COORDINATING RESEARCH COUNCIL ANNUAL REPORT

September 2013

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STATE OF THE COUNCIL - 2013

The Coordinating Research Council (CRC) provides the means for the automotive and energy industries to work together and also with government and other stakeholders to address mobility and environmental issues of international interest. The technical programs in CRC have continued again this year with broad cooperation from many partners on research projects and on other activities such as international technical workshops. This cooperation results in a finer focus on the important issues and leverage of both technical expertise and financial support to meet common goals. Partnerships in 2013 have included: The California Air Resources Board (CARB), Growth Energy, the Health Effects Institute (HEI), the National Biodiesel Board (NBB), the Renewable Fuels Association (RFA), 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 with research organizations worldwide, with Japanese, European, and Canadian collaborations emphasized during the past year.

CRC has completed its assessment on the impact of intermediate-level ethanol blends, a significant research program that has been generating results since 2006. It is essential that all stakeholders including industry, government and consumers understand the potential impacts of changing fuel composition on vehicle performance in the current fleet. A journal article summarizing the results generated by CRC and others conducting work in this area is anticipated near the end of the calendar year.

A very important highlight for 2013 is the completion of Phase 2 of the Advanced Collaborative Emissions Study (ACES) in collaboration with the Health Effects Institute (HEI). This study provides 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). Engine testing was completed during the program year and the Final Report was published. Meanwhile HEI is concluding health effects testing at Lovelace Respiratory Research Institute (LRRI) and other select laboratories on 2007 technology engine exhaust.

In addition to the ACES study, the CRC Emissions Committee has been active in several key areas of new research. The Final Report for Project E-89, "Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles Certified to Tier 2 Standards" was released following testing collaborations with EPA and DOE. This study (EPAct/V2/E-89) presented detailed emissions data collected on a fleet of vehicles tested on a matrix of fuel properties. EPA and DOE conducted independent data analysis efforts which were published separately. The CRC Atmospheric Impacts Committee commissioned a related study (A-73-1, Development of Inventory and Speciation Inputs for Representing Ethanol Blends") based in part on the DOE data analysis. Studies on performance of on-board diagnostic (OBD) systems and evaporative emissions system durability (Projects E-90-2b and E-91) were completed and results are included in the comprehensive overview of CRC and others' intermediate ethanol blend research programs mentioned above under Project E-97. The E-89 study results will also be reviewed in the E-97 journal article.

The Emissions Committee continued new studies on "Evaluation and Investigation of Gaseous and Particulate Emissions from SIDI In-Use Vehicles with Higher Ethanol Blend Fuels" (E-94-1), "Exhaust Emissions of Average Fuel Composition" (E-98), and "Very Low PM Mass Measurement" (E-99). An important new start is Project E-108, "Sub-Regular Grade (85 AKI) Octane Study," that will evaluate lower octane number gasoline performance of modern vehicles at low altitude.

The Advanced Vehicle/Fuel/Lubricants (AVFL) Committee released their concluding study on intermediate ethanol blend impacts on fuel system durability under Project AVFL-15a, supplementing the initial study on this topic report last year. The AVFL Committee also made significant progress in developing diesel fuel surrogates formulations for research under Project AVFL-18a with plans to begin engine testing and combustion modeling by the end of the year. The committee completed its initial study on advanced characterization methods under Project AVFL-19, "Characterization of Advanced Alternative and Renewable Fuels" with two Final Reports issued. A new investigation on "Biodiesel and Renewable Diesel Characterization and Testing in Modern LD Diesel Passenger Cars and Trucks" (AVFL-17b) completed the first phase of testing with a goal of filling existing gaps in the literature. Additional vehicle testing will be conducted in AVFL-17b. Significant new project starts this year include AVFL-20, "Engine Efficiency / Refinery Stream-Ethanol Interactions," AVFL-22, "Advanced Fuel and

Engine Performance Workshop," 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.

The Diesel Performance Group of the Performance Committee continues their evaluation of field problems observed in modern diesel fuel injection systems where at least two types of fuel deposits have been documented in operations of high pressure common rail fuel systems. A new report has been issued describing rig tests designed to screen fuels for internal injector sticking character. The goal is to establish detection methods and ultimately recommend possible solutions for correcting the field problems. Significant progress has been made in identifying potential sources and possible solutions.

The Octane Group of the Performance Committee continued its timely evaluations of performance contributions from motor octane number (MON) and research octane number (RON) on current light-duty engines and control systems. A follow-on literature study resulted in publication of the Final Report for Project CM-137-11-1b, "Review to Determine the Benefits of Increasing Octane Number on Gasoline Engine Efficiency: Task 2-5 Analysis and Recommendations."

The Volatility Group of the Performance Committee completed a new driveability field study in March 2013 (Intermediate Temperature E15 Cold-Start and Warm-Up Driveability Program). The objective of this program is to identify E15 fuel blend correction factors that could be used to update the ASTM D4814 standard. ASTM will review results in cooperation with all relevant government and industry stakeholders to determine what changes may be appropriate.

A new Volatility Group project entitled, "Risk Analysis/Hazard Assessment of High Ethanol Content Fuels at the Service Station," will determine the incremental change in risk due to a change in fuel composition (at higher levels of ethanol). The benchmark will be the currently accepted public safety level of the terminal blender making an E10 gasoline. The analysis will include the tanker truck driver loading/blending/delivering blends such as E51, E83, and E98 and, ultimately the consumer dispensing E10 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" and is supporting this project via the National Renewable Energy Laboratory.

Another new activity in the Performance Committee is a joint program initiated with co-sponsorship of the American Gas Association (AGA). This program is designated PC-2-12, "Natural Gas Fuel Survey." This effort will include sampling natural gas from vehicle refueling stations across the United States to assess the current quality of natural gas.

The Atmospheric Impacts Committee continued work examining 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) and secondary aerosols which are formed in the atmosphere. The committee is supporting Phase 2 of the Air Quality Modeling Evaluation International Initiative (AQMEII) in cooperation with EPA and the Joint Research Centre (JRC) of Europe. The CRC contribution is funded under Project A-87 where coupled air quality and meteorology modeling runs from the European and North American domains will be analyzed with guidance from the EPA/JRC program leaders.

The Atmospheric Impacts Committee published a Final Report for A-76-2 in which light-duty vehicle emissions impacts from past, present, and future control scenarios were evaluated by applying several air quality modeling scenarios to compare relative improvements in ambient air quality as a function of vehicle emission standards that have been implemented and are now contemplated. This study extends the related scenario modeling conducted earlier under A-76-1.

Previous CRC projects in the Atmospheric Impacts Committee resulted in the publication of four books by Oxford University Press: *Mechanisms of Atmospheric Oxidation of the Alkenes*, *Mechanisms of Atmospheric Oxidation of Aromatic Hydrocarbons*, *Mechanisms of Atmospheric Oxidation of the Alkanes*, and *Mechanisms of Atmospheric Oxidation of the Oxygenates*. Another project concluding this year under A-78 has generated a manuscript for a fifth book on "*Chemistry of Tropospheric Ozone Generation and the Influence of Trace Gases*."

The 6th Mobile Source Air Toxics Workshop was held February 4-6, 2013 at Cal-EPA headquarters in Sacramento, CA. The workshop was hosted by the California Air Resources Board and brought together key local, state, and federal government researchers, academic and industry researchers, and other stakeholders to discuss current air toxics data and future research needs.

The 23rd CRC Real World Emissions Workshop was held in San Diego, CA on April 7-10, 2013 with sponsorship from the California Air Resources Board (CARB), South Coast Air Quality Management District, and the US Environmental Protection Agency (OTAQ). There were approximately 200 attendees with 15 different countries represented. Highlights from the workshop were published in the August 2013 issue of *EM* Magazine of the Air and Waste Management Association.

The 3rd Life Cycle Analysis (LCA) Workshop on Transportation Fuels will be held at Argonne National Laboratory, October 15-17, 2013. An international organizing committee has invited world-renowned experts to present the latest information on life cycle analysis techniques and associated uncertainties. Participation at this "invitation only" event is limited to individuals actively working in the field of life cycle analysis techniques and applications. The workshop proceedings will identify a consensus position on the status of modeling technology and associated uncertainties/gaps in current data and procedures used in transportation fuel life cycle assessments.

