Exclusive Content

Highlights from the Coordinating Research Council's

28th Real-World Emissions Workshop

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The 28th Coordinating Research Council's Real-World Emissions Workshop was held March 18–21, 2018, in Garden Grove, CA, and featured 50 presentations in 10 sessions and 48 posters, as well as 8 demonstrations of analytical and technical services by various vendors. A total of 245 attendees set a record for event attendance.

Light-Duty In-Use Emissions

Measurement of in-use vehicle emissions with portable emissions measurement systems (PEMS) and remote-sensing devices (RSD) has been increasingly important to understand excess emissions, fleet emissions and energy use, as well as to explain the association between emissions and community socioeconomic status (SES). Although only presenting snap-shot emissions at low speed and hard acceleration, RSD data could be very useful in tracking long-term exposure trends to emissions that vary depending on community SES. Based on RSD data collected in Los Angeles over decades, it was found that vehicle emissions are highly correlated with SES; emission factors for the disadvantaged communities were 3–10 times higher than the lowest SES value communities, depending on pollutants.

The difference between laboratory and in-use emissions test results is sometimes due to uncontrolled real-world factors. The differing results can be explained by weighing both test results by vehicle activity characterized by vehicle-specific power (VSP). An activity profile obtained on an urban test route in Los Angeles was characterized by VSP and produced a similar activity profile as constructed by the Federal Test Procedure cycle. This activity weighting method could be useful to the assessment of excess emissions observed in the real world.

Variability of in-use emissions is often associated with uncertainties such as sampling errors, measurement errors, and inadequate variable characterization. Using in-use emissions data obtained from selected test routes in Raleigh, NC, Monte Carlo and Bootstrap simulations were used to examine the range of variability in the in-use emissions. Per-vehicle test repeats and vehicle sample size could depend on VSP distribution, target precision of mean emissions, vehicle type, test route, and others.

Heavy-Duty In-Use Emissions

Roadside in-use fuel specific emission measurements observed significant reductions in fuel specific oxides of nitrogen (NOx) emissions for the heavy-duty diesel vehicles (HDDVs) over the past 20-year period with significant reductions occurring since 2012. The U.S. Environmental Protection Agency (EPA) conducted a data analysis on the manufacturer-run Heavy-Duty In-Use Testing (HDIUT) program data focusing on the on-board NOx sensor data and concluded that newer model-year HDDVs have lower NOx emission rates.

Based on the same dataset of HDIUT, the Engine Manufacturers Association (EMA) believes it is important to separate Non-Credit engine family (certified to 0.20 g/hp-hr without using banked credits) from

the Credit engine family (certified using banked emissions credits). In the meanwhile, the California Air Resources Board (CARB) points out current Not-To-Exceed (NTE) testing procedure used in the HDIUT excludes important information on the vehicles operation, and the NTE average may not be representative of the overall emissions.

Field studies showed that European trucks exhibit a lower NOx profile compared to U.S. trucks, however, U.S. trucks do perform better handling the greenhouse gas (GHG)/NOx trade-off. The NOx, mainly nitric oxide (NO), is still the dominant nitrogen species emitted from HDDVs. The higher ammonia-to-NOx ratio might lead to higher "solid" particle emissions, even when correcting for a diesel particulate filter (DPF) regeneration event.

Off-Road Emissions

Unique research is being conducted on emission inventories at ports and emission rates from a diverse collection of off-road sources, including construction and mining equipment. Automatic Identification System (AIS) data transmitted by ships at ports was utilized to determine the real-time emissions and activity. Emissions calculation utilizing the AIS data provides real-time emissions and better data on vessel activities. CARB proposed investigating emissions from real-world and engine dynamometer tests. The primary goals are to verify NTE compliance, understand the real-world emissions impact of Auxiliary Emission Control Device (AECD) and verify real-world regeneration emissions and frequency.

Nonroad Tier 4 engine emission rates with various aftertreatment systems were determined using EPA certification data. The emission rates on Tier 4 equipment with DPF and selective catalytic reduction (SCR) after-treatment systems were significantly lower than equipment without them. The updates will be incorporated in the MOVES 2014b model, planned for release in 2018.

Air Quality

Air quality research includes secondary organic aerosols (SOA), evaporative emissions, carbonyl emissions, and ozone trends in the South Coast air basin. The environmental impact of biofuels needs to be evaluated in greater detail because studies showed ethanol can promote SOA formation. Another study showed ethanol and aromatics have inverse effects on tailpipe particulate matter (PM). Current pleasure craft evaporative emission inventory may underestimate the reactive organic gas. Thus, the emissions inventory for pleasure craft will continue to be studied.

