SERVICING LIGHT DIESELS

By Peter Crosby

Clean and efficient diesel-powered vehicles are poised for rapid sales growth in this country. A clear understanding of the underlying technology will be essential when maintenance is required.

America is going to need a lot more technicians to work on diesels five years from now. Diesel sales are expected to outstrip hybrid sales, and will contribute to diesel-electric hybrid sales. Numerous European diesels will be arriving at American shores between now and 2010. Advanced technology that reduces clatter and smoke will convince many drivers that diesels are the answer to rising fuel prices. Future diesel techs can take classes and attend seminars, to be sure, but they can be solving some of the more common problems on today's diesels now.

Not every diesel repair is a fuel system fix requiring specialized tools or knowledge. Diesels require by-the-clock maintenance, which provides an excellent opportunity for diesel techs-in-training. Since diesel engines can last hundreds of thousands of miles—outlasting such components as suspensions, transmissions and hubs, not to mention clutches, brakes and other consumables—those vehicles should be around a long time. The current crop of diesels add dual-mass flywheels, catalysts, cooled EGR, oxidation catalysts and other technology. Much of this can be serviced without advanced diesel diagnostic skills. Current (2007) and later diesels add particulate filters, positive crankcase ventilation, NO_X-reduction technology and more. Since many diesel-powered vehicles will outlast factory warranties even for emissions gear, there will be plenty of work for independent techs.

Let's not kid ourselves. There's no substitute for a trained diesel technician. But there just aren't enough diesel techs to go around, even today, before

Montage by Harold A Perry; photos: Ford Motor Co. and Jupiter Images


MOTOR

Photos: Peter Crosby

The venturi exhaust tip on GM Duramax diesels helps cool extra-hot exhaust gases that are produced during DPF regeneration.

the anticipated surge in diesel sales. You'd be wise to plan a self-education program to get yourself up to speed.

Emissions-Driven Technology

The EPA is tightening diesel emissions requirements like thumbscrews on diesel manufacturers. The current standard is called Tier 2 Bin 5, and 2007 and later diesel passenger vehicles must meet this standard to be sold in all 50 states. The new emissions requirements treat diesels and gasoline engines essentially the same. Manufacturers are entering the market with diesel-powered pickups and SUVs first because the standards for these heavier vehicles are less stringent than they are for passenger vehicles.

The addition of a diesel oxidation catalyst (DOC) on most engines is the first step in meeting the new emissions standards. The DOC consumes unburned hydrocarbons the same way a catalytic converter does on a gasoline engine. Following the DOC is a diesel particulate filter (DPF), which is designed to trap and incinerate soot. It works like a self-cleaning oven. Burn-off, or "regeneration," cycles are under the control of the ECU. A regen cycle heats the DPF to sufficient temperature to convert backpressure-causing soot to ash. At 150,000 miles or so, the DPF must be removed and cleaned of ash, or replaced.

The high temperatures associated with DPF regeneration in turn require so-called flamethrower exhaust tips that dilute hot exhaust gases with air passing beneath the vehicle during regeneration events. *Passive regeneration* occurs when the vehicle is operated at sufficient rpm and load to clean out the

Diesel particulate filter differential pressure and temperature sensors monitor DPF backpressure and signal the ECU when regeneration is required.

This photo shows the combined diesel oxidation catalyst, particulate filter and resonator that help to reduce emissions on a Ford 6.4L PowerStroke engine.

Installation of custom intake and exhaust systems will be problematic on 2007 and later diesels equipped with intake throttling, catalysts and particulate filters.

DPF automatically—such as when towing a trailer up a hill. *Active regeneration* adds fuel and increases engine rpm, and perhaps throttles the intake or exhaust enough to raise exhaust temps to regenerate the filter on an as-needed basis. This typically occurs once per tankful of fuel.

The ECU monitors one or more sensors that measure backpressure and/or DPF temperature and, based on preprogrammed mileage and other factors, decides when to activate the regeneration cycle. Regen can occur at idle. An exhaust hose in a shop can add sufficient backpressure to cause the PCM to go into regen and melt the hose. You've been warned!

Reducing NO_X

Most diesels, car or truck, will be required to add some sort of NO_X-reducing system by 2010. This may be a BlueTec system, which may or may not include urea injection, or a nitrogen reduction converter (see "BlueTec NO_X-Reducing System" below). Honda has developed a converter that reportedly generates its own ammonia (as does urea), to reduce NO_X to oxygen and harmless nitrogen. Two years ago, Delphi announced a fuel reformer device that modifies diesel fuel so it scrubs NO_X when injected into the exhaust.

The DPF is going to pose a problem for diesel owners who want to in-

BlueTec NO_X-Reducing System

DaimlerChrysler (now Daimler *and* Chrysler), VW and Audi have all put their eggs in the same basket by collaborating on a NO_X-reducing technology known as BlueTec. Two variants of the system are being implemented: The AdBlue System, which injects ammonia-generating urea, and the NO_X absorber catalyst/selective catalyst reduction (NAC+SCR) system. Most AdBlue-equipped cars will be introduced in the 2008 model year and be legal in all 50 states.

