SOURCE TESTING METHODS DEVELOPMENT

22) TITLE: Improve Size and Chemical Species Profiles for Particulate Matter and Organic Gas Emissions from Combustion in Commercial Ships.

PROBLEM: Near-term Agency modeling analyses will involve the need to use computer models to estimate the impacts of fine and ultra-fine particulate matter on the population, including the effects of secondary aerosol formation, and to provide analyses for potential control strategies (e.g. PM2.5 State Implementation Plans, shipping port analyses, health risk assessments, etc.). Size and chemical species profiles for categories of particle emissions are necessary to generate the emission inputs required by computer models. However, the profile used to characterize PM is derived from on-road diesel engine measurements. The profile used to characterize organic gases is derived from measurements from farm equipment diesels. Also, where profile fractions for 5 to 10 size bins below 2.5 microns are needed to meet the emission input requirements for PM2.5 models, the current PM profiles only provide two size bins (0 to 2.5 microns and 2.5 to 10 microns). The structure of the bins varies with application but can range from 8 to as many as 18. In addition, 18 chemical species for each of the size bins will be utilized. To prioritize how to meet the needs of PM2.5 modeling, a source prioritization based on chemical mass balance analyses was conducted under the California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS). On-road and off-road diesel sources are the highest priorities. Diesel combustion from commercial ships is a high priority due to lack of measured data.

PREVIOUS WORK: The ARB is currently in the process of developing a research project work plan for TOG and PM speciation profiles from modern commercial aviation engine emissions, using modern, commonly used jet aviation fuel. The Central California Air Quality Study (CRPAQS) sponsored a $350,000 project through U.C. Riverside that involved collecting total mass and total chemical composition data from various sources for all particles below a *single* particle size threshold (current needs are for emission estimates to be broken down into *several* size ranges).

OBJECTIVE: The intent of this research proposal is to provide for fine and ultra-fine size and chemical species profiles for a high priority source that cannot be conducted using ARB's in-house resources and laboratory. Commercial ships are significant sources of PM emissions. In addition, the organic gases from these sources are likely to be highly reactive which may lead to elevated ozone production and possibly secondary PM production. In addition to source testing, analyses of the resulting data is required to develop size and chemical profiles applicable to the specific chemical mechanism used for PM2.5 modeling.

BENEFITS: Accurate estimates of emission inputs to air quality models for use in State Implementation Plans as well as other population exposure and control strategy analyses.

23) TITLE: Evaluation of the New European Methodology for Determination of Particle Number Emissions and its Potential in California for In-Use PM Compliance Testing

PROBLEM: The need for a robust, on-vehicle PM sampling methodology or a surrogate for determining over-the-road “real world” emissions is undisputed. A sufficiently robust and defensible set of on-vehicle measurements for particle emissions could be used to determine in-use compliance with engine emission standards if presented in consistent units. However, a suitable option has not been identified at present time.

PREVIOUS WORK: Under the auspices of the United Nations, a multi-country Particle Measurement Program (PMP) has been underway for a few years in Europe and Japan. Recognizing the limitations of the gravimetric method for PM emission determination, the PMP is focused on the identification of new and/or improved test methods for type approval (or certification as is known in the U.S.). Significant progress has been accomplished by the PMP. At present, validation of the new proposed method is underway in Europe and Japan. In addition, the PMP suggested approach has been in use for field measurements in Europe since 1998. Since 2001, the method is used for the verification of efficiency of diesel filters. The robustness and merit of the new PMP method has led to the development of a new regulation by the Swiss Agency for the Environment, Forests, and Landscape to limit the number of particles emitted by diesel-powered vehicles. This new regulatory limit would complement the existing limit on total particle mass. It is noted that there is current work in the U.S. (in California specifically) that involves the investigation of on vehicle measurement options. But none has included the specific investigation of the PMP approach.

OBJECTIVE: The objective is to conduct a critical evaluation of the proposed PMP method for determination of particle emissions and its potential in California for in-use PM compliance testing.

DESCRIPTION: The proposed project is a two-prong effort. Initially, the technical merits of the PMP protocol would be evaluated critically, giving consideration to all of the technical aspects associated with the correlation of solid particle number emission measurements and measurements of total particle mass under the existing certification guidelines. The ARB currently has the required instrumentation dictated in the PMP method. Thus, some of the necessary assessment work may be carried out in house. The second phase would involve an investigation of the potential for application of the PMP method for in-use compliance testing. This task is not trivial and would entail establishing a universal and statistically significant correlation between the established measurement of total particle mass and the new proposed metric of solid particle number.

