common rail, with improved emissions and little required in the way of engine redesign and tooling. Today's trucks must be OBD II compliant, with electronic systems managing the engine and powertrain. Some incorporate automatic start/stop of engines of parked vehicles (based on engine and cab/coach temperature and battery voltage) to lower diesel tailpipe emissions.

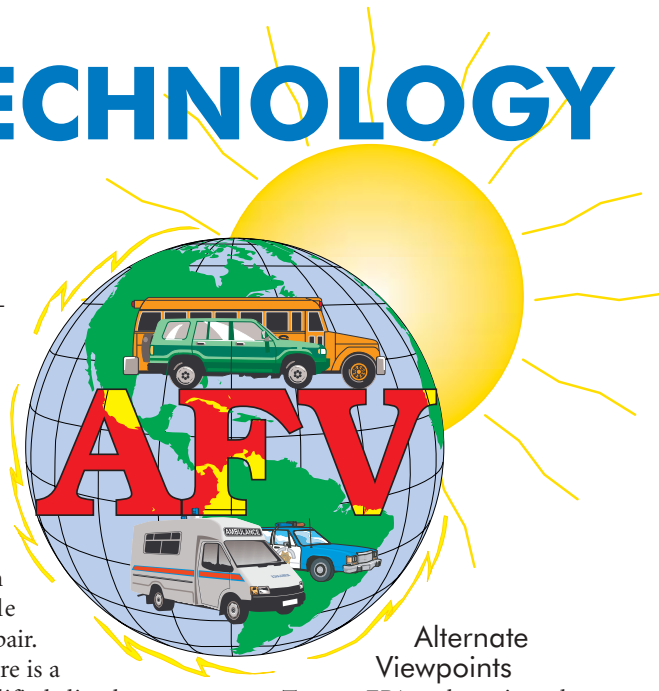
Consumer Perceptions

Along with the era of clean diesel technology comes changing perceptions of diesels by some U.S. light vehicle drivers, and for good reasons. VW with its 1.9 TDI (Turbo-Diesel Direct Injection) hallmarked direct injection and EDC in a diesel passenger vehicle. Reportedly, VW's four-cylinder diesel engine produces 25 more horsepower than did the 1978 Olds V-8 diesel, but is exactly *one-third the size*.[4]

Other OEs have joined the race: diesel 2WD and 4WD pickups and SUVs have become popular alternatives to gasoline powered cars. Joining the traditional farm and construction light diesel vehicle markets are commuters, outdoorsman, sports enthusiasts and the like seeking greater economy or hauling, towing and off-road power in their diesel vehicles. The Chevy Duramax, Ford Powerstroke, and the Dodge/Cummins 24 valve turbo-diesel packages offer popular "premium diesel" options to suit buyers' wants and needs, and are selling briskly.

In the service sector, diesel injection service dealers (SDs) have taken note of the market trend. Where once reluctant to do on-vehicle repairs (preferring instead "over-the-counter" servicing of injectors, pumps, governors and turbos), progressive SDs now offer drive-through diesel vehicle service and repair. As always, there is a need for qualified diesel technicians, and programs exist for becoming certified.[5] Diesel fuel injection test equipment is increasingly sophisticated, more precise, and more expensive as aftermarket fuel system calibration is increasingly expected to equal highly precise factory calibration standards.

Dual Fuel Technology. *Westport's dual-fuel diesel/natural gas HPDI injector for heavy-duty diesel engines. Check the business end: the center pintle sprays a small amount of liquid diesel fuel to start combustion; the circumferential holes inject the main spray (up to 97%) of high pressure natural gas to complete the combustion process.*



Alternate Viewpoints

To meet EPAct, clean air, and cost requirements, some fleet owners have opted to run dual-fuel diesels. A number of suppliers offer OE and/or conversion systems for dual-fuel operation. With such a system, the ignition cycle starts with a very small (as little as 3%) pilot-spray of

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Clean Diesel Technology

The "Nuts and Bolts" of Clean Diesel Technology

What's so special about today's diesel engines? The new breed of "clean diesels" have the ability to more completely and efficiently burn fuel within the engine. Primary enhancements include improved fuel delivery systems, improved configuration of combustion chambers, and turbocharging.