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

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

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

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

The ACES program is 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 is 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).

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- 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 with health measurements. HEI is leading this Phase, which is being performed by the Lovelace Respiratory Research Institute (LRRI).

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

The Phase 1 evaluation was based on Federal certification test procedures (FTP) but also included testing on a new engine cycle based on a heavy-duty chassis dynamometer test cycle developed by CARB and employed extensively in 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 will be used for all engine characterization and exposure activities in the ACES project.

The Final Reports for the ACES-1 and ACES-1a cycle development projects and the Phase 1 project Final Report have been released and are available on the CRC website. An article on the Phase 1 engine emissions test program was published in the Journal of Air and Waste Management Association in April 2011.

CRC's technical panel continues to be apprised of developments in Phase 3 of ACES, which is ongoing. SwRI was selected to perform Phase 2. Phase 2 testing was completed in December, 2012. The final report for Phase 2 will be released in 2013. An accompanying journal article for Phase 2 is being planned. The Phase 3 report is expected to be released by HEI in 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
M. I. Watkins

Scope and Objective

The objective of this study is to collect fuels from Flex Fuel pumps in the US and determine actual market vapor pressures and ethanol contents and determine compliance with ASTM standard D5798. The ASTM standard has recently been revised to facilitate blending of compliant fuel and its effects at the fuel dispenser should be determined. Also, a new volatility class (class 4) was added in the -11 revision of the spec.

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

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

Current Status and Future Program

Sample collection will begin in the second half of 2013 and continue into the first half of 2014, with reporting anticipated in mid-2014.

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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.

Current Status and Future Program

CRC previously funded a study of transportation fuel LCA (CRC Project E-88) that was intended to review the state of the science, compare the results of different models, and provide information on key inputs to LCA modeling that contribute to uncertainty in the emissions estimates. That study was also to lay out 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 the E-88-2 project as a follow-on to the E-88 study. E-88-2 focused on issues related to indirect land use change (iLUC) and agricultural N2O 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 this project, the following tasks would be performed, with an eye on how best to reduce the uncertainty in the LUC estimates.

Task 1 - Review and compare economic models used for iLUC estimates. This will include those models used by both EPA (i.e., FASOM and FAPRI-CARD) and CARB (GTAP). In addition, other land use change models will be 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 extent possible, the quantitative impact of key data and model parameters in the various models reviewed.

Task 3 - To the extent possible, duplicate EPA and CARB results based on available documentation; this will help identify assumptions that are not clearly specified.

After a competitive solicitation, this project was awarded to a team led by Life Cycle Associates. This project is ongoing with a final report release anticipated in 2013.

EMISSIONS

EPACT LIGHT-DUTY VEHICLE FUEL EFFECTS

CRC Project No. E-89

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

Scope and Objective

EPA initiated this study (referred to as EPAct) with CRC and DOE/NREL (referred to as DOE V2). EPAct / V2 / E-89 examined the effects of changes in fuel parameters on the exhaust emissions of late-model, light-duty vehicles.

Current Status and Future Program

- Phases 1 and 2 were run by EPA and DOE/NREL.
- Phase 3 includes fuels recommended by CRC, and is intended to establish the effects of Reid Vapor Pressure (RVP), T50, T90, aromatics and ethanol content on exhaust emissions from Tier 2 vehicles.
- DOE/NREL funded additional phases 4 and 5 that include emissions measurements at temperature extremes, and separately on high-emitting vehicles.

CRC reviewed the test fuels matrix for Phase 3 and recommended expanding it with the inclusion of two additional fuels, supported by statistical analysis, to improve the strength of the test fuel experimental design. These two fuels enhance the understanding of the effect of the fuel distillation parameters.

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

- Phase 1:
  - Testing at 75°F over LA92
  - 3 'typical' fuels E0, E10, and E15
  - 19 high sales volume Tier 2, 2 high-emitter and 1 high-mileage NLEV vehicles

- Phase 2: Repeat of Phase 1 except at 50°F
- Phase 3: Main Program
    - 27 fuels tested in 16 Tier 2 vehicles, E85 tested in FFVs that are included in the 16
    - Fuel Matrix, 5 variables in matrix
    - 2 levels of RVP, T90, aromatics
    - 5 levels of T50
    - 4 levels of ethanol (E0, E10, E15, E20) plus E85
    - 2 additional fuels from CRC for resolving potential T90 non-linear effects
    - Variables span the 5th and 95th percentiles of in-use fuel properties
    - Measured emissions: PM, CO_2, NO_2, VOCs, ethanol, carbonyls, N_2O, NH_3 and HCN (by FTIR), and SVOC speciation in Phases 1, 2, and 3

Fifteen of these vehicles were also used in the E-83 and E-98 projects.

The report documenting the testing and data from Phase 3 was reviewed and approved by the Emissions Committee, and has been released by EPA. Links to the EPA report and data were posted to the CRC website in April 2013. EPA presented an overview of their Phase 3 results and of their independent statistical analysis of the Phase 3 data at the CRC 2013 Real World Emissions Workshop.

EMISSIONS

IMPACT OF E15/E20 BLENDS ON OBDII SYSTEMS

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

Leaders: J. Jetter
P. L. Heirigs

Scope and Objective

The objectives of this study are to collect On-Board Diagnostics (OBD) and related data from in-use vehicles and analyze these data to determine vehicle potential to illuminate the Malfunction Indicator Lights (MIL) when fueled with intermediate ethanol blends (i.e., E15 or E20). Target data include long-term fuel trim and any stored OBD diagnostic trouble codes (DTCs) related to enleanment.

Current Status and Future Program

De la Torre Klausmeier Consulting, Inc. was chosen to perform the first phase of this project. To facilitate data interpretation, some vehicle data were collected in regions where E10 was marketed exclusively, and some in regions where E0 was marketed exclusively. Given that specific OBD threshold values for MIL illumination are considered confidential, the automotive Original Equipment Manufacturers (OEMs) provided general input during the data analysis phase.

Description of the study approach:

1. Obtain approval from states with Inspection/Maintenance (I/M) programs to conduct additional tests at inspection stations on a sample of high mileage vehicles.

2. Develop a plan for conducting these tests at inspection facilities.

3. Coordinate the collection and analysis of data.

4. Prepare draft and final reports.

This project was initiated in late 2008; a pilot study in the regions of Austin, TX, Dallas, TX and Chicago, IL. The Final Report for the pilot study was released on the CRC website in March 2010.

Following completion of the initial phase of the project (E-90), two additional elements were initiated: an analysis of existing data from I/M programs (E-90-2a) and an experimental program (E-90-2b). The E-90-2a project, "Evaluation of Inspection and Maintenance OBD II Data to Identify Vehicles that May be Sensitive to E10+ Blends," was awarded to Sierra Research after a competitive solicitation process. This project has been completed, with the Final Report posted to the CRC website in January 2011.

Project E-90-2b, "Impact of Ethanol Blends on the OBDII System of In-Use Vehicles," was awarded to SwRI. Vehicle screening was concluded, and testing of the recruited vehicles is now complete. This project was extended to include varied ethanol percentage, ambient temperature, and geographic range for vehicle procurement. An interim report was released on the CRC website in November 2012. Testing concluded in March 2013. Results were presented in the CRC Real World Emissions Workshop in April 2013. The Final Report for this project will be released in fall 2013.

EMISSIONS

EVAPORATIVE EMISSIONS DURABILITY TESTING

CRC Project No. E-91

Leaders: J. Y. Sigelko
S. Bohr

Scope and Objective

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

Current Status and Future Program

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

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

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

All twenty vehicles were driven on road twice per day for 360 days, with eight hour minimum soak time between drives. The vehicles were parked outdoors during the aging period. At quarterly intervals, the vehicles were tested using two SHED procedures:

- The “Baseline Test” was similar to a two-day diurnal supplemental certification test sequence. The Baseline Test was always performed using ethanol-free certification gasoline. Results from this test provided information on how E20 fuel substitution and vehicle aging may affect the vehicle's compliance with EPA evaporative emissions standards.