BENEFITS: The U.S. was absent from the PMP initiative as the U.S. EPA declined to actively participate. The PMP has generated leading and state-of-the-science advances in metrology for engine emissions. This project would leverage all the PMP lessons in an integrated effort with clear California benefit.

24) TITLE: The Development of Exhaust Speciation Profiles for Commercial Jet Engines

PROBLEM: There are currently no commercial jet engine exhaust speciation profiles, using modern engines and modern fuels, available for either volatile organic compounds (VOCs) or particulate matter (PM). Current commercial jet exhaust modeling efforts, as well as Environmental Impact Report (EIR) efforts, rely on previous military aircraft testing results. This

makes production of accurate ozone and toxic models, as well as EIR efforts in regions heavily impacted by commercial jet aircraft, impossible.

PREVIOUS WORK: Currently used jet engine exhaust speciation profiles were developed in the past using older fuels and engines, principally from military applications. They have limited applicability to modeling commercial aviation emissions. Recent programs have only begun to test engines and fuels that are somewhat similar to modern commercial engines and fuels. In addition, the specific compounds selected for testing, issues of limits of detection, needs for changes in overall methodology, and test equipment issues, currently limit the ability of previously-collected data to be applied to current commercial jet engine speciation profile needs.

OBJECTIVE: The objective is to develop accurate VOCs and PM speciation profiles for a modern, widely-used commercial aviation engine, using modern, commonly used jet aviation fuel.

DESCRIPTION: U.S. federal agencies, in conjunction with other interests, are currently working on projects to test and speciate exhaust from military jet engines in the 2004-2005 timeframe. Some of this previous testing has included an engine and fuel mix with similarities to current commercial engines and fuels. The currently proposed project could build on and extend these commercial-like tests to better characterize typical commercial jet engines and fuels. The same testing apparatus and methodology could be applied to the testing of a typical modern commercial aviation engine, using typical modern commercial jet aviation fuel, at a relatively low additional cost to these currently-planned projects.

BENEFITS: Successful completion of this project would facilitate accurate modeling of commercial jet engine exhaust emissions for ozone, PM and toxics, as well as aid informed decision-making during the EIR process for airport expansion projects.

25) TITLE: Development of In-field Diesel Particulate Matter Compliance Method for Stationary and Portable Combustion Ignition Engines

PROBLEM: The current stationary source test methods used for measuring diesel particulate matter (PM) in the field are slow and very costly to conduct. The two accepted stationary source test methods for measuring diesel PM are ARB Method 5 and the ISO 8178 compliant mini-dilution system. The ARB Method 5 sampling (samples raw exhaust) of PM requires sampling the exhaust for 20 minutes to two hours to gather enough particulate on the sampling filter, depending on whether the engine is dirty or clean. Each sample has to be repeated at least three times over five engine loads. Also the laboratory requirements to separate and weigh the condensable fraction takes days or weeks to get results. The ISO 8178 compliant source test method is based on exhaust dilution and requires a mini-dilution tunnel. The mini-dilution tunnel correlates to the EPA certification emission source test method and requires weighing only a sampling filter with no condensable fraction and associated laboratory work. The sampling time is much shorter, even for clean engines, 15 minutes is adequate. The mini-dilution system can cost tens of thousands of dollars to purchase. We need an enforcement sampling system that can quickly screen for potentially dirty engines and use equipment available and/or inexpensive.

PREVIOUS WORK: While developing the stationary diesel engine air toxic control measure, ARB participated in a demonstration with the California Energy Commission to measure diesel PM from stationary back up generators. Part of the demonstration compared the EPA dilution method with the ARB Method 5 for measuring diesel PM. This demonstration source testing provides data that can be used to support the development of an alternative compliance test method. Further work is needed to develop an in-field test method.

OBJECTIVE: The objective is to statistically relate parts of the ARB Method 5 to the EPA certification dilution method as a way to quickly estimate the diesel PM emission rate and find a way to sample raw exhaust at a single load from stationary diesel engines and correlate to the certified PM emission rate. By knowing the approximate load and respective PM emission rate at which an ARB Method 5 test is conducted, the EPA certification PM emission rate can be calculated.

DESCRIPTION: Conduct emissions source tests using both ARB Method 5 and the EPA dilution method on diesel engines at the certification loads to better correlate the ARB Method 5 front-half filter to the EPA dilution method. Analyze this data to relate an ARB Method 5 front-half filter at various mid-range loads to the EPA certification level.

