CRC

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2009

COORDINATING RESEARCH COUNCIL, INC.

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ANNUAL REPORT

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PART ONE

STATE OF THE COUNCIL

STATE OF THE COUNCIL: 2009

The Coordinating Research Council (CRC) provides the means for the automotive and energy industries to work together and with government to address mobility and environmental issues of national and international interests.

The U.S. Department of Energy (DOE) through the National Renewable Energy Laboratory (NREL) and Oak Ridge National Laboratory (ORNL), the California Air Resources Board (CARB), the Engine Manufacturers Association (EMA), the U. S. Environmental Protection Agency (EPA), and the South Coast Air Quality Management District (SCAQMD), the Renewable Fuels Association (RFA), the National Biodiesel Board (NBB), and many others have continued their cooperation this year with CRC in co-sponsoring research projects and on other activities such as international technical workshops. This cooperation results in a finer focus on the important issues and leveraging of both technical expertise and financial support to meet common goals. CRC has also continued its coordination with research organizations worldwide, with European and Canadian collaborations emphasized during the past year.

CRC research on the use of renewable fuels such as ethanol and biodiesel has once again increased this year. Proposals for replacement of conventional petroleum sources with renewable sources are being promoted in many sectors around the world. A proposed waiver was submitted this year to EPA to increase the allowable content of ethanol in gasoline from 10 volume percent (E10) up to 15 volume percent (E15), and CRC continued its assessment on the impact of such mid-level ethanol blends. It is essential to understand the impacts such a change may bring to fuel quality and performance in the current fleet. Several studies on the potential impacts of E15 and E20 were continued this year and several more were undertaken including major studies on engine durability (CM-136-09-2), impacts on OBD II systems (E-90), and evaporative emissions systems durability (E-91). CRC is coordinating its research program on mid-level ethanol blends with EPA, DOE, and many other stakeholders such as RFA, EMA, and several off-road engine/vehicle associations through regular face-to-face meetings.

The impacts of biodiesel use on fuel quality and vehicle performance especially under cold ambient temperatures are also being evaluated by our technical committees. CRC is coordinating this research with government agencies and other stakeholders including the NBB and EMA.

CRC Emissions Committee Project E-80, being conducted cooperatively with CARB, continued this year evaluating the exhaust emission performance of flexible-fuel vehicles operating on a full range of ethanol fuels from E6 to E85. This project has examined what happens to emissions during a transition from one ethanol blend level to another. Evaporative emissions have also been measured and final results are expected to be released at the end of 2009.

CRC Project E-77, conducted in cooperation with EPA, has expanded this year to further study the impact of evaporative emissions from the in-use fleet emphasizing vehicles with the most advanced evaporative emission control systems. Test fuels being evaluated in this study include E0, E10, and E20. The E-77 pilot study demonstrated new test procedures to isolate and quantify canister losses, leak rates, and other full vehicle evaporative emission levels. Additional vehicles are being tested under new phases of E-77. A new highly successful measurement technique has been added to the test program using remote sensing to identify high evaporative emissions vehicles on the road.

An important new study on the effect of vapor pressure on carbon monoxide emissions was completed this year with the publication of Final Report No. E-74b. This study is a significant addition to the CRC database of fuel effects on emissions of modern vehicles. Ethanol content including E20 was a part of this study.

CRC completed Phase 1 of the Advanced Collaborative Emissions Study (ACES) in collaboration with the Health Effects Institute (HEI). This study has provided an evaluation of the advanced diesel engine and aftertreatment systems meeting 2007 on-road heavy-duty diesel standards for particulate matter (PM) and nitrogen oxides (NO_x). ACES Phase 1 results (engine and emissions characterization) were presented in the final report and a representative test engine was selected for health effects testing by HEI which commenced at Lovelace Respiratory Research Institute (LRRI). The ACES Steering Committee has expressed a desire to follow through with the Phase 2 program plan by conducting an evaluation of engines meeting the 2010 standards.

The Advanced Vehicle/Fuel/Lubricants (AVFL) Committee completed a new study of bio-distillates as potential blendstocks for transportation fuels. This study was a comprehensive evaluation of current renewable diesel fuel options covering both properties and performance resulting in publication of CRC Final Report No. AVFL-17. The AVFL Committee is also supporting the evaluation of mid-level ethanol blends with Project No.

AVFL-15 to assess fuel system material compatibility of E15 and E20 blends.

A new initiative was developed this year to identify a diesel fuel surrogate mixture of selected pure component hydrocarbons that could be used for advanced kinetic and combustion modeling studies. This project is being accomplished under the guidance of a broad group of researchers forming CRC Project Panel AVFL-18. The AVFL Fuels for Advanced Combustion Engines (FACE) Working Group has been active this year on many fronts, successfully making available to the public a complete set of advanced diesel research fuels for interlaboratory comparison purposes.

The Diesel Performance Group of the CRC Performance Committee completed their study of a bench test method for evaluating the lubricity of diesel fuels in fuel injector equipment test with the goal of confirming performance predictions from current laboratory tests. The Diesel Performance Group also completed new studies on low temperature operability of biodiesel blends in a vehicle test program conducted in an all-weather chassis dynamometer, again with the goal of correlating results against laboratory prediction methods (DP-2).

The impact of gasoline quality on the current vehicle fleet performance has long been an area of research in CRC. Changing fuel quality and new vehicle technologies can have unexpected impacts that were not previously observed. The Performance Committee released the first phase final report of a study on the impacts of fuel sulfur composition on corrosion of silver components used in modern fuel system sensors (CM-136-06).

The Octane Group of the Performance Committee initiated its test program to evaluate the relative contributions of motor octane number (MON) and research octane number (RON) in current engine and control systems. The first phase of testing was conducted at Chrysler and the second phase is underway at General Motors.

The Volatility Group of the CRC Performance Committee conducted a driveability study on E85 and related Class 3 fuel blends under cold temperature conditions in the Imperial Oil all-weather chassis dynamometer facility in Sarnia, Canada (CM-138-08-2). Plans are in place for another driveability study to be started this year to evaluate the influence of winter gasoline front-end volatility, mid-distillation temperature, and ethanol content on modern vehicles.

The Atmospheric Impacts Committee is looking into future air quality scenarios through the use of air quality grid models. These models not only evaluate gaseous pollutant transport and reactions, but also direct emissions of aerosols (PM) and secondary aerosols formed in the atmosphere. Due to the non-linearity of atmospheric reactions, predicted future reductions in emissions may lead to only modest improvements in ozone levels. The Atmospheric Impacts Committee released Final Report No. A-64 in which various modeling subroutines (probing tools) used to identify key parameters responsible for net changes in air quality were evaluated.

As air quality improves across the U.S., the background sources of pollutants are becoming more important, and the committee studied the impacts of background air quality under its current program scope along with its continued interest in weekend emission changes. Project A-65 on the accuracy of regional simulations of background ozone and PM was completed this year showing the influence of existing background levels of these pollutants.

Previous CRC projects resulted in the publication of three books by Oxford University Press, *Mechanisms of Atmospheric Oxidation of the Alkenes, The Mechanisms of Atmospheric Oxidation of Aromatic Hydrocarbons,* and *Mechanisms of Atmospheric Oxidation of the Alkanes.* The Atmospheric Impacts Committee has developed a new manuscript on the atmospheric reactions of the oxygenates with the help of in-kind cost-sharing from the authors. This manuscript will be submitted to Oxford University Press for publication.

The 4th Mobile Source Air Toxics Workshop was held in December 2008 in Phoenix, AZ. This workshop built on the previous successful events bringing together key local, state, and federal government, academic and industry researchers, and other stakeholders to discuss the state-of-the-art and future research needs. The organizing committee for the 2008 workshop included key participants from EPA, CARB, and many other important stakeholders.

The 19th CRC On-Road Workshop was held March 23-25, 2009, in San Diego, California. Participants included representatives from government, universities, commercial organizations, and several international organizations. The 2009 keynote speaker was David Patterson of Mitsubishi North America who brought the automotive perspective to the workshop. Proceedings of the 19th Workshop were provided to the Workshop attendees. A summary journal paper has been submitted to the *Journal of the Air and Waste Management Association (JAWMA).* The 20th

CRC On-Road Workshop will be held March 22-24, 2010, at the Hyatt Mission Bay in San Diego, California.

A new workshop on Life Cycle Analysis of Biofuels was developed this year and will be held at Argonne National Laboratory, October 20-21, 2009. CRC led a broad international organizing committee consisting of both industry and government stakeholders. The main goal of the workshop is to identify uncertainties in the current data and procedures used in biofuel life cycle assessments.

Details on these and other CRC projects appear in Part Two of this Annual Report. Reports issued since the last CRC Annual Report are listed in Part Three, and organization memberships comprise Part Four.

PART TWO

DETAILED REPORTS OF CRC PROJECTS

ADVANCED COLLABORATIVE EMISSIONS STUDY

CRC Project Nos. ACES, ACES-1, ACES-1a

Leaders: M. Natarajan
C. J. Tennant

Scope and Objective

The Advanced Collaborative Emissions Study (ACES) is a cooperative, multi-party effort to characterize the emissions and assess the possible health impacts of the new, advanced engine systems and fuels that are being introduced into the market during the 2007–2010 time period.

Current Status and Future Program

The ACES program is being carried out by the Health Effects Institute (HEI) and the Coordinating Research Council (CRC), using established emissions characterization and toxicological test methods to assess the overall health impacts of production-intent prototype engine and control technology combinations.

Funding for ACES is provided by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), the California Air Resources Board (CARB), the American Petroleum Institute (API), the Engine Manufacturers Association (EMA), and manufacturers of emissions control equipment.

ACES is divided into three phases:

- In Phase 1, extensive emissions characterization of four 2007 production heavy heavy-duty diesel (HHDD) engines has been performed. Emissions characterization results were used as the basis for selecting one HHDD engine/aftertreatment system for health testing (Phase 3). In addition to the measurement of regulated pollutants, the exhaust gases were speciated to quantify nearly 700 compounds of interest.
- Phase 2 is analogous to Phase 1, but will be performed on the 2010 HHDD engine models.
- In Phase 3, the selected 2007 engine has been installed in a specially designed emissions generation and animal exposure facility; it is being used in a chronic inhalation study with health measurements.

EMISSIONS

Southwest Research Institute (SwRI) and Desert Research Institute (DRI) were selected to perform Phase 1. LRRI was selected to perform Phase 3. Four manufacturers (Caterpillar, Cummins, Detroit Diesel, and Volvo) supplied de-greened new 2007 engines for Phase 1 testing, using a common lubricant supplied by Lubrizol.

The Phase 1 evaluation was based on Federal certification test procedures (FTP) but also included testing on a new engine cycle based on a heavy-duty chassis dynamometer test cycle developed by CARB, and employed extensively in the CRC Project E-55/59. The development of this engine cycle was performed by West Virginia University (WVU) under the ACES-1 project, funded by CARB. As a follow-on project to ACES-1, the ACES-1a project was performed by WVU with funding from HEI to create a 16-hour test schedule. The 16-hour test schedule is comprised of the FTP and portions of the CARB test cycles; it will be used for all engine characterization and exposure activities in the ACES Project.

The Final Reports for the ACES-1 and ACES-1a cycle development projects were released earlier, and are available on the CRC website. Phase 1 of ACES was completed, and an engine was selected for Phase 3. Individual manufacturers, including the one selected for the health study, will not be identified in the results while the project is ongoing. Hence, the engines have been designated by the letters A, B, C, and D; Engine B is the Phase 3 engine. The Phase 1 project Final Report was released in June 2009.

EVALUATIONS OF THE MOVES MOBILE EMISSION FACTOR MODEL

CRC Project Nos. E-68, E-68a

Leaders: M. Natarajan
D. M. DiCicco

Scope and Objective

The objective of these projects is to conduct assessments of the new MOVES emission factor model at appropriate levels of development. The first assessment (E-68) was applied to the general model outline and greenhouse gas (GHG) portion of the model. The second assessment (E-68a) is being applied to the draft release of the complete model.

Current Status and Future Program

EPA is cooperating with CRC to facilitate these independent reviews of MOVES. The Final Report for the first assessment, E-68 "Analysis of EPA's Draft Plan for Emissions Modeling in MOVES and MOVES GHG," published in May 2004, is on the CRC website.

The follow-on project, E-68a, was planned to begin when the complete MOVES Model was available for study. In preparation for this, special meetings between the CRC Committee and EPA were held in 2006 and 2007. The meetings preceded a new FACA MOVES Workgroup led by EPA. CRC Committee members or staff attend the FACA meetings on an ongoing basis.

In 2008, EPA announced that a draft version of the model would be available in early 2009, and thus the statement of work for this project was developed, leading to a competitive request for proposals. This project was awarded to a team led by Air Improvement Resources, Inc.

