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Diesel Fuel is Changing—Again

The Engine Manufacturers Association (EMA) and the American Petroleum Institute (API) agree that there is a need to reduce sulfur in diesel fuel to aid the engine manufacturers in meeting future exhaust emissions requirements. Texaco's Roger Leisenring examines the need to improve fuel quality and the effect it will have on additives.

Many of my plans are paved with good intentions and my plan to spring clean my office was no different; however the actual cleaning did not occur until the beginning of the summer. Many of the papers and mail that had accumulated on my desk throughout the year found their way to the recycle bin except for two. The two that I found interesting were a press release and a document generated by the Engine Manufacturers Association (EMA) and the American Petroleum Institute (API).

EMA is a trade association that is comprised of domestic and international manufacturers of internal combustion engines for trucks and buses, locomotives, marine vessels and construction and utility equipment. EMA has 35 member companies that build the engines, which range in size from one to more than 7,000 horsepower.

API is the major national trade association representing the entire petroleum chain: exploration and production, transportation, refining, and marketing.

What was interesting about these documents was that EMA and API were in agreement. When it comes to reducing sulfur in diesel fuel to help the engine manufacturers meet future exhaust emissions requirements, there is no argument. These two organizations have had a history of being diametrically opposed on many issues (oil vs. engine makers). But on the sulfur issue, the only disagreement that remains is how much sulfur should be removed from the diesel fuel. But, before we delve further into this issue, let's discuss some basic facts about emission standards and engine technology.

Emission standards

The need for improved fuel quality—especially improved sulfur content—is integrally linked to establishing emission standards that can be met. By way of an example, a new low-sulfur fuel standard of 500 ppm maximum sulfur came into effect for on-highway fuel in October 1993. That standard was directly linked to the 0.1 g/bhp-hr particular matter (PM) standard that became effective for the 1994 model year. Without low-sulfur fuel, the 0.1 g/bhp-hr PM standard would not have been technologically feasible. Engine emission controls and reductions in diesel fuel sulfur resulted in a 90 percent reduction in the engine-out particulate emissions from unregulated levels. Without this linkage of the engine standard and fuel standard, such a dramatic reduction in PM emissions would not have been achievable.

The standards for diesel fuel also are integrally linked to future emission standards. EPA recently released its Tier 2 Proposal covering light-duty gasoline and diesel vehicles. The Tier 2 Proposal represents a sweeping revision to EPA's light-duty vehicle regulatory program. As discussed above, it would establish extremely stringent standards for light-duty vehicles. Moreover, in various recent meetings, EPA has declared its intent to increase the stringency of standards for both heavy-duty on-highway engines and non-road engines beyond the levels set forth in the historic agreement (Statement of Principles) the EPA signed with the leading manufacturers of heavy-duty engines to reduce engine emissions, bringing the nation closer to the goal of clean, healthy air. Areas where EPA has indicated its intent to increase stringency include:

- Adding supplemental tests for heavy duty on-highway engines.
- Expanding the operating conditions—temperature, humidity and altitude—included in in-use testing.
- Eliminating control strategies that reduce white smoke.
- Adding supplemental tests for non-road engines, possibly including transient tests.
- Changing the Tier 3 PM standard for non-road engines.
- Moving towards adopting aftertreatment-forcing standards for heavy-duty on-highway engines in the next set of standards after 2004.

The technological feasibility in each of these areas of increased stringency must be examined carefully. The engine system technology expected to be available must be considered, along with quality of available fuel. Only then can a cost-effective and commercially viable approach to emission reductions be established.

Wear on a vane in a fuel injection pump due to low lubricity fuel

Engine system technology

Once the available fuel and the emission standards are known, appropriate engine system technology can be developed, tested and put in place. The connection among fuel, standards and technology can be illustrated, in part, through a review of the factors that create diesel engine emissions. Diesel engines convert diesel fuel to useful work through a combustion process that takes place in the engine cylinders. The engine emissions that result from the combustion process are a direct result of the following factors:

- The chemical composition of the fuel
- The chemical composition of the inlet mixture
- The temperature of the air and of the fuel

- The motion of the air and of the fuel
- The delivery method of the fuel to the air
- The distribution of the fuel in the air during combustion
- The motion of the combustion process
- The temperature of the combustion process
- The chemical reactions that take place after the combustion process

Each of the above factors must be carefully controlled if emissions are to be minimized. Initially, emissions are controlled within the combustion chamber. For example, most of the recent oxides of nitrogen (NOx) reductions from diesel-fueled engines have been achieved through reductions in the air temperature (achieved through air-to-air aftercooling) and reductions in the combustion temperature (achieved through retarded timing).