For vehicles in the 1976–2015 model years, the average formaldehyde and total carbonyl levels decreased in the California South Coast region. Ozone levels in 2016 and 2017 increased, corresponding with more frequent and intense occurrences of meteorological conditions favorable to ozone formation (see Figure 1). Short-term ozone increases in the Southern California air basin (SoCAB) have been observed in the past and have corresponded with years with higher ozone conducive meteorology. In the past, the downward ozone trend has resumed, although at a lower rate. Higher emission of biogenic volatile organic compounds in 2017 may have enhanced NOx disbenefits by counteracting the beneficial ozone reduction effect as a result of anthropogenic volatile organic compound (VOC) emission reductions.

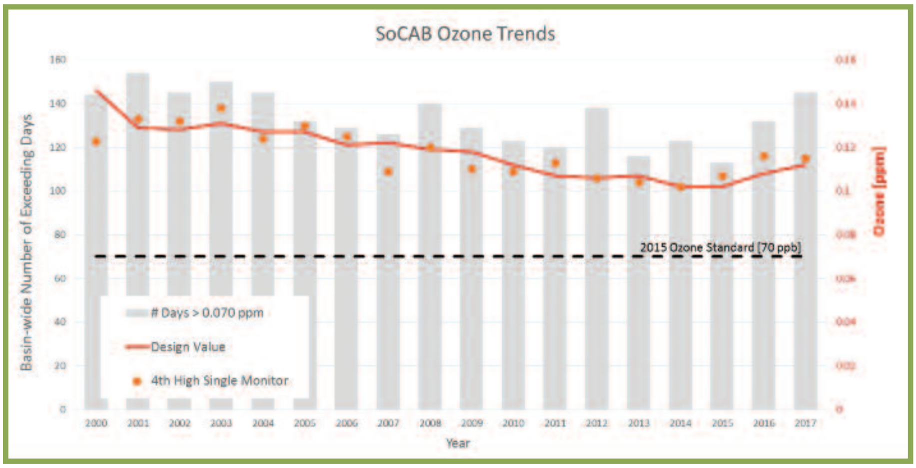

Figure 1. 2000–2017 SoCAB ozone trends.

Emissions Modeling

There are recent updates to California's EMFAC2017 model and planned updates for EMFAC and for EPA's MOVES model. EMFAC's new transit bus module includes emission rates and bus characteristics, and predicts a shift to more compressed natural gas, diesel-hybrid, and gasoline buses. Evaluation of data from instrumented heavy-duty trucks provided information on driving patterns, including idling time, starts, and soak time that will be used to better model this activity in MOVES. EPA's review of real-world light-duty NOx emissions in high-speed and high-acceleration modes suggests that these emissions have not yet been well characterized at the fleet-wide level.

Rates and Inventory

With the introduction of heavy-duty in-use testing, EPA changed the paradigm of engine certification 14 years ago. Daily aggregated emissions rates based on multiple vehicle and engine operating characteristics were calculated to allow for comparison with CARB's EMFAC model. A field study to measure the evaporative emissions of 642 vehicles revealed two categories of vehicles with potential high and low running losses. Results are being used to make recommendations for modeling evaporative emissions in CARB's EMFAC model.

Additionally, monitoring of 200 diesel-powered short-haul trucks, as part of a Drayage Truck Replacement program, was done to provide data for transportation and air quality planning purposes. Pathways to measure particulates from vehicle brake-wear is being researched. As tailpipe PM from mobile sources has decreased, the impact of non-exhaust sources is estimated to contribute about half of all PM_{10} and a significant portion of $PM_{2.5}$.

Developments in Emissions Measurements

Preliminary findings of telematics data from over 48,000 vehicles in five states indicate that there is no significant difference in activity patterns of plug-in hybrid electric vehicles (PHEVs) when compared to conventionally powered vehicles. Light-duty vehicle PM emissions were measured gravimetrically with a constant volume sampling (CVS) and a partial flow dilution (PFD) system. Using a single filter with PFD allows for an approximately 30-percent increase in the collected PM mass, which also results in a significant decrease in variability.

Emissions of NOx, carbon dioxide (CO_2), and water (H_2O) were measured using a PEMS, a Fourier-transform infrared spectroscopy (FTIR), and a dilution tunnel. The NOx PEMS measurement agreed with the CVS across all tested ranges but the 200–300 °C temperature range. In that same range, the PEMS and FTIR agreed within 3 percentage points. For NO_2, the PEMS exhibited a consistent negative bias of 25–30 percent.