EMISSIONS

Major tasks in the E-68a project are as follows:

Review and evaluate the methods used in MOVES2009 to estimate exhaust and evaporative emissions: The team reviewed, documented, and critically assessed the data and methods used to create the criteria pollutant emissions and toxics emissions for MOVES2009. The criteria pollutant emissions included HC (exhaust and evaporative), CO, NO_x, and PM (exhaust, brake and tire wear).

Exercise the MOVES2009 model: The team developed a protocol to exercise MOVES2009 and evaluated the ability of the model to represent real world emissions impacts associated with changes in the values of selected model parameters.

Provide recommendations to CRC: The Final Report provides recommendations to CRC for future work and changes or updates regarding the MOVES model as quickly as they are identified to permit immediate communication from CRC to EPA.

This project started in late 2008; a draft Final Report (without the review of the forthcoming revised fuel effects section of the model) has been reviewed by the Real World Group. This project is expected to continue into early 2010.

NONROAD VEHICLE EMISSIONS

CRC Project No. E-70

Leaders: C. Hart
M. Natarajan

Scope and Objective

The goal of this study is to collect data to quantify populations, usage, and emissions of diesel nonroad equipment in EPA Region 7. CRC is cooperating with EPA and the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Offices (STAPPA/ALAPCO) to conduct a systematic data collection designed to improve the methods and tools used by the EPA to estimate emissions from nonroad equipment. Data being collected include populations, usage rates (activity), and "in-use" or "real-world" emission rates.

Current Status and Future Program

This data collection study by the Office of Transportation and Air Quality (OTAQ) in the Office of Air and Radiation (OAR) is being performed as a work assignment under a new EPA contract for National Portable Emissions Measurement Systems (PEMS)/Portable Activity Monitoring Systems (PAMS) research. In 2007, CRC and EPA initiated a new Cooperative Research and Development Agreement (CRADA) to support an expansion of the testing.

ERG, the prime contractor, is working with EPA to integrate statistical sampling techniques, the latest in-use activity and emissions measurement technology, and rigorous quality assurance and quality control methods to characterize in-use, real-world emissions from 52 nonroad diesel engines. Prior to the fieldwork, 500 establishments were briefly interviewed regarding their equipment ownership and use.

During this pilot study, portable on-board instruments are being used to measure exhaust emissions and usage of commercial nonroad diesel engines in the construction sector. Statistical sampling is being used to randomize the recruitment and screening of participants and the selection of equipment to be instrumented. Fieldwork for this study was conducted in EPA Region 7, which includes the states of Iowa, Nebraska, Kansas, and Missouri.

EMISSIONS

Information gathered during the course of this study will be used to help refine methods and protocols for a larger-scale project to estimate the population, usage, and emissions of nonroad equipment in various economic sectors. After undergoing analysis and quality assurance review, these data are stored in OTAQ's Mobile Source Observation Database, where they may help expand and improve the data currently used to support emission inventory modeling for nonroad engines.

The project started in 2007, and CRC funded an expansion of this project through the new CRADA with the EPA. Testing is complete, and data quality assurance and analysis are ongoing. This project is expected to be completed in late 2009.

CO vs. RVP

CRC Projects No. E-74a, E-74b

Leaders: J. P. Uihlein
M. Valentine

Scope and Objective

The objective of this project was to generate data to confirm the effects of gasoline vapor pressure and ambient temperature on CO exhaust emissions from the in-use vehicle fleet. It is anticipated that these data will be used to update the predictive relationships regarding vapor pressure, temperature, and CO exhaust emissions embodied in the EPA MOBILE6.2 emission factor model.

Current Status and Future Program

Begun in 2004, this project consisted of two tasks to be performed in sequence. Task 1 (E-74a) involved a statistical analysis of existing emissions certification data contained in the EPA database. The database contains Federal and California emissions certification data for the vehicle model years 1979 through 2004. Specifically, there is interest in an analysis of the subset of these vehicles for which both standard FTP and low temperature CO certification results are available. EPA began phasing in the low temperature CO certification test in model year 1994; with 100% compliance required beginning model year 1996.

The research performed under Task 1 sorted through the available certification data for 1994 through 2004 model year vehicles and extracted the data for those vehicles where both standard FTP and low temperature CO certification results were provided. The low temperature CO test was run at 20°F, while the standard FTP was run between 68°F and 86°F, but manufacturers have also provided some data at 50°F. Statistical analyses of the data identified the response of vehicle CO emissions to changes in temperature and (potentially) vapor pressure. The results of this analysis were used to design the experimental test program conducted in Task 2 (E-74b) of this program.

Air Improvement Resources (AIR) conducted Task 1 (E-74a). AIR's Final Report, "Examination of Temperature and RVP Effects on CO Emissions in EPA's Certification Database," issued in April 2005, is posted on the CRC website.

EMISSIONS

Task 2 was designed with the assumption that both vapor pressure and temperature effects needed evaluation. Other fuel properties were targeted to be typical of regular-grade winter conventional gasolines blended with alcohol. Fuels were blended from standard refinery gasoline blending streams, without use of special chemicals or chemical blendstocks, such that all carbon numbers of each hydrocarbon type were represented in the blends.

The contractor acquired 15 vehicles for testing. The objective of the fleet selection was to balance several requirements:

- Combination of existing and advanced emission control technology.
- Representative of current and future US vehicle fleet.
- Tier 1-, NLEV-, and Tier 2-certified vehicles.
- Generally split between cars and trucks.
- High volume vehicle/engine/emission control systems.

After discussions with EPA on how this project could help meet their data needs, the project was expanded to include additional fuel formulations. The key fuel parameters that varied among the final test fuel set are vapor pressures (7, 9, and 13 psi) and ethanol contents (0, 10, and 20 volume percent).

For Task 2, a contracting team led by Harold Haskew & Associates, including ATL and Sierra Research, was selected in September 2006. The Final Report on E-74b was published on the CRC website in June 2009.

DIESEL UNREGULATED EMISSIONS CHARACTERIZATION

CRC Project No. E-75-2

Leaders: J. C. Ball
N. J. Barsic

Scope and Objective

The objective of Project E-75-2 is to develop average emission rates of air toxics and other compounds of interest for various diesel vehicle classes by mining the database created in CRC Project E-75, "Unregulated Diesel Emissions Characterization." Until the development of this database, there had been scant coordination of data among studies regarding driving cycles, fuels, lubricants, measurement methods, and diesel vehicle classes. This database also contains emission rates for both engine dynamometer and chassis dynamometer studies.

The focus of E-75-2 is the examination of the data from a variety of studies to determine what data can logically be grouped together, considering both the variables mentioned above and other complicating factors, such as vehicles built to different emission standards and malfunctioning vehicles.

Current Status and Future Program

It is anticipated that broad definitions of emission categories will have to be accepted with results presented as averages, means, and ranges. Large numbers of compounds have been measured in some studies. The first priority was the identification of those compounds commonly present in diesel exhaust that have been characterized as possible air toxics. CARB's list of 41 Air Toxic Contaminants and EPA's mobile source air toxics documents were used as guides.

One anticipated use of this program's results is the comparison of current on-road, HHDD truck unregulated emissions from properly functioning engines or vehicles to the emissions from engines that are compliant with the 2007 HD emissions certification standards.

E.H. Pechan was selected as the contractor for this project. They have completed the examination of the data, and are writing the draft Final Report.

EMISSIONS

ENHANCED EVAPORATIVE EMISSIONS VEHICLES

CRC Project Nos. E-77, E-77-2, E-77-2b, E-77-2c, E-77-3

Leaders: C. Hart
K. J. Wright

Scope and Objective

CRC, working with EPA, determined a need for an evaporative emissions test program to characterize real-world evaporative emission events for planning and inventory modeling purposes. The goal of this program is to characterize the aging fleet of enhanced evaporative emissions vehicles and to collect data on the newer technology vehicles. The effects of fuel vapor pressure and ethanol content in the fuel are being evaluated, along with the level of evaporative emissions control technology on the vehicle.

Current Status and Future Program

The pilot program (E-77) focused on a fleet of ten vehicles of varying evaporative emissions control technologies and hydrocarbon-only fuels. The Final Report for this work was posted to the CRC website in 2007.

The first main study following the pilot was E-77-2. Testing is complete and the draft Final Report is under review.

The tested vehicles include:

- 4 Tier 2/Near Zero LEV
- 4 Enhanced 1996-2001
- One implanted leak (gas cap) vehicle in each vehicle category above.

The tested fuels are gasolines having the following ethanol content and vapor pressure (VP):

- Ethanol: 0% VP: 7 psi
- Ethanol: 0% VP: 9 psi
- Ethanol: 10% VP: 7 psi
- Ethanol: 10% VP: 10 psi
- Ethanol: 20% VP: 10 psi

EPA is funding two follow-on projects to this work, E-77-2b and E-77-3. CRC's contributions to these projects are technical review assistance and vehicles and fuels donation. E-77-2b began in 2008; it continues the E-77-2 test program, using the same test methods with additional cars.

E-77-3 targets the identification of potential fuel leaks in vehicles, and characterizes the emissions of found leaks. The project screens a high number of vehicles passing remote sensing devices (RSD). After identifying potential leaks in the RSD phase, temporary Sealed Housings for Evaporative Determination (SHEDs) are used to obtain data on emissions characterization. Two successful pilot studies for this project were completed in 2008.

E-77-2c is a direct follow-on project to E-77-2 and E-77-2b, intended to expand the database from this series of projects. One purpose of this particular study is to evaluate the effects of ethanol up to 20% volume on late model vehicle evaporative emissions. This is accomplished by expanding the work scope of Project E-77-2b to include fuels containing up to 20% ethanol, at two vapor pressures, 7 and 9 psi RVP. 8 new vehicles will be tested using these two fuels, and vehicles from earlier phases of the research will be tested with implanted fuel system leaks on a variety of fuels. The E-77-2c project was awarded to HHA in the summer of 2009.

EMISSIONS

EXHAUST AND EVAPORATIVE EMISSIONS TESTING OF FLEXIBLE-FUEL VEHICLES

CRC Project No. E-80

Leaders: D. M. DiCicco
H. Maldonado

Scope and Objective

The objective of this project is to test a small fleet of seven late model California-certified Flexible-Fueled Vehicles (FFVs) or their equivalent to determine the impact of varying ethanol-gasoline blends on their exhaust and evaporative emissions. Documenting the procedures, time, and mileage required to adjust engine fuel control systems is an important aspect of this testing, which will enhance understanding of the effect of switching fuels on emissions. Another project objective is the chemical speciation of exhaust and evaporative emissions of the test vehicles.

Current Status and Future Program

The testing is outlined as follows:

- Pilot Program
  - Measure exhaust emissions (Unified Cycle) while vehicle learns new ethanol level
  - Transitions: E85 to E6, E6 to E85, E85 to 50/50 mix
- Main Program
  - After stabilizing fuel learning on four blends of gasoline and ethanol E6, E32, E59 and E85, measure tailpipe exhaust emissions on the following test cycles:
    - -FTP
    - -US06
    - -Unified Cycle
  - After stabilizing fuel system (three week soak with weekly driving and one hour steady temperature SHED test), measure evaporative emissions over the following procedures:
    - -FTP Running Loss
    - -Unified Cycle Running Loss
    - -2-Day Diurnal

HHA is the contractor for this project, which is still in progress and expected to conclude in late 2009 or early 2010.

NATIONWIDE SURVEY OF E85 QUALITY

CRC Project No. E-85

Leaders: K. Wright
D. Hogan
T. Alleman

Scope and Objective

NREL /DOE has partnered with CRC for this study. The objective of this study is to compare the quality of E85 currently sold in the US with the ASTM D5798 quality specification, and additionally to investigate other real or potential quality issues for this fuel.

The DOE Alternative Fuels Data Center E85 station database was used to select E85 public (both retail and fleet) and government fleet pumps for sampling. Locations were selected to cover the broadest possible U.S. continental geographic area. Sampling occurred at three times over the course of a year. The purpose of sampling at different times is to gather seasonally specific samples that cover all volatility grades. Locations were selected to avoid transition classes. All fuel samples were tested for properties shown in D5798 and a short list of other fuel properties. A subset of samples was selected for more detailed characterization.

Current Status and Future Program

Based on results from the Class 1 samples in the summer of 2008, an addendum of 10 Class 1 samples was added to this project. These samples were collected in August 2009.

The data are currently being analyzed, and the draft report is being written. This project is expected to be complete near the end of 2009.

EMISSIONS

REAL-TIME PM MEASUREMENT WORKSHOPS

CRC Project No. E-86

Leaders: M. M. Maricq
H. Maldonado

Scope and Objective

The area of PM emissions measurement is currently undergoing a number of concurrent and rapid changes. Regulatory changes include significant tightening of motor vehicle PM emissions and rule making in the areas of off-road, locomotive, marine engines, and stationary generators. Technology changes include new engine designs, development of diesel aftertreatment systems, and hybrid vehicles. There is also development of new PM sampling techniques and measurement instrumentation.

