Abstracts

Session 11 – Diesel Engine Exhaust Aftertreatment, Part II

USE OF A MOBILE ON-ROAD LABORATORY TO MEASURE HEAVY-DUTY DIESEL "REAL WORLD" EMISSIONS FROM STANDARD AND NON-STANDARD OPERATING CYCLES

Wayne Miller, David Cocker, Kent Johnson, Carlos Gaeta, and Joe Norbeck
University of California at Riverside

Heavy-duty diesel engines are abundant and will remain the workhorse of the commercial sector for years to come. Thus, it is important to understand emissions from heavy-duty diesel (HDD) engines both as certified and while operating under 'real world' conditions. Towards that end, the University of California at Riverside College of Engineering Center for Environmental Research and Technology (CE-CERT) developed a HDD mobile on-road emissions laboratory with the capability of measuring gaseous, semi-volatile, and particulate emissions, while in motion, from heavy-duty tractors operating under actual conditions. The report will detail some of the verification phases that were used to complete the development of the lab and the new secondary dilution tunnel.

Results will be presented to show that the mobile laboratory can achieve similar driving repeatability for a standard cycle while under "real world" conditions as in a stationary laboratory. This driving precision leads to analytical precision for the various emissions. As a result, CE-CERT is able to determine actual operating emissions of HDD emissions over various on-road cycles to compare with existing certification results
and emission inventories. In addition, CE-CERT has developed the capability of assessing the performance of emission reduction technologies in actual operating conditions. The presentation will also discuss the HDD emissions from non-standard cycles, such as a four-mode transient cycle or one developed to represent HDD vehicles that are entering or leaving the Los Angeles Basin. Future plans for the HDD mobile laboratory will be discussed.

NO_X ADSORBERS FOR HEAVY-DUTY TRUCK ENGINES – TESTING AND SIMULATION

N. Hakim, J. Hoelzer, and Y. Liu

Detroit Diesel Corporation

This feasibility study of NO_x adsorbers in heavy-duty diesel engines examined three configurations (dual-leg, single-leg, and single-leg-bypass) in an integrated experimental setup, composed of a Detroit Diesel Class-8 truck engine, a catalyzed diesel particulate filter, and the NO_x absorber system. The setup also employed a reductant injection concept, sensors, and advanced control strategies.

The study included the development of thermal and empirical NO_x absorber characteristic models. These models were further applied to the development of regeneration strategies and were used for a comparative performance analysis of the three NO_x adsorber configurations.

The reported steady-state experimental and simulation results show relatively high NO_x conversion efficiencies, with various levels of fuel economy deterioration. Further, the findings confirm that the development of acceptable regeneration and desulfation control logics is a major technical challenge for practical NO_x absorber system applications. These logics are further complicated by such factors as engine transient operation, drivability, and durability.

UPDATE ON MODELING FOR EFFECTIVE DIESEL ENGINE AFTERTREATMENT IMPLEMENTATION -- MASTER PLAN, STATUS, AND CRITICAL NEEDS

B. Bolton, X. Fan, N. Hakim, K. Sisken, and H. Zhang

Detroit Diesel Corporation

An integrated diesel engine-aftertreatment-vehicle system is extremely complex with numerous interacting variables and an unlimited number of control options. An experimental approach to developing an optimized viable system is tedious, if at all possible. Sophisticated component, subsystem, and integrated simulation tools offer an excellent option of a virtual laboratory approach to the development of such a complex system. A viable and robust diesel engine aftertreatment system can thus be developed within optimum time and resources when this virtual simulation is integrated with selective hardware-based testing.

Detroit Diesel has developed an effective virtual laboratory integrated system package. A multi-level common platform embodies 0-, 1-, and multi-dimensional models of selected components and subsystems. Different models can be coupled or integrated, and simulated tests can be carried out in order to define optimum control parameters or to predict system response. This paper will present the technology development master plan, update technical status of the simulation fidelity, and outline critical needs that impact simulation tool development and serious application.