HDDV's on-board NOx sensors were found to have an accuracy of more than 90 percent compared with NOx concentration measurement using FTIR, within 25–200 parts per million (ppm) range. In the lower concentration range, their correlation turned much worse. CARB has completed preliminary work on a Portable Emissions AcQuisition System (PEAQS) that can help identify high-emitting in-use heavy-duty vehicles by capturing their exhaust plumes on the roadside.

Particle Emissions Measurements

Emissions from hybrid electric vehicles using gasoline direct injection (GDI) and port fuel injection (PFI) during cold weather driving were studied. CRC Project E-99-2 evaluated three commercially available PFD devices against CVS tunnel measurement method at low PM (LEV III) emission levels (see Figure 2). Calibrations and proportionality tests showed good performance for the PFDs. GDI engines with Gasoline Particulate Filters (GPF) showed capability of better filter performance to attain future European particle number (PN) limits.

Fuel Effects/Fuel Economy

Often there are emissions and fuel economy trade-offs of alternative fuels and fuel formulations. Results from recent fuel quality surveys show there are inconsistencies and changes in fuel quality over time, as a result of fuel programs and market forces. The most significant fuel trends were the increase in ethanol and decrease in sulfur and benzene. The characterization of hydrocarbons and PM from partially-premixed compression ignition (PPCI) combustion using light-end distillates showed that under PPCI conditions and compared to ultra-low sulfur diesel (ULSD), soot emission was significantly reduced with RON80 and RON93 fuels at the same engine-out NOx level, while hydrocarbon and carbon monoxide emissions slightly increased.

New fuel composition required by Tier 3 standards on light-duty vehicle results in all vehicles experiencing a small reduction in fuel economy and CO_2 emissions with the new test fuel, compared with Tier 2 certification fuel. The fuel effects on gaseous and PM emissions from Spark-Ignited Direct-Injection (SIDI) in-use vehicles, including PM, PN, fuel economy, and GHG emissions, were investigated over a range of fuel properties of match- and splash-blended fuels.

Emissions Control Measures

There are emissions control measurement programs and techniques for evaluating the emissions from heavy-duty vehicles.

To assess the potential benefits of a HDDV Inspection and Maintenance (I/M) Program in Texas, the On-Road Heavy-Duty Emissions Measurement System (OHMS) was used to characterize NOx emissions from HDDVs by sampling exhaust generated as trucks start from a stopped position and pass through a test setup (see Figure 3).

In-Use Compliance (IUC) Program can be the key to air quality improvement because it ensures that vehicles/engines meet applicable emission standards. CARB and EPA established a manufacturer HDIUT and compliance program based on meeting the NTE requirements. In these studies, the Moving Average Windows (MAW) method was compared to the NTE by comparing their respective accuracies. Serious challenges in controlling real-world NOx emissions from heavy-duty vehicles can result from SCR controls and it was noted that controls such as CARB's Heavy-Duty on-board diagnostics (OBD) regulation could significantly reduce NOx emissions. **em**

Figure 3. The OHMS system samples truck exhaust as trucks start from a stopped position and pass through the test setup.

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For more information on this workshop and others, as well as technical information regarding vehicle emissions, fuels and performance, please see the CRC website at **www.crcao.org.**

Next Workshop

The 29th Real-World Emissions Workshop is scheduled for March 10–13, 2019 in Long Beach, CA.

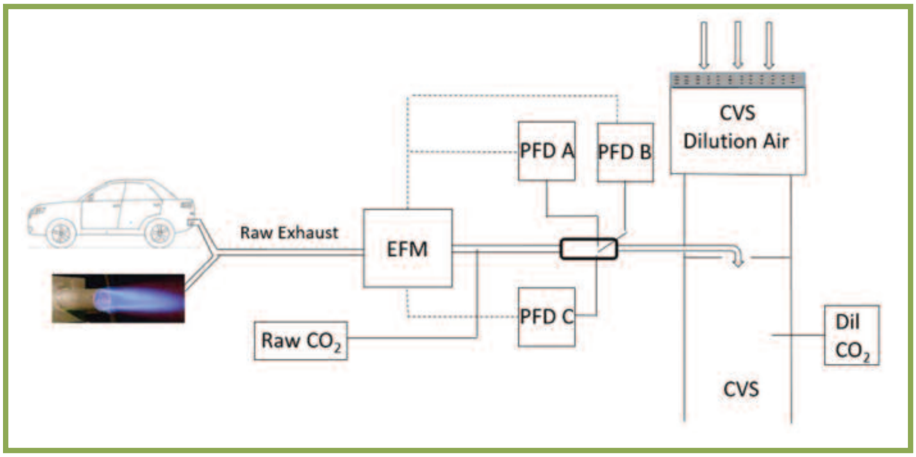

Figure 2. Laboratory setup for comparing three PDF systems with the CVS system.