The CRC Real World Group PM Measurement Panel's objective is to explore the form that effective future PM measurement might take from a research and technology perspective. The panel's primary activity is to conduct focused, invitation-only workshops to gather expert information on the relative importance of various PM characteristics such as size, structure, and composition, in the context of measurement methods. This information is critical to a meaningful understanding of various PM measurement techniques applicable to the broad range of combustion sources.

Current Status and Future Program

Two 2-day workshops were held: the first on the impact of transport and transformation between source and receptor, and the second on the evaluation of sampling and measurement methods. Each workshop was split into four half-day sessions; each session was devoted to a specific question. Two talks by invited experts led off each session. Those talks were followed by breakout sessions that provided opportunities for detailed discussion about current status and future directions of PM measurement.

The first workshop was held in Phoenix, Arizona, on December 4-5, 2008. The second workshop was held in San Diego, CA on March 19-20, 2009. A special issue of the *Journal of Air and Waste Management* (*JAWMA*) is in development, to consist of papers authored by the workshops' speakers and organizers.

MID-LEVEL ETHANOL BLENDS CATALYST DURABILITY STUDY

CRC Project Nos. E-87-1, E-87-2

Leader: C. Jones
B. West

Scope and Objective

The purpose of these studies is to investigate the effects of ethanol-blended fuel on open loop air-fuel ratio and catalyst and oxygen sensor temperatures. When a vehicle engine is operated at heavy loads, the control system will enrich the fuel-air mixture to cool the exhaust and protect the catalyst from overheating. A switching type oxygen sensor will not operate in the rich environment, and the control system will lose feedback from the sensor and go to "open-loop" operation. If the enrichment calculation does not take the possibility of higher ethanol in the fuel into account, then the calculation may be in error and the catalyst protection could be compromised.

The objective of E-87-1 was to test a small fleet of 25 U.S. and California certified vehicles to determine whether the fuel ethanol content affects the combustion stoichiometry and the catalyst and oxygen sensor temperatures when the vehicle is operated in catalyst protection mode. E-87-1 was a screening study to identify vehicle types (make, model, model year) of interest for the main study, E-87-2.

The objective of E-87-2 is to determine the effects of intermediate-level ethanol blends on catalyst durability and exhaust emissions, using a larger selection of vehicles.

Current Status and Future Program

The Transportation Research Center was selected as the contractor for the screening study through a competitive solicitation awarded by CRC. DOE/ORNL and DOE/NREL conducted their own pilot studies in parallel to E-87-1, and both national laboratories are represented on the CRC E-87 Project Panel. The E-87-1 Final Report was released in July 2009.

EMISSIONS

Four fuels were used in the projects, defined here by their ethanol volume percent content: E0, E10, E15, and E20.

For the main study, run by DOE/ORNL, ten vehicle types or more (multiple vehicles of each type for different fuels) are being aged for 50,000 miles or full useful life, whichever is greater, with emissions measurements performed at every 25,000 miles.

CRC Emissions Committee members were represented on an advisory panel for the DOE/ORNL contractor selection process for E-87-2, "Catalyst Screening and Durability Study for Intermediate Ethanol Blends." SwRI was selected as the contractor for the main study through a competitive solicitation awarded by DOE/ORNL. CRC is contributing funding to purchase 24 of the vehicles that will be used in this study. The E-87-2 project is in progress and is expected to continue through 2010.

REVIEW OF TRANSPORTATION LIFE CYCLE ANALYSIS

CRC Project No. E-88

Leaders: C. H. Schleyer
P. Heirigs

Scope and Objective

There is increasing interest in energy consumption and GHG emissions from use of transportation fuels. A life-cycle analysis (LCA) or well-to-wheels analysis is required to get a comprehensive estimate of energy use and GHG emissions from use of various transportation fuels. This analysis consists of a well-to-tank (WTT) portion which covers the steps required to deliver the finished fuel to the vehicle and the tank-to-wheels (TTW) portion which covers vehicle use of the fuel.

This project will ivolve a broad review of the methodology, analytical tools, and models used in transportation fuel LCA with a particular focus on biofuels. This review will identify gaps and provide recommendations for improvement in methodology, data, analysis tools, and models.

Current Status and Future Program

A number of models have been developed for conducting transportation fuel LCA analyses including GREET, LEM, and GHGenius. The TTW portion of transportation also uses separate models to evaluate fuel and powertrain effects on vehicle fuel consumption and GHG emissions. U.S. examples are ADVISOR and PSAT developed by NREL and Argonne. Output from these models may be used to provide factors or input to the "Greenhouse gases, Regulated Emissions, and Energy use in Transportation" model (GREET) and other models.

After a competitive selection process, this project was awarded to Life Cycle Associates. Begun in late 2008, the project will run through 2009.

CRC is organizing an invitation-only LCA Workshop in October 2009 to present results from E-88 and other studies. The workshop organizing committee includes representation from API, CARB, CONCAWE, DOE, Environmental Defense Fund (EDF), EPA NBB, NR Canada, USDA, Ford Motor Company, Chevron Global Downstream, RFA, Marathon Oil Company, ExxonMobil Research & Engineering, Argonne National Laboratory, and SCAQMD.

EMISSIONS

EPAct LIGHT-DUTY VEHICLE FUEL EFFECTS

CRC Project No. E-89

Leaders: J. P. Uihlein
C. Hart
D. H. Lax

Scope and Objective

EPA initiated this study with CRC and DOE/NREL. E-89 will examine the effects of fuel parameters on emissions of late-model, light-duty vehicles. It has these specific objectives:

- Phases 1 and 2 were run by EPA and DOE/NREL.
- Phase 3 includes the fuels recommended by CRC, and is intended to establish the effects of Reid Vapor Pressure (RVP), T50, T90, aromatics and ethanol content on exhaust emissions from Tier 2 vehicles.

Current Status and Future Program

After review of the test matrix, CRC funded a small project to review the matrix and recommend an expansion of the project by two additional fuels, supported by statistical analysis, to improve the value of the project. These two fuels will enhance the understanding of the effect of the fuel distillation parameters.

EPA agreed to partner with CRC and has incorporated the recommended additional fuels for testing in the main program. The project is structured as follows:

- Objective: Program Design
  - Phase 1:
    - Testing 75°F over LA92
    - 3 'typical' fuels E0, E10, and E15
    - 19 high sales volume Tier 2, 2 high-emitter and 1 high-mileage NLEV vehicles
  - Phase 2: Repeat of Phase 1 except at 50°F
  - Phase 3: Main Program
    - 27 fuels tested in 19 Tier 2 vehicles, E85 tested in 4 FFVs that are included in the 19
    - Fuel Matrix, 5 variables in matrix
    - 2 levels of RVP, T90, aromatics

- 5 levels of T50
- 4 levels of ethanol (E0, E10, E15, E20) plus E85
  - 2 additional fuels from CRC for resolving potential T90 non-linear effects
  - Variables span the 5th and 95th percentiles of in-use fuel properties
  - Measured emissions: PM, CO_2, NO_2, VOCs, ethanol, carbonyls, N_2O, NH_3 and HCN by FTIR, and SVOC speciation in Phases 1, 2, and 3

Recent funding limitations have resulted in a near-term reduction of the test fleet to up to 12 vehicles, but the full test fuel suite has been retained. Testing is expected to continue through the third quarter of 2009, with final reporting near the end of 2009 or early 2010.

EMISSIONS

IMPACT OF E15/E20 BLENDS ON OBDII SYSTEMS

CRC Project No. E-90

Leader: J. Jetter
M. Natarajan

Scope and Objective

The objectives of this study are to collect OBD and related data from in-use, high-mileage vehicles and analyze these data to determine the vehicles' potential to illuminate the Malfunction Indicator Lights (MIL) when fueled with intermediate ethanol blends. Target data will include long-term fuel trim and any stored OBD DTCs related to enleanment.

Current Status and Future Program

De la Torre Klausmeier Consulting, Inc. was chosen to perform the first phase of this project. To ensure data are collected in a consistent manner and under the conditions of interest, a specific test protocol has been defined. To facilitate data interpretation, some vehicle data are being collected in regions where E10 is marketed exclusively, and some in regions where E0 is marketed exclusively. Given that specific On-Board Diagnostics (OBD) threshold values for MIL illumination are considered confidential, the Auto Original Equipment Manufacturers (OEMs) will provide general input during the data analysis phase.

Description of the study approach:

1. Obtain approval from states with inspection/maintenance (I/M) programs to conduct additional tests at inspection stations on a sample of high mileage vehicles.
2. Develop a plan for conducting these tests at inspection facilities.
3. Coordinate the collection and analysis of data.
4. Prepare draft and final reports.

This project was initiated in late 2008; a pilot study was completed in Austin in the spring of 2009. This phase is expected to conclude in late 2009. A second phase will be planned based on the outcome of the initial effort.

EVAPORATIVE EMISSIONS DURABILITY TESTING

CRC Project No. E-91

Leader: C. Jones
C. Schleyer

Scope and Objective

The objectives of the evaporative emissions durability test program are to quantify effects of differing levels of ethanol and to document any detrimental effects of long-term ethanol exposure on the evaporative emissions and emissions durability of selected vehicles.

Current Status and Future

This project will test ten vehicle models representing a variety of evaporative emission control strategies. Two of each type of vehicle will be tested on two test fuels, federal emissions test fuel (E0), and federal emissions test fuel blended with 20 (E20) percent ethanol by volume. E0 will serve as the baseline fuel. Vehicles operating on E20 will be compared to the vehicles operating on E0 to determine the effects of increased ethanol levels in gasoline.

The approach will consist of: (a) conducting baseline evaporative emissions testing on the fleet of test vehicles, (b) exposing vehicles to a 3-month aging cycle consisting of ambient diurnals and (c) repeating this cycle 4 times by driving the vehicles over the course of a year.

Intermediate testing (at the end of each 3-month aging cycle) and final testing using both federal certification fuel and the individual vehicle's ethanol evaluation fuel will document any deterioration in evaporative emissions performance. The testing with the federal certification fuel will use the EPA two-day cycle; these data can compare the vehicle response to the certification standards. The testing with the individual vehicle's ethanol evaluation fuel will use the procedure from the CRC E-77 pilot study.

The basic aging protocol consists of driving the vehicle one EPA standard road cycle (SRC) twice per day, allowing the vehicle to cool completely between drives. The SRC is an EPA-devised test cycle of 25.9 miles duration and a 46.3 mph average speed. Between drives, the vehicle is parked outside in ambient conditions. Each aging cycle lasts for 90 days.

EMISSIONS

The evaporative emissions testing portion of the program will consist of both the EPA two-day cycle performed on federal emissions test fuel and the CRC E-77 Pilot Program procedure, using E20 and E0.

The overall program is expected to last approximately 74 weeks. By performing the evaporative diurnal tests on the fuel that is used for aging, a real-world emissions measurement can be generated: a measurement that may be used to understand the real effects on air quality in urban areas. Further, using the E-77 Pilot Program test cycle will allow the isolation of parameters for emissions modeling. These parameters are leaks, diurnal vapors, and permeation.

A competitive procurement process was initiated in the spring of 2009. The project award is anticipated later in 2009.

EVALUATION OF AUTOMOTIVE AFTERTREATMENT SYSTEMS

CRC Project No. AVFL-7a

Leaders: T. Kowalski
K. J. Wright

Scope and Objective

The objective of this project was to develop a new approach for NO_x reduction in an oxidative environment. The approach was to develop precious metal/carbon nanotube composite materials as active, selective, and oxidation-resistant catalysts.

Current Status and Future Program

This project was motivated by Project AVFL-7 that assessed state-of-the-art systems showing promise of non-urea selective catalytic reduction of vehicle NO_x emissions. The University of Kentucky (UK) was selected for a three-year project through a competitive solicitation. The UK project examined a combined high temperature/low temperature dual bed catalyst system that incorporated multi-walled carbon nanotube (MWNT) technology.

In Phase 1, a literature study confirmed that the proposed catalysts were promising candidates for low temperature Selective Catalytic Reduction using hydrocarbon reductants (HC-SCR). MWNTs to be used as catalyst supports were synthesized and treated with mineral acids. Both treated and untreated MWNTs were characterized.

In Phase 2, metals were deposited on pristine MWNTs and functionalized multi-walled carbon nanotubes (fMWNTs), and the resulting catalysts were characterized and tested in a microflow reactor. Once the catalysts with the best performance were identified, experiments were performed with the aim of optimizing these formulations with respect to the support, preparation method, and supported metal phase. The optimized catalyst system was also tested using automotive exhaust to determine its performance.

The Final Report was released in early 2009.

