06

annual progress report

ADVANCED COMBUSTION, EMISSION CONTROLS, HEALTH IMPACTS, AND FUELS MERIT REVIEW AND PEER EVALUATION

FreedomCAR and Vehicle Technologies Program

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Energy Efficiency and Renewable Energy
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FreedomCAR & Fuel Partnership

21st CENTURY TRUCK PARTNERSHIP

Department of Energy

Washington, DC 20585

October 2006

Dear Colleague:

This document summarizes the comments provided by the Review Panel for the FY 2006 Department of Energy (DOE) Advanced Combustion, Emission Controls, Health Impacts, and Fuels Merit Review and Peer Evaluation Meeting, the "ACE Review," held on May 15-18, 2006 at Argonne National Laboratory (ANL). The raw evaluations and comments of the panel were provided (with reviewers' names deleted) to the presenters in early June and were used by national laboratory researchers in the development of Annual Operating Plans (AOPs) for fiscal year (FY) 2007. The panel's recommendations have been taken into consideration, along with laboratory AOPs, by DOE Technology Managers in the development of work plans for FY 2007.

The table below lists the projects discussed at the review and the major actions to be taken during the upcoming fiscal year. Panel member comments have been consolidated and are not attributed to individuals.

This review covers only national laboratory projects funded by the federal budget. Industry R&D projects, funded competitively, are not reviewed at this annual meeting, but are reviewed semi-annually by DOE Technology Managers.

Topic Title and Organization	FY 2007 Major Actions
Combustion	
A Parametric Study of Diesel Fuel Breakup Near the Nozzle (Jin Wang, Argonne National Laboratory)	Combine effort with *X-Ray Characterization of Light-Duty Diesel Sprays* conducted by Chris Powell at Argonne National Laboratory.
Advanced Hydrogen-Fueled Internal Combustion Engine Research (Chris White, Sandia National Laboratories)	Continue project – (1) Investigate in-cylinder hydrogen-air mixing using planar laser induced fluorescence; (2) Initiate implementation of an emission bench to measure engine-out emissions; (3) Investigate additional speed/load points.
Automotive HCCI Combustion Research (Richard Steeper, Sandia National Laboratories)	Continue project – Characterize strategies for achieving high efficiency and reduced emissions during automotive HCCI operation, including negative-valve-overlap operation.
Automotive Low-Temperature Diesel Combustion Research (Paul Miles, Sandia National Laboratories)	Continue project – Qualify new GM optical engine performance and investigate sources of UHC and CO emissions under high-efficiency, automotive low-temperature combustion operating conditions.
HCCI and Stratified Charge CI Engine Combustion Research (John Dec, Sandia National Laboratories)	Continue project – Determine the effects of EGR and its constituents on HCCI combustion phasing and heat-release rate, and the mechanisms behind these effects. Investigate fuel stratification at low loads using PLIF imaging, which is important for improving low-load efficiency.
High-Efficiency Clean Combustion (HECC) in Light-Duty Multi-Cylinder Diesel Engines (Robert Wagner, Oak Ridge National Laboratory)	Upgrade research platform to GM 1.9 engine. Collaborate with SNL and University of Wisconsin for complementary multi-cylinder plus single-cylinder program, including modeling. Focus on particular multicylinder issue, transient phenomena, for example. Continue attention on efficiency.
Kinetic Modeling of Practical Hydrocarbon Fuels (Bill Pitz, Lawrence Livermore National Laboratory)	Develop surrogate fuels for HCCI combustion analysis. Provide analytical support for low temperature combustion experiments being conducted at other national labs.
Large Eddy Simulation Applied to Low Temp and Hydrogen Engine Combustion Research (Joe Oefelein, Sandia National Laboratories)	Continue project – Conduct simulations of the optically accessible hydrogen-fueled IC-engine configuration and of stand-alone, hydrogen, direct-injection processes (out of engine) with emphasis on pattern optimization. Initiate LES calculations for LTC engine research.

Topic Title and Organization	FY 2007 Major Actions
Modeling of HCCI and PCCI Combustion Processes (Dan Flowers, Lawrence Livermore National Laboratory)	Develop and validate computationally efficient models for partially stratified combustion. Provide analytical support for PCCI/HCCI experiments being conducted at other national labs.
Multi-Diagnostic In-Cylinder Imaging & Multi-Dimensional Modeling of Low-Temp HD CI Combustion (Mark Musculus, Sandia National Laboratories)	Continue project – Develop quantitative in-cylinder unburned fuel diagnostics and investigate high-efficiency, low-temperature combustion (LTC) unburned fuel sources. Determine piston bowl geometry effects on LTC in collaboration with University of Wisconsin.
Optimized Free Piston Engine Generator (Peter Van Blarigan, Sandia National Laboratories)	Begin fabrication of opposed-piston, twin-alternator, free-piston experiment for operation in FY2008
Parallel KIVA-4 (David Torres, Los Alamos National Laboratory)	Continue effort to develop converters to make established grid-generation software compatible with KIVA-4. Implement improved submodels. Improve numerical algorithm governing velocity.
Progress in Hydrogen-Fueled Engine Research at Argonne (Steve Ciatti, Argonne National Laboratory)	Continue to use OH* chemiluminescence to perform 2-D measurements of F/A ratio in DI hydrogen operation and provide to Ford's for modeling. Continue to use gas temperature spectroscopy to assess the performance of DI combustion in retaining low emissions results.
Relating Fluid Flow Characteristics Near the Nozzle Tip to HD Diesel Engine Performance & Emissions (Doug Longman, Argonne National Laboratory)	Continue effort. Build the spray chamber and conduct the first set of x-ray experiments at APS. Incorporate HEUI fuel system and AVL VisioScope instrumentation.
Soot Formation Fundamentals that Limit Low-Temperature Combustion (Lyle Pickett, Sandia National Laboratories)	Continue project – Investigate early-injection transients of liquid spray penetration and soot formation at high-efficiency, low-temperature combustion conditions.
Understanding & Controlling Transition Between Conventional SI Combustion and HCCI (K.D. Edwards, Oak Ridge National Laboratory)	Focus on understanding the physics governing the transition between SI and HCCI operation as well as hybrid SI-HCCI combustion modes. An industry partner has been identified with an appropriate engine platform and advanced controller capabilities.
X-Ray Characterization of Light-Duty Diesel Sprays (Chris Powell, Argonne National Laboratory)	Continue effort to perform spray measurements under realistic light-duty engine densities by increasing the ambient pressure to 35 bar. Further improvements to the data acquisition system will be made to allow measurement and recording of parameters such as fuel temperature and common rail pressure fluctuations.
Emission Control	
Characterizing Lean NOx Trap Regeneration and Desulfation (Shean Huff, Oak Ridge National Laboratory)	Continue project – Address challenges of transient low temperature operation by investigating fuel efficiency of LNT regeneration strategies that employ advanced combustion techniques such as low temperature combustion.
CLEERS DPF Characterization and Modeling (Mark Stewart, Pacific Northwest National Laboratory)	Include thermal effects and catalyzed surface kinetics in micro-scale simulations, including O_2 and NOx regeneration mechanisms. Tie regeneration modeling to actual vehicle tests.
CLEERS-Overview and LNT R&D (Stuart Daw, Oak Ridge National Laboratory)	Continue project with increased emphasis on LNT-SCR integration and ammonia chemistry. Address system integration issues as further work on sulfur effects.
Fuel Efficient Diesel Particulate Filter Modeling and Development (Heather Dillon, Pacific Northwest National Laboratory)	Specify an optimized ACM structure for catalyzed soot oxidation. Complete experimental validation tests on the catalytic ACM structure for optimized soot oxidation. Conduct full-scale engine tests on optimized catalytic ACM structure.
Low Temperature HC/CO Oxidation Catalysis in Support of HCCI Emission Control (Ken Rappe, Pacific Northwest National Laboratory)	Complete bench-scale assessment of transients on Caterpillar-developed model catalyst systems. Initiate testing and optimization of monolithic formulations in realistic exhaust gases

Topic Title and Organization	FY 2007 Major Actions
Mechanisms of Sulfur Poisoning of NOx Adsorber Materials (Charles Peden, Pacific Northwest National Laboratory)	Develop LNT thermal history diagnostics techniques. Improve mechanistic understanding of sulfur removal processes. Apply developing thermal history diagnostic methods to Cummins-supplied, engine-aged samples.
Health Impacts	
Health Impacts of Engine Emissions (Joe Mauderly, Lovelace Respiratory Research Institute)	Current work on clarifying the health hazards of specific emissions components will be completed during FY-07. This includes oil-derived organic nanoparticles, VOCs, and nitro-aromatics, and completes the necessary foundation for screening effects of new fuels and combustion technologies. As recommended, the focus will then shift entirely to evaluating alternate fuels and emerging technologies, with priorities set in part through discussions with OEMs.
Impact of Lubricants on Mobile Source Emissions (Doug Lawson, National Renewable Energy Laboratory)	Since the Merit Review meeting, NREL, South Coast Air Quality Management District (SCAQMD) and California Air Resources Board (CARB) jointly issued an RFP, technical responses have been evaluated and the winning contract has been selected. Work will begin in FY 2007.
Remote Sensing of Air Toxics at the Watt Road Environmental Laboratory (Jim Parks, Oak Ridge National Laboratory)	In FY 07 focus will shift to upstream issues to better align the WREL with the DOE FreedomCAR Health Impacts mission. Begin to characterize MSATs (Mobile Source Air Toxics) produced during engine lab studies from advanced combustion modes, aftertreatment systems, and alternative fuels (issues for 2010+ time frame which are beyond the focus of ACES); Continue real-world studies of MSATs produced by idling trucks or congested traffic areas.
The FCVT Health Impacts Program-Health Effects Studies (Doug Lawson, National Renewable Energy Laboratory)	A proximate modeling study to investigate the weekend ozone effect in Southeast Michigan will be completed in May 2007. Emissions inventories will be submitted to the modelers for review and incorporation into the air quality models; This is the last in a series of activities designed to investigate the impact of NOx emissions on ozone air quality throughout the United States.
Fuels	
Biodiesel Effects on NOx Emissions: Engine vs. Chassis Test Cycles (Robert McCormick, National Renewable Energy Laboratory)	Continue project – Two additional vehicles will be tested; study focus will shift to data analysis, including analysis of real-time chassis test results and drive train modeling.
Conventional and Alternative Fuels Low Temperature Combustion Research (Charles Mueller, Sandia National Laboratories)	Continue project – Determine strategies for using fuel properties to expand the operating range over which high-efficiency LTC is possible and determine how fuel bound oxygen affects NOx formation.
Diesel Range Fuel Effects on Single Cylinder HCCI (Jim Szybist, Oak Ridge National Laboratory)	Continue project – continue study of fuel effects in advanced combustion regimes, increasing attention to chemistry effects including oil sands and bio derived fuels. Consider upgrading research platform.
DPF Performance with Biodiesel Blends (Aaron Williams, National Renewable Energy Laboratory)	Continue project – emphasis on transient testing and measurement of fuel economy penalties associated with actively regenerated systems.
Effects of Biodiesel Blends on Performance of LD Diesel SCR Emission Control Systems (Matt Thornton, National Renewable Energy Laboratory)	Continue project – SCR and system optimization with B20; initiate NAC system aging.
Fuel and Lube Constituent Effects on Emissions Control Aging (Todd Toops, Oak Ridge National Laboratory)	Continue project – Continue LNT aging and characterization research, continue DPF ash effects on performance, start poisoning and aging effects of combined DPF/SCR systems (2010 focus).

Topic Title and Organization	FY 2007 Major Actions
Fuel Property Effects on Diesel High Efficiency Clean Combustion (Scott Sluder, Oak Ridge National Laboratory)	Continue project – Upgrade to GM 1.9L engine, expand the number of operating points and fuels evaluated (include FACE fuels), and continue to provide speciation data for better understanding of fuel effects on HECC efficiency and emissions.
Fuels for Advanced Combustion Engines (FACE) (Wendy Clark, National Renewable Energy Laboratory)	Continue project – Working group team and statisticians analyze results of preliminary blends.
Fundamental Studies of Fuels and Ignition and Their Relevance to Advanced Combustion (Josh Taylor, National Renewable Energy Laboratory)	Continue project – Quantify fuel ignition index parameters for 10 pure compounds and 10 ULSD fuels.
Gasoline-Range Fuel Effects on HCCI (Bruce Bunting, Oak Ridge National Laboratory)	Continue project – Study effects of fuel chemistry and ethanol addition on HCCI combustion, continue to run fully blended fuels and begin partnership in kinetics of surrogate fuels with another laboratory. Look at fuel effects in transition area.
Oxidation Stability of Biodiesel and Biodiesel Blends (Robert McCormick, National Renewable Energy Laboratory)	Continue project – The Phase I study will be completed and results presented to industry stakeholders. Based on industry input additional tests using a broader range of ULSD fuels and investigating the impact of antioxidant additives will be initiated. Ideas for real-world validation tests will be solicited from industry.

The FY 2007 ACE review will be held during the week of April 23, 2007. We would like to express our sincere appreciation to the researchers and reviewers who make this report possible and influence our decisions for the new fiscal year. Special thanks go to the staff at Argonne National Laboratory for hosting the 2006 meeting.

Thank you for participating in the FY 2006 DOE ACE review meeting. Please feel free to provide suggestions for improving this annual meeting. We look forward to your participation in the FY 2007 review.

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Introduction

This report is a summary and analysis of comments from the Advisory Panel at the FY 2006 DOE National Laboratory Advanced Combustion, Emission Control, Health Impacts, and Fuels Merit Review and Peer Evaluation, held May 15-18, 2006 at Argonne National Laboratory. The work evaluated in this document supports the FreedomCAR and Vehicle Technologies Program. The results of this merit review and peer evaluation are major inputs used by DOE in making its funding decisions for the upcoming fiscal year. The objectives of this meeting were to:

- Review and evaluate FY 2006 accomplishments and FY 2007 plans for DOE laboratory programs in advanced combustion engine, emission control, and fuels R&D.
- Provide an opportunity for industry program participants (engine manufacturers, emission control manufacturers, vehicle manufacturers, etc.) to shape the DOE-sponsored R&D program so that the highest priority technical barriers are addressed. The meeting also serves to facilitate technology transfer.
- Foster interactions among the national laboratories conducting the R&D.

The Review Panel members, listed in Table 1, attended the meeting and provided comments on the projects presented. They are peer experts from a variety of related backgrounds including automobile and truck companies, engine manufacturers, emission control system manufacturers, fuels manufacturers, universities, and other U.S. Government agencies. A complete list of the meeting participants is presented as an appendix.

Table 1: Review Panel Members

Member Name	Affiliation
Richard Blint	General Motors Corporation
Joseph Bonadies	Delphi Corporation
Norman Brinkman	General Motors Corporation
Matt Brusstar	U.S. Environmental Protection Agency
Bill Cannella	Chevron
John Farrell	ExxonMobil
Rick Gustafson	Cummins Inc.
Craig Haberger	Caterpillar Inc.
John Hoard	Ford Motor Company
Harry Husted	Delphi Corporation
Alan Karkkainen	International Truck and Engine Corporation
Bernd Krutzch	DaimlerChrysler
Mark Mehall	Ford Motor Company
Heijo Oelschlegel	DaimlerChrysler
Harold Pangilinan	U.S. Army
Peter Schihl	U.S. Army
Harry Sigworth	Chevron
Chun Tai	Volvo Powertrain North America
Rich Winsor	John Deere
Ken Wright	ConocoPhillips
Yi Xu	BP
Tom Yonushonis	Cummins Inc.

Analysis Method

As shown in Table 1, a total of twenty-two advisory panel members participated in the merit review. A total of 38 project presentations were given at the meeting, and a total of 519 review sheets were received from the review panel members (not every panel member reviewed every project). To determine the scores for these projects, the projects were placed into four categories that were established in consultation with DOE program managers. These four categories were:

- In-Cylinder Combustion and Modeling Studies,
- Emission Control Devices for NOx and PM Control,
- Health Impacts, and
- Fuels Technologies.

Review panel members were asked to provide numeric scores (on a scale of one to four, with four being the highest) for five aspects of the research on their review form, a sample of which can be found as an appendix to this report. The five aspects were:

- Relevance to overall DOE objectives;
- Approach to performing the research and development;
- Technical accomplishments and progress toward achieving the project and DOE goals;
- Technology transfer and collaborations with industries, universities, and other laboratories; and
- Approach to and relevance of proposed future research.

The numeric scores given to each project by the reviewers were averaged to provide the overall score for that project for each of the five criteria. An average score for the five criteria was also calculated within each of the four project categories for all projects in that category. In this manner, a project's overall score can be compared to other projects in that category.

Reviewers were also asked to provide qualitative comments on the five research aspects, as well as on the specific strengths and weaknesses of the project and any recommendations for additions or deletions to the work scope. These comments, along with the quantitative scores, were placed into a database for easy retrieval and analysis. These comments are summarized in the following sections, with an indication of how many reviewers provided written comments for that project and that question. All reviewers of a given project provided a numeric score for each of the five criteria, but did not necessarily provide qualitative comments.

Organization of the Report

This report is organized in four main sections, one section for each of the four main R&D categories. The first page of each section presents a summary of the average scores for the projects in that category, highlighting the highest scores for each of the five scoring aspects and the category average for those aspects. A brief description of the general type of research being performed in each category is also presented.

The remaining pages of each section present the results of the analysis for each of the projects discussed at the merit review. Graphs showing how the particular project compared with other projects in its category are presented, as well as a discussion of these results. A summary of the qualitative comments is also provided.

This category includes projects to examine, through the use of optically accessible laboratory test engines and other tools, how diesel combustion occurs in a diesel engine cylinder. Research focuses on how particulates are formed in the cylinder, and how particulate formation might be related to fuel injection pressure and other engine parameters. Studies are also underway to relate experimental data obtained from these engines to thermophysical models of engine operation. This category also includes projects involving the homogeneous-charge compression-ignition engine (HCCI), which combines the high thermal efficiency of a diesel engine with the ability to use fuels other than diesel fuel. HCCI engines can produce lower emissions of NOx and PM than conventional diesel engines. Research is currently being done to combine laboratory HCCI engine experiments with detailed modeling to build a more complete understanding of HCCI combustion and facilitate design of engine control systems. Research is also beginning in this area on hydrogen combustion in internal combustion engines.

Below is a summary of average scores for 2006 for the seventeen projects reviewed in this category, along with the average, minimum, and maximum score for all projects in the combustion and emission control sections of this report. The highest score in this category for each question is highlighted.

