

**CRC**

**ANNUAL REPORT**

**2010**



**COORDINATING RESEARCH COUNCIL, INC.**



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# **COORDINATING RESEARCH COUNCIL ANNUAL REPORT**

**September 2010**



**COORDINATING RESEARCH COUNCIL, INC.**  
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PART ONE

STATE OF THE COUNCIL



## **STATE OF THE COUNCIL: 2010**

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 interest.

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 U. S. Environmental Protection Agency (EPA), the South Coast Air Quality Management District (SCAQMD), the Renewable Fuels Association (RFA) 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.

Proposals for replacement of conventional petroleum sources with renewable sources are being promoted in many sectors around the world. CRC research on the use of renewable fuels such as ethanol and biodiesel has continued. A proposed waiver was submitted last 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 of 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 light-duty vehicle 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, the Engine Manufacturers Association (EMA), and several off-road engine/vehicle associations through regular face-to-face meetings organized by the Mid-Level Ethanol Blend Research Coordination Group stakeholders.

The impacts of biodiesel use on fuel quality and vehicle performance, especially under cold ambient temperatures, continue to be evaluated by our technical committees with a new report issued on critical biodiesel cold flow properties. CRC is coordinating this research with government

agencies and other stakeholders including the National Biodiesel Board (NBB) and EMA with technical support from DOE/NREL.

Last year, CRC completed Phase 1 of the Advanced Collaborative Emissions Study (ACES) in collaboration with the Health Effects Institute (HEI). This study 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<sub>x</sub>). A journal article was submitted for publication to the *Journal of Air and Waste Management Association (JAWMA)* on the Phase 1 engine emissions test program. This year HEI commenced health effect testing at Lovelace Respiratory Research Institute (LRRRI). 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.

CRC Project E-77, conducted in cooperation with EPA, has continued this year to 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. This year Report No. E-77-2 was published characterizing details of various modes of evaporative emissions from modern vehicles including canister losses, liquid leak rates, fuel system permeation levels, and full vehicle evaporative emission levels. Additional vehicles have been tested under new phases of E-77, and data will be reported in the near future including data from a new and highly successful measurement technique using remote sensing to identify high evaporative emissions vehicles on the road.

A major new initiative has been started this year under CRC Project E-91 to evaluate the durability of evaporative emissions control systems in the modern fleet. This study will compare system durability in response to exposures to different levels of ethanol fuel up to 20 volume percent ethanol (E20). Vehicles are being tested at specialized test facilities in Colorado and in Detroit. Final results are expected to become available in 2011.

The Advanced Vehicle/Fuel/Lubricants (AVFL) Committee completed a new study on development of diesel surrogate fuels as described in Report No. AVFL-18a. This initiative was developed to identify a diesel fuel surrogate mixture of selected pure component hydrocarbons that could be used for advanced kinetic and combustion modeling studies. Additional diesel fuel characterization was also reported by the Fuels for Advanced Combustion Engines (FACE) Working Group in Report No. FACE-1, "Chemical and Physical Properties of the FACE Research Diesel Fuel."

The AVFL Committee is also continuing its support in the evaluation of mid-level ethanol blends under Project No. AVFL-15 to assess fuel system material compatibility of E15 and E20 blends.

The Diesel Performance Group of the CRC Performance Committee has formed three special sub-panels to evaluate new field problems observed in modern diesel fuel injection systems. At least two types of fuel deposits have been documented in field operations of high pressure common rail fuel systems. The special CRC project teams are working with the EMA to define the issues, identify sources of the problems, and recommend solutions for correcting the field problems.

The Octane Group of the Performance Committee continued its important test program to evaluate the relative contributions of motor octane number (MON) and research octane number (RON) in current light-duty engines and control systems. The first phase of testing was conducted by Chrysler, and the second phase was completed this year at General Motors. These initial results are the beginning of a much improved understanding of fuel combustion performance in today's fleet with an opportunity for increasing overall systems efficiency through more finely targeted refining and vehicle designs.

The Volatility Group of the CRC Performance Committee conducted two new studies this year evaluating the driveability performance of gasoline containing varying levels of ethanol and distillation properties. The first study was conducted in cooperation with ASTM to evaluate the influence of winter gasoline front-end volatility, mid-distillation temperature, and ethanol content on modern vehicles in warm temperature environments at low altitude. This study was completed in San Antonio, TX during the fall of 2009 and spring of 2010. The second study was conducted to evaluate the effect the hot fuel handling performance of a set of 13 test fuels at high altitude. The test site was Pueblo, CO at an altitude of 5000 feet. Results from these studies will be available later in 2010 and in 2011.

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 emissions of primary aerosols, i.e., 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 unless all the interactions are properly understood. The Atmospheric Impacts Committee released Final Report No. A-67 in which a new modeling tool called CONCEPT was demonstrated as a method to characterize the impacts from possible fuel changes in the future.

As air quality improves across the U.S., the background sources of pollutants are becoming more important to the total ambient pollution levels. 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 published this year quantifying 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 developed a manuscript on the atmospheric reactions of the oxygenates with the help of in-kind cost-sharing from a team of authors led by Jack Calvert. This manuscript was accepted by Oxford University Press for publication.

The 5<sup>th</sup> Mobile Source Air Toxics Workshop will be held in December 2010 in Sacramento, CA. This workshop will build on the previous successful events bringing together key local, state, and federal government researchers, academic and industry researchers, and other stakeholders to discuss the state-of-the-art and future research needs. The organizing committee for the 2010 workshop includes key participants from EPA, CARB, and many other important organizations performing research in this field.

The 20<sup>th</sup> CRC On-Road Workshop was held March 22-24, 2010, in San Diego, California. Participants included representatives from government, universities, commercial organizations, and several international organizations. The 2010 keynote speaker was Tom Cackette of the California Air Resources Board who shared a perspective of future transportation systems. The 21<sup>st</sup> workshop, now named the “CRC Real World Emissions Workshop” will be held March 21-23, 2011, at the Hyatt Mission Bay in San Diego, California.

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



## EMISSIONS

### 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 Programs

The ACES program is 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/after treatment 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 HHDD engine models compliant with the emissions regulations in effect for 2010 and later.
- 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. Lovelace Respiratory Research Institute (LRRI) was selected to perform Phase 3. Four manufacturers (Caterpillar, Cummins, Detroit Diesel, and Volvo) supplied new de-greened 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 and the Phase 1 project Final Report have been released and are available on the CRC web site. A journal article was submitted for publication to the *Journal of Air and Waste Management Association (JAWMA)* on the Phase 1 engine emissions test program.

