COORDINATING RESEARCH COUNCIL ANNUAL REPORT

September 2014

COORDINATING RESEARCH COUNCIL, INC.
5755 NORTH POINT PARKWAY • SUITE 265 • ALPHARETTA, GEORGIA 30022
TEL: 678-795-0506 • FAX: 678-795-0509 • WWW.CRCAO.ORG

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STATE OF THE COUNCIL - 2014

The Coordinating Research Council (CRC) continues to maintain its original institutional scope and objectives established in 1942. These objectives were initially developed by the Cooperative Fuel Research Committee circa 1919. CRC provides the means for the automotive and energy industries to work together on joint research of mutual interest. CRC also encourages cooperative research with government and other stakeholders to address mobility and environmental issues of general interest. As a technical organization, CRC focuses on the fuel/hardware interface to maximize performance of transportation fuels and the equipment in which they operate. CRC's scope covers fuel composition and quality of existing commercial fuels and fuels anticipated for future use. Research is conducted both in the laboratory and in the field to provide more complete characterization of conditions and performance. Research goals include gathering data to understand fuel/hardware performance with respect to consumer satisfaction while at the same time meeting environmental requirements. Understanding larger scale impacts of changes in fuel and hardware and the performance of other vehicle fluids such engine lubricants are also included in the scope of CRC operations.

The CRC technical programs in 2014 have again enjoyed broad cooperation from many research partners on projects and on other important collaborative activities such as technical workshops where current research results and other issues are discussed. This cooperation results in a higher resolution focus and improved perspective on the important issues. Collaboration also leverages both technical expertise and financial support to meet common research goals under conditions of limited resources. Partnerships in 2014 have included: the American Gas Association (AGA), the California Air Resources Board (CARB), the Health Effects Institute (HEI), the National Biodiesel Board (NBB), the South Coast Air Quality Management District (SCAQMD), the Truck and Engine Manufacturers Association (EMA), the U.S. Department of Agriculture, the U.S. Department of Energy (DOE) and many of its national laboratories, the U.S. Environmental Protection Agency (EPA), and many others. CRC has also continued coordination efforts among research organizations worldwide, with European and Canadian collaborations emphasized this year.

CRC deliverables are technical reports that are approved by the committees and research partners that oversee the research. One major accomplishment this year is a peer-reviewed publication in journal *Energy & Fuel* that summarized many years of research by CRC and others on the impact of intermediate-level ethanol blends. This extensive research program is a prime example of CRC research on the impacts of changing fuel composition on vehicle performance in the current fleet. This research is intended to benefit associated industries, the government, and the consumer. Another very important highlight for 2014 is the publication of Phase 2 results of the Advanced Collaborative Emissions Study (ACES) conducted in collaboration with the Health Effects Institute (HEI). This phase of the research program provided an evaluation of advanced diesel engine and aftertreatment systems meeting 2010 on-road heavy-duty diesel standards for particulate matter (PM) and oxides of nitrogen (NOx). Integral to the ACES research program, HEI concluded health effects testing at Lovelace Respiratory Research Institute (LRRI) on 2007 technology engine exhaust and reported a summary of their results at their 2014 Annual Meeting.

In addition to the two major studies mentioned above, the CRC Emissions Committee has been active in several key areas of new research. Projects E-94, E-96, and E-99 are examining minute details of low-level aerosol and particulate matter (PM) emissions to measure and to characterize true emission rates and determine potential downstream chemical and physical changes as a function of vehicle type. In project E-102 the Emissions Committee assessed approaches for calculating life-cycle impacts of several existing and new fuel options to expand on previous studies on this area of research.

The Advanced Vehicle/Fuel/Lubricants (AVFL) Committee made significant progress in developing diesel fuel surrogates formulations under Project AVFL-18a and will begin engine testing and combustion modeling by the end of the year. The committee completed its formulation and full chemical and physical property evaluation of the FACE gasoline reference fuel set. FACE gasoline characterizations including selected ethanol blends were reported in the Final Report for project AVFL-24. An Interim Report on results from a study on "Biodiesel and Renewable Diesel Characterization and Testing in Modern LD Diesel Passenger Cars and Trucks" (AVFL-17b) was approved by the committee. The Final Report for this study will document results from 8 light-duty diesel vehicles to meet the project goal of filling an existing gap in the literature. Additional vehicle testing is being conducted under AVFL-17c.

A major accomplishment for the AVFL Committee was successful completion of a new international collaboration called the "Advanced Fuel and Engine Performance Workshop" held February 25-26, 2015 in Baltimore, MD. Full technical proceedings from this workshop were published on the CRC website. Significant progress was also made on project AVFL-20, "Gasoline-Ethanol Interactions & Effects on Engine Efficiency," and AVFL-26, "Gasoline Fuel Properties Impacts on Future Engine Design." The AVFL's Fuels for Advanced Combustion Engines (FACE) Working Group continued its broad collaborations with industry and government fuel experts this year with a new project (AVFL-23) designed to mine the data generated from extensive engine testing of the FACE diesel fuels. An expert research team at Natural Resources Canada is leading this effort.

The Diesel Performance Group of the Performance Committee has produced three important new reports in 2014 continuing their evaluation of field problems observed in modern diesel fuel and associated high pressure injection systems. Project DP-04-13a resulted in CRC Report No. 665, "Internal Diesel Injectors Deposits." This was followed by Final Report No. DP-04-13b, "Internal Injector Deposits: A Scoping Study to Evaluate the Delphi Test Rig" which was aimed at demonstrating a bench rig that duplicates full scale equipment tests. The goal for this program is to establish detection methods and ultimately recommend possible solutions for correcting field problems. A third project, "ULSD Corrosion Study Screening Criteria for Site Selection," resulted in Final Report No. DP-07-13 guiding a new field study of diesel fuel corrosion tendencies in commercial refueling stations.

The Octane Group of the Performance Committee continued its evaluations of performance contributions from motor octane number (MON) and research octane number (RON) on current light-duty engines and control systems. The Octane Group in collaboration with the Emissions Committee (E-108) completed a study called "Sub-Regular Grade (85 AKI) Octane Study." This study was conducted at Chrysler, Ford, and General Motors vehicle testing facilities using a standard set of test fuels designed to determine the effects of low octane gasoline used in some locations at low altitude.

The Volatility Group of the Performance Committee documented results of its 2013 driveability field study and published the findings in April

2014 (Intermediate Temperature E15 Cold-Start and Warm-Up Driveability Program). The objective of this study conducted in Yakima, WA is to identify E15 fuel blend factors that could be used to update Driveability Index coefficients in the ASTM D4814 standard. ASTM will review results in cooperation with all relevant government and industry stakeholders to determine if changes are appropriate. A new volatility study was commenced this year with two field campaigns conducted at the General Motors Proving Grounds in Yuma, AZ. The new study will complete Hot Fuel Handling evaluations reported in earlier CRC studies to cover performance of gasoline Volatility Classes AA through E.

An additional Volatility Group study entitled, “Risk Analysis/Hazard Assessment of High Ethanol Content Fuels at the Service Station,” has estimated the incremental change in risk due to a change in fuel composition (at higher levels of ethanol). This project was conducted in cooperation with the U. S. Department of Energy through its National Renewable Energy Laboratory.

The Performance Committee conducted a joint program co-sponsored by the American Gas Association (AGA). This project, PC-2-12, “Natural Gas Fuel Survey,” included sampling and detailed analysis of the composition of natural gas from vehicle refueling stations across the United States to assess current fuel quality. Results from this study are being applied to a new vehicle performance program to measure the effects of the fuel quality ranges observed in the CRC/AGA survey.

The Atmospheric Impacts Committee expanded its ongoing efforts to examine future air quality scenarios through development of improved data and through the use of air quality grid models. Air quality grid models evaluate not only gaseous pollutant transport and reactions, but also directly emitted primary aerosols (PM or POA) and secondary aerosols (SOA) which are formed in the atmosphere. The committee supported Phase 2 of the Air Quality Modeling Evaluation International Initiative (AQMEII) in cooperation with EPA and the Joint Research Centre (JRC) of Europe. CRC contributed funding under Project A-87 where coupled air quality and meteorology modeling evaluations of the European and North American domains were analyzed with guidance from the EPA/JRC program leaders.

The Atmospheric Impacts Committee completed Project No. A-84 to identify high payback approaches for improving data inputs for the National Emissions Inventory (NEI), resulting in publications by CRC and by the Transportation Research Board (TRB). A-84 was quickly followed by application of the new approaches under Project A-88, where datasets were documented and made available to states and regional planning offices for their submittals to the NEI. These two projects were conducted with close cooperation of the U.S. EPA, various Regional Planning Offices (RPO), and numerous states that will be end-users of the information developed under A-84 and A-88.

The Atmospheric Impacts Committee also continued its progress on reporting the effects of trends in fleet vehicle emissions and resulting impacts on ambient air quality. Project A-76-2 resulted in a publication on one phase of its work entitled, "Trends in On-Road Vehicle Emission and Ambient Air Quality in Atlanta, Georgia, USA from the Late 1990s Though 2009," by the *Journal of the Air and Waste Management Association*. Other related studies underway in the committee are also anticipated to result in peer-review publications in the near term.

The 24th CRC Real World Emissions Workshop was held in San Diego, CA on March 30-April 2, 2014 with sponsorship from the California Air Resources Board (CARB), South Coast Air Quality Management District, the National Renewable Energy Laboratory (NREL), and the US Environmental Protection Agency (EPA). A summary article presenting technical highlights from the workshop was prepared for publication in "*em*" (Environmental Manager) a magazine of the Air and Waste Management Association.

The AVFL Committee in cooperation with the Octane Group of the Performance Committee organized an international workshop on Advanced Fuel and Engine Efficiency held in Baltimore, MD February 25-26, 2014. The workshop was co-sponsored by DOE and API with in-kind support contributed by MIT. An international group of scientists convened in this forum to discuss current status and opportunities to improve vehicle efficiency through application of advanced engine and fuel technology. This was the first workshop to be conducted by CRC on this topic. Proceedings of the workshop were published on the CRC website.

Details on these and other CRC projects appear in Part Two of this Annual Report. Final Reports issued since the last CRC Annual Report are listed in Part Three. Organization and Memberships are presented in Part Four.

PART TWO

DETAILED REPORTS OF CRC PROJECTS

ACES, ACES-1, ACES-1A 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) was a cooperative, multi-party effort to characterize the emissions and assess the possible health impacts of the new, advanced engine systems and fuels introduced into the market during the 2007–2010 time period.

The ACES program was 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 new technology diesel engine and emissions controls.

Funding for ACES was 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 Truck and Engine Manufacturers Association (EMA), and a group of manufacturers of emissions control equipment.

The ACES program was divided into three phases:

• In Phase 1, extensive emissions characterization of four 2007 production heavy heavy-duty diesel (HHDD) engines was performed. Emissions characterization results were used as the basis for selecting one HHDD engine/aftertreatment system for health testing (Phase 3). In addition to the measurement of regulated pollutants, the exhaust gases were speciated to quantify nearly 700 compounds of interest.

• Phase 2 was analogous to Phase 1, but was performed on 2010 HHDD engine technology. Additional measurements were made to account for potential compounds from the NOx aftertreatment technology, urea selective catalytic reduction systems (urea-SCR).

• In Phase 3, the selected 2007 engine was installed in a specially designed emissions generation and animal exposure facility; it was used in a chronic inhalation study (using rats and mice) with health measurements. HEI was the leader for this Phase, which was performed by the Lovelace Respiratory Research Institute (LRRI).

Four manufacturers (Caterpillar, Cummins, Detroit Diesel, and Volvo) supplied de-greened new 2007 engines for Phase 1 testing, using a common lubricant supplied by Lubrizol. The Phase 1 evaluation was based on the US 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 CRC Project E-55/59. The engine cycle was developed 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 was used for all engine characterization and exposure activities in the ACES project.

Three manufacturers (Cummins, Detroit Diesel, and Volvo) supplied de-greened new 2010 engines for Phase 2 testing, using a common lubricant supplied by Lubrizol.

Southwest Research Institute (SwRI) and Desert Research Institute (DRI) performed both Phases 1 and 2.

Current Status and Future Program

The Final Reports for the ACES-1 and ACES-1a cycle development projects, the Phase 1 Final Report, and the Phase 2 Final Report have been released and are available on the CRC website. An article on the Phase 1 engine emissions test program was published in the *Journal of Air and Waste Management* in April 2011. A journal article for Phase 2 is in development. HEI presented the final Phase 3 results at their Annual Meeting in May 2014, and the Phase 3 report is expected to be released by HEI in late 2014.

CRC/NREL NATIONWIDE SURVEY OF FUEL DISPENSED FROM FLEX FUEL SERVICE STATION PUMPS

CRC Project No. E-85-3

Leaders: T. Alleman
J. Y. Sigelko
K. D. Rose

Scope and Objective

The objective of this study is to collect fuels from public fuel dispensing pumps delivering ethanol/gasoline blended fuel for use in flexible fuel vehicles (Flex Fuel pumps) and determine actual market vapor pressures and ethanol contents and compliance with ASTM D5798. The ASTM standard has recently been revised to facilitate blending of compliant fuel, and the new standard's effects at the fuel dispenser should be determined. Also, a new volatility class (class 4) was added in the 2011 revision of the standard.

With support from NREL, the DOE Alternative Fuels Data Center is being used to identify and confirm locations of Flex Fuel pumps throughout the US. Locations have been selected to cover the broadest geographic range possible, though Flex Fuel pumps are still predominantly located in the Midwestern US.

Fuel Quality Tests: The volatility of the Flex Fuel is being compared to the applicable requirements of D5798-13. The ethanol content of the Flex Fuel is being measured and compared to the appropriate ASTM specification and/or pump labeling. Vapor pressure and ethanol content are being measured in each sample. On a subset of the samples, density, ethanol content, water content, acidity, inorganic chloride and potential sulfate, and existent (total) sulfate are being measured.

Current Status and Future Program

Sample collection started in the second half of 2013 and will be completed by September 2014, with the final report completed by the end of 2014.

EMISSIONS

FOLLOW-ON STUDY OF TRANSPORTATION LIFE CYCLE ANALYSIS: REVIEW OF ECONOMIC MODELS USED TO ASSESS LAND USE CHANGE EFFECTS

CRC Project No. E-88-3

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

Scope and Objective

The overall objective of this project is to review the agro-economic models used to estimate land use change impacts as a result of the production of biofuels.

CRC previously funded a study of transportation fuel LCA (CRC Project E-88) that reviewed the state of the science, compared the results of different models, and provided information on key inputs to LCA modeling that contribute to uncertainty in the emissions estimates.

That study also provided specific recommendations for targeted research to reduce those uncertainties. To address a number of gaps and uncertainties highlighted in the E-88 study, as well as those identified by participants of the 2009 CRC Workshop on the LCA of Biofuels, CRC funded Project E-88-2. E-88-2 focused on issues related to indirect land use change (iLUC) and agricultural N_2O emissions. Although both E-88 and E-88-2 touched on the economic models used for the assessment of land use change emissions, there was not a targeted review and assessment of those models.

Both EPA and CARB have relied on agro-economic models as the basis of the iLUC estimates for biofuels included in their RFS2 and LCFS rulemakings. Under the E-88-3 project, the following tasks were performed to identify how best to reduce the uncertainty in the LUC estimates:

Task 1 - Review and compare economic models used for iLUC estimates. This included those models used by both EPA (i.e., FASOM and FAPRI-CARD) and CARB (GTAP). In addition, other land use change models were reviewed, including the IMPACT model developed by International Food Policy Research Institute and other European models used for this purpose (e.g., LEITAP, CAPRI, AGLINK-COSIMO).

Task 2 - Isolate, to the greatest extent possible, the quantitative impact of key data and model parameters in the various models reviewed.

Current Status and Future Program

This project was conducted by a group of researchers, led by Life Cycle Associates and including Air Improvement Resources, Tyner Economic Analysis Associates, the Policy Institute at Indiana University, and the Desert Research Institute. The final report has been released and is available on the CRC web site.

EMISSIONS

LCA WORKSHOPS

CRC Project No. E-93

Leader: P. L. Heirigs

Scope and Objective

CRC has been holding invitation-only LCA Workshops every other year starting in 2009. The 2009, 2011, and 2013 Workshops held in October at Argonne National Laboratory near Chicago were each attended by more than 100 representatives from government, industry, academia, and NGOs. Summaries from the workshops are posted on the CRC website.

The 2013 Workshop Goals were to:

- Outline technical needs arising out of policy actions and ability of LCA analysis to meet those needs.
- Identify research results and activities that have come to light in the past two years that have helped to close data gaps previously outlined as outstanding issues.
- Identify data gaps, areas of uncertainties, validation/verification, model transparency, and data quality issues.
- Establish priorities for directed research to narrow knowledge gaps and gather experts' opinions on where scarce research dollars would best be spent.

The workshop organizing committee throughout the years has included representatives from API, CARB, Conservation of Clean Air and Water in Europe (CONCAWE), U.S. DOE, Environmental Defense Fund (EDF), U.S. EPA, National Biodiesel Board (NBB), Natural Resources Canada, USDA, Ford Motor Company, Chevron Global Downstream, Renewable Fuels Association (RFA), Marathon Petroleum Company LP, ExxonMobil Research & Engineering, Argonne National Laboratory, the South Coast Air Quality Management District (SCAQMD), the University of Michigan, the University of Toronto, Joint Research Center – Institute for Environment and Sustainability, and the Union of Concerned Scientists.

Current Status and Future Program

The 2013 CRC LCA Workshop was held October 15-17 at the Argonne National Laboratory in Chicago. The proceedings from the Workshop have been published on the CRC web site.

Planning for a 2015 LCA Workshop will begin in the latter half of 2014.

EMISSIONS

EVALUATION AND INVESTIGATION OF GASEOUS AND PARTICULATE EMISSIONS FROM SIDI IN-USE VEHICLES WITH HIGHER ETHANOL BLEND FUELS

CRC Project No. E-94-1 / E-94-1a / E-94-2

Leaders: M. B. Viola
S. A. Mason

Scope and Objective

In the E-94-1 pilot study, vehicles with spark ignition direct injection (SIDI) engines were purchased and operated on fuels containing a range of ethanol concentrations (E0 to E20 or higher). Key objectives were to:

- Determine gaseous and PM/PN (particulate mass/particle number) emissions with E0 fuels as a baseline.
- Determine gaseous and PM/PN emissions with splash-blended E10 and E20 fuels.
- Measure the effect of higher boiling point aromatic compounds on the PM/PN emissions by utilizing two different base fuels.
- Characterize particulates from all testing.

