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Future Systems for Light- and Medium-Duty Vehicle Exhaust Aftertreatment

Developed by the Technology & Maintenance Council's (TMC)
Future LMV Task Force

ABSTRACT

The mandate for reduced tailpipe emissions from heavy-duty diesel powered vehicles has already left its mark on the trucking industry with the implementation of EPA's 2004 standards. Technologies developed to meet the 2004 standards have been reasonably successful and, for the most part, have not required the use of expensive aftertreatment devices. While in-cylinder control of the combustion process should ultimately prove to be the most effective way to control emissions, there are those within the industry that believe that the cost-benefit peak has been reached. As the industry begins implementing 2007 and 2010 standards, the complexity of the emissions reduction puzzle will increase.

This position paper challenges engine and vehicle manufacturers to develop and implement emission control technology that will meet regulatory demands with minimal life-cycle cost impact. These technologies should:

- operate in a passive state,
- exhibit a life expectancy equal to the design life of the vehicle,
- require little to no maintenance, and;
- not place additional burden on the operator.

TMC recognizes that much of the success of the coming technology's operation will depend on the successful introduction of ultra low sulfur diesel (ULSD) fuel at retail outlets beginning September 1, 2006 . The aftertreatment devices described in this document include those that could be used on light heavy-duty diesel engines (LHDDE) and medium heavy-duty diesel engines (MHDDE). These engines are typically found in Class 2-7 vehicles ranging from 8,501 to 33,000 GVWR.

Technology & Maintenance Council (TMC)
2200 Mill Road • Alexandria, VA 22314 • Ph: (703) 838-1776 • FAX: (703) 684-4328
tmc@trucking.org • http://tmc.truckline.com

INTRODUCTION

There are four basic aftertreatment technology strategies currently used by industry:

- Diesel Oxidation Catalyst
- Diesel Particulate Filter
- NOx Adsorber
- Selective Catalytic Reduction

A. Diesel Oxidation Catalyst

The diesel oxidation catalyst (DOC) is a flow-through device that consists of a shell containing a honeycomb-shaped structure. This structure has a large surface area and is coated with a catalyst. This catalyst contains a small amount of precious metal such as platinum or palladium. As the exhaust gas passes through the catalyst-coated structure carbon monoxide, liquid and gaseous hydrocarbons are oxidized—thereby reducing unwanted emissions. DOCs have been used successfully within the light- and medium-duty segments, in one form or another, for more than 10 years.

B. Diesel Particulate Filter

The diesel particulate filter (DPF) is a flow-through device that serves as a trap for particulate matter (PM). During the course of vehicle operation, the DPF collects PM from the exhaust stream on its substrate. Periodic cleaning of this substrate, known as regeneration, is required to maintain the efficiency of the DPF. This regeneration can be passive or active.

In systems using a catalyzed DPF, the DOC also turns nitric oxide (NO) into nitrogen dioxide (NO_2), which is used downstream of the DOC to oxidize the PM trapped in the DPF (also known as passive regeneration). The passive regeneration occurs providing the exhaust temperature is high enough and sustained long enough based on the duty cycle of the vehicle.

Active regenerating filters require the injection of a hydrocarbon, usually diesel fuel, to raise the temperature of the substrate high enough and for a long enough period of time for the collected PM to oxidize leaving only ash which is mostly a product of burnt engine oil. Periodic maintenance to remove the collected ash will be required with the use of a DPF.

C. NOx Adsorber

The NOx adsorber—like the DOC and DPF—is a flow-through device that stores NO_x during lean operation and releases and catalytically reduces the stored NO_x under rich conditions. The challenge is to ensure regeneration, which requires rich exhaust gas, and to control for the best compromise between fuel efficiency and the required conversion rate.

D. Selective Catalytic Reduction

Selective Catalytic Reduction (SCR), when applied to a diesel-powered vehicle, simultaneously reduces NO_x, PM, and hydrocarbon emissions. Similar to an oxidation catalyst, SCR uses a catalyst to cause chemical reactions. However, SCR requires the addition of a reactant in the exhaust stream, usually ammonia or urea, to convert NO_x to nitrogen and oxygen in an oxidizing environment.

Unlike the DOC, DPF and NO_x adsorber, SCR will require the vehicle operator to monitor the level of reactant onboard the vehicle to ensure compliance. Routine replenishment of the onboard reactant supply will be required to maintain proper function.

EQUIPMENT USER EXPECTATIONS

While one or more these four types of technology may be necessary to meet new emissions standards, TMC believes that manufacturers must consider equipment users' needs when designing these systems. For example:

- Though component design is based on many factors, such as engine displacement, designs must have the fewest number of components covering the broadest number of applications. This approach benefits equipment users by leveraging economies of scale.

- Components are often combined to enhance packaging and reduce assembly plant complexity. However, components must not be welded into the exhaust system. What's more—in the case of DOC, DPF and NOx adsorbers—multiple technologies must not be combined in a single shell. This would result in unnecessary expense for the replacement of a good element in the event of a failure of one sharing the same shell.
- Minimal sulfating of substrate must not create a condition where components would require replacement. Cross fueling could occur at the onset due to limited availability of (15 ppm sulfur content) ULSD fuel beginning September 1, 2006. After this date up to 20 percent of the highway diesel fuel produced may continue to meet the current 500 ppm sulfur limit through May 2010.
- Monitoring systems should include prognostics to alert the operator of upcoming maintenance events.
- Service procedures, when necessary, should limit downtime and only require the use of basic shop tools. Specifically pertaining to DPF service:
    - Removal and installation must not exceed 30 minutes excluding time to clean substrate.
    - Removal and installation must not require the use of an overhead lifting device on vehicles equipped with vertical exhaust.
    - Removal and installation must be independent of DOC, NO_x adsorber, muffler, intermediate and tail pipes, sensors or wiring.
    - Sensors, when used, must not require removal as a step in the service process.
    - Exhaust system design, particularly horizontal, must include joints before and after the DPF that will allow for axial expansion. Thus providing room to remove and install the DPF.
    - Gaskets, if used, must have features that allow for removal and installation of the DPF without becoming dislodged or damaged. Gasket design should allow for reuse a minimum of two removal-and-installation cycles once in service.
    - All fasteners accessed during the service procedure should be sized as to require the use of only one tool, i.e., a 13mm deep socket. This may include, but is not limited to, V-band clamps, brackets, heat shields, steps, etc.
    - All fasteners accessed during DPF service must be stainless steel. Vehicle design must also allow orientation as to be immediately and easily accessible.
- Service must not be required more than once per year, based on vocation and application. ❑