



South Coast Air Quality Management District

21865 E. Copley Drive, Diamond Bar, CA 91765-4182
(909) 396-2000 • www.aqmd.gov

Off-Road Emission Reduction Technology Forum and Technical Roundtable (Held on May 1, 2007)

Forum Summary and Report

Executive Summary

Introduction

Diesel-powered construction equipment are major sources of nitrogen oxide (NO_x) and particulate matter (PM) emissions in the South Coast Air Basin. The majority of diesel engines in construction applications generally operate for more than 8 years before being rebuilt. As such, the emissions from construction equipment can have significant, long-lasting effects on air quality. On May 1, 2007, the South Coast Air Quality Management District (AQMD) convened a one-day Technical Forum and Roundtable on emission control technology for construction equipment. The goals of the Forum were:

- 1) Assess the current state of selective catalytic reduction (SCR) system and diesel particulate filter (DPF) technologies for construction equipment
- 2) Understand any outstanding SCR/DPF issues that may hinder the delivery of the technologies to the market
- 3) Presentation and discussion of the California Air Resources Board's (CARB) showcase and retrofit verification programs, and CARB's proposed rule for off-road equipment
- 4) Discuss the next sets of near and future actions that can be taken to reduce NO_x and PM emissions from construction equipment.

Participants of the forum included Dr. Barry Wallerstein, Dr. Chung Liu, and Adewale Oshinuga of the AQMD, Erik White of CARB, and an expert panel of invited SCR and DPF technology manufacturers and other industry experts. This expert panel included:

- 1) Dr. Timothy Johnson, Corning Environmental Technology
- 2) Mr. Andreas Mayer, Technik Thermische Maschinen, Switzerland
- 3) Mr. Chris Weaver, Engine, Fuel, & Emission Engineering
- 4) Mr. Richard Carlson, Extengine Transport Systems

Cleaning the air that we breathe...

- 5) Dr. Bradley Edgar, Cleaire Advanced Emission Controls
- 6) Dr. Sougato Chatterjee, Johnson Matthey
- 7) Dr. Michael Readey, Caterpillar Emissions Solutions
- 8) Mr. Frank Caponi, Los Angeles County Sanitation District
- 9) Mr. John Mooney, Consultant
- 10) Mr. Julian Imes, Donaldson
- 11) Mr. Curtis Knapper, Clean Diesel Technology

Dr. Johnson assisted the AQMD in the organization of this forum and served as moderator of the discussion sessions.

Summary of Expert Panel Presentation

There were a total of ten formal presentations from the eleven Expert Panel members, AQMD, and CARB.

- 1) Dr. Barry Wallerstein introduced the forum and gave the state of air quality in the South Coast Air Basin (basin). He presented charts showing that over 50% and 25% of US population exposed to PM and ozone levels above national standards live in the basin; a condition that is unacceptable to the AQMD Governing Board. He also explained that construction equipment account for majority of the PM and NOx emissions; as such, aggressive emission control measures are needed on off-road diesel engines for attainment.
- 2) Adewale Oshinuga established the forum goals, and presented AQMD's staff position on CARB proposed control measure for off-road equipment. He explained that additional 3.9 and 12.2 tons per day (tpd) NOx emission reductions from Tier 0 and Tier I off-road diesel engines are feasible by year 2014.
- 3) Erik White presented CARB's showcase and retrofit verification programs, and CARB's proposed rule for off-road equipment. He expressed concerns and needs for PM and NOx emissions to be significantly reduced from off-road diesel engines for California to meet the federal PM and ozone standards.
- 4) Dr. Timothy Johnson presented an overview of diesel emission control retrofit technology for reducing PM and NOx emissions from existing diesel engines. He explained that many vehicles in the US and Europe have been retrofitted with PM and NOx technologies ranging from diesel particulate filters, exhaust gas recirculation coupled with continuous regenerating technology system, active lean NOx catalyst, to selective catalytic reduction systems.
- 5) Andreas Mayer provided European's perspective on applying NOx technology in addition to particulate technology on off-road equipment. He explained that

over 15,000 DPF-equipped diesel-powered construction vehicles of different sizes are currently operating in Switzerland, while roughly 100,000 on-road vehicles are equipped with SCR-related technology. In addition, there are now three SCR systems available for off-road vehicles. He recommended that all existing diesel-engines of all sizes should be retrofitted with diesel particulate filters, while SCR with DPF should be further investigated.

- 6) Chris Weaver cited that locomotive contributes over 37 tpd of NO_x and 1 tpd PM of the total AQMD emissions inventory, and predicted that these emissions will continue to increase as demand for locomotive goes up. He gave several strategies to control emissions from locomotives: replaced older land-haul switchers with dedicated switch locomotive technology with smaller off-road engines equipped with SCR and DPF; stationary source control technology may be applicable to locomotives in servicing/maintenance applications; retrofit existing line-haul locomotives with one or combination of diesel oxidation catalyst, SCR, and DPF. He presented his ongoing work involving retrofitting F-59 HP passenger locomotive engine with SCR to reduce NO_x and PM emissions, and cited several challenges such as vibrations, high oil consumption, low backpressure tolerance, and crankcase vent eductor, all of which were addressed in the design of the control system.
- 7) Richard Carlson presented Extengine ADEC-II system for control of NO_x and PM emissions from off-road diesel equipment. He cited ADEC-I (an older generation of ADEC-II) as the only CARB-verified SCR system under Level I PM control category capable of reducing NO_x emissions by at least 80%; ADEC-I is applicable to selected Tier 0 off-road diesel engines, and currently installed on over 100 off-road equipment. He explained that ADEC-II uses urea as reductant and non-vanadium catalyst, and presented charts showing that ADEC-II reduced NO_x and PM emissions by at least 75 and 95% with a 1% fuel penalty. He concluded that ADEC-II technology can be installed on off-road equipment powered by at least 150hp, and a verification application will be submitted to CARB shortly for off-road applications.
- 8) Dr. Bradley Edgar presented the application of Cleaire's Longview system to off-road equipment. He explained that the Longview system is an integration of DPF and a hydrocarbon selective catalytic reduction (HC-SCR) system to reduce NO_x and PM emissions, respectively; the reductant for the HC-SCR system is the resident diesel fuel. In addition, he cited that: (1) Longview system has been verified for on-road vehicles by CARB, and has been proven successful for controlling NO_x and PM emissions from over 3,000 vehicles ranging from transit buses to refuse trucks to line-haul vehicles; (2) they can also be applied to off-road diesel-powered equipment. He explained that there are several on-going in-field programs to demonstrate the potential of

