# CRC

## ANNUAL REPORT

## 2019

COORDINATING RESEARCH COUNCIL, INC.

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**September 2019**

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

# STATE OF THE COUNCIL

# STATE OF THE COUNCIL - 2019

In 1919, a technical committee was formed for the purpose of cooperative research between the automotive and energy industries, government scientists, and academia. That Committee became the Coordinating Research Council in 1942. A century after this beginning, CRC continues to provide a forum and process for industries to work together on joint research of mutual interest, and encourages cooperation and communication on research between industries, governments, and the scientific community at large. The operation of the Council has evolved to meet the needs of this community, and currently includes four Automotive-focused Committees, an Aviation Committee, and a multitude of active Working Groups and Technical/Advisory Panels.

CRC technical work during the 2019 research program year, as in years past, includes broad cooperation on research projects and in technical workshops. Research partners in 2019 span the stakeholder community, including: the U.S. Environmental Protection Agency (EPA), the California Air Resources Board (CARB), the Health Effects Institute (HEI), the South Coast Air Quality Management District (SCAQMD), the Truck and Engine Manufacturers Association (EMA), the U.S. Department of Agriculture (USDA), many of the U.S. Department of Energy (DOE) National Laboratories, Trade Organizations, individual equipment manufacturers, and representatives of alternative/emerging fuels and technologies.

CRC technical reports are approved by the committees and research partners that oversee the research, and are then made available on the CRC website, www.crcao.org. Select research projects conducted by CRC are also reported in the peer-reviewed literature. Workshop summaries and, if available, proceedings are also made available. Brief highlights from the technical committees' efforts in the last year are summarized as follows:

The CRC Emissions Committee and the associated Real World Group reported on ongoing efforts to improve emissions measurements techniques, and the effects of new fuels or fuel properties on vehicle emissions. Results continue to be reported from the multi-decade study of in-use automobile fleet emissions levels. This Group held the 29$^{th}$ Real World Emissions Workshop in Long Beach, CA which set yet another attendance record, and was supported by sponsorship from government and industry. The 30th event will be held on March 15-18, 2020, in San

Diego, CA. The 6th 2017 CRC Life Cycle Analysis of Transportation Fuels will be held on October 15-17, 2019, hosted by the US DOE Argonne National Laboratory and again co-sponsored by a broad list of stakeholders.

The Advanced Vehicle/Fuel/Lubricants (AVFL) Committee published research on autoignition of diesel fuel surrogates in a rapid compression machine, one aspect of a large multi-year study in partnership with several of the US DOE National Laboratories.

The Atmospheric Impacts Committee published reports and journal articles this year that improve the knowledge on source apportionment, the effects of emissions reductions, the projected changes in pollutants in the atmosphere, and information to improve the state of the art in atmospheric modeling. Additionally, the biennial Mobile Source Air Toxics (MSAT) Workshop was held February 4-6, 2019 in Sacramento, CA hosted by CARB.

The Performance Committee reported on a review of recent technical literature on low-speed pre-ignition, and updated an analysis from the 1960s on temperature data to assist the ASTM. The development of a car to train human raters was documented. From the Committee's Diesel Performance Group, the results of a study exploring the effects of fuel parameters on diesel injector deposit formation was published, a milestone in years of effort on this topic.

The Aviation Committee published the results of measurements and analysis of the heat of vaporization and enthalpy for common jet fuels.

Details on these completed studies and ongoing CRC committee 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

## CRC WORKSHOP ON LIFE CYCLE ANALYSIS OF TRANSPORTATION FUELS

CRC Project No. E-93-6

Leaders: R. De Kleine
J. Han
A. Levy

### Scope and Objective

CRC has hosted five biennial, invitation-only Life Cycle Analysis (LCA) workshops, starting in 2009. The 2009, 2011, 2013, 2015, and 2017 workshops held in October at Argonne National Laboratory (ANL) near Chicago were each attended by more than 100 LCA experts from government, industry, academia, and non-governmental organizations (NGOs). Workshop summaries are posted on the CRC website. The sixth workshop is being planned for October 15-17, 2019 at ANL.

### Current Status and Future Program

This year's workshop organizing committee includes representatives from American Petroleum Institute (API), ANL, CARB, Conservation of Clean Air and Water in Europe (Concawe), U.S. DOE, U.S. EPA, National Biodiesel Board (NBB), Natural Resources Canada, USDA, Ford Motor Company, Chevron Global Downstream, Phillips 66, Oak Ridge National Laboratory, Renewable Fuels Association (RFA), Marathon Petroleum Company LP, Neste, ExxonMobil Research & Engineering, the European Joint Research Center's Institute for Environment and Sustainability, the Union of Concerned Scientists, and the International Council on Clean Transportation (ICCT). The 2017 workshop sponsors included API, ANL, CARB, Canadian Fuels Association, Concawe, NBB, RFA, USDA, University of Michigan Energy Institute, and the Union of Concerned Scientists. Neste and the DOE are welcomed as a new sponsors in 2019.

**EMISSIONS COMMITTEE**

The current workshop goals are to:

- Outline technical needs arising out of policy actions and ability of LCA 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 and 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.

Past workshop proceedings and summary articles can be found on the CRC website.

Sessions at the 6$^{th}$ Workshop in October, 2019 will include technical presentations on Transportation Fuel Policy, Liquid Petroleum Fuels, Recent Modeling of Crop-Based Biofuels, Examining Counterfactual Scenarios, Advanced Liquid Fuel Pathways, and Electrical Pathways.

## REAL WORLD VEHICLE EMISSIONS WORKSHOP

CRC Project No. E-110

Leaders: D.M. DiCicco
S.A. Mason

### Scope and Objective

For nearly three decades, CRC has held an annual vehicle emissions workshop, gathering international experts in the field of vehicle/engine emissions to discuss the latest activities in modeling, measurement, and analysis.

### Current Status and Future Program

The 29th Real World Emissions Workshop, held in Long Beach, CA on March 10-13, 2019, consisted of 52 technical presentations, 54 posters, and 9 demonstrations. In addition, two Keynote addresses were given by Christopher Cannon, Director of Environmental Management at the Port of Los Angeles, and Kurt Karperos, Deputy Executive Officer at California Air Resources Board. A record number of 268 participants from 13 countries attended. Co-sponsors for the Workshop were CARB, EPA, NREL/DOE, and SCAQMD.

A summary journal article on the research reported at the 29th Workshop authored by the Organizing Committee, was published in the July, 2019 edition of EM Magazine of the *Air and Waste Management Association,* and a link to the article is available on the CRC website.

The 30th Workshop will return to the Hyatt Regency Mission Bay in San Diego, California, March 15 - 18, 2020 for the Anniversary year.

## EMISSIONS COMMITTEE

### COMBUSTION AND EMISSIONS CHARACTERISTICS OF A LIGHT-DUTY VEHICLE OPERATING ON A HYDROGENATED VEGETABLE OIL RENEWABLE DIESEL

CRC Project No. E-117

Leaders: J. Cruz
D.Z. Short

#### Scope and Objective

Recently, renewable diesel fuel has been offered at 32 stations within California. This fuel has a much higher cetane number of 70-95 compared to the average Ultra Low Sulfur Diesel (ULSD) cetane number of 40-45. In addition, the fuel has a different energy density, distillation, hydrocarbon content, and viscosity compared to the average ULSD fuel in the U.S. market.

Hydrogenated vegetable oil (HVO) renewable diesel has been introduced into the market in response to Renewable Fuel Standard (RFS) and Low Carbon Fuel Standard (LCFS) requirements for more renewable fuels. There is a poor understanding of how this particular type of renewable fuel may influence a change in either the combustion process or the emissions from an engine relative to operation on a conventional petroleum-based ULSD fuel.

#### Current Status and Future Program

This study aimed to determine the effects of a commercially available renewable diesel fuel on the engine-out gaseous and PM emissions of a light-duty vehicle. In addition, engine combustion characteristics associated with the use of renewable diesel fuel were measured.

This project was awarded to University California, Riverside's Center for Environmental Research and Technology (CE-CERT) in 2017. The Final Report was published on the CRC website in July 2019.

## LIGHT-DUTY PORTABLE EMISSIONS MEASUREMENT SYSTEM - PHASE TWO

CRC Project No. E-122-2/ E-122-2a/ E-122-2b/ E-122-2c

Leaders: M.B. Viola
P. Loeper

### Scope and Objective

With Europe adopting the use of portable emissions measurement systems (PEMS) to determine light-duty real world emissions, there is a greater interest in the functionality and use of these systems.

The objective of Project E-122-2 is to understand PEMS performance in measuring changes during on-road and chassis-roll tests. The on-road cycle developed in CRC Project E-122, which incorporates city, urban and highway driving, will be used. Several engine technologies are represented in the test fleet, which will be tested with different fuel properties to investigate how well PEMS can detect fuel property impacts on emissions. Summer and Winter fuels, each having a low and high Particulate Matter Index (PMI), as described by the Honda method, will be used for testing. A total of four fuels will be run on each of four vehicles multiple times to understand the variation in emissions that occur and how they change on the same route on a daily basis. A PEMS will be used to measure the tailpipe emissions. Repeat testing will be conducted on a chassis-dynamometer for comparison to the PEMS unit, which will also measure emissions at the same time on the chassis roll for direct comparison. Specific goals of this project include determination of:

- Repeatability of the chassis roll testing to compare to the PEMS unit;
- Repeatability and accuracy of PEMS unit under real on-road driving conditions and changing ambient temperatures;

- PEMS ability to measure differences in gaseous and PM emissions with respect to changes in PMI and/or Vapor Pressure (VP) of the fuel; and,
- How exhaust flow measurement from the individual PEMS system correlates with the direct vehicle exhaust flow meter from the test cell and with the CVS bags based on $CO_2$.

To make certain the testing data collected would be suitable for statistical analysis, a statistician (CRC Project E-122-2a) developed the test matrix for this project, defining how many:

- Tests to conduct on each fuel and vehicle as well as order of testing;
- Vehicles of each technology to test, (one hybrid or two of the same type, etc.); and,
- Market fuels to test and what fuel properties to investigate.

The statistician will be involved throughout the project on regular project calls to help guide decisions and conduct all the statistical analysis on the project data at the end of testing and will provide all of the analysis for the Final Report.

**Current Status and Future Program**

The contract for E-122-2 was awarded to Southwest Research Institute (SwRI) in April 2019. Experimental testing will continue at their facilities in San Antonio into 2020.

## EVALUATION OF REMOTE SENSING DEVICES AND TECHNOLOGY – PHASE TWO

CRC Project No. E-119-3

Leaders: D.M. DiCicco
S.A. Mason

### Scope and Objective

Since the early 1970's, many heavily populated U.S. cities have violated the National Air Quality Standards (NAAQS) established by the EPA pursuant to the requirements of the federal Clean Air. The NAAQS regulate emissions of six criteria pollutants: carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), lead, ground-level ozone (O3), and sulfur dioxide (SO2). Carbon monoxide (CO) levels are elevated primarily due to direct emission of the gas, and ground-level ozone, a major component of urban smog, is produced by the photochemical reaction of NOx and hydrocarbons (HC). Ambient levels of particulate emissions can result either from direct emissions of particles or semi-volatile species, or from secondary reactions between gaseous species, such as ammonia (NH3) and nitrogen dioxide. On-road vehicles continue to serve as one of the sources for atmospheric criteria pollutant emissions, contributing CO, volatile organic compounds (VOCs), NH3 and NOx to the national emission inventory. Ambient air measurements taken over the last three decades illustrate the dramatic emissions reductions from on-road sources achieved by the automotive and petroleum industries.

Alternate remote sensing device (RSD) measurement systems may provide an opportunity for future data collection campaigns. The objective of this study is to evaluate other RSD systems' ability to measure on-road emissions (CO, CO2, and HC, NO and NO2, SO2 and NH3 and PM) over a five-day period, making real time comparisons to the Fuel Efficiency Automobile Test (FEAT) device, responsible for the historical CRC record of on-road emissions data for over three decades. Measurements will also capture evaporative emission and PM emissions when available to complement emissions measurements from the FEAT device.

**Current Status and Future Program**

Two contractors have been selected to co-locate alternate RSD technologies alongside the Denver University FEAT system during a test campaign in Phoenix, AZ in Spring 2020.

## CONTINUED MONITORING OF E-23/E-106 SITE EMISSIONS

CRC Project No. E-123

Leaders: D.M. DiCicco
S.A. Mason

### Scope and Objective

Project E-23 achieved historically significant on-road emission measurements from six cities, Chicago, Denver, Los Angeles, Phoenix, Omaha, and Tulsa using consistent equipment and calibration methods between 1997 and 2006. Project E-106 and a companion California Air Resources Board contract extended those measurements beginning in 2013 in Chicago, Denver, Los Angeles, and Tulsa. The longer the historical record is, the more that can be learned, because the effect of age on fleet emissions can be observed without the confusion caused by the effect of changing model years.

### Current Status and Future Program

Project E-123 repeats the E-106 schedule to return to Tulsa, Denver, and Chicago on an alternating two-year schedule for one measurement campaign (one five-day week) in each location every other year. The project schedule returns to the E-106 Tulsa site in the early fall of both 2017 and 2019, to Denver in the winters of 2018 and 2020, and the Chicago site in the early fall of 2018 and 2020. The equipment that will be used is the same equipment used in E-23 and E-106; it can monitor CO, HC's, NO, $NH_3$ and $NO_2$ in real time from each passing vehicle. Typically, each test campaign yields 20,000 to 25,000 valid emissions readings. Project E-123 is therefore expected to provide between 120,000 and 140,000 vehicle emissions readings.

As a continuation of earlier research, this project was awarded to Denver University (DU). The Chicago Fall 2018 Final Report is available on the CRC website (June 2019). Testing will be completed in 2020, following a return to each of the three cities.

## EMISSIONS COMMITTEE

### REMOTE SENSING DEVICE DATA MINING FOR I/M PROGRAM EFFECTIVENESS

CRC Project No. E-123-4

Leaders: D.M. DiCicco
S.A. Mason

#### Scope and Objective

As on-road vehicle emissions in the U.S. have decreased dramatically over the past 30 years, the distribution itself has become increasingly skewed. This is reflected in the fact that a smaller percentage of the fleet is responsible for a larger percentage of the emissions. This should provide opportunities for current Inspection/ Maintenance (I/M) programs to produce large percentage reductions in fleet emissions as they are positioned to successfully find and fix a small number of high emitting vehicles. However, computer model estimates of percentage fleet emission reductions for I/M programs have been going in the opposite direction during this period with published estimates of 15% or less benefits depending on the emission species.

The University of Denver began collecting on-road fuel specific vehicle emissions in 1989 for CO with HC and nitric oxide added during the 1990's. To date, there are 92 databases collected in the U.S that contain more than 1.5 million records. The large majority of these have been collected in areas with I/M programs, and at least 20 databases with more than 200,000 records have been collected in areas that do not have a program.

Project E-123-4 will explore how the worst-performing vehicles' emissions have changed in I/M versus non I/M areas by comparing differences in emissions species, quantification, and shape of the emissions distribution seen during this extended period of time.

#### Current Status and Future Program

This project is being conducted by Denver University. Work began in January 2019 and is expected to be completed at the end of 2019.

## RSD MEASUREMENTS IN LYNWOOD, CA

CRC Project No. E-124

Leaders: D.M. DiCicco
S.A. Mason

### Scope and Objective

In 1989, Denver University (DU) visited Los Angeles, California with their first FEAT instrument that was only capable of measuring carbon monoxide and carbon dioxide and collected measurements in a number of locations. One of the sites visited was Lynwood, CA. In 1991, DU revisited Lynwood with a newer FEAT instrument that also included hydrocarbon capabilities and again collected emission measurements. In 1989, vehicle fleets on Long Beach Blvd. averaged 8.7 years old while fleets surveyed at the other locations ranged from 5 to 7 years old. When DU returned in 1991, the Long Beach Blvd. fleet had increased in age to almost 11 years old, which is still the oldest fleet that DU has ever sampled. The fleet ages were a reflection at that time of the economic conditions found in the Lynwood area.

### Current Status and Future Program

In Project E-124, DU returned to the Lynwood area in May 2018, nearly 30-years later, and collected measurements using the latest FEAT instrument and collected measurements at both the Long Beach Blvd. and I-710/Imperial Highway locations. These measurements were compared with the 1989 and 1991 Lynwood measurements along with more recent data sets collected at the West Los Angeles and other E-23/E-106 sites.

The Final Report detailing the comparisons was published on the CRC website in January2019.

## EMISSIONS COMMITTEE

### DETAILED HYDROCARBON ANALYSIS (DHA) AND PARTICULATE MATTER (PM) EMISSIONS DATA MINING

CRC Project No. E-127-1

Leaders: D.M. DiCicco
P. Loeper

#### Scope and Objective

Recently, several CRC projects investigating oxygenated gasoline fuels and the resultant effects on emissions have been completed. In CRC Project E-94-2, exhaust emissions data (with a focus on particulates) was collected over the LA92 drive cycle for 12 vehicles utilizing gasoline direct injection (GDI) engines. Fuels were differentiated by ethanol content, octane number (AKI), and particulate matter index (PMI) resulting in a total of 6 fuels. Fuels were "match" blended so that ethanol, octane, and PMI targets could be reached. PMI, developed by Honda, provides a means to assess particulate formation "potential" of a given fuel. To provide a comprehensive picture of how varying ethanol content, octane, and PMI affect vehicle emissions, CRC Project E-94-3 was created to utilize "splash" blended fuels. More recently, CRC Project E-129 investigated emission effects of iso-butanol and MTBE in addition to ethanol.