Fuel delivery systems have gone largely from RPM and load dependent mechanical governing systems to electronic diesel control, or EDC. Fuel injection is now done under much higher pressures for complete atomization of fuel sprayed directly into the superheated air of the combustion chamber. Furthermore, electronic control means varying rates of fuel delivery *per cylinder and crankshaft degree* can be done under varying speed and load conditions for quieter and smoother performance. To reduce ignition clatter at idle, a smaller "pilot" spray initiates the combustion cycle, with greater amounts of fuel following ignition. Delivery tapers off near the completion of the combustion cycle for complete burn and low emissions.

EDC enables cleaner, more complete combustion with lower emissions, greater economy and power, and lower noise not previously achievable with either direct or indirect (pre-cup) combustion chambers. The fuel injection industry is moving away from mechanically governed in-line and distributor-type injection pumps to common rail systems (CRS), hydraulic electronically controlled unit injectors (HEUI) and much more.

The shape and depth of the combustion chamber and piston, the number and placement of valves, and intake ports designed for greater swirl, and placement of the injectors all play a role in clean-diesel design and reduction of PM and NO_x.

Turbocharging (for improved swirl and greater air volume) and air-to-air intake intercoolers (to cool down the compressed intake air) increase volumetric efficiency and reduce NO_x. Turbos also mean more power can be derived from smaller displacement (less weight) engines for greater fuel economy.Aftermarket accessories and electronic "chips" are increasingly popular for improving performance within clean air limits for the popular clean-technology diesel engines. OBD-II is now standard.

Reportedly, the EPA's 2007 on-road diesel tailpipe standards will cut NO_x and PM emissions by *98% compared to 1988 levels*. Meeting these standards will require a systems approach. Refinements to systems now used, or new ones soon-to-come, include various types of exhaust after-treatment (catalysts) for NO_x, and particulate traps for reduction of PM.

Thanks to electronics and the inevitable incorporation of 42 volt systems, expect to see the incorporation of "instant-hot" glow plugs; variable valve timing, EGR cooling; electronic variable geometry/electronically assisted turbocharger nozzle and waste gate management; electric water pumps, PS pumps, and A/C compressors; drive-by-wire, brake-by-wire; collision avoidance; increased OBD (the entire powertrain will be monitored); satellite connectivity; and more. The OEs are saying that on-board technology can't do it alone and that the much lower sulfur content in diesel fuel will help (More on that in an upcoming issue of *ASE TechNews*).

Dual-fuel diesels may make use of direct-replacement high-pressure injectors or use electronically controlled port-type gaseous injectors. A pilot ignition spray of diesel fuel starts combustion, followed by a main spray (typically around 88 percent) of the mix. (See main text.)

And all of these developments should mean favorable job opportunities for talented truck technicians who keep ahead of the technology curve with on-going training and study.

This is another in a series of articles on alternate fuels, AFVs, and advanced technology vehicles. For questions or inquiries, contact ASE's Bob Rodriguez at 703-669-6634, or e-mail him at brodriguez@asecert.org.