CRC's technical panel continues to be apprised of developments in Phase 3 of ACES, and key members have provided input on fuels analysis. Detailed planning for Phase 2 is underway with an expectation of testing up to five heavy-duty diesel engines in 2011.

## EMISSIONS

### **EVALUATIONS OF THE MOVES MOBILE EMISSION FACTOR MODEL**

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

Leaders: D. M. DiCicco  
D. H. Lax  
P. L. Heirigs

#### **Scope and Objective**

The objective of these projects is to conduct assessments of EPA's new Motor Vehicle Emission Simulator (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 Programs**

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 Federal Advisory Committee Act (FACA) MOVES Workgroup led by EPA. CRC Committee members attended the FACA meetings on an ongoing basis until their conclusion this year.

When the draft version of the model was made available in early 2009, 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<sub>x</sub>, 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. The revised draft final report is being reviewed by the Emissions Committee.

## EMISSIONS

### NONROAD VEHICLE EMISSIONS

CRC Project No. E-70

Leaders: J. Koupal  
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 collected included populations, usage rates (activity), and “in-use” or “real-world” emission rates.

#### Current Status and Future Programs

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

Eastern Research Group (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 were used to measure exhaust emissions and usage of commercial nonroad diesel engines in the construction sector. Statistical sampling was 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 were 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 reporting is ongoing. The final report for this project is in review.

## EMISSIONS

### **DIESEL UNREGULATED EMISSIONS CHARACTERIZATION**

CRC Project No. E-75-2

Leader: 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.

#### **Current Status and Future Programs**

The focus of E-75-2 is the examination of 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.

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 the contractor for this project. The final report and associated databases were released in 2010.

## **EMISSIONS**

### **ENHANCED EVAPORATIVE EMISSIONS VEHICLES**

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

Leaders: K. J. Wright  
C. Hart

#### **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 goals of this program are 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 Programs**

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.

The tested vehicles included:

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

The tested fuel was gasoline with 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

## EMISSIONS

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. The final report has been reviewed by the Real World Group and the Emissions Committee, and is being revised at the direction of EPA by its subcontractors.

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. The EPA has continued related research in collaboration with the Colorado Department of Public Health and Environment, and reports on the progress at CRC Real World Group meetings.

E-77-2c is a direct follow-on project to E-77-2 and E-77-2b, 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. Eight new vehicles are being 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 is being performed by Harold Haskew and Associates (HHA).

Final reports have been released for the E-77 (pilot) and the E-77-2 projects. The E-77-2b report has been finalized and will be released in 2010 by EPA. The E-77-2c draft final report is in review.

## **EMISSIONS**

### **EXHAUST AND EVAPORATIVE EMISSIONS TESTING OF FLEXIBLE-FUEL VEHICLES**

CRC Project No. E-80

Leaders: D. M. DiCicco  
M. Natarajan

#### **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 Programs**

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 completed testing for this project in early 2010. The final report is in development with anticipated completion in 2010.

## EMISSIONS

### **EFFECTS OF OLEFINS CONTENT ON EXHAUST EMISSIONS**

CRC Project No. E-83

Leader: J. P. Uihlein

#### **Scope and Objective**

The objective of this program is to evaluate the potential emissions impacts of different concentrations of fuel olefins on recent model light-duty gasoline vehicles. For this project, two gasoline fuels with differing olefin content (3% and 15%) will be tested on a fleet of 15 modern gasoline-powered vehicles. Vehicles will be tested over the LA92 cycle at least twice on each of the test fuels. Measurements will include regulated emissions, fuel economy, and modal tailpipe emissions. Speciated emissions of toxic emissions, including benzene, 1,3 butadiene, formaldehyde, and acetaldehyde, will also be measured. A comprehensive analysis of the resulting data including statistical and other analyses of the trends in regulated emissions and toxics will be performed.

#### **Current Status and Future Programs**

The E-83 project has been awarded to the University of California-Riverside's Center for Environmental Research and Technology (CE-CERT), with an anticipated start in late 2010 when the test fleet becomes available from the EPA Act Fuel Effects testing / E-89 Project. Fuels have been blended, tested, and approved, and are in place for testing. Due to the advanced age of the lubricating oil in the test fleet (currently in use for the E-89 study), an oil-change and degreening process has been funded at SwRI, where the fleet currently resides.

## **EMISSIONS**

### **NATIONAL SURVEYS OF E85 QUALITY**

CRC Project No. E-85 / E-85-2

Leaders: K. J. Wright  
T. Alleman

#### **Scope and Objective**

NREL /DOE has partnered with CRC for these studies. The objective of the studies 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.

#### **Current Status and Future Programs**

For the first study, 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. Based on results from the Class 1 samples in the summer of 2008, an addendum of ten Class 1 samples was added to this project. These samples were collected in August 2009. The final report for the E-85 project was released on December 7, 2009.

The follow-on project, E-85-2, is also being performed in partnership with NREL, and follows a similar approach. Sampling will be performed on all three volatility classes throughout the year while avoiding transitional classes, but will test all samples for only key properties of interest. Locations are being selected to cover the broadest possible U.S. continental geographic area, focusing on urban areas, where possible. Class 1 sampling began in July 2010. Class 3 sampling will occur in February 2011, with Class 2 sampling being conducted periodically throughout the year. The final report for this project is anticipated to be released in mid-2011.

**REAL-TIME PM MEASUREMENT WORKSHOPS**

CRC Project No. E-86

Leaders: H. Maldonado  
M. M. Maricq

**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 Programs**

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 for publication in October 2010, to consist of seven papers authored by the workshops' speakers and organizers (six from the invited experts, and one from the project leadership).

## **EMISSIONS**

### **MID-LEVEL ETHANOL BLENDS CATALYST DURABILITY STUDY**

CRC Project No. E-87-1, E-87-2

Leaders: 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 if 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 Programs**

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.

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

## **EMISSIONS**

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 some of the vehicles that will be used in this study. DOE, ORNL, and NREL are also running parallel testing projects at other laboratories, without CRC participation.

The E-87-2 project is in progress and is expected to continue through 2010.

## **EMISSIONS**

### **REVIEW OF TRANSPORTATION LIFE CYCLE ANALYSIS**

CRC Project No. E-88

Leaders: C. H. Schleyer  
P. L. 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.