As part of these projects, detailed hydrocarbon analysis (DHA) was performed for all test fuels using both the traditional ASTM method, as well as a newer, enhanced method developed under CRC Project AVFL-29 that can identify more "unidentified" HC components (thus resulting in a more-accurate PMI value). In considering the spectrum these programs covered with respect to oxygenate type and fuel blending strategies, this project seeks to perform a meta-analysis of the DHA methods used in these studies.

The contractor for this work will analyze and compare the traditional and enhanced DHA results along with the particulate emissions data from the E-94 and E-129 programs to identify hydrocarbon species groups that positively correlate with increased particulate emissions

The contractor will look at each vehicle's PM emissions individually, determine hydrocarbons that correlate with the vehicles PM emissions, and repeat for all other valid vehicles. Upon completing this task, the list of hydrocarbons for each vehicle will be compared to each other and those hydrocarbons that correlate to PM emissions for multiple vehicles will be noted.

**Current Status and Future Program**

Proposals received in response to an open solicitation are under review by the project panel.

## EMISSIONS COMMITTEE

### ALTERNATIVE OXYGENATE EFFECTS ON EMISSIONS

CRC Project No. E-129/ E-129a

Leaders: S.K. Berkhous
M. Valentine

**Scope and Objective**

The objective of this study is to evaluate the impact of oxygenated blendstocks on tailpipe emissions, in particular PM emissions, from current in-use SIDI vehicles. Four SIDI vehicles from Project CRC E-94-2 were used for this testing program, and seven new fuels were blended, including a base hydrocarbon fuel intended to replicate the low PMI, 87 AKI fuel from the E-94-2/3 studies. Six oxygenates were splash-blended into the base hydrocarbon, and evaluated over the same test protocols established in Project E-94. The oxygenated blends included:

- 10% Volume Ethanol
- 15% Volume Ethanol
- 16% Volume Isobutanol
- 24% Volume Isobutanol
- 19% Volume MTBE
- 29% Volume MTBE

**Current Status and Future Program**

SGS was awarded the contract for testing in Decebmber 2017, and Robert Crawford of Rincon Ranch Consulting was awarded the contract in March 2018 to provide statistical support of the data collected during the project.

The Final Report was published May 2019 on the CRC website.

## PLAN FOR PUBLICATION OF THE STORY OF THE (NEAR) ELIMINATION OF GASOLINE VEHICLE EMISSIONS

CRC Project No. E-130

Leaders: D.H. Lax
C.J. Tennant

### Scope and Objective

Since the 1970's and earlier, the dramatic reductions of automotive pollution have contributed to significant improvements in air quality This project seeks to produce a lay level, easily understood story of how automotive emissions have been reduced to present-day levels to educate a broad audience of the achievement of near-zero gasoline vehicle emissions accomplished over many years. Existing literature and accounts from industry and government agency participants directly involved in the research, investigations, and regulatory development that enabled this achievement will be included. The project is divided into three phases:

- Phase 1: the contractor will identify and acquire literature and conduct and document interviews of expert individuals working on emissions reductions technology during the period of focus.
- Phase 2: a technical publication writer will be contracted to compile and distill all the information collected by the contractor in Phase 1. The deliverable will be a pamphlet or publication that presents the story to a broad, non-technical audience.
- Phase 3: additional publications or reporting avenues will be explored.

### Current Status and Future Program

Steve Welstand, consultant, has been contracted for this project, which is expected to continue in 2020.

## EMISSIONS COMMITTEE

### STUDYING CAPABILITIES AND LIMITATIONS OF VEHICLE TELEMATICS DATA

CRC Project No. E-131

Leaders: P. Loeper
M.B. Viola

**Scope and Objective**

Due to increasingly stringent ambient air quality standards in the U.S., both the EPA and CARB work to improve the fidelity and predictive capabilities of their emissions inventory models (e.g., MOVES and EMFAC, respectively). One example of these efforts are recent presentations by the EPA using vehicle telematics data (e.g., auto insurance driving behavior programs managed by Verizon) to improve understanding of vehicle usage patterns. Data from these programs can include key-on/off sequences, vehicle speed, vehicle acceleration, idle time, and vehicle soak times. In turn, this type of information could prove invaluable to improving model inputs/assumptions in MOVES, for example.

While these vehicle telematics databases can undoubtedly serve as an important component for future model development, CRC is interested in learning more about the capabilities and limitations of these systems.

**Current Status and Future Program**

The RFP for this project is available for open-solicitation on the CRC website through August 2019.

## LIQUID LEAKER TEST VEHICLE DETECTION IN E-119-3 RSD TEST CAMPAIGNS

CRC Project No. RW-105

Leaders: M.M. Maricq
R. Sager

### Scope and Objective

The objective of this project is to understand the capabilities of RSD systems to measure and interpret high evaporative emitters as well as particulate matter emissions. Roadside measurements of PM will include installation of an on-board PEMS unit on test vehicles to serve as a reference measurement.

Under the project, the contractor will co-locate and coordinate with three RSD systems under contract E-119-3 at a single test site. During that test campaign, the contractor will operate two or more test vehicles to run through the RSD roadside location. The vehicles will be set up as liquid leakers to identify each system's capability of detecting evaporative emissions. Additionally, a vehicle with zero emissions is expected to drive through the test site several times per day releasing known levels of pollutants to serve as calibration points.

To detect PM emissions, a PEMS that has robust capability to measure particle mass will be installed on both of the test vehicles. Installation can be completed at the same time as the evaporative measurements if PEMS does not interfere with these test cases. PM and criteria pollutants will be measured during each test run.

### Current Status and Future Program

Revecorp was selected as the contractor for RW-105. The three RSD systems for E-119-3 will be separately contracted by CRC. Discussions are on-going with all four contractors to co-locate at a test site in Spring 2020.

## EMISSIONS COMMITTEE

### ASSESSMENT OF THE RELATIVE ACCURACY OF THE PM INDEX AND RELATED METHODS

CRC Project No. RW-107

Leaders: J.J. Jetter
R.P. Lewis

#### Scope and Objective

The EPA, Honda, and others have confirmed that the PM Index (PMI) can reasonably predict the relative particulate-forming tendency of a gasoline. The only fuel analysis required to calculate a PM Index is a detailed hydrocarbon analysis (DHA). However, performing the high-quality DHA required for PMI determination may be beyond the capability of some laboratories. This has led to the search for potential alternatives to the original PMI that do not require a DHA. For example, Ford has developed an Oxygen Extended Sooting Index (OESI), which incorporates fuel smoke point measurements and various fuel volatility metrics. GM has developed the Particulate Evaluation Index (PEI) which is based on fuel aromatic content, and also the Particle and Soot Correlation Equation (PASCE), which uses E170 and the C/H ration of the fuel. JAMA has proposed a Simplified PMI that uses only the volatility parameters of the fuel; one version of the equation uses E130 and E170, and another version uses only E150.

These variations of PMI have all been developed using different vehicles and fuel matrices. The project objectives were to compare the performance of PMI alternatives to the original PMI using datasets representing a variety of vehicle technologies and fuel formulations and to compare the performance of an enhanced PMI to the original PMI, where the enhanced Index is calculated using the results of the new DHA developed in AVFL-29.

#### Current Status and Future Program

Project RW-107 was awarded to Rincon Ranch Consulting and began in the second quarter of 2018. The Final Report was released May 2019 on the CRC website.

## ASSESSMENT OF ALTERNATE FORUMLATIONS FOR THE PM INDEX

CRC Project No. RW-107-2

Leaders: J.J. Jetter
R.P. Lewis

### Scope and Objective

CRC Project RW-107 examined the performance of PMI and a number of other PM-indices for their ability to predict particle emissions from gasoline fuels. A chief issue was that none of the available PM indices were able to accurately predict PM emissions for fuel groups that contain both neat (E0) and E10 gasolines. In the CRC E-94-2 and -3 and the EPAct studies, E10 and higher fuels were found to have consistently higher PM emissions than E0 gasolines of the same PMI values. PM emissions of E10 to E20 fuel blends were higher than indicated by PMI values while E0 emissions were lower. Improving the indices to remove the emissions bias with respect to ethanol was identified as a priority.

This follow on project will seek to:

- Optimize the mathematical form of the PMI equation.
- Investigate potential adjustments for net heating value and heat of vaporization.
- If an ethanol bias remains after these steps, determine an appropriate adjustment factor.

### Current Status and Future Program

Proposals received are under consideration.

## EMISSIONS COMMITTEE

### E-15 FUEL SURVEY

CRC Project No. RW-115

Leaders: M. Moore
P. Loeper

#### Scope and Objective

Through two separate actions in 2010 and 2011, the EPA approved the use of E15 fuel in model year 2001 and newer light duty vehicles. In March 2019, the EPA issued a final rule to extend the summertime 1 psi RVP waiver to gasoline-ethanol blends up to 15% ethanol. This action facilitates the year-round sale of E15 in conventional gasoline areas. E15 is available today at more than 1,800 refueling stations in 30 states, and federal programs have offered funding designed to expand the infrastructure for renewable fuels via the installation of blender pumps.

Fuel properties, quality, dispenser configuration, and labeling are all important factors and are not well understood for E15. The objective of this project is to analyze fuel properties of E15 fuel samples from a wide array of retail stations and document their labeling, naming, dispenser style, and configuration. This project seeks to improve the understanding of E15 fuel quality and how E15 is being marketed and dispensed.

#### Current Status and Future Program

This project is leveraging the Summer 2019 Alliance of Automobile Manufacturers North American Fuel Survey to collect and analyze 30-40 market fuel samples from around the U.S.

## IMPROVED DIESEL SURROGATE FUELS FOR ENGINE TESTING AND KINETIC MODELING

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

Leaders: S. McConnell
B. Pitz

### Scope and Objective

The objective of this research is to establish and evaluate a methodology for formulating surrogate fuels with compositional, ignition-quality, volatility, and density characteristics that are representative of diesel fuels produced from real-world refinery streams. Such fuels will enable more valuable study of combustion in both experimental engines and computer simulations, which will help in the development of better fuels and engines.

### Current Status and Future Program

A surrogate fuel is a mixture of generally less than a dozen pure compounds that matches 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 could enable improved engine function at significant cost savings relative to current optimization strategies, which rely on physical testing of hardware prototypes. A literature review was performed in support of this research, published on the CRC website in December 2009.

The project team identified compounds representing the major hydrocarbon classes found in real diesel fuels to be included in surrogate fuel formulations. First-generation surrogates were 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.

Project AVFL-18 is being performed in collaboration with researchers at several DOE national laboratories: Sandia National Laboratory (SNL), National Renewable Energy Laboratory (NREL), Lawrence Livermore National Laboratory (LLNL), Pacific Northwest National Laboratory (PNNL), and Oak Ridge National Laboratory (ORNL); as well as a Canadian federal laboratory (CanmetENERGY) and the Army Research Laboratory. The National Institute of Standards and Technology (NIST) assisted 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 published in May 2012 in *Energy & Fuels* and is currently available on their website, as well as on the CRC website, as the Final Report for the first phase of AVFL-18.

Research was extended 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 and combustion vessel testing of selected surrogate fuels. Panel members worked to identify and obtain compounds of sufficient purity and sulfur content for blending surrogate fuels, using a variety of synthesis approaches. All four surrogates have been blended by Chevron for the selected surrogate formulations.

Researchers at the Army Research Laboratory, SNL, and National Research Council Canada are performing single-cylinder engine and combustion vessel testing of the surrogate fuels. Combustion modeling of engine performance is also being conducted in an independent fashion to predict the performance of the surrogate fuels in the selected engine test platforms. Publications are in development by the individual participating laboratories to document the testing and evaluation of the surrogate diesel fuels, and links will be posted to the CRC website when they are available.

The second article under AVFL-18a was published in *Energy & Fuels* (January 2016) covering creation of the surrogate fuels in sufficient quantities for engine and combustion-vessel testing, as well as subsequent physical and chemical property measurements.

CanmetENERGY provided CRC with a report describing work conducted under AVFL-18a on GCxGC analysis of surrogate component purity, titled: “GC×GC Studies of Palette Compounds Used in the Next Generation of Diesel Fuel Surrogate Blends.” This report is available on the CRC website (June 2016.)

Freezing point evaluations at elevated pressures have been conducted at Pacific Northwest National Laboratory on the surrogate test fuels to determine phase change conditions that may impact laboratory combustor and engine operations. NIST supported the project with additional surrogate fuel property analyses. NIST published their most recent work in January 2017, “Preliminary Models for Viscosity, Thermal Conductivity, and Surface Tension of Pure Fluid Constituents of Selected Diesel Surrogate Fuels” as a NIST report.

The Panel directed the research conducted under CRC Contract No. AVL-18a-1, “Autoignition Study of CRC Diesel Surrogates in a Rapid Compression Machine,” at the University of Connecticut. The Final Report was published on the CRC website in October, 2018.

Sandia National Laboratory has performed Optical Engine measurements on the surrogate fuels; results from this research will be reported in 2020.

## AVFL COMMITTEE

### OCTANE NUMBER, ENGINE EFFICIENCY, AND CO2: FILLING LITERATURE GAPS

CRC Project No. AVFL-20 and AVFL-20a

Leaders: J.E. Anderson
A. Iqbal
C. S. Sluder

#### Scope and Objective

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

#### Current Status and Future Program

The project consists of dynamometer testing on engines to evaluate the effects of fuel octane rating, sensitivity, and ethanol content on engine efficiency.

CRC and ORNL are working together to conduct both phases of engine testing and performance modeling for this study. The first phase was conducted on a Ford 1.6L turbocharged direct injection (DI) EcoBoost engine. Flint Hills Resources was a co-sponsor of both phases of this project. Gage Products prepared test fuels according to the matrix of 19 test fuels approved by the project panel members and the committee. Detailed Hydrocarbon Analysis (DHA) of the test fuels was performed by Chevron.

The test fuel matrix allowed exploration of a wide range of ethanol content (10 to 30 vol%), research octane number (91 to 102), and sensitivity (S=RON-MON) (6 to 7 and 10 to 12). ORNL completed the first stage of engine testing of all 19 fuels for knock resistance at a single compression ratio in the Ford EcoBoost engine. Subsequently, six of the test fuels were chosen for more detailed engine performance characterization at appropriately matched compression ratios. Using these data, vehicle-level modeling was used to estimate efficiency, fuel economy, and tailpipe CO2 emissions for these fuels in two vehicles. The Final Report for

AVFL-20, "Effects of Octane Number, Sensitivity, Ethanol Content, and Engine Compression Ratio on GTDI Engine Efficiency, Fuel Economy, and CO2 Emissions," was published on the CRC website in November 2017.

A naturally aspirated 1.4L test engine with port fuel injection (PFI) was provided by FCA for the companion Project AVFL-20a. Testing on the PFI engine is being conducted by ORNL/DOE. Reporting is anticipated in 2020.

## AVFL COMMITTEE

### GASOLINE FUEL PROPERTIES IMPACT ON FUTURE ENGINE DESIGN

CRC Project No. AVFL-26

Leaders: M. B. Viola
S. McConnell
C.S. Sluder

**Scope and Objective**

The objective of AVFL-26 is to evaluate the effects of a range of combinations of gasoline properties and compositions on a next-generation advanced engine platform aimed at maximizing fuel efficiency.

**Current Status and Future Program**

The fuel matrix in this study includes E0, E10, E30; high and low Research Octane Number (RON); and high and low distillation end point to represent possible impacts on particulate matter (PM) emissions. The test engine is a GM 2.0L I4 turbocharged LTG engine modified to create a possible next generation advanced technology configuration, reaching for a 25% reduction in crude oil consumption with a 2-stage turbo, 25% EGR, high energy ignition, and a higher compression ratio.

Gage Products Company prepared the fuels. The engine was provided and set up by GM. Testing and analysis of the results was performed by IAV. ORNL is providing modeling to support the analysis of the results. Final reporting is anticipated in late 2019.

## HEAT OF VAPORIZATION MEASUREMENTS OF GASOLINE AND ETHANOL BLENDS

CRC Project No. AVFL-27 and AVFL-27-2

Leader: M. B. Viola
S. McConnell

### Scope and Objective

These projects are evaluating methods for measurement of the heat of vaporization (HOV) for gasoline and ethanol/gasoline blends and are exploring alternate methods of determining the HOV as a function of boiling point and composition.

### Current Status and Future Program

The University of Delaware (UDEL) and the National Renewable Energy Laboratory (NREL) were involved to examine the selected test fuels in the first phase of the project. Three fuels from the FACE gasoline fuel set (Fuels A, D, and H) were selected by the project panel. Fuels A and H were tested at three ethanol blend levels (10%, 15%, and 30%). Iso-octane served as a reference compound for which the HOV is well known. Thermogravimetry with Differential Scanning Calorimetry (TGA/DSC) methods were used by both laboratories. In addition, a method based on Detailed Hydrocarbon Analysis (DHA) compositional data was explored at NREL.

The Final Report for Phase 1 of the project, "Heat of Vaporization Measurements of Gasoline and Ethanol Blends" was published on the CRC website in August 2016 and consists of a single document with both contractor reports (Parts A and B) and an Executive Summary prepared by the committee.

NREL is performing Phase Two of the project: "Full and Partial Heat of Vaporization Measurements of Gasoline and Ethanol/Gasoline Blends." Reporting is expected in 2020.

