Reducing Diesel Engine Particulate Emissions

NFESC Demonstrates Potential of Self-Regenerating Filters

The Naval Facilities Engineering Service Center (NFESC) recently completed a four-year project to demonstrate the potential of self-regenerating soot filters in reducing diesel engine particulate matter (PM) emissions.

These filters are installed in the engine's exhaust system to trap engine PM emissions and periodically chemically oxidize the soot through a process called "regeneration." The Environmental Security Technology Certification Program (ESTCP) sponsored the project, with additional funding provided by Cummins, Inc. Two types of soot filters were demonstrated, catalyzed soot filters (CSF) that are regenerated using only the heat of the engine and electrically regenerated soot filters.

Removed Thomas bus muffler (left) next to catalyzed soot filter (right).

For the CSFs, a greater than 90 percent particulate matter emission reduction was achieved. The electrically regenerated soot filters exhibited a 62 percent average reduction in particulate emissions. The CSFs also demonstrated a minimum carbon monoxide (CO) and hydrocarbon (HC) reduction of 49 percent and 72 percent, respectively.

The goal of reducing diesel engine PM emissions has become more important in recent years. Although diesel engines are known to emit several other types of air pollutants including CO, HC, and nitrous oxides (NOx), the emissions of PM are of special concern because of their effect on human health. Small particulate matter, specifically those having diameters of less than 2.5 microns, have been identified as a potential human carcinogen. To address this concern, the Environmental Protection Agency (EPA) has recently issued regulations to reduce the allowable PM emissions. These standards are applied to equipment and vehicles at the time of manufacture.

As an example, the model year 2007 EPA highway emissions limits of 0.01 gram per brake horsepower hour (g/bhp-hr) represent a 90 percent reduction from the 2000 model year baseline and a 98 percent reduction from the 1990 baseline. Because these emissions decreases do not affect existing diesel engines, the full benefit of these new regulations will take more than 20 years to achieve. In an effort to achieve the benefits sooner, several states have proposed additional regulatory strategies to reduce emissions for existing engines.

Data logger in installed gray box above Thomas bus soot filter.

To verify that soot filters would be a suitable technology for reducing Department of Defense (DoD) diesel engine PM emissions, the ESTCP sponsored a demonstration project that included laboratory testing, field

The demonstration showed that soot filters can be effective in reducing particulate matter emissions from diesel engines.

Air Force tactical diesel generator with Rypos soot filter installed on top of unit.

investigations, and the field demonstrations. In the laboratory phase, filter aging tests were performed to obtain an estimate of the expected filter life. This work suggests that soot filters should last from five to 12 years in typical DoD applications. In the field demonstration phase, 10 engines located at various DoD field activities in Southern California were used. Soot filters were installed in place of the existing mufflers on buses, stake trucks, and trailer-mounted portable generators. The filters were field tested over a four- to nine-month period using the engine's normal duty cycle. At the completion of the demonstration, the filters were returned to their manufacturers for destructive analysis. This analysis identified some required minor design changes and supported the previous filter life estimates.

The CSFs demonstrated by the project were composed of a ceramic substrate washcoated with a platinum-based catalyst. Such a system, developed by Engelhard, Inc., oxidizes the trapped soot at temperatures as low as 360 degrees Celsius, in essence cleaning out the filter. This regeneration method is referred to as passive since no external heat energy enters into the system to achieve soot oxidation. Rather, the system relies on the duty cycle of the engine to generate high enough temperatures to initiate soot combustion. Unfortunately, many light-duty engines do not generate exhaust temperatures conducive to passive regeneration of soot filters. Even heavy-duty engines operating under light load conditions or in cold weather can result in partial or complete plugging of the filter, thereby, inducing high engine back-pressures, reduced engine power, and unsuccessful vehicle operation. These factors limit the potential applications for CSFs to highly loaded, heavy-duty diesel engines (like those in highway buses).

The second type of soot filter tested was the Rypos, Inc. electrically regenerated active soot filter. The Rypos system applies an electrical current to supply the heat energy to oxidize the soot and regenerate the filter. Rypos uses a novel approach to electrically regenerating filters. Rypos developed a sintered metal fiber media that acts as the substrate to capture particulate matter as well as the resistive element by which an electric current can be supplied to produce the heat to oxidize the soot. This material is unique in that it performs both functions, thereby reducing system size and manufacturing cost. The filter is composed of multiple cartridges that are regenerated separately and sequentially. This results in a lower instantaneous power consumption and a reduced fuel penalty. Electrically regenerated soot filters are particularly attractive for diesel generator applications since the required electric power source is already available.

During the laboratory testing and at the completion of the project, several air pollution emissions and fuel mileage tests were performed with both the filters installed and removed. The results from this testing were PM reductions between 47 percent and 99 percent depending on test method and driving cycle, and statistically insignificant decreases in fuel mileage.

NFESC's demonstration project showed that soot filters can be effective in reducing diesel engine PM emissions. Although soot filters are not appropriate for all potential DoD applications, they can be used as part of a comprehensive program to reduce overall PM emissions at the activity level. Since soot filters have a relatively low purchase and installation cost of $5 to $10K per application, and a very low annual operating cost of less than $500, they can be a cheaper fix than addressing other PM sources. Additional project results and cost information along with information on potential equipment suppliers can be found at the ESTCP web site: http://www.estcp.org/projects/compliance/.

CONTACT

Bruce Holden
Naval Facilities Engineering Service Center
805- 982-6050
DSN: 551-6050
HoldenBB@nfesc.navy.mil