A number of models have been developed for conducting transportation fuel LCA analyses. The TTW portion of transportation also uses separate models to evaluate fuel and powertrain effects on vehicle fuel consumption and GHG emissions.

This project involves 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 Programs**

After a competitive selection process, this project was awarded to Life Cycle Associates. The project began in late 2008 and is expected to conclude in 2010. The draft final report is in review by the Real World Group and the project panel.

CRC held 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, Conservation of Clean Air and Water in Europe (CONCAWE), U.S. DOE, Environmental Defense Fund (EDF), U.S. EPA, The National Biodiesel Board (NBB), Natural Resources Canada, USDA, Ford Motor Company, Chevron Global Downstream, Renewable Fuels Association (RFA), Marathon Oil Company, ExxonMobil Research & Engineering, Argonne National Laboratory, and the South Coast Air Quality Management District (SCAQMD). Plans are to have another workshop on this topic in 2011.

**EPAct LIGHT-DUTY VEHICLE FUEL EFFECTS**

CRC Project No. E-89

Leaders: C. Hart  
J. P. Uihlein  
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.
- DOE/NREL is funding additional testing to include temperature extremes and high-emitting vehicles.

**Current Status and Future Programs**

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:

- 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

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- 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 5<sup>th</sup> and 95<sup>th</sup> percentiles of in-use fuel properties
  - Measured emissions: PM, CO<sub>2</sub>, NO<sub>2</sub>, VOCs, ethanol, carbonyls, N<sub>2</sub>O, NH<sub>3</sub> and HCN by FTIR, and SVOC speciation in Phases 1, 2, and 3

Due to funding limitations, the test fleet was adjusted to 16 vehicles. CRC agreed to purchase the test vehicles currently in use, to avoid high leasing costs to complete the project that could reduce the amount of testing that EPA & DOE can support. Fifteen of these vehicles will also be used in the E-83 project. Testing will continue through mid-2010, with final reporting in late 2010 or early 2011.

**IMPACT OF E15/E20 BLENDS ON OBDII SYSTEMS**

CRC Project No. E-90, E-90-2a, E-90-2b

Leaders: J. J. Jetter  
M. Natarajan

**Scope and Objective**

The objectives of this study are to collect On-Board Diagnostics (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 includes long-term fuel trim and any stored OBD diagnostic trouble codes (DTCs) related to enrichment.

**Current Status and Future Programs**

De la Torre Klausmeier Consulting, Inc. was chosen to perform the first phase of this project. 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 OBD threshold values for MIL illumination are considered confidential, the automotive 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 in the regions of Austin, TX, Dallas, TX and Chicago, IL was completed in the spring of 2009. The final report for the pilot study has been released on the CRC website. The main program is in development, and will include two elements: an analysis of existing data from I/M programs (E-90-2a) and an experimental program (E-90-2b). The E-90-2a project, "Evaluation of Inspection and Maintenance OBD II Data to Identify Vehicles that May be Sensitive to E10+ Blends" was awarded to Sierra Research after a competitive solicitation process. The Project E-90-2b, "Impact of Ethanol Blends on the OBDII System of In-Use Vehicles" has been awarded to SwRI, and is expected to begin in August and run through the end of 2010.

## **EMISSIONS**

### **EVAPORATIVE EMISSIONS DURABILITY TESTING**

CRC Project No. E-91

Leaders: J. Y. Sigelko  
S. Bohr

#### **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 Programs**

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 percent ethanol by volume (E20). 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 four 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.

This project was awarded to ETC of Aurora, CO, with the sea-level work to be performed by Chrysler, working as a subcontractor. The project is ongoing, and is expected to continue through 2011.

## **EMISSIONS**

### **BLENDER PUMP FUEL SURVEY**

CRC Project No. E-95

Leaders: K. J. Wright  
T. Alleman

#### **Scope and Objective**

The objective of the Blender Pump Fuel Survey is to follow the general approach of the E-85 and E-85-2 National Surveys of E85 Quality, but to focus specifically on blender pumps that are designed to allow the consumer to select the percentage of ethanol in the blend. Additional collection procedures are being developed, such as how to ensure that the last fuel blend purchased does not carryover into the new sample, and the use of digital photos to verify the pump selection setting for comparison to the actual ethanol content of the sample. Samples will be collected only from stations using a single hose to distribute gasoline and higher blended ethanol products. Stations that dispense higher ethanol products and E85 out of a single hose will be allowed. Samples will be collected only from stations with pre-set, discrete blends available (e.g. E30 and E50).

#### **Current Status and Future Programs**

NREL is co-sponsoring this project, in a similar fashion to the E-85 and E-85-2 projects. The sampling was conducted in the summer of 2010, and analysis is ongoing, with reporting expected in late 2010.

## EMISSIONS

### **LINKING TAILPIPE AND AMBIENT PM (A-74)**

CRC Project No. E-96

Leaders: M. M. Maricq  
H. Maldonado

#### **Scope and Objective**

The objective of this project is to define the relationship between semi-volatile organic compounds (SVOC) and other aerosols contained in vehicle exhaust and subsequent formation of secondary organic aerosols (SOA) and other compounds formed in the atmosphere via dilution and chemical reactions. The main project objective includes obtaining sufficient definition of the relationship between SVOC and SOA to model the behavior in the atmosphere. This project has application to both the Real World Group and the Atmospheric Impacts Committee and thus is a joint project, with the Atmospheric Impacts Committee referring to Project No. A-74.

#### **Current Status and Future Programs**

This project was awarded to Carnegie Mellon University (CMU). CMU has also been awarded a grant from EPA and is receiving in-kind support from CARB to conduct vehicle testing on this topic. The 2010 test campaign has been completed and the analysis is ongoing. Additional testing is planned for early 2011.

## **EMISSIONS**

### **LONGITUDINAL EMISSIONS STUDY (PILOT)**

CRC Project No. E-100a

Leaders: M. B. Viola  
C. Hart  
D. R. Lawson

#### **Scope and Objective**

The US Environmental Protection Agency (EPA) has developed an inventory model, MOVES, which has replaced MOBILE6.2. The modal structure of MOVES requires continuous rather than aggregate measurements. Currently the light-duty emissions in MOVES are based primarily on Inspection and Maintenance (I/M) data. As I/M programs discontinue tailpipe testing, less of these data will be available in the future. The FACA MOVES Review Workgroup recommended that EPA develop a long-term systematic data-collection plan to support MOVES.