- The "Permeation Test" quantified the amount of permeation that contributed to evaporative emissions. Results from this test provided information on the possible sources of the permeation, vapor leaks and fuel pressure driven leaks, isolating each parameter to support emissions modeling. The Permeation Test procedure was adapted from CRC E-77.

Over 600 individual SHED tests were performed to assess the effect of aging and fuel exposure on permeation and evaporative emissions.

This project was conducted by ETC (now SGS) of Aurora, Colorado, with the sea-level work being performed by Chrysler as a subcontractor. The Final Report for this project was published on the CRC website in September 2012.

EMISSIONS

LCA WORKSHOP 2013

CRC Project No. E-93-3

Leader: P. L. Heirigs

Scope and Objective

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

The Workshop Goals for 2013 are:

- 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 includes or 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.

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Current Status and Future Program

Planning is underway for a 2013 workshop on October 15-17, at the Argonne National Laboratory in Chicago.

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-94-2

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 have been purchased and are being operated on fuels containing a range of ethanol concentrations (E0 --> E20 or higher). Key objectives are as follows:

Current Status and Future Programs

- Determine gaseous and PM/PN (particle 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 heavy aromatic compounds on the PM/PN emissions by utilizing two different base fuels.
- Characterize particulates from all testing.

Vehicles - Three vehicles are being used for this pilot phase of the program. One vehicle has a naturally-aspirated 4-cylinder engine, one has a turbo-charged 4-cylinder engine, and one has a naturally-aspirated V6 engine.

Fuels - Ethanol has been splash-blended to produce E10 and E20, with the potential to blend fuels higher than E20. Each fuel will be sampled and measured for RON, MON, sulfur, olefins, aromatics, oxygen, benzene, hydrogen, RVP, ethanol, and boiling point distribution. Two different base test fuels were procured directly from refineries, selected to maximize the difference in the Particulate Matter Index (PMI) between the base fuels.

Emissions Measurements - Using the LA92 test cycle, all tailpipe gaseous emissions will be collected along with instantaneous PN emissions. Fuel economy and GHG emissions (CO2, N_2O and methane) will also to be collected. PM characterization will include:

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 or equivalent.

d. PM size distribution: EEPS or similar.

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

This project was awarded to SwRI in May 2012. The approach to fuel procurement was particularly challenging because information about PMI is not available for refinery fuels, so correlations were developed with more typically measured fuel properties. Testing is currently underway with reporting anticipated in late 2013.

The main study, E-94-2, is in development by the Emissions Committee with an anticipated start in late 2013.

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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 is to collect fuels from ethanol blender pumps in the US and determine vapor pressure and ethanol content to determine compliance with ASTM standards where they exist.

The DOE Alternative Fuels Data Center was used to identify and confirm locations of blender pumps throughout the US. Locations will be selected to cover the broadest geographic range possible, though blender pumps are still predominantly in the Midwestern US. Where possible, pumps will be selected from both RFG and conventional areas. The parent gasoline and Flex Fuel will be collected, along with every blend offered at each station.

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

Current Status and Future Programs

NREL has contributed to the project through technical resources and collaboration. Sample collection occurred in the latter half of 2012 and the first half of 2013. The draft final report for the project is in development, with a release anticipated in late 2013.

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

Current Status and Future 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 arise 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, and the CMU contract was modified to fund this work. Phase 4, has been approved and authorized in the 2012 committee budget to support modeling of SVOC primary emissions and their conversion to SOA.

Summary results were presented at the 21st Real World Emissions Workshop in March 2011 and follow-on presentations were given at the 22nd and 23rd Workshops. The Phase 1-3 Interim Final Reports were reviewed and approved. Nine journal articles are in development covering the research in this project to serve as the publically available reports for this project.

EMISSIONS

CRC MID-LEVEL BLEND RESEARCH

CRC Project No. E-97

Leader: M. I. Watkins

Scope and Objective

This study includes an overview of the entire CRC program on intermediate-level ethanol blends, as well as a summary of each research project. The study is organized to group together CRC projects addressing a single topic area such as: exhaust emissions, evaporative emissions or driveability. The summary of each study and group of related studies includes both methodology and results. Implications for in-use emissions, performance and durability will be included where there are clear findings. The report will also cover studies by other groups that were closely related to the CRC program, but the project will not conduct a broad literature survey of mid-level blend impacts. Areas of uncertainty and limitations in the CRC program will also be described.

Current Status and Future Program

After a competitive solicitation, this project was awarded to a team of consultants, Albert Hochhauser and Charles Schleyer. The project is ongoing. The draft final report in the form of a peer-reviewed journal publication, and several detailed summaries will be posted on the CRC website as appendices to the journal article. The draft final report is currently in review by the project panel.

EXHAUST EMISSIONS OF AVERAGE FUEL COMPOSITION

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

Leader: J. Uihlein

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 will be a re-blend of one of the fuels from the EPAct/V2 program (a "tie" fuel); the other fuels occupy 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 will be measured using standard exhaust emission tests.

Current Status and Future Program

Fifteen vehicles used in the EPAct/V2/E-89 program have been tested. Each vehicle-fuel combination was tested using the LA-92 emissions test cycle, with the fuel order randomized for each vehicle. Speciated emissions measurements were carried out for the designated toxics benzene, 1,3-butadiene, formaldehyde, and acetaldehyde for all tests. Speciated emissions work is co-funded through CRC Project A-80. VOC speciation of the exhaust emissions for one test of one fuel for each vehicle for each bag is planned. Cumulative PM mass measurements were made for each pair of back-to-back tests. This project was awarded to SwRI. Testing is complete, and statistical analysis is underway. A Final Report release is anticipated in late 2013.

EMISSIONS

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 modifications to gravimetric PM mass measurement that preserve the integrity of the method but decrease 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

Present motor vehicle PM emissions measurement regulations (CFR 40 Part 1065, 1066) require gravimetric determination of PM collected onto filter media from diluted exhaust. But with current sampling practices, the method is a challenge at the proposed 3 mg/mi PM emissions standard and likely to reach its limit at 1 mg/mi. The combined effects of the more stringent PM standard and CFR minimum dilution requirements have reduced typical filter loadings to about 20 ug at a tunnel flow of 350 cfm and a PM emissions rated 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 ug weight gain, with outliers exceeding 10 ug, even in the absence of a test vehicle (i.e., tunnel and trip blanks). This artifact itself can have a high variability (~100%) and is susceptible to variation from facility to facility. The impacts on vehicle emissions testing are increased measurement uncertainty, and cost.

The project is structured into the following tasks:

Task 1: Identify hypothesized 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 includes test method, test engines/vehicles, test cycles, and fuels. Also included are parameters to measure 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.

The project was awarded to CE-CERT. CARB is co-sponsoring this work.

After the project kick-off meeting in February, 2013, a process was initiated to broadly poll other laboratories measuring low levels of PM to compare methods and aid in the final design of the experiments to be performed in this project. The detailed test plan has been finalized after consultation with the project panel. Testing will be performed in late 2013, and the final report will be issued in 2014.

EMISSIONS

2013 MOVES REVIEW

CRC Project No E-101

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

Scope and Objective

The Real World Group has planned to conduct an evaluation of the MOVES model (MOVES2013) anticipated for release to the general public near the end of 2013. The approach for this project is anticipated to be similar as that for the E-68a project.

Current Status and Future Program

The Real World Group is evaluating a draft statement of work, with the goal of a project start in late 2013 if approved.

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 is intended to better quantify sources of uncertainty and variability in LCA models by conducting an in-depth evaluation of model inputs and uncertainties around those inputs for several specific fuel pathways.

Current Status and Future Program

The project is structured into the following tasks:

Task 1: Selection of Fuel Pathways – identify the specific fuel pathways for evaluation. Initial suggestions are 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, will be identified and validated. The focus of this assessment is on the inputs that have the greatest impact on the final GHG results.

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

This project was awarded to $(S\&T)^2$ Consultants. The draft final report is in review, with the release of the final report anticipated in fall 2013.