Summary of Scores for Projects in this Section

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Project Average Score
5	*A Parametric Study of Diesel Fuel Breakup Near the Nozzle* (Jin Wang, Argonne National Laboratory)	3.31	3.44	3.19	3.25	3.06	3.25
8	*Advanced Hydrogen-Fueled Internal Combustion Engine Research* (Chris White, Sandia National Laboratories)	2.85	3.31	2.54	3.00	3.08	2.95
11	*Automotive HCCI Combustion Research* (Richard Steeper, Sandia National Laboratories)	3.53	3.12	2.94	3.35	3.18	3.22
14	*Automotive Low-Temperature Diesel Combustion Research* (Paul Miles, Sandia National Laboratories)	3.60	3.47	3.13	3.67	3.33	3.44
17	*HCCI and Stratified Charge CI Engine Combustion Research* (John Dec, Sandia National Laboratories)	**3.88**	**3.69**	**3.50**	3.63	**3.50**	**3.64**
20	*High-Efficiency Clean Combustion (HECC) in Light-Duty Multi-Cylinder Diesel Engines* (Robert Wagner, Oak Ridge National Laboratory)	3.05	3.00	2.88	3.05	2.89	2.98
24	*Kinetic Modeling of Practical Hydrocarbon Fuels* (Bill Pitz, Lawrence Livermore National Laboratory)	3.40	3.33	3.00	3.30	3.22	3.25
26	*Large Eddy Simulation Applied to Low Temp and Hydrogen Engine Combustion Research* (Joe Oefelein, Sandia National Laboratories)	3.30	3.44	2.67	3.10	3.20	3.14
28	*Modeling of HCCI and PCCI Combustion Processes* (Dan Flowers, Lawrence Livermore National Laboratory)	3.56	3.56	3.25	3.47	3.29	3.43
31	*Multi-Diagnostic In-Cylinder Imaging & Multi-Dimensional Modeling of Low-Temp HD CI Combustion* (Mark Musculus, Sandia National Laboratories)	3.63	3.63	3.31	3.56	**3.50**	3.53
34	*Optimized Free Piston Engine Generator* (Peter Van Blarigan, Sandia National Laboratories)	2.79	2.64	2.17	2.69	2.75	2.61
37	*Parallel KIVA-4* (David Torres, Los Alamos National Laboratory)	3.15	3.31	3.08	2.92	3.31	3.15
39	*Progress in Hydrogen-Fueled Engine Research at Argonne* (Steve Ciatti, Argonne National Laboratory)	2.88	2.81	3.06	3.25	2.93	2.99
42	*Relating Fluid Flow Characteristics Near the Nozzle Tip to HD Diesel Engine Performance & Emissions* (Doug Longman, Argonne National Laboratory)	3.00	3.17	2.70	3.17	2.83	2.97
44	*Soot Formation Fundamentals that Limit Low-Temperature Combustion* (Lyle Pickett, Sandia National Laboratories)	3.39	3.54	3.23	3.69	3.23	3.42

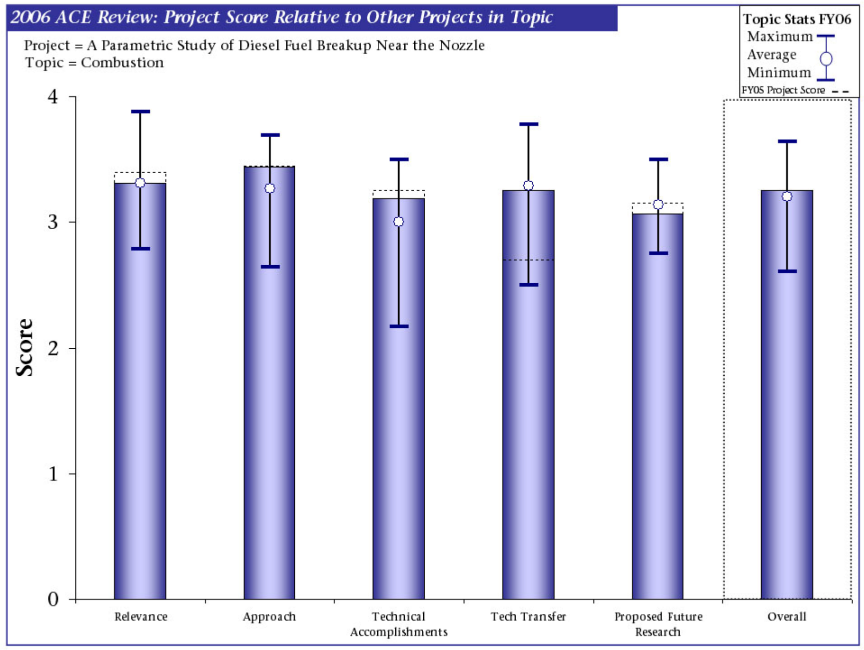
Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Project Average Score
46	*Understanding & Controlling Transition Between Conventional SI Combustion and HCCI* (K.D. Edwards, Oak Ridge National Laboratory)	3.23	3.08	3.18	2.50	3.08	3.01
48	*X-Ray Characterization of Light-Duty Diesel Sprays* (Chris Powell, Argonne National Laboratory)	3.44	3.22	2.77	3.78	3.00	3.24
	Average Score for This Category	**3.31**	**3.27**	**3.00**	**3.29**	**3.14**	**3.20**

Overall Scores for Combustion and Emission Control

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Score
Average	3.29	3.27	3.04	3.30	3.11	3.20
Maximum	3.88	3.69	3.50	3.94	3.50	3.64
Minimum	2.77	2.64	2.17	2.50	2.75	2.61

In-Cylinder Combustion Studies and Modeling

A Parametric Study of Diesel Fuel Breakup Near the Nozzle, Jin Wang of Argonne National Laboratory



Brief Summary of Project

The objective of this project is to understand diesel fuel spray breakup and atomization from fuel injectors, and correlate injection conditions to diesel fuel spray breakup in a parametric fashion. Researchers are using x-ray techniques to gain a quantitative look at the diesel fuel spray in a pressure chamber.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 16 reviewers)

Comments were positive in general. One reviewer noted the useful tools for injector design. Another person said that it is very important to understand the fuel spray on the fundamental level. One evaluator commented that spray formation is right at the beginning of understanding combustion phenomena and helps significantly to finally improve and optimize combustion technology. Another person agreed, adding that the fundamental understanding and modeling of fuel spray breakup, nozzle behavior, and pintle movement is very important to combustion processes. This work is important to fuel injection system suppliers. Another reviewer felt that the investigation is very relevant for diesel modelers, adding that if there is an effect of in-nozzle flow dynamics on subsequent spray structure, this information can be a significant breakthrough. One person remarked that injector design makes a huge difference in combustion characteristics, and this work uses unique instrumentation to improve injector nozzle design which should have significant long term benefits. Another reviewer had detailed observations that this project is focused on developing a new technique for visualization of spray behavior near the injector nozzle and thus is not directly focused on pushing CIDI technology to the commercial marketplace. Instead, this technique may eventually be used by industry to assess the interaction between early spray formation and engine-out emissions. Another person simply stated that they really liked the work progress to date and that this work is relevant to work going on now at Cummins. The final reviewer cautioned that the contributions of this research, while important, may not be central to DOE objectives.

Question 2: Approach to performing the research and development (Written responses from 8 of 16 reviewers)

Results were mixed to this question. One reviewer noted that the researchers seem to be solving the problems of measuring the injector sprays using the high energy x-ray source. Another also noted that the x-rays help to understand real world injector nozzles and tips. One reviewer commented that the capabilities provided here are unique, and lend important insights into spray formation processes. One person felt that it seems like the technology is ready, but needs additional equipment to be used more effectively (e.g. beam access and reduced setup time). Others cautioned about attaining realistic injection and charge pressures to generate realistic data. One person commented that it is important to keep increasing the chamber pressure and understand the underlying effects of the resulting changes. One reviewer noted the good approach over the last few years that has led toward a continual improvement in the spray chamber operating pressure from 1 atm to 30 atm. They added that the only improvement is to focus on higher ambient pressure conditions versus lower pressure conditions which exhibit different break-up behavior than higher pressure jets. Another reviewer had similar detailed comments, noting that the approach is to use pressure measurement, displacement measurements, and flow visualization information to determine in-nozzle effects on spray structure. They add that the effort tries to determine with some certainty what mechanisms affect spray dynamics. They add that the injection pressure is a bit low but not irrelevant; however the charge pressure is low making the results a bit more irrelevant. Another reviewer agreed, adding that most sprays have been injected into low-density gases, which gives misleading results. The final reviewer simply stated that the nozzle geometry is not representative of current technology.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 16 reviewers)

One reviewer felt that the project is achieving its main objectives, and is providing very insightful data on high pressure fuel sprays. Another added that the group is producing good data and has shown good mechanism analysis. They add that some relationships for future work can be used to direct resources and data acquisition probes. Another reviewer stated there has been good progress since last year. One evaluator noted the nice pictures and that capturing images of the interior of the injector and external plume density profile at the same time is great. One person simply stated that the researchers are starting to make real contributions. Another reviewer felt that there has been very good progress during the last two years redesigning the spray chamber to accommodate higher operating pressures. However, they point out that work must continue toward even higher and more realistic in-cylinder pressures. Another reviewer agreed that utilizing the x-ray source is a solid accomplishment, but added that so far they have not seen any clear injector improvements from this program. The final reviewer commented that it is time to apply the tool for combustion studies. They added that higher backpressure and temperature are desired and that the cavitation phenomena inside the nozzle are important in understanding spray break-up.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 16 reviewers)

Several reviewers noted the good collaboration with universities (UW, WSU) and industry (Visteon, GM) to both model nozzle flows and supply updated fuel injection equipment. Another person added that the level of collaboration with others is consistent with this type of project. Another person added that it seems that the researchers need to work on getting the collaboration for next steps. One reviewer stated that the work has been well presented; however, they did not yet see any of the collaborators show quantifiable injector improvements. Another person suggested that they would like to see the work tied to engine test or performance modeling results. The final reviewer suggested that the researchers have more interaction with other projects working on nozzle design and optical access engines recommended.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 16 reviewers)

Several reviewers noted the work towards reaching more realistic pressures. One reviewer noted that imaging the spray under more realistic pressures and temperatures is crucial, adding that they would also like to see more of an indication that the injector designers can and are using this information. Another person also acknowledged that the future work is focused on higher pressure spray chamber pressures - this is the highest priority in light of practical diesel spray boundary conditions, i.e. higher chamber pressures. Two reviewers noted the planned work towards multi-hole nozzle designs. One person commented that work with multi-hole nozzles is more representative of production injectors, while another simply added that it is logical to move on to multi-hole nozzles. One reviewer suggested that the investigator requires more sensors and that the effort can address more realistic engine nozzle geometries instead. They added that the work can also address higher charge pressure dynamics but does not. The final reviewer cautioned that improvement of the tool is always required, but focus should be the application of the tool to currently open issues.

Specific Strengths and Weaknesses (Written responses from 9 of 16 reviewers)

- Specific Strengths
  - The Argonne high energy x-ray beam system.
  - The results of this research are one-of-a-kind in terms of providing invaluable physical insight into the direct effects of the needle lift to the near-field spray breakup, and promise to lead to much improvement in computational spray models.
  - Really like ability to connect internal injector phenomena with spray.
  - Unique methodology, starting to make useful contribution to understanding of sprays.
  - Excellent use of phase-contrast look inside injector nozzle correlated with x-ray look inside the fuel spray. Modeling activity to complement is important.
  - Real world injector nozzle tips can be investigated.

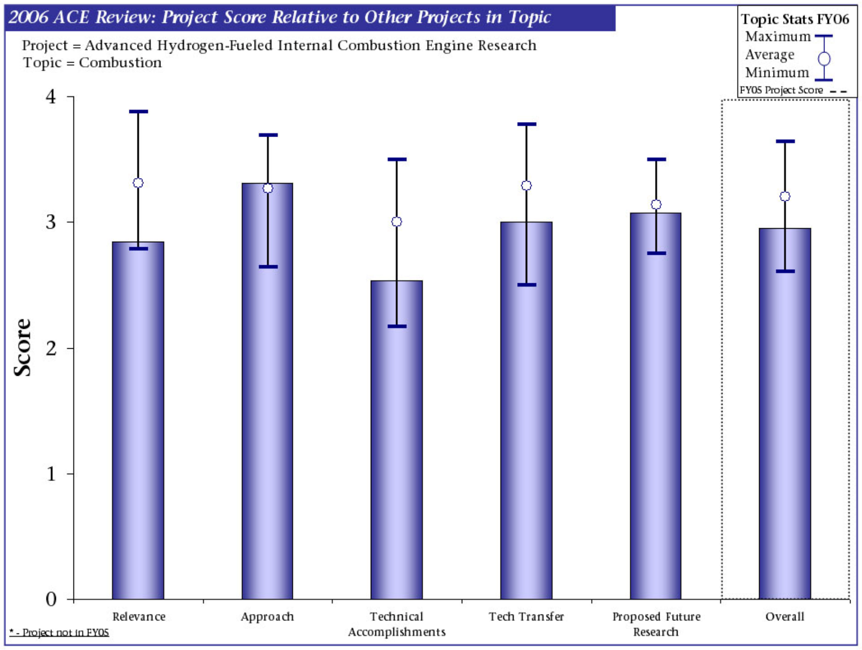
- – Truly unique experimental facility.
  - – Good tool and design information developed; good collaborations.
  - – In-nozzle physics is examined as to its relationship to spray structure.
- Specific Weaknesses
  - – The measurements are time-intensive, and so do not offer the promise of imaging over a broad range of parameters that is needed for developing effective, universal models.
  - – Set-up and additional required expenditure although Cummins is very interested in these topics, if big front end investment is required, may not be financially possible next year.
  - – Difficult test method, not very portable!
  - – Work is being done at low injection pressures. Modern systems will be running at 2000-3000 bar. Also, we'll be going to smaller orifices / multiple rows to support advanced combustion processes. Also consider spray formation with multiple injections and sweeping dwells. Consider amplified systems versus common rail systems & ROI effects on spray formation/breakup, as well as L/D effects.
  - – Limited to the application at Argonne site. Low power X-ray investigations limited to low pressure/temperature vessel.
  - – Chamber pressure is still a little low.
  - – Incomplete work.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 12 of 16 reviewers)

- Stronger ties are needed to the injector designers.
- The sensitivity to injection pressure should also be explored, out to perhaps 3000 bar, as the relative importance of the physical mechanisms identified may change.
- Would be good to tie combustion performance of individual injectors to your scans (i.e., run prescribed combustion experiments in a single cylinder engine after or before you scan). You could use the SCE engines at Cummins or Caterpillar (or use more capable equipment at Sandia?).
- Keep going.
- Adding 3D tomography of the spray plumes could build additional understanding of spray breakup effects. Use of phase-contrast investigation of needle movement of advanced nozzle technologies can help foster improved fuel spray and combustion performance.
- Include cavitation phenomena to be investigated inside the nozzle during injection. Improve backpressure and temperature capabilities.
- Push chamber pressure above 50 atm as soon as possible.
- Better identify real-engine pressure and temperature effects on results.
- They should calculate how much fuel is in the dense core as the ambient gas density is increased.
- May add some downstream spray image to explain how upstream affects downstream, just mie-scattering image will be enough.

In-Cylinder Combustion Studies and Modeling

Advanced Hydrogen-Fueled Internal Combustion Engine Research, Chris White of Sandia National Laboratories



Brief Summary of Project

This project had several objectives: build a state-of-the-art laboratory to investigate in-cylinder hydrogen internal combustion engine combustion and emissions processes; investigate combustion and mixture formation in a direct injection hydrogen-fueled internal combustion engine using OH* chemiluminescence; develop a correlation between OH* chemiluminescence emission intensity and equivalence ratio; provide data to support modeling efforts using the Large Eddy Simulation (LES) technique; and begin assembly of the laser based optical diagnostic experimental setup.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 14 reviewers)

Not all of the reviewers agreed on the relevance of this project to the overall DOE objectives. One reviewer acknowledged the good work, but mentioned that it is difficult to understand how this will lead to better fuel economy. According to him, the impact on emissions is clear. A comment was made that this work is reasonably directed toward identifying the combustion characteristics of a spark-ignited hydrogen fueled engine. The value of hydrogen fueled internal combustion engines as an appropriate intermediate step for a hydrogen economy was questioned, but recognized as a separate issue. It was noted that hydrogen combustion is relevant when the target is to become independent of oil imports, but not for low emissions and high efficiency. A comment was made that although there appears to be some potential for a contribution, the project is ill-posed in some respects, as it is unclear whether the operating points examined and techniques used will lend valuable insight. One reviewer mentioned that this is truly an applied research project that is focused on developing measurement techniques for assessing local in-cylinder mixing. According to him, this is necessary for the development of fundamental mixing understanding with highly diffusive fuels; however, this will not directly address barriers toward bringing spark ignited hydrogen engines to the marketplace.

Question 2: Approach to performing the research and development (Written responses from 6 of 14 reviewers)

The comments regarding the approach were relatively positive with several suggestions for improvement. One reviewer stated that the project design is very good. Another agreed by saying that the application of different diagnostic tools together with close link to simulation is a good approach. One thought that exploring mixing effects with visualization tool is exciting. A comment was made that the optical combustion chamber design is reasonable. He added that it is a two-dimensional system, but follows in the pathways of gasoline and diesel work. He also thought that the data look good. Someone indicated that the project does not appear to be as well-coordinated with Argonne hydrogen engine efforts as one would hope. He added that the parallel effort at Argonne seems to have more clearly identified key areas of focus that somehow have not been carried over to the Sandia program. A comment was made that the approach could be improved by measuring engine-out emissions, adding boost to the induction system, and by looking at additional speed/load points.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 14 reviewers)

Reviewers acknowledged that the project is still in its incipient stage and their comments are reflective of that. One reviewer mentioned the importance of attempting to characterize the flame speed behavior of hydrogen engines, to allow for improved engine designs for this application. One felt that there apparently was good progress. A comment was made that two years seems like an awfully long time to refurbish a laboratory. On the other hand, a note was made of the test cell establishment in a short time. There was a mention of chemiluminescence results looking very promising. One felt that this project has a good start to date but only a minimum amount has been learned concerning local fuel-air mixing. Future work through collaboration with LES modelers should aid in generating future understanding.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 14 reviewers)

Most of the reviewers' comments acknowledged the collaboration with Ford and Sandia. One reviewer praised the collaboration with Ford as a major industrial partner. Close relationship with Sandia simulation group was also noted. Someone also mentioned good involvement with other laboratories. It was stated that the generated data is currently shared with modelers who will hopefully exploit this information toward better understanding of hydrogen-air mixing. In addition, industry appears to be partners in providing and setting up engine hardware. A suggestion was made to connect with the Argonne hydrogen engine work, since it is similar in nature. It was added that this project would provide insights that could be useful to Argonne hydrogen engine research. One reviewer thought that only Ford is involved and a comment was made that more coordination with other DOE efforts is needed.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 14 reviewers)

Reviewers thought that the future research plan is well thought-out. One reviewer stated that the approach and relevance of the proposed future research appears to be solid with a strong interaction with Ford, strongly influencing the future plans. It was noted that this effort seems to focus on areas where there may be no technical barrier. One commented that the program needs to shift its focus to key operating conditions where there may be mixing issues (i.e., idle, lower speed and high load). One thought that application of PLIF, although challenging, seem to be a nice approach for identifying inhomogeneities. It was mentioned that future work plans are logical, but it would be fruitful if additional speed/load points were added to the current test strategy.