Exhaust leaves the engine on a NAC+SCR system and passes through a diesel oxidation catalyst (DOC), which reduces carbon monoxide and combusts unburned hydrocarbons. Next is a NO_X absorber catalyst, which removes and traps oxides of nitrogen. During periods of lean operation (high air/fuel ratio) NO_X is stored; under richer conditions, the NAC undergoes a regeneration process that releases ammonia into the exhaust. The ECU can intentionally cause NAC regeneration with consequent ammonia release to occur by richening the mixture.

The released ammonia is stored downstream in the SCR catalyst, which uses it to further chemically reduce NO_X. In between the NAC and SCR catalysts is a particulate filter that traps particulate emissions. As the filter becomes full, backpressure is detected, and a DOC regen cycle is commanded on.

The AdBlue system houses the DOC and particulate filter in a single housing. In addition to the NAC catalyst, ammonia is supplied by injecting a urea-based compound called AdBlue into the exhaust upstream of the SCR catalyst. The addition of AdBlue fluid enables the SCR catalyst to further reduce NO_X. AdBlue is carried in an on-board tank that can be replenished when the vehicle is serviced; a gallon lasts approximately 2400 miles.

BlueTec-equipped vehicles won't meet emissions standards unless the on-board urea tank is occasionally replenished, typically at oil change intervals. The EPA is considering rules that will require a vehicle to reduce power and eventually stop running if the driver doesn't keep the tank filled.

Finally, since inquiring minds want to know, AdBlue is approximately 35% urea, human urine only 5%. Urine also contains salt, which would seriously corrode the injection system. A urea-quality sensor already in use in Japan may not stop owners from filling the tank with, *ahem*, a foreign substance, but it will set a MIL.

This is a cutaway of the fuel injector and glow plug installation on the GM LBZ Duramax diesel. Extended warranties have been introduced for some Duramax injectors.

The revolutionary Honda diesel catalyst generates its own ammonia. It's likely to use plasma technology, details of which were revealed in a recent patent filing.

stall super-sized exhaust systems. Manufacturers aren't keen on such upgrades. There are sensors in the exhaust system that are integrated with the engine ECU. If you remove the DPF and disconnect its sensors, the ECU will throw multiple fault codes and immediately send the engine into a reduced power mode.

New Fuels, New Oil

Ultra-low sulfur diesel (ULSD) fuel is the key to many current and future diesel engine emissions reductions. It contains 97% less sulfur than conventional diesel—reduced from 500 to 15 parts per million (ppm). Sulfur, phosphorous and other undesirable elements are capable of poisoning a DOC catalyst, just like leaded gas could poison a gasoline engine's catalytic converter. Sulfur also increases soot production, another reason why the EPA mandated its removal. Biodiesel poses other problems, and late-model diesel vehicles shouldn't use more than B5 biodiesel.

According to Ford, the new ULSD fuel is compatible with the Ford diesel trucks already on the road, including models with the 6.0 and 7.3L PowerStroke diesel engines. Yet there is the potential for fuel leaks on any model of diesel engine originally designed to run on high-sulfur diesel (HSD) or low-sulfur diesel (LSD) fuel when switched to ULSD. Stanadyne injection pumps used on Ford 6.9 and 7.3L engines, and GM 6.2 and 6.5L engines, experienced similar problems when LSD fuel was first introduced.

GM makes similar claims of backward fuel compatibility. Aside from some possible seal problems due to a reduction of the seal-softening and swelling aromatics in ULSD, it should be fully compatible. Lubricity additives ensure that ULSD fuel is just as slippery as LSD, although the actual additives are different.

The inclusion of a diesel particulate filter in the exhaust also requires use of the new CJ-4 rated oil. Use of this oil is, in a word, *critical* to the proper operation of most diesels, particularly Ford PowerStroke engines, which use oil pressure to pressurize injectors. Scheduled oil and filter changes are maintenance procedures that simply cannot be deferred without potentially costly results. Diesel blowby became much more acidic with the introduction of EGR, consequently contaminating oil much quicker.

CJ-4 rated oils contain new detergent packages that rely on less phosphorus, sulfated ash and sulfur, to avoid poisoning catalytic converters (with phosphorous) and to reduce clogging of particulate filters. Consumed oil is reportedly the primary source of ash in the exhaust. CJ-4 is backward compatible with older diesels, although it works best with ULSD fuel. Filling 2007 and later diesels with LSD or HSD instead of ULSD will cause problems . . . and possibly void the vehicle warranty.

New Technologies

The new technology incorporated into 2007 diesels to help meet tighter emissions standards is just the beginning. Additional diesel technologies already adopted, or coming down the road, include closed-loop operation, multiple-injection events, BlueTec (again, see the sidebar on page 56), increased and cooled EGR, variable-geometry turbos and accelerometer pilot control. Let's look at what these are all about:

Closed-loop operation. Just as oxygen sensors enabled closed-loop fuel control in spark-ignition engines, GM has announced plans to "close the loop" on diesels with piezoresistive cylinder pressure sensors integrated into the glow plugs. The Bosch-supplied units send real-time data to the ECU, which in turn provides precise, closed-loop command of injection timing and cooled exhaust gas recirculation (EGR).