EMISSIONS

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 has introduced standards for nitrous oxide (N_2O) for the first time. 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 will examine a variety of instruments for the measurement of N_2O, using light-duty vehicles operating on a chassis dynamometer. It will be conducted in conjunction with a study focused on heavy-duty on-highway applications, which will include both bench-top evaluations and engine testing.

Two test vehicles from the fleet used for the EPAct/V2/E-89, E-83, and E-98 studies will be used to conduct this research. 7 cold-start FTPs will be performed on each vehicle over the course of two weeks with all of the N_2O analyzers in operation (currently 5 different instruments are anticipated).

This project has been awarded to SwRI. The heavy-duty study is being funded by EMA, and will be conducted first. The light-duty testing is expected to occur in late 2013.

HEI BIOFUEL EMISSIONS WORKSHOP

CRC Project No. E-104

Leaders: C. J. Tennant
R. Shaikh

Scope and Objective

HEI initiated planning of a Biofuels Emissions Workshop in cooperation with CRC. The timing of this workshop was delayed, awaiting the ability of EPA to participate. The Emissions Committee plans to assist with technical and limited financial support of the workshop.

Current Status and Future Programs

HEI is convening an internal meeting in the fall of 2013 to evaluate the approach for this workshop, which is now in consideration for 2014.

EMISSIONS

ON-ROAD EMISSIONS MEASUREMENT VIA RSD

CRC Project No. E-106

Leader: D. M. DiCicco

Scope and Objective

This project will be performed by the University of Denver (DU), following the general methodology of the E-23 project to use remote sensing devices to measure the emissions of in-use fleets. The researchers will make measurements in Chicago and Tulsa on an alternating two-year schedule. One measurement campaign will be conducted for one five-day week each year, alternating locations, for 2013-2016. The plan is to return to the E-23 Chicago site at the same time of year as before, in early fall of 2013 and 2015, and to return to the Tulsa site in the early fall of 2014 and 2016. The equipment will be the same as was used in E-23, but with the new capability of monitoring ammonia, sulfur dioxide, and nitrogen dioxide in real time from each passing vehicle. This project is expected to provide between 80,000 and 100,000 vehicle emissions readings.

Current Status and Future Program

Testing is planned to begin in Chicago in early fall 2013.

SUB-REGULAR GRADE (85 AKI) OCTANE STUDY

CRC Project No. E-108

Leaders: B. Studzinski
D. M. DiCicco

Scope and Objective

This study will evaluate vehicle performance and emissions effects of an 85 AKI gasoline relative to an 87 AKI gasoline at two elevations.

- Test Locations
  - Variable Altitude Chassis Dynamometer Emissions Chambers (GM, Ford, & Chrysler)
  - Two test elevations: Low = 1,000 ft and High 5,000 ft
- Metrics for evaluation
  - Fuel economy
  - Emissions (CO_2, CO, NO_x, THC, NMOG)
  - Pre-cat inlet temperature
  - Spark retard/frequency of knock
  - Stoichiometry
- 10 Test vehicles
  - Purposely varied engine architectures, load factors, model years, manufacturers, and passenger cars and trucks.
- Test Fuels
  - Matched E10 blends of 85 and 87 AKI fuel pair
  - 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 to be performed in A-B-A format (85-87-85)
  - Half the tests to be performed in B-A-B format (87-85-87)

Current Status and Future Program

Testing is planned to initiate in late summer 2013 and complete in fall 2013.

EMISSIONS

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 vehicles which utilize “closed loop” engine control. Primary areas of interest:

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

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

NGVs currently in the US market fall into two categories: Dual-fuel and dedicated. The former include a gasoline tank and can switch between fuels, while the latter are optimized for CNG operation only. It is expected that at least one vehicle from each category will be selected for testing.

The results from the CRC Performance Committee Project PC-2-12, the nationwide fuel survey, will ultimately inform the test fuel selection for this project.

Current Status and Future Program

A request for proposals has been released for this project, and the competitive solicitation is ongoing. The project is expected to start in late 2013.

DURABILITY OF AUTOMOTIVE FUEL SYSTEMS EXPOSED TO E15

Project No. AVFL-15a

Leaders: S. W. Jorgensen
M. Foster

Scope and Objective

AVFL-15a was developed to examine durability of fuel pumps and fuel level senders during exposure to E15 fuel blends, drawing on the knowledge of potentially sensitive parts and using the test procedures developed in the parent AVFL-15 pilot project. Aggressive and non-aggressive fuel formulations of E15 test fuel were included in this continuation of the pilot project.

Current Status and Future Programs

After a competitive solicitation, the project was awarded to the Testing Services Group (TSG). Testing for the initial phase of AVFL-15a was completed in the first quarter of 2012. An interim draft data report was submitted to CRC, presenting results from the first phase of the test program. The committee elected to conduct supplemental testing that was completed in the fall of 2012. The committee reviewed the data, completed data analysis for both phases of AVFL-15a, and compiled the results into a final report. The Final Report was published in January 2013 as CRC Report No. 664. It includes results and analyses of pump soak durability performance, pump endurance performance, and fuel level sensors exposed to E15 test fuels compared against E0 and E10 base fuels.

AVFL

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

CRC Project No. AVFL-17b

Leaders: M. Natarajan
S. Jorgensen

Scope and Objective

The objectives of the LD diesel biodiesel characterization and testing project are to:

1. Identify and procure high-quality biodiesel B100 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 was procured and blended with commercially available Federal ULSD. One CARB B20 blend is also being 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 hydroprocessed animal fat is also being 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: At the start of the project, four LD diesel passenger cars were being sold in the U.S. market including models manufactured by Audi, BMW, Mercedes and VW. In addition, Ford, GM and Chrysler sell LD diesel trucks. The goal is to procure a variety of vehicle types, perhaps one car from each manufacturer for testing. The contractor will perform break-in, preconditioning, and engine/exhaust system monitoring, using protocols reviewed and agreed to by the project technical panel. Eight vehicles are planned for testing.

Emissions to be measured include: 1) Regulated Emissions: HC, CO, NOx, PM; 2) Unregulated emissions, including Carbonyls, PAH and NitroPAH. Optional measurements the committee hopes to include are 1) PM number, 2) EC/OC, 3) NMHC, 4) Fuel Economy, 5) NH3 for SCR systems, and 6) DPF regenerations emissions. Tests will be done in duplicates. Allowing for repeats to meet criteria set by the project panel, it is expected that the total number of tests will be around 115.

All test fuels have been acquired by CE-CERT. Three vehicles have completed testing on all fuels. 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. 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 are beyond the original scope of the program and are being given secondary priority in terms of completing the test matrix. These instruments are being used in conjunction with this testing if they are available and fully running at the time for any given test. The results are being provided to CRC at no additional cost.

An Interim Draft Report on regulated emissions, particle number and sizing, carbonyl compounds, NH_3, and EC/OC on the first three vehicles has been submitted for review. A complete Phase 1 report will also be prepared which will include complete data set for all three vehicles, including EC/OC fraction and PAH/nitro-PAH emission results from one of the test vehicles. Phase 2 testing of up to five additional vehicles will proceed in 2013.

AVFL

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 in the fuel such as the onset/presence of free radicals, peroxide formation, acid number, 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 planned as a new start near the end of CY2013.

High quality ASTM compliant B100 biodiesel will be 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 may be 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:

- High concentration hydrocracked and hydrotreated baseline diesel fuels respectively for a total of 2 hydrocarbon-only fuels
- 4 biodiesels representing 2 levels of saturation and 2 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)
- 2 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.

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 on fuel exposure to these conditions.

AVFL

Technical Approach: The following tasks are suggested to 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 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 should be suitable for use by ASTM to specify the test repeatability.

Task 7: Recommendations for Phase II on fuel effects testing

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), NREL, Lawrence Livermore (LLNL), Pacific Northwest (PNNL), ORNL and the 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 both first and second generation surrogate fuels. Panel members are working to identify and obtain compounds of sufficient purity and sulfur content for blending surrogate fuels, using a variety of synthesis approaches.