The long-term program currently under development by EPA will be designed to measure exhaust emissions from current vehicle technologies using portable instruments (PEMS/PAMS). The scope of this project covers the conduction of remote sensing measurements for purposes of the pilot program, and delivery of those data to EPA. EPA will use the RSD to develop, test and refine screening methods for purposes of vehicle sampling and recruitment.

#### **Current Status and Future Programs**

The work plan is to initiate a pilot program during 2010 in the Detroit Metropolitan Statistical Area. The objectives of the pilot study are to develop, test and refine one or more screening indices for exhaust emissions and to develop and field-test methods for sampling, recruitment and measurement.

The project will be performed in three tasks:

**Task 1:** A work plan and standard operating procedures will be developed. The remote sensing system will be verified. Students will be trained. Suitable sample sites will be selected within the Detroit urban area for the follow-up field measurements.

**Task 2:** Road-side remote sensing measurements will be performed with the objective to obtain at least 30,000 valid measurements. Data will be

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processed (in the shortest time possible), analyzed and reviewed. License plate images will be read and matched to the measurements.

**Task 3:** Progress, results, system performance and data quality will be summarized in scheduled reports. A complete database will be delivered for future use.

The project is being performed by Michigan Technological University. Sampling was completed in the summer of 2010, and analysis is ongoing with reporting anticipated in late 2010.

AVFL

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

CRC Project Nos. AVFL-13b / AVFL-13c

Leaders: 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 AVFL-13c project, Oak Ridge National Laboratory (ORNL) applied 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. This was pursued as an alternative to the conventional statistical treatment applied in AVFL-13 and AVFL-13b.

**Current Status and Future Programs**

The AVFL-13, AVFL-13b, and AVFL-13c Final Reports are available on the CRC website.

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

CRC Project No. AVFL-14

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

### **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 MD vehicles are also being evaluated.

### **Current Status and Future Programs**

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.

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- 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.

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.

Vehicle testing has been completed, and analysis is ongoing. Reporting is anticipated in 2011, and will include journal articles as well as project reports.

**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 Programs**

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 105°F. 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. In late 2009, this project was extended to include additional fuel pump durability soak testing, an extension of the fuel rig soak testing, and additional material analysis. Finally in 2010, the project was extended again to test additional fuel pumps. This project is still considered a pilot evaluation, and additional testing is likely to be needed. The testing is ongoing and reporting is anticipated in late 2010.

AVFL

**FUELS TO ENABLE LIGHT-DUTY DIESEL ADVANCED  
COMBUSTION REGIMES**

CRC Project No. AVFL-16

Leaders: W. J. Cannella  
C. S. Sluder

**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 light-duty (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 nine test fuels; five fuels selected from this set will be used for this project.

**Current Status and Future Programs**

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).

The Committee selected WVU to perform this research. Testing is ongoing, and reporting is expected in early 2011.

## **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, consists 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 fuel-relevant properties such as cold flow, cloud point, cetane number, 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 Programs**

This project was awarded to Desert Research Institute. This project is ongoing, and reporting is expected in late 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 many hundreds of compounds.

### **Current Status and Future Programs**

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 make 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.

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. The technical panel is currently refining the palette of compounds that will be purchased and blended to make the surrogate fuel for further testing. A second round of analysis with the NIST has been funded. Chemical compounds have been procured and are housed at NREL to support analyses and the blending of the initial surrogates. Reporting on this project is expected later in 2010.

**FUELS FOR ADVANCED COMBUSTION ENGINES (FACE)  
WORKING GROUP**

Leaders: W. J. Cannella  
R. M. Wagner  
B. T. Zigler

**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 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 Programs**

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 website. The final report, "FACE-1 Chemical and Physical Properties of the Fuels for Advanced Combustion Engines (FACE) Research Diesel Fuels" has been published to the CRC website, and an accompanying conference paper was given at the 2009 SAE Fall Powertrains, Fuels, and Lubricants meeting.

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The gasoline-range fuel set design has been finalized by the group. These fuels are expected to be available from CPChem. Plans for characterization of the gasoline fuel set 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.

## ATMOSPHERIC IMPACTS

### AIR TOXICS WORKSHOP

CRC Project No. A-45

Leaders: S. Japar  
R. S. MacArthur

#### Scope and Objectives

The objective of this project is to bring together key individuals and organizations working on current issues of mobile source air toxics for in depth technical discussions in a workshop format.

#### Current Status and Future Programs

The Atmospheric Impacts Committee hosted the CRC Mobile Source Air Toxics (MSAT) Workshop 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.

Additionally, there were four posters presented. The proceedings and summary of presentations 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,” continued questions about accountability in terms of regulations already in place and how they have

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performed against stated objectives, developing a better understanding of exposure to multiple pollutants as well as several other research needs.

Planning for the 2010 workshop (A-45c) is underway. The organizing committee selected December 1-2, 2010 in Sacramento, CA for the next workshop. The organizing committee is actively developing the program content and nominating speakers. The technical sessions are planned to be held at CARB in their Sacramento offices with a welcome reception held at the nearby Citizen Hotel on November 30, 2010.

## ATMOSPHERIC IMPACTS

### ACCURACY OF REGIONAL OZONE AND PM BACKGROUND

CRC Project No. A-65

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

#### Scope and Objectives

The objective of this project is to determine whether the emission inventories for natural sources yield O<sub>3</sub> and PM concentrations that 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<sub>3</sub> and PM control strategies. This objective will allow determination of whether the anthropogenic increment contribution to O<sub>3</sub> and PM is correctly predicted in regional simulations, and, if not, what the implications are for control strategies.

#### Current Status and Future Programs

Regional simulations of O<sub>3</sub> and PM employ emission inventories for natural and anthropogenic sources. The anthropogenic increment contribution to O<sub>3</sub> 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<sub>3</sub> or PM plus the anthropogenic increment to the pollutant meets the relevant standard.

The accuracy of regional simulations of O<sub>3</sub> 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<sub>3</sub> and PM concentrations in reasonable agreement with estimates of background O<sub>3</sub> 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<sub>3</sub> and PM concentrations consistent with these “clean” boundary concentrations.

If regional simulations with natural emissions give O<sub>3</sub> 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<sub>3</sub> and PM will be too high or too low, respectively. If the anthropogenic increments of O<sub>3</sub> and PM

## ATMOSPHERIC IMPACTS

are inaccurate, then emission control strategies developed from regional modeling (particularly NO<sub>x</sub> 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.