Specific Strengths and Weaknesses (Written responses from 9 of 14 reviewers)

- Specific Strengths
  - Sandia's engine measurement expertise strengthens this project.
  - Techniques identified could lend better insight into fuel-air mixing in H_2 internal combustion engines.
  - Visualization to support model development is key.
  - Building capability for in depth diagnostics of H_2 engines.
  - Up-to-date engine with well established diagnostic tools and close link to detailed simulation.
  - Unique experimental facility – direct injection hydrogen engine experiments are a good parallel to the Argonne PFI/DI experiments.
  - Very good work in setting up and getting data from experimental setup and working to get quantitative understanding.
  - Direct injection seems a reasonable direction to go.
  - Appears to be following the optical engine work at Sandia; therefore, this project has a strong technical approach.
- Specific Weaknesses
  - The operating conditions need to be focused on a few key, standard points.
  - Definition of goals is perhaps a bit fuzzy; perhaps inevitable as program is getting ramped up.
  - Lean operation may limit power density or boosting is required.
  - Lack of engine-out emissions measurements - will add capability in future.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 14 reviewers)

- Given the focus on mixing, examining the challenges at idle and low-speed/high-load operation seems appropriate.
- Mixing is only one aspect of the NO formation; other parameters need to be considered, including EGR/boost, temperature, etc.
- Develop ideas: how will you recognize success? Goals should reflect utility of injection schemes evaluated.

How do we maximize efficiency (accounting for work to compress H_2) at acceptable emissions?

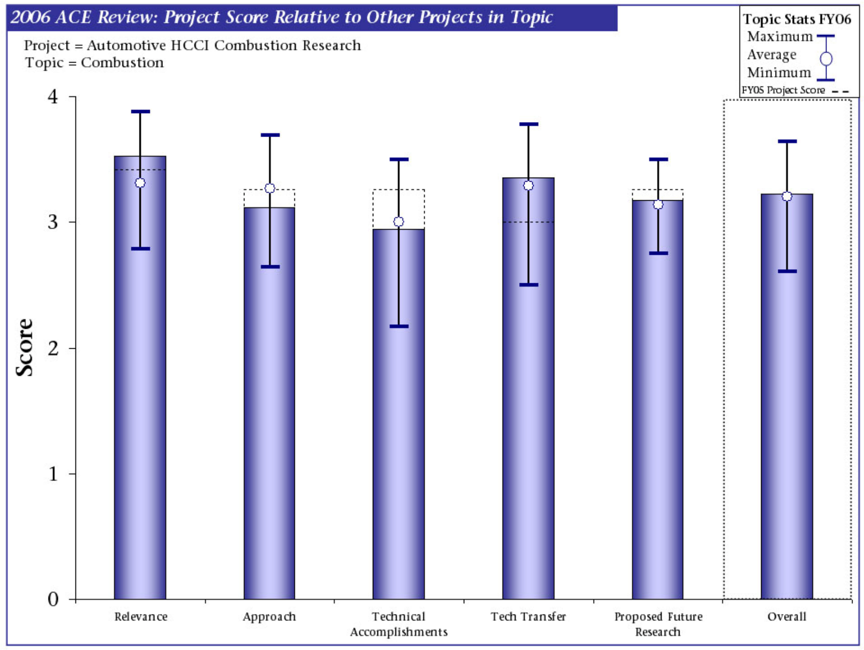
- Think about stoichiometric operation with three way catalyst which would be a low cost application. This should be at least considered in comparison to lean operation.
- Add more operating points to speed/load matrix.
- Future plans seem appropriate.

In-Cylinder Combustion Studies and Modeling

Automotive HCCI Combustion Research, Richard Steeper of Sandia National Laboratories

Brief Summary of Project

The objective of this project is to understand the fundamentals of HCCI charge preparation and how it can be controlled to improve the combustion/emission performance of automotive HCCI engines. This is being done through a combination of chemical kinetics modeling and optical engine work.



Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 17 reviewers)

Real and uniform enthusiasm was expressed by the reviewers regarding relevance to DOE's objectives. One reviewer noted that the work appeared well directed to make HCCI gasoline systems feasible. It was added that the work is critical to next-step improvement in light duty engines. One person pointed out that investigation into mixture non-homogeneities is one of the key issues to achieving better performance. A reviewer commented that this was an excellent project, addressing the relationship between mixing and nitrous oxide formation. He added that the work has focused on various injection strategies for controlling mixing and will focus in the future on valve timing strategies that also will indirectly impact in-cylinder mixing rate. In addition, he indicated that it is also addressing the differences between single and multi-hole nozzles and their impact on mixing. Another felt that this was relevant and useful research for NOx and CO_2 emissions and combustion efficiency.

Question 2: Approach to performing the research and development (Written responses from 6 of 17 reviewers)

The reviewers were in favor of the approach, however they did point out some weaknesses. One reviewer noted that the combination of developing PDF's, detailed engine measurements and CFD modeling give this project considerable opportunity to provide useful data. One thought that modeling is being used out in front of, or at the same pace as the experimental work and in that case, the progress will be glacial at best. Another felt the approach to date was difficult to criticize because the investigators have obviously worked very hard to isolate various strategies for controlling in-cylinder mixing rate through injection timing schemes. According to him, the only area of improvement is to push toward more realistic fuels which is part of the future work plan. It was mentioned that the approach investigates nozzles and sweeps while using PDF and LIF while measuring spatial distribution of fuel rich regions for each of the given test setups. One commented that the benefit and logic of the PDF methods versus other techniques should be shown. Another indicated that no testing at lower air/fuel ratios requires relying on simulation. However, the simulation results using PDF methods are poor (even trends are hard to see). He added that the effect of GDI injectors on homogeneity is well known.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 17 reviewers)

One reviewer stated that each of the accomplishments incrementally improves our understanding of the gasoline HCCI combustion approach. It was noted that work on 8-hole injector shows promise for achieving lower NOx at acceptable combustion efficiency. A reviewer noted the demonstration of the improved tradeoff for multihole injectors and explanation for that difference. One reviewer felt that there was good progress in refining mixture preparation metric (PDF of fuel). He added that the modeling work is welcome and needs to continue in coordination with experimental work in order to build understanding and improve the models at the same time. A comment was made that an explanation of importance of local temperature is appreciated. Very good work to date, according to a reviewer, has highlighted the impact of various injection schemes on nitrous oxide formation at lighter loads in a CIDI engine given a particular valve timing strategy. He suggested the work moves toward more realistic fuels and also includes potential variable valve timing strategies over a wide engine operating range to determine which fuel injection strategies truly are optimal for a real world engine application over a given load profile. A comment was made that these are significant experimental results for HCCI field which provide insight to HCCI calibration. It was noted that split injections, strategies, nozzle geometries, were looked at in good detail. One the negative side, a comment was made the program seems somewhat mired in injector/nozzle issues, distracting the overall focus. It was also indicated that the tested engine conditions are distant from modern engines. In particular, they are limited to light load and low speed.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 17 reviewers)

It was noted that the communication with industry is very good. A comment was made that the investigators took last year's recommendation for augmented collaboration to heart and pursued additional university and industry interaction for the current and future activities. One felt that this project is an excellent example of government, academic, and industry collaboration. Another indicated that the CFD interaction appears to be successful. Someone thought that more collaboration with industry is needed. One praised the collaborations with government and university laboratories (Stanford), but pointed out that industry involvement was limited to General Motors. This was echoed by a comment that cooperation with OEMs needs to be improved.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 17 reviewers)

One reviewer felt that future research is well positioned to address the operating conditions necessary for this technology. Another agreed, adding that the future work looks interesting and relevant. It was noted that cooperation with Stanford allows online temperature measurement which is interesting. A reviewer felt that very good future work of investigating valve timing effects on NOx formation under various injection timing strategies was proposed. His only recommendation was to explore single versus multi-hole nozzles within the context of the valve timing/fuel injection scheme study while utilizing real world fuels. One reviewer felt that the program is headed into another distraction, unless the NVO cams can be quickly screened. He did not see evidence of a clear definition of the barriers that are preventing full-map HCCI operation that would justify the relatively heavy emphasis on valve timing. A comment was made that the research is after more engine conditions which were not specified.

Specific Strengths and Weaknesses (Written responses from 9 of 17 reviewers)

- Specific Strengths
  - Good collaboration with industry, good interaction with universities (University of Wisconsin and Stanford) and good experimental engine laboratory.
  - The potential upside of this research is tremendous.
  - Detailed HCCI information is much needed.
  - Good fundamental work enhancing knowledge of mixtures prior to HCCI combustion.
  - Issues of spatial mixture homogeneity are one of the key factors for good HCCI combustion, and are well addressed.
  - Excellent experimental tool with very good industry collaboration.
  - Good development of additional tools; injector strategies discussion was useful.
  - Experimental work is solid and well founded.
  - Demonstration of improved tradeoff for multihole injector and explanation for that difference.
- Specific Weaknesses
  - The issues that prevent a wider range of operation do not appear clearly defined, and so the hardware iterations explored do not show a clear path for success. The modeling needs to be focused on one or more areas that represent barriers, not on elements that appear well understood.
  - Need to hold careful perspective - broad questions of strategy and goals (i.e., stratification) versus fine details.
  - This work would be more beneficial if done on Diesel engine platform.
  - No measurement at lower air-fuel ratios and weak simulation results.
  - Lack of data for real world fuels.

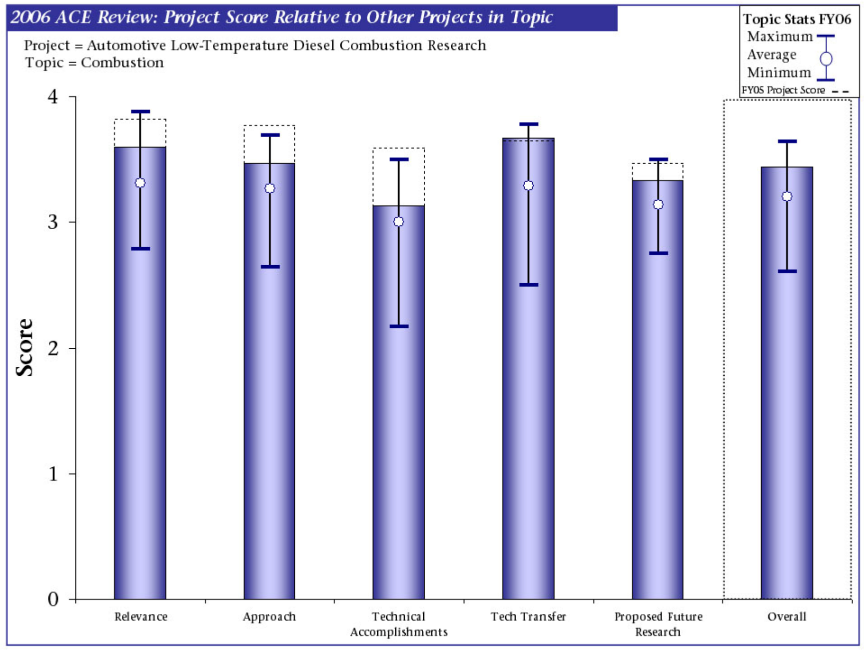
- Engine conditions are not reflective of modern engines.
- Results so far limited by inability to do NVO.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 11 of 17 reviewers)

- Include effects of fuel chemistry, looking at both different hydrocarbon species and ethanol.
- Focus on three operating points: idle, maximum efficiency point (~80% of full load, 1500-2000 rpm), and maximum power. Identifying the issues with these points will give better focus to the hardware and modeling efforts. Emphasis needs to be given to defining boost/EGR requirements, assuming that this will be part of the operating strategy.
- Continue to look at broader range of operation.
- The fuel injector nozzle configuration likely has significance in the mixture preparation. Some work to explore the effect of nozzle geometries might bear fruit (e.g., number of holes, spray angle).
- Testing with complex fuels similar to those used in the production engines would be an interesting check to insure that the PDF approach translates well to complex fuels. This will be admittedly much more difficult to model from a chemistry perspective.
- Would comparing results of a "fumigated" fueling be relevant? This would provide more of an ideal fully-premixed charge as a comparative boundary condition - the associated PDF might be interesting.
- Expand scope to wider range of operation.
- Try to achieve measurements at lower air-fuel ratios by applying EGR instead of larger amounts of fuel. Work hard on simulation code to improve results.
- Future work should push toward more realistic fuels and also include various nozzles to further assess nozzle mixing.
- Will be good to see the full cycle simulation results; good to see this project coming along.
- They need to apply the PDF calculation to compare the 8-hole and swirl injectors. Also, more than 8 holes should be investigated and VCO tip should be compared to LSN.
- Can anyone run one of these engines through a cycle or is this still too difficult?

In-Cylinder Combustion Studies and Modeling

Automotive Low-Temperature Diesel Combustion Research, Paul Miles of Sandia National Laboratories



Brief Summary of Project

Overall, this project seeks to investigate in-cylinder low-temperature combustion and emissions formation processes in a HSDI Diesel engine,with the objective of obtaining the physical understanding and predictive capabilities necessary to reduce engine out emissions while retaining fuel economy. Specific objectives included examining CO emissions and efficiency variation in high-dilution, early-injection low-temperature combustion (LTC) regimes, investigating new, full-field diagnostic techniques and analysis approaches, and enhancing laboratory capabilities and personnel.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 15 reviewers)

Review comments were positive for this aspect of the research. A reviewer said that this was a good investigation of mixture motion in light-duty engines. Another felt that the degree of program focus points to a strong probability of a significant long-term contribution. A reviewer commented that the improved diagnostic tools like flow pattern and 3-D smoke figures help a lot to understand and finally optimize combustion systems—in particular premixed combustion. A reviewer said that this is a fundamental mixing-emissions formation study that is scientifically interesting but not directly relevant toward the goal of pushing CIDI engine technology into the commercial marketplace. The value of this project is to possibly improve in-cylinder modeling of CIDI engines, to raise questions concerning the impact of in-cylinder vortices on emissions formation, and to push other researchers toward the development of improved combustion diagnostics for engines. The final reviewer noted that this project offered a good examination of local area mixing at low temperature conditions, and that this was essential work to address emissions improvements. This final reviewer said that HSDI work is valuable to light-duty applications. The work can lead to the preservation of efficiency and power density of current gains made by modern engines under the duress of future U.S. emission regulations.

Question 2: Approach to performing the research and development (Written responses from 5 of 15 reviewers)

A reviewer felt that the correlation of modeling and experimental results lends a good fundamental understanding of the in-cylinder LTC process. Another said that there was a very balanced mix of experimental and modeling approach to the determination of soot production and the relationship with fluid structures within the combustion chamber. This reviewer added that the approach is very effective in showing how flow structures are important. A reviewer offered that the squish flow area is important to understand air utilization in the combustion chamber. The diagnostic tools seem to enable the investigation of this region. A reviewer would like to see a more systematic, design of experiment approach to the data plan. This reviewer saw some of this in the presentation but would like to see more. Finally, a reviewer said that the approach is good, but limits the experimental engine speed/load space due to the inherent time required to conduct experiments and perform analysis. Thus, flowfield visualization is limited to a couple of speeds and loads, thus narrowing the applicability of any observed flowfield/emissions relationships.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 15 reviewers)

Review comments were mixed on this aspect of the research. One reviewer said that the accomplishments were useful to modelers and therefore progress has been made in addressing mixing questions and the relationship with

CO and soot. Another said that the results point to a means of improving combustion efficiency, but may not be such that they would be universally applicable to other low-temperature diesel combustion systems. A reviewer noted that the investigation of under-mixed fuel at high dilution, leading to high CO emissions, is interesting information. One reviewer simply noted that he did not have a good reference for the technical accomplishments.

On the other hand, a reviewer felt that progress is slow but noticeable, and that repeatability may need to be addressed more carefully. A final reviewer said that the progress is slow due to the inherent nature of in-cylinder flow visualization, which is very time intensive both in performing experiments and in conducting visualization analysis. Furthermore, the lack of progress toward an overall understanding of flowfield structures and emissions formation is also limited to the time consumption necessary to perform and analyze experiments.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 9 of 15 reviewers)

Reviewers generally were positive about the technology transfer of this project. Several reviewers noted the good collaboration with the University of Wisconsin ERC and GM Research, collaboration which was very valuable. A reviewer said that the collaboration list is impressive, while another noted the good interchange with other researchers. A reviewer pointed out that all of the engine companies are involved in the program. A reviewer said that this project is linked with industry and universities with the universities performing important flowfield CFD analysis in order to explore flowfield/emissions formation relationships. A final reviewer said that the project might benefit from more input from industry on the range of operating parameters and test conditions on which to focus.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 15 reviewers)

A reviewer said that the proposed plan is logical, and suggested that the team look at additional speed/load points. Another noted that the future work is pretty much predetermined and that the effort must complete the current undertaking. The PIV measurements together with the simulation may help understand current issues like valve cutouts, piston bowl geometries, swirl pattern, etc, in the opinion of a reviewer. A reviewer said that it would be very interesting to see the optimization of the combustion chamber design to minimize the “smoke ring.” A reviewer suggested that the team should use more design of experiments methods. A final reviewer said that the experimental work needs to lead the analytical work more directly. The proposed modeling work should be preceded by an experimental investigation to evaluate the usefulness/relevance of the modeling.