Once reductions in the combustion chamber have been achieved, additional emission reductions must be obtained through the use of aftertreatment technologies or through improvements in fuel quality. For example, initial reductions in PM have been achieved through the distribution of the fuel in the air during combustion (achieved through high injection pressure) and through transient air-to-fuel ratio control. Significant additional PM reductions, however, were achieved through improvements in the composition of diesel fuel (500 ppm sulfur). Current engines are highly optimized and exhibit emissions levels very close to the lowest levels that can be achieved with base engine modifications alone.

EMA anticipates that future reductions in emissions will be achieved through control of the inlet chemistry, through exhaust gas recirculation ("EGR") or through the use of aftertreatment systems to reduce emissions in the exhaust stream after the combustion process. As EPA establishes more stringent standards for diesel-fueled engines, EPA must determine technological feasibility based on a systems approach to compliance in which engine technology and fuel quality are integrally linked.

In its rulemaking on the desulfurization of diesel fuel, EPA must recognize the linkage between fuel specifications, emission standards and engine system technology. There is no engine technology that is not affected by fuel sulfur levels. In addition, fuel sulfur levels have a direct impact on the appropriate formulations for lubricating oil, lubricating oil life, engine durability (including pistons, rings, liners, valves and turbochargers), fuel system life, the amount of EGR that can be employed on an engine and the life of various aftertreatment devices. Fuel sulfur content is the property that has the greatest overall impact on engine system design and future emissions capability.

PM emissions control

According to a paper written by the Manufacturers of Emissions Controls Association (MECA), two exhaust control strategies are available to control PM emissions: oxidation catalysts and particulate filters (traps). However, current sulfur levels in diesel fuel preclude the introduction and use of the most promising particulate filter technology. Current diesel fuel also significantly impedes the effective use of other catalyst-based PM-control technologies.

Oxidation catalysts reduce PM emissions, as well as volatile organic compounds (VOCs) and carbon monoxide (CO). Oxidation catalysts also are durable, with little or no deterioration in emissions over time. With current diesel fuel, however, sulfur in the fuel converts to sulfate, offsetting the reductions in organic particulate matter. In addition to reducing sulfate conversion, very-low sulfur fuel also would enable the use of more active catalysts, allowing for greater organic particulate emission reductions.

Particulate filter technology also can be very effective at reducing PM emissions to very stringent levels, provided that sulfur in the fuel is greatly reduced. Advanced particulate filter technologies utilize pre-filter catalysts to convert NO to NO2 which reduces the temperature required for filter regeneration. Sulfur in the fuel inhibits the NO to NO2 conversion process causing regeneration light-off temperature to increase outside the normal exhaust temperature, with the result that the filter eventually plugs. This is particularly critical for light-duty applications, which generally operate at lighter loads and lower exhaust temperatures. As a result, ultra-low sulfur fuel is required in order to enable the effective use of particulate filter technology.

Here come the changes

According to EMA, new, more-stringent oxides of nitrogen (NOx) and particulate matter (PM) engine exhaust emission standards for heavy-duty on-highway engines and vehicles are set to become effective in 2004. As part of the 1999 EPA Technology Review, which is expected to be published soon, EPA will review the feasibility of the 2004 standards and is expected to include new and expansive test procedures and compliance requirements for 2004, including a wider range of in-use test conditions that will directly affect stringency. A portion of those new procedures and requirements will be in place for some engine manufacturers as early as 2002. Key to meeting those new—and significant—challenges in complying with current and future standards are significant further reductions in diesel fuel sulfur. It is clear that reductions from current diesel fuel sulfur levels are needed for heavy-duty engines by 2002/2004.