## AVFL COMMITTEE

### GASOLINE TURBOCHARGED DIRECT INJECTION (GTDI) ENGINE WEAR TEST DEVELOPMENT

CRC Project No. AVFL-28 and AVFL-28-2

Leaders: G. C. Gunter
T. Kowalski

#### Scope and Objective

Gasoline turbocharged direct injection (GTDI) engines often produce more severe operating conditions than port fuel injection (PFI) engines. GTDI engines operate at higher temperature, higher cylinder pressure, and higher specific torque. GTDI engines are often downsized, causing them to operate at higher load for a larger fraction of operating time. Some modern engines also use alternative combustion cycles (Miller/Atkinson, for example) or stop/start technology which subjects the engine and lubricant to new types of stress compared to conventional PFI engines. Some GTDI engines use certain lubricated components not represented in current wear tests based on PFI engines; for example, turbocharger bearings, polymer-coated bearings, and aluminum alloy bearings. For these reasons, a new test for GTDI engines is needed to represent current and future engine technologies.

The objective of this research is to develop a procedure for testing wear performance of engine lubricant (motor oil) for use in GTDI engines operating in high-fuel-economy duty cycles. Elements of this test protocol include:

- Test engine candidates
- Test engine configuration and component selection
- Test engine operating conditions
- Test methods and criteria to measure engine wear
- Criteria to rate lubricant performance

CRC does not establish lubricant specifications or define certification procedures. Data generated from CRC research can be used by lubricant standards-setting organizations that may develop lubricant specifications and engine wear tests as they see fit.

The research is expected to determine general sensitivities of GTDI engine technology and to develop appropriate operating conditions to test those sensitivities. The purpose is not to point out the sensitivities or weaknesses of any particular engine model.

**Current Status and Future Program**

In AVFL-28, a series of in-field operating conditions were selected, and the engine operated at these conditions using both a SAE 5W-30 oil and a SAE 0W-16 oil with the same additive package. Engine components were examined using Radionuclide Tracer (RNT) techniques to identify sensitive engine parts and performance conditions.

The Final Report for AVFL-28, "Gasoline Direct Injection (GDI) Engine Wear Test Development" was published on the CRC website in January 2018.

In AVFL-28-2, SwRI is evaluating GTDI engine wear performance using the same GTDI engine model, operating procedures, and test matrix as in AVFL-28, with a focus on different engine components to extend the work of the prior project. Testing is complete; final reporting is expected in late 2019.

## AVFL COMMITTEE

### ENHANCED SPECIATION OF GASOLINE / ENHANCED DHA AND PMI REPRODUCIBILITY

CRC Project No. AVFL-29 and AVFL-29-2

Leaders: J.J. Jetter
G.C. Gunter

**Scope and Objective**

Most Detailed Hydrocarbon Analyses (DHAs) are performed with ASTM Methods D6729, D6730, or variations thereof. These are gas chromatography methods in which many species are left unidentified. Labs can leave ≥5% of the species listed as unidentified, typically for species eluting late in the chromatogram which have comparatively strong effect on the particulate matter index (PMI). Unidentified or misidentified peaks in this region can result in an inaccurate PMI determination and can misrepresent the composition of a given sample.

The objective of AVFL-29 was to develop an enhanced method for the speciation of gasoline. Desired attributes of the method:

- Capable of being used on a routine basis by a typical chemical analysis laboratory.
- Easy to perform qualitative and quantitative calibration. A detector with a linear response to pure hydrocarbons is preferred to minimize the number of species in the calibrant.
- Provides accurate quantification of oxygenated species.
- Resolves, identifies, and quantifies species to the greatest reasonable extent. Identifies specific isomers whenever possible; compound class and carbon number are the minimum identification requirements for species > C9.
- Capable of quantifying species with a boiling point up to 280°C at a minimum; 350°C is the preferred target.

The objective of AVFL-29-2 is to determine the magnitude of variability of DHA and PMI results as measured by various test labs in practice for a set of gasoline samples covering a wide range of PMI. A secondary objective is to determine which components contribute most to PMI variability. The approach is expected to include a distribution of gasoline samples covering a range of PMI to various commercial and industry laboratories, using enhanced and standard DHA methods, and analysis of results.

### Current Status and Future Program

AVFL-29 was performed by Separation Systems, Inc. The Final Report, “Enhanced Speciation of Gasoline,” and Master Database were published on the CRC website in June 2018.

A competitive procurement for AVFL-29-2 “Enhanced DHA and PMI Reproducibility” is in progress.

## AVFL COMMITTEE

### AUTOIGNITION CHARACTERIZATION OF AVFL-20 TEST FUELS

CRC Project No. AVFL-31a, AVFL-31b, and AVFL-31c

Leaders: J.E. Anderson
A. Iqbal
S. McConnell

#### Scope and Objective

The objectives of these projects are to evaluate combustion properties of the AVFL-20 test fuel set using laboratory autoignition characterization methods to develop correlations between fuel properties, composition, and autoignition characteristics.

#### Current Status and Future Program

Rapid Compression Machine (RCM) testing of AVFL-20 fuels has been performed by the Massachusetts Institute of Technology (MIT) [AVFL-31a], and additional testing has been conducted at Argonne National Laboratory (ANL) [AVFL-31b]. Different approaches for evaluating the RCM ignition delay data in conjunction with the engine test data are being considered. Modeling results to support the comparison research are being performed under AVFL-31c. Reporting is anticipated in 2020.

## EFFECTS OF BOOST PRESSURE AND FUEL COMPOSITION ON COMBUSTION KNOCK CHARACTERISTICS

CRC Project No. AVFL-32

Leaders: S. McConnell
A. Iqbal

### Scope and Objective

The main objective of this project is to learn how boosting affects the knock characteristics of fuels with varied levels of important hydrocarbon classes found in modern commercial gasolines. A secondary objective is to investigate how boosting affects the operation of the standard RON Cooperative Fuel Research (CFR) test engine and what further information would be required to propose modifications to the octane test method to improve the correlation between octane number and knock propensity in modern SI engines.

During Phase 1 of this research, several fuels of similar RON rating, but varied chemical composition, were analyzed under standard RON conditions on the instrumented CFR F1/F2 engine at Argonne National Laboratory. Important parameters affected by fuel composition during RON testing, despite constant RON level, include indicated mean effective pressure (IMEP), lambda, onset of auto-ignition, peak rate of heat release during auto-ignition, and knock over-pressure (mean amplitude of pressure oscillations), and more.

Phase 2 is exploring how increased boost pressure on the CFR engine affects the knocking characteristics of several fuels with similar RON and varied chemical composition.

### Current Status and Future Program

Project AVFL-32 is being conducted by Argonne National Laboratory. Final reporting is anticipated in 2020.

## AVFL COMMITTEE

### FUNDAMENTAL STOCHASTIC PRE-IGNITION (SPI) STUDY

CRC Project No. AVFL-33

Leaders: E. Chapman
G. C. Gunter

#### Scope and Objective

The goal of this project is to characterize the impact of fuel properties on wall wetting and how this affects SPI frequency and severity in a Gasoline Turbocharged Direct Injection (GTDI) engine. Fuel properties of interest include ethanol, aromatics, RON, Motor Octane Number (MON), and heavy-end volatility.

The approach will be to perform dynamometer testing of a GTDI engine at SPI-prone conditions to determine fuel effects on SPI and influence of wall wetting.

#### Current Status and Future Program

The project is being performed by Oak Ridge National Laboratory. Reporting is expected in 2021.

## ADVANCED CHARACTERIZATION OF E-117 DIESEL FUELS

CRC Project No. AVFL-34

Leaders: M.B. Viola
T. Bays

### Scope and Objective

The goal of this project is to use advanced characterization techniques to better understand differences in fuel composition that could help explain emissions differences observed in CRC Project E-117, "Combustion and Emissions Characteristics of a Medium-Duty Vehicle Operating on a Hydrogenated Vegetable Oil Renewable Diesel."

### Current Status and Future Program

The Pacific Northwest National Laboratory (PNNL) and CanmetENERGY are performing detailed fuel composition analyses on fuel samples provided from Project E-117. Analysis is ongoing. Final reporting is anticipated in late 2019.

## AVFL COMMITTEE

### ADVANCED COMBUSTION LITERATURE SURVEY

CRC Project No. AVFL-35

Leaders: J.J. Jetter
A. Ickes

**Scope and Objective**

The goal of this project is to obtain an understanding of (1) current, state-of-the-art advanced combustion concepts – approaches, limitations, and performance, (2) how fuel properties affect operation of the different concepts, and (3) the key supporting literature references.

This project will consist of a literature search along with a summary of findings and analysis of the specific combustion techniques. With the breadth of different concepts (and acronyms) falling into the advanced combustion area, concepts will be curated and grouped as appropriate to highlight key trends.

**Current Status and Future Program**

A competitive solicitation for this project is in progress.

## IMPACT OF MON ON ENGINE PERFORMANCE

CRC Project No. AVFL-36

Leaders: A. Iqbal
B. Woebkenberg

### Scope and Objective

The primary objective of this study is to investigate the impact of fuel MON on engine performance under a wider range of operating conditions, including those where the sensitivity weighting factor between RON and MON (K) may be positive (and potentially greater than 0.5). Testing under a wider range of operating conditions will help establish the relevance of fuel MON for modern engines, especially from the perspective of durability and safe operation. To this end, the study will evaluate the impact of MON at multiple operating conditions including but not limited to:

(a) High speed high load (high power) operation with elevated air charge temperatures. This engine operation regime is representative of real-world driving conditions such as towing a trailer up a steep grade on a hot day. For future powertrains, this operating regime is expected to become even more challenging as criteria emissions regulations are driving elimination of enriched engine operation as a strategy for managing exhaust gas temperatures.

(b) Knock-limited part load operation which is relevant for drive cycle fuel economy. This operating regime is of interest for downsized boosted SI engines.

### Current Status and Future Program

A competitive solicitation for this project is in progress.

## AVFL COMMITTEE

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

Leaders: J. E. Anderson
S. McConnell

The AVFL Committee formed the FACE Working Group to foster collaboration with other industry and government research laboratory experts. The mission statement for this group was developed in 2005 and updated and approved again in 2015. The original mission of the FACE group was to recommend sets of test fuels well-suited for research so that researchers evaluating advanced combustion systems can 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 collaboration includes scientists and engineers from ANL, LLNL, NREL, ORNL, PNNL, SNL and NRCAN/CanmetENERGY. The activities of the Working Group formally commenced in January 2006.

An initial key activity of this group was developing two sets of fuels for research in advanced combustion in the diesel and gasoline ranges. The diesel fuel set, defined in 2007, became commercially available for purchase from Chevron Phillips Chemical Company, LLC (CPCHEM). Extensive characterization work has been performed by laboratories participating in the FACE Working Group; a summary of standard analyses of these fuels is available from the CRC website.

The Final Report, "FACE-1 Chemical and Physical Properties of the Fuels for Advanced Combustion Engines (FACE) Research Diesel Fuels" was published on the CRC website, and an accompanying conference paper was given at the 2009 SAE Fall Powertrains, Fuels, and Lubricants Meeting.

A gasoline-range fuel set design was also developed by the FACE Working Group. All ten fuels were blended in large batches and became commercially available for sale from CPCHEM. Detailed characterization of the gasoline fuel set is available on the CRC website in tabular form and further documented in CRC Final Report AVFL-24, "FACE Gasolines and Blends with Ethanol: Detailed Characterization of Physical and Chemical Properties."

Current and future activities may 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. ORNL published a 2014 SAE paper summarizing advanced combustion engine test programs utilizing the FACE diesel fuels. The latest publication (2016) is the Final Report on AVFL-23, "Data Mining of FACE Diesel Engine Fuels," produced by NRCAN that identified a number of correlations between advanced engine performance parameters and test fuel properties.

The FACE Working Group has created a number of sub-teams to address various technical aspects of their work plan. Spin-off projects generated by ideas from this group include: AVFL-16, AVFL-18, AVFL-19, AVFL-23, AVFL-24, AVFL-26, AVFL-31, and AVFL-32.

**AVFL COMMITTEE**

**AVFL LUBRICANTS ADVISORY PANEL**

Leaders: G. C. Gunter
T. Kowalski

The AVFL Committee technical scope includes evaluation of impacts of current lubricants on advanced vehicles and future lubricants on current or advanced vehicles. The AVFL Committee organized a panel of engine lubrication experts from industry that serves as a resource for CRC Committees and Project Panels to consult on matters involving lubricants. The AVFL Lubricants Panel is also developing studies focused primarily on lubricant impacts for consideration by the full Committee.

The Panel meets periodically to develop project ideas for consideration by the AVFL Committee. The recently completed Project AVFL-28 and the ongoing Project AVFL-28-2 were developed by this Panel.

## ATMOSPHERIC IMPACTS OF VOC EMISSIONS: FORMATION YIELDS OF ORGANIC NITRATES IN REACTIONS OF ORGANIC PEROXY RADICALS WITH NO

CRC Project No. A-107

Leaders: D.C. Baker
T.J. Wallington

### Scope and Objective

The main goal of the work is to determine the overall air quality impact of four- to six-carbon (C4-C6) alkanes and their atmospheric by-products. This is particularly relevant in areas impacted by oil and/or natural gas (O/NG) extraction and urban areas in general.

The specific objectives are to obtain yields of organic nitrates from oxidation of the alkanes, as a function of the structure and size of the alkane, and also as a function of temperature. This collective dataset can be made available for incorporation into process- and regional-scale models, so that more accurate predictions of ozone production can be obtained on urban / regional scales, and in areas impacted by these alkanes.

### Current Status and Future Programs

University Corporation for Atmospheric Research (UCAR) member entity National Center for Atmospheric Research (NCAR) was selected as the contractor for this project, initiated in March 2017. NCAR is investigating the OH-initiated oxidation of a suite of C4-C6 alkanes, and determining the organic nitrate yield from the reactions of relevant peroxy radical with NO, using end-product analysis. The work is being done in environmental chambers at NCAR. The temperature of the chamber can be regulated between roughly 240 and 340K by flowing a suitable fluid through a jacket surrounding the chamber. Hydroxyl radicals are generated by the photolysis of isopropyl nitrite in the presence of NO, which produces a suite of alkyl peroxy radicals ($RO_2$) depending on the number of unique sites of attack available in the hydrocarbon.

The alkoxy (RO) radical reacts further to produce a carbonyl compound, which can typically be detected by the GC-FID. The relative proportion of the different sites of attack are estimated from the rules given in the literature, with additional information about the relative abundance of peroxy radicals coming from the GC-FID measurements of the carbonyl products. Authentic standards are available for most of these nitrates and carbonyls, which are used for identification and quantification.

Additional experiments are planned in a 10 $m^3$ Teflon chamber, equipped with basic instrumentation for monitoring NOx and $O_3$, and Proton-Transfer Reaction–Mass Spectrometer (PTR-MS) and GC-MS systems for further characterization of reaction products. These studies will provide the opportunity to identify and quantify some of the less volatile nitrates that may not be amenable to analysis by GC-FID. Use of the two chambers, with very different surface-to-volume ratios, will also give added confidence in the results.

Better understanding of the chemistry and surface-to-volume considerations in chambers were both high priorities from CRC's Air Quality Modeling Research Needs Workshop held in February 2016.

Chamber experiments are nearing completion, and the Final Report and related journal article are expected in 2019.

## DEVELOPMENT AND EVALUATION OF DATABASES AND ESTIMATION METHODS FOR PREDICTING AIR QUALITY IMPACTS OF EMITTED ORGANIC COMPOUNDS

CRC Project No. A-108

Leaders: C.G. Rabideau
T.J. Wallington

### Scope and Objective

The objectives of this project are to bring together an expert panel to evaluate the structure-reactivity and other estimation methods needed to develop complete detailed mechanisms, and make recommendations for approaches judged to be the most consistent with available knowledge. This is analogous to the work of the International Union of Pure and Applied Chemistry (IUPAC) or NASA kinetic data panels, or the books on atmospheric mechanisms by Calvert and co-workers, but it is focused on compiling and evaluating estimation methods rather than the underlying experimental data themselves. As with these other efforts, this project has significant in-kind and ongoing support with periodic updates as new data and methods become available.

### Current Status and Future Programs

A proposal from Dr. William Carter at UC Riverside was approved by the Committee. A contract was awarded to UC Riverside in April 2017.

Prior to the initiation of this project, a group of experts (participants) were assembled in various areas related to this project and were in communication via email and teleconferences concerning the work to be carried out. It was decided to form various working groups to organize the efforts, objectives, tasks, and current status of the work of each group.

## ATMOSPHERIC IMPACTS COMMITTEE

The working groups include the following:

- Project Coordination and Leadership
- Preparation of a Perspective Article
- MAGNIFY/EUROCHAMP-2020/MCM Coordination
- Experimental Data Collection
- Quantum Calculation Data Collection
- Organic SAR Group/ Estimates for Reactions of Organic Compounds
- Radical SAR Group/ Estimates for Reactions of Organic Radicals
- Estimates for Photolysis
- Chemical Mechanism Working Group
- Thermochemistry Working Group
- Mechanism Generation Working Group

The groups consist of “full active participants” as well as “observers” who have expressed an interest and will, on occasion, weigh in with their expertise. During the second year of the project, a perspective article that provides a general overview of gaps for improving atmospheric kinetic modeling was published in the *International Journal of Chemical Kinetics.* The project continues into 2020.