Longview system to reduce NO_x and PM emissions from off-road equipment such as excavators, graders, loaders, and scrapers. He concluded that Longview system is capable of reducing NO_x and PM emissions by at least 40 and 85%, and Cleaire is currently pursuing CARB verification for Longview system.

- 9) Dr. Sougato Chatterjee presented the status of Johnson Matthey's selective catalytic regenerating technology (SCRT) system for on-and off-road mobile sources. He explained that SCRT system combines continuous regenerative technology (CRT) and a urea-based SCR system to reduce NO_x and PM emissions, respectively. In addition, he cited many on-going on-road demonstration projects (Ralphs Grocery, Los Angeles County Sanitation District, BP, and City of Long Beach) where SCRT system is being used, and anticipates beginning similar programs for off-road equipment. He reminded the audience that several design parameters such as limited space, line of sight, mechanical durability (vibration), exhaust pressure and temperature, and engine-out emissions, must be considered as part of design strategy for retrofitting off-road equipment with SCRT. He concluded that SCRT is capable of reducing NO_x by 60 – 85% and PM emissions by at least and 85%.
- 10) Dr. Michael Readey presented Caterpillar's perspective on reducing NO_x and PM emissions in today's engines. He cited that Caterpillar's path to emissions reduction includes, engine repower, component replacement during engine upgrade or overhaul, and aftertreatment device. He recognized that SCR and particulate filters are matured technologies capable of significantly reducing NO_x and PM emissions; however, emphasized that their usage in construction equipment is limited by available space, costs, and high backpressure. He noted in his slides that "CAT [Caterpillar] continues to evaluate the viability of a combination DPF-Urea SCR system for [off-road] applications."
- 11) Mr. Frank Caponi presented the Los Angeles County Sanitation District (LACSD) experience on the application of Johnson Matthey's SCRT on a 1998 Kenworth Class 8 transfer truck with Cummins M-11 diesel engine. He noted that SCRT weighs 750 pounds and fits comfortably on the chassis, and cited that the transfer truck equipped with SCRT has now accumulated over 39,000 miles, consumed roughly 1 gallon per day of urea, and shows no significant change in performance; however, the fuel mileage dropped by 10 percent. He received several questions from the audience and other presenters ranging from program cost to technical explanation for the high fuel penalty; he responded that (1) operators should resist from extrapolating or interpolating an actual commercial cost of a similar program from the cost incurred by LACSD program, which is heavily subsidized by the project proponents, and (2)

LACSD will revisit the fuel penalty estimate, and provide a result at some later time.

Key Conclusions

The following conclusions emerged from the forum presentation and discussion.

Air Quality Objective

The AQMD and CARB expressed strong consensus that further reduction of NOx and PM emissions from off-road equipment is necessary for AQMD's attainment with federal and state standards, and for CARB to meet the goals of diesel reduction plan. However, they differ in terms of the amount or strategies on how to achieve these reductions. While CARB noted that it will take up-to 5 years for retrofit technologies to be commercially available for off-road applications, AQMD emphasized that control technology manufacturers are making impressive achievements in the area of retrofit technology for off-road applications, and some have begun activities that will lead to their technologies being verified by CARB much sooner than 5 years.

Strategy for reducing NOx and PM emissions

Several panel participants addressed different strategies for reducing NOx and PM emissions from construction equipment. CARB favored repowering equipment with newer and cleaner engines over retrofitting with NOx technology, which is still under development and cost prohibitive. Andreas Meyer argued for a strategy that is based on retrofitting all older engines with particulate filters rather than repowering; he agreed with Michael Readey that a repowered engine will be suitable candidate for retrofit with SCR and DPF.

Availability of SCR/DPF technology

The panel agreed that SCR is an efficient technology for controlling or reducing NOx emissions from stationary and mobile sources, and has been used for many years in on-road vehicles. Likewise, DPFs are being used in many on-road vehicles and off-road equipment. The control manufacturers on the panel proclaimed that their companies would have verified-SCR or other NOx technologies combined with DPF for off-road applications by the end of 2008; however, cautioned that CARB verification process could delay their technologies to be verified before 2008. For example, a panelist noted that he submitted a verification protocol to CARB in October 2006, but has not yet received any feedback from CARB on the status of the application.

Challenges to SCR/DPF technology

The panel was in unison regarding the need to address outstanding challenges that may hinder the retrofit of off-road construction equipment with a combined SCR and DPF on a large commercial scale. These challenges range from limited space, limited number of filter/substrate configuration, urea availability, to exhaust back pressure. Chris Weaver commented that there is sufficient amount of urea in California to accommodate the potential demand.