AVFL

THE FUEL CHEMISTRY IMPACTS OF GASOLINE/ETHANOL BLENDS IN AN HCCI SINGLE CYLINDER RESEARCH ENGINE & DATA ANALYSIS

CRC Project No. AVFL-13b / AVFL-13c

Leader: W. J. Cannella

Scope and Objective

In Project AVFL-13b, 16 gasoline-like test fuels with percentages of ethanol varying from 0 – 30% were tested in a single cylinder engine equipped with a hydraulic variable valve train (VVT) and gasoline direct injection (GDI) system. By using VVT and GDI, two different intake charge preparation modes are implemented: recompression early injection (RCEI) and re-breathing early injection (RBEI). For each intake charge preparation mode, three engine operating conditions were investigated:

- 1.5 bar Indicated Mean Effective Pressure (IMEP) at 1000 rpm
- 3 bar IMEP at 2000 rpm
- 5.5 bar/(degree crank angle) of maximum rate of pressure rise (MRPR) at 3000 rpm

For all engine operating conditions and intake charge preparation modes, the combustion phasing, represented by the 50% mass fraction burned location, was fixed at 5 degrees after top dead center (ATDC).

In the related AVFL-13c project, ORNL is applying principal components analysis (PCA) techniques to the data from the AVFL-13 and AVFL-13b projects, developing overall models for understanding fuel property and chemistry effects on Homogeneous Charge Compression Ignition (HCCI) combustion; an alternative to the conventional statistical treatment applied in AVFL-13 and AVFL-13b.

Current Status and Future Program

This project is a follow-on to AVFL-13, using the same contractor, test engine, and protocol. The AVFL-13 Final Report is available on the CRC website. Dr. William Leppard, GM retired, is serving as a consultant to the committee on this project.

The AVFL-13b draft Final Report is under review. It is expected to be released later in 2009. The AVFL-13c project is in progress, and is also expected to conclude in 2009.

AVFL

INVESTIGATION OF THE ROLE OF LUBRICATING OIL ON PARTICULATE MATTER EMISSIONS FROM VEHICLES

CRC Project No. AVFL-14

Leaders: D. R. Lawson
C. H. Schleyer

Scope and Objective

The objective of this project is the evaluation of PM emissions in eight types of vehicles using conventional and advanced lubricants. The emissions are being tracked by each vehicle/lubricant combination. Testing is conducted at cold operating conditions (30°F) and at normal operating conditions (72°F) on two lubricant formulations. The impact of ethanol at a 10% blend level is being studied in light duty (LD) vehicles, and the impact of biodiesel at a 20% blend level is being studied in the medium-duty (MD) vehicles. Natural gas-fueled medium duty (MD) vehicles are also being evaluated.

Current Status and Future Program

Study vehicles include the following:

- Normal-emitting gasoline vehicle – Model year 2002 or newer gasoline-powered LD vehicle with fewer than 75,000 miles.
- High-emitting gasoline vehicle – LD, gasoline-powered vehicle with known PM emissions rate of greater than 200 mg/mile over the Unified Driving Cycle and whose emissions are consistently high with high lubrication oil consumption, and/or has visible smoke related to lubrication oil.
- Normal-emitting diesel vehicle – HD vehicle with a diesel engine displacement of at least 7.2 liters and a minimum rated torque of 660 ft-lbs. Engine model year 2002 or newer with fewer than 270,000 miles. No PM control technology (filter, trap, oxidation catalyst).

- High-emitting diesel vehicle – HD vehicle with a diesel engine displacement of at least 7.2 liters and a minimum rated torque of 660 ft-lbs. Engine/vehicle model year 1996 or older and known to emit high levels of PM. High lubrication oil consumption, and/or visible smoke related to lubrication oil
- Normal-emitting natural gas vehicle – modern CNG- or LNG-fueled transit bus or school bus of model year 2002 or newer with fewer than 270,000 miles. Displacement of at least 7.6 liters and a minimum rated torque of 660 ft-lbs.
- High-emitting natural gas vehicle – high-mileage CNG- or LNG-fueled transit bus or school bus, known to emit measurable levels of PM. High lubrication oil consumption, and/or visible smoke related to lubrication oil.
- Normal-emitting MD diesel vehicle – a MD pickup truck with a diesel engine. Model year 2002 or newer with fewer than 30,000-75,000 miles on the odometer.
- High-emitting MD diesel vehicle – a pickup truck with a diesel engine. Model year 1996 or older and known to emit high levels of PM, has high lubrication oil consumption, and/or visible smoke related to lubrication oil.

This project, also known as the Collaborative Lubricating Oil Study on Emissions (CLOSE) Project, includes the participation of co-sponsors DOE/NREL, SCAQMD, and CARB. The American Chemistry Council (ACC) joined the project after its inception, providing technical expertise and test lubricants, including the used oils from other ongoing ACC programs.

A kick-off meeting was held in San Antonio in May 2007. In 2008, CRC and other sponsors expanded the study to include some repeat testing, in the interest of better separating fuel and lubricant effects from testing variances.

The Final Report for the project is expected to be released by mid-2010.

AVFL

E20 DURABILITY STUDY

CRC Project No. AVFL-15

Leaders: D. M. DiCicco
M. Foster

Scope and Objective

The objective of this project is to determine the durability of wetted fuel system components when exposed to gasoline containing 20% ethanol (E20). Functional testing of individual components is one metric that can be used to evaluate the impact on wear of fuel pumps and fuel injectors. Investigators are gathering quantitative data on the impact of E20 on the performance of plastics and elastomers, including fuel system O-rings, hose materials, and fuel tank materials. The research focuses on older (late 1990s) vehicles that are at risk for durability issues and represent a substantial fraction of the current in-use fleet.

Current Status and Future Program

New fuel system pairs (E0 and E20) are being tested, focusing on components exhibiting the most susceptibility to ethanol content in the fuel. A pilot phase exposed fuel pump components to each of the fuels. Besides fuel pump and fuel injector testing, the program calls for material testing of the complete fuel system after 11 months of aging at 105ºF. The impact of wear on the fuel system components when exposed to E20 will be measured.

DOE/NREL is a co-sponsor of this project. In early 2009, the contract was modified to increase the overall level of effort, adding fuel damper and fuel level sensor testing in the process. Testing for this project is expected to be completed in 2009. This project is considered a pilot evaluation, and additional testing is likely to be needed.

FUELS TO ENABLE LIGHT-DUTY DIESEL ADVANCED COMBUSTION REGIMES

CRC Project No. AVFL-16

Leaders: B. T. Zigler
W. J. Cannella

Scope and Objective

The objective of this effort is to identify the characteristics of advanced fuels that affect the achievable advanced combustion operating range of LD diesel engines and includes two main tasks:

> Task 1 – Establish Engine Test Platform -- A research engine test platform will be established that is capable of investigating fuel effects in advanced combustion regimes.
>
> Task 2 – Investigate the Effect of Fuel Properties on Advanced Combustion Engine Operation -- This project will investigate the impact of cetane number, T90, and aromatic content in a matrix of test fuels. The Fuels for Advanced Combustion Engines (FACE) Working Group has developed a matrix of 9 test fuels; 5 fuels selected from this set will be used for this project.

Advanced combustion operation with the fuels will be defined in terms of quantitative metrics which will include gaseous and particulate emissions, engine Coefficient of Variance (COV), cylinder pressure rise rate, and timing for 50% burn. Measured values will be Exhaust Gas Recirculation (EGR) level, emissions, combustion parameters, and engine performance parameters including torque, air consumption, and fuel consumption. Two operating points will be investigated. The first operating point will be 2100 rpm and highest achievable load and the second will be a low speed-low load test point (such as idle, if achievable).

Current Status and Future Program

The Committee selected WVU to perform this research. DOE/NREL is a co-sponsor of the project, which is scheduled to continue to December 2010.

AVFL

INVESTIGATION OF PLANT DERIVED BIO-FUELS AS POTENTIAL BLEND STOCKS FOR TRANSPORTATION FUELS

CRC Project No. AVFL-17

Leader: M. Natarajan

Scope and Objective

The objective of Project AVFL-17 was to provide a comprehensive assessment of the state-of-knowledge regarding plant-derived biodistillate fuels. The topics of biofuel feedstocks, production technologies, fuel properties and specifications, vehicle emissions characteristics, fuel handling and performance, and life-cycle analyses were investigated from existing data in the literature.

Existing technical data on plant-derived biofuels such soy, rapeseed, jatropha, and palm products were organized in terms of product volumes, properties, and any available emission characteristics. Data from appropriate well-to-wheel analyses (WTW) analyses were also included.

Current Status and Future Program

Desert Research Institute performed this project. The Final Report was released and posted to the CRC website in June 2009. Three SAE papers developed from this work are planned for the SAE 2009 Powertrains, Fuels, and Lubricants Meeting.

INVESTIGATION OF BIODIESEL CHEMISTRY, CARBON FOOTPRINT, AND REGIONAL FUEL QUALITY

CRC Project No. AVFL-17a

Leader: M. Natarajan

Scope and Objective

This project, conceived as the second stage of the research performed in Project AVFL-17, will consist of three tasks:

Task 1 - To investigate and evaluate the fatty acid methyl esters (FAME) in terms of their chemistry and composition and their influence on the emission characteristics. For example, the carbon chain length, the location, and the number of double bonds in the FAME structure will be considered in how they influence the FAME properties and emissions. Significant information in this area was already collected in AVFL-17; therefore, this task will be more focused - for example, examining such things as the location of the double bonds in the FAME structure and how they influence the FAME properties such as cold flow, cloud point, CFPP, CN, oxidation stability, density and emissions.

Task 2 - To investigate the carbon footprint of the various biodiesels. Literature data will be collected on life cycle analysis of the various biodiesels using different models. A critical evaluation of the various studies which are most complete and based on sound science is required in this Task. An attempt will be made to explain the various assumptions associated with land use change, including international scenarios.

Task 3 - To collect literature data on the regional and national biodiesel fuel quality specifications and measurement methods used in the various regions of the world and how they are enforced.

Current Status and Future Program

A request for proposals for this project was released in July 2009; the project is expected to start in the fall of 2009 and conclude in 2010.

AVFL

SURROGATE FUELS FOR KINETIC MODELING

CRC Project No. AVFL-18

Leaders: C. J. Mueller
W. J. Cannella

Scope and Objective

The objective of this research project is to develop an improved surrogate diesel fuel that accurately captures the ignition, volatility, and emissions characteristics of a real diesel fuel by including compounds that represent the major chemical classes found in real diesel fuel. Typical commercial diesel fuel is comprised of hundreds of compounds.

A diesel surrogate fuel is defined as a fuel that accurately reproduces the ignition, combustion, emissions, and other relevant characteristics of a full-boiling-range real diesel fuel, but consists of approximately a dozen pure compounds. Diesel surrogate fuels are important because they help enable the design and optimization of combustion strategies; the limited chemical reaction paths possible in a surrogate makes complete computational combustion chemistry tractable, avoiding costly experimental iteration. A valuable by-product of formulating an accurate diesel surrogate fuel is enhancement of the fundamental understanding of effects of specific fuel components on processes in advanced engines.

This project will identify compounds for possible inclusion in the surrogate fuel and conduct experiments to verify that the surrogate fuel matches the relevant characteristics of the targeted real diesel fuel.

Current Status and Future Program

This project is being performed in collaboration with researchers at DOE's National Laboratories: NREL, Sandia, Lawrence Livermore, and ORNL. The National Institute of Standards and Technology (NIST) is acting as a contractor assisting with surrogate formulation. This project is ongoing, with reporting expected in early 2010.

FUELS FOR ADVANCED COMBUSTION ENGINES (FACE) WORKING GROUP

Leaders: K. J. Wright
W. Clark
R. L. Graves

Scope and Objective

The AVFL Committee formed the Fuels for Advanced Combustion Engines (FACE) Working Group to foster collaboration with DOE, NREL, and ORNL. The mission statement for this group was approved by the CRC Board of Directors in late 2005. The mission of the FACE Group is to recommend sets of test fuels well suited for research so that researchers evaluating advanced combustion systems may compare results from different laboratories using the same set (or sets) of fuels.

Current Status and Future Program

The FACE Group is composed of volunteers from industry, government, and academia. Its membership includes researchers from the fuel industry, as well as members representing the engine, automobile and emission control technology manufacturers, academia, and U.S. Department of Energy National Laboratories. The activities of the group formally commenced in January 2006. The initial collaboration has expanded to include scientists and engineers from other National Laboratories: Sandia, Lawrence Livermore, and Pacific Northwest, as well as Canada's National Centre for Upgrading Technology (NCUT), and private laboratories: Battelle, Ricardo, and AVL.

The group has been working on recommending two sets of fuels for research in advanced combustion in the diesel and gasoline ranges. The diesel fuel set, defined in 2007, is commercially available from the Chevron Phillips Chemical Company, LLC (CPChem). Extensive characterization work has been performed by laboratories participating in the working group; a summary of standard analyses is available from the CRC web site, with a report on the detailed characterization planned for release in 2009, with an accompanying conference paper at the SAE Fall Powertrains, Fuels, and Lubricants meeting.