## IMPROVING WEST COAST OZONE BOUNDARY CONDITIONS (BCS) FOR REGIONAL AIR QUALITY MODELS

CRC Project No. A-111

Leaders: D.C. Baker
S. Tanrikulu
T.J. Wallington

### Scope and Objective

Historically, boundary conditions for atmospheric modeling have been developed in several ways, each with its own degree of uncertainty. Recent work by the Bay Area Air Quality Management District (BAAQMD) has shown that uncertainty in western boundary conditions impacts both the model's ability to replicate measured air quality patterns, and the model's response to emissions reductions. As US emissions have decreased while contributions from international transport have increased over the past 20 years, it has become increasingly important to properly characterize boundary conditions entering the domain from the northeastern Pacific Ocean.

The objective of this project was to develop a methodology, which can be codified into a distributed software tool and associated database, to adjust western ozone boundary conditions derived from global model output using observational data along the US west coast. The project was conducted in two phases:

In the first phase, the project team retrieved MOZART data for a 5-year period, including the summer 2016 California Baseline Transport Study (CABOTS) period along with routine ozone profile data from Trinidad Head monitoring site along Eastern Coastal Pacific Ocean for the same period. Using both datasets, a statistical comparison and classification analysis involving MOZART and measured ozone profiles and routine upper-air meteorological data was derived.

The project team then developed a file of regression model-based adjusted ozone concentration profiles for each day of the time period. The software tool was tested and evaluated against data collected during the 2016 CABOTS and new BAAQMD regional simulation results, and can be used to directly replace ozone values in CMAQ boundary condition files within user-defined portions of the model domain.

### Current Status and Future Programs

This project was jointly conducted by Ramboll and the BAAQMD to develop and demonstrate a method to improve the characterization of global model-derived ozone fields over the northeastern Pacific Ocean using routine ozone measurements. The project was jointly funded by the BAAQMD, CARB, and CRC.

The Final Report was published on the CRC website in April 2019. The tool developed in this project is now available to further investigate and test additional boundary condition modifications and adjustments.

## RELATIVE REDUCTION FACTORS USING ANTHROPOGENIC OZONE INCREMENTS

CRC Project No. A-112

Leaders: S. Winkler
C.G. Rabideau

### Scope and Objective

Current attainment status for the National Ambient Air Quality Standard (NAAQS) for ozone is determined by measured ambient ozone expressed as the design value (DV). EPA guidance for demonstrating future attainment of the ozone NAAQS recommends using photochemical grid model results analyzed by Relative Reduction Factors (RRFs). The RRF is the ratio of the simulated concentration in a future year with emission reductions in place to the simulated concentration in the base year.

Many sources contribute to ground level ozone in a non-attainment area and can be categorized as:

- U.S. Background ozone originating from all sources except U.S. anthropogenic emissions, including stratospheric ozone, ozone transported from foreign countries, and ozone from natural emissions within the U.S.
- Local ozone increment from anthropogenic emissions within the non-attainment area; these sources are the particular focus of local air quality management activities.
- Regional ozone increment from US anthropogenic emissions outside of the non-attainment area; these sources are typically reduced by national strategies such as mobile source or power plant programs.

With the current RRF methodology, categories that may have individual contributions to ground level ozone are combined in the RRF (and the DV), which obscures individual contributions and generates errors. The overall objective of this project was to develop improved RRF procedures that focus on the U.S.

anthropogenic increments to ozone that are influenced by air quality management activities. The procedure was demonstrated on a modeling platform with a base year of 2012 and a future year of 2028.

**Current Status and Future Programs**

This project was supported by co-sponsorship from API and Houston $O_3$ Coalition, and began in August 2017.

The Executive Summary of the Final Report was posted on the CRC website in October 2018, and a journal article has been published in *Atmospheric Environment* (April 2019).

## THE INFLUENCE OF $NO_X$ ON SECONDARY ORGANIC AEROSOLS AND OZONE FORMATION: CHAMBER STUDY

CRC Project No. A-113

Leaders: T.J. Wallington
S. Gao

### Scope and Objective

This study directly addresses one of the Research Needs (Influence of NOx on SOA Formation and Ozone) from the CRC Air Quality Modeling Research Needs (AQMRN) Workshop held in February 2016. The complex interplay of VOCs and NOx on atmospheric ozone formation (e.g., the ozone isopleth) requires a detailed, mechanistic understanding of the underlying chemical processes leading to its formation. Similarly, it has become readily apparent that condensable species formed in peroxide rich (low-NO) environments and organic nitrate formation in higher NOx environments both contribute significantly to enhanced aerosol formation. Classic environmental chamber experiments using VOC and $NO/NO_2$ mixtures may miss important SOA formation pathways leading to errors in atmospheric predictive models. As stringent NOx controls continue to reduce ambient NOx levels, it is critical that secondary pollutant formation be evaluated under such peroxide rich (low NOx) environments to greatly improve prediction of secondary pollutants under future environmental situations.

The project objectives are to conduct novel environmental chamber experiments to elucidate the key roles of $NO_x$ on SOA formation by performing experiments specifically designed to investigate the role of peroxide chemistry. Primary objectives are to:

- Design new experimental methods using environmental chambers to best elucidate the interplay of NOx with select anthropogenic and biogenic precursors at atmospherically relevant (current and projected) oxidant levels;
- Identify SOA formation potential of select VOC precursors within these well-controlled environments;
- Evaluate ozone prediction under these scenarios; and,
- Provide guidance to regional air quality models on how to implement improvements to SOA predictive models.

### Current Status and Future Programs

The committee approved a proposal from David Cocker at UC Riverside, and the project began in January 2018. The investigation of NOx effects on SOA formation will be conducted through a minimum of 100 defined chamber experiments over the course of 3 years, which will be guided by SAPRC model predictions of oxidant and gas-phase species including measurement of ozone, NOx, hydrocarbon decay, aerosol number and volume time traces along with aerosol density, volatility (at 100°C), and bulk chemical composition (bulk chemical composition derived from aerosol mass spectrometer).

The experiments will be conducted in large, state-of-the-art environmental chambers at UC Riverside designed specifically to study atmospheric chemistry at low NOx concentrations (atmospherically relevant NOx loadings). The project will perform in-depth analysis of select aerosol precursor compounds aimed at a deeper mechanistic understanding of the processes influencing SOA formation.

This three-year project is expected to continue into 2020.

## CHARACTERIZING PRIMARY ORGANIC AEROSOL EMISSIONS FROM IN-USE MOTOR VEHICLES

CRC Project No. A-114/ RW-111

Leaders: M.E. Moore
J. Geidosch

### Scope and Objective

It has been shown that primary organic aerosol (POA) mass from combustion emissions evaporates as it is diluted to ambient conditions. The semi-volatile partitioning of a large fleet of gasoline vehicles has been demonstrated on a chassis dynamometer and the volatility profiles have been quantified using a combination of thermodenuder and mass spectrometer analysis. Large scale model studies have also shown that treating POA compounds as semi-volatile has a significant impact on the average magnitude of emissions from combustion sources as well as on the spatiotemporal variability of organic aerosol (OA) concentrations, particularly in urban areas and close to sources. Although many chemical transport models (CTMs) now include POA semi-volatile partitioning, standard emissions measurements procedures do not collect the information needed to inform gas/particle partitioning calculations.

Current vehicle emissions measurements report total hydrocarbons, non-methane organic compounds, and particulate mass. However, in order to calculate OA partitioning, one needs to know how the emissions themselves respond to swings in the pollutant particle concentrations, for example. Without this information, many CTMs have relied on ambient OA measurements to constrain the total OA mass emitted from combustion sources like vehicles, and parameters vary widely depending on the model and application. While there has been extensive recent work on the detailed measurement of POA volatility and composition, these scientific findings need to be connected to standard measurements and methods that are the most common source of data for emissions inventories and models like CMAQ.

## ATMOSPHERIC IMPACTS COMMITTEE

### Current Status and Future Program

The goal of this project is to quantify the volatility profile and particle concentration in exhaust emissions. Measurements will focus on physical properties of exhaust and particulate and gas-phase concentrations. Results from this study will be used to:

- Confirm that varying dilution leads to organic evaporation behavior that is consistent with published volatility profiles and partitioning theory,
- Better understand the interpretation of existing emissions datasets where particle concentration and volatility information does not exist,
- Determine the accuracy and limitation of using dilution factor to quantify the volatility profile of individual vehicles during standard emissions measurement efforts, and
- Add to the growing body of data documenting the volatility profiles of individual vehicles by tier, model, and model year, etc.

West Virginia University was awarded the contract for this project in February 2019. Work will continue into the third quarter of 2019.

## DEVELOPING IMPROVED VEHICLE POPULATION INPUTS FOR THE 2017 NATIONAL EMISSIONS INVENTORY (NEI)

CRC Project No. A-115

Leaders: S. Collet
M. Janssen
M. Beardsley

### Scope and Objective

While data are sometimes provided by state and local air quality agencies as part of the NEI process, many states are unable to provide such data. Thus, significant additional efforts are needed to augment the efforts of air agencies to further improve the MOVES inputs. Previous CRC projects, including CRC A-88 and CRC A-100, have provided states and local areas with detailed vehicle activity information to improve their vehicle emission inventory inputs to their air quality analysis. Project A-115 builds on that progress by developing vehicle population inputs needed for the next round of EPA's NEI for calendar year 2017 with the goal of providing states and local air agencies with up-to-date activity information for their air quality estimates.

### Current Status and Future Program

ERG was awarded this project in September 2018, with the objective to provide state and local air agencies and US EPA with more accurate county-level vehicle population inputs for the MOVES model and the SMOKE modeling system from 2017 vehicle registration data. A major goal of the new 2017 registration data effort was to incorporate data-driven adjustments to possible overestimation of older populations of light-duty vehicles.

The primary products of this work include three nationwide, county-level data tables formatted for use in MOVES and an additional summary that includes the gross vehicle weight rating category. county- and regional-specific estimates of age distributions and vehicle counts for the 2017 calendar year. The use of these data in a consistent and enhanced manner will be a significant improvement over using national default age distributions and can have a meaningful effect on emissions. As demonstrated in CRC A-84, vehicle age distributions are one of the most important factors in determination of fleet emissions.

A Final Report was published along with the data files on the CRC website in April 2019.

## 2019 MOBILE SOURCE AIR TOXICS WORKSHOP

CRC Project No. A-117

Leaders: S. Collet
S. Yoon

### Scope and Objective

The Atmospheric Impacts Committee, in conjunction with CARB, hosted the 2010, 2013, 2015 and 2017 CRC Mobile Source Air Toxics (MSAT) workshops 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, industry researchers, and stakeholders working in this area. The objective of this MSAT 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 9$^{th}$ MSAT Workshop was held in Sacramento, CA on February 4-6, 2019, with co-sponsors including CARB, API, HEI and SCAQMD. There were 30 technical presentations and over 120 attendees at the Workshop, which was hosted by CARB at their headquarters. Dr. Kent Hoekman was selected again to support organization of the 2019 MSAT Workshop with the aid of organizing committee participants. A Summary article has been published in the July 2019 edition of *EM Magazine.*

## ATMOSPHERIC IMPACTS COMMITTEE

### ROLE OF METEOROLOGY, EMISSIONS, AND SMOKE ON OZONE IN THE SOUTH COAST AIR BASIN

CRC Project No. A-118

Leaders: G. Myers
S. Winkler

**Scope and Objective**

The greater Los Angeles air basin is home to approximately 18 million people and has the highest $O_3$ design value in the country. Despite great progress on reducing $O_3$ in the region, levels are still well above the NAAQS. In addition, recent $O_3$ concentrations have risen with little understanding why. This project seeks to examine complex relationships between $O_3$, emissions, meteorology, and wildfire impacts to improve knowledge on $O_3$ processes in this region through three objectives:

- Develop statistical models using meteorology and satellite observations over a 13-year period from 2006-2018 that can characterize the maximum daily 8-hour average $O_3$ for four sites in the greater LA air basin to examine impacts of daily variations in meteorology on $O_3$ in the region.
- Evaluate wildfire impacts on $O_3$ for the greater LA air basin using statistical models along with indicators for wildfire smoke, such as surface $PM_{2.5}$ and satellite data.
- Examine short and long-term changes in $O_3$ due to emissions, meteorology and smoke in the greater LA air basin to understand the causes for the recent lack of improvement in $O_3$ levels.

**Current Status and Future Programs**

This project addresses one of the top priority research needs for additional meteorology research identified at the 2018 SCORES workshop. The contract for this project was awarded to University of Washington, and work is expected to continue until the end of 2019.

## IMPROVING MODELING TECHNIQUES AND DATA AVAILABILITY FOR SOURCE CHARACTERIZATION

CRC Project No. A-119

Leaders: S. Collet
M. Janssen

### Scope and Objective

Emerging data in Chemical Transport Modeling (CTM) and related measurements are improving our understanding of the relationships of different sources of emissions. Changes in emissions over the past 10 years are making us re-think traditional ideas about the most significant source of emissions. For example, images from Geotaso data showing the concentration of emissions on a high ozone day in Metropolitan Chicago indicate that interstates where light duty vehicles dominate the fleet are less important; and interstates with high heavy-duty truck and rail yards and intermodal trucking facilities are showing higher than expected NOx concentrations.

There are two activities that need minor upgrades to help us understand this shift in source contributions. The first are changes to the newest CTM source apportionment tools. The second is improved reporting tools that extract critical high-resolution inventory data that can be compared to measurement data including both terrestrial and remote sensing technologies. This project addresses the spatial needs priority from the 2016 AQMRN workshop.

### Current Status and Future Programs

University of North Carolina (UNC) was awarded this contract in June 2019. During the course of the project, UNC will develop a new tool that can read existing sectors as grouped source apportionment output files from SMOKE. This tool will allow users to review existing values and make simple changes to group numbers. Additionally, the tool will generate a gridded map of before- and after- classifications with state and county boundaries.

## ATMOSPHERIC IMPACTS COMMITTEE

### EMPIRICAL ANALYSIS OF HISTORICAL AIR QUALITY AND EMISSIONS INFORMATION TO DEVELOP OBSERVATIONALLY-BASED MODELS OF OZONE-VOC-NOX RELATIONSHIPS IN SOUTHERN CALIFORNIA AND THE COMPARISON TO AIR QUALITY MODELS

CRC Project No. A-120

Leaders: S. Gao
S. Collet
T. French

**Scope and Objective**

The South Coast Air Basin (SoCAB) of California has the highest peak ozone levels in the U.S. in spite of stringent controls. While significant ozone reductions have been realized, the recent trend has found a leveling off in the ozone design value (ODV), and the last two years have seen an increase. Multiple questions arise, including: How will ozone respond to proposed emissions changes? What is the most effective approach forward? How effective have past controls been in relationship to the advantages of NOx vs. VOC controls? What is the ultimate background ozone level? How well do chemical transport models, which are used to develop control strategies, capture ozone trends and, importantly, sensitivities to emissions?

The objective of this study is to conduct extensive and detailed modeling of SoCAB for a number of historical and future years, with extensive uncertainty analysis, to understand how well the current CTMs capture ozone dynamics. While the focus here is on ozone, the modeling will provide similar results for particulate matter. There will be three specific approaches to go beyond typical studies:

- Extensive sensitivity analysis (with uncertainty analysis of sensitivities),
- Use of isopleths to provide a more direct, visual analysis tool (that can also be quantitative), and

- Direct comparison of modeled sensitivities with empirically-derived sensitivities (including the use of isopleths).

**Current Status and Future Programs**

The project being conducted by Georgia Tech meets several of the top research priority needs resulting from the 2018 CRC SCORES workshop, including addressing data gaps in the observational response of ozone to changes in $NO_x$ and VOC. The contract was awarded in May 2019, and will continue through 2020.

## ATMOSPHERIC IMPACTS COMMITTEE

### DIRECT MEASUREMENT OF OZONE SENSITIVITY TO $NO_X$ AND VOC IN THE SOUTH COAST AIR BASIN

CRC Project No. A-121

Leaders: D. Baker
T. Wallington
T. Kuwayama

**Scope and Objective**

The combined results from past studies using photochemical grid models and indicator species suggests that $NO_x$ emission controls provide an efficient method to reduce surface ozone concentrations in California, but recent increases in ambient ozone concentrations in Los Angeles highlight the need for additional air pollution mitigation strategies. Direct measurements of the change in ozone per unit change in precursor species in the atmosphere would build confidence in the model prediction. In 2014, the SCAQMD funded a pilot project to measure the sensitivity of ozone formation to NOx and VOC using smog chambers deployed at sites across the SoCAB.

This project will use the methods previously developed in the SCAQMD pilot project to measure ozone sensitivity to precursor $NO_x$ and VOC concentrations at a number of locations over an entire summer period in the SoCAB. The results will provide direct measurements to compare against model predictions for optimal ozone control strategies.

**Current Status and Future Programs**

This project meets the top research priority needs resulting from the 2018 CRC SCORES workshop to observe response of ozone to changes in $NO_x$ and VOCs. The project is co-funded by California Air Resources Board. The contract for this project was awarded to UC-Davis in May 2019. The multi-year effort will continue through 2020.

## GASOLINE ENGINE DEPOSITS

CRC Project No. CM-136

Leader: J. Axelrod
J. Cruz

### Scope and Objectives

The current 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 in Port Fuel Injection (PFI) and Direct Injected (DI) vehicles.
- Determine the extent of SI fuel injector fouling and intake valve deposits and assess the adequacy of current deposit control additive dosages to prevent deposit formation.