Specific Strengths and Weaknesses (Written responses from 8 of 15 reviewers)

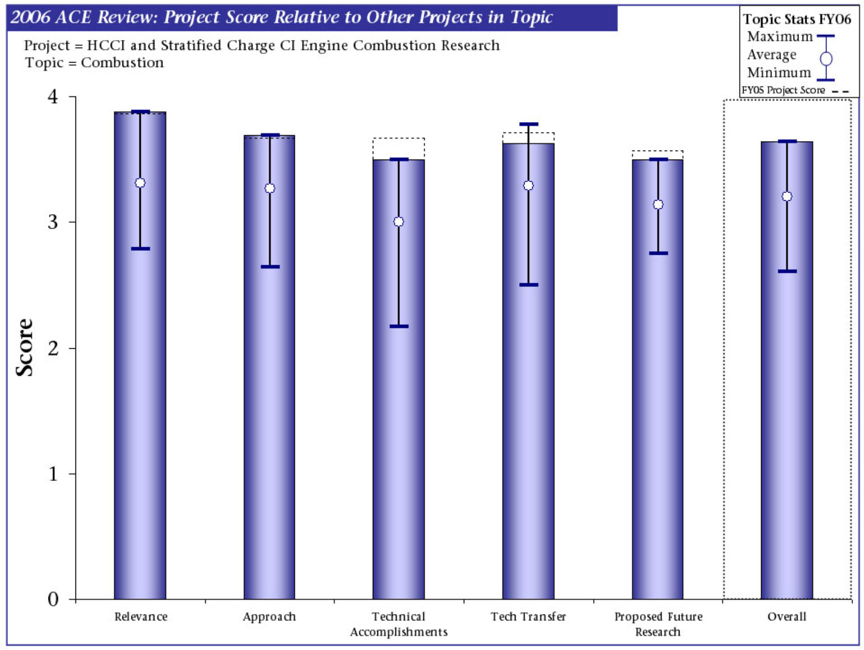
- Specific Strengths
  - Excellent data analyses, innovative ideas.
  - Strong analysis and strong interactions.
  - The fundamental contribution to combustion efficiency improvements is significant.
  - Benchmark of program quality. Great stuff.
  - Excellent optical access engine with good diagnostic tools.
  - Excellent experimental facility and very good collaboration with UW-ERC for modeling/analyzing flowfield/emissions formation behavior.
  - Persistent and useful experimental and modeling results to help with engine optimization.
  - In-cylinder mixing work.
- Specific Weaknesses
  - None specific.
  - The work needs stronger experimental support to bolster the modeling efforts.
  - Focuses very much on one combustion system only.
  - Lack of engine variable speed/load data.
  - Engine running conditions must be expanded.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 6 of 15 reviewers)

- None.
- Stated future directions are appropriate.

- Step up the experimental work at a few key engine operating points, and use that to give more direction to the modeling efforts.
- I would like to see a comprehensive list of critical parameters leading to functional responses (like smoke, NOx, HC, isfc, noise, etc.), leading to models of those responses based on critical parameters, followed by optimization and statistical analysis of data. Design of experiment procedures would help. I think it would be good to list noise parameters in your experiment as well (items that could affect results, but not controlled.) I think with these data, it would be easier to put results into context.
- Having the engine and diagnostic tools working properly, several variations of piston, swirl, and injector tip configurations should be investigated. Careful validation of the simulation recommended.
- Perform additional experiments at various speed/load conditions.

HCCI and Stratified Charge CI Engine Combustion Research, John Dec of Sandia National Laboratories



Brief Summary of Project

Researchers are seeking to provide the fundamental understanding required to overcome the technical barriers to the development of practical HCCI engines by industry. This is being done through use of a combination of metal- and optical-engine experiments and modeling to build a comprehensive understanding of HCCI processes.

Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 16 reviewers)

Overall, the reviewers clearly saw the relevance of this project to the overall DOE objectives. One reviewer pointed out that it is clear that advanced combustion modes are going to be incorporated into future production engines and that this work provides the pre-proprietary studies that impact the development of those future production diesels. Another added that HCCI in gasoline engines remains a fundamental future technology for light duty engines. Someone noted that there is a very good alignment/relevance between the objective of this work and the overall DOE objectives. A reviewer added that this is "world leading stuff." Another thought that this work was very interesting fundamental combustion research. One commenter pointed out that understanding HCCI is still a key issue in low-emission, high-efficiency combustion. Another agreed and added that HCCI combustion continues to hold promise for future engines.

Question 2: Approach to performing the research and development (Written responses from 6 of 16 reviewers)

In general the reviewers felt that this project had a solid research approach. One noted that optical access engines provide good technology to investigate the combustion processes. He added that the compromises inherent in optical engines can produce disconnects between this work and actual production development. He also stated that this work is generally successful in describing the limitations encountered in use of optical engines for these studies. Another reviewer felt that this was a very well-designed program for gaining a basic understanding of the mechanisms. One commenter noted that this project has a very good approach to tie observations in the optical engine to the actual engine and to modeling. Someone pointed out that the top/bottom view and side view help a lot in understanding temperature stratification. One stated that a number of questions have been answered in a timely manner. It was also noted that the approach is spread across a broad expanse of diesel engine research and includes the use of chemiluminescence, PLIF, ignition behavior, EGR, in-cylinder temperature, and variable valve actuation systems. On the negative side, one reviewer felt that the project seems to be discontinuous without a solid foundation of direction. He added that this research is more "trendy" than work that will have high significance towards a field in diesel combustion.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 16 reviewers)

All of the comments on this topic were very positive. One reviewer noted that the balance between the thermal effects, fuel composition, and specific kinetic effects are going to make or break HCCI as a production technology. He added that this work carefully separates out those effects and the correlation between the chemiluminescent signal and the heat release rate is an encouraging direction to be able to monitor the crucial fuel effects. He also added that it will be necessary soon to run actual fuel blends in this system and that two-component fuels are probably not sufficiently representative of how the HCCI configured engine will respond to actual in-use fuels.

Another person stated that he would like to see more progress toward advancing the technology to a wider range of operating conditions. He posed a question as to whether a 1200 rpm baseline speed is placing an unfair upper bound on load. He also asked if the metal engine can be used to look at a wider range of power (higher speed/load). Someone felt that this project has made very good progress in meeting its objectives. He added that the learning will help to determine commercial feasibility of HCCI. It was noted that the thermal stratification work and the single/two-stage fuels research both appear to contribute to fundamental knowledge and understanding of combustion processes. A comment was made that variable valve actuation needs to be brought into the project to ensure adequate combustion control. One comment stated that this project has many accomplishments in many areas.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 16 reviewers)

All of the reviews praised the collaborative efforts as part of this research. A reviewer pointed out that the communication level with the industry is very good and it is clear that these researchers "hear" the concerns and needs of industry and attempt to respond to them. Another felt that this project has an outstanding level of coordination with academia and industrial partners and sets a benchmark for ACE research programs. This statement was echoed by another reviewer who noted that this project is a model for other technology programs. Someone stated that there are a number of good collaborations. Another pointed out the impressive list of cooperative work and collaboration with Navistar, GM and universities. It was mentioned that collaborations include the U.S. automotive and diesel industry, as well as the National Laboratories and Universities. It was mentioned that this project "seems to have all the bases covered."

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 16 reviewers)

Comments regarding the future research were mixed. One reviewer indicated that this work has a good history of delivering useable results. However, he was concerned that "real-fuel" surrogates are not sufficiently representative of actual in-use fuels and that it would be helpful if some of the work evaluated future multi-component fuels. Another stated that the major technical areas are being addressed, but he does not see a clear path toward achieving full load operation under HCCI. Several reviewers praised the use of variable valve actuation since it will help a lot together with EGR. It was mentioned that different fuels should not be the focus of this project (2-stage vs. single stage combusting fuels). It was also noted that the simulation approach was not addressed in the presentation. One reviewer said that there was no mention of the proposed future research.

Specific Strengths and Weaknesses (Written responses from 12 of 16 reviewers)

- Specific Strengths
  - This project has a good history of delivering relevant results, good experienced technical staff and good interaction with the industry.
  - Extraordinarily well-designed and coordinated project to achieve a basic understanding of light-load and moderate-load HCCI combustion.
  - There is a very good focus on understanding of HCCI fundamentals and variables that affect performance.
  - This is great research with the best tools and good experimental design.
  - Combining optical engine work with both a single cylinder engine and computational modeling work is an excellent approach.
  - Explores fundamentals of HCCI combustion using matched metal and optical engines.
  - Acronym identification before their use is appreciated, since not all of the reviewers are experts on every aspect of each of these projects.
  - There is great analysis of visualization data at operational data points.
  - Excellent optical access to engine combustion. Good cooperation between simulation and testing allows for understanding the details of HCCI combustion.
  - Excellent tools and equipment linked with strong modeling capability is being used to understand HCCI combustion mechanisms in detail.
  - Good balance of testing and analysis.
  - Carefully conducted research has addressed and answered a number of critical questions.
- Specific Weaknesses
  - Is it believed that this is not a full-load technology? In case it is not, will the transitions from

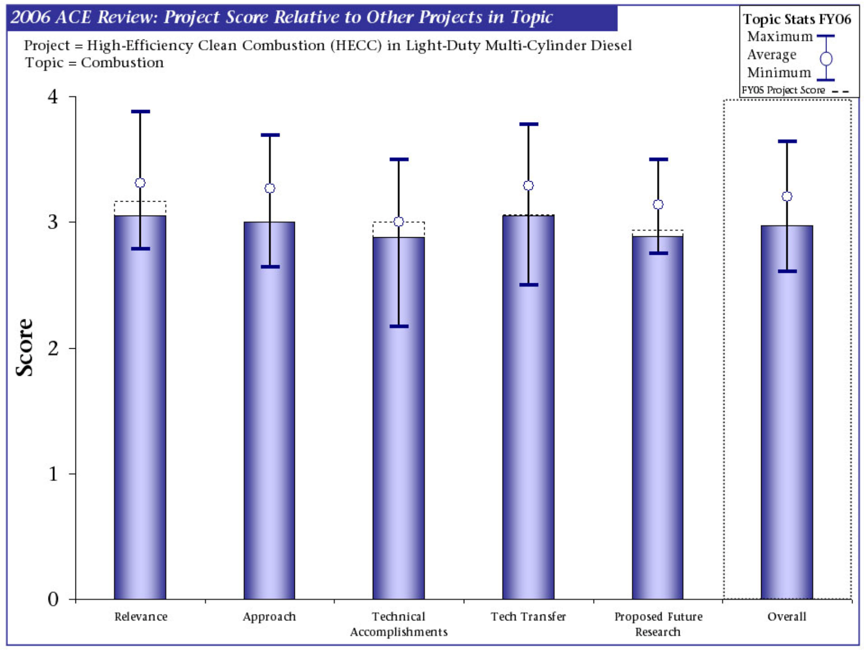
“conventional” combustion to HCCI be investigated? If it is believed that something greater than 6 bars or so is possible, then the focus should be given to higher loads.
  - There is too much material covered in a single presentation. It was hard to see what are the most important results and implications.
  - Variable valve actuation is urgently required to ensure that the system is up to date with industry HCCI-investigations.
  - Concentration on gasoline-like fuels has slowed progress.
  - Add work on E100 and E85 to pursue engine optimized for these fuels.
  - HCCI will likely not be able to handle high loads and transients without losing efficiency and emissions controls. Some work will be needed to indicate that there are not some major issues that can not be addressed. For instance, what happens at high load for heavy duty diesel engines which operate on the torque curve all the time?

<u>Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 9 of 16 reviewers)</u>

- Run some multi-component fuels in the engine to see if the continuum of fuel components makes the ignition response even less sensitive to the engine variables such as injection timing and EGR levels.
- Focus should be on full-map/high load operation. There is also a need for a better understanding of transients - can the present control system perform meaningful load acceptance tests or speed transients to explicate the thermal effects during transients?
- Keep going!
- More details on how the Aramco funding would be interesting; will there be a focus on gasoline like (2 stage) fuels?
- Explain the different effects of EGR by applying simulation. The testing should focus on diesel-like fuels (hardware setup) (i.e., two-stage combustion fuel).
- Work on fuel effects of a wider range of fuels is encouraged, especially 2-stage fuels. Could test some diesel fuels (#1 and #2), until now only gasoline fuel has been studied.

In-Cylinder Combustion Studies and Modeling

High-Efficiency Clean Combustion (HECC) in Light-Duty Multi-Cylinder Diesel Engines, Robert Wagner of Oak Ridge National Laboratory



Brief Summary of Project

Here, the Oak Ridge National Laboratory is pursuing a project to explore strategies for implementing and expanding the range of HECC (PCCI, LTC, HCCI-like, etc) combustion in a multi-cylinder engine, estimate the potential of HECC combustion strategies to meet future emissions Regulations, and characterize exhaust chemistry for improved understanding of emissions formation and implications on after-treatment systems.

Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 19 reviewers)

In general, the comments showed good relevance of the project with DOE objectives. One reviewer implied that this work should be done by the OEMs. According to him, much of what is reported here can be due to the individual engine combustion chamber design. He did not see this as universal information, nor did he see it as work that would not repeat as they are involved in engine design. Another commented that this work is expanding the range of advanced engine operating modes and is therefore relevant to the overall DOE objectives. Someone mentioned that in concept, HECC fits among the DOE/USCAR goals for clean and efficient engines. However, according to him, the approach taken here seems off-target, not showing a path to success. It was noted that the project objectives (expand the operating range of HECC modes and improve transitions within and between combustion modes) are in line with DOE objectives. One person mentioned that brake-specific fuel consumption data was not shown and wondered whether it exists. A comment was made that the application efforts for HCCI-kind of combustion (HECC) are important. Someone indicated that this is a good project that highlights the potential of homogeneous combustion strategies for maintaining diesel like thermal efficiencies while reducing nitrous oxides and particulates in a modified commercial engine. He went on to say that the findings are preliminary in nature and much work must be done in the future to substantiate the proposed strategies as aftermarket modifications to commercial engines. For example, much effort is still required to optimize the low- and high-pressure EGR loops and the associated cooler for the low-pressure loop, and also the development of an overall engine control strategy over an entire engine map. A comment was made that EGR investigations are relevant to meeting DOE emission goals. It was noted that the investigation is also sensitive to efficiency losses due to EGR utilization; therefore, light-duty small multi-cylinder engine investigation is very relevant to DOE goals.

Question 2: Approach to performing the research and development (Written responses from 11 of 19 reviewers)

The comments regarding the research approach were mixed. One reviewer felt that this is basically an engineering study and it is performed on an engine which does not have particularly new technology. Another thought that the research approach slide was helpful. It was noted that the operating loads chosen seem like gasoline engine points and not diesel. He added that the injection pressures are much lower than state-of-the-art. Another reviewer agreed, adding that modern injection systems have 2000 bar capability and suppliers are working on systems with pressures greater than 2300 bar. A comment was made that emissions data trends shown suggest inadequate control of operating conditions for gaining more universally-comparable results. Someone felt that the approach of testing with real equipment and modeling of performance was good. One reviewer would prefer to see design of experiment approach (i.e., how was IMT included in the interpretation of results). He felt that there is a need to include more critical parameters, list all of them, and then explain which ones are being held constant. Another mentioned that the approach is likely to improve when the simulation is ready and integrated. A comment was made that the compression ratio of the Mercedes 1.7L engine is high for PCCI work at 19 to 1. A compression ratio near 16 to 1 might be more appropriate for this advanced combustion work. Someone mentioned that systematic application work is appreciated and that multi-cylinder investigations with a combination of low- and high-pressure EGR are important. Also, using the same engine platform as University of Wisconsin will help explore synergies. A comment was made that the approach is relatively good as a starting point, but more thought should be given to the cooling strategy for the low-pressure EGR loop. Currently, the investigators are using ambient temperature as the boundary condition for the EGR 'out' loop, when realistically it should be a bit higher when one considers integration of the EGR loop into the overall vehicle thermal management system. A question was raised regarding the effect of a higher low-pressure EGR 'out' loop on efficiency, emissions, and engine control strategy. It was also noted that the approach uses a small diesel engine to expand EGR performance envelopes. However, the EGR temperatures are not reflective of modern engine applications; they are too low. According to this reviewer, the ambient temperature EGR is not realistic and the results of this work are hence skewed to an unreachable EGR condition. He added that as a result, the efficiency will be severely affected if realistic EGR conditions are implemented.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 19 reviewers)

In general, the comments recognized the progress of this project; however some reviewers felt that more could be done. One reviewer indicated that this was a good, well-rounded project. Another felt that this investigation shows that there are areas where real EGR conditions are still not investigated. Someone stated that good technical progress has been made with interesting findings especially considering the budget level. A comment was made that the accomplishments are progressing. A reviewer indicated that good progress has been made to date that highlights the potential of modifying a commercial engine to improve engine out emissions while maintaining thermal efficiency. Nevertheless, much work is required to further validate the proposed overall engine control system strategy over an engine map and within a practical vehicle propulsion system. One reviewer mentioned that he did not see any clearly universal discoveries from this work. It was noted that based on the amount of work done by the industry and other laboratories, this work appears irrelevant to modern diesel engines, and the rate of approach over the past year toward relevance is slow.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 19 reviewers)

The comments regarding collaborations were mixed. A comment was made that this work is regularly shared with the industry (i.e. combustion chamber design) to make the results more universally useful. One reviewer pointed out good collaboration with universities (University of Wisconsin and Texas A&M), other government laboratories (Sandia) and industry (GM). Someone indicated that the industry and universities have supported this project and appear to aide in analyzing and therefore understanding generated data sets. Another felt that the upcoming cooperation with GM and University of Wisconsin will improve the situation. It was noted that a tighter coordination with Sandia and University of Wisconsin on the GM 1.9L engine work would benefit the project overall. One reviewer indicated that this program has a long way to go toward offering something that industry would want to collaborate on. Another stated that he did not see evidence of a great deal of collaboration during the presentation. One stated that no specific interactions were mentioned.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 19 reviewers)

Reviewers agreed that the presented future research plan looks good. It was mentioned that all major hardware issues with HECC are addressed. It was also noted that use of the same engine platform as other research programs is a good idea. One stated that future work is generally pointed in the right direction and it would be fruitful if the investigators performed more work on understanding the influence of the low pressure EGR loop temperature-out before proceeding toward a variable compression ratio study. Someone would like to see validation of the aftertreatment comments and a shot at a transient validation. One thought that load expansion work is relevant; however, the rest of the work mentioned is not realistic until EGR is investigated. It was noted that improving the technology of the combustion chamber will hopefully move this from an engineering study on old technology engine to generating results that are more universal as is needed for government funding. One felt that the approach needs to be re-evaluated in the context of Tier II/Bin 5 light-duty diesels. Another suggested expanding studies to include additional engines with other features (VGT, VCR) and additional work on fuel properties. One thought it would be good to narrow the focus of this work and identify a particular problem/barrier to be worked on. At present, the work is broad and touches a lot of areas. Another reviewer was glad to see the planned engine upgrade and VCR work. A reviewer offered support for the upgrade to the 1.9L engine, but questioned whether variable compression ratio is important.