EXPANDED CAPACITY MICROWAVE-CLEANED DIESEL PARTICULATE FILTER

Dick Nixdorf
Industrial Ceramic Solutions, LLC

Beginning in FY 2000, the DOE Partnership for a New Generation of Vehicles (PNGV) Program has funded the development of a ceramic-fiber, diesel particulate filter system that is cleaned by microwave energy (Mw-DPF). That silicon carbide fiber filter cartridge was a round, corrugated wall-flow configuration. The shape was adequate for the relatively low exhaust flows experienced on a PNGV-type vehicle.

Recently, Industrial Ceramic Solutions (ICS) has developed a flat, pleated, multiple-filter cartridge design, which has demonstrated 1/20th of the back-pressure of the classic wall-flow cartridges. This higher exhaust capacity, multiple-cassette design will allow the use of the Mw-DPF's in Class 8 diesel vehicles or even larger electric cogeneration diesels and locomotives.

The pleated cassettes are inexpensive to fabricate and can be used as catalyst carriers without the microwave unit. The design and operation of the pleated ceramic-fiber filter system is discussed. Data are presented comparing the flat, pleated-media back-pressure to that of a wall-flow DPF.

Emissions testing on the first flat, pleated-filter unit by the National Transportation Research Center shows the particulate removal efficiency. Photographs of a complete microwave filter system, mounted on a 7.3-liter diesel vehicle, will be discussed.

This system is being prepared for a 7,000-mile controlled track test to demonstrate system durability using periodic chassis dynamometer FTP emissions testing. The filter will be microwave cleaned at a variety of engine operating conditions from idle to full load.

“RYPOS TRAP” ACTIVE DIESEL PARTICULATE FILTER SYSTEM: FIELD DEMONSTRATIONS

Frank DePetrillo, Zachary Nardi, Amin Saeid, and Kevin Lubinsky
Rypos, Inc.

Rypos Trap is an actively regenerated diesel particulate filter that has high efficiency and very low electrical power consumption for regeneration. The regeneration is independent of engine exhaust temperature and fuel sulfur content. The filter material is made of sintered metal fibers and has high porosity, high soot-holding capacity, and low thermal mass. The filter material is capable of capturing 85-95 percent of the soot in diesel exhaust.

The operation of the Rypos Trap is controlled by a microprocessor that allows it to function automatically during normal engine operation. Periodically, as required, an electric current is passed through a filter element, which then acts as a heating element.

The Rypos Trap is currently undergoing field demonstrations in several locations in California. In conjunction with Cummins and the Naval Facilities Engineering Service Center, Rypos Traps are used to remediate exhaust from aircraft ground power units. Additional demonstrations have been supported by a grant from the Innovative Clean Air Technologies (ICAT) program of the California Air Resources Board.

These field demonstrations had shown that the Rypos Trap is capable of keeping back-pressure under control while operating with very high efficiency.

INVESTIGATION OF DIESEL SOOT OXIDATION PROCESS AND CATALYSTS DEGRADATION

Alex Yezerets and Neal Currier
Cummins, Inc.

Flow-reactor tools have been successfully employed by Cummins in recent years to study the performance and degradation of aftertreatment devices under well-controlled conditions. In particular, a micro-reactor system has been used to investigate reactivity of diesel soot samples collected from different engines and duty cycles under different simulated exhaust conditions. It was found that the properties and origin of the soot substantially affect its ability to be oxidized.

The discussion will include information obtained using kinetic analysis about the behavior of soot at different temperatures. Also, the reaction systems were used to obtain information about catalysts' degradation using probe reactions. The developed methodology allows us to measure the degradation and, in some cases, determine its cause.

THERMOLYSIS CHARACTERIZATION OF UREA-SELECTIVE CATALYTIC REDUCTION

Howard L. Fang and Herbert M. DaCosta
Cummins, Inc.