### Current Status and Future Program

**<u>Gasoline Engine Intake Valve Deposit Testing (CM-136-18-1)</u>**

ASTM D5500 is the test recognized by EPA for certifying additives to protect against Intake Valve Deposits. CARB has a separate test, and there is also a private program Top Tier certification test. The CRC Gasoline Deposit Group is considering a re-evaluation of the test procedures to possibly update the vehicles and the fuels used to assess deposit levels and the impact of fuels. The ASTM standard was implemented in 1994. Since that time there have been changes in fuel properties, engine technologies, ethanol usage rates, and new performance requirements. The composition of the fuel sold at retail today has changed, with Tier III regulations reducing sulfur content. Since 1994, refining changes have been made and crude oil type has shifted with changing crude slates. Changes in engine technology include hybrids, FFVs (Flex Fuel Vehicle), DISI (Direct Injection Spark Ignition), turbo boost, downsizing, and VVT (Variable Valve Timing). The extent of ethanol use has also dramatically changed. The current engine test platforms, which include dated BMW 318i and Ford 2.3L (ASTM D6201), do not represent the majority of the current vehicle population. The certification fuel requirements are also quite different from today's fuel composition.

Additive companies of the American Chemistry Council (ACC) are working to develop a new PFI-based intake valve test. The primary goal is to replace the existing tests, in particular the BMW test required by EPA and the Ford 2.3L required by CARB, with a more modern test. A project panel has been formed to plan CRC research on this topic.

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

## PERFORMANCE COMMITTEE

**Investigation into Filter Plugging Due to Sulfate Salt Contamination of Ethanol, Gasoline, and Gasoline-Ethanol Blends (CM-136-15-1 / CM-136-18-2)**

The objective of the first project was to develop a thorough understanding of the formation of particulate sulfate salts in ethanol, gasoline, and fuels containing ethanol, including the impacts of water and ethanol concentration, the level of sulfates and cations, and the influence of temperature, gasoline aromatic content and detergent additives on fuel-borne particulate formation and filterability. Based on filterability experiments, the goal was to determine the relative maximum levels of cations and sulfate anions in ethanol and in fuel blends containing ethanol with current levels of detergent additives that will result in filter plugging and vehicle performance problems.

The first project consisted of two phases:

The first phase was a literature search of the published information on the possible sources of the cations and sulfate anions, the solubility of various sulfate salts in alcohols, hydrocarbons, and their blends, filter plugging due to sulfate salts, potential interactions between fuel additives and sulfate salts and automotive performance problems associated with sulfate salts in gasoline and gasoline-ethanol blends. This information was categorized and summarized to guide the next phase.

The second phase consisted of laboratory work to determine the solubility and filterability of sulfate/sulfite salts in ethanol, gasoline and gasoline-ethanol blends, and higher amounts of gasoline detergent additives. This is the foundation for understanding the chemistry of the formation of sulfate salts and their ability to plug filters and vehicle fuel handling equipment.

**PERFORMANCE COMMITTEE**

In the laboratory experimental phase, the variables were determined based on the literature search. The first set of lab experiments looked at the solubility of sulfate salts in denatured fuel ethanol. The variables included temperature, water content, cation (ammonium, sodium), and sulfate anion level. The second set of lab experiments studied the solubility of sulfate salts in gasoline. The variables considered include temperature, water content, cation (ammonium or sodium), aromatic content, detergent level, and sulfate anion level. The third set of experiments studied the solubility of sulfate salts in gasoline-ethanol blends and focused on the variables that were determined to be important in sets 1 and 2.

Testing involved preparing the required solutions and heating/cooling them to test temperature. The solutions were then filtered using an appropriate ASTM test procedure. The amount and composition of precipitate were determined and compared with the initial dosage.

RFA and Flint Hills Resources co-sponsored this project. The Final Report, “Investigation into Filter Plugging Due to Sulfate Salt Contamination of Ethanol, Gasoline, and Gasoline-Ethanol Blends” was published on the CRC website in January 2018.

The objectives of the follow-on work are to address a narrower range of solubility issue, and the researchers are focused on investigations of sodium sulfate, sodium bisulfite and sodium metabisulfite in ethanol. “Investigation of Sulfate Salt Solubilities in Ethanol and Gasoline-Ethanol Fuel Blends” is being conducted by DRI and is in progress with reporting anticipated in early 2020.

## VOLATILITY

CRC Project No. CM-138

Leader: R. Lewis
M. Valentine

### 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

**Development of an Engine Based Test for Determining the Effect of Spark-Ignition Engine Fuel Properties on Combustion and Vehicle Driveability (CM-138-15-2)**

The objective of this project is to take a more fundamental approach toward measuring the in-cylinder combustion instability that is the root cause of poor vehicle operability. CRC would like to determine whether fuels of differing compositions and physical characteristics (e.g., Driveability Index) can be distinguished from vehicle performance differences using an instrumented engine in a vehicle on an all-weather chassis dynamometer. In addition, CRC would like to identify the measurements that are most effective at differentiating the physical and compositional characteristics between fuels. Finally, CRC would like to establish the resolution and repeatability of the measurements.

The test program consists of testing instrumented whole vehicles on a chassis dynamometer. The vehicles are being tested one at a time with time between each vehicle for the evaluation of the data and potential test program adjustment to apply the learnings from the last test to the next test. The engines in these vehicles are instrumented with cylinder pressure indication on each cylinder, Engine Control Unit (ECU) taps of the primary engine controls parameters, as well as temperature and pressure instrumentation of all major intake and exhaust components. All data are being captured using various measurement equipment (crank angle resolved and time based) and will be merged into one combined dataset which will be used for assessment. The driving pattern applied in CRC Report No. 666, "2013 CRC Intermediate-Temperature E15 Cold-Start and Warm-Up Vehicle Driveability Program" is being replicated with the instrumented vehicle on a chassis dynamometer. Test fuels are a series of hydrocarbon and hydrocarbon-ethanol blends of differing compositional and physical properties with the goal of determining discrimination sensitivity. FEV performed the testing. RFA co-sponsored this research. Final Reporting is expected in late 2019.

**Comparison of Ambient Temperatures from 'Doner Report' to Modern Day Ambient Temperatures for the Same Geographic Areas (CM-138-16-2)**

Table 4 Schedule of U. S. Seasonal and Geographical Volatility Classes in ASTM D4814 Standard Specification for Automotive Spark-Ignition Engine Fuel was generated from state ambient temperatures obtained by the U.S. Army during the 1970s, known as the "Doner Report". Concerns were expressed in the industry that the original "Doner Report" information may be outdated. The objective of this project was to conduct a review of modern day ambient temperatures for the geographic regions in ASTM D4814 Table 4 with the new data then compared to that in the "Doner Report." The report and data review were done in a manner similar to that of the original "Doner Report" but with computer-generated isothermal maps. The new study included data covering 1996 through 2016 (twenty-one years, which is similar to that from the "Doner Report"), and Hawaii (left out of the original study). State temperature data (excluding Panama Canal which was part of the original report) were analyzed in multi-geographic regions when appropriate as was done for the prior study.

DRI performed this project. The Final Report was published on the CRC website in December 2018.

**<u>Computer Controlled Poor Driveability on Demand Training Vehicle (CM-138-17-1)</u>**

Numerous projects over the years have been performed in order to refine and better understand the relationship between gasoline and gasoline-ethanol blended fuels with driveability issues that drivers experience in their vehicles. In carrying out these projects, the CRC developed a system and nomenclature to better discriminate between the types of driveability events and their severity. The task of scoring these events utilizes trained operators called raters. The raters perform a pre-set series of maneuvers on a test vehicle and determine if a potential driveability event the vehicle experienced is either a hesitation, a stumble, or a surge. The rater then assigns a severity score of high, medium, or low to the driveability event. Once the current trained raters retire, the knowledge and methodology will retire along with them. A solution is to develop a means where the driveability events can be created, controlled, and be reproducible. This way, newer raters can be trained to identify and rate the events. Additionally, using a dedicated vehicle where the driveability events can be created could offer a different level of versatility in the types of driveability projects. Instead of leaving projects to the unknown characteristics of vehicles in the field to create driveability problems, the projects can be designed around the dedicated vehicle. Utilizing a Driveability on Demand Training Vehicle will also result in not having to develop and source high Drivability Index (DI) test fuels that may or may not result in a poor driveability event for some future correlation from Road to Lab test programs.

The project objective was to develop calibration software and hardware to control driveability events through an easy-to-use user interface system in a vehicle. The project resulted in a vehicle with the means for an operator to easily and reproducibly cause hesitation, stumble, surge, stall, and/or poor idle quality driveability events. These events vary in intensity (high, medium, and low) at the discretion of the operator.

## PERFORMANCE COMMITTEE

This project was performed by SwRI. The Final Report was published on the CRC website in October 2018.

### **"Driveability Workshop to Train and Calibrate Raters Using the CRC Trick Car" – CM-138-18-1**

CRC has used trained raters for many years to assess the driveability vehicle performance for test programs. The existing driveability rater pool consist of retirees or from testing facilities. Therefore, CRC sees the need to establish new trained raters for future volatility projects. CRC has not conducted a rater workshop to train and calibrate driveability raters since 2002, where a 'trick car' was used to train and calibrate driveability raters by subjecting them on demand to various driveability malfunctions at different intensities. Calibrating raters will improve test result precision. CRC has a new 'trick car' (Driveability on Demand Training Vehicle) which was developed under CRC Project CM-138-17-1. The objective of this project is to meet at a common test site to train novice and inexperienced personnel to be driveability raters and to calibrate experienced driveability raters using the CRC Driveability on Demand Training Vehicle.

This Workshop is being conducted by SwRI in 2019. Final reporting is anticipated in 2020.

## OCTANE

CRC Project No. CM-137

Leader: W. Woebkenberg
M. Winston-Galant

### 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

**Advanced Fuel and Engine Efficiency Workshop**

The Octane Group of the Performance Committee worked with the CRC AVFL Committee to organize the "Advanced Fuels and Engine Efficiency (AFEE) Workshop" in Baltimore, MD on February 25-26, 2014. The workshop was designed to address advanced fuels and methods for improving engine efficiency, focusing on light-duty engine technology and associated fuel effects, and included discussion of octane research (past and potential for the future). The workshop was co-sponsored by DOE and API with in-kind support contributed by MIT. This was the first workshop to be conducted by CRC on this topic. The 2nd AFEE Workshop was conducted in late 2016 and again co-sponsored by the CRC AVFL and Performance Committees. Proceedings of both Workshops are published on the CRC website.

**Review of LSPI Or Low Speed Pre-Ignition (AKA Stochastic Pre-Ignition, SPI) – (CM-137-17-1)**

Abnormal ignition, especially low speed/stochastic preignition (LSPI/SPI), in gasoline engines has been reported in the literature for many decades, going back to at least the 1920s. This phenomenon was something initially noted by the CRC in 1954, and a document was created so that a common set of terms were used to discuss and communicate the nuances of normal and abnormal combustion. At that time, engine manufacturers were testing designs that included both higher compression ratio and evaluating the use of turbochargers and superchargers for improved performance and economy. In recent years, low speed/stochastic preignition issue has is a renewed topic of interest for modern engines. Current designs continue on the trend towards downsized, higher compression ratios and turbocharging in the pursuit of improved fuel economy. Quick resolution of the current low speed/stochastic preignition issue is required to minimize risk of engine hardware damage and enable utilization of advanced technologies. Therefore, all aspects that can yield improvement need to be understood.

The objectives of this project were to:

- Investigate, through reviews of the academic, commercial and government literature and interviews with OEMs and suppliers, the factors associated with the onset and/or severity of LSPI/SPI as related to current market fuels and engine design/hardware and engine lubricating oil.
- Identify critical technology gaps in understanding LSPI/SPI and suggest R&D efforts where CRC could contribute with possible future programs.

This project was performed by FEV. The Final Report was published on the CRC website in June 2019.

## DIESEL PERFORMANCE GROUP

CRC Project No. DP

Leader: G. Gunter
S. Lopes

### Scope and Objective

The objective of the Diesel Performance Group is to help to define the minimum diesel fuel requirements for light-duty diesel vehicles in North America. This will be achieved by providing supporting technical data for diesel performance issues that are needed by the fuel, engine, equipment, and additive industries and can be used by technical groups such as ASTM International, the International Organization for Standardization (ISO), and the National Conference on Weights and Measures (NCWM). Much of the knowledge gained is common to other diesel applications such as heavy-duty diesel (HDD). This Group works closely with industry stakeholders and benefits from their contributions.

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

- Biodiesel & Renewable Diesel
- Cleanliness
- Corrosion
- Deposit
- Low Temperature Operability

### Current Status and Future Program

**Biodiesel & Renewable Diesel**

In 2017, the Biodiesel Panel was expanded to include renewable diesel and the panel name updated to reflect the change. The panel has utilized the expertise of its members over the last year to develop a guidance document, entitled, "Review of the Properties and Performance of Hydrocarbon Renewable Diesel Fuel." The Guide was published on the CRC website in September 2018. This document serves as a guide to industry and the public.

## PERFORMANCE COMMITTEE

### Cleanliness

The objective of the Cleanliness panel is to address, to investigate, and to provide information for general housekeeping and other issues for diesel fuel. The focus is fuel cleanliness and fuel properties that are outside the defined fuel properties in existing CRC DPG panels. These fuel cleanliness properties should have relevance from the point of diesel production to the point of customer use (refinery to vehicle fuel tank). Modern high-pressure common-rail injection systems require much cleaner diesel fuel.

The panel generated a CRC guide to compile best available current knowledge and practice regarding cleanliness of diesel fuel. CRC Report No. 667, "Diesel Fuel Storage and Handling Guide," was published on the CRC website in September 2014. ASTM periodically holds Workshops on this topic and distributes the guide to participants.

The Panel developed a summary one-sheet guide targeted to benefit fuel station operators. CRC Report No. 672, “Preventive Maintenance Guide for Diesel Storage and Dispensing Systems,” was published on the CRC website in July 2016.

The Panel meets periodically and is developing plans for future research in this topic.

## Corrosion

Accelerated corrosion has been observed in some retail underground tanks storing and dispensing ultra-low sulfur diesel (ULSD) since 2007. In addition, corrosion is affecting metallic equipment in both the wetted and un-wetted portions of some ULSD underground storage tanks (USTs). To identify the root cause of accelerated corrosion, multiple stakeholders in the diesel, vehicle, regulatory, and truck stop industries, through the Clean Diesel Fuel Alliance, sponsored a field research study by Battelle Memorial Institute in 2012.

The CRC Panel developed a protocol for selecting sites with diesel fuel systems that had severe corrosion. This was posted to the CRC website with the goal of informing the EPA and others in their current and future research on this topic. Using the CRC protocol, the EPA, in consultation with the CRC Panel, conducted a survey of USTs in the field.

To identify possible root causes of the excessive corrosion, the CRC Panel developed a laboratory test program titled:

### Identification of Potential Parameters Causing Corrosion of Metallic Components in Diesel Underground Storage Tanks (DP-07-16-1)

The project objective is to identify parameters that directly contribute to accelerated corrosion of metal parts and tank equipment in USTs that are in ULSD service, including retail sales, fleet suppliers, and fuel storage for emergency power generation. The parameters being evaluated were generated by identifying all major changes that took place related or independent of the introduction of ULSD.

Battelle is performing this project. Reporting is expected in late 2019.

## PERFORMANCE COMMITTEE

### Deposit

The objective of the Deposit Panel is to identify or develop a laboratory bench top or test rig for evaluating diesel fuel's tendency to cause internal injector deposits in diesel engines and to use a tool to evaluate possible effects by fuels, impurities, and additives.

An initial scoping study of limited screening used three 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. The Delphi rig was identified as one that had the potential for this application. Results of these studies are in two CRC reports on the CRC website:

CRC Project DP-04, "Scoping Study to Evaluate Two Rig Tests for Internal Injector Sticking," July 2012.

CRC Project DP-04-13b, "Internal Injector Deposits: A Scoping Study to Evaluate the Delphi Test Rig," August 2013.

A comprehensive rig/engine test program was conducted to verify correlation between the Delphi rig and actual engines. Results were positive and have been documented in CRC Report DP-04-10, "Internal Injector Deposits; Correlation of the Delphi Test Rig with Production Engines," published March 2016 on the CRC website.

The Deposit Panel designed a program to set up and use the test rig at a U.S. research facility to begin evaluation of fuels, additives, and impurities. The project, titled "Fuel Research Using the Internal Diesel Injector Deposit (IDID) Rig" (CRC DP-04-17), was performed by SwRI.

The Final Report was released on the CRC web site in September 2019.

### Low Temperature Operability

The panel has utilized members' expertise to generate CRC Report No. 671, "Diesel Fuel Low Temperature Operability Guide." The guide was written for general use by end users, fuel producers/distributers, and OEMs in providing guidance on the best ways to keep diesel vehicles operating under most low temperature conditions. The guide was released on the CRC website in September 2016.

The Panel is conducting a project titled, "Low Temperature Filterability of Diesel Fuel at Retail Pumps," using resources provided by Panel members. A test rig is being used to determine limitations in dispenser filters in operation in cold temperature. This test rig may be able to evaluate any relationship between filter pore size and operational issues at low temperatures. Reporting on this research is expected in 2020.