AVFL

The gasoline-range fuel set design was recently finalized by the group. These fuels are expected to be available from CPChem in the coming months. Plans for characterization are not yet defined.

Current and future activities include review of available data using the FACE fuels from combustion studies, along with recommendations for parameters to measure in the studies, outreach to the technical community to raise awareness of the availability of the test fuels, and ongoing discussions of how best to approach alternative fuels research when also working with the FACE fuel sets. The group also serves in a support role for the AVFL projects that are employing FACE fuels in research.

AIR TOXICS WORKSHOP

Project No. A-45

Leaders: J. C. Ball
D. C. Baker

Scope and Objective

The objective of this project is to bring together key individuals and organizations working on current issues on mobile source air toxics.

Current Status and Future Program

The Atmospheric Impacts Committee hosted the CRC Mobile Source Air Toxics Workshop (MSAT) in Phoenix in 2006 as a follow-up to the first two workshops held in Scottsdale in 2004 and in Houston in 2002. As with the two previous events, this workshop brought together key government, academic, and industry researchers, and stakeholders working in this area.

The 2008 Workshop (A-45b) program was held December 1-3, 2008, in Phoenix, AZ, with support from the extensive organizing team assembled to manage the previous workshops (EPA, CARB, FHWA, API, SCAQMD, NREL, NESCAUM (Northeast States for Coordinated Air Use Management), DRI, and NUATRC (National Urban Air Toxics Research Center). Dr. Steve Japar led this effort under contract to CRC. Over the course of the two days there were seventy-seven participants from 49 different technical organizations. Participants heard 38 presentations on topics including:

- Needs of Regulators; Air Quality and Exposure Measurements of MSATs;
- Source Apportionment and Atmospheric Formation of Air Toxics;
- Uncertainties/Accountability; Air Quality and Exposure Modeling of
- MSATs; and Vehicle Emissions and Vehicle Emissions Modeling.

ATMOSPHERIC IMPACTS

Additionally, there were four posters presented. The proceedings and summary of presentations for this workshop were distributed to all attendees in March 2009.

The general sense from attendees was that research needs remain diverse and include such things as: Continued testing of new-technology vehicles and alternative fuels, continued development of exposure models capable of predicting behavior in pollution “hot spots,” accountability questions in terms of regulations already in place and how they have performed against stated objectives, better understanding of exposure to multiple pollutants as well as several other research needs. Because of these ongoing research questions, the group discussed plans to hold another workshop in about two years.

IMPACT OF REACTIVE HALOGEN GASES ON CA AIR QUALITY

Project No. A-62-1, A-62-2

Leaders: J. C. Ball
E. McCauley

Scope and Objective

The objective of this project is to measure reactive halogen gases and associated pollutants at a Southern California coastal site and to assess the potential significance of reactive halogen chemistry on air quality.

Current Status and Future Program

Hydroxyl radical (OH) is widely considered the dominant daytime oxidizing species, initiating ozone (O_3) chemical formation in the presence of volatile organic carbons (VOC) and NO_x. However, there is increasing evidence that halogen atoms, specifically chlorine and bromine, are also significant oxidants in coastal areas. Reactive halogen gases (Cl_2, BrCl, Br_2) are produced from chemical reactions on sea-salt particles and readily photolyze in the early morning to produce halogen atoms. Cl-atoms oxidize hydrocarbons 100 times faster than OH, thus initiating ozone production and aerosol formation earlier than possible from OH chemistry alone. For these reasons, it is suspected that this accelerated chemistry could lead to higher daytime O_3 concentrations, affect aerosol particle formation and composition, and potentially increase human exposure in highly populated coastal cities of California, including Los Angeles, San Diego, and San Francisco. Conversely, Br-atoms do not rapidly react with most organics, but do react with O_3 and lead to its destruction. Regional photochemical models used to evaluate the effectiveness of emission control strategies in O_3 non-attainment areas do not account for halogen reactions and, therefore, may be flawed when applied to coastal regions. Measurements of reactive halogen gases in coastal areas are needed to assess their potential importance and to determine if halogen chemistry should be included in air quality models.

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Direct measurements of up to 150 pptv Cl_2 on the Long Island, NY coast and indirect measurements of up to 127 pptv Cl_2 on the Florida coast have been made. Direct measurements of up to 27 pptv Br_2 and 35 pptv BrCl have been made in the Arctic prior to polar sunrise. Until Project A-62 was started, no halogen measurements had been made on the U.S. West Coast. Laboratory studies have established that Cl_2 is likely present in on-shore marine airflow due to reactions involving sea-salt particles, which are ubiquitous in California coastal regions. Modeling studies of Southern California have shown that including chlorine chemistry increases ozone levels by as much as 12 ppb over a base case at Long Beach. However, chlorine and bromine effects on California photochemical air pollution cannot be truly assessed until measurements of these gases are made and analyzed.

A two-week early fall field measurement campaign occurred during Year 1 (2006, 2007) in the Los Angeles area. The gases Cl_2, BrCl, and Br_2 were measured on-line by atmospheric pressure chemical ionization mass spectrometry to quantify their diurnal variation. Differential optical absorption spectroscopy was used to measure halogen oxide concentrations, as well as O_3, NO_2, and HCHO. On-line size resolved aerosol composition measurements were made to characterize the urban/marine aerosol and the evolution of its composition (SO_4, NH_4, NO_3, Cl, Br, Na, K, organics). In Year 2 (2007, 2008), these data were used in an appropriate gas-aerosol model to analyze the impacts of measured halogen gases on urban air O_3 and aldehyde concentrations, and on aerosol composition and size distributions. This collaborative effort involves scientists from Battelle Memorial Institute (who performed the only existing direct measurements of Cl_2, BrCl, and Br_2 and have extensive expertise with on-line, size-resolved aerosol composition measurements), University of California, Los Angeles (UCLA) (who first identified ClO in the troposphere near Salt Lake City), and researchers at Washington State University (WSU).

The knowledge to be gained from this project is needed to assess emission controls for reducing ozone concentrations. The committee approved proposals received from the research team. CARB is supporting work at UCLA and one-half the work at WSU. CRC is supporting the research at Battelle and one-half the WSU research in separate agreements, respectively. Researchers from the University of New Hampshire and the University of California at Irvine are also contributing to the study supported by the National Science Foundation.

The overall results revealed gaps in the current understanding of chemistry forming Cl_2 at night. Kelp was identified as a key source of iodine but there remains the inability to accurately estimate total amount of halogens emitted from it. Further research is needed to complete the picture and close the gaps in order to better understand halogen chemistry in polluted coastal areas.

A series of poster presentations (Battelle, UCLA, and WSU) reviewed and approved by the project sponsors were given at the American Geophysical Union (AGU) conference in December 2007.

The draft Final Report was received in December 2008 and sent to Committee for review. Reviewer comments were returned to the investigators in early 2009. The Final Report was released in August 2009 and posted to the CRC website. In summary, the field experiment showed the presence of reactive halogen species including chlorine, bromine, iodine and some derivatives all mostly in the low part per trillion levels.

ATMOSPHERIC IMPACTS

PHASE II DDM FOR CAMx PROBING TOOLS

Project No. A-64

Leaders: A. M. Dunker
R. S. MacArthur

Scope and Objective

The objectives of this project are to (1) complete more rigorous testing and evaluation, and (2) demonstrate air quality grid model probing tools in a relevant database.

Current Status and Future Program

Several probing tools are emerging for PM models. These include DDM (decoupled direct method), PSAT (particulate source apportionment technology), and PA (process analysis) for CAMx; and TSSA (tagged species source apportionment) and PA for CMAQ. Later tasks of the original probing tools project (A-51), including full-scale testing, were not funded. The approach to be used in this study included using a Regional Planning Organization (RPO) modeling database to give the results a real-world application.

The project was conducted by ENVIRON, Project A-51 contractor. ENVIRON worked with the CMAQ TSSA developers at the University of California at Riverside to collaborate with a RPO or leverage the existing applications being used. The project deliverables included a final report and a journal paper on probing tool implementation and comparison with updated CAMx source code as appropriate. The results give encouragement for the use of probing tools by states and the EPA in PM and visibility modeling for improved diagnostics leading to better modeling and a more detailed understanding of source contributions and/or sensitivities.

The committee scheduled a start date of September 2007. ENVIRON completed the modeling plan for the study and the committee approved a small expansion of the project scope to explicitly track NO_x area and point sources.

ATMOSPHERIC IMPACTS

This study focused on determining the advantages and limitations of two main tools, the PSAT and the DDM. PSAT is better at apportioning sulfate, nitrate, and ammonium to sources emitting SO_2, NOx, and NH_3, respectively. PSAT is also better at estimating the impact on PM concentrations of removing all emissions from a source than removing a fraction of the emissions. DDM is more accurate than PSAT in determining the impact of emissions that have indirect effects on secondary PM. This is especially true for sources such as motor vehicles that have substantial emissions of multiple pollutants (e.g., VOC and NO_x) because complicated indirect effects are more likely for such sources.

ENVIRON submitted a draft Final Report in late November 2008. The Final Report was approved for distribution and posted on the CRC website in March 2009. In July 2009 an article was published in *Environmental Science & Technology* describing the key findings of the study.

ATMOSPHERIC IMPACTS

ACCURACY OF REGIONAL OZONE AND PM BACKGROUND

Project No. A-65

Leaders: A. M. Dunker
R. S. MacArthur

Scope and Objective

The objective of this project is to determine whether the anthropogenic increment contribution to O_3 and PM is correctly predicted in regional simulations, and, if not, what the implications are for control strategies. This objective includes determining whether the emission inventories for natural sources yield O_3 and PM concentrations are in reasonable agreement with accepted background concentration ranges and if agreement is not reasonable, determine possible deficiencies in the natural emission inventories and the potential impacts on O_3 and PM control strategies.

Current Status and Future Program

Regional simulations of O_3 and PM employ emission inventories for natural and anthropogenic sources. The anthropogenic increment contribution to O_3 and PM is simply the difference between a simulation with all sources present and a simulation with only natural sources present. Emission control strategies seek to reduce the anthropogenic emissions so that the background O_3 or PM plus the anthropogenic increment to the pollutant meets the relevant standard.

The accuracy of regional simulations of O_3 and PM has been determined by comparing model predictions for historical episodes or entire years to ambient data. However, there have apparently been no tests reported in the literature on whether regional simulations using only natural emissions give O_3 and PM concentrations in reasonable agreement with estimates of background O_3 and PM concentrations. In particular, regional simulations normally use “clean” boundary concentrations, but it is unclear whether simulations with natural emissions alone will give O_3 and PM concentrations consistent with these “clean” boundary concentrations.

If regional simulations with natural emissions give O_3 and PM concentrations that are too low or too high compared to background concentrations but simulations with all emissions included agree with measurements, then the anthropogenic increments of O_3 and PM will be too high or too low, respectively. If the anthropogenic increments of O_3 and PM are inaccurate, then emission control strategies developed from regional modeling (particularly NO_x control strategies) are also likely to be inaccurate.

The Committee selected ENVIRON to conduct this study with a start date of November 2007. The Committee received the literature review and the contractor-recommended modeling approach in March 2008 and both were approved. The project team submitted a detailed progress report at the end of November 2008. The draft Final Report was received in July 2009 and is currently under review. A journal article will be submitted to *Atmospheric Environment.*

Natural emissions adopted in current regional air quality modeling were updated to better describe natural background O_3 and PM concentrations for North America. The revised natural emissions include organosulfur from the ocean, NO from lightning, sea salt, biogenic secondary organic aerosol (SOA) precursors, and pre-industrial levels of background methane. The model algorithm for SOA formation also was revised. Natural background ozone concentrations increase by up to 4 ppb in annual average over the southeastern US and Gulf of Mexico due to added NO from lightning while the revised biogenic emissions produced less O_3 in the central and western US. Natural $PM_{2.5}$ concentrations generally increased with the revised natural emissions. Future year (2018) simulations were conducted for several anthropogenic emission reduction scenarios to assess the impact of the revised natural emissions on anthropogenic emission control strategies. Overall, the revised natural emissions did not significantly alter the O_3 responses to the emissions reductions in 2018.

ATMOSPHERIC IMPACTS

ESTIMATE OZONE FROM FUEL REFORMULATION

Project No. A-67

Leaders: R. S. MacArthur
A. M. Dunker

Scope and Objective

The objective of this project is to estimate ambient O_3 changes due to the prospective use of new fuel blends or increased usage rates of existing fuels. An emissions-processing scheme is to be developed which quickly applies on-road and nonroad emissions changes due to transportation fuel reformulation to result in a grid-model-ready emissions inventory. A "companion" CAMx grid model O_3 application (e.g., a SIP (state implementation plan) episode) will serve to predict the results from the emissions inventory changes, thus a "model suite."