CHARACTERIZATION OF ADVANCED ALTERNATIVE AND RENEWABLE FUELS

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

Leaders: W. J. Cannella
C. Fairbridge
S. W. Jorgensen

Scope and Objective

The objective of this project is to characterize the physical and chemical properties of advanced alternative and renewable diesel fuels. 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 the energy companies, OEMs, and U.S. 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 U.S. National Laboratories and at Natural 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, & 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 2013. AVFL-19a is focusing on renewable gasoline-type components including samples of renewable naphtha, ethanol, butanol, and others. Suppliers of samples have been identified, and arrangements for delivery of test fuels are underway. SwRI will perform standard ASTM testing; NREL, CanmetENERGY, PNNL, Phillips 66, GM, and Chevron will provide additional testing of fuel samples under AVFL-19a.

ENGINE EFFICIENCY/REFINERY STREAM-ETHANOL INTERACTIONS

CRC Project No. AVFL-20

Leaders: W. J. Cannella
J. Dolch

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.

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. A work statement has been prepared and is under review.

AVFL

ADVANCED FUEL AND ENGINE PERFORMANCE WORKSHOP

CRC Project No. AVFL-22

Leader: K. B. Wrigley

Scope and Objective

This project will produce a workshop that will bring together key individuals and organizations working on current issues centered on improvements to transportation system efficiency. The workshop will focus on light-duty engine technology and associated fuel effects for in-depth technical discussions.

Current Status and Future Program

A preliminary test plan was reviewed by the project panel. A poll of Committee members requesting their input on the areas of most interest yielded additional information, and following further discussion, the project leaders are preparing an expanded plan with more specific details on a workshop to be held in early 2014.

DATA MINING OF FACE DIESEL FUELS

CRC Project No. AVFL-23

Leaders: W. J. Cannella
C. Fairbridge

Scope and Objective

This study will be done in cooperation with Natural Resources Canada (NRCan). This project will look at engine performance using FACE fuels as related to combustion efficiency.

Current Status and Future Program

A work statement is being prepared for review.

AVFL

FACE GASOLINE ETHANOL BLEND TESTING

CRC Project No. AVFL-24

Leaders: W. J. Cannella
J. Dolch

Scope and Objective

This project will evaluate the impacts on fuel properties including octane number when ethanol is blended with fuels from the hydrocarbon-only FACE gasoline fuel matrix.

Current Status and Future Program

Funding was authorized for supplemental support by the CRC Board of Directors. A subset of the FACE gasoline fuels representing a wide range of properties spanned by the fuel matrix have been selected for blending experiments. The test blends will be prepared and submitted for property analysis. Data analysis will be conducted to determine the blending effects of ethanol on the various FACE gasoline samples.

AVFL LUBRICANTS PANEL

CRC Project No. AVFL-25

Leader: T. Kowalski

Scope and Objective

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.

Current Status and Future Program

The AVFL Committee organized a panel of engine lubrication experts from industry that serve as a resource for committee projects. The AVFL Lubricants Panel may also develop studies focused directly on lubricant impacts beginning in 2014.

AVFL

GASOLINE FUEL PROPERTIES IMPACT ON FUTURE ENGINE DESIGN

CRC Project No. AVFL-26

Leader: M. B. Viola

Scope and Objective

The AVFL 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 working group. With this task completed, the committee is investigating needs for future fuel investigations.

Current Status and Future Program

The AVFL Committee has initiated a planning process to identify key factors that should be evaluated for the next generation of research test fuels. Surveys have been 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 may result in specific projects within the committee in 2014. Either in-kind projects under the FACE Working Group or funded projects conducted by the main AVFL committee will be considered.

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 DOE, NREL, ORNL, and 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 initial collaboration expanded to include scientists and engineers from SNL, LLNL, and PNNL, as well as Natural Resources Canada (NRCan), CanmetENERGY, and private laboratories Battelle, Ricardo, and AVL.

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 from the Chevron Phillips Chemical Company, LLC (CPChem). Extensive characterization work has been performed by laboratories participating in the working group; a summary of standard analyses is available from the CRC website. The Final Report, “FACE-1 Chemical and Physical Properties of the Fuels for Advanced Combustion Engines (FACE) Research Diesel Fuels,” has been published 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.

AVFL

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 and AVFL-19.

AIR TOXICS WORKSHOP

Project No. A-45d

Leaders: S. Japar
R. S. MacArthur

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.

Current Status and Future Programs

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.

The most recent workshop was held on February 4-6, 2013 at Cal-EPA Headquarters in Sacramento, CA. Dr. Steven Japar, under contract to CRC, helped organize the latest workshop with the aid of the previous organizing committee participants (see the A-45d panel members under Membership). Dr. Japar and the organizing committee developed the technical program and identified speakers. The proceedings of the 2013 workshop, including a summary review, have been posted to the CRC website. A separate journal article summary was published in May 2013 by *EM* (the Magazine for Environmental Managers).

ATMOSPHERIC IMPACTS

CONCEPT/CAMX MODELING OF EXPANDED USE OF RENEWABLE FUELS

CRC Project Nos. A-73-1 and A-73-2

Leaders: S. Collet
R. S. MacArthur

Scope and Objective

The committee proposed a new approach for performing air quality modeling of intermediate level ethanol blends using emissions data from CRC and other related studies by applying a method initially demonstrated in Project A-67. This modeling approach is application of the emissions modification model CONCEPT integrated with CAMx as the grid modeling tool (CONCEPT/CAMx).

Current Status and Future Programs

The committee approved a work statement for the project in 2009. The project was divided into two main efforts to be developed in parallel to meet the overall project objectives of demonstrating the CONCEPT/CAMx modeling tool:

1. A-73-1, "Protocol for Analyzing Data and Developing Inputs to the CONCEPT Emission Model for Representing Ethanol Blends."

2. A-73-2, "Perform CONCEPT/CAMx Modeling of Expanded Use of Renewable Fuels."

The Committee and Working Group selected contractors to work on each project – Sierra Research Associates for Project A-73-1 and Alpine Geophysics for Project A-73-2. Sierra Research completed its survey of emissions data under A-73-1 and delivered the Task 1 Literature Survey. A project work plan for A-73-2 by Alpine Geophysics was approved by the committee. A-73-1 and A-73-2 continued through 2011 due to a delay in release of important data on the impacts of intermediate-level ethanol blends on new vehicle emissions. Regular communication meetings were held with Sierra Research and Alpine Geophysics to aid progress and assist in final data collection.

Initial plans to incorporate the MOVES model under CONCEPT were reassessed due to unanticipated complexities of this tool in a combined modeling package. It was determined that the SMOKE model would be required to complete all the contemplated modeling work scope. The modeling suite for the project therefore was changed to CAMx/SMOKE.

Fuel adjustment factors (FAF) and final speciated emissions data for E10 and E20 blends updated with CB5 chemistry were provided by Sierra Research to Alpine Geophysics in 2012.

The A-73-1 Final Report was approved by the Committee in May 2012 but was not released until a related NREL statistical report prepared by Richard Gunst was published in May 2013. Additional delays in A-73-2 are now pointing towards the committee electing to take an entirely new approach for work in this general topic area.

ATMOSPHERIC IMPACTS

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 compounds (SOA) generated in the atmosphere via dilution and chemical reactions. The main project objective includes obtaining sufficient definition of the relationship between SVOC and SOA to model the behavior in the atmosphere. The project is also sponsored by EPA and CARB. This project has application to both the Atmospheric Impacts Committee 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 have been prepared and reviewed by the CRC committees for final documentation covering all work conduced through Phase 3 of the project. Two of the draft articles were reviewed and approved for publication early in 2013. CRC committee members reviewed and approved the additional five draft articles in summer 2013. Two additional journal articles are in the preparation stage.

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.

The Final Report for Phase 1-3 will be comprised of a complete set of the journal articles generated from this part of the study along with an Executive Summary. The Final Report for the Phase 4 work will also be comprised of all related journal articles and an Executive Summary covering this segment of the program.

ATMOSPHERIC IMPACTS

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 to be 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.

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 VMT 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.

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. The A-76-1 project was initiated in April 2011 and completed in January 2012. A draft journal article was submitted to *Atmospheric Environment* and the final approved A-76-1 article was published and made available on the CRC and *Atmospheric Environment* websites.