# PART THREE

# RELEASED REPORTS

## RELEASED REPORTS - 2019

## AIR POLLUTION & ADVANCED TECHNOLOGY*

| CRC Project No. | Title | Publication/NTIS Accession No. |
|---|---|---|
| A-105 | Source Apportionment of Organic Aerosol and Ozone and the Effects of Emission Reductions | *Atmospheric Environment* October 2018, https://doi.org/10.1016/j.atmosenv.2018.10.042 |
| A-109 | Projected Changes in Particulate Matter Concentrations in the South Coast Air Basin Due to Basin-Wide Reductions in Nitrogen Oxides, Volatile Organic Compounds and Ammonia Emissions | *Journal of the Air & Waste Management Association* https://doi.org/10.1080/10962247.2018.1531795 |
| A-111 | Improving West Coast Ozone Boundary Conditions for Regional Air Quality Models | PB2019-100802 |
| A-112 | Relative Reduction Factors Using Anthropogenic Ozone Increments Executive Summary | PB2019-100039 |
| | Standard and alternative procedures for projecting future ozone in the Houston area using relative reduction factors | *Atmospheric Environment*, March 2019, https://doi.org/10.1016/j.aeaoa.2019.100029 |
| A-115 | Developing Improved Vehicle Population Inputs for the 2017 National Emissions Inventory | PB2019-100625 |
| A-116 | Highlights from the Coordinating Research Council's 2018 Southern California Ozone Research Symposium | *EM Magazine*, December 2018 |

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|---|---|---|
| A-117 | Highlights from the Coordinating Research Council's 2019 Mobile Source Air Toxics Workshop | *EM Magazine*, July 2019 http://pubs.awma.org/flip/EM-July-2019/emjuly19.pdf |
| AVFL-18a-1 | Autoignition Study of CRC Diesel Surrogates in a Rapid Compression Machine | PB2019-100034 |
| E-99-2 | Evaluation of Partial Flow Dilution Systems for Very Low PM Mass Measurements | *Emission Control Science and Technology* November 2018 https://doi.org/10.1007/s40825-018-0099-1 |
| E-117 | Combustion and Engine-Out Emissions Characteristics of a Light Duty Vehicle Operating on a Hydrogenated Vegetable Oil Renewable Diesel | PB2019-101233 |
| E-119a | Fall 2016 On-Road Emissions Measurements in the Chicago Area: Comparison of two University of Denver Remote Sensing Datasets | PB2019-101234 |
| E-123 | On-Road Remote Sensing of Automobile Emissions in the Chicago Area: Fall 2018 | PB2019-100978 |
| E-123-2 | Diminishing Benefits of Federal Reformulated Gasoline (RFG) | *SAE Int. J. Fuels. Lubr.* Vol 12 (1): 5-28, 2019 https://doi.org/10.4271/04-12-01-0001 |
| E-124 | 3 Decades of On-Road Mobile Source Emissions Reductions in S. Los Angeles | *Journal of the Air & Waste Management Association* Vol. 69 (8), 2019 https://doi.org/10.1080/10962247.2019.1611677 |
| E-129 | Alternative Oxygenate Effects on Emissions | PB2019-100980 |

| | | |
|---|---|---|
| RW-107 | Assessment of the Relative Accuracy of the PM Index and Related Methods | PB2019-100981 |
| RW-110-18 | Highlights from the Coordinating Research Council's 28th Real World Emissions Workshop | *EM Plus Magazine*, Q3 2018 |
| RW-110-19 | Highlights from the Coordinating Research Council's 29th Real World Emissions Workshop | *EM Magazine*, July 2019 http://pubs.awma.org/flip/EM-July-2019/emjuly19.pdf |

## RELEASED REPORTS (Cont.) - 2019

## AVIATION & PERFORMANCE*

| CRC Project No. | Title | Publication/NTIS Accession No. |
|---|---|---|
| AV-20-14 | Determination of Heat of Vaporization and Creating Enthalpy Diagrams for Several Common Jet Fuels | PB2019-100876 |
| CM-137-17-1 | Review of Low-Speed Pre-Ignition Literature | PB2019-100979 |
| CM-138-17-1 | Computer Controlled Poor Driveability on Demand Training Vehicle | PB2019-100038 |
| CM-138-16-2 | Comparison of Ambient Temperatures from 'Doner Report' to Modern Day Ambient Temperatures for the Same Geographic Areas | PB2019-100242 |
| DP-04-17 | Fuel Research Using the Internal Diesel Injector Deposit (IDID) Rig | PENDING |

The primary source for CRC 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.

*"PENDING" reports are available now on CRC website, www.crcao.org.

# PART FOUR

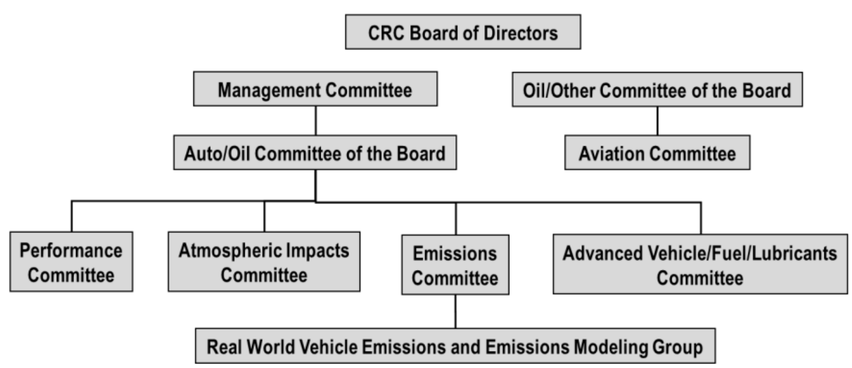
# ORGANIZATION AND MEMBERSHIP

## ORGANIZATION – 2019

The sustaining members of the CRC are the American Petroleum Institute (API) and a consortium of automobile manufacturers [Fiat Chrysler Automobiles (FCA), Daimler, Ford, General Motors, Honda, Mitsubishi, Nissan, Toyota, and Volkswagen]. For over 77 years, CRC has provided the means for the automotive and petroleum industries to study problems of mutual interest. The objective of CRC, as stated in our charter, is:

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

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



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

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

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

CRC has two basic types of research programs:

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

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

CRC's Auto/Oil Committee of the Board of Directors oversees the cooperative research summarized in this report. Board membership is comprised of seven representatives from the petroleum industry and nine 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.

**MEMBERSHIP**

## COORDINATING RESEARCH COUNCIL, INC.

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| M. Block | Mitsubishi Mtrs. R&D Am. |
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| E. Hillawi | Nissan Tech. Ctr. N.A. | R. Sutschek | Volkwagen of America |
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| J. T. Bays | PNNL | A. Iqbal | FCA USA LLC. |
| E. M. Chapman | General Motors | N. Killingsworth | LLNL |
| V.S. Constanzo | Aramco Services | D. H. Lax | API |
| J. Cruz | Daimler | R. P. Lewis | Marathon Petroleum Corp. |
| D. M. DiCicco | Ford Motor Co. | G. K. Lilik | ExxonMobil |
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| | | C. S. Sluder | ORNL |
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| | | M. B. Viola | General Motors |

## MEMBERSHIP

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| R. Sutschek | Volkwagen of America |
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| W. J. Pitz, Co-Leader | LLNL |

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| J. T. Bays | PNNL |
| H. Dettman | CanmetENERGY |
| R. Gieleciak | CanmetENERGY |
| M. Kweon | U.S. Army Research Lab |
| A. Ickes | Chevron Energy Techn. |
| C. J. Mueller | SNL |
| S. Neill | NRC Canada |
| M. Ratcliff | NREL |
| J. E. Temme | U.S. Army Research Lab |
| M. B. Viola | General Motors |

## MEMBERSHIP

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| C. S. Sluder, Co-Leader | ORNL |

| | | | |
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| E. M. Chapman | General Motors | G. K. Lilik | ExxonMobil |
| V. S. Costanzo | Aramco Services | S. McConnell | Marathon Petroleum Corp. |
| J. Cruz | Daimler | J. Mengwasser | Shell Global Solutions |
| D. M. DiCicco | Ford Motor Co. | C. Pritchard | Flint Hills Resources |
| M. Foster | BP | J. Y. Sigelko | Volkswagen of America |
| G. C. Gunter | Phillips 66 | J. J. Simnick | BP |
| R. Hardy | Flint Hill Resources | M. Valentine | Toyota |
| D. H. Lax | API | M. B. Viola | General Motors |
| T. Leone | Ford Motor Co. | W. Woebkenberg | Aramco Services |
| R. P. Lewis | Marathon Petroleum Corp. | | |

### AVFL-26 PANEL

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| S. McConnell, Co-Leader | Marathon Petroleum Corp. |
| C. S. Sluder, Co-Leader | ORNL |
| M. B. Viola, Co-Leader | General Motors |

| | | | |
|---|---|---|---|
| R. Adams | Mitsubishi Mtrs. R&D Am. | T. Leone | Ford Motor Co. |
| E. M. Chapman | General Motors | G. K. Lilik | ExxonMobil |
| V. S. Costanzo | Aramco Services | A. S. Mabutol | Mitsubishi Mtrs. R&D Am. |
| J. Cruz | Daimler | J. Mengwasser | Shell Global Solutions |
| D. M. DiCicco | Ford Motor Co. | H. Miller | General Motors |
| M. Foster | BP | B. Reed | Mitsubishi Mtrs. R&D Am. |
| D. Ganss | Nissan Tech. Ctr. NA | J. Y. Sigelko | Volkswagen of America |
| G. C. Gunter | Phillips 66 | R. Sutschek | Volkwagen of America |
| A. Ickes | Chevron Energy Techn. | M. Valentine | Toyota |
| A. Iqbal | FCA USA LLC. | W. Woebkenberg | Aramco Services |
| J. J. Jetter | Honda R&D Am. | | |
| D. H. Lax | API | | |

**MEMBERSHIP**

## AVFL-27-2 PANEL

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| S. McConnell, Co-Leader | Marathon Petroleum Corp. |
| M. B. Viola, Co-Leader | General Motors |

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|---|---|---|---|
| J. E. Anderson | Ford Motor Co. | R. P. Lewis | Marathon Petroleum Corp. |
| E. M. Chapman | General Motors | G. K. Lilik | ExxonMobil |
| G. C. Gunter | Phillips 66 | J. Y. Sigelko | Volkswagen of America |
| A. Ickes | Chevron Energy Techn. | M. Valentine | Toyota |
| J. J. Jetter | Honda R&D Am. | W. Woebkenberg | Aramco Services |

## AVFL-28 PANEL

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|---|---|
| G. C. Gunter, Co-Leader | Phillips 66 |
| T. D. Kowalski, Co-Leader | Toyota |

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| B. Anderson | Afton Chemical | K. Engelman | Afton Chemical |
| D. Bansal | Infineum USA LP | A. K. Gangopadhyay | Ford Motor Co. |
| D. H. Blossfeld | General Motors | D. Ganss | Nissan Tech. Ctr. NA |
| B. Calcut | Afton Chemical | A. Gauer | General Motors |
| E. M. Chapman | General Motors | S. McConnell | Marathon Petroleum Corp. |
| F. Cooney | General Motors | J. Pastor | Infineum USA LP |
| J. Cruz | Daimler | M. P. Raney | General Motors |
| T. Cushing | General Motors | R. Stockwell | Chevron |

## AVFL-29-2 PANEL

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| G. C. Gunter, Co-Leader | Phillips 66 |
| J. J. Jetter, Co-Leader | Honda R&D Am. |

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| J. E. Anderson | Ford Motor Co. | G. K. Lilik | ExxonMobil |
| E. M. Chapman | General Motors | S. McConnell | Marathon Petroleum Corp. |
| J. Cruz | Daimler | J. Mengwasser | Shell Global Solutions |
| A. Ickes | Chevron Energy Techn. | M. E. Moore | FCA USA LLC. |
| D. H. Lax | API | J. Y. Sigelko | Volkswagen of America |
| R. P. Lewis | Marathon Petroleum Corp. | M. Valentine | Toyota |
| | | A. K. Voice | Aramco Service |

# MEMBERSHIP

## AVFL-32 PANEL

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|---|---|
| A. Iqbal, Co-Leader | FCA USA LLC. |
| S. McConnell, Co-Leader | Marathon Petroleum Corp. |

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|---|---|---|---|
| J. E. Anderson | Ford Motor Co. | G. K. Lilik | ExxonMobil |
| E. M. Chapman | General Motors | A. S. Mabutol | Mitsubishi Mtrs. R&D Am. |
| V. S. Costanzo | Aramco Services | | |
| J. Cruz | Daimler | J. Mengwasser | Shell Global Solutions |
| D. M. DiCicco | Ford Motor Co. | B. Reed | Mitsubishi Mtrs. R&D Am. |
| M. Foster | BP | | |
| D. Ganss | Nissan Tech. Ctr. NA | C. S. Sluder | ORNL |
| G. C. Gunter | Phillips 66 | R. Sutschek | Volkwagen of America |
| J. Holland | Phillips 66 | M. Valentine | Toyota |
| A. Ickes | Chevron Energy Techn. | M. B. Viola | General Motors |
| J. J. Jetter | Honda R&D Am. | J. Wellhousen | Phillips 66 |
| D. H. Lax | API | W. Woebkenberg | Aramco Services |
| R. P. Lewis | Marathon Petroleum Corp. | | |

## AVFL-33 PANEL

| | |
|---|---|
| E. M. Chapman, Co-Leader | General Motors |
| G. C. Gunter, Co-Leader | Phillips 66 |

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|---|---|---|---|
| R. Adams | Mitsubishi Mtrs. R&D Am. | A. Iqbal | FCA USA LLC. |
| | | G. K. Lilik | ExxonMobil |
| J. E. Anderson | Ford Motor Co. | M. McCarthy | Toyota |
| S. Bartley | Lubrizol | S. McConnell | Marathon Petroleum Corp. |
| D. Boese | Infineum | J. Mengwasser | Shell Global Solutions |
| B. Chinta | General Motors | A. Michlberger | Lubrizol |
| V. S. Costanzo | Aramco Services | M. E. Moore | FCA USA LLC. |
| J. Cruz | Daimler | G. Parker | Lubrizol |
| A. Ickes | Chevron Energy Techn. | J. Y. Sigelko | Volkswagen of America |
| | | M. Valentine | Toyota |
| | | M. B. Viola | General Motors |

## MEMBERSHIP

### AVFL-35 PANEL

| | |
|---|---|
| J. J. Jetter, Co-Leader | Honda R&D Am. |
| A. Ickes, Co-Leader | Chevron Energy Techn. |

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|---|---|---|---|
| V. S. Costanzo | Aramco Services | G. K. Lilik | ExxonMobil |
| G. C. Gunter | Phillips 66 | S. McConnell | Marathon Petroleum Corp. |
| A. Iqbal | FCA USA LLC. | J. Y. Sigelko | Volkswagen of America |
| D. H. Lax | API | M. Valentine | Toyota |
| R. P. Lewis | Marathon Petroleum Corp | | |

### AVFL-36 PANEL

| | |
|---|---|
| A. Iqbal, Co-Leader | FCA USA LLC. |
| W. Woebkenberg, Co-Leader | Aramco Services |

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|---|---|---|---|
| J. E. Anderson | Ford Motor Co. | T. Leone | Ford Motor Co. |
| A. Aradi | Shell | G. K. Lilik | ExxonMobil |
| V. S. Costanzo | Aramco Services | S. McConnell | Marathon Petroleum Corp. |
| G. C. Gunter | Phillips 66 | J. Y. Sigelko | Volkswagen of America |
| A. Ickes | Chevron Energy Techn. | M. Valentine | Toyota |
| D. H. Lax | API | | |

## MEMBERSHIP

### EMISSIONS COMMITTEE

| | |
|---|---|
| P. Loeper, Co-Chair | Chevron Global Downstream |
| M. B. Viola, Co-Chair | General Motors |

| | | | |
|---|---|---|---|
| B. Alexander | BP | F. Khan | Nissan Tech. Ctr. NA |
| T. Bera | Shell Global Solutions | S. A. Mason | Phillips 66 |
| E. Barrientos | ExxonMobil | M. Moore | FCA USA LLC. |
| M. Block | Mitsubishi Mtrs R&D Am. | J. Y. Sigelko | Volkswagen of America |
| | | M. Valentine | Toyota |
| J. Cruz | Daimler | D. Vu | Marathon Petroleum Corp. |
| D. M. DiCicco | Ford Motor Co. | W. Woebkenberg | Aramco Services |
| J. J. Jetter | Honda R&D Am. | | |

### E-117 PANEL

| | |
|---|---|
| D. Z. Short, Co-Leader | Marathon Petroleum Corp. |
| J. Cruz, Co-Leader | Daimler |

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| B. Alexander | BP | S. Lopes | General Motors |
| S. Berkhous | ExxonMobil | J. Mengwasser | Shell Global Solutions |
| D. M. DiCicco | Ford Motor Co. | M. Moore | FCA USA LLC. |
| G. Gunter | Phillips 66 | M. Valentine | Toyota |
| J. J. Jetter | Honda R&D Am. | M. B. Viola | General Motors |
| F. Khan | Nissan Tech. Ctr. N.A. | D. Vu | Marathon Petroleum Corp. |
| P. Loeper | Chevron Global Dnstrm. | W. Woebkenberg | Aramco Services |