BENEFITS: Current diesel engine source testing is very expensive and time consuming. Development of a simplified and less expensive emissions test procedure for stationary diesel engines would be a benefit to the Districts determining compliance with prohibitory rules and in identifying dirty engines.

26) TITLE: Evaluation of the In-Use Not-To-Exceed Requirements for Heavy-Duty Diesel Engines

PROBLEM: Heavy-duty diesel engines/vehicles (HDDEs/HDDVs) are substantial contributors to the motor vehicle emissions inventory for NOx and particulate matter (PM). In the 1990s it was found that seven of the largest HDDE manufacturers violated certification regulations by defeating emissions controls during in-use highway driving. As a consequence of these violations, the USEPA, and ARB negotiated the Consent Decree (CD) and Settlement Agreement (SA), respectively with these HDDE manufacturers. The CD and SA stipulate the implementation of in-use Not-To-Exceed (NTE) requirements. The NTE requirements call for the HDDE manufacturers to perform in-use emissions measurements and report results to the USEPA and ARB. The CD and SA NTE requirements have been carried over into the upcoming 2007 HDDE emissions standards, and the ARB has also adopted NTE requirements for 2005-06. The NTE requirements are expected to result in compliant in-use HDDEs, but this has not been independently verified.

PREVIOUS WORK: The USEPA/Engine Manufacturers Association (EMA) Calibration Standards Task Force and NTE in-use Measurement Workgroup have been working to implement the 2007 emissions standards, including the NTE requirements for HDDEs.

OBJECTIVE: The objective of this project would be to perform in-use HDDE/HDDV testing to verify the in-use emissions performance of post-1998 HDDEs complying with the NTE requirements.

DESCRIPTION: A small fleet of in-use HDDVs would be emissions tested, including over the road testing and dynamometer testing. On-board emissions measurement instrumentation would be utilized as part of all emissions testing, including dynamometer testing. The over the road NTE testing would include typical HDDV in-use operation, while dynamometer testing would include the HDDE Federal Test Procedure (engine testing), and transient and steady state test cycles. The emphasis of the project would be on NOx plus non-methane hydrocarbons, but consideration would also be given to PM measurements.

BENEFITS: The results from this project would permit a rigorous and systematic comparison of on-board, over-the-road emissions measurements against laboratory emissions measurements to permit an evaluation of the NTE requirements as a means of ensuring in-use compliance for HDDEs.

27) TITLE: Dioxin Emissions from Heavy-duty Diesel Vehicles

PROBLEM: Dioxins and dioxin-like compounds include polychlorinated dibenzo-*p*dioxins, dibenzofurans, and polychlorinated biphenyls (PCBs), and are referred to here as dioxins. The U.S. EPA recently reassessed the issue of dioxin toxicity and exposure. They concluded that dioxins cause adverse health effects at common ambient levels, with exposure due primarily to releases into air from combustion processes. The concentration of dioxins emitted from diesel vehicles is uncertain. This is largely due to the lack of a suitable method to sample dioxins from mobile sources. In view of the identification of particulate matter from diesel exhaust as a toxic air contaminant by the ARB, and the known toxic effects of dioxins, further study of dioxins in heavy-duty diesel emissions is warranted.

PREVIOUS WORK: Dynamometer studies, roadway tunnel studies, and direct on-road sampling have been conducted to estimate dioxin emissions from motor vehicles. Data indicate that dioxin emissions from diesel vehicles are greater than from gasolinepowered vehicles equipped with catalytic converters. Dioxin emissions from a diesel engine were sampled for an ARB-sponsored study titled "Evaluation of Factors that Affect Diesel Exhaust Toxicity" (1998). Relatively low dioxin levels were reported, but the investigators believed this was due to losses of dioxins in the dilution tunnel system used to sample emissions. A recent draft U.S. EPA document cited a roadway tunnel study (Gertler, et al. 1996) as the basis for its estimate of the contribution of diesel emissions to total "releases to air", although the emission factor from this study was assigned a "low confidence" rating.

OBJECTIVE: The goal of this project to determine the total emissions of dioxins from heavy-duty diesel vehicles in California, and, if possible, the effect of control technologies and variations in chlorine levels in the fuel, oil, and ambient air entering the engine.

DESCRIPTION: Possible sampling methods to measure dioxins in heavy-duty diesel emissions will be reviewed. After developing and validating the optimal method, dioxins will be measured from heavy-duty diesel vehicles in “real-world” or controlled settings (e.g., tunnel roadway, on-road, or dynamometer) in order to estimate the total emissions of dioxins from heavy-duty diesel vehicles in California. If funds permit, the levels of chlorine entering the engine through the fuel, oil, and ambient air will be varied to investigate the effect of chlorine content on dioxin production. In addition, the tests will be conducted using various control

technologies (e.g., catalyzed diesel particulate filters, diesel oxidation catalysts) to measure their effectiveness in reducing dioxin emissions.