Natural emissions adopted in current regional air quality modeling were updated to better describe natural background O<sub>3</sub> and PM concentrations for North America. The revised natural emissions include organosulfur species 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 model applications over the southeastern US and Gulf of Mexico due to added NO from lightning while the revised biogenic emissions produced less O<sub>3</sub> in the central and western US. Natural PM<sub>2.5</sub> 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<sub>3</sub> responses to the emissions reductions in 2018.

The Final Report was published on the CRC website in September 2009. A journal article based on the A-65 Final Report has been published in *Atmospheric Environment* (Vol. 44, Issue 19, June 2010).

## ATMOSPHERIC IMPACTS

### ESTIMATE OZONE FROM FUEL REFORMULATION

CRC Project No. A-67

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

#### Scope and Objectives

The objective of this project is to develop a modeling tool to estimate ambient O<sub>3</sub> 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. An integrated model suite with the Comprehensive Air Quality Model with extensions (CAMx) grid model will serve as a simple tool to predict results from emissions inventory changes.

#### Current Status and Future Programs

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 possible increases in permeation HC emissions due to ethanol and in NO<sub>x</sub> emissions from both biodiesel and ethanol.

Although generalizations about VOC- or NO<sub>x</sub> -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<sub>x</sub> increases render the predictability less certain. Since grid modeling applications of the simplest of control strategies are time consuming and burdensome, and since the release timing of vehicle emissions testing results is highly uncertain, it is prudent to develop a flexible modeling methodology which enables timely grid modeling investigation of how vehicle emissions testing results may be represented in the mobile source fleet and the consequent response of ambient ozone.

Through close coordination with Lake Michigan Air Directors Consortium (LADCO), the Consolidated Community Emissions Processing Tool (CONCEPT) has been modified to enable flexibility in changes in on-road (link-based) and nonroad temporal and spatial distribution of vehicle-specific ozone precursor emissions external from the grass-roots emissions

## **ATMOSPHERIC IMPACTS**

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 model user’s guide, public domain-resident code, models, and model inputs. CRC issued a request for proposal for this study and selected Atmospheric and Environmental Research (AER) to conduct the study with a focus on modeling in the LADCO region with a project start of December 2007. AER worked directly with LADCO on selection of modules and use of the most recent CONCEPT software.

A new CONCEPT model update was released in April 2009, and AER conducted model runs using the interim version to demonstrate the operability of the model. The Final Report was received by CRC and approved by the committee in May 2010.

## ATMOSPHERIC IMPACTS

### THE MECHANISMS OF ATMOSPHERIC OXIDATION OF THE OXYGENATES

CRC Project No. A-68

Leaders: T. J. Wallington  
R. S. MacArthur

#### Scope and Objectives

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 Programs

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 completed 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).

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- 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, hydroxy 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 final product to ensure a more comprehensive report. The draft manuscript was delivered to CRC in fall 2009 and submitted separately for technical editor and technical content review. Reviewer comments were addressed by the author team, and the revised Final Manuscript was delivered to CRC and accepted as the final contract deliverable. The authors negotiated a contract through CRC with *Oxford University Press* in March 2010. The final manuscript will be submitted to the book publisher for final publication estimated to be in February 2011.

## ATMOSPHERIC IMPACTS

### REGIONAL MODELING OF WEEKEND/WEEKDAY EMISSIONS CHANGES

CRC Project No. A-69

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

#### Scope and Objectives

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<sub>3</sub>, and 3) Determine to what extent the emission changes in upwind cities affect downwind cities and rural areas.

#### Current Status and Future Programs

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.

There has been little or 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.

## **ATMOSPHERIC IMPACTS**

An ozone episode in the eastern U.S. containing at least one weekend was chosen. The modeling domain covers most of the eastern U.S. with fine grids over the major urban areas. The weekend emission inventory for the entire region was 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. The report will document 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.

Task 1 and Task 1a Technical Memoranda have been reviewed and approved by the committee on ENVIRON's A-69-1 project. The project schedule was delayed to allow input from LADCO on non-road emission inventories with weekend activity definitions, which have now been delivered. Completion of the Final Report is expected near the end of 2010.

## ATMOSPHERIC IMPACTS

### CONCEPT/CAMx MODELING OF EXPANDED USE OF RENEWABLE FUELS

CRC Project No. A-73

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

#### Scope and Objectives

The committee proposed a new focus on performing air quality modeling of mid-level ethanol blends using emissions data from other CRC and related studies as an extension and application of Project No. A-67. The modeling approach selected is development of the new emissions inventory model CONCEPT suite with CAMx (CONCEPT/CAMx) for this purpose, for possible application in the Lake Michigan area in cooperation with Lake Michigan Air Directors Consortium (LADCO).

#### Current Status and Future Programs

To bracket air quality predictions from ethanol emissions changes, the application of CONCEPT/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 a major urban complex, Atlanta would help in characterizing changes in a biogenics-VOC-dominated airshed, and Dallas would be an extension of work done previously in the Auto/Oil program.

The committee worked on developing a final statement of work in the second quarter of 2009. The original Mobile6.2 emissions factor model has been replaced and some script recoding has resulted in faster computation. Prior plans to incorporate the MOVES model under CONCEPT have been postponed due to the complexity of this application. Competitive solicitations for this project were conducted during the final quarter of 2009. The project was divided into two main efforts to be developed in parallel to meeting the overall project objectives of demonstrating the CONCEPT/CAMx modeling tool:

1. A-73-1, "Protocol for Analyzing Data and Developing Inputs to the CONCEPT Emission Model for Representing Ethanol Blends.
2. A-73-2, "Perform CONCEPT/CAMx Modeling of Expanded Use of Renewable Fuels

The committee and working group reviewed proposals submitted to CRC and selected contractors to work on each project. Final contract awards were made in December 2009.

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During the first quarter of CY2010 Sierra Research began its survey of emissions data for A-73-1 and delivered the Task 1 Literature Survey in the second quarter. A project work plan for A-73-2 was received from Alpine Geophysics and approved by the committee. A-73-1 is expected to be completed in 2010 and A-73-2 will continue work into 2011.