Vehicles - Three vehicles equipped with SIDI engines were used for the pilot phase of the program: one vehicle had a naturally-aspirated 4-cylinder engine, one had a turbo-charged 4-cylinder engine, and one had a naturally-aspirated V6 engine.

Fuels – Two different base test fuels were procured directly from refineries, selected to maximize the difference in the Particulate Matter Index (PMI). Ethanol was splash-blended in the base fuels to produce E10 and E20. Each fuel was analyzed for RON, MON, sulfur, olefins, aromatics, oxygen, benzene, hydrogen, RVP, ethanol, and boiling point distribution.

Emissions Measurements - Using the LA92 test cycle, all tailpipe gaseous emissions were collected along with instantaneous PN emissions. Fuel economy and GHG emissions (CO_2, N_2O and methane) were also collected. Particulate/particle characterization included:

a. For PM number (i.e., PN): Solid particles >23 nanometers in size.

b. For PM mass: Standard filter method using the EPA 1065 protocol.

c. Real-time Black Carbon or soot (mass-based): AVL Micro-Soot Sensor.

d. PM/PN size distribution: EEPS.

e. Soot morphology using organic carbon / elemental carbon (OC/EC); also amount of sulfur contained in particulate.

Current Status and Future Programs

SwRI performed the E-94-1 pilot study, and the final report is available on the CRC web site.

A follow-on study, E-94-1a: "Determination and Evaluation of New Prep Cycle on the Fuel Effects of Gaseous and Particulate Emissions on SIDI In-Use Vehicles," has been performed by SwRI. This study used the same vehicles as in the pilot study, with similar fuels to evaluate the benefits of a more extensive vehicle prep procedure on stabilizing the emissions measurements after a fuel change. The final report for this project is in review with release anticipated in the fall of 2014.

The main study, E-94-2 "Fuel Effects on Gaseous and Particulate Emissions on SIDI In-Use Vehicles," will expand the SIDI fleet to 12 vehicles, and use a matrix of eight match-blended fuels to better understand how a range of SIDI engine technologies are impacted by varying fuel parameters. A request for proposals for E-94-2 was released in May 2014, and the proposals are in review by the Emissions Committee.

EMISSIONS

CRC/NREL NATIONWIDE SURVEY OF BLENDER PUMP FUELS

CRC Project No. E-95-2

Leaders: T. Alleman
J.Y. Sigelko
M. I. Watkins

Scope and Objective

The objective of this study was to collect fuels from ethanol blender pumps in the US and determine vapor pressure and ethanol content to determine compliance with applicable ASTM standards.

The DOE Alternative Fuels Data Center was used to identify and confirm locations of blender pumps throughout the US. Locations were selected to cover the broadest geographic range possible, though blender pumps are still located predominantly in the Midwestern US. Where possible, pumps were selected from both RFG and conventional areas. The parent gasolines and Flex Fuels were collected and analyzed, along with every Mid-Level Ethanol Blend (MLEB) offered at each station.

Fuel Quality Tests: The volatilities of the gasolines and the Flex Fuels were compared to the applicable ASTM requirements (D4814 or D5798). The volatility of the MLEBs was compared to the requirements in D5798, per D7794, Section 6.7. The ethanol content of the gasolines, Flex Fuels, and MLEBs were measured and compared to the appropriate ASTM specification and/or pump labeling.

Current Status and Future Programs

NREL contributed to the project through technical resources, including station identification, report writing and analyzing data. Sample collection occurred in the latter half of 2012 and the first half of 2013. The final report was posted to the CRC web site in March 2014.

LINKING TAILPIPE AND AMBIENT PM

CRC Project No. E-96 (see also A-74)

Leaders: M. M. Maricq
H. Maldonado

Scope and Objective

The objective of this project was 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 goal is to obtain 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 is a joint project, with the Atmospheric Impacts Committee referring to Project No. A-74.

Current Status and Future Program

This project was awarded to Carnegie Mellon University (CMU). It leverages considerable additional funding provided through an EPA STAR grant and in-kind testing by CARB. The project consists of three test phases and a fourth modeling phase. Phase 1 addressed light-duty vehicle emissions. Phase 1 testing was carried out in May 2010. Testing for Phase 2, aimed at heavy-duty diesel emissions, was completed in July 2011.

Phase 3 had two aims. The first was to revisit light-duty vehicles and address issues or questions that arose in the analysis of Phase 1 data. The second was to examine non-road engine emissions. Testing for Phase 3 was conducted in early 2012.

Summary results from Phase 1 were presented at the 21st Real World Emissions Workshop in March 2011, and follow-on presentations were given at the 22nd and 23rd Workshops. Seven journal articles were published covering the research in the first three phases of this project. In addition to the journal articles, CRC has published an Executive Summary report on the CRC web site which makes reference to the journal articles.

EMISSIONS

Phase 4 is in progress now; it will examine PM emissions data and SOA information in connection with the CalNex inventory and compare these data against transport modeling (air quality grid modeling) results. The CRC Atmospheric Impacts Committee is taking the lead on the Phase 4 effort.

CRC INTERMEDIATE-LEVEL BLEND RESEARCH

CRC Project No. E-97

Leader: M. I. Watkins

Scope and Objective

This study completed a review of all CRC research on intermediate-level ethanol blends with gasoline. The report also covered studies by other groups that were closely related to CRC research. Thirty published studies were analyzed and grouped to address specific topics such as: driveability, exhaust emissions, evaporative emissions, flexible-fuel vehicles, onboard diagnostics, and durability of engine, fuel, and emissions control systems.

Current Status and Future Program

This study was completed by two consultants, Albert Hochhauser and Charles Schleyer. The final report was published by the ACS journal *Energy and Fuels* in April 2014 as a peer-reviewed article.

EMISSIONS

EXHAUST EMISSIONS OF AVERAGE FUEL COMPOSITION

CRC Project No. E-98 (see also A-80)

Leader: J. Rutherford

Scope and Objective

The objective of this project is to measure exhaust emissions from a range of recent model light-duty gasoline vehicles operating on three fuels. One fuel was a re-blend of one of the fuels from the EPAct/V2 program (a "tie-point" fuel) while the other two fuels occupied the mid-space defined by the properties of all of the fuels tested in the EPAct/V2 program. Regulated emissions as well as speciated emissions were measured using standard exhaust emission tests.

Current Status and Future Program

Fifteen vehicles used in the previous EPAct/V2/E-89 program were tested. Each vehicle-fuel combination was tested at Southwest Research Institute (SwRI) using the LA-92 emissions test cycle, with the fuel order randomized for each vehicle/fuel combination. Duplicate tests were conducted "back-to-back," with the option for a third test based on repeatability criteria provided by CRC. Measurements of criteria emissions and designated toxics benzene, 1,3-butadiene, formaldehyde, and acetaldehyde were carried out in all tests. VOC speciation of the bag exhaust emissions was completed for one test of one fuel for each vehicle. The final report was posted to the CRC web site in June 2014.

VERY LOW PM MASS MEASUREMENT

CRC Project No. E-99

Leaders: M. M. Maricq
H. Maldonado

Scope and Objective

The objective of this project is to examine possible changes to gravimetric PM measurements that would preserve the integrity of the method but reduce the variability and gaseous adsorption artifacts that limit the usability of this method at LEV III / Tier 3 emissions standards.

Current Status and Future Program

Current motor vehicle PM emissions measurement regulations (CFR 40 Part 1065, 1066) require gravimetric determination of PM collected on filter media from diluted exhaust. However, the current gravimetric method is a challenge at the proposed 3 mg/mi PM emissions standard and is likely to reach its limit at the future 1 mg/mi emissions standard. The combined effects of the more stringent PM standard and CFR minimum dilution requirements have reduced typical filter loadings to about 20 µg at a tunnel flow of 350 cfm and a PM emissions rating of 1 mg/mi. At the same time, a number of studies show that filters, including Teflon® membrane, are susceptible to gaseous adsorption artifacts that can contribute as much as a 3 – 7 µg weight gain, with outliers exceeding 10 µg, even when the procedure is run without a test vehicle (i.e., tunnel and trip blanks). This artifact itself can have a high variability (~100%) and can be different from one facility to another. The impacts on vehicle emissions testing are increased measurement uncertainty and cost.

This project is structured into the following tasks:

Task 1: Identify potential method modifications that will reduce variability of PM mass test results.

Task 2: Prepare and submit the project test plan for CRC Committee review and approval. The test plan should statistically demonstrate how method changes affect test measurement capability. The matrix of method modifications includes changes to test procedures, test engines/vehicles, test cycles, and fuels. Also included are parameters to measure additional environmental conditions, such as ambient outside air, ambient chamber air, ozone level, tunnel air, tunnel wind velocity, and dew point of diluted exhaust mixture, reporting frequency (e.g., 1 Hz), and the methods used to measure and calculate these parameters.

Task 3: Perform testing according to test plan. Provide EC/OC data. Change plan as necessary to ensure a sufficient number of tests and repeatability. Provide a statistical assessment. Identify and quantify any ancillary impacts of the method modifications.

Task 4: Analyze data set and produce final report.

This project was awarded to the University of California at Riverside CE-CERT, and CARB is co-sponsoring the research. After the project started in 2013, a process was initiated to broadly poll other laboratories measuring low PM levels to compare methods and aid in the final design of the experiments to be performed in this project. Vehicle testing is in progress and the final report is expected to be issued in late 2014.

2014 MOVES REVIEW

CRC Project No. E-101

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

Scope and Objective

The Real World Group is conducting an evaluation of the MOVES model (MOVES2014) that was released to the general public in mid-2014. MOVES is the EPA's MOtor Vehicle Emission Simulator (MOVES) that estimates emissions for mobile sources covering a broad range of pollutants.

Tasks included in this assessment include:

- Task 0: Scoping Assessment
- Task 1: Review and critically evaluate the methodologies and data used in MOVES2014 to estimate exhaust and evaporative emissions, particularly those related to fuel effects
- Task 2: Exercise the MOVES Model
- Task 3: Provide recommendations

Current Status and Future Program

This project was awarded to Sierra. MOVES2014 was released at the end of July 2014, allowing the assessment to begin at mid-year. Reporting is anticipated in early 2015.

EMISSIONS

TRANSPORTATION FUEL LIFE CYCLE ASSESSMENT: VALIDATION AND UNCERTAINTY OF WELL-TO-WHEEL GHG ESTIMATES

CRC Project No. E-102

Leader: P. L. Heirigs

Scope and Objective

This project was intended to better quantify sources of uncertainty and variability in LCA models by conducting an in-depth evaluation of model inputs and input uncertainties for several specific fuel pathways.

Current Status and Future Program

The project was structured into the following tasks:

Task 1: Selection of Specific Fuel Pathways to Be Evaluated.

Initial suggestions were the following:

- Corn ethanol
- Soy biodiesel/renewable diesel
- Sugarcane ethanol
- Petroleum gasoline/diesel
- Cellulosic ethanol
- Natural gas

Task 2: Identification of and Critical Review of Model Inputs – For the primary LCA models used for regulatory purposes (i.e., CA-GREET, EPA's modeling for RFS2, GHGenius, and Biograce), the inputs to the models for each fuel pathway, and the basis of those inputs, were identified and validated. This assessment focused on the inputs with the greatest impact on final GHG results.

Task 3: Assessment of Variability/Uncertainty in the Task 2 Inputs. Alternative data sources for the inputs were identified where possible, and a reasonable range for the most important input parameters was established. Overall uncertainty in the model results were estimated based on the range of uncertainties established above.

This project was conducted by $(S\&T)^2$ Consultants. The final report was published in November 2013.

EVALUATION OF N_2O MEASUREMENT INSTRUMENTS WITH LIGHT-DUTY VEHICLES

CRC Project No. E-103

Leaders: D. B. Nagy
S. A. Shimpi

Scope and Objective

In recent years, EPA has promulgated greenhouse gas (GHG) regulations for various industry segments. As part of these regulations, EPA for the first time has introduced standards for nitrous oxide (N_2O) measured at the vehicle tailpipe. The standards given in these regulations will require the measurement of N_2O at relatively low levels, in some cases well below 1 ppm.

Current Status and Future Program

This project examined a variety of instruments for the measurement of N_2O, using light-duty vehicles operating on a chassis dynamometer. It was conducted in conjunction with a study focused on heavy-duty on-highway applications, which included both bench-top evaluations and engine testing.

Two test vehicles from the fleet used for the EPAct, E-83, and E-98 studies were used to conduct this instrument evaluation. Seven cold-start FTPs were performed on each vehicle over the course of two weeks with five different N_2O analyzers in operation (four vs. a standard method).

This project was awarded to SwRI. A heavy-duty study, funded by EMA, was conducted first. The final report for this project was released in August 2014.

EMISSIONS

ON-ROAD EMISSIONS MEASUREMENT VIA RSD

CRC Project No. E-106

Leader: D. M. DiCicco

Scope and Objective

This project is being performed by the University of Denver (DU), following the general methodology of the previous E-23 project that used remote sensing devices to measure the emissions of in-use vehicle fleets. The researchers will make measurements in Chicago and Tulsa on an alternating two-year schedule. Measurement campaigns are being conducted for one five-day week each year from 2013 to 2016. The previous E-23 Tulsa site will be retested in the early fall of 2013 and 2015, while the Chicago site will be retested in the early fall of 2014 and 2016. The equipment will be the same as was used in E-23, but with new capabilities to monitor ammonia, sulfur dioxide, and nitrogen dioxide in real time from each vehicle driving through the test location. This project is expected to provide between 80,000 and 100,000 vehicle emissions readings.

Current Status and Future Program

Testing commenced in 2013 for this project. Reports for a given city will be published each year with a final comprehensive report on all cities in the program at the end of the 4-year effort. The final report for the 2013 testing in Tulsa, OK was released in August 2014.

SUB-REGULAR GRADE (85 AKI) OCTANE STUDY

CRC Project No. E-108

Leaders: W. Studzinski
D. M. DiCicco

Scope and Objective

This study is evaluating vehicle performance and emissions effects of an 85 AKI gasoline relative to an 87 AKI gasoline at two altitudes. AKI or Anti-Knock Index is the average of Research and Motor Octane (RON and MON). This project is being conducted in coordination with the Octane Group of the Performance Committee.

- Test Locations:
    - Variable Altitude Chassis Dyno Emissions Chambers (Chrysler, Ford , and GM)
    - Two simulated altitudes: Low = 1,000 ft and High = 5,000 ft
- Measurements for evaluation:
    - Fuel economy
    - Emissions (CO_2, CO, NO_x, THC, NMOG)
    - Pre-catalyst inlet temperature
    - Spark retard/frequency of knock
    - Stoichiometry (relative air/fuel ratio)
- Test Vehicles
    - 10 various combinations of engine architectures, load factors, model years, manufacturers, and passenger cars and trucks.
- Test Fuels:
    - Matched E10 blends of 85 and 87 AKI fuel pairs
    - Equivalent properties including heating value, composition, (aromatics, olefins and sulfur), RVP, distillation (T50 and T90) and H/C ratio
- Test cycles:
    - 1×USFTP (cold) + 1×LA92 (hot) + 1×US06 (hot)
    - Half the tests were performed in an A-B-A format (85-87-85)
    - Half the tests were performed in a B-A-B format (87-85-87)

EMISSIONS

Current Status and Future Program

Testing for this project has been completed in the laboratories of GM, Ford, and Chrysler. Analysis is ongoing, and final reporting is expected in late 2014. Results from this study will provide relevant data to ASTM and NCWM discussions regarding minimum AKI values in different US geographical regions.

EFFECT OF FUEL COMPOSITION ON THE EMISSIONS AND PERFORMANCE OF MODERN, LIGHT-DUTY NATURAL GAS VEHICLES

CRC Project No. E-109

Leader: J. J. Jetter

Scope and Objective

The objective of this program is to gain an understanding of natural gas fuel quality effects upon modern light-duty natural gas vehicles (NGVs) which utilize "closed loop" engine control. Primary areas of interest:

- Tailpipe emissions
- Fuel economy
- Engine knock
- Basic driveability (startability, acceleration, etc.)

This project consists of operating instrumented NGVs on a dynamometer over various driving cycles. Basic driveability performance will be assessed during these dynamometer cycles, although this test configuration is designed primarily for emission evaluation.

NGVs currently marketed in the US fall into two categories: dual-fuel and dedicated. The former vehicle type includes a gasoline tank and can switch between NG and gasoline fuels, while the latter are optimized for NG operation only. Two dedicated vehicles and one dual-fuel vehicle have been selected for testing.

The results from the CRC Performance Committee Project PC-2-12, that surveyed the properties of market NG in different regions of the US, was used to inform the test fuel selection for this project.

Current Status and Future Program

This project was awarded to SGS after a competitive solicitation. Testing for this project is expected to occur in late 2014 with final reporting in early 2015.

EMISSIONS

E-110 REAL WORLD VEHICLE EMISSIONS WORKSHOP

CRC Project No. E-110

Leaders: D. M. DiCicco
G. C. Gunter

Scope and Objective

For decades, the Coordinating Research Council (CRC) has held an annual vehicle emissions workshop, gathering international practitioners in the field of vehicle/engine emissions to discuss the latest activities in modeling, measurement, and analysis. The 24th Real World Emissions Workshop, held March 30 - April 2, 2014 in San Diego, covered topics including trends, modeling, measurements, fuel effects, and inspection/maintenance. The workshop consisted of presentations, posters, and demonstrations. Two hundred participants from 14 countries attended the workshop. Co-sponsors for the Workshop included CARB, EPA, NREL/DOE, and SCAQMD.

Current Status and Future Program

A summary journal article on the research reported at the 23rd workshop in 2013 was published in the '*em*' magazine of the Air and Waste Management Association in August 2013. The workshop organizing committee has submitted a similar summary article on the research reported at the 24th Workshop to the same magazine for publication in late 2014. The 25th workshop is planned for March 22-25, 2015 in Long Beach, California.