## MEMBERSHIP

### E-122-2 PANEL

P. Loeper, Co-Leader — Chevron Global Dnstrm.
M. B. Viola, Co-Leader — General Motors

| | | | |
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| B. Alexander | BP | S. A. Mason | Phillips 66 |
| E. Barrientos | ExxonMobil | M. Moore | FCA USA LLC. |
| T. Bera | Shell Global Solutions | M. Olson | Mitsubishi Mtrs R&D Am. |
| M. Block | Mitsubishi Mtrs R&D Am. | M. Rosenbaeck | Volkswagen of Amercia |
| J. Cruz | Daimler | J. Y. Sigelko | Volkswagen of America |
| D. M. DiCicco | Ford Motor Co. | J. Unsworth | FCA USA LLC. |
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| J. J. Jetter | Honda R&D Am. | W. Woebkenberg | Aramco Services |
| F. Khan | Nissan Tech. Ctr. NA | Y. Xu | ExxonMobil |
| A. S. Mabutol | Mitsubishi Mtrs R&D Am. | M. Yassine | FCA USA LLC. |

### E-127-1 PANEL

D. M. DiCicco, Co-Leader — Ford Motor Co.
P. Loeper, Co-Leader — Chevron Global Dnstrm.

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| J. E. Anderson | Ford Motor Co. | D. Lax | API |
| B. Alexander | BP | R. Lewis | Marathon Petroleum Corp. |
| T. Bera | Shell Global Solutions | S. A. Mason | Phillips 66 |
| E. Barrientos | ExxonMobil | J. Mengwasser | Shell Global Solutions |
| M. Block | Mitsubishi Mtrs R&D Am. | M. Moore | FCA USA LLC. |
| | | M. Rosenbaeck | Volkswagen of America |
| J. Cruz | Daimler | J. Y. Sigelko | Volkswagen of America |
| D. M. DiCicco | Ford Motor Co. | R. Sutschek | Volkswagen of America |
| J. J. Jetter | Honda R&D Am. | M. Valentine | Toyota |
| C. Jones | General Motors | M. Viola | General Motors |
| F. Khan | Nissan Tech. Ctr. NA | D. Vu | Marathon Petroleum Corp. |
| F. Krich | FCA USA LLC. | W. Woebkenberg | Aramco Services |

## E-129 PANEL

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| | M. Valentine, Co-Leader | Toyota | |

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|---|---|---|---|
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| S. Decarteret | General Motors | J. Mengwasser | Shell |
| D. M. DiCicco | Ford Motor Co. | M. Moore | FCA USA LLC. |
| J. Glodich | Ford Motor Co. | D. Z. Short | Marathon Petroleum Corp. |
| D. Lax | API | | |
| R. P. Lewis | Marathon Petroleum Corp. | J. Y. Sigelko | Volkswagen of America |
| P. Loeper | Chevron Global Dnstrm. | M. B. Viola | General Motors |

## E-130 PANEL

| | | |
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| | D. Lax, Co-Leader | API |
| | C. Tennant, Co-Leader | Coordinating Research Council |

| | | | |
|---|---|---|---|
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## MEMBERSHIP

### REAL WORLD VEHICLE EMISSIONS & EMISSIONS MODELING GROUP

| | |
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| S. A. Mason, Co-Chair | Phillips 66 |

| | | | |
|---|---|---|---|
| B. Alexander | BP | A. S. Mabutol | Mitsubishi Mtrs R&D Am. |
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| A. Cullen | US EPA | M. Rosenbaeck | Volkswagen of America |
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| T. A. French | EMA | S. A. Shimpi | Cummins |
| C. R. Fulper | US EPA | J. Y. Sigelko | Volkswagen of America |
| D. Ganss | Nissan Tech. Ctr. NA | M. R. Smith | Navistar |
| R. Giannelli | US EPA | D. Sonntag | US EPA |
| C. Hart | US EPA | M. Spears | EMA |
| J. J. Jetter | Honda R&D Am. | R. Sutschek | Volkswagen of America |
| F. Khan | Nissan Tech. Ctr. NA | M. Thornton | NREL |
| F. A. Krich | FCA USA LLC. | M. Valentine | Toyota |
| C. Laroo | EPA | M. B. Viola | General Motors |
| D. H. Lax | API | D. Vu | Marathon Petroleum Corp. |
| R. P. Lewis | Marathon Petrol. Corp. | W. Woebkenberg | Aramco Services |
| P. Loeper | Chevron Global Dnstrm. | M. K. Yassine | FCA USA LLC. |
| J. E. Long | CARB | S. Yoon | CARB |
| T. R. Long | US EPA | | |

## MEMBERSHIP

## 29TH REAL WORLD EMISSIONS WORKSHOP ORGANIZING COMMITTEE

| | |
|---|---|
| D. M. DiCicco, Co-Chair | Ford Motor Co. |
| S. A. Mason, Co-Chair | Phillips 66 |

| | | | |
|---|---|---|---|
| M. Beardsley | US EPA | T. R. Long | US EPA |
| N. Berry | SCAQMD | R. Purushothaman | Caterpillar |
| K. N. Black | FHWA | S. A. Shimpi | Cummins |
| S. Collet | Toyota | M. Thornton | NREL |
| T. Huai | CARB | S. Yoon | CARB |

## MEMBERSHIP

### RW-105 PANEL

| | |
|---|---|
| M. M. Maricq, Co-Chair | Ford Motor Co. |
| R. Sager, Co-Chair | FCA USA LLC. |

| | | | |
|---|---|---|---|
| B. Alexander | BP | P. Loeper | Chevron Global Dnstrm. |
| N. J. Barsic | John Deere | J. E. Long | CARB |
| M. Beardsley | US EPA | T. R. Long | US EPA |
| T. Bera | Shell Global Solutions | A. S. Mabutol | Mitsubishi Mtrs R&D Am. |
| E. Barrientos | ExxonMobil | M. E. Moore | FCA USA LLC. |
| K. N. Black | FHWA | J. Mengwasser | Shell Global Solutions |
| B. Blomquist | FCA USA LLC. | R. Nankee | FCA USA LLC. |
| S. Bohr | Ford Motor Co. | R. Nine | DOE/NETL |
| K. Borgert | US EPA | M. Olechiw | US EPA |
| S. Collet | Toyota | F. Parsinejad | Chevron Oronite |
| J. Cruz | Daimler | R. Purushothaman | Caterpillar |
| A. Cullen | US EPA | M. Rosenbaeck | Volkswagen of America |
| R. De Kleine | Ford Motor Co. | C. Ruehl | CARB |
| D. M. DiCicco | Ford Motor Co. | S. A. Shimpi | Cummins |
| T. A. French | EMA | J. Y. Sigelko | Volkswagen of America |
| C. R. Fulper | US EPA | M. R. Smith | Navistar |
| D. Ganss | Nissan Tech. Ctr. NA | D. Sonntag | US EPA |
| R. Giannelli | US EPA | M. Spears | EMA |
| M. Grote | FCA USA LLC. | R. Sutschek | Volkswagen of America |
| C. Hart | US EPA | M. Thornton | NREL |
| S. Horetski | General Motors | M. Valentine | Toyota |
| J. J. Jetter | Honda R&D Am. | M. B. Viola | General Motors |
| F. Khan | Nissan Tech. Ctr. NA | D. Vu | Marathon Petroleum Corp. |
| F. A. Krich | FCA USA LLC. | W. Woebkenberg | Aramco Services |
| C. Laroo | EPA | M. K. Yassine | FCA USA LLC. |
| D. H. Lax | API | S. Yoon | CARB |
| R. P. Lewis | Marathon Petrol. Corp. | | |

## MEMBERSHIP

### RW-107 PANEL

J. J. Jetter, Co-Leader — Honda R&D Am.
R. P. Lewis Co-Leader — Marathon Petroleum Co.

| | |
|---|---|
| J. E. Anderson | Ford Motor Co. |
| C. Bailey | US EPA |
| R. Baldauf | US EPA |
| N. J. Barsic | John Deere |
| M. Beardsley | US EPA |
| E. Barrientos | ExxonMobil |
| K. N. Black | FHWA |
| A. Butler | US EPA |
| K. Borgert | US EPA |
| E. Chapman | General Motors |
| J. Cruz | Daimler |
| A. Cullen | US EPA |
| D. M. DiCicco | Ford Motor Co. |
| T. A. French | EMA |
| C. R. Fulper | US EPA |
| B. Alexander | BP |
| R. Giannelli | US EPA |
| C. Hart | US EPA |
| K. Helmer | US EPA |
| F. Khan | Nissan Tech. Ctr. NA |
| F. A. Krich | FCA USA LLC. |
| C. Laroo | EPA |
| D. H. Lax | API |
| P. Loeper | Chevron Global Dnstrm. |
| J. E. Long | CARB |
| T. R. Long | US EPA |
| A. S. Mabutol | Mitsubishi Mtrs. R&D Am. |
| M. M. Maricq | Ford Motor Co. |
| S. A. Mason | Phillips 66 |
| J. Mengwasser | Shell Global Solutions |
| M. Moore | FCA USA LLC. |
| R. Nankee | FCA USA LLC. |
| R. Nine | DOE/NETL |
| M. Olechiw | US EPA |
| F. Parsinejad | Chevron Oronite |
| R. Purushothaman | Caterpillar |
| C. Ruehl | CARB |
| S. A. Shimpi | Cummins |
| J. Y. Sigelko | Volkswagen of America |
| M. R. Smith | Navistar |
| R. Sobotowski | US EPA |
| D. Sonntag | US EPA |
| M. Thornton | NREL |
| M. Valentine | Toyota |
| M. B. Viola | General Motors |
| D. Vu | Marathon Petroluem Corp. |
| W. Woebkenberg | Aramco Services |
| M. K. Yassine | FCA USA LLC. |

## MEMBERSHIP

### 2019 CRC LIFE CYCLE ANALYSIS WORKSHOP ORGANZING COMMITTEE

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| A. Levy, Co-chair | US EPA |
| R. DeKleine, Co-Chair | Ford Motor Co |
| J. Han, Co-Chair | ExxonMobil |

| | | | |
|---|---|---|---|
| B. Fayyaz | Chevron | D. O'Grady | Natural Resources Canada |
| H. Hamje | CONCAWE | A. Prabhu | CARB |
| K. Hoekman | DRI | D. Scott | National Biodiesel Board |
| A. Kapur | Phillips 66 | D. Z. Short | Marathon Petroleum Corp. |
| K. Kline | ORNL | S. Richman | RFA |
| S. Kuusisto | Neste | S. Searles | ICCT |
| D. Lax | API | S. Rangaraju | CONCAWE |
| A. Lindauer | DOE | T. Radich | USDA |
| J. Martin | Union of Concerned Scientists | D. Vu | Marathon Petroleum Corp. |
| | | M. Wang | ANL |

## MEMBERSHIP

### ATMOSPHERIC IMPACTS COMMITTEE

S. Collet, Co-Chair — Toyota
S. Gao, Co-Chair — Phillips 66

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|---|---|---|---|
| D. C. Baker | API Consultant | J. I. Moutinho | ExxonMobil |
| E. Hillawi | Nissan Tech. Ctr. N.A. | G. F. Myers | Marathon Petroleum Corp. |
| D. Johnson | BP | C. Rabideau | Chevron |
| C. Jones | General Motors | J. Y. Sigelko | Volkswagen of America |
| A. S. Mabutol | Mitsubishi Mtrs. R&D Am. | R. Sutschek | Volkswagen of America |
| | | T. J. Wallington | Ford Motor Co. |
| M. E. Moore | FCA USA LLC. | S. Winkler | Ford Motor Co. |

### ATMOSPHERIC IMPACTS WORKING GROUP

S. Collet, Co-Chair — Toyota
S. Gao, Co-Chair — Phillips 66

| | | | |
|---|---|---|---|
| Z. Adelman | LADCO | T. Kuwayama | CARB |
| D. C. Baker | API Consultant | C. Lawson | Shell |
| M. Beardsley | US EPA | D. H. Lax | API |
| D. Choi | US EPA | S. M. Lee | SCAQMD |
| D. M. DiCicco | Ford Motor Co. | M. M. Maricq | Ford Motor Co. |
| H. J. Feldman | API | R. Mathur | US EPA |
| T. A. French | EMA | J. Price | TX Comm. on EQ |
| J. Geidosch | US EPA | K. Sargeant | US EPA |
| M. L. Gupta | FAA | J. Smith | TX Comm. on EQ |
| M. Janssen | LADCO | S. Tanrikulu | BAAQMD |
| C. Kalisz | API | B. Timin | US EPA |
| D. M. Kenski | LADCO | C. Yanca | US EPA |
| M. Koerber | US EPA | J. Zietsman | TX A&M Trans. Inst. |

## MEMBERSHIP

### A-114/RW-111 PANEL

| | |
|---|---|
| M. E. Moore, Co-Leader | FCA USA LLC. |
| J. Geidosch, Co-Leader | US EPA |

| | | | |
|---|---|---|---|
| D. C. Baker | API Consultant | M. Hays | US EPA |
| S. Berkhous | ExxonMobil | G. F. Myers | Marathon Petroleum Corp. |
| K. N. Black | FHWA | R. Purushothaman | Caterpillar |
| S. Collet | Toyota | B. Murphy | US EPA |
| T. Kuwayama | CARB | J. Y. Sigelko | Volkswagen of America |
| P. Loeper | Chevron | D. Z. Short | Marathon Petroleum Corp. |
| M. M. Maricq | Ford Motor Co. | M. R. Smith | Navistar |
| S. A. Mason | Phillips 66 | | |

### A-115 PANEL

| | |
|---|---|
| M. Beardsley, Co-Chair | US EPA |
| S. Collet, Co-Chair | Toyota |
| M. Janssen, Co-Leader | LADCO |

| | | | |
|---|---|---|---|
| D. H. Lax | API | S. Winkler | Ford Motor Co. |
| T. Kuwayama | CARB | J. Y. Sigelko | Volkswagen of America |

### 2019 MSAT ORGANIZING COMMITTEE
### (Project No. A-117)

| | |
|---|---|
| D. C. Baker, Co-Chair | API Consultant |
| S. Collet, Co-Chair | Toyota |

| | | | |
|---|---|---|---|
| S. K. Hoekman | DRI | C. Ruehl | CARB |
| G. F. Meyers | Marathon Petroleum Corp. | J. Y. Sigelko | Volkswagen of America |
| | | T. J. Wallington | Ford Motor Co. |
| T. Kuwayama | CARB | S. Yoon | CARB |

## MEMBERSHIP

### A-120 PANEL

| | |
|---|---|
| S. Collet, Co-Chair | Toyota |
| T. A. French, Co-Chair | EMA |
| S. Gao, Co-Chair | Phillips 66 |

| | | | |
|---|---|---|---|
| D. C. Baker | API Consultant | J. Y. Sigelko | Volkswagen of America |
| T. Kuwayama | CARB | T. J. Wallington | Ford Motor Co. |
| C. Rabideau | Chevron | S. Winkler | Ford Motor Co. |

### A-121 PANEL

| | |
|---|---|
| D. C. Baker, Co-Leader | API Consultant |
| T. Kuwayama, Co-Leader | CARB |
| T. J. Wallington, Co-Leader | Ford Motor Co. |

| | | | |
|---|---|---|---|
| S. Collet | Toyota | S. M. Lee | SCAQMD |
| T. A. French | EMA | J. I. Moutinho | ExxonMobil |
| S. Gao | Phillips 66 | C. Rabideau | Chevron |
| M. Janssen | LADCO | J. Y. Sigelko | Volkswagen of America |
| C. Jones | General Motors | | |

**MEMBERSHIP**

## PERFORMANCE COMMITTEE

| | |
|---|---|
| A. Iqbal, Co-Chair | FCA USA LLC. |
| J. J. Simnick, Co-Chair | BP |

| | | | |
|---|---|---|---|
| J. Axelrod | ExxonMobil | M. E. Moore | FCA USA LLC. |
| J. Cruz | Daimler | B. Raney-Pablo | Ford Motor Co. |
| D. Ganss | Nissan Tech. Ctr. NA | J. Russo | Shell |
| G. C. Gunter | Phillips 66 | M. Sheehan | Chevron |
| J. Jetter | Honda | J. Y. Sigelko | Volkswagen of America |
| R. P. Lewis | Marathon Petroleum Corp. | W. Studzinski | General Motors |
| | | M. Valentine | Toyota |
| S. Lopes | General Motors | M. Winston-Galant | General Motors |
| A. Mabutol | Mitsubishi Mtrs. R&D Am. | W. Woebkenberg | Aramco Services |

## GASOLINE DEPOSIT GROUP
## (Project No. CM-136)

| | |
|---|---|
| J. Axelrod, Co-Leader | ExxonMobil |
| J. Cruz, Co-Leader | Daimler |

| | | | |
|---|---|---|---|
| B. Alexander | BP | A. McKnight | Innospec |
| S. Bartley | Lubrizol | M. Miller | Sunoco Inc. |
| D. Bohn | Flint Hills | K. Mitchell | Shell Canada Ltd. |
| S. Broughton | Marathon Petroleum Corp. | R. Monroe | General Motors |
| K. Brunner | SwRI | C. L. Muth | Nalco Energy Services |
| R. Chapman | Innospec | F. Parsinejad | Chevron Oronite Co. |
| J. Draper | Motiva | C. M. Pyburn | Pytertech Intl. |
| I. Gabrel | FCA USA LLC. | B. Raney-Pablo | Ford Motor Co. |
| L. M. Gibbs | Consultant | J. Russo | Shell |
| G. C. Gunter | Phillips 66 | D. Schoppe | Intertek |
| C. Huang | ITW | J. Y. Sigelko | Volkswagen of America |
| J. J. Jetter | Honda R&D Am. | W. Studzinski | General Motors |
| A. M. Kulinowski | Afton Chemical | W. Y. Su | Huntsman Corp. |
| D. H. Lax | API | M. Valentine | Toyota |
| R. P. Lewis | Marathon Petroleum Corp. | M. Winston-Galant | General Motors |
| P. Loeper | Chevron | W. Woebkenberg | Aramco Services |
| M. Lynch | ExxonMobil | H. Zhao | Huntsman Adv Tech. |
| I. Mathur | Haltermann | | |