BENEFITS: The method developed in this study will enable accurate quantification of dioxins in motor vehicle emissions, and produce data on emissions of dioxins from typical California heavy-duty diesel vehicles necessary for possible control decisions.

28) TITLE: Assessment of Toxic Substances Produced by Diesel Emission Controls

PROBLEM: Efforts to reduce diesel exhaust emissions have resulted in the development of varied control technologies, such as catalyzed diesel particulate filters (DPFs), diesel oxidation catalysts, lean-NO X catalysts, and NO X adsorbers. However, their use may lead to the formation of toxic substances. For example, under some engine operating conditions, noble metal catalysts can lead to increased emissions of carcinogenic nitro-polycyclic aromatic hydrocarbons (nitro-PAH). We should determine the extent of adverse health impacts from use of these technologies.

PREVIOUS WORK: DPFs and oxidation catalysts have been shown to increase the mutagenic potency of diesel emissions, likely resulting from the formation of nitro-PAH. The use of fuel-borne catalysts (such as cerium and copper) has been shown to increase particle number, unless used in conjunction with a DPF. Copper as a fuelborne catalyst led to increased dioxin emissions in a DPF-equipped diesel engine, and copper is used as the catalyst for lean-NO X technology. Decreased levels of fuel sulfur may also increase dioxin emissions. Recent research has highlighted health concerns from several nitro-PAHs derived from diesel exhaust. For example, 2-nitrodibenzopyranone is highly mutagenic in human cells, and 3-nitro-benzanthrone is an extremely potent bacterial mutagen. Diesel oxidation catalysts can increase the mutagenicity of diesel exhaust, and recently were found to produce a dramatic increase in nitro-PAH under some conditions.

OBJECTIVE: The goal of this project is to evaluate the potential health impacts posed by the deployment of diesel emission control technologies.

DESCRIPTION: This project will assess emissions from diesel emission control technologies likely to become widespread in the near future. This will include both retrofitted and original engine manufacturer DPFs, and NOX control devices. Emission parameters of concern include toxic VOC species, PAHs and nitro-PAHs, particle number, and particle size distribution. For each control technology assessed, a net risk analysis will be conducted. Each emission control technology will be compared to the baseline technology and baseline fuel as appropriate. Finally, residue from a catalystbased DPF will be analyzed for ash and soot components.

BENEFITS: Significant health impacts could arise from the introduction of diesel exhaust control systems. This study will provide data on emissions of toxic substances from diesel exhaust control systems, determine whether DPF residues are toxic, and find ways to control toxic exposure before widespread introduction of these systems. The information obtained from this study will allow us to analyze the health impacts of diesel emission control technologies, and will lead to the use of technologies that provide the greatest health protection.

29) TITLE: Improvement of Emissions Inventory for Stationary and Portable Engines

PROBLEM: The current emissions inventory does not contain an accurate estimate of the emissions from engines used in stationary and portable applications. Emissions inventories for these engines have been difficult to develop for the following reasons: 1) the large number of sources within this category; 2) the exemption of certain categories of engines from district permit programs, such as emergency standby generators and agricultural irrigation pumps; and 3) until recently, certain classes, such as diesel-fueled engines, have not been targeted for emissions reduction.

PREVIOUS WORK: Overall, the 1996 inventory for stationary and portable engines constitutes about 1% of the total inventory for nitrogen oxides (NOx). Review of this data established that emissions from stationary and portable engines are under-represented. For example, the emissions inventory for agricultural irrigation pumps contains estimates for only two districts and no estimates for a number of districts with significant irrigated farmland. Staff estimates that the inventory for agricultural irrigation pumps may be understated by 50% or more. Updating of the off-road inventory has resulted in draft estimates that are about 300% higher than those contained in the 1996 emissions inventory, not including certain categories of engines operating within the Statewide Portable Equipment Registration Program.

OBJECTIVE: To develop a more accurate emissions inventory of engines used in stationary and portable applications, with the focus on collecting information to improve the weaker aspects of the inventory.

DESCRIPTION: The first step of this project is to work with ARB staff to identify the areas of the overall inventory for stationary and portable engines in need of major improvement. Once these areas are identified, the necessary information will be collected from district permit systems and the Statewide Registration Program, including descriptive information of the engine and activity information that describes the engine's operation in the field. Finally, a proposed procedure would be developed to estimate the number, size, and operating characteristics of engines that are not operating under either a district permit or the Statewide Registration Program.