E-112 BIODIESEL (>B6) FUEL SURVEY

CRC Project No. E-112

Leaders: J. Y Sigelko
R. George

Scope and Objective

The State of Illinois recently created some tax advantages for stations that sell greater than 11% biodiesel blends. The labeling regulation for pumps selling these blends only requires that the label list a biodiesel range from B6 to B20. Because fuel blends up to B5 do not require a label, the actual biodiesel content of the fuel may be anywhere from B0 to B20, which could be confusing to consumers. The objective of this project is to evaluate the biodiesel content and other properties of diesel fuel that is being sold in Illinois and Minnesota at a given point in time. Specific sampling locations have been selected to cover the broadest geographic range possible in the geographic area of interest.

Current Status and Future Program

Proposals from a competitive solicitation are being reviewed by the Emissions Committee; fuel sample collection and analysis are expected to occur in the late summer or fall of 2014.

EMISSIONS

E-114 EFFECTS OF ORGANOMETALLIC ADDITIVES ON GASOLINE VEHICLES: ANALYSIS OF EXISTING LITERATURE

CRC Project No. E-114

Leader: J. J. Jetter

Scope and Objective

Members of an ASTM/NCWM Joint Task Force formed to evaluate the effects of organometallic compounds on gasoline vehicles have been asked to submit documents and information pertinent to this topic to a database maintained by the NCWM. The material is organized only by date of submission; an approximate list of the collected material is as follows:

- 15 studies
- 9 SAE papers
- 2 compilations
- 20 other documents and papers

The Joint Task Force requested that CRC perform this project, in which the database will be organized and summarized. The report is expected to provide overall conclusions and impacts of organometallic compounds on modern vehicles. The objective is to provide an independent and objective accounting of the publications and other material contained in the NCWM database. Following an initial screening of the database, additional documents may be added if relevant information is found to be missing.

The expected output from this project is a report that would include the following components, at a minimum:

- An organized list of the information contained in the NCWM database, including author and affiliation, subject, relevance and/or quality, etc.
- A short summary of the key findings / points in each document.

The report will be made available to the ASTM and NCWM Task Forces and published on the CRC web site.

Current Status and Future Program

A request for proposals has been released on the CRC website. The research is expected to be conducted in the Fall of 2014, with reporting in late 2014.

AVFL

BIODIESEL AND RENEWABLE DIESEL CHARACTERIZATION AND TESTING IN MODERN LD DIESEL PASSENGER CARS AND TRUCKS

CRC Project No. AVFL-17b

Leaders: G. C. Gunter
S. W. Jorgensen

Scope and Objective

The objectives of the light-duty (LD) biodiesel and renewable diesel characterization and testing project are to: 1) Identify and procure high-quality biodiesel B100 and renewable diesel from four different sources, 2) Develop B20 and RD20 blends with Ultra Low Sulfur Diesel (ULSD), 3) Develop a B20 blend with CARB Diesel, 4) Procure or lease suitable vehicles, and 5) Characterize the criteria and unregulated emissions from the vehicles using the LD FTP cycle.

Current Status and Future Program

A competitive solicitation process for this project was conducted in the first quarter of 2012. The technical review panel selected CE-CERT to conduct the project, which started in June 2012.

Fuels: High quality B100 ASTM compliant biodiesel were procured and blended with commercially available Federal ULSD. One CARB B20 blend was also tested. The sources of biodiesel include soy and other feedstocks that span the range of degree of saturation common in the marketplace. A Renewable Diesel, also known as Hydrogenated Vegetable Oil (HVO), and a hydro-processed animal fat were also tested. A CRC member laboratory performed fuel analyses to determine properties. The fuels matrix includes 1) Federal ULSD baseline diesel, 2) Four B20 fuels blended with the Federal ULSD fuel (including one renewable diesel blend), 3) CARB baseline diesel, and 4) One B20 fuel blended with the CARB fuel, for a total of seven test fuels.

Vehicles: In the current US market, LD diesel passenger cars are available from manufacturers including Audi, BMW, GM, Mercedes, and VW. In addition, Ford, GM, and Chrysler sell LD diesel trucks. The goal was to procure a variety of vehicle types representing each manufacturer, for testing. The contractor performed break-in, preconditioning, and engine/exhaust system monitoring, using protocols reviewed and agreed to by the project technical panel. Eight vehicles were scheduled for testing.

Emissions measured included: 1) Regulated Emissions: HC, CO, NOx, PM; 2) Unregulated emissions, including Carbonyls, PAH and Nitro-PAH. Optional measurements are 1) PM number, 2) EC/OC, 3) NMHC, 4) Fuel Economy, 5) NH_3 for SCR systems, and 6) DPF regenerations emissions. Tests were done in duplicate allowing for repeats to meet criteria set by the project panel.

All test fuels were acquired by CE-CERT. In Phase 1, three vehicles completed testing on all fuels, and one vehicle completed regeneration emissions testing on select fuels. Testing on a second vehicle included regeneration emissions testing on Federal ULSD and Federal-SME20 fuels in Phase 1. Fuel samples were submitted to a CRC member company analytical laboratory for fuel property analyses.

An engine exhaust particle sizer (EEPS) spectrometer and a Dekati Mass Monitor (DMM) were added to the suite of instruments used to characterize particles. The EEPS provides real-time particle size distributions during transient operation, while the DMM measures real-time second-by-second PM mass. These instruments were beyond the original scope of the original test program and were given secondary priority in terms of completing the test matrix. These instruments were used in conjunction with testing if they were available and fully running at the time for any given test. The results of the special instrumentation are being provided to CRC at no additional cost.

An Interim Phase 1 Draft Report on regulated emissions, particle number and sizing, carbonyl compounds, NH_3, and EC/OC from the first three vehicles was submitted for review. A complete Phase 1 report was also prepared which included a complete data set for all three vehicles, including EC/OC fraction and PAH/nitro-PAH emission results from one of the test vehicles.

Testing of the five vehicles in Phase 2 was completed in the second quarter of 2013. The final report will include a detailed statistical analysis of emission trends and is expected to be completed by the end of 2014.

IN-VEHICLE BIODIESEL OXIDATION STABILITY

CRC Project No. AVFL-17c

Leaders: W. Woebkenberg
G. C. Gunter

Scope and Objective

The overall objective of this project is to investigate the effects of biodiesel and other baseline petroleum fuels from oxidation and thermal instability that may occur during onboard fuel storage and in-use vehicle operation.

The goals of Phase 1 of the study are to examine the impacts of various challenges to stability (temperature, pressure, oxidation, free radical formation, acid formation, etc.) on biodiesel blends during onboard vehicle use and storage conditions to:

1. More accurately capture and identify the environmental conditions and chemical processes which drive thermal and oxidative instability (literature search as it applies to onboard storage conditions)

2. Develop relationship between such processes and a measurable attribute of the fuel such as the onset/presence of free radicals, peroxide formation, acid number, induction period (IP), etc.

3. Develop a surrogate process or performance test to simulate those impacts and create oxidized biodiesel according to a given oxidation specification

4. Determine the statistical uncertainty in reaching a selected degree of oxidation of such a simulated process in the laboratory (repeatability)

5. Provide a project report with complete details of the project including the detailed final oxidation process and its repeatability analysis.

Current Status and Future Program

The program will consist of two phases, the first of which will develop a bench test methodology to replicate rapid oxidation induction period (IP) depletion in vehicle. The second phase may involve aging fuels to various IP numbers and to various acid numbers. The effects on injectors and other components and their impacts on criteria and unregulated emissions may be observed to measure potential impacts from in-vehicle fuel stability issues. This project began in late CY2013 with a contract issued to Southwest Research Institute.

High quality ASTM compliant B100 biodiesel was procured. B100 will be blended with selected commercially available hydrocarbon diesel fuels comprised of high levels of hydrotreated and hydrocracked components, respectively. The hydrocarbon-only petroleum diesel fuels may also be evaluated separately for their stability performance. Sources of biodiesel are soy and palm or other feedstocks that span the range of degree of saturation and initial stability. CRC member laboratories may be requested to perform fuel analyses to determine their properties, including cetane number, or the contractor may arrange for property inspections at a commercial laboratory. In summary, the following fuel sets will be considered for evaluation:

• One high concentration hydrocracked diesel fuel and one high concentration hydrotreated baseline diesel fuels for a total of 2 hydrocarbon-only fuels;

• Four biodiesels representing two levels of saturation and two levels of stability as measured by induction times in a 2x2 matrix with selected diesel fuels from above (B100 containing no antioxidant may be selected as part of the stability-level matrix);

• Two additional fuel blends from the above fuel sets with cetane number improver added to explore the impact of this additive.

Identification of Onboard Fuel Storage and In-use Conditions and Laboratory Simulations - CRC will identify some modern diesel vehicle technologies and their generic fuel system conditions that will serve as a minimum baseline to define in-use engine operation and onboard fuel storage conditions that can be more fully evaluated directly during vehicle onboard vehicle exposure operations. The baseline test conditions to be evaluated in this study will include fuel tank breathing during diurnal storage, recirculation of fuel to the tank during operation, and exposure of fuel flowing in the pump/injection systems. Onboard vehicle conditions will also be simulated in the laboratory to duplicate conditions that may be observed on a test track.

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Fuel Stability Monitoring - The contractor will propose analytical procedures to monitor fuel stability during simulated onboard vehicle storage and use to define any changes that may occur in fuel exposed to these conditions.

Technical Approach: The following tasks address the project objectives:

Task 1: Literature Search of potential oxidation and thermal stability impacts during onboard vehicle storage and in-use conditions and availability of potential screening tools.

Task 2: Vehicle Technology Selection and Identification of Onboard Fuel Exposure Conditions including fuel time, temperature, and pressure exposure conditions to bracket engine operating conditions.

Task 3: Fuel Procurement (see list above) including full fuel characterizations of base fuels and blends.

Task 4: Vehicle Dynamometer/Proving Ground/Test Track Evaluations (Baseline and Experimental Fuels).

Task 5: Bench Test Development to mimic an onboard fuel exposure history (thermal, oxidation, etc.) to develop potential screening tool(s). An Experimental Design for statistical analysis of all data generated will be prepared for review and approval by the Project Management Team.

Task 6: Repeatability testing will be conducted on the selected final test procedure. The design of experiments and analytic techniques will be suitable for consideration by ASTM to specify the test repeatability.

Task 7: Recommendations for Phase II on fuel effects testing.

The AVFL-17c technical review panel selected SwRI to conduct this study following a competitive solicitation. A literature review on biodiesel oxidation and thermal stability in vehicle systems was conducted. Mercedes-Benz provided a test vehicle for the project. The test fuels were chosen. The petroleum diesel fuel arrived at SwRI, and the National Biodiesel Board arranged delivery to SwRI of the biodiesel to be used for this project. SwRI has conferred with the project panel members on vehicle instrumentation to monitor in-use fuel temperature and pressure conditions. These conditions will be measured and applied to separate evaluations of fuels in the test matrix. A draft report on the first phase of this study is anticipated in the first quarter of 2015.

IMPROVED DIESEL SURROGATE FUELS FOR ENGINE TESTING AND KINETIC MODELING

CRC Project Nos. AVFL-18 and AVFL-18a

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

Scope and Objective

The objective of this work is to establish and evaluate a methodology for formulating surrogates with compositional, ignition-quality, volatility, and density characteristics that are representative of diesel fuels produced from real-world refinery streams.

Current Status and Future Program

A surrogate fuel is a mixture of generally less than a dozen pure compounds that match certain selected characteristics of a target fuel composed of many hundreds to thousands of compounds. Surrogate fuels are of interest because they can provide a better understanding of fundamental fuel composition and property effects on combustion and emissions-formation processes in internal-combustion engines. Ultimately, their application in numerical simulations with accurate vaporization, mixing, and combustion models could revolutionize future engine designs by enabling computational optimization for evolving real fuels. Dependable computational design would not only improve engine function, it would do so at significant cost savings relative to current optimization strategies, which rely on physical testing of hardware prototypes.

The project team identified compounds representing the major hydrocarbon classes found in real diesel fuels to be included in surrogate fuel formulations. Surrogates have been formulated for two ultra-low-sulfur #2 diesel reference fuels. Analyses have been conducted to quantify the extent to which the surrogate fuels match the ignition-quality, volatility, and density characteristics of their corresponding target fuels.

This project is being performed in collaboration with researchers at several DOE National Laboratories: Sandia (SNL), National Renewable Energy Laboratory (NREL), Lawrence Livermore (LLNL), Pacific Northwest (PNNL), and Oak Ridge National Laboratory (ORNL); a Canadian Federal Laboratory (CanmetENERGY). The National Institute of Standards and Technology (NIST) is assisting with fuel property measurements and regression optimization techniques to support surrogate formulation.

Final evaluation of the first-generation surrogates was completed. A project report was reviewed and approved by the Project Panel and Committee for journal publication. The journal article describing the surrogate fuel formulation process was accepted for publication by *Energy & Fuels* and is currently available on their website, as well as on the CRC website. This article represents the Final Report for the first phase of AVFL-18.

Research was extended in 2012 and 2013 under AVFL-18a to facilitate the development of second generation surrogates with improved capabilities for matching market diesel fuels, blending engine research test quantities of surrogates, as well as single-cylinder engine testing of selected surrogate fuels. Panel members have worked to identify and obtain compounds of sufficient purity and sulfur content for blending surrogate fuels, using a variety of synthesis approaches. Nearly all components have been received for blending which will be conducted at Chevron for the selected surrogate formulations. Sandia National Laboratory along with two or three additional laboratories plan to begin engine testing of the final surrogate fuels in the fourth quarter of 2014. Combustion modeling of engine performance is also being conducted to predict the performance of the surrogate fuels in the selected engine test platforms.

CHARACTERIZATION OF ADVANCED ALTERNATIVE AND RENEWABLE FUELS

CRC Project Nos. AVFL-19 and AVFL-19a

Leaders: W. J. Cannella
C. Fairbridge
S. W. Jorgensen
R. L. McCormick

Scope and Objective

The objective of these projects is to characterize the physical and chemical properties of advanced alternative and renewable fuels designed for use in diesel and spark-ignition engines. This information is needed by OEMs, fuel producers, and combustion researchers to be able to predict the performance of these emerging fuel components in current and advanced combustion engines.

Current Status and Future Program

The project team consists of fuel, engine, and combustion researchers from energy companies, OEMs, and US and Canadian national laboratories. The current work builds on and complements the detailed characterization work that the team performed on the FACE Diesel Fuels (CRC Report No. FACE-1, "Chemical and Physical Properties of the Fuels for Advanced Combustion Engines (FACE) Research Diesel Fuels"). The advanced alternative and renewable fuels targeted for characterization include second generation bio-derived diesel fuels from non-food sources such as jatropha, algae, lignocellulose, and pyrolysis oils; "renewable" diesels from hydrogenated vegetable oils, animal fat and algae; Fischer-Tropsch type diesels from natural gas, coal, and biomass; oil shale; and oil sands. In addition, several conventional petroleum diesels have been characterized as references. Samples were obtained from commercial/semi-commercial producers of these fuels that were willing to provide samples for analysis and allow publication of the results in a blinded fashion (no assignment of producer name to the sample).

The physical and chemical properties of each sample in the first round of testing (AVFL-19) were characterized using standard ASTM-type analyses plus state-of-the-art advanced chemical composition techniques that were used to characterize the FACE Research Diesel Fuels. Research partners at the US National Laboratories and at Natural

AVFL

Resources Canada/CANMET Energy conducted the advanced characterization analyses in their laboratories, while standard tests were performed at SwRI.

Standard ASTM testing on the samples under AVFL-19 included:
1) Cetane number by D613 engine test,
2) Cetane index by D976,
3) Distillation by D86 and D2887,
4) Specific gravity by D4052,
5) Kinematic viscosity by D445,
6) Cloud point by D2500,
7) Flash Point by D93,
8) Net heat of combustion by D240,
9) Lubricity by D6079,
10) Elemental Analysis by D5291, D5453, D5623, and D4629,
11) Hydrocarbon types by fluorescent indicator adsorption (FIA) D1319,
12) Hydrocarbons by D2545,
13) Aromatics by super critical fluid chromatography (SFC) D5186,
14) Bromine Number by D1159, and
15) Sulfur by D5453.

Advanced characterization tests included:

1) Ignition Quality Tester Derived Cetane Number by D6890 and Predictive Ignition Delay Time based on parametric ignition experiments,
2) One-dimensional (1D) GCMS; Two-dimensional (2D) GCxGC-TOFMS (time of flight mass spectroscopy); GCxGC with flame ionization detection (FID); and GC-Field Ionization Mass Spectrometry (GC-FIMS) for components >200°C,
3) Paraffins, Isoparaffins, Olefins, Naphthenes and Aromatics (PIONA) analysis for components <200°C,
4) Saturates, Olefins, Aromatics, and Polar Compounds (SOAP), solid phase extraction for components >200°C,
5) Detailed hydrocarbon analysis (DHA) for components <200°C, and
6) ^{13}C and ^{1}H Nuclear Magnetic Resonance (NMR).

Standardized testing at SwRI and advanced characterization tests by partnering laboratories were completed. The AVFL-19 project produced two final reports. The FACE diesel fuel report was published as CRC Report AVFL-19-1. The Final Report for the analysis of the other renewable fuels was published as CRC Report AVFL-19-2 in May 2013.

Additional renewable fuel samples will be analyzed under AVFL-19a as part of an extension of this work in 2014. AVFL-19a is focusing on renewable gasoline-type components including samples of renewable naphtha, ethanol, butanol, and others. Samples of the test fuels have been sent to the selected project test laboratories. SwRI will perform standard ASTM testing; NREL, CanmetENERGY, PNNL, Phillips 66, GM, and Chevron will provide additional testing of fuel samples under AVFL-19a. All results will be compiled and reported in a document similar to the AVFL-19-2 final report.

AVFL

OCTANE NUMBER ENGINE EFFICIENCY AND CO_2: FILLING LITERATURE GAPS

CRC Project No. AVFL-20

Leaders: W. J. Cannella
J. Anderson

Scope and Objective

This study will investigate efficiency advantages for increased octane number fuel quality that may be available from ethanol or other blend components in modern light-duty vehicles.