Specific Strengths and Weaknesses (Written responses from 14 of 19 reviewers)

- Specific Strengths
  - Good planning and interaction from industry.
  - Excellent approach, good scope; interactions with AEC working group.
  - Combination of analytical and modeling skills. Low fuel pressure is significant to reducing cost of fuel system.
  - HECC is an important goal for light-duty diesels.
  - Testing in "real" equipment (Mercedes 1.7L engine) coupled with modeling.
  - Seems to be realistic in approach.
  - Better understanding of PCCI and related issues is critical.
  - Keeping drive cycle considerations in mind and choosing test points accordingly is appreciated.
  - Broad system-level multi-cylinder approach.
  - Very relevant topic and work.
  - HECC combustion on multi-cylinder engines is important.
  - Nice experimental set-up to perform the proposed research scope.
  - Good engine parametric studies; added analytic component is helpful.
  - This work is showing some interesting combustion modes for low engine-out emissions at lighter loads.
  - Multi-cylinder engine testing.
- Specific Weaknesses
  - This work does not seem to be stepping out into universal discoveries.
  - The program needs to be re-evaluated, hopefully with significant input from industry, and with consideration of state-of-the-art light-duty diesels and future industry directions. The test program needs to be more appropriately focused on a set of operating conditions typical of light-duty diesel engines. The subsystem requirements (fuel injection system, combustion chamber, boost systems, aftertreatment) have not even begun to be addressed, yet are fundamental to start along the path toward HECC.
  - Did not see evidence of design of experiment, sorting out noise parameters or critical parameters neglected.
  - All steady state; future work might want to think about transient issues including cold starts.
  - An updated engine would be beneficial. GM 1.9L is a good move in this direction.
  - Integration with aftertreatment programs could be improved.
  - Expand to transient operation and better quantify fuel efficiency.
  - Combustion control is not addressed. VCR is a challenge.
  - Lack of data concerning low pressure EGR loop temperature-out on engine performance.
  - They have not shown the ability to maintain these HECC modes during transients.
  - Inability to get to high power points in the load map and indicate what happens at those points. No discussion of impact on transients or stability of combustion going into and coming out of transients.
  - EGR conditions are not real.

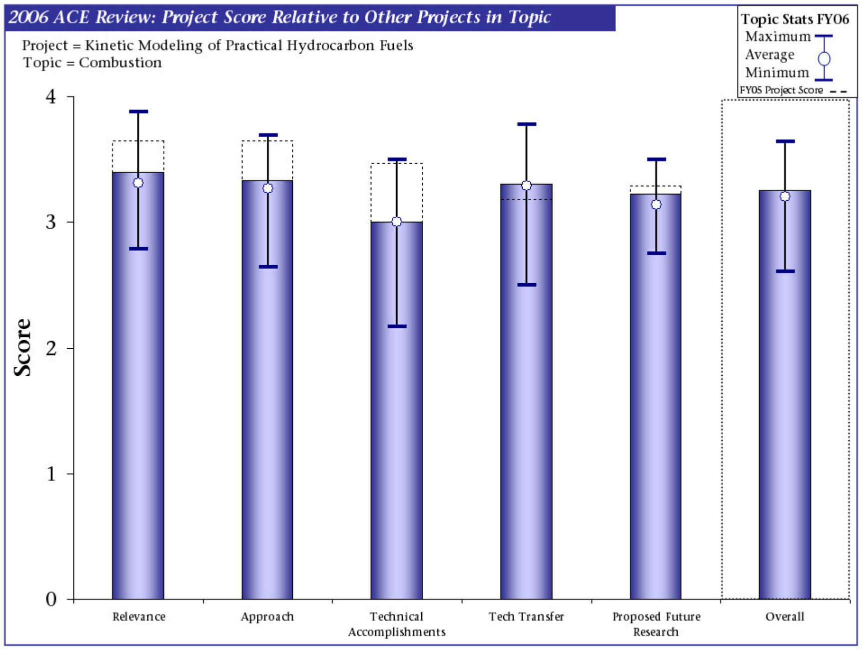
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 12 of 19 reviewers)

- Upgrade the engine technology with a more modern combustion chamber design.
- Add variable valve timing to explore potential; understand HC emissions increase with low pressure EGR.
- Light-duty diesels need to meet Tier II as a basic boundary condition, so efficiency needs to be worked upon in this context. Work needs to be focused on defining subsystems to meet high efficiency goals with manageable emissions levels. Explore full-map operation for the diesel, with realistic and consistent test conditions, to "learn what you don't yet know."
- Variable valve timing/Miller cycle critical parameters would be interesting to see.
- Integrate simulation and testing.
- Focus the work on a particular problem. Perhaps coordinate with Sandia doing SCE work and try to correlate their results with multi-cylinder work at ORNL, to verify that single-cylinder results are transferable to the multi-cylinder domain. Work with Wisconsin on the modeling aspects, and use their models to improve the

understanding of the underlying phenomena.

- Variable valve actuation may be easier to install than VCR with comparable results. Need to address combustion control.
- Perform more experiments that highlight the influence of low pressure EGR temperature-out on engine performance.
- Continue emphasis on parallel modeling efforts.
- Comparison between single- and multi-cylinder results to show the effect of engine-to-engine variation.
- All the experiments seemed to be conducted independently. A Design of Experiments would give information on interactions. It appears that the test system is stable enough to permit obtaining information on interactions.

In-Cylinder Combustion Studies and Modeling
Kinetic Modeling of Practical Hydrocarbon Fuels, Bill Pitz of Lawrence Livermore National Laboratory



Brief Summary of Project

This project develops and applies chemical kinetic modeling techniques to the analysis of key combustion processes in diesel, HCCI and spark-ignition engines. Working in collaboration with industry partners, this technique can address important practical concerns for limiting pollution emissions, including NOx, soot, and unburned hydrocarbons. Modeling can study conceptual issues including oxygenated and oil-sand derived fuels, sources of emissions specific to particular engine types, and feasibility of proposed new design strategies.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 10 reviewers)

All of the comments regarding the relevance to the DOE goals were positive. It was indicated that developing fundamentals to reduce emissions is consistent with DOE goals. One person mentioned that he is not an expert in the fuels chemistry, but to him it seems reasonable to support modeling efforts with KIVA-like codes. Another commented that kinetics is interesting and useful for improving model accuracy but not critical. It was noted that detailed kinetic models are absolutely essential to long term goals, and DOE should fund them appropriately. One stated that this is a perfect example of a fundamental study which should be supported by the government.

Question 2: Approach to performing the research and development (Written responses from 4 of 10 reviewers)

One reviewer complimented the focus on selecting molecules that represent gasoline and diesel and working to understand fundamental combustion chemistry of those molecules at low temperatures. A comment was made that the approach, including careful experimental validation of subsets of the model, is excellent. Another agreed that this is a tried-and-true approach.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 10 reviewers)

One person indicated that good progress has been made during the past year. Another stated that it seems like the chemistry model still needs improvement to match the experimental data at Sandia. A comment was made that this research is off to a good start.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 10 reviewers)

Good interactions with other organizations were pointed out. The connection with Sandia and engine model development was singled out. One reviewer indicated that industry looks to the LLNL group for kinetics, but he was not clear on the extent to which "active" participation is present.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 10 reviewers)

A comment was made that this is very important research. Another comment was that the investigation of fuel molecular structure on sooting tendency of fuels should be especially beneficial.

Specific Strengths and Weaknesses (Written responses from 7 of 10 reviewers)

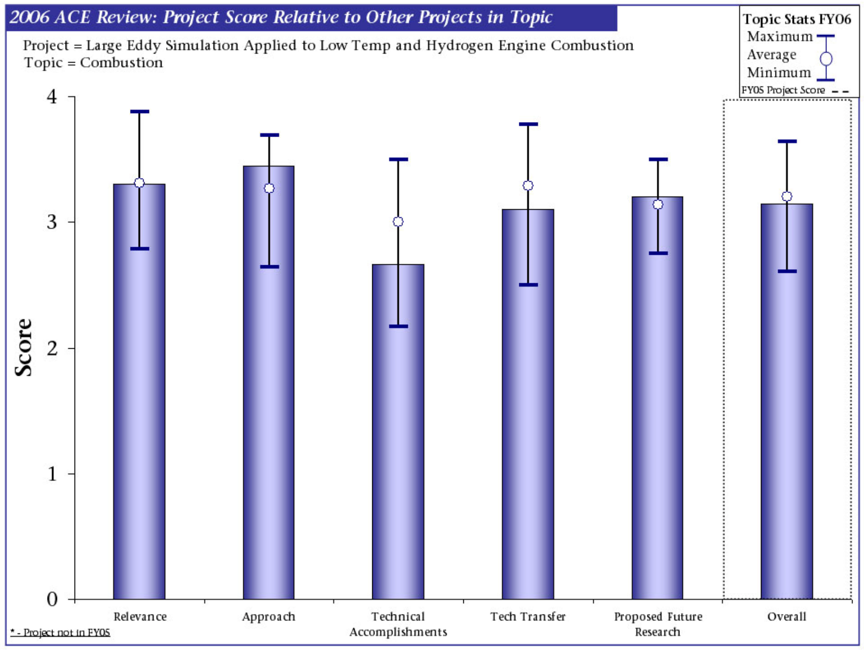
- Specific Strengths
  - Construction of reduced kinetic models for key fuel components.
  - Good focus on understanding kinetics and mechanisms of low temperature combustion of molecular classes found in real fuels.
  - Provides basic mechanisms used by many others.
  - Very good and careful development of fundamental kinetic modeling building blocks.
  - The work is good quality and helps improve model accuracy.
  - History of success.
- Specific Weaknesses
  - Needs more validation with engine work, particularly in predicting the impact of a wider variety of engine operating variables.
  - Models still don't work as well as we would like.
  - Shot-gun approach at times; current efforts seem to be focused on inclusion of new fuels in bits and pieces.
  - Thanks to the LLNL researchers, characterization of heptane and iso-octane are largely done. Toluene was next, but it is still not completed. In the meantime, pentane, iso-pentane, methylcyclohexane, pentene, and oxygenates have all been started, but I don't think any of them are "done" in the sense that heptane and iso-octane are.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 6 of 10 reviewers)

- Add work on ethanol for inclusion in gasoline surrogate; incorporate findings into tools that industry can use to apply these findings to engine and fuel design.
- Keep going.
- Finishing toluene experiments before doing more with methylcyclohexane, which may prove to be a very complicated system.
- Give some simplified implications for advanced combustion (HCCI, LTC) for those molecules that have mechanisms developed.

In-Cylinder Combustion Studies and Modeling

Large Eddy Simulation Applied to Low Temp and Hydrogen Engine Combustion Research, Joe Oefelein of Sandia National Laboratories



Brief Summary of Project

This project combines highly-specialized state-of-the-art capability based on the Large Eddy Simulation (LES) technique with Advanced Engine Combustion R&D activities in order to numerically probe direct-injection (DI) hydrogen internal combustion engines and Low Temperature Combustion (LTC) processes in a manner that directly complements and enhances optical engine experiments.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 10 reviewers)

It was noted that basic support for enhanced modeling is very important for Cummins (and other engine manufacturers) and that DOE support is appreciated. One reviewer pointed out that understanding the details of combustion via exact simulation helps understanding any combustion phenomena. Another commented that Large Eddy Simulation seems to be a promising, although expensive, tool for engine research. One person felt it was too early for him to determine whether this has an impact on DOE objectives.

Question 2: Approach to performing the research and development (Written responses from 4 of 10 reviewers)

The comments regarding the approach to performing research were generally positive. A comment was made that using high performance computers and applying them to a one-of-a-kind combustion case is a valuable approach in understanding combustion fundamentals. It was mentioned that this is a very useful program and builds foundation for the next generation of modeling. One reviewer stated that it is a good approach to start with a small amount of funding to test the idea and method. Another saw the approach as adequate; however, it was difficult to determine the status of the program from the presentation.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 2 of 10 reviewers)

One person mentioned that only very first and limited (but promising) simulation results were shown. Another indicated that this research is still in very early stages and questioned whether it should be reviewed at this time.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 10 reviewers)

One reviewer felt that there is very good cooperation with hydrogen combustion investigations in the testing area. A comment was made that leverage with DOE Office of Science is a plus.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 10 reviewers)

One reviewer asked how this work fits with developments at the University of Wisconsin and in Aachen. Another indicated that extension to hydrocarbon and HCCI combustion is very valuable. A question was also raised whether the modeling work is coordinated within the DOE.

Specific Strengths and Weaknesses (Written responses from 7 of 10 reviewers)

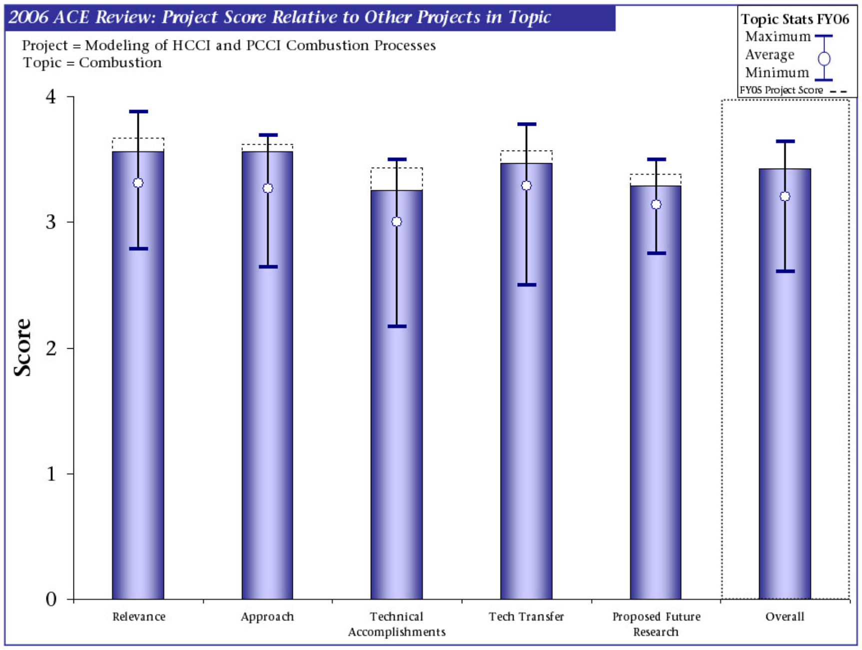
- Specific Strengths
  - Good application of unique DOE laboratory capability. Industry would not get this done, but will benefit from the work.
  - Focusing on a single combustion event and applying "exact" numerical formulas together with high computer performance.
  - Very important work as a foundation for future modeling work.
  - Focused on theoretical side. Could be helpful in revealing the fundamentals.
  - This modeling technique will provide information that is not otherwise available.
  - Powerful modeling capability and hardware to conduct modeling.
- Specific Weaknesses
  - Still in early stages – results are desired.
  - Does not directly help in generating simplified simulation models; significant efforts are required.
  - Seems an expensive tool. Preparation of the simulation cases will be important for using the tool wisely.
  - It appears early in the program so it is not possible to determine what the current status is on this modeling. Pretty pictures, however.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 10 reviewers)

- Keep going; scale up as planned.
- Look forward to meaningful conclusions upon completion and comparison of results.
- Include wall heat transfer that seems to be important for temperature fields inside the cylinder, wall wetting, etc.
- None to add, good to see extension to HCCI (from hydrogen).
- The work on the hydrogen ICE should be minimized and the work on HCCI engine started sooner.
- Work closely with KIVA group to help calibrate the turbulent model validation.

In-Cylinder Combustion Studies and Modeling

Modeling of HCCI and PCCI Combustion Processes, Dan Flowers of Lawrence Livermore National Laboratory



Brief Summary of Project

This project's research is designed to develop numerical tools that predict HCCI/PCCI combustion with complex fuels in reasonable computational time (hours to days, not weeks to months) to develop a fundamental and practical understanding of these processes.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 16 reviewers)

Reviewers generally approved of the relevance of this project to DOE objectives. A reviewer said that this group has a long history of providing codes that can be used in engine design, and that the newest improvements to the code are clearly continuing that success. Another comment was that the contribution to modeling of HCCI is significant, and points to a means of improved simulations with more-accessible computational resources. Similarly, a reviewer felt that development of computational tools that can provide reasonable predictions in reasonable time is consistent with DOE goals. A reviewer said that the model development by National Labs is very helpful to Cummins and DOE support is appreciated. Simulation of premixed combustion can help to understand and optimize the process, in another reviewer's opinion. Finally, a reviewer noted that the output of this project should aid industry in developing future HCCI-like engines through clever use of both CFD and a multi-zone kinetic solution routine under the assumption that kinetics are available for the real world fuel in question. As of today, n-heptane is the best surrogate for DF-2 but it was unclear to this reviewer if the associated reduced mechanisms are accurate enough for HCCI-like applications.