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 examines ozone and PM levels and benefits from existing emissions controls and other possible future controls. The Phase 2 effort includes a data analysis component in addition to emissions and air quality modeling. Tasks include analysis of Atlanta 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 to include a journal article and 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. has been published and is now available on the CRC website. ENVIRON also prepared a draft journal article on statistical analysis of trends in mobile emissions and air quality in Atlanta.

The committee elected to initiate the third phase (A-76-3) in December 2012. The third phase extends the evaluation on the air quality impacts of a gasoline light-duty vehicle (g-LDV) 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.

ATMOSPHERIC IMPACTS

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 includes:

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 develop details of the above chapters and to 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. This manuscript will be revised based on committee review and converted to the format required for submission to Oxford University Press for publication.

ASSESSMENT OF NEAR-ROADWAY NO_2 CONCENTRATIONS

CRC Project No. A-79

Leaders: S. Collet
M. Koerber

Scope and Objective

The objective of this study is to establish a baseline dataset from two year-long studies that can be used by federal, regional, and state agencies to understand the range of concentrations of NO_2 emissions near roadways as a function of traffic load and weather conditions.

Current Status and Future Programs

The project was started in 2012 to evaluate data collected in recent near-road air quality studies to document ambient levels of NO_2. A contract was established with Sonoma Technology (STI) to report on data available from studies in Las Vegas and Los Angeles. The Los Angeles dataset was provided by SCAQMD. A Las Vegas dataset for this project was immediately available. Additional data collected in Las Vegas were also being evaluated by FHWA and EPA. Preliminary conclusions were presented to the committee and working group members at the summer 2012 committee meeting. STI completed the study and the Final Report was published in November 2012. STI also reported results from this study at the 2013 CRC MSAT workshop.

ATMOSPHERIC IMPACTS

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 will be 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. Project A-80, "Speciation of EPAct Test Fleet Exhaust Emissions," 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 has been completed and statistical analysis is underway. A draft final report is in preparation.

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 and 2011, 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; N-recycling from organic nitrates to NOx. An example application is that product yields for organic nitrates currently are temperature-independent. If mechanism predictions are sensitive to organic nitrate yields, temperature effects may need to be considered.

The implementation of DDM for PM in CAMx is not complete yet. Because the release date of the revised model is not certain, the contractor will focus on the chemistry of ozone formation. However, if DDM for PM is completed early within this project, then the options for including work on PM may be included. 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

The final report will be a manuscript submitted for publication in a peer-reviewed journal. An executive summary will be prepared for CRC. Results that are too lengthy to include in the manuscript will be provided as supplemental material to the manuscript. A contract award for Project A-83 was given to ENVIRON during the second quarter of 2013. ENVIRON expects to complete the project draft report in the first quarter of 2014.

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 will require extensive knowledge of the MOVES 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.

Current Status and Future Programs

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, will be critical to achieving the goals in A-84.

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. 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 will compare MOVES input data submitted by the states for the 2011 NEI to current best practice, and perform in-depth comparison of the submitted data across states, and with MOVES defaults, to understand the magnitude of difference in the submissions and the implications on inventory estimates. Following from this, Task 2 will perform MOVES sensitivity runs to assess the impact the state submissions have on MOVES emissions, relative to default inputs. Task 3 will discuss 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 is a reporting task which will produce documentation as directed by CRC. ERG will prepare 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 will produce a final report that is ready for submission to a journal. ERG will also deliver in electronic format the MOVES run specification files, and MySQL input and output databases used for Task 2.

The project began in the second quarter of 2013 when a final set of state-submitted inputs became available to begin analysis. As ERG is supporting EPA in quality assuring the inputs is was possible to get an early start on the data analysis. ERG projects the work could be completed within 3 months. The project should conclude no later than December 2013. A draft publication on Task 1-2 efforts has been prepared for submission to Transportation Research Board (TRB) annual meeting.

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.

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 is 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 will be explored. An SOW for this project is currently under preparation.

ATMOSPHERIC IMPACTS

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 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 is currently coordinating support work under the Phase 2 of the AQMEII program with EPA and JRC. ENVIRON was selected to assist in evaluating modeling results from AQMEII Phase 2 by supporting the current effort being led by JRC.

NATURAL GAS FUEL SURVEY

Project No. PC-2-12

Leader: J. J. Jetter

Scope and Objective

The objective of this program is 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 will be used 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 include:

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

Current Status and Future Programs

After a competitive solicitation, this project was awarded to SwRI. The American Gas Association (AGA) has provided co-funding and technical participation. This project is ongoing, with testing expected to begin in late 2013.

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

Engine Durability for Intermediate Ethanol Blends

A Request for Proposal was released by CRC in February 2009 for a new study to evaluate the potential effect of mid-level ethanol blends in the U.S. LD vehicle fleet. Objectives of the test program are to determine engine durability effect of mid-level ethanol blends (e.g., E20, E15) on a group of engines from vehicles that may be considered sensitive to the effects of mid-level ethanol blends. Test fleet selection was determined cooperatively by CRC member companies and original equipment manufacturers (OEMs).

The approach consisted of laboratory testing of eight vehicles, following an OEM engine test cycle to test for engine durability in an accelerated manner. Accelerated testing is standard practice in the automotive industry to reduce test time and reveal possible failures. FEV performed this project. The Final Report, CM-136-09-1B, "Intermediate-Level Ethanol Blends Engine Durability Study," was posted on the CRC website in May 2012.

Gasoline Engine Intake Valve Deposit Testing

ASTM D5500 is the test for certifying additives to protect against Intake Valve Deposits (IVD) recognized by EPA. CARB has a separate test and there is also a 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 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 oil and Syncrude being used. Changes in engine technology include hybrids, FFVs, DISI, turbo boost, downsizing, and VVT. Ethanol use has also dramatically changed. The current test platforms, 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 considering 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 new 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 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 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

2009/2010 CRC/ASTM TVL20, T50 EtOH Volatility

This project was conducted in cooperation with ASTM to determine, for two cool ambient temperature conditions below 5,000 feet altitude, the effect on hot-fuel-handling driveability performance of these fuel variables:

- the front-end volatility parameter involving the temperature for a vapor-liquid ratio of 20 (TVL20),
- the 50% evaporated distillation point,
- the ethanol content.

The study was conducted on a large group of late model vehicles equipped with fuel injection systems. Testing was conducted at SwRI in fall 2009, but due to delays caused by weather conditions was not completed at that time. Steps were taken by one of the project sponsors to cost-effectively maintain the current fleet throughout the project delay.

Funding to complete the first phase in spring 2010 was obtained, and testing was reinitiated at SwRI in April 2010 and completed in June 2010. Data analysis was completed and results were published in CRC Report No. 658, "2009-2010 CRC/ASTM Hot-Fuel-Handling Program (For Classes D-4 and E-5 Gasoline)" in October 2010. The second phase to test summer fuel blends under hot ambient conditions is under development for consideration by CRC.

2009/2010 Low T50 High Altitude Hot-Fuel Handling

This study determined the effects of TVL20, 50% evaporated distillation point (T50), and ethanol content up to 20 vol % on hot-fuel-handling driveability performance at high altitude (5000+ft.) under hot ambient temperature conditions in a fleet of 20 late model vehicles. This was a follow-on program to the 2006 CRC Hot-Fuel-Handling Program (CRC Report No. 648). The test site for this program was Pueblo, CO at the Transportation Technology Center, Inc. (TTCI) facility. Testing was conducted in July-August 2010. The test fuel matrix for this program was approved in 2009, and invitations for participation were issued to interested parties. Several contractors were hired to assist in conducting the field program.

The project was supported with supplemental funding from NREL, RFA, and Suncor. Primary support contractors for the project included TTCI and Gage Products (for test fuels). The data analysis and draft report were reviewed by the project panel and the Final Report was released for publication as CRC Report No. 659 and is now available on the CRC website.

2013 Intermediate Temperature E15 Cold-Start and Warm-up Driveability Program

The objective of this new project is to determine an accurate ethanol offset for the Driveability Index equation in ASTM D4814, "Specification for Automotive Spark-Ignition Engine Fuel" covering ethanol contents from 10 to 15 volume percent.