Current Status and Future Program

A literature search is planned to identify the current state of information. Test blends may also be prepared and tested for resulting octane number quality. The project may also consist of limited engine dynamometer testing on a modified engine to evaluate which hydrocarbon types are best suited for blending with ethanol to maximize their synergistic effects to promote increased engine efficiency.

An agreement has been established between CRC and ORNL to conduct the first phase of engine testing and performance modeling for this study on a 1.6L Ford Ecoboost Engine. Flint Hills Resources is also a co-sponsor of the first phase of this project. Gage Products is preparing the test fuels according to the matrix of 19 test fuels approved by the project panel members and the committee. Samples of the test fuels are being analyzed by Chevron.

The test fuel matrix allows exploration of a wide range of ethanol content (10 to 30 volume %), Research Octane Number (91-102), and sensitivity (S=RON-MON) at two levels between 6-7 and 10-12. Following engine screening of all 19 test fuels for knock resistance, six of the test fuels will be chosen for more detailed engine performance characterization. Engine performance modeling is also planned in the ORNL test agreement.

An additional phase of this project is planned on a more conventional PFI engine after completion of the first phase. PFI engine work will be conducted under Project AVFL-20a.

ADVANCED FUEL AND ENGINE EFFICIENCY WORKSHOP

CRC Project No. AVFL-22

Leaders: K. B. Wrigley
M. Valentine

Scope and Objective

This project produced a workshop that brought together key individuals and organizations working on current issues centered on improvements to transportation system efficiency. The workshop was designed to address both advanced fuels and methods for improving engine efficiency. The workshop objective is to focus on light-duty engine technology and associated fuel effects for in-depth technical discussions.

Current Status and Future Program

The AVFL Committee led a coordinated effort to develop this new CRC workshop aimed at current developments in both fuels and engines that could be integrated to achieve system efficiency improvements. The Octane Group of the CRC Performance Committee played an important role in organization and planning of the workshop. A CRC panel was established to select the workshop topics and potential speakers. A poll of Committee members requesting their input on the areas of most interest yielded additional information. Following further discussion, the project leaders prepared an expanded plan with specific details and logistics for conducting the event. The resulting workshop was held February 24-26, 2014 in Baltimore, MD. The US Department of Energy and API provided co-sponsor funds to support the workshop. CRC members met on February 27, 2014 to review the results of the workshop, resulting in a list of potential new projects for CRC and others to included in their research. A Summary Report of the workshop was prepared and is included in the Proceedings of the Workshop now available on the CRC website.

AVFL

DATA MINING OF FACE DIESEL FUELS

CRC Project No. AVFL-23

Leaders: W. J. Cannella
C. Fairbridge

Scope and Objective

This study is being conducted in cooperation with Natural Resources Canada (NRCan). This project will examine engine performance correlations based on various engine test programs conducting using FACE fuels. A selection of performance parameters will be evaluated including those related to combustion efficiency.

Current Status and Future Program

This project is being conducted as a cooperative venture between CRC and NRCan. The project was officially started January 2014. The project is studying the extensive database on the chemical and physical properties of the FACE diesel fuels and all available engine performance data, such as that collected by WVU in CRC Project AVFL-16 and other test programs. The project is conducting statistical analysis to find new fuel property and engine performance relationships. NRCan has developed several correlations associating fuel properties and composition with engine performance. An important tool in developing the correlations is Principal Component Analysis (PCA) where collinear variables are eliminated to find the best parameters for characterizing performance. A draft final report from the contractor is expected near the end of calendar year 2014.

FACE GASOLINE ETHANOL BLEND TESTING

CRC Project No. AVFL-24

Leaders: W. J. Cannella
J. Paul

Scope and Objective

This project was designed to provide detailed results from a variety of standard ASTM International-type analyses and advanced characterization techniques conducted to measure the chemical and physical properties of a matrix of gasoline test fuels known as the Fuels for Advanced Combustion Engines (FACE) Gasolines. In addition, results are reported from analyses conducted on blends of ethanol at levels of 10, 15, and 30 volume % with four of the FACE gasolines.

Current Status and Future Program

The work was coordinated by a subgroup of the CRC AVFL Committee FACE Working Group. It parallels and complements the work done previously on the FACE Diesel Fuel matrix reported in Final Report FACE-1 available on the CRC website.

The FACE Gasoline matrix consists of ten fuels designed around four properties of primary importance to the performance of advanced gasoline-fueled engines: Research Octane Number (RON); Octane Sensitivity (S=RON-MON); aromatics content; and normal-paraffin (n-paraffin) content. The RON and S parameters are measures of a fuel's auto-ignition quality, while the aromatics and n-paraffin content are measures of a fuel's composition. The fuel target levels selected were: RONs of 70, 85, and 95; "low" and "high" octane sensitivities of ≤2 and ~ 10, respectively; aromatics contents of 5 and 35 vol.%; and n-paraffin contents of 5 and 25 vol.%. It was recognized that some of these targets are conflicting (e.g., high aromatics content with low octane sensitivity), and that required trade-offs would result in some of the target parameters not being completely met for some fuels.

A full-factorial set of test gasolines with these target levels would consist of 24 fuels. Statistical techniques were used to reduce this to a tractable number of ten fuels, while still maintaining a statistically sound matrix.

AVFL

Although the RON values of 70 and 85 and the octane sensitivity of 2 are lower and n-paraffin content of 25 vol.% are higher than currently found in market gasolines, they appear to be potentially relevant for emerging advanced low temperature combustion engines and so were included in this matrix of research fuels. The CRC FACE Working Group designed this matrix of research fuels. A commercial vendor (Chevron Phillips Chemical Co. – CPChem) has produced and made the fuels available for purchase in research quantities to engine and advanced combustion researchers to enable consistent comparisons of results from different laboratories and test platforms based on the same set of fuels.

A key goal of AVFL-24 was to characterize as fully as possible the chemical and physical properties of the FACE Gasolines and selected blends with ethanol and to make that information available to the engine and advanced combustion research and development (R&D) communities to enable selection of standardized test fuels for their programs and correlation of test results to fuel composition and properties. A significant part of the characterization was net heat of combustion measurements of the base FACE gasolines and the respective ethanol blends.

In support of this project, standard ASTM tests were conducted at several different laboratories to measure the following properties: Research Octane Number (RON); Motor Octane Number (MON); API gravity; density; Reid vapor pressure (RVP); distillation profile; net heat of combustion; elemental carbon, hydrogen, and sulfur; and fuel composition. The fuel composition analytical methods consisted of fluorescent indicator adsorption (FIA), supercritical fluid chromatography (SFC), and detailed hydrocarbon analyses (DHA) by one-dimensional gas chromatography with a flame ionization detector (1D GC-FID). Results of the blending and property analysis work are documented in Final Report No. AVFL-24 (July 2014) available on the CRC website.

GASOLINE FUEL PROPERTIES IMPACT ON FUTURE ENGINE DESIGN

CRC Project No. AVFL-26

Leaders: M. B. Viola
W. J. Cannella

Scope and Objective

The Committee technical scope includes evaluation of advanced fuels and advanced combustion systems. Within this scope, sets of diesel and gasoline-based test fuels were respectively developed by the Fuels for Advanced Combustion Engines (FACE) Working Group. With these tasks completed, the committee investigated potential composition and property changes for the next generation of ground transportation fuels.

Current Status and Future Program

The AVFL Committee initiated a planning process to identify key factors that should be evaluated for the next generation of research test fuels. Surveys were conducted among government and industry members of the committee to identify the areas of further study needed to address developments seen on the horizon for new fuels and combustion systems. The outcome of this effort resulted in a proposal to examine the impact of gasoline fuel properties on future engine designs.

The fuel matrix in this study will include E0, E10, E30; High and Low RON; and High and Low Distillation End Point to represent potential impacts on particulate matter emissions. The proposed test engine is a GM 2.0L L4 turbocharged LTG engine modified to make a more advanced technology configuration, reaching for a 25% improvement in fuel economy with a 2-stage turbo, 25% EGR, high energy ignition, and higher compression ratio.

An opportunity for co-funding has been identified in a U.S. Department of Energy Funding Opportunity Announcement (FOA). The preliminary concept paper was approved by DOE, and a more detailed application was prepared for submission on April 1, 2014. The FOA award announcement was made August 2014 and the project will move forward at testing facilities at ORNL.

AVFL

FUELS FOR ADVANCED COMBUSTION ENGINES (FACE) WORKING GROUP

Leaders: W. J. Cannella
R. M. Wagner

The AVFL Committee formed the FACE Working Group to foster collaboration with other industry and government research laboratory experts. 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.

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. DOE and Canadian National Laboratories. The activities of the group formally commenced in January 2006. The collaboration includes scientists and engineers from ANL, LLNL, NREL, ORNL, PNNL, and SNL as well as NRCan/CANMET Energy.

A key activity of this group has been developing two sets of fuels for research in advanced combustion in the diesel and gasoline ranges. The diesel fuel set, defined in 2007, is now commercially available for purchase 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" was published on the CRC website, and an accompanying conference paper was given at the 2009 SAE Fall Powertrains, Fuels, and Lubricants meeting. The group continues to support the blender in decisions relating to blending new batches of the fuels, as there are periodic changes in the availability of blendstocks.

The gasoline-range fuel set design was finalized by the group. All ten fuels have been blended in large batches and are commercially available for sale from CPChem. Detailed characterization of the gasoline fuel set is available on the CRC website in tabular form and further documented in CRC Final Report No. AVFL-24.

Current and future activities include publishing a 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. Presentations have been made at: the SAE High Efficiency Engines Symposium, the AEC/HCCI consortia meetings, and the DOE Annual Merit Review meeting. This year ORNL prepared a compilation paper for SAE on engine test programs where the FACE diesel fuels were tested in advanced combustion engines. The group also serves in a support role for the AVFL projects that are employing FACE fuels in research.

The FACE Working Group has created a number of sub-teams to address various technical aspects of their work plan. Spin-off projects generated by ideas from this group include: AVFL-16, AVFL-18, AVFL-19, AVFL-24, and AVFL-26.

AVFL

AVFL LUBRICANTS PANEL

Leader: T. Kowalski

The AVFL Committee technical scope includes evaluation of impacts of current lubricants on advanced vehicles and impact of future lubricants on current or advanced vehicles. The AVFL Committee organized a panel of engine lubrication experts from industry that serve as a resource for committee projects. The AVFL Lubricants Panel is also developing studies focused primarily on lubricant impacts for consideration by the full Committee

RELATIONSHIP BETWEEN SEMI-VOLATILE ORGANIC COMPOUNDS AND SECONDARY ORGANIC COMPOUNDS

CRC Project No. A-74

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

Scope and Objective

The objective of this project is to define the relationship between semi-volatile organic compounds (SVOC) contained in vehicle exhaust and subsequent formation of secondary organic aerosols (SOA) generated in the atmosphere via dilution and chemical reactions. The main project goal is to obtain sufficient definition of the relationship between SVOC and SOA to model the behavior in the atmosphere. The project is also sponsored by EPA and CARB. This project has application to both the Atmospheric Impacts Committee (AIC) and the CRC Real World Vehicle Emissions and Emissions Modeling Group (RWG). Therefore, a joint project was implemented in conjunction with CRC Project No. E-96.

Current Status and Future Programs

A proposal was submitted to CRC by Dr. 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 was previously awarded a grant from EPA and also received in-kind support from CARB to conduct vehicle testing. The CMU proposal to CRC covered smog 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 was reviewed and approved by the project panel members. The project began with Phase 1 testing in May 2010 at the CARB El Monte, CA vehicle test laboratories. Summary results from Phase 1 were presented at the 21st Real World Emissions Workshop in March 2011.

A second phase of vehicle testing and smog chamber evaluations was conducted in June-July 2011 at the CARB/MTA heavy-duty chassis dynamometer facility. A third phase to add more vehicle and chamber testing to the project matrix was completed in mid-2012.

The Phase 1 Final Interim Report was completed in May 2012. The Phase 2 Final Interim Report was completed in November 2012. The Phase 3 Final Interim Report was reviewed and approved by the project teams and committee members early in 2013.

Seven derivative journal articles were prepared and reviewed by the CRC committees for final documentation covering all work conducted through Phase 3 of the project.

The Phase 4 effort is now underway. Phase 4 was initiated by the project team and respective committee members to support modeling of SVOC primary emissions and their conversion to SOA based on data collected in the earlier phases. Photochemical grid modeling in Phase 4 will be compared to inventory data collected during the CARB CalNex field study.

An Executive Summary of the Phase 1-3 effort was approved by the respective committees for publication in parallel with the seven journal articles. The Executive Summary with link references to the journal articles and the database appendices have been posted to the CRC website. The final report for the Phase 4 work will also contain links to all related journal articles and an Executive Summary covering this segment of the program.

EFFECTS OF LIGHT-DUTY VEHICLE EMISSIONS ON OZONE AND PM WITH PAST, PRESENT, AND FUTURE CONTROLS

CRC Project Nos. A-76-1, A-76-2, and A-76-3

Leaders: S. Collet
R. S. MacArthur

Scope and Objective

The objective of this research program is to investigate the effect of historical, current, and future controls on LDV emissions outside California on ozone and PM in the U.S. LDV emissions standards in the U.S. have become increasingly stringent since the 1970s. Additional controls are planned, with the aim of improving ambient air quality. The incremental and cumulative air quality benefits of these emissions standards in the context of contributions from other mobile sources and other source categories are of primary interest. The projects require the use of MOVES and other emissions models coupled with regional 3D air quality modeling to estimate the absolute and relative contributions of LDV emissions to ozone and PM under various emission control scenarios for a representative month in winter and summer. Scenarios studied under A-76-1 (in addition to a 2008 base case) include Tier 1, Tier 2, California LEV III nationwide, and a zero-out of LDV emissions, all for a 2022 future year, with emphasis on four urban areas outside California. Additional scenarios were selected for A-76-2 and A-76-3 including extending the modeling time frame to 2030.

Current Status and Future Programs

Emissions from on-road motor vehicles in the U.S. have decreased over the past four decades even with dramatic increases in traffic volume. Highway vehicle VOC emissions were reduced by approximately 75% from 1970 to 2005, and PM and NOx emissions were reduced by over 50%, while total Vehicle Miles Traveled for highway vehicles increased more than twofold. These reductions have been due, in part, to the Federal Tier 0, Tier 1, and Tier 2 emission control programs.

ENVIRON was selected through a competitive bid process to conduct the initial study in this program using CAMx for air quality modeling. EPA approves the use of CAMx for numerous ozone and PM State Implementation Plans throughout the U.S, and they have used it to evaluate regional mitigation strategies. CAMx was also used recently by EPA in its Clean Air Transport rulemaking process.

The A-76-1 project was initiated in April 2011 and completed in January 2012. ENVIRON performed modeling for nominal periods of February and July in the Phase 1 study to represent a winter and summer month in the base year (2008) and in the future year (2022) scenarios. The geographic region of interest was the eastern United States with focus on the four urban areas discussed in EPA's Risk Assessment analysis. These areas were Atlanta, Detroit, Philadelphia, and St. Louis. The air quality modeling domain proposed was the regional planning office (RPO) unified continental U.S. (CONUS) domain with 36 km horizontal resolution with an inner-nested domain with 12 km resolution over the eastern U.S. A journal article was published by *Atmospheric Environment* and is also available on the CRC website.

An extension to A-76-1 designated A-76-2, "Effects of Light-Duty Vehicle Emissions on Ozone and PM with Past, Present, and Future Controls, Phase 2," further examined ozone and PM levels and benefits from existing emissions controls and other possible future controls. The Phase 2 effort included a data analysis component in addition to emissions and air quality modeling. Phase 2 comprised an analysis of Atlanta air quality based on National Emissions Inventory (NEI) adjustments using MOVES, new modeling scenarios of 100% Tier 0 for 2008 and 2022 on a 12 km grid using MOVES inputs, and reporting in the form of a CRC report and a journal article with all associated documentation. Project A-76-2 started in January 2012 and was completed in April 2013. The Final Report on Task 1 modeling of the effect of historic, current, and future controls on LDV emissions, ozone, and PM in the U.S. was published on the CRC website. ENVIRON also prepared a journal article on statistical analysis of trends in mobile emissions and air quality in Atlanta. The journal article on Task 2 statistical analysis was approved by *JAWMA* for publication. CRC has posted an open access link to article on the *JAWMA* website.

The committee elected to initiate the third phase (A-76-3) to extend the evaluation of the fleet more fully penetrated by LEV-III and will also identify source sectors with large contributions to future (2030) ambient ozone and PM in the US. The draft journal manuscript, "Emission Source Apportionment for Ozone and Particulate Matter in 2030," has been submitted to *Atmospheric Environment*.

CHEMISTRY OF TROPOSPHERIC OZONE GENERATION AND THE INFLUENCE OF TRACE GASES

CRC Project No. A-78

Leader: T. J. Wallington

Scope and Objective

CRC arranged contracts with Jack Calvert, John Orlando, Robert Stockwell, and Timothy Wallington to prepare a new manuscript to update and add to the Oxford University Press books previously published through committee sponsorship. The title of the new work is "Chemistry of Tropospheric Ozone Generation and the Influence of Trace Gases." The focus in the new manuscript proposal included:

Chapter I	Trace Gases in the Troposphere and the Chemistry of Their Interactions
Chapter II	Tropospheric Reactions of Ozone
Chapter III	Tropospheric Reactions of the Oxides of Nitrogen
Chapter IV	Tropospheric Reactions of OH Radicals with Hydrocarbons and Oxygenates
Chapter V	Tropospheric Reactions of Other Inorganic Trace Gases
Chapter VI	Photochemistry of the Oxygenates
Chapter VII	Effect of NOx, Hydrocarbons, and Other Trace gases on the Generation of Tropospheric Ozone

Current Status and Future Programs

The A-78 author team met in the first and second quarters of 2012 to refine the chapter outline above, develop details of the chapter contents, and make writing assignments. A third meeting of the writing group was held in September 2012. The Draft Final Report in the form of a manuscript was prepared and reviewed by the committee near the end of the second quarter of 2013. The final manuscript was approved by the Oxford University Press for publication. The publication contract with OUP has been approved by the authors and finalized with CRC. The new manuscript title is, "Ozone and Its Atmospheric Chemistry."