Alt Fuels

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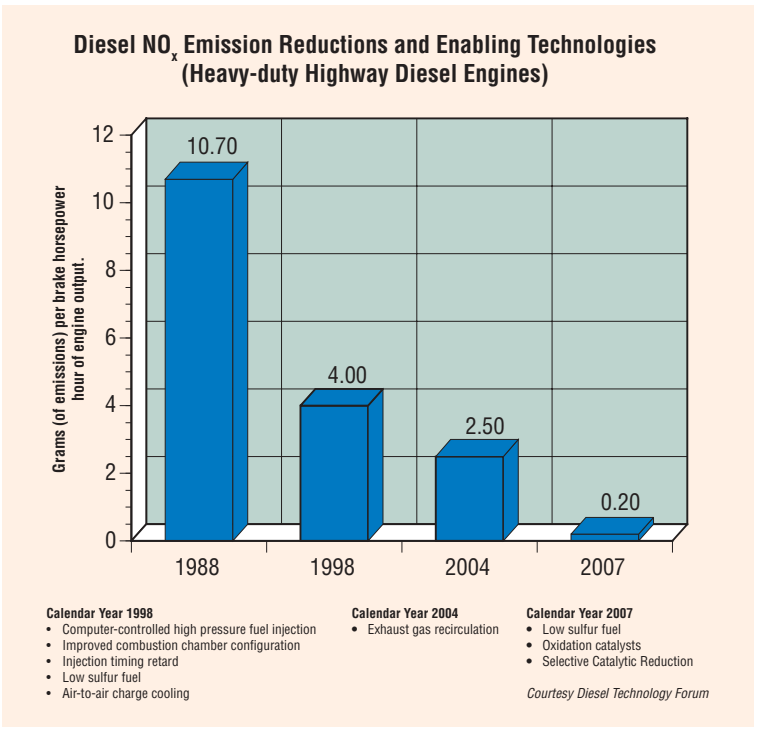
atomized diesel fuel, followed by a main-spray of gaseous fuel such as natural gas or propane. (*See illustration*.) One company, Westport Innovations, makes a "drop-in" replacement injector for dual-fueling heavy duty diesels like Cat, Cummins and Detroit Diesel with natural gas.[6] They're also demonstrating light-duty dedicated compressed natural gas (CNG) diesel vehicles using "glow plugs" for ignition. Other companies offer gaseous fuel conversion systems which use gaseous fuel port injectors for diesels. The decision to run dual-fuel natural gas or propane depends upon costs saved on vehicle purchase, number of miles driven annually, disparity of fuel costs to diesel fuel, state/local tax incentives, and other factors.[7]

Some are unimpressed by the obvious improvements demonstrated by clean diesel technology. Clean air advocates point out that even the cleanest diesels emit smog forming NO_x and as-yet unregulated tailpipe emissions. They also claim that while after-treatment of diesel exhaust may reduce pollution levels *locally*, the resulting altered pollutants transport to other areas, raising pollution levels *regionally*. The Natural Resources Defense Council and the Coalition for Clean Air[8] report they measured high levels of air toxics, NO_x and PM both inside and behind new school buses, claiming that even "so-called 'clean and green' diesel school buses remain dirtier than alternative fuel school buses" such as those powered by natural gas. John Deere, Cat and other OEs offer dedicated CNG engines for medium duty applications like school buses, trash haulers, etc. traditionally powered by diesel. An "apples and oranges" debate rages between advocates of clean diesels and CNG powered vehicles as to which pollute less.

Where We're Headed

For improved emissions and engine performance, mechanically governed rotary and in-line injection pumps are being phased out; common-rail systems, electronic unit-pump systems, and second-generation unit/electronic injectors are phasing in. Admittedly, both gasoline and diesel power will eventually make way for clean, zero-pollution fuel-cell engines. But with clean diesel technology and cleaner diesel fuels available here and now[9], diesels will remain competitive in the marketplace for years to come. As if to lend testimony, one spokesperson recently said: "Dinosaurs became extinct due to changes in climate, and [clean] diesel technology is changing the business climate."



1. Engineering Clean Air: The Continuous Improvements of Diesel Engine Emission Performance, The Diesel Technology Forum, Herndon, VA; www.dieselforum.org.

2. Engineering Clean Air, ibid.

3. Standards drop from present on-road limits of 500 ppm (federal) sulfur content to 15 ppm by 2007.

4. Bill Visnic, The Plain Dealer, *March 7, 2002.*

5. ASE offers certification programs for diesel vehicle technicians, and the Association of Diesel Specialists (ADS) offers credentialing via their TechCert program for diesel injection and related systems technicians. Visit www.asecert.org and www.diesel.org.

6. Westport High Pressure Direct (HPD) Injection: www.westport.com

7. SAE paper 972664 discusses Caterpiller's favorable engine test results using 12% petro-diesel and 88% natural gas.

8. No Breathing in the Aisles, NRDC, Los Angeles, CA: *www.nrdc.org.*

9. Clean fuels will be covered in a future issue of TechNews.