The U.S. EPA 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 27 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.

Growth Energy provided funding for this project. Testing was performed in February and March of 2013. The draft final reports are in development.

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

The objective of this new program is to simultaneously evaluate hot-fuel-handling driveability of current ASTM D4814 vapor pressure, T50, and vapor lock protection class limits for late model year (2005 – 2013) and if practical some older conventional vehicles. Further, to assess the effects of high volatility gasoline on cold start performance (50°F) of a subset of Gasoline Direct Injected (GDI) vehicles. Other objectives are to determine a correlation between all-weather chassis dynamometer and road (outdoor) hot-fuel-handling driveability ratings and to determine a correlation between CRC hot-fuel-handling driveability ratings and AVL-DRIVE™ System auto-ratings.

Recent CRC Performance Committee reports (Nos. 658 and 659) detail the effects of D4814 Class D and E gasoline T50, TVL20, and ethanol content effects on vehicle hot-fuel-handling driveability, both at sea level and altitude. To further understand Class D and E volatility effects on modern vehicle hot-fuel-handling performance, an additional hot-fuel-handling vehicle driveability study is planned that will set the vapor pressure (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 will be held as constant as reasonably possibly from blend to blend and consistent with the U.S. gasoline market. The test fuels will contain 10 volume percent ethanol (E10), but blends containing 15 volume percent ethanol (E15) could be included, if funding is available and testing of these fuels is deemed necessary. Forty vehicles will be screened to obtain 18 responsive vehicles (6 PFI 1998 – 2005, 6 PFI 2005 – 2013, and 6 GDI 2013).

In addition, tests will be conducted to further understand how the maximum volatility gasoline fuel affects the GDI engine types while cold starting at 50°F during "open loop - cold start" conditions. There is a need to develop new driveability test methodology; a small 6 – 8 vehicle hot-fuel handling driveability program will be conducted to evaluate the correlation between the driveability ratings measured during the classic CRC outdoor test track maneuvers and driveability ratings obtained in a heat-soaked vehicle chassis dynamometer facility. The AVL-DRIVE System showed a promising correlation with trained driveability raters in the 2013 program. Ten model year 2013 vehicles will be instrumented with the AVL-DRIVE System and evaluated in a cold-start and warm-up driveability program.

Detailed planning is underway, but funding is not yet available.

2011 Mathematical Prediction of Flammability of Ethanol-Containing Fuels

This contract program predicted the vapor flammability of various ethanol-gasoline blends using well validated modeling techniques. With the increased interest in mid-level ethanol blends and the introduction of blending pumps, concern has been raised about the safe handling, distribution, and storage of such blends. The blends covered in the study included E10, E15, E20, E30, E40, E50, E85, and E100. Equations and/or nomographs were developed for estimating the flammability temperatures of ethanol-gasoline blends as a function of vapor pressure.

Funding for this contract study was provided by Growth Energy and the Renewable Fuels Association. The Final Report, released in September 2011 as CRC Report No. 661, is available on the CRC website.

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

The objective of this new project is to determine the incremental change in risk due to a change in fuel composition (higher levels of ethanol). The benchmark will be 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 will include the tanker truck driver loading/blending/delivering blends such as E51, E83, and E98 and, ultimately the consumer dispensing E10 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 an unintended consequence (e.g., a fire) to occur. A risk analysis/hazard assessment is required to fully judge the

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safety implications, if any, of the introduction of these new fuel blends into the hands of the public.

After a competitive solicitation, the project has been awarded to AcuTech and is underway. NREL is providing co-funding for this project.

The subcontractor was engaged to survey the literature to determine what gasoline-ethanol blends can create and hold sufficient static during product transfers activities which promote static generation. The subcontractor will work with the Risk Assessment/Hazard Analysis (RA/HA) team to define possible service station 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 will be developed that can be used to facilitate a semi-quantitative risk analysis. The analysis will be used to determine the adequacy of any existing safeguards on current fuel handling/dispensing systems.

This analysis will 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 will not be considered.

This project is ongoing, with reporting anticipated in 2014.

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. Initial funding was made available from 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.

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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 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:

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

Current Status and Future Programs

<u>Biodiesel/Low Temperature Operability</u>

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. Conventional diesel, B5, and B20, as well as cold flow additives are being evaluated. The program has two phases. Phase 1 is a laboratory bench testing to simulate weekend cool-down and warm-up 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 phase has been completed. The draft report is in development.

Phase 2 has been funded by CRC and will duplicate the laboratory experience in LD (and perhaps some HD) vehicles to verify any issues identified in the laboratory test work. The same or similar fuels would be used. Low temperature operability limits would be determined for the fuel/vehicle combinations. Tests then would be repeated with simulated overnight and weekend heating/cooling cycles to compare results.

A competitive solicitation process was completed. Negotiations with the contractor are ongoing in order to match the work plan with the budget. Testing is expected to start in late 2013.

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 (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 startability
        - 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
        - Evaluates malfunctions over a 104-second driving cycle repeated 12 times
- Ambient and one low temperature, preferably -30°F.

This program has been allocated CRC funding to commence the scoping study. Details of the work plan are currently being discussed.

Diesel Deposits

This panel operated with 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 are as follows:

- Data Analysis and Recommendations
- Bench/Rig/Engine Investigation; Na-Soap Deposits
- Engine Investigation

The data analysis sub-panel's goal is 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 has prepared a final report that is in review by the Diesel Performance Group.

Sub-panel 2 is 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.

An initial scoping study at no cost to CRC 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 deposit-forming and EPA non deposit- forming diesel, CARB diesel assumed not to form deposits, and an EPA diesel that was formulated to cause deposits.

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. Tests were conducted in the later part of 2012. Results were encouraging. Details of the Delphi rig evaluation were reviewed in late March 2013. A final report for this research will be available shortly.

The ultimate goal of this effort is to establish an industry-standard tool that can evaluate and discriminate among fuels and additives. One approach is the use of an engine on a test stand, similar to what is being pursued in Europe by the CEC. 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

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.

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, as related to fuel cleanliness, that are outside the defined fuel properties in existing CRC DPG panels and that have relevance from the point of diesel production to the point of customer use.

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The initial goal is to generate a single CRC guide to compile best available current knowledge 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. This effort has been on a volunteer basis so far with no CRC funding. The draft report is near completion. Focused programs are being discussed for future activity.

PART THREE

RELEASED REPORTS

RELEASED REPORTS - 2013

AIR POLLUTION & ADVANCED TECHNOLOGY*

CRC Project No.	Title	NTIS Accession No.
A-45	Highlights from the Coordinating Research Council's 2013 Mobile Source Air Toxics Workshop	*EM Magazine* (2013) p. 26-29
A-73-1	Development of Inventory and Speciation Inputs for Representing Ethanol Blends	PB2013-107743
A-74	Gas-particle partitioning of primary organic aerosol emissions: (1)Gasoline vehicle exhaust	*Atmospheric Environment* Volume 77, (2013) p. 128-139
A-76-1	Effects of light duty gasoline vehicle emission standards in the United States on ozone and particulate matter	*Atmospheric Environment* Volume 60, (2012) p. 109–120
A-76-2	Effects of Light-duty Vehicle Emissions on Ozone and PM with Past, Present, and Future Controls: Tier 0 versus Other Scenarios	PB2013-107071
A-79	Assessment of Near-Roadway NO2 Concentrations	PB2013-102731
AVFL-15a / CRC Report No. 664	Durability of Fuel Pumps and Fuel Level Senders in Neat and Aggressive E15	PB2013-104945
AVFL-16	Fuels to Enable Light-Duty Diesel Advanced Combustion Regimes	PB2012-114618
AVFL-19-1	Detailed Characterization of the Physical and Chemical Properties of the Reformulated FACE Diesel Fuels: FD2B, FD4B, and FD7B	PB2013-104927
AVFL-19-2	Advanced Alternative and Renewable Diesel Fuels: Detailed Characterization of Physical and Chemical Properties	PB2013-108435