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SPECIATION OF EPACT TEST FLEET EXHAUST EMISSIONS

CRC Project No. A-80

Leader: R. S. MacArthur

Scope and Objective

The project objective is to obtain complete speciation exhaust emissions data for several average property gasolines selected by the CRC Emissions Committee as part of Project E-98 (see E-98 under Emissions Committee) and compare new speciation data results against data reported in EPA's SPECIATE4.3 database.

The project approach includes adding appropriate tasks to the Emissions Committee project to collect detailed intermediate ethanol blend speciation data. All testing was conducted using the same vehicle fleet used in the EPAct Fuel Effects Study for a direct comparison of results.

Current Status and Future Programs

The committee worked with the E-98 Project panel to select SwRI as the contractor to conduct this work. A contract was established to conduct both standard exhaust emissions testing and speciation analysis of the exhaust. The project was started in May 2012. The EPA test fleet was used to evaluate emissions performance of a "tie" fuel from the original study and two new "mid-point" fuels to assess model performance. Vehicle testing was completed and additional statistical analysis was conducted. The Final Report and the emissions database including speciation results are available on the CRC website.

SENSITIVITY OF ATMOSPHERIC CHEMICAL MECHANISMS TO MAJOR FEATURES

CRC Project No. A-83

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

Scope and Objective

Photochemical mechanisms are central to air quality modeling assessments for O_3 and particulate matter (PM) using Photochemical Grid Models (PGMs). PGM applications include impact assessments of Federal rules, State Implementation Plans, and long-range pollution transport assessments. CRC sponsored a series of books (Calvert et al., 2000, 2002, 2008, 2011, and 2013) to compile and disseminate chemical data for reactions, rate constants and products that are needed for mechanism development. Numerous citations provide evidence that the books are used in mechanism development. The value of the books would be increased further by using them in mechanism evaluation.

The objectives of this project are (1) to improve tools for analyzing how PGM predictions depend upon chemical mechanisms and their uncertainties, (2) identify important mechanistic uncertainties in chemical mechanisms of regulatory importance, and (3) use published data (e.g. the Calvert books) to determine whether uncertainties can be narrowed or new data are needed.

Current Status and Future Programs

Two methods for chemical mechanism evaluation are available in the most widely used PGMs, namely Process Analysis (PA) and the Decoupled Direct Method (DDM). PA gathers information about model processes (e.g., chemistry) during a model simulation and makes the data available for post-analysis (Jeffries and Tonnesen, 1994). CAMx (ENVIRON, 2012) includes a particular form of PA called Chemical Process Analysis (CPA) wherein the post-analysis is moved inside CAMx for convenience. DDM is a mathematical method for computing sensitivity of model outputs (e.g., concentrations) to perturbations in model inputs, such as emission rates, initial and boundary conditions, and reaction rate constants (Dunker, 1984).

The project includes use of DDM to study mechanism attributes of groups of reactions, e.g., radical generation (e.g., OH from isoprene at low NOx); NOx removal by organic nitrate formation; NOx removal by nighttime reactions; and N-recycling from organic nitrates to NOx. An example application is product yields for organic nitrates that currently are temperature-independent. If mechanism predictions are sensitive to organic nitrate yields, temperature effects may need to be considered.

Technical tasks for the project include:

- Task 1. Extend DDM in CAMx
- Task 2. Evaluate Stoichiometric Coefficient Sensitivities in a Box Model
- Task 3. Evaluate Stoichiometric Coefficient Sensitivities in 3-D Simulations
- Task 4. Final Report

A contract for Project A-83 was awarded to ENVIRON during the second quarter of 2013. ENVIRON authors completed the work and the draft manuscript was approved and submitted for publication as "Sensitivity of Atmospheric Models to Rate Terms with Complex Chemical Mechanisms." An executive summary of the work was also prepared for CRC and posted on the CRC website. Results that were too lengthy to include in the manuscript are provided as supplemental material to the manuscript. The draft manuscript was submitted for publication to *Atmospheric Environment* and is currently under review. Once released, CRC will post an open access link on the CRC website.

STUDY OF MOTOR VEHICLE EMISSION SIMULATOR (MOVES) FOR THE NATIONAL EMISSIONS INVENTORY

CRC Project No. A-84

Leaders: S. Collet
R. S. MacArthur

Scope and Objective

Properly evaluating state-submitted inputs for the 2011 National Emissions Inventory (NEI) on-road emissions inventory requires extensive knowledge of the MOVES (Motor Vehicle Emission System) input structure, the sensitivity of the model to changes in these inputs, the application of MOVES to produce the on-road portion of the inventory, and evolution of the on-road emissions methodology for the NEI. This is because the 2011 NEI will be the first to rely solely on MOVES for on-road vehicle emission estimates.

EPA has developed an approach for applying MOVES to generate NEI on-road inventories, using the SMOKE-MOVES air quality pre-processing tool and an approach which groups all 3,222 U.S. counties into approximately 100 "representative" counties, grouped by location specific attributes such as fuels, I/M program and vehicle age distribution. EPA is also continuing to transition to a more transparent data submittal process, with states being encouraged to submit inputs to be used by EPA to produce the NEI results. For the 2011 NEI, EPA has developed guidance for states to submit MOVES inputs through the MOVES County Data Manager (CDM), which provides a set structure for inputs to allow more ready comparison across states, and with MOVES defaults that the local data will be replacing. Knowledge of how this approach will influence data submissions, and the resulting impact on a MOVES-based emissions inventory, was critical to achieving the goals in A-84.

Current Status and Future Programs

Proposals were reviewed as part of a competitive solicitation process for CRC Project A-84 and a contract was awarded to ERG during the first quarter of 2013. The project began in the second quarter of 2013 when a final set of state submitted inputs became available to begin analysis. Because ERG was also supporting EPA in quality assuring the inputs, it was possible to get an early start on the data analysis.

ATMOSPHERIC IMPACTS

To accomplish CRC's objectives for this project ERG proposed to break the work into three tasks, plus a reporting task. Under Task 1, ERG compared MOVES input data submitted by the states for the 2011 NEI to current best practice, and performed in-depth comparisons of the submitted data across states and with separate MOVES defaults, to understand the magnitude of difference in the submissions and the implications on inventory estimates. Following from this, MOVES sensitivity runs to assess the impact the state submissions have on MOVES emissions, relative to default inputs, were performed in Task 2. Task 3 involved discussions of possible improvements to the state-submitted MOVES inputs based on recent advancements in activity data sources, including work underway by ERG to assist EPA in updating national defaults for MOVES. Task 4 was the reporting task which produced documentation as directed by the technical panel. ERG prepared a draft report with the results of Tasks 1-3 including evaluation of state data, MOVES sensitivity runs, and recommendations for improvement of state-submitted data.

ERG delivered electronic MOVES run specification files and MySQL input and output databases used for Task 2. The project concluded in December 2013 with submission of the Final Report to CRC. A draft manuscript on Task 1-2 efforts was accepted by the Transportation Research Board (TRB) and presented at the annual TRB meeting in January 2014. Both the Final Report and the TRB paper are available on the CRC website.

MODELING SENSITIVITY TO SPECIATION

CRC Project No. A-85

Leader: R. S. MacArthur

Scope and Objective

The overall goal of this project is to improve LDV ozone and PM characterization by evaluating the impact from changing speciation profiles to determine the magnitude of such changes on model results. The evaluation will examine both exhaust and evaporative emission profile impacts.

Photochemical air quality models must represent differences in reactivity between individual volatile organic compounds (VOCs). Condensed chemical mechanisms (e.g., CB05) use model species to represent the multitude of VOCs present in emissions. Some model species are explicit VOCs whereas others represent classes of VOCs. A "speciation profile" assigns total organic gas (TOG, which is VOC plus methane, ethane and acetone) emissions to model species. The TOG speciation profile influences photochemistry and consequently affects the predicted ozone concentrations. The speciation profile depends on the emissions source category and process and may be subject to considerable uncertainty and/or variability.

The CRC Atmospheric Impacts Committee funded measurements of hydrocarbon speciation in the exhaust emissions of vehicles fueled with gasoline without ethanol and with two levels of ethanol added in the CRC Emissions Committee Project E-98.

The specific objective of this project is to investigate the sensitivity of modeled ambient ozone concentrations to variability in vehicle exhaust TOG speciation in the E-98 data and the default EPA speciation profile used in a prior CRC study.

Current Status and Future Programs

Exhaust and evaporative VOC emissions differ in reactivity from fuel to fuel. The project will evaluate the relative importance of differences in speciation profile reactivity on the ability to accurately model ozone or particulate matter. Since air quality models require VOC inputs and speciation profiles to represent those VOCs, it is important to get an accurate speciation profile. The relative impacts from different VOC speciation profiles are not clear at this time. VOC speciation profiles appear to be less regarded during the model application process. Ad hoc research on the statewide level has probably been performed to investigate this, but widely distributed results are less abundant. Explicitly, VOC emissions factors for light-duty vehicle evaporative and exhaust emissions must be broken down into species for the air quality model chemistry to work appropriately because each species has a unique reactivity. There is a difference between the aggregate reactivity of exhaust VOC compared with the aggregate reactivity of evaporative VOC.

It was proposed that a SoCAB model application be examined where the mobile source speciation profiles' uncertainty is bracketed to investigate the magnitude of the change in ozone or PM. Various approaches describing uncertainty using statistical software packages are being explored. This project was awarded to ENVIRON in January 2014. ENVIRON received the CRC Project E-98 speciation data from SwRI.

ENVIRON completed Tasks 1 and 2. Two gasoline vehicle exhaust VOC speciation profiles compiled and selected in Task 1 (Fuel 2 Bag 1 (start) and Fuel 2 Bag 3 (hot start)) were assigned to SPECIATE database species ID and subsequently used as input to the speciation tool to create CB05 mechanism profiles. The SMOKE processor was applied to develop CAMx-ready on-road mobile emissions using the two new profiles. These mobile emissions were then combined with emissions from other source categories from a prior CRC study to prepare four sets of CAMx-ready emissions files for July 2030: two profiles, each for two domains (36 km and 12 km).

Task 3 modeling will be conducted next and a final report is scheduled for completion by January 2015.

LOW CARBON FUEL STANDARD PROGRAM AIR QUALITY

CRC Project No. A-86

Leaders: R. S. MacArthur

Scope and Objective

The California Air Resources Board (ARB/Board) approved the LCFS regulation in 2009 to reduce GHG emissions by achieving a ten percent reduction in the carbon intensity of transportation fuels used in California by 2020. ARB approved some amendments to the LCFS in December 2011, which became effective on November 26, 2012, and were implemented by ARB on January 1, 2013. ARB is expected to propose a comprehensive re-adoption of the LCFS regulation in the fall of 2014. ARB has provided two sets of staff reports on the effects of LCFS and will continue to conduct a series of public workshops in preparation for the re-adoption proposal.

Air quality benefits may accrue from LCFS regulation, but to date ARB has only provided its expectation of how emissions may be affected, where it is inferred, for example, that emissions reductions of some primary pollutants (e.g., sulfur dioxide and carbon monoxide) result in nearly proportional reductions in ambient concentrations. While precursor emissions (i.e., nitrogen oxides, volatile organic compounds) reductions do not always provide air quality benefits (i.e., NOx reductions can result in ozone increases—known as the NOx disbenefit), it is important to first understand potential emissions changes before evaluating air quality changes.

The project objective is to conduct a literature review that will include California Air Resources Board’s methods and results on the evaluation of the LCFS on air emissions and air quality and may also include other information on other approaches for assessing air quality under the LCFS scenarios that may be followed.

Current Status and Future Programs

Work began on this new project in June 2014. ENVIRON has reviewed the original ARB staff report and other recent public materials including information presented at ARB meetings concerning the LCFS. The draft final report was submitted to CRC in August 2014..

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INTERCOMPARISON AND EVALUATION OF COUPLED METEOROLOGY/CHEMISTRY MODELS OVER NORTH AMERICA AS PART OF PHASE 2 OF AQMEII

CRC Project No. A-87

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

Scope and Objective

The overall goal of the Air Quality Modeling Evaluation International Initiative (AQMEII) Phase 2 is to assess how well the current generation of coupled regional-scale air quality models can simulate the observed spatio-temporal variability in the optical and radiative characteristics of atmospheric aerosols and associated feedbacks among aerosols, radiation, clouds, and precipitation. Modeling is being conducted in the European and North American domains. This will help establish the state-of-the-science in regional-scale modeling using coupled modeling systems over North America.

Current Status and Future Programs

CRC continued participation in AQMEII Phase 2 with EPA and Joint Research Centre (JRC). ENVIRON was selected to assist in evaluating modeling results from AQMEII Phase 2 in conjunction with the overall analysis and assessment effort led by JRC. ENVIRON gathered the necessary data and began processing the data in coordination with other AQMEII participating groups.

ENVIRON submitted their draft final manuscript on the North American domain review to the committee. The manuscript was submitted in May 2014 for publication in a special AQMEII issue of *Atmospheric Environment* along with results from other Phase 2 program participants. An additional evaluation covering results from both the North American domain and the European domain is being conducted in preparation for a peer-review journal publication.

STATE SUPPORTED MOVES INPUTS IMPROVEMENTS

CRC Project No. A-88

Leaders: S. Collet
M. Janssen

Scope and Objective

The ultimate goal of this project is to provide to state and local air agencies and U.S. EPA more accurate input for the MOVES model. There are many parameters and many inputs for those parameters, but this project intends to focus its efforts on a limited number of parameters previous studies (see A-84) have identified as critical. To achieve the ultimate goal, this project is to provide improved data for the database of on-road mobile inputs used to create emissions for the 2011-amended National Emissions Inventory (NEI), with particular focus on obtaining default data following EPA best practices. The intent of the project is to provide improved default inputs that are state specific and reflect any known differences between various areas of the state. This can be provided either as county by county data, or data grouped by the existing county groups in the most recent version of NEI inputs or differences between urban and rural areas of the state. These inputs are especially important to provide data for states that do not provide inputs to EPA for the NEI.

Current Status and Future Programs

The project was awarded to ERG and work began in January 2014. The project panel was comprised of a wide range of state and regional air quality planning office (RPO) representatives along with members of EPA to provide additional oversight and technical input to the project. The Task 1 deliverables ("Evaluation of Data Sources for Improving NEI Inputs" and associated databases) were approved posted to the CRC website. Task 2 draft deliverables were completed and approved by the committee and an expanded Panel. The Task 2 effort included state-by-state details on vehicle age and population distributions. The project Panel also developed a method for estimating vehicle populations for vehicles over 30 years old where data were not already specified. The Task 2 deliverables also included detailed information on estimating long-haul truck vehicle miles travelled (VMT). A draft manuscript on

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has been prepared for submission to the Transportation Research Board (TRB). A CRC final report will also be posted to the CRC website.

USING UNCERTAIN REGIONAL AIR QUALITY MODEL OUTPUTS FOR OZONE SOURCE APPORTIONMENT

CRC Project No. A-89

Leaders: S. Collet
R. S. MacArthur

Scope and Objective

The objective of this project is to obtain modeling verification of ozone apportionment techniques from a long history of modeling runs. Techniques for estimating ozone response in photochemical models to changes in model emissions already exist (i.e., brute force, DDM and OSAT). These source apportionment experiments predict future changes in air quality at a particular location given changes to selected emission sources. Results from this type of experiment cannot be verified in the real-world because there is no corresponding set of observations. The proposed research will use an 18-year simulation study to cross-validate results, permitting quantitative assessment of model input uncertainties and their impact on apportionment results.

Current Status and Future Programs

This project was awarded to Porter-Gego and began in November 2013. Supporting Porter-Gego in this study are principle investigators from the AQMEII, S.T. Rao (EPA, retired) and Stefano Galmarini (JRC). The concept and preliminary modeling results were presented at the 9th International Conference on Air Quality – Science and Application in Garmisch-Partenkirchen, Germany, on March 24-28, 2014. Some preliminary results were also presented at the annual Atmospheric Impacts Committee meeting held on April 22, 2014. A manuscript based on the Garmisch presentation is close to completion. It will be submitted to *Atmospheric Environment* after review and approval by the committee.

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APPORTIONMENT OF OZONE ABOVE THE BACKGROUND CONCENTRATION TO EMISSION SOURCES

CRC Project No. A-90

Leaders: S. Collet
R. S. MacArthur

Scope and Objective

The objectives of this project are (1) to demonstrate a new source allocation method (Path Integral Method, "PIM") to an existing modeling data set and (2) to determine the contributions of light-duty vehicles (LDV's) and other major sources to anthropogenic ozone. A secondary objective is to display and place greater focus on the uncontrollable ozone background concentration.

Current Status and Future Programs

This project was awarded to Dr. Alan Dunker and ENVIRON; work began May 2014. Task 1 of the project, "Develop and Test the Numerical Procedure for Integrating the Sensitivity Coefficients," was initiated by developing and testing the numerical procedure. Task 2, "Apportion the Anthropogenic Ozone Increment for the Full Month of July" was also started. ENVIRON and Dr. Dunker are conducting the sensitivity simulations for the alternate integration paths and analyzing the impact on the PIM source contributions.

FUTURE MOBILE SOURCE EMISSION CONTROLS AND OZONE TRENDS IN THE SOUTH COAST AIR BASIN

CRC Project No. A-91

Leaders: S. Collet
T.A. French
R. S. MacArthur

Scope and Objective

The objective of this study is to assess and demonstrate an optimized approach for reducing mobile source NOx emissions in California's South Coast Air Basin that minimizes the potential increases in ozone levels that could result from a NOx-focused control strategy (i.e., NOx disbenefit).

Current Status and Future Programs

This project was awarded to Desert Research Institute (DRI) with funding co-sponsorship by the Truck and Engine Manufacturers Association (EMA). DRI will first assess and demonstrate the effects of lowering on-road NOx emissions on ambient ozone and PM2.5 levels in the California South Coast Air Basin (SoCAB) using a series of base and sensitivity air quality model simulations. All CMAQ-ready emissions and meteorological inputs will be obtained from the South Coast Air Quality Management District (SCAQMD) for the 2008 base year, 2023 and 2030. Appropriate adjustment factors will be applied to the mobile source NOx emissions in the future year inventories. Second, DRI will demonstrate the effect of concomitant adjustments in the mobile source hydrocarbon emissions that address potential underestimations indicated by the recent 2010 Van Nuys Tunnel Study (Fujita et al, 2012) and an updated reconciliation of ambient and emission inventory data.