Current Status and Future Program

Biofuel blends in transportation fuel are being required by many states--as well as by the federal Renewable Fuel Standard (RFS)—consequently, requiring regulatory decision-makers to demonstrate National Ambient Air Quality Standards (NAAQS) compliance with these measures in place. There is concern since vehicle emissions tests have indicated some increase in permeation HC emissions due to ethanol, and some increase in NO_x emissions from both biodiesel and ethanol.

Although generalizations about VOC- or NO_x -limitation in the airshed may be helpful, mixed blends, the market penetration of the blends, and spatial and temporal variation of both mobile source HC and NO_x increases render the predictability less certain. Since grid modeling applications of the simplest of control strategies are time consumptive and burdensome, and since the release timing of vehicle emissions testing results is highly uncertain, it seems prudent to develop a flexible modeling methodology which enables the timely grid modeling investigation of how the vehicle emissions testing results may be represented in the mobile source fleet and the consequent response of ambient ozone.

ATMOSPHERIC IMPACTS

Through close coordination with Lake Michigan Air Directors Consortium (LADCO), the Consolidated Community Emissions Processing Tool (CONCEPT) will be modified to enable flexibility in changes in on-road (link-based) and nonroad temporal and spatial speciated- process- vehicle-specific ozone precursor emissions external from the grass-roots emissions development process. The emissions inventory can then be used as input to CAMx to show the effects of fuel reformulation in the airshed. The "model suite" is intended for decision-makers' and consultants' use to speed up delivery of results and reduce costs.

The project deliverables include a journal article, a model user's guide, public domain-resident code, models, and model inputs. CRC issued a request for proposal for this study, and after committee review, Atmospheric and Environmental Research **(**AER**),** was selected to conduct the study with a focus on modeling in the LADCO region with a project start of December 2007. AER is working directly with Mark Janssen at LADCO to begin selection of modules and use of the most recent CONCEPT software.

Due to a delay in the release of the entire CONCEPT code and the associated input files required to perform modeling tasks, AER requested a no-cost extension for this project. AER estimated 5 months to complete the modeling and requested an extension for submission of the draft final report. The committee approved the extension. In addition to the extension, the principal investigator on the project was replaced due to the resignation of Betty Pun from AER. Dr. Pun has been replaced with Kristen Lohman from AER and the committee chairs approval. All work has been transitioned to Kristen as of December 2008. Work on the project was further delayed due to problems with release of the final updates on the new CONCEPT model. A new CONCEPT model update was released in April 2009, and AER is conducting model runs on the interim version.

ATMOSPHERIC IMPACTS

THE MECHANISMS OF ATMOSPHERIC OXIDATION OF THE OXYGENATES

Project No. A-68

Leaders: T. Wallington
R. S. MacArthur

Scope and Objective

The objective of this project is to prepare a comprehensive inventory of fundamental data and information on the atmospheric reactions of oxygenates in a format suitable for publication as a reference textbook.

Current Status and Future Program

In recent years, a major interest has developed in alternative fuels such as ethanol, butanol, fatty acid methyl esters, and other biofuels that are largely oxygenates. The effects of these fuels and their oxidation products on the atmospheric chemistry of the urban, rural, and "free" atmospheres are of increasing interest. The development of the three previous books supported by CRC dealt with the atmospheric chemistry of the three major classes of hydrocarbons: the alkenes, the aromatic hydrocarbons, and the alkanes, including the haloalkanes. In each of these books, some of the oxidation products of these hydrocarbons were discussed, but the accent in each book was on the hydrocarbons themselves. This textbook is related directly to the atmospheric chemistry of the many oxygenates.

Discussions of the alcohols, aldehydes, and ketones from the three previous books will be drawn on, updated, and included in the proposed "Oxygenates" book, but the new book will also include discussion related to ethers and other classes of oxygenates; e.g., the esters which are major components of biodiesel fuels. The development of a realistic outline of a book on Oxygenates requires discussion and planning by the authors. This project is underway and the following chapter topics were included in this book:

- The Oxygenates: Their Properties, Sources, and Uses as Alternative Fuels
- The Rate Coefficients and Mechanisms for the Atmospheric Oxidation of the Alcohols (Sections on acyclic, cyclic, aromatic alcohols, and haloalcohols)
- The Rate Coefficients and Mechanisms for the Atmospheric Oxidation of the Ethers (Sections on acyclic, cyclic, aromatic ethers, and haloethers)
- The Rate Coefficients and Mechanisms for the Atmospheric Oxidation of Aldehydes (Sections on acyclic, cyclic, aromatic aldehydes, and haloaldehydes)
- The Rate Coefficients and Mechanisms for the Atmospheric Oxidation of the Ketones (Sections on acyclic, cyclic, aromatic, hydoxy ketones, and haloketones)

An author team led by Jack Calvert (including Tim Wallington, Michael Pilling, Abdelwahid Mellouki, and John Orlando) was assembled, and the project started in September 2007. The authors held a coordination meeting at the start of the project, and met again in April 2008, August 2008, and December 2008.

In March 2009 discovery of a large amount of literature not previously anticipated was reported. The significance of the new literature warranted a delay in the draft Final Report in order to ensure a more comprehensive report. The manuscript will be delivered to CRC late in 2009.

ATMOSPHERIC IMPACTS

REGIONAL MODELING OF WEEKEND/WEEKDAY EMISSIONS CHANGES

Project No. A-69

Leaders: A.M. Dunker
R. S. MacArthur

Scope and Objective

The main objectives of this study are to improve regional emission inventories, models, and control strategies by simulating the impact of weekday/weekend emission changes. The objectives will encompass three steps: 1) Review and improve the weekend emission inventory in the eastern U.S., 2) Test the ability of a regional model to simulate the impact of weekday/weekend emission changes on O_3, and 3) Determine to what extent the emission changes in upwind cities affect downwind cities and rural areas.

Current Status and Future Program

CRC funded two projects on modeling the impact of weekday/weekend emission changes in Los Angeles. Project A-36 focused on simulation of an episode during the Southern California Ozone Study (SCOS) in 1997. In Project A-56, Los Angeles emissions were projected to 2010, and the simulated weekday/weekend ozone changes in 2010 were compared to those obtained with emissions for 1997. NREL funded a modeling study of a weekday/weekend ozone episode in southeast Michigan in 2002. Although the modeling domain was larger than southeast Michigan, the review of the weekend emission inventory and the updates to the inventory were confined to southeast Michigan.

To date, there has apparently been no modeling study of weekday/weekend ozone (and PM) changes over a large regional domain using a consistent set of weekend emission changes for the entire domain. Simulating a weekday/weekend episode provides a more stringent test of a regional model (and the associated emission inventory) than simulating a weekday episode. Because the weekend emission reductions are substantial, a weekday/weekend episode can test the model's ability to simulate the effects of emission reductions. Modeling a regional weekday/weekend episode is also of interest because the emission changes in one urban area may impact ozone concentrations in a downwind urban area, delayed by the time required for atmospheric transport. Thus, the weekday/weekend ozone changes in a large region may be different or more complicated than those seen in Los Angeles, which has no large urban area upwind.

An ozone episode in the eastern U.S. containing at least one weekend will be chosen. The modeling domain will cover most or all of the eastern U.S. with fine grids over the major urban areas. The weekend emission inventory for the entire region will be reviewed and adjustments made as necessary to apply a consistent set of assumptions and to use the latest information on weekend activity data. A regional model (CAMx or CMAQ) will be used to simulate the episode. Model predictions for ozone (and other pollutants, if possible) will be compared to ambient measurements within and downwind of urban areas. Analyses of model results, sensitivity tests, and applications of probing tools will be used as appropriate to determine the impact of weekend emission changes in large urban areas on downwind urban and rural areas.

Project deliverables will include a regional emission inventory updated for weekday/weekend changes, quarterly reports, and a final report, part of which is a draft journal article with recommended improvements in modeling longer ozone and PM episodes that include weekends, especially improvements to the weekend regional emission inventory for on-road and off-road vehicles. An RFP was prepared and sent out to prospective bidders in 2008. ENVIRON and Sonoma Technology, Inc. (STI) responded and their proposals were approved by the committee. Contracts were issued in January and March 2009, respectively for A-69-2 and A-69-1. A final data report containing inputs necessary for modeling the weekend effects was received by the committee in May 2009 from STI. ENVIRON is using these data to begin their modeling activities.

ATMOSPHERIC IMPACTS

CMAQ TRAJECTORY GRID (PHASE 2)

Project No. A-70

Leaders: D. P. Chock
R. S. MacArthur

Scope and Objective

The objective of this project is to improve grid model predictions and cost-effective attainment by reducing the CMAQ advection solver numerical diffusion error through evaluation and reconciliation of the model packets management issue. This project's final objective was to complete the roll out of CMAQ-TG.

Current Status and Future Program

The University of Houston was under CRC contract to deploy the Trajectory-Grid (TG) approach of Chock and Winkler into the EPA-preferred grid model CMAQ. Known as CRC Project A-55, "Implementation of the Trajectory-Grid Advection Algorithm in CMAQ," the document reported a "packet management issue" which remained as the biggest obstacle to CMAQ-TG becoming competitive with the standard CMAQ. The code was not considered adequate for public release by project conclusion. At first, TG was not considered deployable in CMAQ. However, there are indications that TG can work well by eliminating advection solver error but requiring nominal coding for packets management.

Additional objectives of the project were to build a working CMAQ-TG, provide an independent evaluation of the TG approach, and to describe how TG may be used to reduce advective transport errors and lead to a better understanding of the turbulent diffusion process. AER submitted a proposal defining a project approach that addressed the three outlined objectives. AER was selected to conduct a timely evaluation and improvement of the TG under Dr. Chock's direction with work beginning in January 2008. The project demonstrated CMAQ-TG in a modeling venue, comparing results with a standard CMAQ application. Initial simulations identified significant differences in behavior of CMAQ vs. CMAQ-TG when diffusion was deactivated. Further work was done to investigate the treatment of vertical advection and diffusion as well as looking at increasing the number of concentration points to determine effects on simulation results. AER worked with Dr. Chock and the Committee co-chair, Rory MacArthur, to finalize the report, incorporating and addressing reviewer comments to the draft version. They also identified next steps for improving the TG model.

The AER draft final report was approved by the Committee and the Final Report was published in January 2009.

ATMOSPHERIC IMPACTS

MODELING SECONDARY ORGANIC AEROSOL FORMATION FROM SEMI-VOLATILE ORGANIC COMPOUNDS EMITTED FROM MOBILE SOURCES AND OTHER COMBUSTION SOURCES

Project No. A-72

Leaders: J. C. Ball
A. J. Krol

Scope and Objective

The objective of this study is to investigate whether the inclusion of secondary organic aerosol (SOA) formation from semi-volatile organic compounds (SVOC) emitted from combustion sources, particularly including mobile sources, can reconcile observations and model simulations in the Atlanta region.

Current Status and Future Program

AER recently completed an analysis of carbonaceous $PM_{2.5}$ data at two monitoring sites in Georgia (CRC Project A-60) and the major conclusions were: (1) Both emissions and SOA formation were important contributors to high observed organic aerosol (OA) events, while modeled episodes of high OA in Atlanta were driven mostly by primary emissions, (2) Rural SOA concentrations were fairly well simulated by the model, but urban SOA concentrations were not, (3) The observed diurnal SOA concentration profile was poorly reproduced by the model, suggesting that the SOA vaporization enthalpies are overestimated in the model, and (4) Day-of-the-week variability of SOA concentrations was not well reproduced by the model, probably because of incorrect emission profiles.

A possible hypothesis to explain several of these conclusions is that SVOC emitted by mobile sources and other combustion sources are not treated in models. Once emitted, SVOC partition between the gas and particulate phases depends on the ambient temperature. The oxidation of SVOC can lead to rapid formation of SOA when photochemistry is favorable, especially in the vicinity of urban sources. Such a pathway has been proposed in the recent literature to explain SOA concentrations in the Pittsburgh area.

The following tasks were proposed for this new project: 1) Develop SVOC emission profiles for mobile source emissions; 2) Develop pathways for SOA formation from SVOC; 3) Incorporate the SVOC/SOA module into a 3-D air quality model; and 4) Make recommendations.

This project was postponed indefinitely at the beginning of 2009 in favor of technical and financial support of CRC Project No. A-73.

ATMOSPHERIC IMPACTS

CONCEPT/CAMx MODELING OF EXPANDED USE OF RENEWABLE FUELS

Project No. A-73

Leaders: A. J. Krol
R. S. MacArthur

Scope and Objective

The committee proposed a new focus of performing air quality modeling of mid-level ethanol blends using emissions data from other CRC and related studies. The modeling approach selected is development of the new emissions inventory model CONCEPT ("suite" with CAMx) for this purpose, to be used in the Lake Michigan area in cooperation with Lake Michigan Air Directors Consortium (LADCO) and also to be used for California in cooperation with CARB and other local agencies if it can be arranged. The California application will require additional effort due to extensive code changes required.

