Clean Air Facts

Cleaner Fuels for Cleaner Motor Vehicles

Overview

Motor vehicle exhaust emissions are influenced not only by the emission control system but by engine design and fuel quality as well. Since the mid-1970s, catalyst technology and engine designs have advanced dramatically, contributing to significant reductions in exhaust emissions. Changes in fuel quality, most notably eliminating lead in gasoline and reducing fuel sulfur levels, have also helped reduce emissions.

Adverse Impacts of Fuel Sulfur

- Sulfur in gasoline or diesel fuel inhibits the emission control performance of various emission control technologies.

- Sulfur competes with exhaust pollutants for space on the active catalyst surface (see Figure 1). Upon combustion, fuel sulfur is oxidized to sulfur oxides, primarily sulfur dioxide (SO_2), with small amounts of sulfur trioxide (SO_3). SO_2 and SO_3 are known to inhibit the catalytic function of catalytic converters.

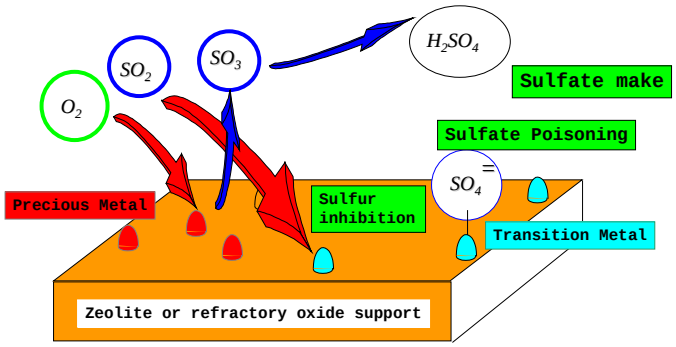

Figure 1. Diagram of the adverse impact of fuel sulfur on emission control technology – sulfur species react with catalyst materials resulting in degraded catalyst performance.

- Sulfur inhibition of precious metal-based catalyst emission performance depends on a variety of catalyst- and vehicle-related parameters, including: precious metal type/precious metal catalyst concentration; oxygen storage composition/concentration; catalyst design (e.g., placement of precious metals and/or oxygen storage components); catalyst location/converter volume/operating temperature; catalyst aging history; inlet exhaust gas composition (i.e., engine calibration); and fuel sulfur level.

Sulfur in Gasoline Fuel

- Numerous vehicle studies have been completed that consistently show lower exhaust emissions result from a wide range of vehicle technologies operating with lower gasoline sulfur levels (e.g., see the CRC E-84 report from August 2008 available at: www.crcao.org).

- A recent published study (SAE paper number 2011-01-300) shows sulfur inhibition for a late model, aged vehicle's three-way catalysts operating at very low emission levels (SULEV exhaust emission levels) and at very low fuel sulfur levels (33 ppm sulfur vs. 3 ppm sulfur fuel comparison). The vehicle emission system included close-coupled and underfloor catalytic converters utilizing advanced three-way catalysts. The performance of the vehicle's cooler-running, underfloor converter was most impacted by operation on higher fuel sulfur levels.

U.S. EPA's Tier 2/Gasoline Sulfur Rulemaking

- The current light-duty vehicle emission standards are the U.S. EPA's Tier 2 program (finalized in December 1999) and the California ARB's Low Emission Vehicle II (LEV II) program (finalized in November 1998). Both programs began their phase-in with the 2004 model year. Phase-in for the LEV II program was completed with the 2006 model year, while the Tier 2 program was fully phased-in with the 2009 model year.

- The Tier 2/LEV II programs have several common features: fuel neutral requirements (emission standards are equivalent for gasoline- and diesel-fueled vehicles); 120,000-mile full useful life durability; and a single set of standards that does not vary with light-duty vehicle weight class

- In the Tier 2 rulemaking, EPA concluded that new light-duty vehicle emission standards could be achieved cost-effectively with available technology and that current levels of sulfur in gasoline must be reduced because sulfur impedes the performance of catalytic converters. The rule required the nation's gasoline suppliers to meet a 30 ppm average sulfur level with a maximum cap of 80 ppm in 2006. California's gasoline sulfur cap was reduced from 60 ppm to 30 ppm in 2006, and will be reduced further to 20 ppm effective in 2012.