Although urea-selective catalytic reduction (SCR) is one leading contender for NO_x control in engine emissions, surface passivation caused by deposit formation and non-stoichiometric balance of urea consumption are critical detriments to catalyst performance. The deposit formation deactivates catalytic performance by not only consuming part of the ammonia produced during urea decomposition but also by degrading the structural and thermal properties of the catalyst surface.

We have characterized urea thermolysis with and without urea-SCR catalyst using both spectroscopic (DRIFTS and Raman) and thermal analysis (TGA and DSC) to identify the deposit components and their corresponding thermal properties. The thermolysis of urea exhibits two stages, involving ammonia generation and consumption, respectively. The second stage involves the formation of melamine complexes, $(HNC{=}NH)_x(HNCO)_y$, which hinders catalytic performance. The presence of catalyst and a good spray of urea solution help to eliminate the second stage. The concept using additive in urea solution to rejuvenate the catalytic surface will be discussed.

ACTIVE SOOT FILTER REGENERATION

Bruce Bunting, Arvind Suresh, and John Chi
Cummins, Inc.

Passive soot filters can only be successfully applied to part of needed applications due to the need for elevated exhaust temperature to trigger soot regeneration. Some form of active regeneration assist is needed to make a soot filter robust under all duty cycles. This regeneration assistance can take the form of additional heat, active engine management, or increasing the reactivity of the soot or the catalyst. This presentation will discuss the requirements of an active regeneration system and presents results indicating the performance of such a system.

A SYSTEMATIC INVESTIGATION OF PARAMETERS AFFECTING DIESEL NO_x ADSORBER CATALYST PERFORMANCE

Danan Dou, Thomas R. Pauly, Ken Price, and Laurie Salyers
Delphi Corporation

NO_x adsorber catalysts, also called lean NO_x traps (LNT), have proven to be successful in meeting Japanese LEV and European Level IV emission standards for light-duty passenger cars powered by gasoline direct- injection engines. Much interest has been generated in the last several years regarding the use of NO_x adsorber catalysts for both light-duty and heavy-duty diesel engines. However, before successful application of this catalyst technology, it is essential to understand the parameters relevant to these diesel exhaust conditions and their implications for the performance of NO_x adsorber catalysts.

In the current study, we systematically investigated the parameters that could influence the conversion efficiency of NO_x adsorber catalysts. Results showing the effect of catalyst technology, PGM loading, substrate, temperature, flow rate, and exhaust composition will be reported. Results regarding sulfur poisoning and desulfations of NO_x adsorber catalysts will also be presented.

PERFORMANCE OF JOHNSON MATTHEY EGRT ä EMISSION CONTROL SYSTEM FOR NO_X AND PM EMISSION REDUCTION IN RETROFIT APPLICATIONS