Question 2: Approach to performing the research and development (Written responses from 7 of 16 reviewers)

Reviewers were approving of the approach of this project, but offered a few suggestions. One reviewer said that the approach appears to give good agreement with experimental results. Similarly, a reviewer said that the simulation approach seems reasonable, and the results seem to agree reasonably well with experimental data. A reviewer said that the model-based control aspect and the multi-zone, reduced-order model is valuable. A reviewer noted that improving the efficiency of the multi-processor version of the code is helpful, that providing a much faster lower resolution multi-zone model is a good approach, and that developing a neural network approach to describing the kinetics are major improvements. A reviewer liked the simplified approaches, and said it is very important to get CPU times down due to large design of experiment studies completed at Cummins and other companies. The need to make thousands of model runs was noted. A reviewer said that this project represented very good continuation of past efforts. Investigators have addressed many potential problem areas associated with integration of CFD with multi-zone kinetics. The final reviewer offered a suggestion that the KIVA-ANN approach deteriorates accuracy even further and that other approaches would be beneficial.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 16 reviewers)

Technical accomplishments were judged to be quite good. A reviewer said that it looks like very good progress has been made in developing models that are accurate, but take less time to run. A similar comment from another reviewer was that faster speeds and new tools are good. A reviewer said that the solid implementation of the three improvements in the KIVA code is a significant accomplishment. A reviewer offered that the advances in modeling show good success over a reasonable range of parameters. Good agreement of multi-zone model to SNL experimental results, noted another reviewer. The simulation methodology seems fairly mature to another reviewer who pointed out that the methodology is now undergoing optimization schemes to improve its capability to more accurately at reduced computational time predict HCCI-like combustion. Additionally, effort will be spent comparing predictions with newly generated optical engine data as a means to further gain confidence in the predictive capability of this tool. The final reviewer said that trends can be predicted but results are sometimes 50% off.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 16 reviewers)

Collaborations were generally felt to be good. A reviewer said that KIVA is such a standard in the industry that it is hard to fault their technical collaborations. Similarly, a reviewer said that KIVA is a standard tool in several applications and well acknowledged. A reviewer said that the level of collaboration is appropriate for the work performed. This reviewer felt that at some point, a joint effort with a commercial code developer would be useful, to make the models more available to industry. A reviewer noted the collaborations with a number of universities, national labs, and industrial groups. Likewise, a reviewer said that there was very good collaboration with industry, and that the work has been very helpful improving our internal understanding of the technology. A reviewer said that the project seems to include industry and national lab support in modeling and interpreting experimental data, but it is not clear if industry is attempting to use this tool or if it is available for such use at this time. Finally, a reviewer was not clear about what collaborations with industry or direct feedback from industry are occurring.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 16 reviewers)

A reviewer said that a simplified model for combustion control is important. Another felt that applying the improved codes to combustion applications will cement their use in the industry. A reviewer said that the integration of this effort with experimental research is significant, and this tool promises to significantly aid advancement in this area. Plans look very reasonable to another reviewer. A reviewer offered the opinion that the approach is fair and will focus on the continual validation of the proposed methodology through comparison with optical engine data and also application to PCCI-like engines. Again, it is unclear if this tool is mature enough for industry use for future engine development efforts and it this is not the case, maybe more effort could be spent in transitioning this tool to the relevant parties. The final reviewer commented just that he was not a combustion CFD expert but uses the results from those experts.

Specific Strengths and Weaknesses (Written responses from 9 of 16 reviewers)

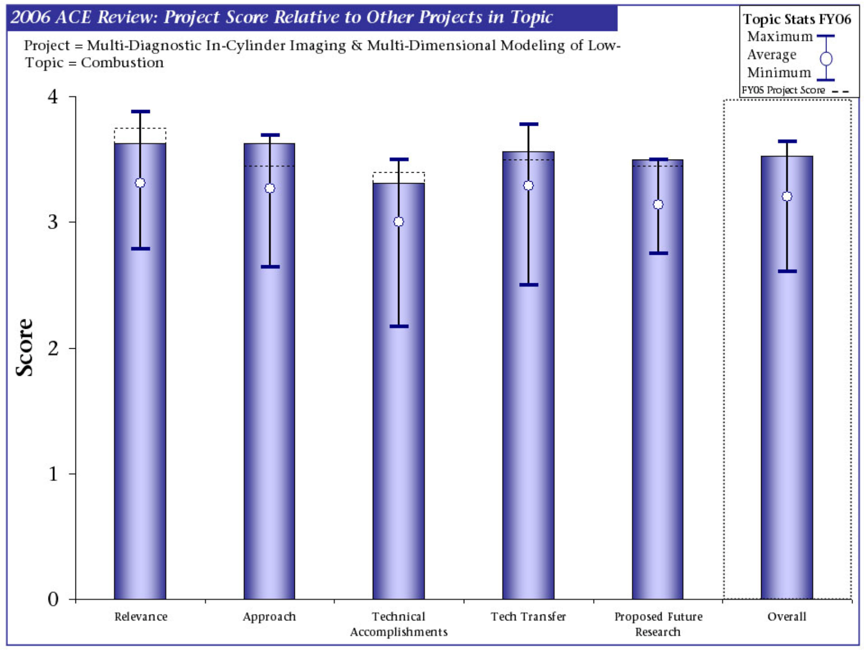
- Specific Strengths
  - Good team and long history of industrial applications.
  - Very good group of investigators that are making significant progress is modeling combustion in HCCI like engines while optimizing computation time.
  - DOE Lab strength in massive computing. KIVA tools and their use.
  - The improved computational results are significant, and seem to offer accurate prediction of HCCI combustion over a reasonably wide range of operating conditions.
  - Working to get CPU time down! (hours instead of weeks).
  - The controls-oriented aspects of this project, with model-based control, are valuable and a good complement to some of the more fundamental research.
  - Good work to extend this modeling to more routine use in engine design.
  - Simplified simulation model has the power to be used in industrial applications.
  - They have shown accurate and cost-effective modeling of HCCI combustion.
- Specific Weaknesses
  - None identified.
  - NA
  - Nothing significant.
  - Most of us don't have such computers—ANN should be a step forward.
  - How accurate can a simulation be with simplified models? 50% off in some points is not acceptable.
  - Not clear the extent to which industry feedback being used.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 16 reviewers)

- None at the moment.
- Nothing to offer at this time.
- Keep going.
- Next steps seem appropriate
- Work toward extending the model to a wider range of operating conditions, as experimental validation allows.
- When simplifying the code so that the model can be used for combustion control: check what parameter shall be used for measuring (sensors?) and control (actuators?).
- Transition tool to industry or assess this possibility and determine the proper avenue to make this event occur.
- Interesting approach to combine neural network technique with 3D modeling. Is it still a predictive model?

In-Cylinder Combustion Studies and Modeling

Multi-Diagnostic In-Cylinder Imaging & Multi-Dimensional Modeling of Low-Temp HD CI Combustion, Mark Musculus of Sandia National Laboratories



Brief Summary of Project

Sandia is using multiple laser/optical diagnostics to broadly characterize in-cylinder processes for multi-mode conditions. They are also developing and improving computer modeling tools for low-temperature combustion, and have initiated a study of sources of unburned fuel emissions for low-temperature combustion.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 16 reviewers)

Most of the reviewers acknowledged the importance of this work for heavy-duty engines. It was pointed out that this investigation aims towards the DOE goal of emissions reduction. One reviewer mentioned that the investigators are very aware of the DOE objectives because of a long project history. He added that the instrumentation is very helpful to probing combustion conditions under diesel conditions. According to him, one does come away from these reviews that this project is self-propagating instead of necessarily having been started to address a specific problem. A comment was made that this project is very relevant and appears to have a good chance for significant contribution to low-temperature combustion development in heavy-duty diesel engines. It was also mentioned that advancement of the understanding of low temperature combustion processes is in-line with DOE goals. It was noted that the fundamental visualization is very interesting. One person felt that this work is a key step in getting KIVA working well with low temperature combustion. Another added that such a detailed, fundamental study of different premixed combustion modes is an important step for advanced combustion systems towards lower emissions.

Question 2: Approach to performing the research and development (Written responses from 8 of 16 reviewers)

The reviewers had mixed opinions on the approach to performing this research. One reviewer felt that the basic science contributions are invaluable to the work by industry and others in this area. The good use of fundamental laser and optical techniques and computer modeling in advancing the understanding of low-temperature combustion was pointed out. A comment was made that Cummins uses KIVA-RIF for everyday models and this research approach looks reasonably connected to industry needs. It was noted that linking experiments and several modeling approaches is a good platform for learning. Addition of multiple combustion conditions also seemed good to a reviewer. One thought that simultaneous use of diagnostic tools with simulation is an excellent approach. In addition, new diagnostics have provided important understanding to diesel combustion.

One reviewer pointed out that the instrumentation and experimental design drive the engine conditions. He did not like the fact that the researchers need to stretch the operating range of the engine to get to a regime that newer engines are designed to reach easily. Another person mentioned that low load, low boost, cold EGR, and low speed are not modern engine conditions unless the investigation is suggesting a decrease in efficiency and power density. According to him, model validity is very limited. He also pointed out that heptane was used for some of the experiments and not diesel.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 16 reviewers)

In general the reviewers felt that the progress is good. One mentioned that incorporation of a glass window into the piston helps to keep engine conditions closer to production engine configuration. Another reviewer felt that the interaction with modeling is a good accomplishment. According to him, this provides great validation for the future applications where there is not such a complete set of accompanying validation experiments. He also mentioned the addition of an optical technique to follow formaldehyde fluorescence to image the unburned fuel in the cylinder. One person stated that good progress has been made to date with interesting results. It was noted that sources of unburned fuel emissions for low temperature combustion is an area of interest. A comment was made that generation of data from a combination of methods is very exciting. One reviewer mentioned that the imaging points to mechanisms that are not yet fully understood, but are of fundamental importance. Excellent comparison of models and experimental results was also mentioned because it is important to improving models.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 16 reviewers)

The reviewers felt that collaborations are appropriate for the work involved. One stated that collaborations with industry, university, and governmental laboratories are good. It was mentioned that there is no single highly-coupled partner. A comment was made to include more regularly scheduled industry exchanges or workshops because this work is excellent. According to a reviewer, cooperation with the University of Wisconsin is well accepted but the influence of Cummins is not obvious. Another mentioned that major engine manufacturers are present in this project.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 16 reviewers)

One felt that the future plans are appropriate. According to him, identifying unburned fuel is a high priority task. He did mention that the work did not detail why the formaldehyde measurements were not appropriate to measure unburned fuel. Another reviewer indicated that the approach is well-designed for lending insight into representative operating conditions. However, the sensitivity to important operating parameters may also be insightful. One thought that future plans look reasonable and advance project goals. Another agreed and added that the list of future work looks directionally correct and relevant (a natural extension of past work). He also mentioned that looking at injector nozzle variants is important, and modeling work should continue. A reviewer pointed out that the goal is to find the “right” premixed combustion system by applying fundamental tools.

Specific Strengths and Weaknesses (Written responses from 11 of 16 reviewers)

- Specific Strengths
  - This is the benchmark for government sponsored research; it has taught us how diesels work, and is teaching us how low-temperature combustion works.
  - Applying different diagnostic tools simultaneously and link the results to simulation is an excellent approach.
  - Excellent work including experimental and optical work with parallel modeling efforts.
  - There have been substantial contributions to understanding of different engine combustion processes.
  - Very good instrumentation and good interaction with the modelers.
  - The capability is largely unique for engine researchers in this area, and the approach taken is very relevant to 2010 heavy-duty engines.
  - Good use of optical and laser techniques in a single cylinder device to observe the combustion process.
  - Extensive use of modeling with the experimental work.
  - Very relevant to work we are doing in the industry!
  - Diagnostics and the ability to tie predictions and engine information.
  - Methods of data acquisition.
- Specific Weaknesses
  - Is the combustion chamber design suitable to study some of the LTC modes that are the goal of the work?
  - No major weaknesses, but would like to see a clearer path toward gaining insight into high-load operation.
  - As usual, we wish we had all the results for every possible case.
  - Fundamental understanding of the different combustion techniques is not yet completely established through simulation.
  - Not realistic engine operating conditions.

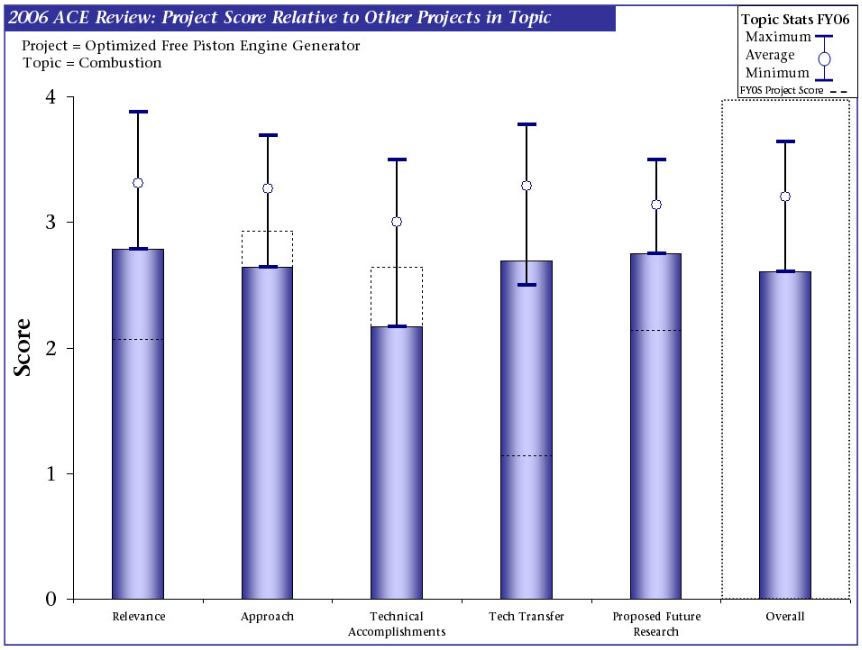
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 16 reviewers)

- Explore sensitivity to various design and operating parameters. For example, examine the effects of charge temperature during the expansion stroke (appropriate combination of intake temperature, charge mass, and compression ratio), intake and exhaust oxygen concentration, ROI effects of the different injection systems used, and possibly nozzle hole size.
- Would like to have research include effects of pilot injection on extending operating range (at reasonable HC) for late PCCI.
- Molecular Kinetics - this may be in the plan, but not sure. As with several of the presentations, I appreciated the summary of past review comments.
- Keep going.
- I recommend adding fuel-air ratio (Phi) versus Temperature description of the different premixed combustion systems to be able to distinguish and understand them better.
- Present scope of work and next steps are good; no suggestions for changes.
- Using heptane and toluene mixture for laser diagnostics may represent diesel fuel better than just heptane.

In-Cylinder Combustion Studies and Modeling

Optimized Free Piston Engine Generator, Peter Van Blarigan of Sandia National Laboratories

Brief Summary of Project



In this project, researchers are developing a free-piston engine and linear alternator system to achieve high efficiency for hybrid vehicle applications. The engine uses the linear alternator as a control input to maintain engine stability.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 14 reviewers)

Due to the nature of the project, reviewers had a hard time seeing direct relevance to overall DOE objectives. One reviewer did not see any evidence that this program can produce useful results to support DOE objectives, except in an abstract sense. He had the same question that has been posed for a long time: what are the practical difficulties of making this engine work in a commercial application? He also asked if it is viable at all. To him, there clearly was not enough time in this twenty minute review to state that all possible fail modes have been addressed (like doing an FMEA on feasibility). He asked what would be the "show stoppers." He did like the idea of electronic coupling, and stated that this could be a good product in niche markets, since 50% conversion of fuel to electricity is pretty good. Another reviewer did not believe in significant efficiency gains using this engine concept.

On the other hand, one reviewer saw it as possibly useful for a hybrid application. However, according to him, material selection and emissions will be critical for this application. He pointed out that holding the system together (tribology, seals, etc) will be difficult and should not be underestimated. It was noted that the good potential for high efficiency makes this project a worthwhile investment. Also, the potential for this engine as a power source for a range-extended hybrid vehicle and/or as a home energy source (distributed power) is intriguing. It was mentioned that flex fuel capability is also a plus. It was noted that this project is a full development of an opposed free piston linear alternator engine. If hybrid systems become prevalent, linear engines are going to be more important due to the need for reduction of hybrid components by fully integrating the engine/generator function.

Question 2: Approach to performing the research and development (Written responses from 5 of 14 reviewers)

The approach reviews were also mixed. One reviewer thought that the opposed piston design is a good idea. Another mentioned that the researchers are doing a good job given the funding level for this project. A comment was made that this engine design has very little chance of success, and the controls of the engine are not mature enough to consistently maintain engine performance. It was also pointed out that the packaging of this engine will be a challenge in today's vehicles. One questioned how to increase power or build engine families with this concept. One reviewer had several comments regarding the approach of this project. He stated that the approach is essentially an opposed piston cylinder arrangement similar to the JUMO Junkers diesel engine. Large amounts of data are available for this type of combustion especially in the compression ignition area. Linear alternator technology and the associated control of a free piston system will be the "crucial area" for success for this type of engine. This reviewer said that the investigator is not aware of the control problem or the requirement that the engine will need to be boosted to scavenge an opposed piston system. In addition, the linear mechanism can get unusually large and may not have the capability from a materials aspect to withstand engine operation temperatures. According to this reviewer, the investigator has a large amount of work ahead of him.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 14 reviewers)

Reviewers acknowledged limited funding for this project and commented on the progress accordingly. One reviewer felt that the development of a linear electric generator is a significant step. Another mentioned that no consistent funding means slow progress. This was echoed by a comment of good but slow progress. One stated that he does not see any progress since last year. On the other hand, one thought that very good progress has been made considering budget constraints. A comment was made that primarily plans for the next couple of years have been presented.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 14 reviewers)

Reviewers recognized that this project is a laboratory project by nature; therefore, the lack of interest is not surprising. A reviewer indicated that GM and academic interfaces are a good idea. This was echoed by a comment that it is good to see industry OEM engagement in this project. Someone mentioned that collaborations are improving and are well selected.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 14 reviewers)

Reviewers had had mixed comments regarding the proposed future plans. A comment was made that many fundamental issues remain unresolved, and basic questions have not been asked. One mentioned that it is likely that major technical obstacles will arise and may not be possible to solve in the two year time frame if a major redesign is needed. Another thought that working relationship with GM seems to improve the current situation. It was noted that future work does not address critical areas mentioned above in item 2.