## ATMOSPHERIC IMPACTS

### **RELATIONSHIP BETWEEN SEMI-VOLATILE ORGANIC COMPOUNDS AND SECONDARY ORGANIC COMPOUNDS**

CRC Project No. A-74

Leaders: T. J. Wallington  
R. S. MacArthur

#### **Scope and Objectives**

The objective of this project is to define the relationship between semi-volatile organic compounds (SVOC) and other aerosols contained in vehicle exhaust and subsequent formation of secondary organic compounds (SOA) and other aerosols generated in the atmosphere via dilution and chemical reactions. The main project objective includes obtaining sufficient definition of the relationship between SVOC and SOA to model the behavior in the atmosphere. This project has application to both the committee and the CRC Real World Vehicle Emissions and Emissions Modeling Group (RWG). Therefore a joint project was proposed in connection with CRC Project No. E-96.

#### **Current Status and Future Programs**

A proposal was submitted to CRC by Allen Robinson of Carnegie Mellon University (CMU) entitled, "Linking Tailpipe to Ambient: A Proposal to the CRC RWG and AIC to Add Characterization of Emissions Aging to the Planned CMU/CARB/EPA Vehicle Testing." CMU has been awarded a grant from EPA and is also receiving in-kind support from CARB to conduct vehicle testing on this topic. The CMU proposal to CRC is for atmospheric chamber experiments (approximately 5 gasoline vehicles and 2 diesel vehicles) to be conducted in connection with the vehicle test program (approximately 50 vehicles). This proposal was approved by the committee and the CRC RWG, leading to a contract negotiated with CMU in April 2010. A technical work plan has also been reviewed and approved by the project panel members. The project was initiated with Phase 1 testing in May 2010 at the CARB El Monte, CA laboratories. A second phase is planned with completion expected in 2011.

## **ATMOSPHERIC IMPACTS**

### **AIR QUALITY MODEL EVALUATION INTERNATIONAL INITIATIVE (AQMEII)**

CRC Project No. A-75

Leaders: T. J. Wallington  
P. Roberts  
C. H. Schleyer

#### **Scope and Objectives**

The objective of this project is to evaluate air quality model performance in North America and in Europe. The U.S. E.P.A. approached the committee inviting their participation in this program by supporting modeling of the European Continent using the CAMx air quality grid model. Emissions inventories, meteorology data sets, and data repository tools have been assembled by the AQMEII international organizing committee to evaluate the performance of several models using a 2005 full calendar year data set. AQMEII is jointly hosted by U.S. EPA (S.T. Rao) and the European Union Joint Research Centre (Stefano Galmarini).

#### **Current Status and Future Programs**

The committee requested a proposal from ENVIRON to perform the 2005 CAMx model simulations. This proposal was approved by the committee and resulted in a project start in April 2010. CRC has contacted Peter Roberts of CONCAWE to support the project. The ENVIRON proposal includes other European scientists well-positioned to support the inventory and meteorology for the European domain. ENVIRON was selected because of their extensive experience developing and applying the CAMx model in other CRC programs. ENVIRON was also selected to model the North American domain using CAMx by EPRI as part of the AQMEII program.

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### GASOLINE ENGINE DEPOSITS

CRC Project No. CM-136

Leader: J. Axelrod

#### Scope and Objectives

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), intake valve deposits, and injector deposits.
- 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

In 2004, two auto companies 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

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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 in February 2007 because of several issues. The rig 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 injectors is limited and dwindling. A replacement PFI model has not been identified. Recommendations have been made to focus on new technology hardware to evaluate direct injector fouling performance.

### **Engine Durability for Intermediate Ethanol Blends**

A request for proposal was released by CRC in February 2009 for a new study to evaluate the potential effect of mid-level ethanol blends in the U.S. LD vehicle fleet. The objectives of the test program are to determine engine durability effect of midlevel ethanol blends (e.g., E20, E15) on a group of engines from vehicles that may be sensitive to the effects of mid-level ethanol blends. The test vehicles were selected from among those that are more likely to exhibit some issues with mid-level ethanol blends. The test fleet selection was determined cooperatively by CRC member companies and OEMs.

The approach consists 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 responded to a competitive solicitation, and FEV was selected as the contractor. Testing is underway and monthly status

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reports are being submitted. The project achieved successful completion of Phase I (first set of four pairs of vehicles tested on E20 fuel) and test vehicle/fuel combinations have been approved for the Phase II program (second set of four pairs of vehicles on E20) now underway. Preliminary results were reported at the May 2010 meeting of the Mid-Level Ethanol Blend Research Coordination Meeting. Testing is also planned for susceptible vehicles on E15 and then E0 gasolines.

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## **VOLATILITY**

CRC Project No. CM-138

Leader: L. M. Gibbs

### **Scope and Objectives**

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

### **Current Status and Future Programs**

#### **2008 Cool Ambient Cold Start and Warm-up E85 and E15/20 Volatility Study**

There are two parts to this volatility program: 1) Determine the effect of vapor pressure of E85 Ethanol Fuel 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.

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### **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 0°F and -20°F due to difficulties observed at -30°F. Limited testing was done at 0°F. 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, 3 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 is being conducted in cooperation with ASTM to determine under two 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 was conducted at SwRI in fall 2009, but due to delays caused by weather conditions was not completed at that time. Steps were taken by one of the project sponsors to cost-effectively maintain the current fleet throughout the project delay. Funding to complete the first phase in spring 2010 was obtained, and testing was reinitiated at SwRI in April 2010 and completed in June 2010. Data analysis is underway. A second phase to test summer fuel blends under hot ambient conditions has also been proposed for consideration by CRC.

### **2009/2010 Low T50 High Altitude Hot-Fuel Handling**

This study will determine the effects of TVL20, 50% evaporated distillation point (T50), and ethanol content up to 20 vol % on hot-fuel-handling driveability performance at high altitude (5000+ft.) under hot ambient temperature conditions in a fleet of 20 late model vehicles. This is a follow-

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on program to the 2006 CRC Hot-Fuel-Handling Program (CRC Report No. 648). The test site for this program is Pueblo, CO at the Transportation Technology Center, Inc. (TTCI) facility. Testing was conducted in July-August 2010. The test fuel matrix for this program was approved in 2009, and invitations for participation were issued to interested parties. CRC is working with support from NREL. Contractors for the project are TTCI (test facility in Pueblo) and Gage Products (for test fuels). The data analysis is underway.

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### OCTANE

CRC Project No. CM-137

Leader: J. J. Simnick

#### **Scope and Objectives**

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 Programs**

##### **Determining Octane Number Requirements**

In October 2005, the Octane Group published CRC Report No. 643 in which results from an acceleration octane test round-robin program were recorded. 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.

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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. MIT used CRC historical octane survey data in their assessment.