Work began in January 2014. Task 1 Reconciliation of Ambient and Emission Inventory Data is near completion. Task 2, "CMAQ Modeling" and Task 3, "Box Model Calculations," are also underway.

ATMOSPHERIC IMPACTS

AIR TOXICS WORKSHOP

Project No. A-92

Leaders: S. Collet
E. McCauley

Scope and Objective

The objective of this workshop 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. The Atmospheric Impacts Committee, in conjunction with CARB, hosted the 2010 and 2013 CRC Mobile Source Air Toxics (MSAT) Workshop in Sacramento following the previous workshops held in Houston in 2002, Scottsdale in 2004, and Phoenix in 2006 and 2008. Each of these events brought together key government, academic and industry researchers, and stakeholders working in this area.

Current Status and Future Programs

Dr. Kent Hoekman was selected to support organization of the 2015 MSAT workshop with the aid of new organizing committee participants. Dr. Hoekman and the organizing committee are currently developing the technical program and identifying speakers. The 2015 Workshop will offer speakers an opportunity to have their paper published in a special MSAT issue of the *Journal of the Air & Waste Management Association (JAWMA)*. The new MSAT Workshop is scheduled to take place at CARB headquarters in Sacramento, CA on February 17-19, 2015.

NATURAL GAS FUEL SURVEY

Project No. PC-2-12

Leader: J. J. Jetter

Scope and Objective

The objective of this program was to gain an understanding of natural gas quality in the following locations along the distribution line:

- Large-scale transmission pipelines
- LDC pipelines (Local Distribution Company)
- Vehicle refueling nozzle at station

Resulting data can be used by others to (1) form a basis for the development of a Natural Gas Vehicle (NGV) fuel specification by a consensus organization such as ASTM, and (2) inform NGV developers regarding the range of natural gas fuel properties that can be expected in the U.S. market.

Specific Tasks included:

- Search for existing data and interpret results
- Preparation of equipment for sampling and analysis.
- Arrangements with CNG stations.
- Site visits and on-site analyses.
- Off-site sample analysis.
- Interpret and report results.

Current Status and Future Programs

This project was performed by SwRI. The American Gas Association (AGA) provided co-funding and technical participation. The final report was published to the CRC web site in June 2014.

PERFORMANCE

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 Program

<u>Gasoline Engine Intake Valve Deposit Testing</u>

ASTM D5500 is the test for certifying additives to protect against Intake Valve Deposits recognized by EPA. CARB has a separate test and there is also a private program Top Tier certification test. The CRC Gasoline Deposit Group is considering a re-evaluation of the test procedures. The ASTM standard was implemented in 1994. Since that time there have been changes in fuel properties, engine technologies, changes in ethanol usage rates, and new performance requirements. The composition of the fuel has changed and will change again in 2017 with Tier III with respect to sulfur content and possibly ethanol content. Refining changes have been made and crude oil content has shifted with more heavy and oil Syncrude being used. Changes in engine technology include hybrids, FFVs, DISI, turbo boost, downsizing, and VVT. The extent of ethanol use has also dramatically changed. The current engine test platforms, which include BMW 318i and Ford 2.3L (ASTM D6201), are now nearly obsolete. The certification fuel requirements are also not relevant to today's fuel composition.

The American Chemistry Council (ACC) is approaching EPA to get information on what can be done to address the situation. Determining lowest additive concentration (LAC) for the newer 150,000 mile certification requirements is a completely new situation. Today, the level requirements are not well known (overtreated, undertreated, tolerance, etc.) but there appears to be little or no field problems reported at the present time. However, representatives from the OEM's and additive companies pointed out that formation of excessive IVD is still a major potential problem. The ACC is interested in inviting CRC participation in a new program. CRC is an appropriate venue to develop a new test methodology.

CRC's role is to provide data on performance but does not recommend what limits or variables should be set for standards or regulatory performance.

PERFORMANCE

VOLATILITY

CRC Project No. CM-138

Leader: L. M. Gibbs

Scope and Objective

The objective of the CRC Volatility Group is to investigate the relationship between vehicle driveability performance and fuel volatility characteristics.

Current Status and Future Program

<u>2013 Intermediate Temperature E15 Cold-Start and Warmup Driveability Program</u>

The objective of this project was to determine an accurate ethanol offset for the Driveability Index equation in ASTM D4814, "Specification for Automotive Spark-Ignition Engine Fuel" including ethanol content of 15 volume percent.

The U.S. EPA has issued a partial waiver for ethanol blends containing up to 15 volume percent. The waiver only applies to 2001 and later model light-duty vehicles. It does not apply to heavy-duty vehicles, marine, motorcycles, and small engines. The current Driveability Index (DI) has an ethanol offset as a function of ethanol content, but is limited to a maximum ethanol content of 10 volume percent (E10). One issue in updating ASTM D4814 to make it applicable to 15 volume percent ethanol blends (E15) is to determine the ethanol offset for this higher ethanol concentration.

Hydrocarbon-only fuels and various concentrations of ethanol blends up to 20 volume percent having a range in DI (splash blends, matched DI to splash blends, and constant DI) were evaluated in a group of late-model fuel-injected (including direct injection) vehicles selected through a screening process to represent sensitive vehicles. The program was conducted at a test track test site. An ancillary program was conducted to evaluate the AVL-DRIVE™ System for automated driveability ratings, and will be reported separately.

Ethanol manufacturers' trade associations Growth Energy and Renewable Fuels Association (RFA) provided funding for this project. Testing was performed in February and March of 2013. The final report has been released as CRC Report No. 666.

2014 CRC Hot-Fuel Handling (HFH) Vehicle Driveability Program testing Maximum ASTM D4814 Volatility Class Gasoline Blends (Max. RVP, Min. T50, Min. TVL20)

The objective of this program is to evaluate HFH Vehicle Driveability Performance of a fleet of conventional test vehicles, MYs 1998 – 2014 using a summer through winter test fuel matrix that includes current D4814 volatility class maximums for Vapor Pressure limits, and Vapor Pressure limits plus 1 PSI, along with T50 and TVL20 parameters set to their minimums. The program includes 3 Vapor Pressure levels at each ambient test temperature window in order to assess potential non-linear driveability effects, evaluates E15 blends relative to E10 blends, and utilizes a variety of vehicle hardware content, fuel system designs, and model years.

Recent CRC Performance Committee reports (No. 658 and 659) detail the effects of D4814 Class D and E gasoline T50, TVL20, and ethanol content effects on vehicle hot-fuel handling (HFH) driveability, both at Sea Level and Altitude. To further understand volatility effects on modern vehicle HFH performance for all D4814 volatility classes, this study has set the VP (DVPE) parameter of a series of carefully designed test fuels to its maximum limit, while simultaneously setting the blend's T50 and TVL20 parameters to their minimum D4814 limits or lower. All other test fuel parameters are being held as constant as reasonably possibly from blend to blend and consistent with the U.S. gasoline market. This program will account for all volatility classes (AA through E) and will investigate potential non-linear effects in each temperature range.

Testing began in late March 2014 and will be completed in August 2014 with data analysis and reporting to follow. Flint Hills Resources is co-sponsoring this field study.

2012 Risk Analysis/Hazard Assessment of High Ethanol Content Fuels at the Service Station

The objective of this project was to determine the incremental change in risk due to a change in fuel composition for transport delivery and customer refueling with higher levels of ethanol fuels.

The benchmark was the currently accepted public safety level of the terminal blender making an E10 blend (10 vol % ethanol blended into a base gasoline where the resulting vapor pressure is appropriate for the season and geographic location). The analysis included the tanker truck driver loading/blending/delivering higher ethanol blends such as E51, E83, and E98 and, ultimately the consumer dispensing E10 compared to these higher ethanol blends into personal vehicles at self-serve refueling stations. The U. S. Department of Energy supports efforts to increase the use of ethanol-rich transportation fuels such as “E85.” The Renewable Fuel Standards requirements to vastly increase the amount of ethanol containing fuels into the marketplace will rapidly increase the opportunity for these fuels to be present in the marketplace. A risk analysis/hazard assessment is required to fully judge the safety implications, if any, of the introduction of these new fuel blends into the hands of the public.

The subcontractor was engaged to survey the literature to determine what gasoline-ethanol blends can create a flammable mixture in the vapor space above the liquid in a tank. The subcontractor worked with the Risk Assessment/Hazard Analysis (RA/HA) team to define possible fuel delivery, service station storage, and retail dispensing accident scenarios, and then narrow the choices to approximately six for further analysis by covering a range of possibilities. A consequence vs. frequency risk matrix was developed to facilitate a semi-quantitative risk analysis. The analysis can be used to determine the adequacy of existing safeguards on current fuel handling/dispensing systems.

This analysis did not consider materials compatibility per se, unless directly related to a failure mode that would cause or allow a spark of sufficient energy to enter the headspace above ethanol gasoline blends. Toxicity and environmental impacts such as groundwater or air quality were also not considered.

AcuTech performed this project. NREL provided co-funding. The final report has been posted on the CRC web site.

OCTANE

CRC Project No. CM-137

Leader: J. J. Simnick

Scope and Objective

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

Current Status and Future Program

Literature Review of Octane Number versus Engine/Vehicle Performance

The objective of this program is to conduct a broad literature review of public and private reports and to interview knowledgeable experts to identify the potential benefits of octane number on improved engine efficiency. A competitive solicitation by CRC resulted in selection of HD-Systems to conduct the study under CRC Project No. CM-137-11-1. Funding was also supplemented by USCAR. Literature sources from the previous 20 years were evaluated to develop a searchable database to identify currently known relationships and to identify potential gaps in our current understanding.

The project started in June 2011 and focused on liquid gasoline fuels (primarily hydrocarbon and ethanol-containing fuels) and on hardware that is currently in-use or may be in use in the near future. The Task 1 Final Report and the Tasks 2-5 Final Report have been released on the CRC website in December 2011 and September 2012, respectively.

Development of a work plan for future Octane work is ongoing, through coordination with related projects in the Emissions and AVFL Committees.

Advanced Fuel And Engine Efficiency Workshop

The Octane Group of the Performance Committee worked with the AVFL Committee to organize an international workshop held in Baltimore, MD February 25-26, 2014. The workshop was designed to address advanced fuels and methods for improving engine efficiency, focusing on light-duty engine technology and associated fuel effects, and included discussion of octane research (past and potential for the future).

PERFORMANCE

The workshop was co-sponsored by DOE and API with in-kind support contributed by MIT. This was the first workshop to be conducted by CRC on this topic. Proceedings of the workshop were published on the CRC website.

Sub-Regular Grade (85 AKI) Octane Study (See also E-108)

In coordination with the Emissions Committee, this study is evaluating vehicle performance and emissions effects of an 85 AKI gasoline relative to an 87 AKI gasoline at two altitudes. Results from this study will provide relevant data to ASTM and NCWM discussions regarding minimum AKI values in different US geographical regions. Data analysis for this project is ongoing, with reporting expected in late 2014.

DIESEL PERFORMANCE GROUP

CRC Project No. DP

Leader: M. Nikanjam

Scope and Objective

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 International 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:

- Low Temperature Operability
- Cetane Number
- Biodiesel
- Deposit
- Fuel Cleanliness
- Corrosion

Biodiesel/Low Temperature Operability

A joint Biodiesel/Low Temperature Operability Panel program on "The Effect of Wax Settling and Biodiesel Impurities on Low Temperature Light-Duty Diesel Performance" is in progress. The program objective is to determine if newer fuel blending streams (FT, HVO, severely hydro-processed, etc.) and/or Biodiesel impurities impact vehicle low temperature operability performance during extended periods of non-operation of LD diesel vehicles. Weekend shut-down is an example of extended non-operation. Conventional diesel, B5, and B20, as well as cold flow additives are being evaluated. The program is being run in two phases. Phase 1 is laboratory bench testing to simulate weekend cool-down and warmup cycles to determine visually and through standard cold flow laboratory testing if this has a significant impact on estimated vehicle performance as measured by Cloud Point, Pour Point, Cold Filter Plugging Point (CFPP), Simulated Filter Plugging Point (SFPP), and Low Temperature Flow Test (LTFT). Fuels include blend components representing: Biodiesel, Gas-to-Liquids (GTL), Biomass-to-Liquids

(BTL)/ Hydro-treated Vegetable Oil (HVO), Hydro-cracked and severely Hydro-processed streams. This laboratory phase has been completed. The draft report is in development.

Phase 2 duplicated the laboratory experience in LD vehicles to verify any issues identified in the laboratory test work. Similar fuels were used. Tests were performed with simulated overnight and weekend heating/cooling cycles to compare results.

Mahle-Behr conducted the Phase 2 testing, which is now complete. Data analysis is ongoing, with a report release expected in late 2014.

Cetane Number Program

The initial objective of this panel was to determine the limit of acceptable operation of North American light-duty diesel vehicles as a function of temperature and fuel cetane number quality.

Following a previous CRC AVFL project, this panel had outlined a larger North American program to test appropriate vehicles at lower operating temperatures with a more statistical approach. A lower-cost scoping study was discussed later 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.

In addition to startability and performance at low temperature, the group decided to broaden the objective to include:

- Power
- Driveability/noise
- Fuel economy
- Emissions (scope is outside Performance Committee)

The panel proposed a simple scoping program as follows:

- Three US LDD vehicles
- Three fuels:
    - -20°F cloud point with a 40 cetane number
    - Above fuel additized with cetane number improve to reach a 50 cetane number
    - A fuel with a natural cetane number of 45.

- Combined cycles to evaluate startability and low temperature driveability.
- CEC M-11-T-91 cold weather start ability
- Based on time to start, time for engine speed rise, number of start attempts, number of stalls, idle speed
- CEC M-08-T-83 cold weather driveability
- Evaluate malfunctions over a 104-second driving cycle repeated 12 times
- Ambient and one low temperature, preferably -30°F.

Details of the work plan are currently in development.

Diesel Deposits

This panel had three sub-panels to address the current issue of internal injector sticking reported in a number of common rail systems in certain geographic locations in the U.S. The sub-panels were as follows:

1. Data Analysis and Recommendations
2. Bench/Rig/Engine Investigation; Na-Soap Deposits
3. Engine Investigation

The data analysis sub-panel's goal was to:

- Consolidate existing data on suspected causes
- Identify consistencies and inconsistencies in available literature
- Provide conclusions based on "highly likely," "likely," "possible," "unlikely"

Internal diesel injector deposits were categorized as metal soap, amide lacquer, and carbonaceous. Metal-soap deposit is the more significant issue currently in the U.S. HD application. It also is a concern globally and in LD applications. The data analysis sub-panel prepared CRC Report No. 665, "Internal Diesel Injector Deposits," for CRC Project DP-04-13a, which was released on the CRC website in October 2013.

Sub-panel 2 was charged with identifying or developing a laboratory bench top or test rig for evaluating fuel's tendency to cause internal injector deposits as well as additives effectiveness to avoid such deposit formation.

PERFORMANCE

An initial scoping study consisted of a program to conduct a limited screening program using two in-house tests to determine if fuels which are expected to cause internal injector deposits can be differentiated from those that are not expected to form such deposits.

Seven fuels were tested to cover a range of applications and deposit forming tendencies. Fuels included EPA ULSD deposit-forming and EPA ULSD non deposit- forming diesels, CARB diesel assumed not to form deposits, and an EPA ULSD diesel that was formulated to cause deposits.

Unfortunately results from this scoping study did not confirm that either one of these rigs, in their present state, could discriminate among deposit forming or not deposit forming fuels. The Diesel Performance Group released a final report for CRC Project DP-04, "Scoping Study to Evaluate Two Rig Tests for Internal Injector Sticking," on the CRC website in July 2012.

Sub-panel 2 planned and evaluated a new rig offered by Delphi UK. Tests were conducted in the later part of 2012. Results were more encouraging. Details of the Delphi rig evaluation were reviewed in late March 2013. The final report CRC-DP-04-13b, "Internal Injector Deposits: A Scoping Study to Evaluate the Delphi Test Rig," was published on the CRC website in August 2013.

The ultimate goal of this effort is to establish an industry-standard tool that can evaluate and discriminate among fuels and additives for diesel injector fouling. One approach is the use of an engine on a test stand, similar to what is being pursued in Europe by the CEC. The CRC panel is following that progress but hopes to establish a simpler and quicker test rig such as the Delphi Rig evaluated recently. A program has been funded to correlate this rig with actual engine performance with in-kind funding by the EMA. This program is scheduled to begin later in 2014.

With the accomplishment of the task by the Data Analysis Panel and combination of the rig and engine evaluation, the panel will continue as one group without subpanels. The Diesel Deposit panel held a meeting in February 2014 to plan a test program, DP-04-14, "Internal Diesel Injector Deposit Evaluation Rig / Engine Correlation." Testing for this project is in process, with analysis and reporting to follow.

Fuel Cleanliness

Based on the recommendation by the Diesel Performance Group that diesel fuel cleanliness has become a more important issue for newer injection equipment, this panel has become more active.

The objective of this panel is to address, investigate, and provide information for general housekeeping and other issues for diesel fuel. The focus is fuel cleanliness and fuel properties that are outside the defined fuel properties in existing CRC DPG panels. These fuel cleanliness properties should have relevance from the point of diesel production to the point of customer use.

The initial goal is to generate a single CRC guide to compile best available current knowledge and practice regarding cleanliness of diesel fuel. The proposed CRC document will have the following outline:

1. Introduction / background
2. Scope /what is the supply chain/storage system
3. Types, sizes, and sources of contamination
4. Microbial growth
5. Corrosion and corrosion products
6. Filters and filtration
7. Additives
8. Storage tank design
9. Housekeeping guidelines

Experts in each area are working within this panel to provide technical details.
The draft report CRC 667 "Diesel Fuel Storage and Guide" has been reviewed by the Diesel Performance Group, and is being revised in preparation for ballot by the Performance Committee.