EMA says that “the need for improved fuel quality—especially improved sulfur content—is integrally linked to the emission standards that can be met. For light-duty vehicles, a diesel fuel with near-zero sulfur content at 5 ppm or less is essential. EPA must require that diesel fuel with near-zero sulfur levels, and with improvements to other key constituents, be available for light-duty vehicles in order to support the critical linkage among engine technology, feasible standards and fuel. Such fuel would provide direct PM emission reduction benefits from both new and existing vehicles and enable the use of technologies that provide substantial NOx and PM emission reductions.”

O-ring seals, which were old, developed leaks after low sulfer (500 ppm) was introduced in 1993

The cost of this near-zero sulfur diesel fuel was estimated by an EMA sponsored economic study on the refining costs associated with the desulfurization of diesel fuel. The study concludes that the incremental cost to reduce current sulfur levels in diesel fuel 90 percent—from 500 ppm to below 50 ppm—would average about 5 to 7 cents per gallon. However, the study also found that it would cost only an additional 2 cents per gallon to go from 50 ppm to below 5 ppm sulfur, which is the sulfur cap that emission control device manufacturers have identified to maximize the performance of their control technologies.

API's position is that the oil industry supports cost-effective reductions in on- and off-road heavy-duty diesel engine emissions. The reductions must be based on sound science and involve both vehicle and fuel systems that have been demonstrated to be technically feasible. API strongly opposes the sulfur limits that EMA has suggested. Extremely low sulfur limits are not feasible for the entire industry, according to API. It would be very expensive and could cause supply problems, especially during unanticipated events such as refinery or pipeline accidents. API is, therefore, advocating a 90 percent reduction in diesel fuel sulfur content of both on-road and off-road diesel fuel when aftertreatment systems requiring these low sulfur levels are in the marketplace, but no sooner than 2007. For future on-road diesel fuel, API supports an average sulfur level of 30 ppm, with a 50 ppm cap. For future off-road diesel fuel, API supports a cap of 500 ppm.

This proposal to reduce sulfur in diesel fuel reminds me of the numerous fuel seal failures that occurred in October 1993. These seal failures occurred across a wide spectrum of diesel equipment and were reported by the California Air Resources Board (CARB).

Cummins experienced o-ring seal failure at the throttle shaft of the fuel pump that had been in service 367,000-818,000 miles. It is not surprising that failures would occur on vehicles with this amount of mileage. However, the failures occurred within weeks of the change to low sulfur diesel fuel (500 ppm).

In addition to seal failure, diesel fuel injection equipment manufactures reported an increase in the repair of fuel injection pumps, which they attributed to the lower lubricity of the new low sulfur diesel fuel.

During that time, the public was very upset with CARB and the EPA and, in fact, a fund was set up by the state of California to reimburse any California trucker who may have experienced engine failure due to the fuel. However, seven years after the introduction of the low sulfur diesel fuel, there has not been a definitive answer as to whether or not the low sulfur diesel fuel has caused the problems.

I hope that, with this go around with Ultra Low Sulfur Diesel Fuel, EPA, EMA or API are doing tests to assure that the nation's diesel vehicles don't experience a fate similar to that experienced in 1993. Otherwise, the public will lose faith in the ability of the EPA to protect the environment without unduly harming the consumer. Remember the MTBE in gasoline fiasco?

One thing is certain: as problems occur because of the changes to diesel fuel, additives will continue to provide a vital role in protecting hardware for the consumer.

At the time this article went to print, the EPA announced the proposed particulate matter (PM) emissions standard for new heavy-duty engines of 0.01 grams per brake-horsepower-hour (g/bhp-hr), oxides of nitrogen (NOx) and nonmethane hydrocarbons (NMHC) of 0.20 g/bhp-hr and 0.14 g/bhp-hr.

The new emissions standards are proposed to take full effect in the 2007 heavy-duty engine (HDE) model year.

EPA also announced a proposal for diesel fuel sold to consumers for use in highway vehicles. EPA proposed that, beginning June 1, 2006, deisel fuel must have a sulfur content no greater than 15 parts per million (ppm). This proposed sulfur cap is based on the EPA assessment of how sulfur-intolerant advanced aftertreatment technologies will be, and a corresponding assessment of the feasibility of low-sulfur fuel production and distribution.

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