CRC 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 November 2009 group meeting. GM received the test fuels and completed testing on the second engine in early 2010. GM reported results to the committee at the April 27-28, 2010 meeting in Denver. The report on the results of the Chrysler and GM engine studies is in preparation.

## PERFORMANCE

### DIESEL PERFORMANCE GROUP

CRC Project No. DP

Leader: M. Nikanjam

#### Scope and Objectives

The objective of the Diesel Performance Group is to help define the minimum requirements to make light-duty diesel in North America a success. This will be achieved by providing supporting technical data for diesel performance issues that are needed by the fuel, engine, equipment, and additive industries that can be used by technical groups such as ASTM and the International Organization for Standardization (ISO).

The Diesel Performance Group currently has the following active panels and will adjust and add new ones as needed:

- Lubricity (Ended)
- Low Temperature Operability
- Cetane Number
- Biodiesel
- Deposit
- Fuel Cleanliness

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 Programs

##### 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 due to the fact that ASTM had established a fuel specification and because there have been no apparent field problem. The Final Report CRC Report No. 655 was published in July 2009. Publication of this report concluded this area of study for the panel.

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### **Low Temperature Operability**

Results were produced from a recent program conducted by Infineum to evaluate how well the low temperature laboratory tests correlate with vehicle operability of conventional diesel fuel and biofuel blends in engines equipped with common rail fuel injection systems.

Cloud Point (CP), Cold Filter Plugging Point (CFPP), and Low Temperature Flow Test (LTFT) methods were included. S15, B5 with soy, and B5 with animal fat with higher wax were tested. Each fuel was tested with and without cold flow additive. Target temperature was in the range of -20° C to -30°C. Both heavy-duty and medium-duty vehicles were tested.

The two common rail trucks exceeded the low temperature performance predicted by all three laboratory test methods. Both vehicles exhibited performance loss when B5 was used. Cold flow additives were able to restore the performance.

At this point, there is no major issue but a long term concern may be the fact that a smaller fraction of warm fuel is returned to the fuel tank.

### **Cetane Number Program**

Following a previous CRC AVFL project, this panel outlined a larger North American program to test appropriate NA vehicles at lower operating temperatures with a more statistical approach. A lower-cost scoping study was discussed to determine if test tools and facilities are fit for this purpose. Performance data regarding the effect of fuel cetane number on the operation of North American light-duty diesel vehicles at low temperature was the original deliverable for this project.

Some panel members questioned the limited scope of a program that focuses only on the effect of cetane number in extreme cold areas for the first minute or two of vehicle operation. It was suggested that additional benefits could be realized and included in this program. Some members also reiterated that OEM support in this program is essential. Significant amount of information from the autos is needed to design a valuable program.

To gauge the level and the scope of interest, the panel carried out a survey of the Diesel Performance Members with particular emphasis on the view of the auto side.

Most respondents, including the three participating OEMs, support a program in this category. Startability and performance at low temperature were considered to be important, but additional benefits may exist at higher operating temperatures. General areas of interest in performance were as follows:

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- Power
- Driveability/noise
- Fuel economy
- *Emissions (not in the charter of the Diesel Performance Group)*

The panel plans to propose a test program. Such a plan may include a preliminary scoping / protocol development effort as a start.

### **Biodiesel Panel Program**

The overall program objective was to determine if biodiesel that shows precipitate formation upon cooling to temperatures above the cloud point, based on high cold soak filtration time (CSFT), causes heavy-duty truck operability issues above cloud point. Also included was the evaluation of the correlation between bench test results (CP, CFPP, etc.) and actual HD vehicle performance at low temperatures. Results are available in CRC Report No. 650.

Phase 2 was designed to fill gaps that were identified in the previous phase. B100 with CSFT between 200 and 360 second was not tested in Phase 1. CRC Report No. 656 includes the results of Phase 2.

The panel will consider a number of issues to select the next program. Some initial thoughts follow:

- Impact of biodiesel blends on lube oil dilution for late in-cylinder injection systems
- Improved requirements for biodiesel oxidation stability
- Low temperature operability in LD vehicles
- Potential impurities and problems with biodiesel from novel feedstocks or production methods such as algae and LS9

### **Diesel Deposits**

This panel was formed recently to address a number of issues and engine tests. The EMA's most recent concern regarding new forms of deposits in HPCR systems became the current focus.

Performance problems manifested as poor or no start, rough idle and drivability, excess power and particulate production (sticking open), as well as loss of power (sticking shut). The panel structured their investigation around three subpanels as follows:

1. Data Analysis and Recommendations
2. Bench / Rig / Engine Investigation (Na-Soap Deposits)
3. Engine Investigation (General Cause)

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The first two are active; the formation of the third subpanel is delayed pending recommendations from the other subpanels.

### **Fuel Cleanliness**

This panel reports to the group on field issues for possible future programs. There continues to be some dispensing filter plugging and the need to replace filters as frequently as weekly. Carboxylates have been identified. It appears that 10 to 30 micron porosity filters have no problem. This could mean that material may pass through the filter and reach and possibly affect injectors adversely. Most of the observed problems are with 2 micron filters. The panel has also received some reports of difficulty filtering fuels in long storage applications.

Some EMA members have experienced sporadic vehicle issues in some locations. At this time sufficient data does not exist to make specific recommendations.

### **Density Range**

While density range was considered important at the beginning of this performance group, the resources to address it have not been available. The few members who responded to a recent survey to gauge the current level of interest felt that the group should not allocate resources to this performance category.

PART THREE  
RELEASED REPORTS



## RELEASED REPORTS - 2010

### AIR POLLUTION\*

<b>CRC Project No.</b>	<b>Title</b>	<b>NTIS Accession No.</b>
A-65	Accuracy of Regional Simulations of Background Ozone and Particulate Matter	PB2009-115499
AVFL-18a	Recent Progress in the Development of Diesel Surrogate Fuels	PB2010-108800
A-67	Model Suite to Estimate Ozone and PM from Fuel Reformulation	PB2010-110352
AVFL-13b	Ethanol Effects on Gasoline-Like HCCI Combustion	PB2009-115531
AVFL-13c	Analysis of the Effects of Fuel Chemistry and Properties on HCCI Engine Operation Using a PCA Representation of Fuels	PB2010-112021
FACE-1	Chemical and Physical Properties of the Fuels for Advanced Combustion Engines (FACE) Research Diesel Fuel	PB2010-113764
E-77-2	Enhanced Evaporative Emission Vehicles	PB2010-108797
E-85	National Survey of E85 Quality	PB2010-108799
E-90	Impact of E15/E20 Blends on OBDII Systems -- Pilot Study	PB2010-108798
E-75-2	Diesel Unregulated Emissions Characterization	PB2010-113763
A-62-1 & A-62-2	Impact of Reactive Halogen Species in California Coastal Areas	PB2009-115486

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\*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](http://www.ntis.gov) Phone: 800-553-6847

When ordering a report, be certain to include the NTIS Accession Number.