- Compared to pre-controlled vehicles sold in the U.S. prior to 1975, today's Tier 2 and LEV II cars and trucks are meeting emission standards that require reductions of up to 98+ percent with respect to VOCs, 96 percent for CO, and 98 percent for NOx.

- The European Union has established a 10 ppm sulfur cap for gasoline (required for Euro 5 light-duty emissions compliance).

U.S. EPA's Tier 3/Gasoline Sulfur Rulemaking

- EPA plans to propose additional tightening of light-duty vehicle exhaust emissions that would result in a SULEV fleet average for new vehicles by 2025. The EPA proposal is expected to further reduce the federal cap on gasoline fuel sulfur in the range of 20-30 ppm and reduce the federal average gasoline fuel sulfur to around 10 ppm. The EPA proposal is expected to be released by the end of 2011.

- Further reductions in federal gasoline fuel sulfur levels will deliver significant emission reductions to the existing fleet of U.S. light-duty vehicles and allow for the application of cost optimized, advanced three-way catalyst system designs on future ultra-low emission Tier 3 vehicles. The overall reductions in light-duty vehicle emissions associated with EPA's upcoming proposal are expected to deliver significant health benefits.

- Lower gasoline fuel sulfur limits will enable auto manufacturers to further optimize vehicle fuel efficiencies through the application of lean gasoline engine technologies that utilize sulfur sensitive emission control strategies, such as lean NOx adsorber catalysts to meet future Tier 3 emission limits.

Sulfur in Diesel Fuel

- High sulfur levels in diesel fuel (e.g., above 50 ppm) are a barrier to the commercial introduction of advanced NOx emission control technologies, such as lean NOx catalysts and NOx adsorbers, as well as catalyst-based filter technologies on new engines and the application of similar retrofit-based emission control technologies on existing diesel engines.

- Also, high sulfur levels in on-road diesel fuel inhibits the particulate matter (PM) control efficiencies of oxidation catalysts and catalytic particulate filter technologies, thus preventing the further optimization of these technologies for maximum effectiveness for PM and hydrocarbon (HC) control.

- In the U.S., prior to 2006, sulfur levels in diesel fuel for on-road vehicles were as high as 500 ppm and levels for off-road vehicles and equipment were as high as 5000 ppm.

U.S. EPA's 2007/2010 Heavy-Duty Engine Standards/Low Sulfur Diesel Rule

- Finalized in December 2000, the rule capped sulfur levels in on-road diesel fuel at 15 ppm beginning in 2006.

- In addition, the rule required on-road, heavy-duty engines to meet a 0.2 g/bhp-hr NOx standard that was phased in over the 2007-2010 timeframe and a 0.01 g/bhp-hr PM standard starting in 2007. The standards required a 90 percent reduction of PM emissions and a 95 percent reduction in NOx emissions compared to the previous EPA heavy-duty highway diesel standards. Since 2007, all new heavy-duty truck engines sold in the U.S. and Canada have been equipped with catalyst-based, diesel particulate filters.

- The European Union has established a 10 ppm sulfur limit for on-road diesel fuel (required for Euro V heavy-duty emission compliance).

U.S. EPA's Tier 4 Clean Air Nonroad Diesel Rule

- Finalized in May 2004, EPA's Tier 4 nonroad diesel engine rule set a 500 ppm sulfur limit on diesel fuel produced for nonroad engines, locomotives, and marine applications starting in 2007.

- This EPA rule also set a limit of 15 ppm sulfur for nonroad fuel starting in 2010 (2012 for locomotive and marine applications) to enable the use of advanced diesel emission control technologies such as catalyst-based, diesel particulate filters to meet EPA's Tier 4 nonroad emission limits.

U.S. EPA's National Clean Diesel Campaign/California's Diesel Risk Reduction Program

- EPA's and California's 15 ppm sulfur limits on both on-road and nonroad diesel fuel have allowed for the application of verified, retrofit catalyst-based diesel particulate filters on existing diesel engines. These verified, catalyst-based retrofit filters reduce diesel particulate matter by more than 85 percent from a wide range of older diesel engines. Tens of thousands of these retrofit filters have been installed on older trucks and off-road equipment in the U.S. as a part of EPA's National Clean Diesel Campaign and California's Diesel Risk Reduction-related regulatory programs.

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