RELEASED REPORTS - 2013

AIR POLLUTION & ADVANCED TECHNOLOGY (Continued)*

CRC Project No.	Title	NTIS Accession No.
E-90-2b	Effects of Ethanol Blends on OBDII Systems of In-Use Vehicles	Pending
E-83	Effects of Olefins Content on Exhaust Emissions	PB2012-112208
E-83	Impact of Olefin Content on Criteria and Toxic Emissions from Modern Gasoline Vehicles	*Fuel* Volume 107, (2013) p. 671–679
E-89	EPAct/V2/E-89: Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles Certified to Tier 2 Standards	EPA Report # EPA-420-R-13-0004
E-90-2b	Impact of Ethanol Blends on the OBDII Systems of In-Use Vehicles, Phase 1 Interim Report	PB2013-103272
E-91	Evaporative Emissions Durability Testing	PB2013-101351

RELEASED REPORTS - 2013

AVIATION & PERFORMANCE*

CRC Project No.	Title	NTIS Accession No.
AV-1-10	Update of the Survey of Sulfur Levels in Commercial Jet Fuel	PB2013-102768
CM-137-11-1b	Review To Determine the Benefit of Increasing Octane Number on Gasoline Engine Efficiency Analysis and Recommendations Tasks 2-5	PB2013-104696
DP-04	Scoping Study to Evaluate Two Rig Tests for Internal Injector Sticking	PB2012-114348
DP-04-13b	Internal Injector Deposits: A Scoping Study to Evaluate the Delphi Test Rig	Pending

*The primary source for the CRC Air Pollution, 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

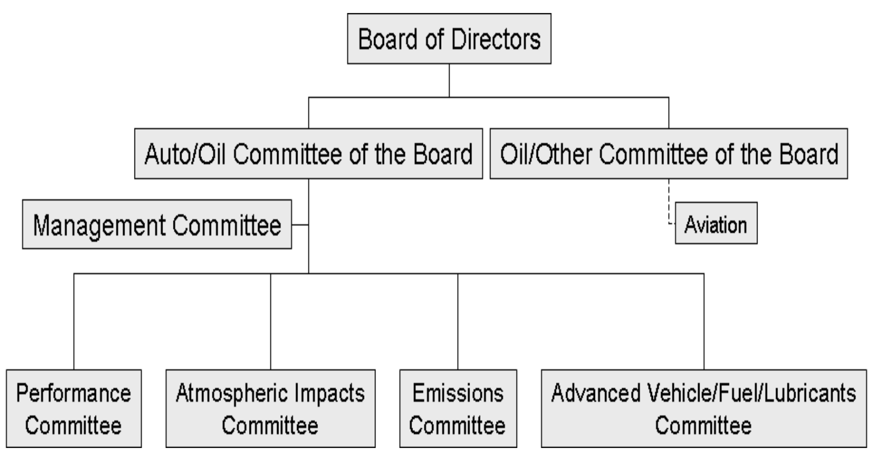
ORGANIZATION AND MEMBERSHIP

ORGANIZATION – 2013

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 71 years, CRC has provided the means for the automotive and petroleum industries to study problems of mutual interest. CRC's objective, as stated in our charter, is:

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

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



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

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

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

CRC has two basic types of research programs:

Cooperative research programs -- where scientists from various organizations come together to conduct cooperative research. This method utilizes the expertise from industry, government, and academia to develop and conduct experimental research programs. The results of these programs are 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. Once again, 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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E-97 PANEL

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A-74/E-96 PANEL

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GASOLINE DEPOSIT GROUP
(Project No. CM-136)

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A. K. Ghosal	Shell	F. Parsinejad	Chevron Oronite Co.
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A. K. Jung	BASF Corp.	W. Y. Su	Huntsman Corp.
V. L. Kersey	Valvoline Co.	R. D. Tharby	Tharby & Associates
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D. H. Lax	API	L. Webster	Nissan Tech. Ctr. NA
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(Project No. CM-136-09-1B)

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K. D. Eng	Shell Global Solutions	J. Mount	Phillips 66
K. Freund	Volkswagen of America	W. J. Most	Fuel Tech. Assoc.
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L. M. Gibbs	Consultant	D. Patterson	Mitsubishi Motors R&D Am.
M. Herr	Ford Motor Co.	C. Richardson	Ford Motor Co.
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J. J. Jetter	Honda R&D Am.	W. Studzinski	General Motors
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D. Lancaster	General Motors	M. Valentine	Toyota Technical Ctr.
D. H. Lax	API	M. Watkins	ExxonMobil
M. E. Leister	Marathon Petroleum Co.	L. Webster	Nissan Tech. Ctr. NA
S. Lindholm	Shell	A. Williams	NREL
S. A. Mason	Phillips 66	J. Williams	API

OCTANE GROUP
(Project No. CM-137)

J. J. Simnick, Ldr. BP

B. Alexander	BP	S. A. Mason	Phillips 66
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R. Chapman	Innospec Fuel Spec.	K. Moore	Renewable Fuels
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K. D. Eng	Shell Global	C. M. Pyburn	Pybertech International
B. Evans	Evans Research	R. Reynolds	Downstream Alternatives
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T. Frank	Lubrizol Corp.	D. Schoppe	Intertek
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P. Geng	General Motors	R. Osman	Flint Hills Resources
G. C. Gunter	Phillips 66	R. Reynolds	Downstream Alternatives
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(Project CM-138-11-3)

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C. Richardson	Ford Motor Co
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J. E. Carter	Haltermann Products
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R. Chapman	Innospec Fuel Spec.
D. A. Daniels	Innospec Fuel Spec.
J. Draper	Nalco
T. Frank	Lubrizol Corp.
K. Freund	Volkswagen of America
R. Gault	EMA
R. George	BP
G. C. Gunter	Phillips 66
C. Hamer	PCS Instruments
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E. Izor	Denso
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N. Kuzhiyi	GE
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H. Martin	Fleetguard / Cummins
R. L. McCormick	NREL
R. Mills	Chevron
K. Mitchell	Shell Canada
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J. Porco	Gage Products
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G.C. Gunter	Phillips 66	K. Mitchell	Shell Canada Products
P. Henderson	GM Powertrain	M. Nikanjam	Chevron Products Co.
D. Hess	Infineum	W. Studzinski	General Motors
S. Howell	National Biodiesel Bd.		

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(Project No. DP-3)

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G.C. Gunter	Phillips 66	W. Studzinski	General Motors
J. J. Jetter	Honda R&D Am.	J. T. Talbert	Shell Global Solutions
S. I. Johnson	Volkswagen of America	W. Woebkenberg	Daimler
T. Livingston	Robert Bosch		

DP - CETANE NUMBER PANEL
(Project No. DP-3)

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T. Frank	Lubrizol Corp	M. Nikanjam	Chevron Products Co.
R. George	BP	J. Y. Sigelko	Volkswagen of America
G. C. Gunter	Phillips 66	W. Studzinski	General Motors
J. J. Jetter	Honda R&D Am.	J. T. Talbert	Shell Global Solutions
S. I. Johnson	Volkswagen of America	W. Woebkenberg	Daimler
T. Livingston	Robert Bosch		

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(Project No. DP-4)

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D. Arters, Co-Ldr. — Lubrizol

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R. Chapman	Innospec Fuel Spec.	R. Mills	Chevron
H. DeBaun	Navistar	M. Nikanjam	Chevron Products
T. Frank	Lubrizol Corp.	R. Osman	Flint Hills Resources
R. Gault	EMA	J. D. Parsons	Caterpillar
R. George	BP	J. Rutherford	Chevron
B. E. Goodrich	John Deere	W. Studzinski	General Motors
G. C. Gunter	Phillips 66	T. Talbert	Shell
J. J. Jetter	Honda R&D Am.	C. Trobaugh	Cummins
S. R. Kirby	Navistar, Inc.	M. Valentine	Toyota Technical Ctr.
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(Project No. DP-06-13)

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J. Frusti	Chrysler	J. J. Simnick	BP
L. M. Gibbs	Consultant	W. Studzinski	General Motors
S. A. Mason	Phillips 66	M. Valentine	Toyota Technical Ctr.
P. W. Misangyi	Ford Motor Co.	L. Webster	Nissan Tech. Ctr. NA
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