Corrosion

The Corrosion Panel was recently formed under the DPG, and held an inaugural meeting in Houston, TX in February 2014.

Severe and rapid corrosion has been observed in some retail systems storing and dispensing ultra-low sulfur diesel (ULSD) since 2007. In addition, the corrosion is coating the majority of metallic equipment in both the wetted and un-wetted portions of some ULSD underground storage tanks (USTs). To investigate this issue, multiple stakeholders in the diesel, vehicle, regulatory, and truck stop industries, through the Clean Diesel Fuel Alliance, sponsored a research study by Battelle Memorial Institute (hereafter termed "Battelle study").

The objective of the CRC effort is to field test clean sites containing fiberglass UST systems following the same test procedures (fuel, vapor, water, scrapings, etc.) that were used in the Battelle study of contaminated sites. The results from this effort will be directly compared directly with those from the Battelle study to determine differences. They also will be used (as part of a subsequent effort) to facilitate development of an appropriate laboratory bench test that replicates the processes and factors determining the corrosion observed in the field.

The panel developed a protocol for selecting sites with ULSD systems determined to have severe corrosion. This was posted to the CRC web site and is expected to inform EPA and others in their current research on this topic.

PART THREE

RELEASED REPORTS

RELEASED REPORTS - 2014

AIR POLLUTION & ADVANCED TECHNOLOGY*

CRC Project No.	Title	Publication/NTIS Accession No.
ACES Phase 2	The Advanced Collaborative Emissions Study	PB2014-103456
A-74/E-96 Phase 1-3	Linking Tailpipe to Ambient	PB2014-106319
	Gas- and Particle-Phase Primary Emissions from In-Use, On-Road Gasoline and Diesel Vehicles	*Atmospheric Environment* Vol. 88, (2014) p. 247-260
	Secondary Organic Aerosol Formation Exceeds Primary Particulate Matter Emissions for Light-Duty Gasoline Vehicles	*Atmospheric Chemistry and Physics* Vol. 14, (2014) p. 4661–4678
	Secondary Organic Aerosol Production from Diesel Vehicle Exhaust: Impact of Aftertreatment, Fuel Chemistry and Driving Cycle	*Atmospheric Chemistry and Physics* Vol. 14, (2014) p. 4643–4659
	Primary Gas- and Particle-Phase Emissions and Secondary Organic Aerosol Production from Gasoline and Diesel Off-Road Engines	*Environmental Science & Technology* Vol. 47, Issue 24 (2013) p. 14137–14146
	Primary to Secondary Organic Aerosol: Evolution of Organic Emissions from Mobile Combustion Sources	*Atmospheric Chemistry and Physics* Vol. 14 (2014) p. 5015-5036
	Gas-Particle Partitioning of Primary Organic Aerosol Emissions: (1) Gasoline Vehicle Exhaust	*Atmospheric Environment* Vol. 77 (2013) p. 128-139

	Gas-Particle Partitioning of Primary Organic Aerosol Emissions: (2) Diesel Vehicles	*Environmental Science & Technology* Vol. 47, Issue 15 (2013) p. 8288–8296
A-76-2	Trends in On-Road Vehicle Emissions and Ambient Air Quality in Atlanta, Georgia, USA, from the Late 1990s Through 2009	*Journal of the Air & Waste Management Association* Vol. 64, (2014) p. 808-816
A-76-3	Emission Source Apportionment for Ozone and Particulate Matter in 2030	*Atmospheric Environment* (in review)
A-83	Sensitivity of Atmospheric Models to Rate Terms within Complex Chemical Mechanisms, Executive Summary	NTIS pending
	Sensitivity of Atmospheric Models to Rate Terms within Complex Chemical Mechanisms	*Atmospheric Environment* Vol. 98, (2014) p.224-230
A-84	Study of MOVES Information for the National Emission Inventory	PB2014-103457
	Evaluation and Sensitivity Analysis of MOVES Input Data Submitted for the 2011 National Emissions Inventory	*Transportation and Air Quality* TRB Paper Number: 14-2989
A-88	Evaluation of Data Sources for Improving NEI Inputs: CRC A-88 Task 1	PB2014-106358
	CRC A-88 Task 2: Age Distribution and Vehicle Population	NTIS Pending
A-89	Using Uncertain Regional Air Quality Model Outputs for Ozone Source Apportionment	9th International Conference on Air Quality - Science and Application
AVFL-22	Proceedings of the 2014 CRC Advanced Fuel and Engine Efficency Workshop, Baltimore, MD, February 24-26, 2014	CRC Website
AVFL-24	FACE Gasolines and Blends with Ethanol: Detailed Characterization of Physical and Chemical Properties	PB2014-108844

FACE	Detailed Hydrocarbon Analysis of FACE Diesel Fuels Using Comprehensive Two-Dimensional Gas Chromatography	Natural Resources Canada, CanmetENERGY–Devon
E-88-3	Study of Transportation Fuel Life Cycle Analsis: Review of Economic Models Used to Assess Land Use Effects	PB2014-108862
E-90-2b	Effects of Ethanol Blends on OBDII Systems of In-Use Vehicles	PB2014-100563
E-94-1	Evaluation and Investigation of Gaseous and Particulate Emissions on SIDI In-Use Vehicles with Higher Ethanol Blend Fuels	PB2014-106342
E-95-2	Blender Pump Fuel Survey	NREL TP-5400-60627
E-97	Summary of Research on the Use of Intermediate Ethanol Blends in On-Road Vehicles	*Energy & Fuels* Vol. 28, Issue 5 (2014) p. 3236–3247
E-98/A-80	Exhaust Emissions of Average Fuel Composition	PB2014-106374
E-102	Transportation Fuel Life Cycle Assessment: Validation and Uncertainty of Well-to-Wheel GHG Estimates	PB2014-101433
E-103	Evaluation of N_20 Measurement Instruments with Light-Duty Vehicles	NTIS Pending
E-106	On-Road Remote Sensing of Automobile Emissions in the Tulsa Area: Fall 2013	NTIS Pending
23rd RWE Workshop	Highlights from the Coordinating Research Council 23rd Real World Emissions Workshop	*em Magazine* (August 2013) p. 24-28
2013 LCA Workshop	CRC Workshop on Life Cycle Analysis of Transportation Fuels Summary Report Argonne National Laboratory October 15-17, 2013	CRC Website

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

RELEASED REPORTS - 2014

AVIATION & PERFORMANCE**

CRC Project No.	Title	Publication/NTIS Accession No.
AV-16-11	Studies of Scanning Brookfield Viscometry as a Replacement for Freezing Point in Aviation Fuel Specifications	PB2014-100620
CRC Report No. 663	Aviation Fuel Properties Handbook	CRC Fourth Edition (2014)
CM-138-11-3 CRC Report No. 666	2013 CRC Intermediate-Temperature E15 Cold-Start and Warm-Up Vehicle Driveability Program	PB2014-106295
CM-138-12-1	A Risk Analysis/Hazard Assessment of High Ethanol Content Fuels at Service Stations	PB2014-108845
DP-04-13a CRC Report No. 665	Internal Diesel Injector Deposits	PB2014-100562
DP-04-13b	Internal Injector Deposits: A Scoping Study to Evaluate the Delphi Test Rig	PB2014-100536
DP-07-13	ULSD Corrosion Study Screening Criteria for Site Selection	NTIS pending
PC-2-12	Natural Gas Vehicle Fuel Survey	PB2014-106373

**The primary source for CRC Performance and Aviation reports is:

National Technical Information Service, U.S. Department of Commerce
5285 Port Royal Road, Springfield, VA 22161
www.ntis.gov Phone: 800-553-6847

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

PART FOUR

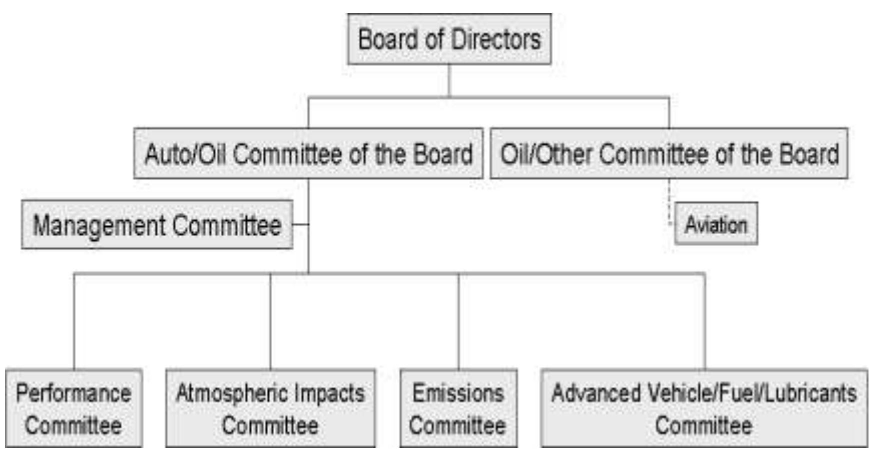
ORGANIZATION AND MEMBERSHIP

ORGANIZATION – 2014

The sustaining members of the CRC are the American Petroleum Institute (API) and a consortium of automobile manufacturers (Chrysler, Daimler, Ford, General Motors, Honda, Mitsubishi, Nissan, Toyota, and Volkswagen). For over 72 years, CRC has provided the means for the automotive and petroleum industries to study problems of mutual interest. CRC's objective, as stated in our charter, is:

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

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



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

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

CRC is not involved in regulation, hardware or fuel development, nor in setting standards. CRC has only one real mandate, and that is to add to the scientific base that may be useful in technology coordination and appropriate regulation. CRC information is made publicly available and is used by industry to help 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 made publicly available through written technical publications.

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. Reports that document the results of the study are made publicly available through written technical publications.

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

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

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D.M.DiCicco	Ford Motor Co.	D. Patterson	Mitsubishi Mtrs. R&D Am.
K. D. Eng	Shell Global Solutions	K. D. Rose	ExxonMobil
M. Foster	BP	J. Y. Sigelko	Volkswagen of America
G. C. Gunter	Phillips 66	M. Valentine	Toyota Tech. Ctr. N.A.
A. Iqbal	Chrysler	L. Webster	Nissan Tech. Ctr. N.A.
J. J. Jetter	Honda R&D Am.	W. Woebkenberg	Daimler
S. McConnell	Marathon Petroleum Co.		

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J. T. Bays	PNNL	C. J. Mueller	SNL
D. M. DiCicco	Ford Motor Co.	W. J. Pitz	LLNL
C. Fairbridge	CanmetENERGY	M. Ratcliff	NREL
M. Foster	BP	K. D. Rose	ExxonMobil
S. Goldsborough	ANL	J. Y. Sigelko	Volkswagen of America
G. C. Gunter	Phillips 66	C. S. Sluder	ORNL
A. Iqbal	Chrysler	M. Valentine	Toyota Tech. Ctr. N.A.
N. Killingsworth	LLNL	M. B. Viola	General Motors
D. H. Lax	API	L. Webster	Nissan Tech. Ctr. N.A .
W. R. Leppard	Consultant	W.Woebkenberg	Daimler
R. P. Lewis	Marathon Petroleum Co.	B. Zigler	NREL
J. Luecke	NREL		
S. McConnell	Marathon Petroleum Co.		

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S. I. Johnson	Volkswagen of America	A. Willis	General Motors
C. Jones	General Motors	W. Woebkenberg	Daimler

AVFL-17b PANEL

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K. D. Eng	Shell Global Solutions	K. D. Rose	ExxonMobil
A. Iqbal	Chrysler	S. Y. Sigelko	Volkswagen of America
D. H. Lax	API	M. Valentine	Toyota Tech. Ctr. N.A.
R. P. Lewis	Marathon Petroleum Co.	W. Woebkenberg	Daimler

AVFL-17c PANEL

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G. C. Gunter, Co-Ldr.	Phillips 66

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W. J. Cannella	Chevron Energy Tech.	K. D. Rose	ExxonMobil
S. Howell	National Biodiesel Bd.	T. Smagala	Chevron Global Dnstrm
S.W.Jorgensen	General Motors		

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AVFL-18a PANEL

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T. J. Bruno	NIST	S. McConnell	Marathon Petroleum Co.
H. Dettman	CanmetENERGY	W. J. Pitz	LLNL
R. Gieleciak	CanmetENERGY	M. Ratcliff	NREL
M. Huber	NIST	K. D. Rose	ExxonMobil
M. Kweon	U.S. Army Research Lab		

AVFL-19a PANEL

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R. L. McCormick, Co-Ldr.	NREL

J. T. Bays	PNNL	N. Killingsworth	LLNL
W. J. Cannella	Chevron Energy Tech.	K. D. Rose	ExxonMobil
C. Fairbridge	CanmetENERGY	J. Y. Sigelko	Volkswagen of America
G. C. Gunter	Phillips 66	M. Valentine	Toyota Tech. Ctr. N.A.

AVFL-20 PANEL

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W. J. Cannella, Co-Ldr.	Chevron Energy Technology

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K. Eng	Shell Global Solutions	J. Paul	Ford Motor Co.
M. Foster	BP	K. D. Rose	ExxonMobil
R. George	BP	J. Y. Sigelko	Volkswagen of America
G. C. Gunter	Phillips 66	J. J. Simnick	BP
R. Hardy	Flint Hill Resources	C. S. Sluder	ORNL
S. W. Jorgensen	General Motors	M. Valentine	Toyota Tech. Ctr. N.A.
D. H. Lax	API	R. Wagner	ORNL
T. Leone	Ford Motor Co.	L. Webster	Nissan Tech. Ctr. N.A.
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S. McConnell	Marathon Petroleum Co.		

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AVFL-22 PANEL

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K. Eng	Shell Global Solutions	J. Paul	Ford Motor Co.
M. Foster	BP	J. Y. Sigelko	Volkswagen of America
G. C. Gunter	Phillips 66	J. J. Simnick	BP
A. Iqbal	Chrysler	L. Webster	Nissan Tech. Ctr. N.A.
S. W. Jorgensen	General Motors	W. Woebkenberg	Daimler
D. H. Lax	API		

AVFL-23 PANEL

W. J. Cannella, Co-Ldr.	Chevron Energy Technology
C. Fairbridge, Co-Ldr.	Canmet ENERGY

J. T. Bays	PNNL	C. J. Mueller	SNL
R. Gieleciak	CanmetENERGY	K. D. Rose	ExxonMobil
N. Killingsworth	LLNL		

AVFL-26 PANEL

M. B. Viola, Ldr.	General Motors

W. J. Cannella	Chevron Energy Tech.	R. P. Lewis	Marathon Petroleum Co.
D. M. DiCicco	Ford Motor Co.	S. McConnell	Marathon Petroleum Co.
K. D. Eng	Shell Global Solutions	D. Patterson	Mitsubishi Mtrs. R&D Am.
M. Foster	BP	K. D. Rose	ExxonMobil
G. C. Gunter	Phillips 66	J. J. Simnick	BP
A. Iqbal	Chrysler	C. S. Sluder	ORNL
J. J. Jetter	Honda R&D Am.	M. Valentine	Toyota Tech. Ctr. N.A.
S. I. Johnson	Volkswagen of America	L. Webster	Nissan Tech. Ctr. N.A.
S.W.Jorgensen	General Motors	W.Woebkenberg	Daimler

EMISSIONS COMMITTEE

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M. Valentine, Co-Chair	Toyota Tech. Ctr. N.A.

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K. D. Eng	Shell Global Solutions	R. S. Monroe	Chrysler
R. George	BP	D. Patterson	Mitsubishi Motors R&D Am.
P. L. Heirigs	Chevron	D. Z. Short	Marathon Petroleum Co.
J. J. Jetter	Honda R&D Am.	M. B. Viola	General Motors
S. I. Johnson	Volkswagen of America	W. Woebkenberg	Daimler
F. Khan	Nissan Tech. Ctr. NA		

E-94 PANEL

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D. M. DiCicco	Ford Motor Co.	R. P. Lewis	Marathon Petroleum Co.
K. D. Eng	Shell Global Solutions	R. S. Monroe	Chrysler
R. George	BP	D. Patterson	Mitsubishi Mtrs R&D Am.
P. L. Heirigs	Chevron Global Dnstrm	K. D. Rose	ExxonMobil
J. J. Jetter	Honda R&D Am.	D. Z. Short	Marathon Petroleum Co.
C. Jones	General Motors	J. Y. Sigelko	Volkswagen of America
F. Khan	Nissan Tech. Ctr.N.A.	M. Valentine	Toyota Tech. Ctr. N.A.
		W. Woebkenberg	Daimler

E-97 PANEL

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W. J. Cannella	Chevron Energy Tech.	D. H. Lax	API
D. M. DiCicco	Ford Motor Co.	R. P. Lewis	Marathon Petroleum Co.
G. C. Gunter	Phillips 66	K. D. Rose	ExxonMobil
J. Horn	Chevron	J. J. Simnick	BP
J. J. Jetter	Honda R&D Am.	M. Valentine	Toyota Tech. Ctr. N.A.
C. Jones	General Motors	L. Webster	Nissan Tech. Ctr. NA

MEMBERSHIP

E-108 PANEL

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		J. Y. Sigelko	Volkswagen of America
R. George	BP	J. J. Simnick	BP
J. Horn	Chevron	W. Studzinski	General Motors
A. Iqbal	Chrysler	M. Valentine	Toyota Tech. Ctr. N.A.
D. H. Lax	API	M. Winston-Galant	General Motors

E-109 PANEL

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W. Studzinski, Ldr. — General Motors

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S. I. Johnson	Volkswagen of America	N. Simon	Chrysler
D. H. Lax	API	M. Valentine	Toyota Tech. Ctr. N.A.
R. P. Lewis	Marathon Petroleum Co.	M. B. Viola	General Motors
S. A. Mason	Phillips 66	T. Wallner	ANL
M. Nikanjam	Chevron Products Co.		