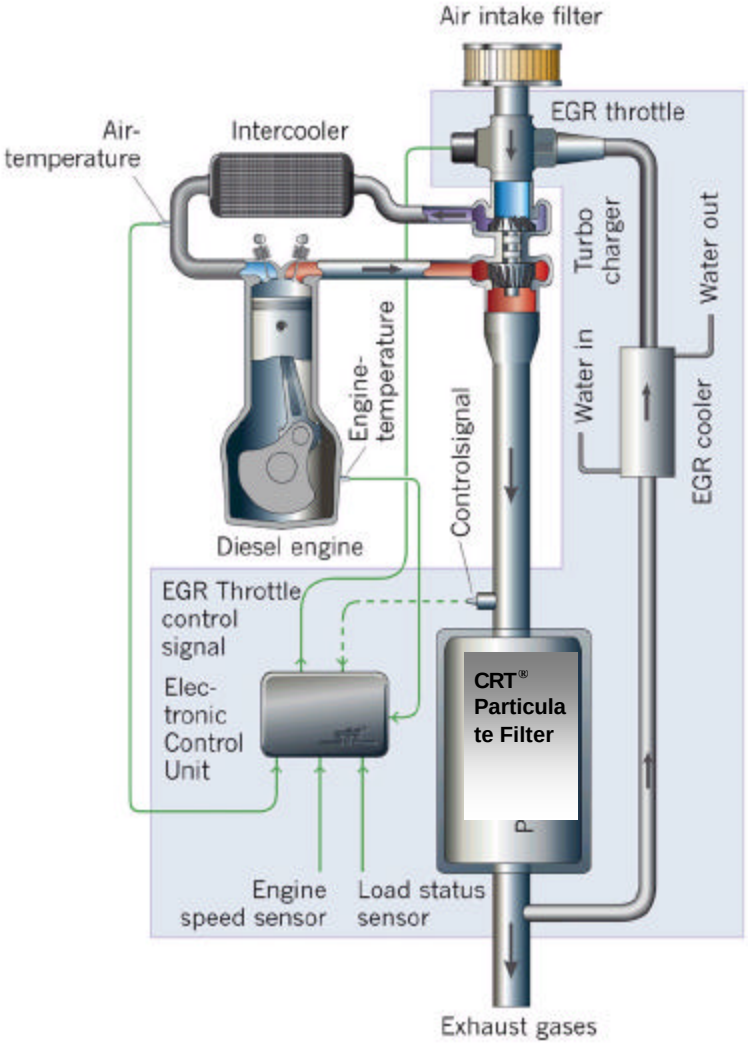
S. Chatterjee, R. Conway, and S. Viswanathan
Johnson Matthey

With growing concerns about NO_x and particulate matter (PM) emissions from diesel engines, stricter emission regulations are being implemented which require advanced emission control technology. In that regard, Johnson Matthey has combined the Continuously Regenerating Technology (CRT®) diesel particulate filter system with a low-pressure exhaust gas recirculation (EGR) system to provide four-way emission control of NO_x, PM, CO, and HC from existing heavy-duty diesel engines. This is known as the EGRT™ system.

The CRT filter is a highly effective technology for diesel PM reduction. The CRT system provides a unique and successful solution to the filter regeneration issue by using NO_2 to combust engine soot under the diesel engine operating temperature without any external heating. The overall system consists of a platinum metal-based oxidation catalyst upstream of the particulate filter. The catalyst oxidizes a portion of the exhaust NO_x into NO_2, which carries out continuous combustion of accumulated soot trapped by the filter, at temperatures above 250°C. In addition, the system also eliminates most of (greater than 90 percent) the CO and HC in the diesel exhaust.

The EGR system used is a low-pressure system which recirculates a portion of the clean exhaust gas from downstream of the CRT filter into the engine intake through an EGR throttle valve. The recirculated exhaust is cooled using an EGR cooler. The EGR flow is controlled by the EGR throttle valve, based on signals from an EGR throttle control unit. The EGR flow is designed based on the engine speed and load conditions as well as exhaust parameters which allow the CRT filter system to operate effectively. The flow is also optimized for NO_x emission reduction.

The EGRT™ system has been used in Europe over the past 4 years, with over 1200 systems installed on urban buses and other on-road applications. This system has shown 40-60 percent NO_x reduction in addition to greater than 90 percent CO, HC, and PM reductions. Recently, several field trial programs have been initiated to evaluate the performance and durability of the EGRT™ system under U.S. operational conditions. These include retrofit applications on urban buses and on a construction truck. FTP tests on an engine dynamometer have demonstrated 48-58 percent NO_x reductions with these systems while chassis dynamometer tests have indicated 50-60 percent NO_x reductions. Simultaneously, the CRT filter has shown greater than 90 percent CO, HC, and PM reductions in these tests. Emissions and on-road performance data of EGRT™-equipped vehicles from these programs will be presented in this paper.


Air intake filter
EGR throttle
Air-
temperature
Intercooler
Turbo
charger
Water out
Water in
EGR cooler
Engine-
temperature
Controlsignal
Diesel engine
EGR Throttle
control
signal
Elec-
tronic
Control
Unit
CRT®
Particula
te Filter
Engine
speed sensor
Load status
sensor
Exhaust gases