Specific Strengths and Weaknesses (Written responses from 10 of 14 reviewers)

- Specific Strengths
  - Novel idea for multi-fuel, high-efficiency propulsion system. This is high risk research, but an excellent candidate for transitioning from traditional combustion engines to one well suited for electric-drive vehicle architectures.
  - The free-piston engine represents an ideal, and has been proven to be a promising option.
  - Potentially interesting concept.
  - High-efficiency concept; electrical coupling control seems like a good direction.
  - Interesting out of the box thinking.
  - Completely new approach. Detailed study may help understand conventional combustion as well (rapid compression).
  - Good concept with impressive high efficiency.
  - New approach with electromagnetic coupling seems attractive.
  - This is an innovative concept with good promise of high efficiency in a small package.
  - Integrates engine generator components of a hybrid system.
- Specific Weaknesses
  - Hasn't been funded, so progress has been slow.
  - This concept will require a lot of unique hardware and control strategy to fit a hybrid concept.
  - Emissions should be tested and presented.
  - Limited to hybrid electric vehicle applications since no mechanical power is available.
  - Needs an application.
  - This concept has a rather limited area of application since only electrical power is produced.
  - The approach does not evidently seek low-risk approaches where possible, and many aspects of the technical design appear flawed. The project has little chance for significant contribution.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 9 of 14 reviewers)

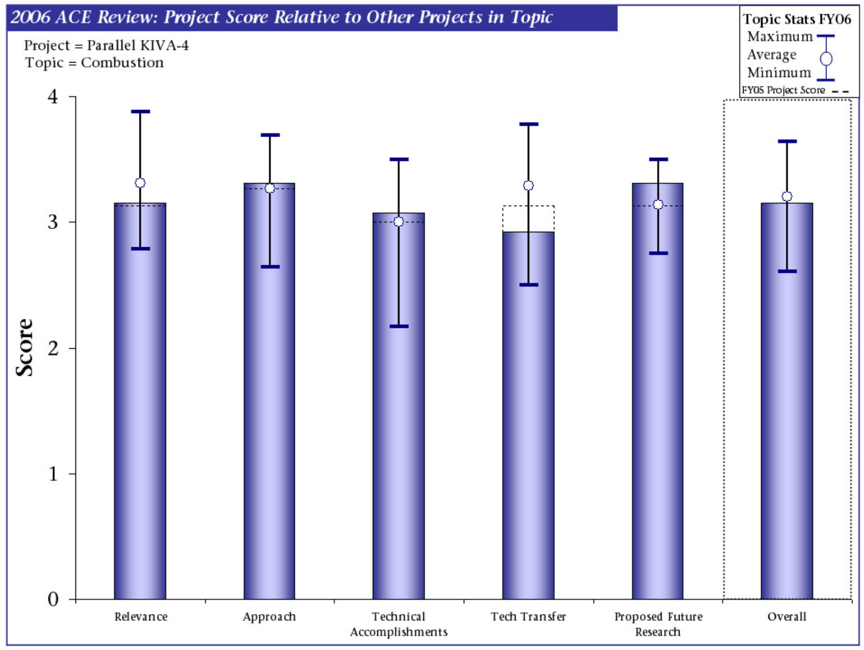
- Appropriate for moderate funding.
- The project needs to be re-evaluated technically. The scope of the program could be reduced to examine an alternative drive mechanism that simulates the free-piston kinematics, and that would enable progress to be

made in evaluating the fundamental aspects of the engine (scavenging, combustion, startup, transients, etc.)

- What do you need to do for control of the inertial compression? It might be nice to emphasize this feature. This may be a misplaced concern though, 20 minutes is hardly enough time to grasp the total engine concept … the FMEA on the concept I mentioned above would be interesting to read.
- Please make sure to include alternator efficiency and power electronics efficiency in overall system efficiency calculations.
- Next steps are appropriate; it will be good to have a running engine.
- Try to use this apparatus for studying fundamental combustion phenomena instead of application into a vehicle.
- Could this approach be linked to a quiet, fuel efficient, low cost APU?
- They should consider operating the engine at 60 Hz for direct generation of AC power for home use.

In-Cylinder Combustion Studies and Modeling

Parallel KIVA-4, David Torres of Los Alamos National Laboratory



Brief Summary of Project

This work is to update the KIVA modeling code (simulating chemically reacting flows with sprays as would be found in an engine combustion chamber) to allow for its use in a parallel computing environment, running on multiple computers simultaneously to reduce calculation times.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 13 reviewers)

The reviews of relevance of this project were very positive. It was mentioned that KIVA is used extensively at Cummins and continued support at the National Laboratories is appreciated. A comment was made that KIVA is an important combustion modeling tool and the enhancements in version 4 are logical and relevant in terms of improving its performance and usefulness. A statement was made that KIVA is a well-established and well-used tool in the whole internal combustion engine community. One reviewer indicated that the fundamental study of KIVA-4 and parallel computing speed provides a useful piece of information for other modelers. According to another, KIVA still is the preeminent code in combustion prediction. Despite some weaknesses, it is the central tool by which true three-dimensional prediction can be made. He added that all DOE goals are addressed with this work. A comment was made that this work is very relevant and that open source nature is extremely important. Only one reviewer did not see any direct relevance to DOE objectives.

Question 2: Approach to performing the research and development (Written responses from 4 of 13 reviewers)

Reviewers were generally in favor of the presented approach. One reviewer stated that the validation is good; however, more comparison with high fidelity simulation would be beneficial. Another agreed that the research approach is good and includes methodical validation. Another praised the systematic set up of simulations. It was mentioned that the main approach of bringing parallelization into the KIVA code is critical in decreasing the cost of operating a viable KIVA program. One reviewer thought that all other component improvements, though valuable, are secondary.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 13 reviewers)

The comments regarding the accomplishments were mostly positive. One exception was a reviewer to whom it was not clear how the accomplishments solve key problems that are critical barriers to achieving DOE objectives. Others though that the presentation indicated progress. A question was raised whether validation of KIVA-4 versus KIVA-3 is taking place (i.e., running them both on the same problem and comparing results). According to one reviewer, this would seem to be a logical step. The influence of meshing was highly appreciated. Someone pointed out solid results from the parallel computational speed study. The same person felt there was great achievement for the given funding level. Another mentioned that parallelization of this code is an outstanding feat. He added that validating the robustness of the code while running parallel is going to be a difficult task. One person mentioned that progress seems good; however, it's been two years since he last heard an update.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 13 reviewers)

Most of the reviewers acknowledged the close collaboration with the University of Wisconsin and the incorporation of their spray and combustion models. One reviewer wondered how the information is being disseminated to the industry. He did mention that it was likely that key CFD engineers from the industry are in contact with the researchers. A point was raised that KIVA is well established in all simulation departments. It was added that more cooperation with University of Wisconsin will be required when combustion simulation is investigated. One reviewer indicated that there is good collaboration with Ford and Sandia as well. Another added that a student from Iowa State is also involved in this work. Someone pointed out that there is a large industry, academic, and international community that watches every step KIVA takes. This person felt that no more collaborators are needed, especially for a code that is distributed for free. One reviewer was not aware of any coordination with industry, although, he presumed that more industry participation will follow the release in October.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 13 reviewers)

The comments regarding the approach were generally positive. One reviewer thought that the future work seems appropriate. Another mentioned that testing and validation with true, versus simplified, engine geometries, such as the Bergin engine, is important. It was noted that parallelization and meshes are the key features for the future, and they are well addressed. One stated that parallelization is the central focus and that he does not see any issues regarding the approach. A point was made that ultimately, the utility of KIVA-4 depends on the combustion calculations. A comment was made that this was discussed in the slides only briefly. The need for more discussion on issues related to emissions and combustion was emphasized.

Specific Strengths and Weaknesses (Written responses from 7 of 13 reviewers)

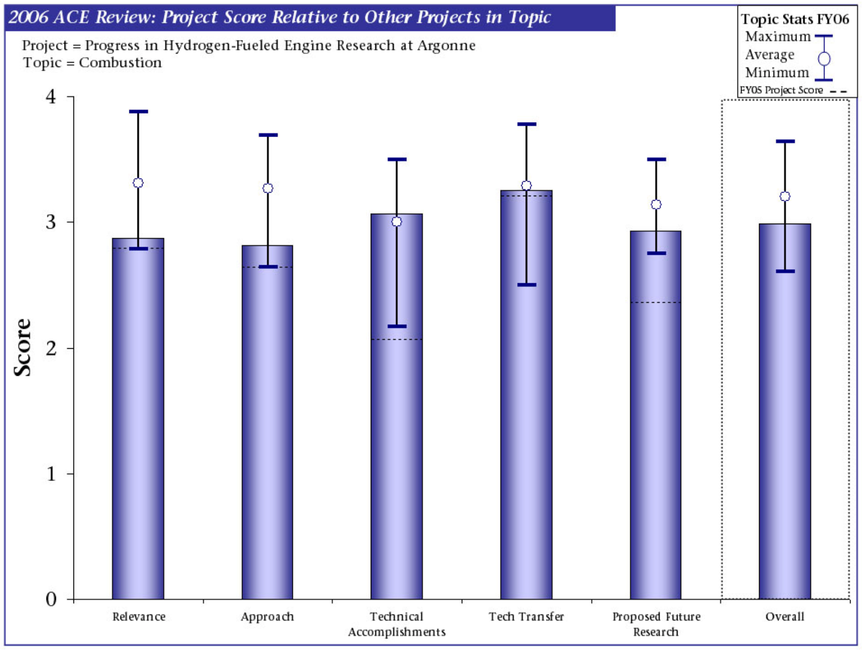
- Specific Strengths
  - I am no expert in this area, but this work seems to be progressing too slowly and is not well enough connected to other researchers developing high efficiency low emission combustion systems.
  - Improving the ease of mesh and flexibility of various cell types is important. This reduces the required mesh skill level and is helpful for industry (a greater number of engineers can use the tool effectively). Parallel processing is required.
  - Good development of basic tools the combustion community will count on in the future.
  - Open code ensures acceptance in the whole engineering community. Since KIVA is used by all researchers, comparisons can be made.
  - Good progress and useful foundation work.
  - Parallelization.
  - Open source, parallelizable.
- Specific Weaknesses
  - Clarify in presentation how KIVA-4 compares with/fits into other modeling work being funded by DOE and others.
  - Needs to get bigger in effort.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 13 reviewers)

- A cohesive plan for improving internal combustion engine CFD is suggested. How does this work merge with work done at other laboratories and universities sponsored by DOE? It would be useful to have an overview of this work and details on how various people are supporting the entire CFD project suite (just a thought).
- Keep going.
- Is there a linkage of this tool development to the modeling work accompanying the Argonne APS injector spray testing and modeling? That is, is it possible to link the Ming Chia Lai nozzle CFD modeling and use this with KIVA-4? (Perhaps this is being accomplished via the University of Wisconsin spray modeling connection.)
- Try to compare KIVA results with high fidelity results of Joe Oefelein.
- Would be nice to see comparisons to real data, rather than idealized systems (I realize the latter are essential for validation).
- Improving combustion and spray model is also a high priority job among others.

In-Cylinder Combustion Studies and Modeling

Progress in Hydrogen-Fueled Engine Research at Argonne, Steve Ciatti of Argonne National Laboratory



Brief Summary of Project

Argonne is exploring several hydrogen internal combustion engine operating conditions (direct injection, high speed and load, etc.) and using chemiluminescence techniques to examine the combustion events in detail to identify causes of knock and preignition in these engines.

Question 1: Relevance to overall DOE Objectives (Written responses from 11 of 16 reviewers)

A wide range of comments regarding relevance of this project to the overall DOE objectives was expressed by the reviewers. One reviewer thought that this is relevant work based on the administration's desire to move to a hydrogen economy. He pointed out that fuel cells are more efficient in utilizing hydrogen emission free if the country does go to a hydrogen economy. Another person thought that the program seems to be appropriately focused toward improving hydrogen engine technology. A comment was made that this is very appropriate research given our national energy situation. It was mentioned that in-cylinder diagnostics are especially interesting. One indicated that this is a good project, but hydrogen availability in the near-term is limited. According to him, other more readily available gaseous fuels will likely have a greater near-term impact. Another felt that hydrogen combustion is relevant when target is to become independent of oil imports but not for low emissions and high efficiency. Someone noted significant progress in a short period of time. This person added that this type of project is very important since it could lead toward an alternate energy source to hydrogen fueled fuel cells at comparable efficiency and emissions levels. On the other hand, several comments were not as supportive. To one reviewer it was not clear what this project is adding to the information already presented in the literature. Another stated that running internal combustion engines on hydrogen makes little sense. A reviewer stated that combustion problems are not the most significant barrier to hydrogen ICE vehicles. A comment was made that it is still difficult to comprehend that hydrogen will be a real fuel that is used in the U.S. It was added that this is not a reflection on the efforts of the researchers.

Question 2: Approach to performing the research and development (Written responses from 8 of 16 reviewers)

Comments regarding the research approach were mixed. It was noted that the approach seems logical, and has identified most of the key parameters that need to be addressed in the program. A comment was made that this project appears focused and well-structured to research key hydrogen internal combustion engine problems. Appreciation was expressed for the solid approach to a plan for feeding information to a 4-cylinder. It was indicated that the approach is very good and has included an innovative element that utilizes the optical expertise of the various investigators. The only suggested improvement to the approach was expansion of the experimental test space (i.e., addition of speed/load points to the test matrix). A few less favorable comments were also expressed. One reviewer did not see a clear path from project requirements through critical parameters to functional responses. He added that it seem the project is focused on instrumentation. Another felt that it was still not clear what are the specific goals of this project. It was noted that port fuel injection is not state-of-the-art technology for hydrogen combustion. For the same power density, a boosted engine version (costs) or stoichiometric operation with three-way catalyst would be a better approach. A reviewer disagreed with commenters from previous years; the hythane work has no practical application and should be deleted.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 10 of 16 reviewers)

Reviewers had favorable comments regarding the technical accomplishments. One reviewer noted that OH chemiluminescence measurements appear to be helpful in tracking the hydrogen oxidation front using an endoscope (2-D measurement). He added that the approach appears to be making strides toward getting temperature measurements from the OH chemiluminescence; unfortunately, no temperature measurements were presented. A comment was made that installation of the single-cylinder engine is a key milestone and the exploration of the ignition timing regimes is also a big step. One felt that good progress has been made in the past year. Another stated that good results have been achieved in the time the program has been running. One person mentioned that solid and methodical process is being followed to build a solid base. He felt that use of modeling and comparison to experimental results is excellent. It was noted that implementation of hydrogen safety issues needs time and was performed well. In addition, OH chemiluminescence was well implemented. One pointed out that this project is still relatively new (15 months) but has already demonstrated possible optimal engine control strategy at two key operating points. Much work is still on the horizon, but a good baseline of understanding has been established and will become very important as future engine optimization continues (i.e., how to avoid pre-ignition issues). One reviewer acknowledged successful equipment operation and gathering of data. Another was not clear on how this project will impact fuel economy, but did see the drastic impact on emissions. A final reviewer felt that progress was too slow, though.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 16 reviewers)

Reviewers acknowledged good collaboration with the Ford hydrogen engine project. One reviewer pointed out that this relationship with Ford helps with engine hardware updates. A comment was made that to the extent that industry is interested in hydrogen engines, the level of collaboration is very good; the challenge is to get a broader community interested in this topic. One reviewer noted that this work would benefit from the hydrogen engine work at Sandia. He added that this activity should be using Sandia's models and experimental insights in order to gain understanding for tackling the pre-ignition/knock problem. This reviewer and another reviewer acknowledged industry involvement and very close collaboration with universities in both providing and supporting hardware, and performing multi-dimensional analysis. One reviewer felt that a higher level of industry involvement is needed as well as more collaboration on fundamentals/modeling.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 16 reviewers)

A reviewer supported the move to direct injection. One reviewer indicated that future work is logical and should address the key issues in controlling and optimizing spark-ignition hydrogen engines throughout precise injection and spark timing. He added that this project will address combustion processes issues related to mixing and pre-ignition that should also point toward an optimal combustion design and control strategy. Another pointed out that this work has followed well what was presented at last year's review. He indicated that it seems reasonable to continue in the same direction. A comment was made that an optical access engine should not be used to test pre-ignition conditions since there are no windows available that survive knocking operating conditions for a longer period of time. One person was not clear on how future plans will advance hydrogen internal combustion engine understanding and design by manufacturers. Another had difficulty seeing how hydrogen will be a major force in the near-term at resolving fuel economy improvements or current emissions except for aftertreatment devices where hydrogen is the feed stream.

Specific Strengths and Weaknesses (Written responses from 9 of 16 reviewers)

- Specific Strengths
  - Argonne is a strong research institution. This project benefits from the institutional experience.
  - The single-cylinder research platform offers the promise of significant improvements in this area. The test approach seems to show a path for achieving the program goals.
  - Measurement capability.
  - In-cylinder measurements of hydrogen combustion - I have not seen that elsewhere.
  - Attempt to use diagnostics to understand limitations of hydrogen combustion.
  - The presenter displayed a very good knowledge of hydrogen engine operation during the question and answer period, which builds confidence in the work.

- Optical access engine to study hydrogen combustion is important for fundamental understanding of ignition and flame propagation.
  - Excellent single cylinder research facility.
  - Good work in getting experimental setup working and obtaining credible data.
- Specific Weaknesses
  - No significant results obtained yet.
  - Need a clearer direction; some parallel modeling/analytical work would be useful.
  - There does not seem to be a lot of excitement on this project.
  - Engine head which is not optimized for hydrogen combustion is being used.
  - Other approaches to mitigating knock and pre-ignition need to be considered. Once "conventional" means are exhausted, a more detailed spectrographic study of OH radicals would be more productive.
  - Connection to implementation and practical application.
  - Old hardware needs to be replaced.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 16 reviewers)

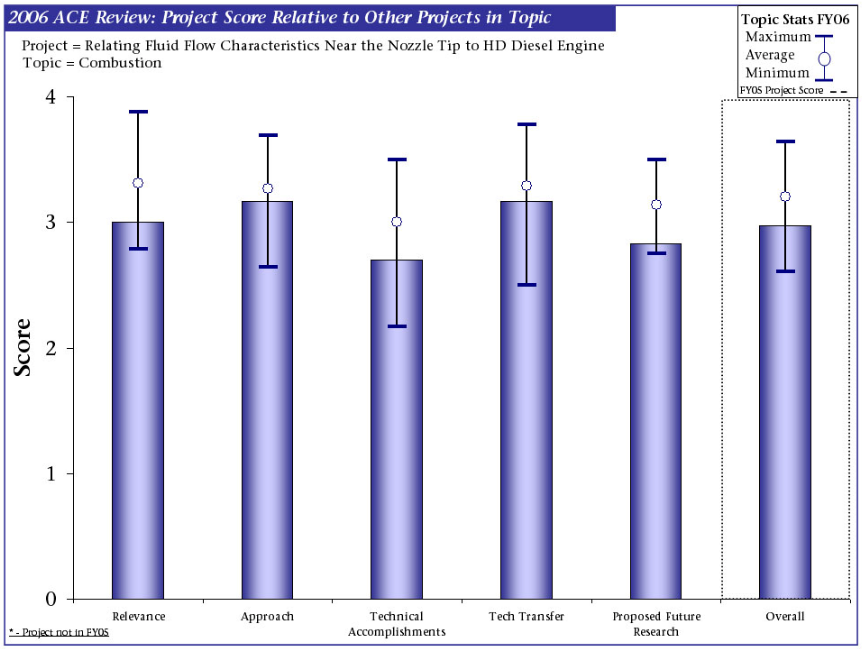
- Work on hythane has no practical application; it should be deleted.
- Work on the design of the combustion chamber to reduce the knock/pre-ignition tendency. Also, the sensitivity of knock and NO formation to intake temperature should be examined to ensure that all major aspects of the problem are addressed.
- The effect of EGR in place of excess air may also be insightful.
- For low-cost engines, stoichiometric operation with direct injection and three-way catalyst may be a better approach and should be investigated.
- Include additional speed/load points in the test matrix.
- Clarify key issues to be addressed and increase work on parallel fundamentals/modeling.
- Identify sources of pre-ignition and knock and incorporate engine changes to reduce these problems.