Current Status and Future Program

To bracket air quality predictions from ethanol emissions changes, the application of CONCEPT ("suite" with CAMx) in an additional domain will likely be needed. The additional domain could be the Northeast, Atlanta, or Dallas. The Northeast would be important for representation of effects for the area, Atlanta might help in characterizing changes in a biogenics-VOC-dominated airshed, and Dallas was used in the Auto/Oil program.

The committee worked on developing the final statement of work in the second quarter of 2009. CONCEPT is ready to be used except for some rework required by LADCO. The original Mobile6.2 emissions factor model has been emplaced and some script recoding has resulted in faster computation. The coding necessary for the CA Predictive model fuels is ongoing. Prior plans to incorporate the MOVES model under CONCEPT have been postponed due to the delay in release of MOVES and due to the complexity of this application. A competitive solicitation is planned for this project later in 2009.

DEPOSITS

CRC Project No. CM-136

Leader: J. Axelrod

Scope and Objective

The objectives of this group are to:

- Develop test procedures for the objective evaluation of spark-ignition (SI) engine fuel and fuel additive contributions to combustion chamber deposits (CCD).
- Determine the extent of SI fuel injector fouling and adequacy of current deposit control additive dosages to prevent injector fouling.
- Establish the relationship of SI vehicle fuel level sensor failures and concentrations of corrosive sulfur gasoline species.
- Identify characteristics of SI engine durability with the use of mid-level ethanol blends in non-flexible fuel vehicles.

Current Status and Future Programs

Port Fueling Injector Fouling Survey

Two auto companies in 2004 reported deposit-related Port Fuel Injector (PFI) plugging problems in cars, with a high incidence rate in Florida. The Deposit Group formed a Panel to determine the extent of fuel injector fouling in this region of the U.S. and the adequacy of current deposit control additive dosages to prevent injector fouling.

The program approach was to sample gasoline from 10 major marketers in Tampa and Miami, analyze the fuel composition, assess PFI fouling tendencies with the CRC PFI bench rig using ASTM D6421, and compare fouling tendency of Honda and GM injectors with standard Chrysler rig injectors. GM provided injectors from Florida that have been known to cause fouling problems. Twenty commercial fuels were collected in Florida, analyzed, and tested in the PFI bench rig. Six of the twenty fuels were shown to be deposit-prone. There appeared to be no correlation between apparent deposit severity and fuel properties or additive dosage. This raised the question of whether the PFI bench test is representative or too severe.

In a second phase of the program, the tendency of OEM and ASTM injectors to foul was compared. All showed fouling in the PFI bench rig. The effectiveness of several detergents and dosage was also evaluated and varying degrees of effectiveness were observed in the PFI bench rig.

The Panel then compared the bench rig with the Chrysler PFI fouling vehicle test. CRC Report No. 646 "Port Fuel Injector Fouling Using PFI Bench Rig Evaluation of Florida gasoline, OEM Injectors and Deposit Control Additives," was issued in September 2005. The panel placed the project on hold since February 2007 because of several issues. The injectors do not foul to the same level previous to December 2006. The rigs have shown poor reproducibility. The test development work is continuing as non-CRC funded work at SwRI. SwRI has not identified enough fouling injectors to conduct precision studies. Only when the PFI Panel and the Deposits Group feel that a reproducible test procedure and proper equipment is in place, will this CRC work be restarted. The Deposit Group and committee members have worked with Bosch to select new injectors for future PFI evaluations since the supply of the existing, old injectors is limited and dwindling. Recommendations have been made to focus on new technology hardware to evaluate direct injector fouling performance.

Silver Fuel Level Sensor Corrosion

In response to an ASTM D02.A Subcommittee request, CRC initiated a study following field reports of fuel level sensor failure due to corrosion of silver contacts by reactive sulfur species. The objective of this study is to establish the relationship of vehicle fuel level sensor failures and concentrations of corrosive gasoline sulfur species. A primary goal of data collected in this study is to assist ASTM in establishing a sound basis for pass/fail criteria.

The study was to be conducted in two phases. In the first phase, the fundamental effects of elemental sulfur, H_2S, and mercaptans have been determined. CRC issued a request for proposal to characterize the response of pertinent levels of sulfur, H_2S, and mercaptans and their interactions using two laboratory test methods (ASTM modified silver corrosion and the new PetroCanada silver wool test). The Phase II plan has been postponed indefinitely as the committee believes the Phase I results provide the essential information required to guard against silver corrosion. The Final Report was published in May 2009 as CRC Report No. 653, "Silver Fuel Level Sensor Corrosion Program."

Engine Durability for Intermediate Ethanol Blends

A request for proposal was released by CRC in February 2008 for a new study to evaluate the potential effect of higher ethanol blends in the U.S. LD vehicle fleet. The objectives of the test program are to determine engine durability effect of E20 on a group of engines from vehicles that may be sensitive to the effects of E20. The vehicles will be selected from among those that are more likely to exhibit some issues with E20. This group shall be determined cooperatively by CRC member companies and OEMs in consultation with any outside organization that participates in funding the study.

The approach will consist of laboratory testing up to 14 engines using an engine durability cycle adapted for use on whole vehicles.

The test procedure calls for accelerated testing to reduce test time and reveal possible failures. Accelerated testing is standard practice in the automotive industry. The severity helps reduce test time and compensate for the inherently small sample size associated with these tests.

A number of companies have responded to the Request for Proposal (RFP) and bids are currently under review.

PERFORMANCE

VOLATILITY

CRC Project No. CM-138

Leader: L. M. Gibbs

Scope and Objective

The objective of this group is to investigate the relationship between vehicle performance/driveability and fuel volatility characteristics.

Current Status and Future Programs

<u>2008 Cool Ambient Cold Start and Warm-up E85 and E15/20 Volatility Study</u>

There are two parts to this volatility program: 1) Determine the effect of vapor pressure of E85 Fuel Ethanol on cold-start and warm-up driveability performance under cool ambient conditions in a large group of late model, flexible-fuel vehicles equipped with fuel injection systems, and 2) Determine the effect of E15 and E20 on cold-start and warm-up driveability performance under cool ambient conditions in a moderate size group of late model and older conventional vehicles.

The minimum vapor pressure required for the two warmer ambient conditions of the three volatility classes in ASTM Specification D5798 (Classes 1 and 2) for acceptable cold-start and warm-up driveability were determined. A follow-on program was required to investigate E85 properties for the coldest Class 3 fuels. The cold-start and warm-up performance of E20 versus gasoline with similar vapor pressures was also determined. This program was conducted in January and February 2008. The Renewable Fuels Association (RFA) and NREL contributed funding and manpower support to the project and Lubrizol contributed some test vehicles. The report was approved by the committee and published as CRC Report No. 652. A follow-on program investigated E85 properties for Class 3 (i.e., winter E85) fuels and was conducted in a low temperature chassis dynamometer facility as described below.

2008 Cold Ambient E85 Class 3 Volatility Study

This study, started in summer 2008, evaluated 20 flexible fuel vehicles on 8 fuels with varying vapor pressure and hydrocarbon content. The target test temperature levels were -10°F and -30°F, but these targets were modified to 0ºF and -20ºF due to difficulties observed at -30ºF. The all-weather chassis dynamometer (AWCD) facility at Imperial Oil in Sarnia, Canada was used to complete the study at the end of 2008. Raters from previous CRC programs evaluated the performance of the test fuels. Slight differences were expected between road and dynamometer testing, but trained raters were able to obtain consistent ratings on the dynamometer.

The Sarnia program was completed in December 2008 after 66 test days (20 vehicles, 2 temperatures). The final data report was received and approved by the project leaders. RFA provided cost sharing and participation on data analysis to support the project. The project analysis panel met in May 2009 to prepare the draft report. The Final Report was published as CRC Report No. 654.

2009/2010 CRC/ASTM TVL20, T50 EtOH Volatility

This new project being conducted with ASTM will plan to determine under cool ambient temperature conditions below 5,000 feet altitude the effect of fuel front-end volatility (i.e., TVL20), 50% evaporated distillation point, and ethanol content on hot-fuel-handling driveability performance in a large group of late model vehicles equipped with fuel injection systems. Testing is expected to begin in fall 2009. A second phase under hot ambient conditions is under consideration.

2009/2010 Low T50 High Altitude Hot-Fuel Handling

A test plan has been developed for a program which will take place in 2010. A request for proposal to prepare the test fuels was issued to three contract labs. The study will determine the effects of TVL20, 50% evaporated distillation point (T50), and ethanol content on hot-fuel-handling driveability performance at high altitude. This is a follow-on program of the 2006 CRC Hot-Fuel-Handling Program (CRC Report No. 648). The test site identified for this program is Pueblo, CO and testing must be conducted in the June – August 2010 timeframe.

PERFORMANCE

OCTANE

CRC Project No. CM-137

Leader: J. J. Simnick

Scope and Objective

The objectives of this group are to conduct surveys of the octane number requirements of current production automotive vehicles, to develop methods for measuring vehicle octane number requirement, and to determine effects on octane number requirement of variables such as mileage accumulation and altitude.

Current Status and Future Program

Determining Octane Number Requirements

In October 2005, the Octane Group published CRC Report No. 643 that recorded the results from an acceleration octane test round-robin program. The report included a brief description of the work done within CRC with the Octane Acceleration Technique, the difficulties encountered with the data analysis of the CRC Interlaboratory study, the variability among laboratories in conducting the testing, and specific recommendations for a future improved test procedure. CRC Report No. 643 is available on the CRC website.

Importance of RON vs. MON

The objective of this program is to assess the relative importance of Research Octane Number (RON) and Motor Octane Number (MON) in current and future fleets. Given these results, it may be possible to ascertain whether the arithmetic average of RON and MON, (R+M)/2, is still the best way to determine the Antiknock Index (AKI).

Shell Oil data indicate that recent production European and Japanese vehicles are more responsive to RON than MON. They found that for a given RON, a fuel of lower MON had better road octane performance and gave better power and acceleration. All vehicles were equipped with knock sensors and 93% were equipped with manual transmissions. This

RON sensitivity differs from historical U.S. data, which showed a pronounced sensitivity to MON. The Octane Group developed a program that verifies and expands on the Shell research, testing vehicles representative of the current and future U.S. fleet.

Experimental work at MIT under Professor John Heywood has corroborated the work at Shell. The MIT study on a single cylinder engine also showed that RON was a better predictor of engine power and performance compared to MON.

At CRC, the group sought OEM support for a test program emphasizing the fuel economy potential that could accrue from changes in fuel sensitivity (RON-MON). A letter was issued to the CRC OEM members of the Performance Committee requesting statements of interest in participating by testing engines at their respective laboratories and reporting summary data back to the committee to assess the RON vs. MON octane response of their engines. The Performance Committee organized a panel to identify the test fuel set for the study and agreed to begin the project with even a limited number of participating laboratories.

A detailed program plan was reviewed and approved by the panel. A request for proposal for test fuel blending was issued by CRC and awarded to Haltermann Products. Hand blends and larger drum quantities of the test fuels were approved by the project group were shipped to Chrysler, and testing was started in 2008 on a 5.7-liter Hemi engine at Chrysler's laboratories. At the October 2008 meeting, the group approved using a GM boosted smaller displacement engine (DISI) in place of the naturally-aspirated small engine proposed by Chrysler. Chrysler reported preliminary results from their engine testing at the April 2009 group meeting. GM received the fuels, and testing on the smaller engine is underway.

PERFORMANCE

DIESEL PERFORMANCE

CRC Project No. DP

Leader: M. Nikanjam

Scope and Objective

The objectives of the Diesel Performance Group are to provide technical supporting data for diesel performance issues that are needed by the fuel, engine, equipment, and additive industry and that can be used by technical groups such as ASTM and the International Organization for Standardization (ISO).

The Diesel Performance Group is addressing LDD performance issues and considered these topics to be of sufficient interest to form panels to develop program proposals as needed:

- Lubricity
- Low Temperature Operability
- Biodiesel
- Cetane Number
- Deposit
- Fuel Cleanliness
- Density Range

Fuel Cleanliness and Density Range topics are under review by the committee, but no projects have been developed due to resources used for projects within other panels.

Current Status and Future Program

Diesel Fuel Lubricity Program

Initially, the Lubricity Panel was selected to determine the relationship between diesel fuel lubricity as measured by laboratory tests and injection equipment wear for the current and near future LDD engines in the U.S. Later, their focus changed to determining if a facility constructed at the contracting laboratory was suitable to be used as a tool for such evaluation.

Upon completion of this evaluation, panel members proposed to end the program since ASTM had established a fuel specification, since there were no apparent field problems, and since resources could be allocated to more urgent projects.

The Final Report CRC Report No. 655 was published in July 2009. Publication of this report concluded this area of study for the panel.

