Clean Air Facts

Emission Controls for Diesel Engines

Overview

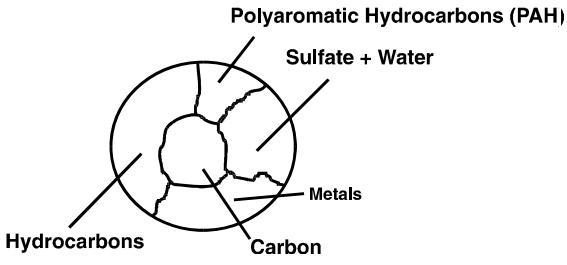
Recently, health experts in the U.S. have identified serious health risks associated with emissions from diesel engines, especially oxides of nitrogen (NOx) and particulate matter (PM) emissions. Cost-effective diesel exhaust control options such as catalysts and particulate filters are available which can significantly reduce emissions from diesel-powered trucks, buses, and off-road equipment.

Health Effects and Emissions Inventory

- Emissions from diesel engines contribute to serious public health problems in the U.S. These problems include premature mortality, aggravation of respiratory and cardiovascular disease, aggravation of existing asthma, acute respiratory symptoms, chronic bronchitis, and decreased lung function.
- A comprehensive assessment of available health information carried out by U.S. EPA in May 2002 concluded that diesel exhaust is likely to be a human carcinogen by inhalation.
- In 2000, on-road diesel-fueled vehicles contributed approximately 25 percent of the NOx emission inventory for mobile sources and approximately 23 percent of the PM_{10} emissions.
- An older, dirtier diesel vehicle can emit almost 8 tons of pollution per year. This amounts to 160 to 240 tons of pollution over the life of the engine.
- A heavy-duty truck can create the same amount of air pollution as 150 passenger cars.

Particulate Matter from Diesel Engines

- Diesel particulate consists of small carbon particles that are coated with several compounds which are formed during the engine combustion process and the subsequent travel of these particulates down the exhaust stream.



- Diesel engines emit a very large number of particulates that are extremely small (less than 10 microns) consisting of a carbon core and known and possible cancer-causing substances (e.g., polyaromatic hydrocarbons) that are carried directly into the lungs where a large fraction remains.
- Diesel particulates are also of concern because they are typically emitted directly into the breathing zone where the urban population works and recreates.

So Why Continue to Use Diesel Engines?

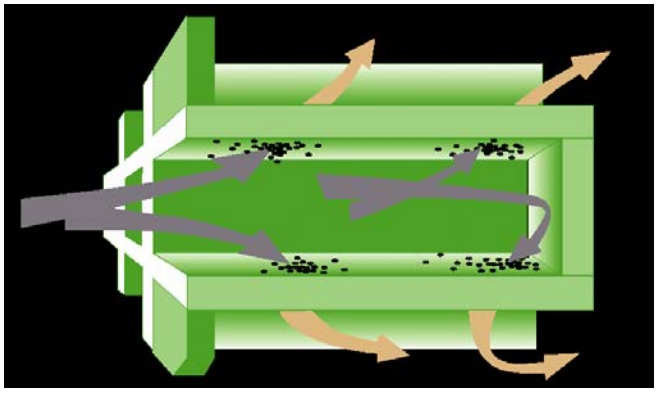
- Diesel engines are reliable, fuel efficient, durable, easy to repair, and inexpensive to operate.
- A diesel engine commonly has a life of one million miles in heavy-duty trucks and can power city buses for 15-20 years.
- Diesel engines are inherently cleaner in some ways, including:
  - better fuel efficiency means lower global-warming emissions, and
  - very low emissions of carbon monoxide and hydrocarbons, although the latter is one of the primary ingredients of urban smog and consists of toxic HC species.

Emission Control Technologies

High Efficiency Diesel Particulate Filters (DPFs)

- High efficiency diesel particulate filter (DPF) removes PM in diesel exhaust by filtering exhaust from the engine. The filter systems can reduce PM emissions by 80 to greater than 90 percent.

Wall-Flow Diesel Particulate Filter



- High efficiency filters are extremely effective in controlling the carbon fraction of the particulate, the portion that some health experts believe may be the PM component of the greatest concern.
- Since the volume of particulate matter generated by a diesel engine is sufficient to fill up and plug a reasonably sized filter over time, some means of disposing of this trapped particulate must be provided. The most promising means of disposal is to burn or oxidize the particulate in the filter, thus regenerating, or cleansing, the filter. This is accomplished through the use of a catalyst placed either in front of the filter or applied directly on the filter, a fuel-borne catalyst, or burners which are used to oxidize or combust the collected particulate.
- Low pressure EGR systems are used for retrofit applications in conjunction with high efficiency DPFs. In a low pressure EGR system, the recirculated exhaust is taken from downstream of the high efficiency DPF.
- Around the world, more than 200,000 DPFs have been installed as retrofits and more than 1 million DPF-equipped cars have been sold in Europe. DPFs have also been used successfully on a variety of off-road engines since the mid-1980s.