According to Charlie Freese, Executive Director of Diesel Engineering at GM's Powertrain division, "The system uses cylinder-pressure feedback loops to address combustion variation and achieve smooth transitions between combustion modes. The benefit is it may allow GM to avoid the fuel-efficiency penalty that comes with other NO_X-reduction strategies. The system is also responsive to variations in diesel fuel quality, particularly cetane."

Multiple-injection events. Ultrahigh common rail pressures allow multiple-injection events—anywhere from three to nine per compression stroke. Not only can multiple-injection events limit both soot and NO_X production, a preinjection event can virtually eliminate diesel rattle. Multiple primary events greatly reduce soot production. Postignition injections can be used for emissions control, or to boost exhaust gas temperature for DPF regeneration activities. Other systems inject fuel directly after the turbo to achieve desired temperatures for DPF regeneration/ burn-off.

Increased and cooled EGR. EGR processes impact diesel fuel economy from 2% to 6%. Current EGR systems recirculate about 10% of the exhaust; but the systems on 2007 and later vehicles will increase that to 20% to 35%, depending on the engine model. Vastly increased amounts of EGR, in efforts to reduce NO_X production, will trash intakes with levels of oil, soot and other combustion byproducts that diesels have never had to deal with before.

Variable-geometry turbos. In an effort to make diesels both as powerful and as efficient as possible, manufacturers have begun adopting variable-geometry turbos (VGTs) and two-stage sequential turbos. Advanced designs eliminate much of the lag, as well as most of the familiar surge, of prior turbodiesels.

VGT technology improves upon traditional turbocharger design by enabling boost control, which is performed by controlling the exhaust turbine inlet pressure. At low engine speeds, the increased pressure generates higher boost than with a traditional design.

The Garrett turbocharger used on Ford 6.0L PowerStroke engines changes boost pressure by using a piston to rotate a cam that rotates a ring that pivots the vanes. A common problem is that surface rust and carbon buildup can cause the unison ring or the vanes to bind or seize in the housing.

Accelerometer pilot control. Accelerometer pilot control is the diesel equivalent of the gasoline knock sensor. It greatly reduces clatter and other diesel NVH problems by measuring minute accelerations for each cylinder, with the ECU continually adjusting pilot injection timing and width. It may also provide some compensation for wear of the injectors and other components, according to manufacturers' literature.

No More Smoke

With new technologies come new challenges. All of the new emissions technologies, including diesel oxidation catalysts, nitrogen-reduction converters, particulate traps, etc., eliminate most of the diesel smoke. Unfortunately, smoke was a helpful diesel diagnostic tool. Piezoelectric fuel injectors may or may not prove to be as reliable as prior designs. One of Ford's "flamethrower" Super Dutys was blamed on a faulty piezo injector, another on a blown turbo seal.

Ford's solution? A reflash. Hopefully, tailpipe flames won't replace black smoke as an injector diagnostic tool! DPF temperature sensors, if cleverly programmed, should suffice to warn owners of higher exhaust gas temperatures caused by stuck-open injectors, perhaps even identifying the offending injector, then shutting it down to prevent engine damage. The venturi exhaust designs added by manufacturers have the unintended consequence, when supplied with excess fuel, of turning into small jet engines.

Service Issues

Three diesels dominate domestic sales today—the Cummins diesel used in Dodges, Ford's PowerStroke and GM's Duramax. GM 6.2 and 6.5L diesels predate the Duramax moniker, but many of these earlier vehicles are still on the road. Even newer, higher-tech diesels are already on the way from Ford and GM, including a 4.5L Duramax from GM. And don't forget there are three or four generations of each diesel engine already on the road—for example, the Ford 6.0, 7.3 and now the 6.4L versions of its PowerStroke.

To outline so-called common problems borders on impossible when you consider that more than 70 TSBs have been issued on PowerStroke engines alone, and there have been more reflashes than you can count. But don't give up! Just keep checking your service information for the latest remedies for any service issues that might arise on diesel engines—just as we're sure you've been doing for gasoline engines.

On the Horizon

A new day in diesels has dawned. While cleaning up diesel emissions is the motivating force, the technological enhancements required to meet the new standards offer benefits far beyond clean air. Added benefits include easier starting, reduced rattle and near complete elimination of smoke. Greater adoption of diesels means greater opportunity for techs willing to learn how to repair them. A diesel seminar from a reputable training vendor might be the best career investment a tech could make today.

Diesel hybrids are a logical next step, and we may see them in passenger vehicles relatively soon. No longer will diesel engines be limited to big trucks. While clean diesels may merely be entering the "feedback carburetor" phase of their development, all the added complexity means even greater need for qualified techs.