Biodiesel Panel Program

The Biodiesel Panel was formed recently to address many issues that need to be investigated regarding this renewable fuel that is being used at a growing rate. Although it serves as a diesel fuel-blending component in most cases, there are a number of performance categories that warrant investigation.

Unlike other panels in this group, the Biodiesel Panel addresses a product instead of a performance category. Therefore, this panel works closely with other panels to conduct research projects. The first project dealt with low temperature operability of biodiesel blends. The study evaluated the correlation between bench test results and actual vehicle performance. This included validation of the proposed ASTM test method for "Precipitates Above the Cloud Point." The study followed protocols similar to those used in the recent CRC Diesel Performance Group cold temperature study, and similar to those described in SAE 962197.

The National Biodiesel Board (NBB), EMA, and NREL joined with CRC to evaluate several blends of petroleum diesel and biodiesel in a low temperature operability study conducted at the Imperial Oil test facility in Sarnia. This project started in December 2007, and the physical test program was concluded in early 2008 with a draft laboratory report supplied by Imperial Oil to the project panel. NREL led development of the final analysis report for the project which was approved by the committee in June and released for publication as CRC Report No. 650. A summary presentation of results was given at the June 2008 ASTM meeting in Vancouver. A follow-on test program under CRC Project DP-2a-2 was completed in 2008. The follow-on project was also conducted at the Imperial Oil Sarnia AWCD facility.

PERFORMANCE

The second phase of this project was designed to fill in some gaps that were identified in the previous phase. A draft final data report was submitted and approved. The draft final analysis report is in preparation by the project panel members.

Cetane Number Program

For Cetane Number, the CRC AVFL Committee performed a study on the effects of Cetane Number on a small fleet of European model LDDs. This was published as CRC Final Report AVFL-11, "The Effect of Fuel Cetane Quality on Light-Duty Diesel Performance." Future work was recommended by AVFL to the Performance Committee to further investigate the observed behavior of Cetane Number effects in LDD vehicles. The panel will focus on determining the availability and timing of the appropriate vehicles, type of fuels, range of cetane number, and possible test cycles. The panel will also try to identify one or more test facilities suitable for conducting a program.

Diesel Deposits

A new project panel on Deposits was formed to investigate deposit-related issues in diesel engines and fuel systems. Initially the panel planned to sponsor a forum to share industry information on diesel deposits to identify significant areas of interest before proposing a specific research project. Since then the EMA presented the panel with a new issue related to high pressure common rail systems. The panel agreed to work with the EMA to determine if sufficient information could be shared and to evaluate if a program could be defined to address this issue through this CRC panel.

PART THREE

RELEASED REPORTS

RELEASED REPORTS - 2009

AIR POLLUTION*

CRC Project No.	Title	NTIS Accession No.
AVFL-7a	Novel Techniques for NO_x Reduction in an Oxidative Environment	PB2009-103938
A-70	Trajectory Grid Transport Algorithm in CMAQ	PB2009-105571
A-64	Evaluation of CAMx Probing Tools for Particulate Matter	PB2009-107887
E-74b	Effects of Vapor Pressure, Oxygen Content, and Temperature on CO Exhaust Emissions	PB2009-111416
AVFL-17	Investigation of Biodistillates as Potential Blendstocks for Transportation Fuels	PB2009-111415
ACES Phase 1	Phase 1 of the Advanced Collaborative Emissions Study	PB2009-112599
E-23-8a	On-Road Remote Sensing of Automobile Emissions in the Tulsa Area: Year 1, September 2003	PB2009-113209
E-87-1	Mid-Level Ethanol Blends Catalyst Durability Study Screening	PB2009-112605
A-62-1 & A-62-2	Impact of Reactive Halogen Species in California Coastal Areas	Pending

*The primary source for the CRC air pollution reports is:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
www.ntis.gov Phone: 800-553-6847
When ordering a report, be certain to include the NTIS Accession Number.

PERFORMANCE & AVIATION*

CRC Project No.	Title	NTIS Accession No.
AV-1-04	Survey of Sulfur Levels in Commercial Jet Fuels	PB2009-106364
CM-136-06	Silver Fuel Level Sensor Corrosion Program (CRC 653)	PB2009-112595
CM-138-08	2008 CRC Cold-Start and Warmup E85 and E15/E20 Driveability Program (CRC 652)	Pending
AV-2-04a	Comparative Evaluation of Semi-Synthetic Jet Fuels	Pending
DP-1-03	Diesel Fuel Lubricity Requirements for LDD Vehicles, Interim Phase Final Report (CRC 655)	PB2009-113214
CM-138-08-2	2008 CRC Cold-Start and Warmup E85 Cold Ambient Temperature Driveability Program (CRC 654)	Pending

*The primary source for the CRC Performance and Aviation reports is:
National Technical Information Service
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5285 Port Royal Road
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When ordering a report, be certain to include the NTIS Accession Number.

PART FOUR

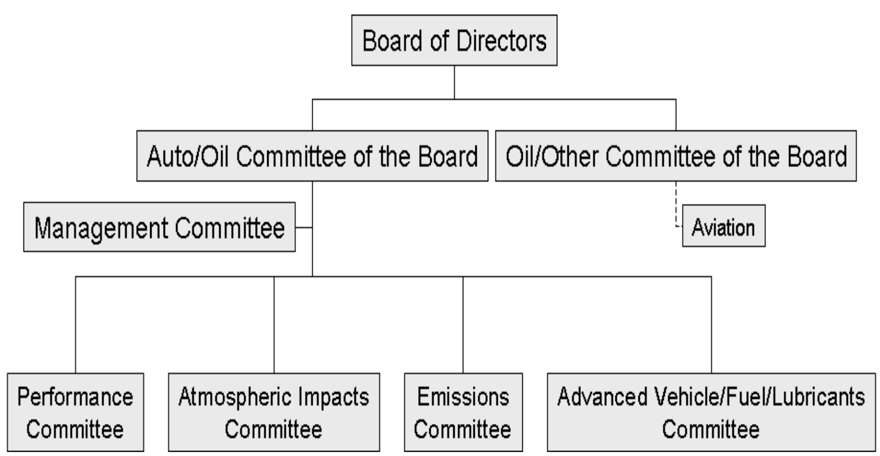
ORGANIZATION AND MEMBERSHIP

ORGANIZATION - 2009

The sustaining members of the CRC are the American Petroleum Institute (API) and a consortium of automobile manufacturers (Chrysler, Ford, General Motors, Honda, Mitsubishi, Nissan, Toyota, and Volkswagen). For over 67 years, CRC has provided the means for the automotive and petroleum industries to study problems of mutual interest. CRC's objective, as stated in our charter, is:

> To encourage and promote the arts and sciences by directing scientific cooperative research in developing the best possible combinations of fuels, lubricants, and the equipment in which they are used, and to afford means of cooperation with the Government on matters of national interest within this field.

CRC manages a range of technical projects designed to keep pace with today's rapidly-changing technology. Industry sponsors support approved projects by equal contributions from the industries directly concerned. Industry and the Government develop projects through committees comprised of their engineers and scientists.



Technical direction in each subject area is handled by an appropriate committee that closely supervises the progress of groups under its jurisdiction. The CRC Board of Directors is responsible for general policy and operation, including providing financial support, manpower, and laboratory facilities.

The diversity of the organizations participating in the various CRC committee activities can be seen in the remainder of this section. Committees and their working groups are made up of professionals of the highest technical competence in their areas.

CRC is not involved in regulation, hardware or fuel development, nor setting standards. CRC has only one real mandate, and that is to add to the scientific base that underlies regulation and technology. All CRC information is made publicly available and is used by industry to ensure optimum compatibility and customer satisfaction with its products and by industry, government, and the public to enhance joint achievement of clean air.

CRC has two basic types of research programs:

Cooperative research programs -- where scientists from various organizations come together to conduct cooperative research. This method utilizes the expertise from industry, government, and academia to develop and conduct experimental research programs. The results of these programs are published and made publicly available.

Contract research programs – where CRC conducts research by contract with independent research laboratories. Requests for proposal are issued to leading research organizations and universities to carry out specific research programs. Committees composed of industry and government representatives design these programs. The committees evaluate the proposals, and the research is carried out under the monitorship of the committees. Once again, reports that document the results of the study are published and made publicly available.

CRC's Auto/Oil Committee of the Board of Directors oversees the cooperative research summarized in this report. Board membership is comprised of six representatives from the petroleum industry and eight representatives from the automobile companies. Each industry has one vote on this committee, and each side must agree on matters concerning research priorities and funding before a project goes forward.

This organizational structure ensures research programs that are relevant to both industries as they change their products to comply with the provisions in the U.S. Clean Air Act Amendments or other regulations that affect the industries. Industry believes that making improvements in air quality can best be achieved through a sound understanding of the scientific issues. Industry working together with involvement from appropriate Government agencies is an effective approach to obtain technical information needed to achieve environmental and other vehicle performance goals.

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(Project No. CM-136)

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(Project No. CM-136)

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(Project CM-136)

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(Project No. CM-138)

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J. Farenback-Brateman	ExxonMobil	D. Schoppe	Intertek
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(Project No. DP)

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D. A. Daniels	Innospec Fuel Spec.	M. Natarajan	Marathon Petroleum
B. Evans	Evans Research	C. Richardson	Ford Motor Co.
M. Foster	BP	J. A. Rutherford	Chevron Oronite
D. R. Forester	Power Service Products	R. D. Tharby	Tharby & Associates
K. Freund	Volkswagen of America	M. Valentine	Toyota Technical Ctr.
J. Frusti	Chrysler	G. Webster	AET
C. Hamer	PCS Instruments	L. Webster	Nissan Tech. Ctr. NA
P. Henderson	GM Powertrain	S. A. Westbrook	SwRI
J. J. Jetter	Honda R&D Americas	K. Woodall	Associated Octel
C. H. Jewitt	Consultant		

MEMBERSHIP

LUBRICITY PANEL
(Project No. DP-01)

M. Nikanjam, Ldr. — Chevron Products Co.

D. Arters	Lubrizol	P. Lacey	Delphi Diesel Systems
J. Axelrod	ExxonMobil	T. Livingston	Robert Bosch
A. Cayabyab	CARB	K. Meyer	Robert Bosch
R. A. Cherrillo	Shell Global Solutions	A. Millard	Infineum USA
M. Foster	BP	K. Mitchell	Shell Canada Products
P. Henderson	GM Powertrain	J. A. Rutherford	Chevron Oronite
A.M. Kulinowski	Afton Chemical	G. Webster	AET

LOW TEMPERATURE OPERABILITY PANEL
(Project No. DP-02)

J. Chandler, Ldr. — Infineum

J. Axelrod	ExxonMobil	J. J. Jetter	Honda R&D Americas
A. Buczynsky	GM Powertrain	H. Martin	Cummins/Fleetguard
D. A. Daniels	Innospec Fuel	K. Mitchell	Shell Canada Products
R. Davidson	Afton Chemical Corp.	M. Nikanjam	Chevron Products Co.
J. G. Dietz	Lubrizol Corp.		

BIODIESEL PANEL
(Project No. DP-02a)

R. McCormick, Ldr. — NREL

D. Arters	Lubrizol	P. Henderson	GM Powertrain
R. Baranescu	Int'l. Truck & Eng.	S. Howell	National Biodiesel Board
A. Buczynsky	GM Powertrain	J. J. Jetter	Honda R&D Americas
J. Chandler	Infineum	T. Livingston	Robert Bosch
D. R. Forester	Power Service Prods.	K. Mitchell	Shell Canada Products
R. Gault	EMA	M. Nikanjam	Chevron Products Co.

CETANE NUMBER PANEL
(Project No. DP-3)

A. M. Kulinowski, Ldr. — Afton Chemical

J. Axelrod	ExxonMobil	K. Freund	Volkswagen of America
A. Buczynsky	GM Powertrain	J. J. Jetter	Honda R&D Americas
E. Casey	ConocoPhillips	S. Johnson	Volkswagen of America
R. A. Cherrillo	Shell Global Solutions	T. Livingston	Robert Bosch
F. Cornforth	ConocoPhillips	K. Mitchell	Shell Canada
D. R. Forester	Power Service Prods.	M. Nikanjam	Chevron Products Co.
M. Foster	BP		

DEPOSIT PANEL
(Project No. DP-4)

J. Axelrod, Co-Ldr. — ExxonMobil
D. Arters, Co-Ldr — Lubrizol

M. Ahmadi	Oronite Additive Co.	P. Lacey	Delphi Diesel Systems
A. Buczynsky	GM Powertrain	T. Livingston	Robert Bosch
E. Casey	ConocoPhillips	C. Millard	Infineum
D. R. Forester	Power Service Prods.	K. Mitchell	Shell Canada
M. Foster	BP	M. Nikanjam	Chevron Products Co.
J. J. Jetter	Honda R&D Americas	W. Westbrook	Southwest Research
A. Kulinowski	Afton Chemical		