## PERFORMANCE & AVIATION\*

<b>CRC Project No.</b>	<b>Title</b>	<b>NTIS Accession No.</b>
AV-7-07	Research Results -- Unleaded High Octane Aviation Gasoline	PB2010-111981
DP-2a-07-2	Biodiesel Blend Low-Temperature Performance Validation (CRC 656)	PB2010-111993
CM-138-08	2008 CRC Cold-Start and Warm-up E85 and E15/E20 Driveability Program (CRC 652)	PB2009-115488
AV-2-04a	Comparative Evaluation of Semi-Synthetic Jet Fuels	PB2009-115487
AV-6-06	Metal Deactivator Additive (MDA) Impacts on Thermal Stability	PB2010-113765
CM-138-08-2	2008 CRC Cold-Start and Warm-up E85 Cold Ambient Temperature Driveability Program (CRC 654)	PB2009-115489

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\*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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PART FOUR

ORGANIZATION AND  
MEMBERSHIP



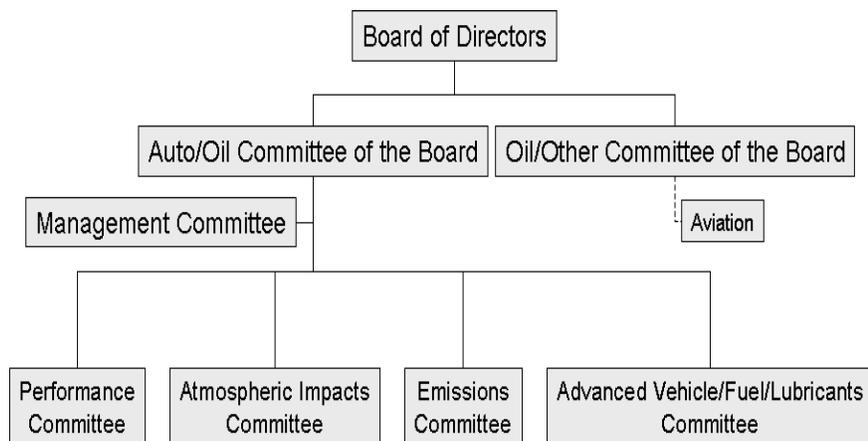
## ORGANIZATION

### ORGANIZATION - 2010

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 68 years, CRC has provided the means for the automotive and petroleum industries and the government 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.



## **ORGANIZATION**

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.

A CRC project is one where CRC committee members 1) identify a research topic, 2) define the work statement and detailed approach, 3) monitor progress and approve any changes during the full project schedule, and 4) review and approve the final report. A CRC Committee may delegate all or part of the responsibility for conducting a project to a project panel composed of contributing stakeholders but retains final approval and decision-making authority on all publications. A CRC Project that complies

## **ORGANIZATION**

with the definition stated above, including CRC management from beginning to end of the project, will display attribution to CRC using the standard cover page with CRC logo. Cost-share collaborations with others will indicate attribution to CRC based on final review and approval of the participating parties and mutual agreement on use of sponsor names and logos. Alternative collaborations where CRC does not have direct involvement throughout the course of the study and does not directly manage the performing organization must not allow attribution to CRC without review and consent of CRC.

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 new 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-138)

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M. Nikanjam, Ldr.      Chevron

D. Altermatt	Chrysler	D. H. Lax	API
D. Arters	Lubrizol	R. Leisening	Sunoco Inc.
J. Axelrod	ExxonMobil	T. Livingston	Robert Bosch
R. Baranescu	Int'l. Truck & Eng.	H. Martin	Fleetguard/Cummins
D. Berman	ChevronPhillips	R. L. McCormick	NREL
P. Biggerstaff	Baker Petrolite	A. A. Millard	Infineum USA
J. E. Carter	Haltermann Products	R. Mills	Chevron
E. Casey	ConocoPhillips	K. Mitchell	Shell Canada
A. Cayabyab	CARB	M. Natarajan	Marathon Oil
R. A. Cherrillo	Shell Global Solutions	R. Osman	Flint Hills Resources
D. A. Daniels	Innospec Fuel Spec.	C. Richardson	Ford Motor Co.
M. Foster	BP	J. A. Rutherford	Chevron Oronite
D. R. Forester	Power Service Products	W. Studzinski	General Motors
K. Freund	Volkswagen of America	R. D. Tharby	Tharby & Associates
M. Frusti	Chrysler	M. Valentine	Toyota Technical Ctr.
C. Hamer	PCS Instruments	G. Webster	AET
J. J. Jetter	Honda R&D Americas	L. Webster	Nissan Tech. Ctr. NA
A. Kulinowski	Afton Chemical	S. A. Westbrook	SwRI
P. Lacey	Delphi Diesel Sys.		

## MEMBERSHIP

### LOW TEMPERATURE OPERABILITY PANEL

(Project No. DP-02)

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

### BIODIESEL PANEL

(Project No. DP-02a)

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

## MEMBERSHIP

### CETANE NUMBER PANEL

(Project No. DP-3)

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

### DIESEL 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
J. Anderson	Paccar Inc.	D. H. Lax	API
R. Baranescu	Navistar	T. Livingston	Robert Bosch
P. Biggerstaff	Baker Petrolite	I. MacMillin	Octel-Starreon
N. C. Blizard	Cummins Engine Tech.	A. A. Millard	Infineum
E. Casey	ConocoPhillips	R. Mills	Chevron
R. Chapman	BP	M. Nikanjam	Chevron Products Co.
H. DeBaun	Navistar	R. Osman	Flint Hills Resources
D. R. Forester	Power Service Prods.	J. D. Parsons	Caterpillar
R. Gault	Engine Manufacturers	T. Smagala	Chevron
B. E. Goodrich	John Deere	L. Webster	Nissan Tech. Ctr. NA
J. J. Jetter	Honda R&D Americas	W. Westbrook	SwRI
A. Kulinowski	Afton Chemical		