BENEFITS: This project is necessary to develop an accurate emissions inventory for stationary and portable engines in support of the development of toxics control measure for diesel-fueled engines, the RACT/BARCT program, and the State Implementation Plan.

30) TITLE: Development of a Test Method to Measure the Emissions from Portable Engines

PROBLEM: Engines registered under the Statewide Portable Equipment Registration Program are required to satisfy specified emission limits and requirements. Current test methods for portable engines are not intended for field use. These methods were intended to determine the compliance of newly manufactured engines with established emission standards. Testing is typically done in a laboratory using a dynamometer to simulate load changes, and only CO, HC and NOx are measured.

PREVIOUS WORK: Historically, stationary source test methods have been used to measure emissions from stationary industrial and portable engines. The stationary source test methods have not been demonstrated to be equivalent to the tests using a dynamometer and it is not practical to take portable engines to a laboratory for testing. The U.S. EPA is developing an in-the-field testing system for engines subject to federal standards. Because of the potential cost of the system, it may not be cost effective for testing State-registered portable engines.

OBJECTIVE: To develop a test method for portable engines that would be used to verify compliance with specified emission limits and newly manufactured engine standards set by the ARB and the U.S. EPA.

DESCRIPTION: The first step of this project would be a review of existing test methods that apply to portable engines and identify the major issues that need to be considered in developing an in-the-field test method. A proposed procedure would be developed based on the issues initially identified. The final step would entail using the proposed test method on a representative sample of portable engines and providing a final evaluation based upon the results of the tests. A test method would be developed that could: 1) be used in the field, 2) be equivalent to current test methods applicable to newly manufactured portable engines and 3) could be done at a reasonable cost.

BENEFITS: The development of an in-the-field test method for portable engines is important for ensuring compliance with the program's requirements. The reductions achieved by the Program are important for maintaining or achieving compliance with State and federal ambient air quality standards. In addition, as more of these portable engines are tested with the newly developed method, staff will be able to provide accurate estimate of emissions from portable engines for the emissions inventory. The inventory currently has limited information for this category. Finally, with the availability of an in-the-field test method, staff could study the impact of engine deterioration on emissions for engines used in portable applications.

31) TITLE: Exhaust Emission Testing of Diesel-Powered Off-Road Equipment -

ABSTRACT

Emissions databases from off-road diesel powered equipment suffer immensely from insufficient real-world activity data. Moreover, there is little information available regarding the validity of standardized dynamometer engine test cycles that are currently used for emissions certification. The present study was initiated in order to fill the current void in the off-road equipment testing cycles and the consequent lack of "real world" emissions data that is needed for accurately modeling emissions inventories.

For this study, onboard engine data was logged from four off-road vehicles in order to generate transient test cycles that could be used to simulate real-world operating conditions for exhaust emissions research. The off-road diesel powered equipment targeted for this study was selected to be representative of the major off-road diesel emissions contributions in California. Specifically, these vehicles were: an Elgin Pelican street sweeper (51-120 hp), a John Deere 444 rubber-tired loader (121-250 hp), a Komatsu PC400LC3 excavator (251-500 hp), and a Caterpillar D-11RCD bulldozer (>500 hp). The engines were removed from the street sweeper, rubber - tired front-end loader, and the excavator and operated according to the

transient test cycles developed from the recorded in-field data, as well as the standard steady-state 8-mode test cycle, prescribed by ISO 8178-6.3 Test Cycles type C, which is used for certification of off-road diesel engines. Regulated gaseous emissions and gravimetric PM emissions were collected according to procedures recommended by the Code of Federal Regulations (CFR) 40, Part 86, Subpart N. In addition, size-selective PM mass emissions, and particle sizing data were collected. Exhaust emissions from the Caterpillar D-11R CD track-type tractor were measured in the field as the dozer performed its normal operating activities. This on-board testing was performed using West Virginia University's mobile Emissions Measurement System (MEMS) for gaseous exhaust components, and a Real time Particulate Mass Monitor (RPM 100) developed by the Mid-Atlantic Research Institute (MARI).

Results indicate that the current steady-state, ISO 8178, 8-mode test cycle does not adequately represent the actual emissions produced by off-road, diesel-powered equipment during day-to-day operations. Furthermore, the exhaust emissions produced by a vehicle are highly vehicle and task-specific.

Link to full report: ftp://ftp.arb.ca.gov/carbis/research/apr/past/98-317.pdf