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R. Giannelli	US EPA
C. Hart	US EPA
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K. Helmer	US EPA
H. Hogo	SCAQMD
J. J. Jetter	Honda R&D Am.
F. Khan	Nissan Tech. Ctr. NA
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D. H. Lax	API
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T. R. Long	US EPA
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R. Nankee	Chrysler
R. Nine	DOE/NETL
M. Olechiw	US EPA
F. Parsinejad	Chevron Oronite
D. Patterson	Mitsubishi Mtrs R&D Am.
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D. Z. Short	Marathon Petroleum
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M. R. Smith	US EPA
D. Sonntag	US EPA
M. Spears	US EPA
M. Thornton	NREL
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L. Webster	Nissan Tech. Ctr. NA
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R. P. Lewis	Marathon Petroleum Co.		

E-99 PANEL

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M. M. Maricq, Co-Chair — Ford Motor Co.

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R. R. Graze	Consultant	D. B. Nagy	General Motors
G. C. Gunter	Phillips 66	K. D. Rose	ExxonMobil
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H. Hogo	SCAQMD	M. K. Yassine	Chrysler

E-103 PANEL

S. A. Shimpi, Ldr. — Cummins, Inc.

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D. M. DiCicco	Ford Motor Co.	D. B. Nagy	General Motors
D. H. Lax	API	J. Y. Sigelko	Volkswagen of America
R. P. Lewis	Marathon Petroleum Co.		

MEMBERSHIP

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S. Collet, Co-Chair	Toyota Technical Ctr. N.A.

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C. Jones	General Motors
S. McConnell	Marathon Petroleum Co.
S. A. Mason	Phillips 66
D. Patterson	Mitsubishi Mtrs. R&D Am.
B. Postel	BP America
K. D. Rose	ExxonMobil
J. Y. Sigelko	Volkswagen of America
N. L. Simon	Chrysler
T. J. Wallington	Ford Motor Co.
L. Webster	Nissan Tech. Ctr. NA

ATMOSPHERIC IMPACTS WORKING GROUP

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A-74/E-96 PANEL

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T. J. Wallington, Ldr	Ford Motor Co.

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N. J. Barsic	John Deere	P. L. Heirigs	Chevron Global Downstream
D. M. DiCicco	Ford Motor Co.	R. P. Lewis	Marathon Petroleum Co.
T. A. French	EMA	S. McConnell	Marathon Petroleum Co.
R. Giannelli	US EPA	S. A. Mason	Phillips 66

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A-83 PANEL

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		G. Tonnesen	US EPA
D. Luecken	US EPA		

A-84 PANEL

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J. DaMassa	CARB	E. K. Nam	US EPA
L. Driver	US EPA	R. Sawyer	U. of CA Berkeley
M. L. Gupta	FAA	C. Takemoto	CARB
M. Houyoux	US EPA	M. I. Watkins	ExxonMobil
M. Janssen	LADCO	S. Zelinka	CARB
R. P. Lewis	Marathon Petroleum Co.	A. Zubrow	US EPA
R. S. MacArthur	Chevron Products Co.		

MEMBERSHIP

A-88 PANEL

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D. Brzezinski	US EPA
A. Dick	Nescaum
G. Dolce	US EPA
L. Driver	US EPA
A. Eyth	US EPA
J. W. Havens	OTC
J. Hornback	Metro 4/SESARM
M. Houyoux	US EPA
J. Jakuta	OTC
R. Kaleel	LADCO
S.L. Jin	VA Dept. of Environment Quality
R. S. MacArthur	Chevron Products Co.
J. McDill	MARAMA
E. Nam	US EPA
N. O'Neil	MO Dept. of Natural Resources
T. Pella	CenSARA
W. Richer	OR Dept. of Environmental Quality
M. Solomon	Nescaum
S. Summers	WA State Dept. of Ecology
D. Wells	CO Dept. of Public Health & Environment
S. Wierman	MARAMA
A. Zubrow	US EPA

A-80/E-98 PANEL

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J. Rutherford, Ldr.	Chevron Global Downstream
M. Valentine, Ldr.	Toyota Tech. Ctr. N.A.

K. D. Eng	Shell Global Solutions
R. George	BP
D. H. Lax	API
R. P. Lewis	Marathon Petroleum Co.

2015 MSAT ORGANIZING COMMITTEE

(Project No. A-92)

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E. McCauley, Co-Chair	CARB

J. Collins	CARB
S. K. Hoekman	DRI
R. S. MacArthur	Chevron Products Co.
T. J. Wallington	Ford Motor Co.

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J. J. Simnick, Co-Chair	BP

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K. D. Eng	Shell Global Solutions	R. R. A. Reese	Chrysler
S. I. Johnson	Volkswagen of America	W. Studzinski	General Motors
R. P. Lewis	Marathon Petroleum Co.	M. Valentine	Toyota Tech. Ctr. N.A.
S. A. Mason	Phillips 66	L. Webster	Nissan Tech. Ctr. N.A.
P.W. Misangyi	Ford Motor Co.	W. Woebkenberg	Daimler
M. Nikanjam	Chevron		

GASOLINE DEPOSIT GROUP

(Project No. CM-136)

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K. D. Eng	Shell Global Solutions	W. J. Most	Fuel Tech. Assoc.
B. Evans	Evans Research	C. L. Muth	Nalco Energy Services
T. Frank	Lubrizol Corp.	R. Osman	Flint Hills Resources
I. Gabrel	Chrysler	F. Parsinejad	Chevron Oronite Co.
A. K. Ghosal	Shell	C. M. Pyburn	Pytertech Intl.
L. M. Gibbs	Consultant	C. Richardson	Ford Motor Co.
T. E. Hayden	BASF	D. Schoppe	Intertek
J. Horn	Chevron	D. Z. Short	Marathon Petroleum Co.
J. J. Jetter	Honda R&D Am.	W. Studzinski	General Motors
A. K. Jung	BASF Corp.	W. Y. Su	Huntsman Corp.
V. L. Kersey	Valvoline Co.	R. D. Tharby	Tharby & Associates
A. M. Kulinowski	Afton Chemical	M. Valentine	Toyota Tech. Ctr. N.A.
D. H. Lax	API	L. Webster	Nissan Tech. Ctr. N.A.
R. P. Lewis	Marathon Petroleum Co.	H. Zhao	Huntsman Adv Tech.
I. MacMillan	Innospec Fuel Spec.		

OCTANE GROUP
(Project No. CM-137)

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B. Alexander	BP	R. P. Lewis	Marathon Petroleum Co.
T. Briggs	SwRI	S. A. Mason	Phillips 66
K. Brunner	SwRI	M. Miller	Sunoco Inc.
R. Chapman	Innospec Fuel Spec.	K. Mitchell	Shell Canada
D. M. DiCicco	Ford Motor Co.	P. J. Morgan	SwRI
K. D. Eng	Shell Global	R. Osman	Flint Hills Resources
B. Evans	Evans Research	C. M. Pyburn	Pybertech International
J. Farenback-Brateman	ExxonMobil	R. Reynolds	Downstream Alternatives
		C. Richardson	Ford Motor Co.
T. Frank	Lubrizol Corp.	D. Schoppe	Intertek
P. Geng	General Motors	D. Z. Short	Marathon Petroleum Co.
J. Horn	Chevron	R. A. Sobotowski	US EPA
A. Iqbal	Chrysler	W. Studzinski	General Motors
J. J. Jetter	Honda R&D Am.	M. Valentine	Toyota Tech. Ctr. N.A.
C. Jewitt	Consultant	R. K. Vick	Chrysler
K. Knapp	Chevron Phillips Chem	L. Webster	Nissan Tech. Ctr. N.A.
D. H. Lax	API	W. Woebkenberg	Daimler

MEMBERSHIP

VOLATILITY GROUP
(Project No. CM-138)

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K. Brunner	SwRI	S. A. Mason	Phillips 66
H. Doherty	Sunoco	K. Mitchell	Shell Canada Ltd.
K. D. Eng	Shell Global Solutions	R. S. Monroe	Chrysler
B. Evans	Evans Research	R. Osman	Flint Hills Resources
J. Farenback-Brateman		W. J. Piel	Lyondell Chemical
	ExxonMobil	J. Porco	Gage Products
T. Frank	Lubrizol Corp.	C. M. Pyburn	Pybertech Intl.
I. Gabrel	Chrysler	C. Richardson	Ford Motor Co.
P. Geng	General Motors	D. Schoppe	Intertek
R. Hardy	Flint Hills Resources	D. Z. Short	Marathon Petroleum Co.
G. Herwick	Trans. Fuels Consult.	W. Studzinski	General Motors
J. Horn	Chevron	M. Valentine	Toyota Tech. Ctr. N.A.
J. J. Jetter	Honda R&D Am.	S. Van Hulzen	POET
D. H. Lax	API	L. Webster	Nissan Tech. Ctr. N.A.
R. P. Lewis	Marathon Petroleum Co.	J. P. Wick	Marathon Petroleum Co.

2013 CRC INTERMEDIATE-TEMPERATURE E15
COLD-START AND WARM-UP VEHICLE DRIVEABILITY
PROGRAM DATA ANALYSIS PANEL
(Project CM-138-11-3)

L. M. Gibbs, Ldr. Consultant

B. Alexander	BP	J. Horn	Chevron
B. Evans	Evans Research	R. Osman	Flint Hills Resources
J. Farenback-Brateman	ExxonMobil	W. Studzinski	General Motors
P. Geng	General Motors	S. Van Hulzen	POET

RISK ANALYSIS/HAZARD ASSESSMENT OF HIGH ETHANOL CONTENT FUELS AT THE SERVICE STATION
(Project CM-138-12-1)

D. P. Boyd, Ldr. — BP
K. Moriarty, Ldr. — NREL

G. Herwick	Transportation Fuels Consulting Inc.	R. McCormick	NREL
		P. W. Misangyi	Ford Motor Co.
L. M. Gibbs	Consultant	C. Richardson	Ford Motor Co
J. Horn	Chevron	D. Z. Short	Marathon Petroleum Co.
J. J. Jetter	Honda R&D Am.	J. J. Simnick	BP
R. P. Lewis	Marathon Petroleum Co.	M. Valentine	Toyota Tech. Ctr.N.A.
S. Mason	Phillips 66		

2014 HOT-FUEL HANDLING DATA ANALYSIS PANEL
(Project CM-138-13-1)

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L. M. Gibbs	Consultant	D. Z. Short	Marathon Petroleum Co.
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J. J. Jetter	Honda R&D Am.	W. Studzinski	General Motors

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P. Biggerstaff	Baker Petrolite	T. Livingston	Robert Bosch
L. Cattani	Chrysler	H. Martin	Fleetguard / Cummins
A. Cayabyab	CARB	R. L. McCormick	NREL
R. Chapman	Innospec Fuel Spec.	R. Mills	Chevron
D. A. Daniels	Innospec Fuel Spec.	K. Mitchell	Shell Canada
J. Draper	Nalco	R. S. Monroe	Chrysler
E. English	Fuel Quality Services	R. Osman	Flint Hills Resources
D. Forester	Fuel Quality Services	J. Porco	Gage Products
T. Frank	Lubrizol Corp.	C. Richardson	Ford Motor Co.
I. Gabriel	Chrysler	S.B.Rubin-Pitel	ExxonMobil
R. Gault	EMA	J.A.Rutherford	Chevron Oronite
R. George	BP	D. Schoppe	Intertek
A. Ghosal	Shell	D. Z. Short	Marathon Petroleum Co.
G. C. Gunter	Phillips 66	W. Studzinski	General Motors
C. Hamer	PCS Instruments	A. Swarts	Sasol
D. Hess	Infineum	R. D. Tharby	Tharby & Associates
J. J. Jetter	Honda R&D Am.	M. Valentine	Toyota Tech. Ctr.N.A.
S. R. Kirby	Navistar, Inc.	G. Webster	AET
A. Kulinowski	Afton Chemical	L. Webster	Nissan Tech. Ctr. N.A .
N. Kuzhiyi	GE	S.A.Westbrook	SwRI
P. Lacey	Delphi Diesel Systems	W.Woebkenberg	Daimler
D. H. Lax	API		

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

J. Chandler, Ldr. Consultant

J. Axelrod	ExxonMobil	S. Lopes	General Motors
D. A. Daniels	Innospec Fuel	H. Martin	Cummins / Fleetguard
T. Frank	Lubrizol Corp.	K. Mitchell	Shell Canada Products
G.C. Gunter	Phillips 66	M. Nikanjam	Chevron Products Co.
D. Hess	Infineum	S.B.Rubin-Pitel	ExxonMobil
J. J. Jetter	Honda R&D Am.	W. Studzinski	General Motors
A.M.Kulinowski	Afton Chemical	A. Swarts	Sasol

DP - BIODIESEL PANEL
(Project No. DP-02A)

R. L. McCormick, Ldr. NREL

R. Baranescu	U. of IL at Chicago	S. Howell	National Biodiesel Bd.
J. Chandler	Consultant	J. J. Jetter	Honda R&D Am.
T. Frank	Lubrizol Corp.	T. Livingston	Robert Bosch
R. Gault	EMA	K. Mitchell	Shell Canada Products
G.C. Gunter	Phillips 66	H. Nanjundaswamy	FEV
P. Henderson	GM Powertrain	M. Nikanjam	Chevron Products Co.
D. Hess	Infineum	W. Studzinski	General Motors

DP - CETANE NUMBER PANEL
(Project No. DP-03)

A. M. Kulinowski, Ldr. Afton Chemical

T. Frank	Lubrizol Corp	S. Lopes	General Motors
R. George	BP	K. Mitchell	Shell Canada
A. Ghosal	Shell	M. Nikanjam	Chevron Products Co.
G.C. Gunter	Phillips 66	S. B. Rubin-Pitel	ExxonMobil
J. J. Jetter	Honda R&D Am.	J. Y. Sigelko	Volkswagen of America
S.I. Johnson	Volkswagen of America	W. Studzinski	General Motors
T. Livingston	Robert Bosch	W. Woebkenberg	Daimler

MEMBERSHIP

DP - DEPOSIT PANEL
(Project No. DP-04)

J. Axelrod, Co-Ldr. ExxonMobil

M. Ahmadi	Oronite Additive	D. H. Lax	API
J. Anderson	Paccar Inc.	T. Livingston	Robert Bosch
P. Biggerstaff	Baker Petrolite	I. MacMillin	Octel-Starreon
N. C. Blizard	Cummins Engine Tech.	R. Mills	Chevron
R. Chapman	Innospec Fuel Spec.	K. Mitchell	Shell Canada Products
H. DeBaun	Navistar	M. Nikanjam	Chevron Products Co.
J. Draper	Nalco	R. Osman	Flint Hills Resources
T. Frank	Lubrizol Corp.	J. D. Parsons	Caterpillar
R. Gault	EMA	J. Rutherford	Chevron
R. George	BP	W. Studzinski	General Motors
B. E. Goodrich	John Deere	T. Talbert	Shell
G. C. Gunter	Phillips 66	C. Trobaugh	Cummins
J. J. Jetter	Honda R&D Am.	M. Valentine	Toyota Tech. Ctr.N.A.
S. R. Kirby	Navistar, Inc.	L. Webster	Nissan Tech. Ctr. N.A.
A. Kulinowski	Afton Chemical	S.A.Westbrook	SwRI
P. Lacey	Delphi Diesel Systems	S. Zeld	BASF

DP – LOW TEMPERATURE OPERABILITY BIODIESEL PROJECT PANEL
(Project No. DP-05-12)

D.A. Daniels, Ldr. Innospec Fuel Spec.

J. Axelrod	ExxonMobil	T. Livingston	Robert Bosch
R. Baranescu	U. of IL at Chicago	S. Lopes	General Motors
J. Chandler	Consultant	R. L. McCormick	NREL
T. Frank	Lubrizol Corp.	H. Martin	Cummins / Fleetguard
R. Gault	EMA	K. Mitchell	Shell Canada Products
G.C. Gunter	Phillips 66	H. Nanjundaswamy	FEV
P. Henderson	GM Powertrain	M. Nikanjam	Chevron Products Co.
D. Hess	Infineum	S.B.Rubin-Pitel	ExxonMobil
S. Howell	National Biodiesel Bd.	W. Studzinski	General Motors
J. J. Jetter	Honda R&D Am.	A. Swarts	Sasol
A.M.Kulinowski	Afton Chemical		

DP – FUEL CLEANLINESS PANEL
(Project No. DP-06-13)

R. Chapman, Ldr. — Innospec Fuel Spec.

N. C. Blizard	Cummins Engine Tech	T. Livingston	Robert Bosch
E. W. English	Fuel Quality Services	S. Lopes	General Motors
R. Gault	EMA	M. Nikanjam	Chevron Products Co.
G. C. Gunter	Phillips 66	F. Passman	BCA Inc.
R. Leisenring	KIOR	D. Z. Short	Marathon Petroleum Co.
R. P. Lewis	Marathon Petroleum Co.	S. A. Westbrook	SwRI

DP – FUEL CORROSION PANEL
(PROJECT NO. DP-07-13)

D. Lax, Ldr. — API

H. Alfano	NATSO	J. Eichberger	NACS
R. Chapman	Innospec	M. Kass	ORNL
T. Covert	Ford	R.P. Lewis	Marathon Petroleum Co.
S. Curran	Fiberglass Tank & Pipe Inst	P. Miller	US EPA
		K. Moriarty	NREL
J. Eckstrom	BP	M. Nikanjam	Chevron Products Co.
E. W. English	Fuel Quality Services	B. Renkes	PEI
L. Gerber	US EPA	P. Searles	API
L. Grainawi	Steel Tank Inst.	D. Z. Short	Marathon Petroleum Co.
A.M. Gregg	Battelle	K. Spiker	Quiktrip
G. C. Gunter	Phillips 66	S. A. Westbrook	SwRI
R. Haerer	US EPA		

NATURAL GAS FUEL SURVEY PANEL
(Project PC-2-12)

J. J. Jetter, Ldr. — Honda R&D Am.

T. Alleman	NREL	C. Richardson	Ford Motor Co.
D. Bowerson	Chrysler	J. Y. Sigelko	Volkswagen of America
K. Clay	AGA	J. J. Simnick	BP
L. M. Gibbs	Consultant	W. Studzinski	General Motors
S. A. Mason	Phillips 66	M. Valentine	Toyota Tech. Ctr. N.A.
P.W.Misangyi	Ford Motor Co.	L. Webster	Nissan Tech. Ctr. N.A.
M. Nikanjam	Chevron Products	A. Williams	NREL