## GASOLINE DEPOSIT SULFATE PANEL
## (Project No. CM-136-18-2)

| | |
|---|---|
| R. P. Lewis, Co-Leader | Marathon Petroleum Corp. |
| C. Jones, Co-Leader | General Motors |

| | |
|---|---|
| B. Alexander | BP |
| J. Axelrod | ExxonMobil |
| J. Cruz | Daimler |
| K. Davis | RFA |
| I. Gabrel | FCA USA LLC. |
| L. Gibbs | Consultant |
| G. C. Gunter | Phillips 66 |
| R. Hardy | Flint Hills Resources |
| A.M. Kulinowski | Afton Chemical |
| D. H. Lax | API |
| M. Lynch | ExxonMobil |
| A. McKnight | Innospec |
| B. Raney-Pablo | Ford Motor Co. |
| J. Russo | Shell |
| M. Valentine | Toyota |
| M. Winston-Galant | General Motors |

## OCTANE GROUP
## (Project No. CM-137)

| | |
|---|---|
| M. Winston-Galant, Co-Leader | Ford Motor Co. |
| W. Woebkenberg, Co-Leader | Aramco Services |

| | |
|---|---|
| B. Alexander | BP |
| S. Bartley | Lubrizol |
| T.Briggs | SwRI |
| S. Broughton | Marathon Petroleum Corp. |
| K. Brunner | SwRI |
| E. Chapman | General Motors |
| R. Chapman | Innospec Fuel Spec. |
| J. Cruz | Daimler |
| D. M. DiCicco | Ford Motor Co. |
| J. Farenback-Brateman | ExxonMobil |
| G. C. Gunter | Phillips 66 |
| A. Iqbal | FCA USA LLC. |
| J. J. Jetter | Honda R&D Am. |
| C. Jewitt | Consultant |
| F. Khan | Nissan Tech. Ctr. NA |
| D. H. Lax | API |
| R. P. Lewis | Marathon Petroleum Corp. |
| P. Loeper | Chevron |
| M. Lynch | ExxonMobil |
| A. McKnight | Innospec |
| J. Mengwasser | Shell |
| M. Miller | Sunoco Inc. |
| K. Mitchell | Consultant |
| P. J. Morgan | SwRI |
| C. M. Pyburn | Pybertech International |
| B. Raney-Pablo | Ford Motor Co. |
| J. Russo | Shell |
| D. Schoppe | Intertek |
| J. Y. Sigelko | Volkswagen of America |
| J. J. Simnick | BP |
| R. A. Sobotowski | US EPA |
| W. Studzinski | General Motors |
| A. Swarts | SwRI |
| M. Valentine | Toyota |

**MEMBERSHIP**

## OCTANE GROUP – LSPI PROJECT PANEL
## (Project No. CM-137-17-1)

W. Woebkenberg, Co-Leader Aramco Services
E. Chapman, Co-Leader General Motors

| | |
|---|---|
| B. Alexander | BP |
| J. E. Anderson | Ford Motor Co. |
| J. Cruz | Daimler |
| R. Davis | GM |
| D. M. DiCicco | Ford Motor Co. |
| J. Farenback-Brateman | ExxonMobil |
| G. C. Gunter | Phillips 66 |
| A. Iqbal | FCA USA LLC. |
| J. J. Jetter | Honda R&D Am. |
| F. Khan | Nissan Tech. Ctr. NA |
| D. H. Lax | API |
| R. P. Lewis | Marathon Petroleum Corp. |
| M. Lynch | ExxonMobil |
| S. McConnell | Marathon Petroleum Corp. |
| J. Mengwasser | Shell |
| B. Raney-Pablo | Ford Motor Co. |
| J. Russo | Shell |
| J. Y. Sigelko | Volkswagen of America |
| J. J. Simnick | BP |
| W. Studzinski | General Motors |
| M. Valentine | Toyota |
| M. Winston-Galant | General Motors |

## MEMBERSHIP

### VOLATILITY GROUP
### (Project No. CM-138)

M. Valentine, Co-Leader — Toyota
R. P. Lewis, Co-Leader — Marathon Petroleum Corp.
.

| | | | |
|---|---|---|---|
| B. Alexander | BP | F. Khan | Nissan Tech. Ctr. NA |
| S. Bartley | Lubrizol | D. H. Lax | API |
| S. Broughton | Marathon Petroleum Corp. | P. Loeper | Chevron |
| K. Brunner | SwRI | M. Lynch | ExxonMobil |
| J. Cruz | Daimler | K. Mitchell | Consultant |
| K. Davis | RFA | B. Raney-Pablo | Ford Motor Co. |
| H. Doherty | Sunoco | J. Russo | Shell |
| J. Draper | Motiva | D. Schoppe | Intertek |
| J. Farenback-Brateman | ExxonMobil | J. Y. Sigelko | Volkswagen of America |
| I. Gabrel | FCA USA LLC. | W. Studzinski | General Motors |
| L.M. Gibbs | Consultant | S. Van Hulzen | POET |
| G. C. Gunter | Phillips 66 | M.Winston-Galant | General Motors |
| R. Hardy | Flint Hills Resources | W. Woebkenberg | Aramco Services |
| G. Herwick | Trans. Fuels Consult. | | |
| A. Iqbal | FCA USA LLC. | | |
| J. J. Jetter | Honda R&D Am. | | |
| C. Jones | General Motors | | |

## MEMBERSHIP

### DEVELOPMENT OF AN ENGINE BASED TEST FOR DETERMINING THE EFFECT OF SPARK IGNITION FUEL PROPERTIES ON COMBUSTION AND VEHICLE DRIVEABILITY PROJECT PANEL (Project No. CM-138-15-2)

C. Jones, Leader — General Motors

| | | | |
|---|---|---|---|
| K. Davis | RFA | D. H. Lax | API |
| L. M. Gibbs | Consultant | J. Y. Sigelko | Volkswagen of America |
| G. C. Gunter | Phillips 66 | J. J. Simnick | BP |
| G. Herwick | Trans. Fuels Consult. | M. Valentine | Toyota |
| A. Iqbal | FCA USA LLC. | M.Winston-Galant | General Motors |
| J. J. Jetter | Honda R&D Am. | W. Woebkenberg | Aramco Services |

### COMPARISON OF AMBIENT TEMPERATURES FROM 'DONER REPORT' TO MODERN DAY AMBIENT TEMPERATURES FOR THE SAME GEOGRAPHIC AREAS PROJECT PANEL (PROJECT NO. CM-138-16-2)

R. P. Lewis, Co-Leader — Marathon Petroleum
M.Winston-Galant, Co-Leader — General Motors

| | | | |
|---|---|---|---|
| B. Alexander | BP | F. Khan | Nissan Tech. Ctr. NA |
| K. Davis | RFA | D. Lax | API |
| H. Doherty | Sunoco | M. Lynch | ExxonMobil |
| J. Farenback-Brateman | ExxonMobil | B. Raney-Pablo | Ford Motor Co. |
| L. M. Gibbs | Consultant | J. Russo | Shell |
| G. C. Gunter | Phillips 66 | M. Valentine | Toyota |

## COMPUTER CONTROLLED POOR DRIVEABILITY ON DEMAND TRAINING VEHICLE PROJECT PANEL (PROJECT NO. CM-138-17-1)

M.Winston-Galant, Leader — General Motors

| | |
|---|---|
| B. Alexander | BP |
| J. Farenback-Brateman | ExxonMobil |
| L. M. Gibbs | Consultant |
| G. C. Gunter | Phillips 66 |
| A. Iqbal | FCA USA LLC. |
| J. Jetter | Honda |
| D. Lax | API |
| R. P. Lewis | Marathon Petroleum Corp. |
| M. Lynch | ExxonMobil |
| K. Mitchell | Consultant |
| J. Russo | Shell |
| J. Y. Sigelko | Volkswagen of America |
| J. J. Simnick | BP |

## DRIVEABILITY WORKSHOP TO TRAIN AND CALIBRATE RATERS USING THE CRC TRICK CAR PROJECT PANEL (PROJECT NO. CM-138-18-1)

M. Sheehan, Leader — Chevron
T. King , Co-Leader — Haltermann Carless

| | |
|---|---|
| L. M. Gibbs | Consultant |
| G. C. Gunter | Phillips 66 |
| R. P. Lewis | Marathon Petroleum Corp. |
| J. Russo | Shell |
| J. Y. Sigelko | Volkswagen of America |
| J. Simnick | BP |
| M. Valentine | Toyota |
| M.Winston-Galant | General Motors |

## MEMBERSHIP

### DIESEL PERFORMANCE GROUP
### (Project No. DP)

| | |
|---|---|
| G. C. Gunter, Co-Leader | Phillips 66 |
| S. Lopes, Co-Leader | General Motors |

| | | | |
|---|---|---|---|
| H. Ahari | FCA USA LLC. | R. P. Lewis | Marathon Petroleum Corp. |
| B. Alexander | BP | T. Livingston | Robert Bosch |
| J. Axelrod | ExxonMobil | R. Long | PEI |
| T. Bera | Shell | R. L. McCormick | NREL |
| P. Biggerstaff | Baker Petrolite | A. McKnight | Innospec |
| D. Bohn | Flint Hills Resources | R. Mills | Chevron |
| S. Broughton | Marathon Petroleum Corp. | K. Mitchell | Consultant |
| L. Cattani | FCA USA LLC. | A. G. Morin | Eurenco |
| A. Cayabyab | CARB | J. Morris | Navistar |
| R. Chapman | Consultant | J. Porco | Gage Products |
| J. Cruz | Daimler | B. Raney-Pablo | Ford Motor Co. |
| D. A. Daniels | Innospec Fuel Spec. | S.B.Rubin-Pitel | ExxonMobil |
| J. Draper | Motiva | K. Salem | Lubrizol |
| E. English | Fuel Quality Services | D. Schoppe | Intertek |
| I. Gabriel | FCA USA LLC. | P. Searles | API |
| R. George | BP | D. Z. Short | Marathon Petroleum Corp. |
| C. Hamer | PCS Instruments | J. Y. Sigelko | Volkswagen of America |
| D. Hess | Infineum | W. Studzinski | General Motors |
| C. Huang | Cummins | T. Sutton | EMA |
| C. Huang | ITW Global | A. Swarts | SwRI |
| J. J. Jetter | Honda R&D Am. | V. Tran | Infineum |
| F. Khan | Nissan Tech. Ctr. N.A. | M. Valentine | Toyota |
| D. Kozub | Daimler | J. VanScoyoc | Chevron Phillips Chem Co. |
| A. Kulinowski | Afton Chemical | S.A.Westbrook | SwRI |
| E. Kurtz | Ford Motor Co. | W.Woebkenberg | Aramco Services |
| P. Lacey | Delphi Diesel Systems | | |
| D. H. Lax | API | | |
| R. Leisenring | Consultant | | |

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

S. Broughton, Leader — Marathon Petroleum Corp.

| | | | |
|---|---|---|---|
| J. Axelrod | ExxonMobil | R. P. Lewis | Marathon Petroleum Corp. |
| J. Chandler | Consultant | S. Lopes | General Motors |
| D. A. Daniels | Innospec Fuel | K. Mitchell | Consultant |
| G.C. Gunter | Phillips 66 | S.B. Rubin-Pitel | ExxonMobil |
| D. Hess | Infineum | P. Searles | AP |
| C. Hodge | Consultant | W. Studzinski | General Motors |
| J. J. Jetter | Honda R&D Am. | V. Tran | Infineum |
| A.M. Kulinowski | Afton Chemical | M. Valentine | Toyota |

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

J. Axelrod, Co-Leader. — ExxonMobil
G. C. Gunter, Co-Leader — Phillips 66

| | | | |
|---|---|---|---|
| D. Abdallah | ExxonMobil | P. Henderson | Consultant |
| H. Abi-Akar | Caterpillar | H. Huang | Cummins |
| M. Ahmadi | Oronite Additive | J. J. Jetter | Honda R&D Am. |
| T. Bera | Shell | A. Kulinowski | Afton Chemical |
| P. Biggerstaff | Baker Petrolite | P. Lacey | Delphi Diesel Systems |
| D. Bohn | Flint Hills Resources | D. H. Lax | API |
| S. Broughton | Marathon Petroleum Corp. | T. Livingston | Robert Bosch |
| | | S. Lopes | General Motors |
| C. Burbrink | Cummins | J. Martinez | Chevron |
| R. Chapman | Consultant | K. Mitchell | Consultant |
| J. Draper | Motiva | T. Sutton | EMA |
| S. Fenwick | National Biodiesel Bd | M. Valentine | Toyota |
| R. George | BP | S.A. Westbrook | SwRI |
| B. E. Goodrich | John Deere | | |

**MEMBERSHIP**

## DP - DEPOSIT PROJECT PANEL
## (Project No. DP-04-17)

| | |
|---|---|
| J. Axelrod, Co-Leader | ExxonMobil |
| G. C. Gunter, Co-Leader | Phillips 66 |

| | | | |
|---|---|---|---|
| D. Abdallah | ExxonMobil | A. Kulinowski | Afton Chemical |
| T. Bera | Shell | P. Lacey | Delphi Diesel Systems |
| R. Chapman | Consultant | T. Livingston | Robert Bosch |
| J. Draper | Motiva | S. Lopes | General Motors |
| G. C. Gunter | Phillips 66 | J. Martinez | Chevron |
| | | T. Sutton | EMA |

## DP – FUEL CLEANLINESS PANEL
## (Project No. DP-06-16-1)

| | |
|---|---|
| R. Chapman, Leader | Consultant |

| | | | |
|---|---|---|---|
| D.Bohn | Flint Hills Resources | T. Livingston | Robert Bosch |
| S. Broughton | Marathon Petroleum Corp. | S. Lopes | General Motors |
| | | J. Martinez | Chevron |
| C. Burbrink | Cummins | F. Passman | BCA Inc. |
| J. Eichberger | Fuels Institute | S. Pollock | Steel Tank Institute |
| E. W. English | Fuel Quality Services | S. Rubin-Pitel | ExxonMobil |
| G. C. Gunter | Phillips 66 | P. Searles | API |
| R. Haerer | US EPA | M. Valentine | Toyota |
| C. Huang | Cummins | T. Sutton | EMA |
| R. Leisenring | Consultant | S. A. Westbrook | SwRI |
| R. P. Lewis | Marathon Petroleum Corp. | | |

## DP – FUEL CORROSION PANEL
## (PROJECT NO. DP-07-16)

D. H. Lax, Leader. API

| | |
|---|---|
| R. Bennick | BP |
| T. Bera | Shell |
| P. Beu | Wawa |
| S. Broughton | Marathon Petroleum Corp. |
| R. Chapman | Consultant |
| T. Covert | Ford |
| J. Eckstrom | BP |
| J. Eichberger | Fuels Institute |
| E. W. English | Fuel Quality Services |
| S. Fenwick | Nat. Biodiesel Brd. |
| L. Gerber | US EPA |
| G. C. Gunter | Phillips 66 |
| R. Haerer | US EPA |
| S. Hernandez | Chevron |
| S. Howell | Nat. Biodiesel Brd. |
| M. Kass | ORNL |
| R.P. Lewis | Marathon Petroleum Corp. |
| R. Long | PEI |
| J. Martinez | Chevron |
| R. McNutt | Sigma |
| K. Moriarty | NREL |
| F. Passman | Biodeterioration Cntrl Assoc. |
| S. Pollock | Steel Tank Institute |
| B. Renkes | Fiberglass Tank & Pipe |
| P. Searles | API |
| K. Spiker | Quiktrip |
| T. Sutton | EMA |
| M. Valentine | Toyota |
| S. A. Westbrook | SwRI |

## MEMBERSHIP

### DP – BIODIESEL AND RENEWABLE DIESEL PANEL
### (Project No. DP-08)

R. L. McCormick, Leader NREL

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| T. Alleman | NREL | J. J. Jetter | Honda R&D Am. |
| T. Bera | Shell | S. Kirby | Navistar |
| D. Bohn | Flint Hills Resources | D. Lax | API |
| J. Chandler | Consultant | R. Lewis | Marathon Petroleum Corp. |
| R. Chapman | Innospec | T. Livingston | Robert Bosch |
| J. Cruz | Daimler | K. Mitchell | Consultant |
| D. Daniels | Innospec | H. Nanjundaswamy | FEV |
| E. W. English | FQS | M. Nikanjam | Chevron |
| S. Fenwick | Nat. Biodiesel Brd. | S.B. Rubin-Pitel | ExxonMobil |
| R. George | BP | K. Salem | Lubrizol |
| B. Goodrich | John Deere | J. Y. Sigelko | Volkswagen of America |
| G.C. Gunter | Phillips 66 | W. Studzinski | General Motors |
| P. Henderson | Consultant | T. Sutton | EMA |
| D. Hess | Infineum | M. Valentine | Toyota |
| C. Hodge | Consultant | S. Westbrook | SwRI |
| S. Howell | Nat. Biodiesel Brd | | |
| C. Huang | Cummins | | |

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