Flow-Through Filters

- Flow-through filter technology is a relatively new method of reducing diesel PM emissions that unlike a high efficiency DPF, does not physically "trap" and accumulate PM. Instead, exhaust flows typically through a catalyzed wire mesh or a sintered metal sheet that includes a torturous flow path, giving rise to turbulent flow conditions. Any particles that are not oxidized within the flow-through filter flow out with the rest of the exhaust.

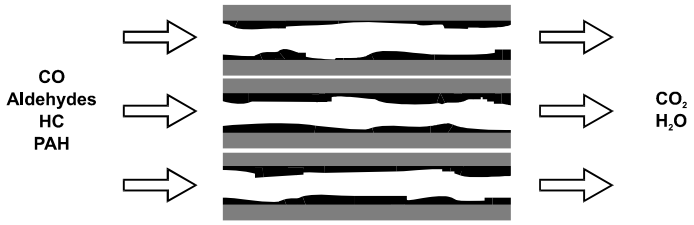
- So far, there have been limited commercial use of the flow-through filters but there is an increasing interest in this technology due to its ability to significantly reduce PM emissions from older, "dirtier" diesel engines.

- Flow-through systems are capable of achieving PM reduction of about 30 to 70 percent.

Diesel Oxidation Catalysts (DOCs)

- Like catalytic converters already used on all new gasoline vehicles, diesel oxidation catalysts (DOCs) cause chemical reactions to reduce emissions without being consumed and without any moving parts.

Diesel Oxidation Catalyst Functional Diagram



- The catalysts reduce particulate emissions by as much as 50 percent, can reduce visible smoke, and can virtually eliminate the pungent odor of diesel exhaust.

- The catalysts can reduce the invisible gaseous ozone-forming hydrocarbons by more than 70 percent and carbon monoxide emissions by as much as 90 percent.

- DOCs have been equipped on over 250,000 off-road diesel engines worldwide for over 30 years, and on over 1.5 million new heavy-duty highway trucks since 1994 in the U.S.

- DOCs can be installed on new vehicles or can be retrofitted on vehicles already in-use.

- DOCs can be used not only with conventional diesel fuel, but have been shown effective with biodiesel and emulsified diesel fuels, ethanol/diesel blends, and other alternative diesel fuels.

Selective Catalytic Reduction (SCR)

- Selective catalytic reduction (SCR) systems use a wash-coated or homogeneous extruded catalyst and a chemical reagent to convert NOx to molecular nitrogen and oxygen in the exhaust stream. In mobile source applications, an aqueous urea solution is usually the preferred reductant.

- As exhaust and reductant pass over the SCR catalyst, chemical reactions occur that reduce NOx emissions. SCR system can reduce NOx emissions by 75 to 90 percent, HC emissions by up to 80 percent, and PM emissions by 20 to 30 percent.

- SCR has been used on stationary sources since the 1980s and is beginning to find use in mobile source applications, including line-haul trucks, off-road equipment, marine vessels, and

locomotives.

NOx Adsorbers

- NOx adsorber technology is a catalyst technology for removing NOx in a lean (i.e., oxygen-rich) exhaust environment for both diesel and gasoline lean-burn direct-injection engines.

- NOx adsorber technology has made significant progress and is currently being optimized for diesel engine emission control. Reductions in engine out NOx emissions of as high as 90 percent have been demonstrated and it appears possible to develop the system into a functional and durable NOx control system for diesel exhaust.

Closed Crankcase Filters

- Closed crankcase filters are used to reduce emissions from crankcase breather tubes in most turbocharged aftercooled diesel engines by using a multi-stage filter designed to collect, coalesce, and return the emitted lube oil to the engine's sump.

- For MY 1994 to 2006 heavy-duty diesel engines, crankcase PM emissions reductions provided by crankcase emission control technologies are about up to 25 percent of the tailpipe emission standards.

Regulations

- In August 2000, EPA reaffirmed that the 2.5 g/bhp-hr NMHC+NOx standard promulgated in October 1997 for heavy-duty diesel engines is both necessary and feasible. This standard, which took effect in 2004, represents about a 50 percent reduction in emissions of nitrogen oxides, as well as reductions in hydrocarbons, from diesel trucks and buses. Several HDE manufacturers met the standard beginning in October 2002 as a result of signing a consent decree with the U.S. Government.

- In December 2000, EPA adopted very stringent emission standards for heavy-duty vehicles that will reduce smog-causing emissions from trucks and buses by 95 percent beyond current levels and PM emissions by 90 percent starting in 2007. The rule also requires the sulfur content of on-road diesel fuel to be capped at 15 parts per million beginning in 2006, a 97 percent reduction from current levels.

- In May 2004, EPA announced a comprehensive rule to reduce emissions from nonroad diesel engines by integrating engine and fuel controls as a system to gain the greatest emission reductions. The new emission standards apply to most construction, agricultural, industrial, and airport equipment. The standards will take effect for new engines beginning in 2008 and be fully phased in for most engines by 2015.

For more information:

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