In-Cylinder Combustion Studies and Modeling

Relating Fluid Flow Characteristics Near the Nozzle Tip to HD Diesel Engine Performance & Emissions, Doug Longman of Argonne National Laboratory

Brief Summary of Project

The overriding objective is to improve CFD modeling predictions of diesel fuel spray droplet breakup and the subsequent ability to predict heavy-duty engine emissions. The program is designed to ultimately study the effects of nozzle orifice processing variations (geometry and surface irregularities) through the use of x-ray techniques to quantify spray characteristics.



Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 12 reviewers)

All of the comments were positive. One person noted that the work is in-line with DOE goals to develop technology to reduce diesel emissions. Another noted that spray characteristics are critical to successful KIVA analysis and more refined plume analysis as allowed by x-ray measurement as compared to optical may lead to better nozzle designs. Another evaluator commented that injection spray investigations near the nozzle exit are important to understand spray atomization. The last reviewer commented that the combined experiment and modeling focus is critical to developing tools that facilitate the development of advanced engines.

Question 2: Approach to performing the research and development (Written responses from 4 of 12 reviewers)

Reactions to this question were mostly positive. One reviewer simply stated that X-ray analysis and simulation work well hand-in-hand. One reviewer commented that at this point no weaknesses were evident; however they would like to see the scope broadened beyond just investigating manufacturing effects. Another person pointed out that work has involved getting the system prepped and noted that the researchers have had little concern about window comments and pressure capability. This reviewer had some questions about the shrouding of a single hole which will put questions into the results. The last person noted that one of the issues raised during the question period at the review was that windows are rated for ~50% of pressures typical of HD engines.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 12 reviewers)

Responses were all neutral given the fact that the program just started and has been limited to equipment setup. One reviewer felt that the accomplishments are good for a first-year project and should pick up with future work.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 12 reviewers)

Reactions were positive in general. One person felt that the collaboration is good for Phase 1 work. Another person noted that the collaboration is typical of CRADAs, in that the collaborations are with a smaller group, but are probably more frequently. One person commented that the researchers have very good partners (CAT, ANL, and UIC) that work closely together. Another person felt that the collaborations were probably limited in part to CRADA partner. The last reviewer noted that the team may include more OEMs.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 12 reviewers)

One reviewer noted that the researchers are still finishing basic equipment, and they need to baseline the system, so there is not much to say. Another person noted that the researchers are using the same nozzle and injector configuration used for hydraulic test bench and engine test cell. One evaluator felt that the plans seem reasonable, although the issue of the windows being unable to withstand pressures typical of actual engines was raised during the question period. The last reviewer commented that they would like to see plans to look at fuel volatility effects to provide additional data for improving the spray sub-models.

Specific Strengths and Weaknesses (Written responses from 7 of 12 reviewers)

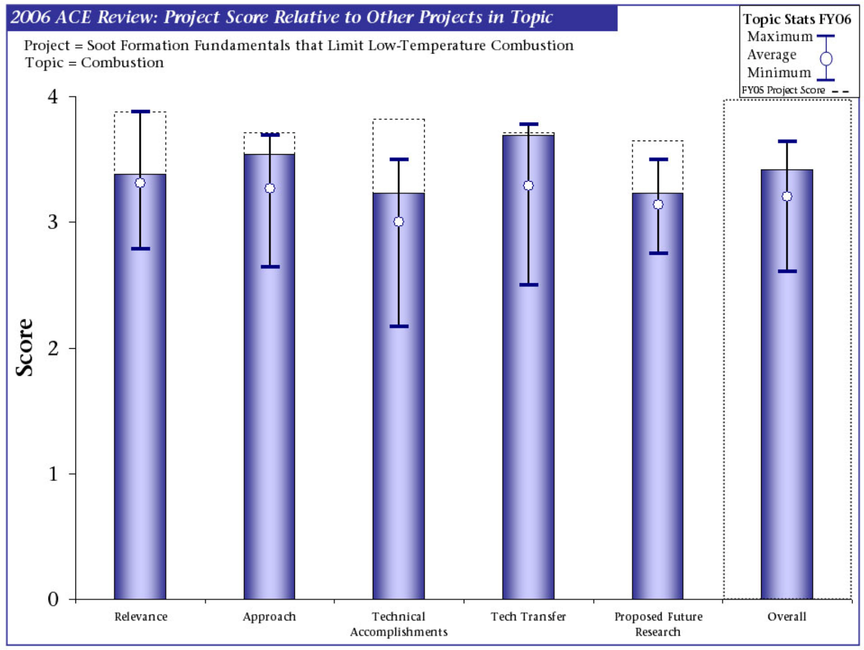
- Specific Strengths
  - Great ability to get 3-D density picture of plume.
  - Coupling engine experiments with analysis method.
  - X-ray investigations help better understanding in-nozzle flow and mass distribution at nozzle exit with liquid spray portion.
  - Test results will be useful, as is collaboration with Caterpillar and KIVA modeling.
  - Use of practical injection nozzles and more realistic pressure and temperature will make the results more meaningful.
  - Good collaboration with CAT; good clear plan.
- Specific Weaknesses
  - Not clear how this work adds to other x-ray spray analysis work at ANL; the only difference seems to be using an injector specific to one manufacturer.
  - Unknown factors of shroud, how close is it to a real engine… can the work be applied well....
  - Hard to match engine and chamber conditions (windows limit pressure) and be sure of the means of segregating one spray from the others.
  - Droplet formation and air entrainment not included. Backpressure limited for spray atomization investigations due to polymer window restrictions.
  - None significant, prior to data.
  - Maximum pressure limit on this experimental study.
  - None evident (though I'm not an expert)

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 12 reviewers)

- Add single cylinder combustion testing to go with individual injectors so KIVA and engine test results can be coordinated.
- Keep going.
- Add "conventional" optic (laser-) diagnostics to describe the spray outside of the plume to help building an accurate simulation model.
- Future work appears appropriate, pending data generation.
- Do some measurement at downstream to illustrate the upstream breakup effects on downstream.

In-Cylinder Combustion Studies and Modeling

Soot Formation Fundamentals that Limit Low-Temperature Combustion, Lyle Pickett of Sandia National Laboratories



Brief Summary of Project

These research efforts use an optically-accessible combustion vessel to develop an improved understanding of low-temperature diesel combustion and emissions processes.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 13 reviewers)

Initial comments were that this was "very good work" and "important fundamental work." A reviewer noted that improved understanding of low temperature diesel combustion and emissions process is in-line with DOE goals. A reviewer felt that this was very appropriate basic work on EGR and PCCI that is very relevant for Cummins. This investigation is very important for "real world" HCCI or comparable premixed combustion techniques, noted another reviewer. The final reviewer said that this is an excellent ongoing research project focusing at sorting out EGR and mixing effects on local soot formation. This work will provide guidelines on what type of injection control strategies may be employed to directionally reduce in-cylinder soot. Much future work is necessary to better quantify potential control strategies over broader engine operating conditions, noted this reviewer.

Question 2: Approach to performing the research and development (Written responses from 4 of 13 reviewers)

A reviewer said that the approach was methodical and logical. Another observed that distinct diagnostic tools are well-used and results are well analyzed. A reviewer said that this team had a well-thought-out use of available optical diagnostics to study local mixing effects and soot formation. The final reviewer said that Dr. Pickett recognizes that high load is important and is addressing critical issues.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 13 reviewers)

Progress was generally judged to be good, with one reviewer noting that the progress versus the team's plans was good. A reviewer said that it seems like Dr. Pickett had good success this year with EGR equivalence ratio data collection. Another noted that fundamental questions (like A/F-ratio inside the spray for different EGR rates) are investigated and answers were given. Finally, a reviewer offered that portions of this work are providing new insight into why and how in-cylinder forms as a function of the injection event and the EGR level; much progress has been made during the last couple of years.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 13 reviewers)

Technology transfer and collaborations were reviewed well. A reviewer said that there seemed to be a good number of collaborations, while another reviewer said that the wide range of collaborations is impressive. The collaborations with the combustion MOU were noted by several, with one saying that this work is clearly connected with MOU and other National Labs, and another saying that the MOU collaboration valuable, but that while industrial partners are involved in MOU, it is not clear that they are "full participants." A reviewer noted the good cooperation with other Sandia projects. A reviewer observed that the principal investigator has posted data on the internet for modelers and has worked very closely with colleagues also performing low temperature combustion research: this reviewer praised the great collaborative effort. Finally, a reviewer noted that this project is part of the AEC, and that data are available on the website.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 13 reviewers)

The first reviewer said that the proposed plans look good. A second reviewer noted the good future plan to focus on understanding soot formation in jets utilizing available optical diagnostics. A reviewer suggested that the team continue with experimental plan, which is very relevant to research at Cummins: findings may provide direction for internal research at the engine companies. The final reviewer said that more detailed 2-stage combustion (cool flame) investigations important. Transient liquid penetration is important for application of HCCI. Soot oxidation phenomena were not shown explicitly, this reviewer observed.

Specific Strengths and Weaknesses (Written responses from 9 of 13 reviewers)

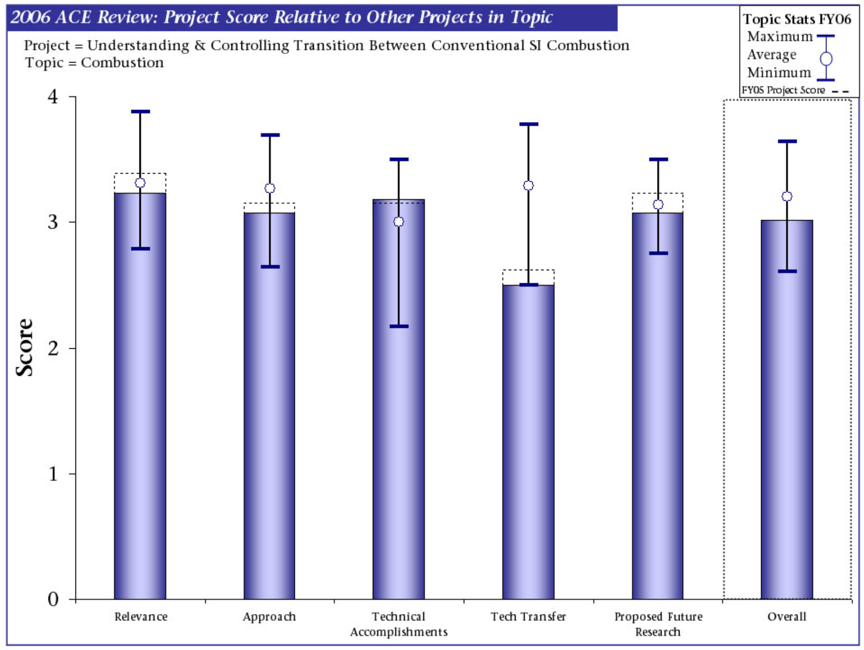
- Specific Strengths
  - Very fundamental work with well-suited diagnostic tools and excellent link to other combustion investigations.
  - Fundamental work at conditions that are well matched to actual engine operating conditions
  - Unique test facility allows study of the fundamentals of LTC.
  - Outstanding experimental facility.
  - Testing capability.
  - Direct injection, manipulation of multi-pulse, all of these are used by commercial engines … more relevant to commercial application.
  - Good work, in-depth understanding is useful and well presented.
  - This research provides useful knowledge that is not available elsewhere.
  - Optical diagnostic capabilities.
- Specific Weaknesses
  - N/A
  - None.
  - None significant.
  - Use of heptane only as a fuel.
  - Limitation to closed vessel hinders the direct link to ICE: pressure and temperature traces after combustion are different.
  - No studies of fuel effects.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 13 reviewers)

- Keep going.
- 2007 plans appear appropriate.
- Add fuel effects studies using FACE fuels and others.
- Would like to see soot visualization of small, many injection at high overall load … what benefit is available? Also, if additional mixing with high EGR rates late in cycle is important for low soot, what mechanism would be effective (other than single pulse post injection) and what does that look like with the experimental apparatus. Good work …
- Explicitly look into soot oxidation.
- Maybe add more potential engine-related operating conditions, i.e. wider boundary conditions on ambient conditions.
- I fully understand the motivation for using heptane (related to availability of detailed models and focus on fundamental aspects of combustion). However, soot formation is very different for n-paraffins, iso-paraffins, naphthenes, and aromatics. It would be very useful to expand the scope to include fuel (and perhaps volatility) effects. I'm not sure at what point the more detailed study of residence time effects reaches the point of diminishing returns compared to other "big picture" questions.
- May use heptane and toluene blend for laser diagnostics so that it represents diesel better.

In-Cylinder Combustion Studies and Modeling

Understanding & Controlling Transition Between Conventional SI Combustion and HCCI, K.D. Edwards of Oak Ridge National Laboratory



Brief Summary of Project

The Oak Ridge team is investigating the potential of nonlinear control methods to stabilize the transition between SI and HCCI combustion modes as well as intermediate hybrid (mixed-combustion) modes which exhibit characteristics and benefits of both SI and HCCI combustion. A major objective for the current year of work was to assess the nature of the instabilities observed during SI-HCCI transitions to determine if they are predictable and if application of nonlinear control to smooth the transition appears feasible.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 13 reviewers)

Responses to this question were positive. One reviewer noted that this work is important from a practical standpoint; extension to more fundamental understanding of nature of combustion instabilities critical. Another commented that this project is working on a key area, the combustion mode transition between SI and HCCI, and that HCCI instability during transitions is a barrier to production implementation. One person agreed with this assessment, noting that the investigation of transition between SI and HCCI modes is consistent with DOE goals. Another person had similar comments, stating that the project is focused on the transition from CAI to SI mode is important for CAI application. The final reviewer felt the project has good focus, with interesting non-linear data analysis.

Question 2: Approach to performing the research and development (Written responses from 2 of 13 reviewers)

One reviewer commented that the approach seems reasonable, especially the fact that the presenter pointed out how this approach differs from what others (e.g. Stanford, MIT) are doing. Another reviewer commented that the project is very interesting and highlighted the helpful approach with "pattern recognition" technique.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 13 reviewers)

One reviewer commented that it looks like there has been very good progress in validating applicability/merits of this approach. Another person felt that the presenter showed very interesting results that now need to be explained applying combustion analysis tools. One evaluator noted the interesting findings on the transient behavior between SI and HCCI operations. Another person noted the good progress, but added that the researchers need to move to the next step by implementing control and feedback concepts in real-time to demonstrate them on a running engine. They suggest that the CRADA with a partner should help with this. The final person felt that it is not clear that non-linear control has any benefits over linear. In principle it should be, but a direct comparison would be useful.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 13 reviewers)

Comments were consistent in general that the researchers need industry partners. One reviewer stated that it seemed most of this was completed by the lab. Several reviewers suggested that working with some industrial/OEM partners would be appropriate and would help this area. One reviewer got the impression that collaborations are increasing. The final reviewer had several comments. They stated that the extent of industrial participation was unclear, but would be surprised if the OEMs were not working in earnest on this. They were not clear whether this work is duplicative, leading edge, or way behind the OEMs capabilities, so it is hard to assess the potential of this work.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 13 reviewers)

Two reviewers felt that the plans for the next steps seem reasonable. One person noted that applying simulation tools will help better understanding of transition. Another reviewer questioned how the future work leads to actually utilizing this data. They wondered what controls on a real engine offer the ability to reduce the instabilities. The final reviewer noted that the proposed work focused on understanding the detailed chemistry and physics during the instabilities is very important, though perhaps not from a practical standpoint. They add that it is not clear how this knowledge would improve control strategy capabilities, adding that it would be interesting to hear the authors' thoughts on this.

Specific Strengths and Weaknesses (Written responses from 7 of 13 reviewers)

- Specific Strengths
  - Great data analysis.
  - Unique method seems promising.
  - System-oriented controls work to solve some fundamental control barriers to practical HCCI implementation.
  - Very interesting techniques used to analyze difficult transition pattern of combustion.
  - Addresses important questions, work is well done and useful.
  - It offers a promising operating mode for a low-emission SI engine.
- Specific Weaknesses
  - Use of port fuel injection engine, failure to focus on optimizing combustion phasing; looking at transition controls without first having a good combustion system.
  - Connection of controls, parameters to real engines (he mentioned some of these during the follow-up questions, but still vague).
  - Need to look at data from multiple HCCI concepts and see if similar effects happen. Will this be useful for controlling HCCI engines in the narrow band needed? Will it help adapt to varying fuels?
  - Need to implement and test the closed-loop control concepts.
  - Investigations are focused on fundamental analysis of causes for transition combustion phenomena. However, no solution is targeted (i.e., sensor or actuator development).
  - It appears that control will require accurate cylinder pressure.

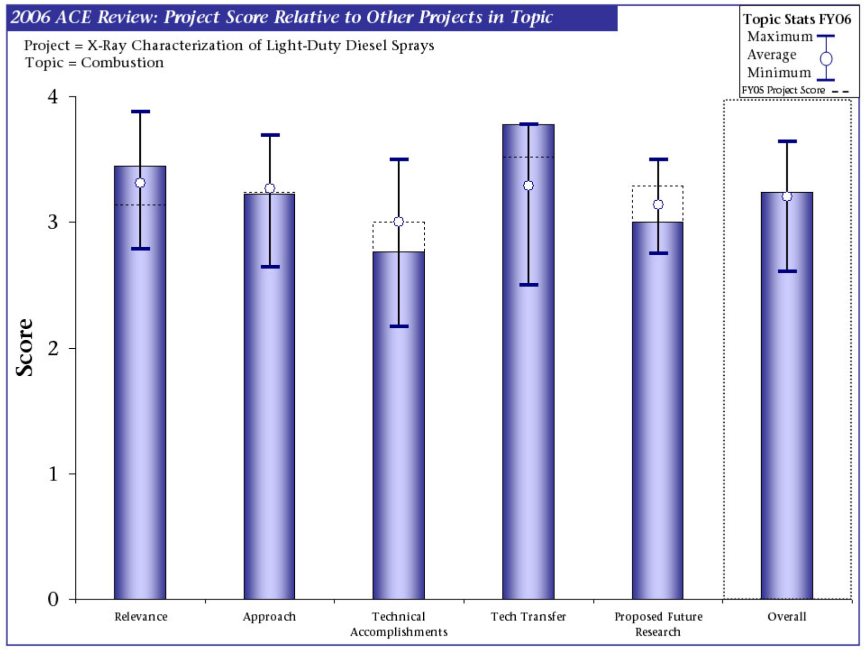
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 13 reviewers)

- Work should be continued only if engine and combustion system can be upgraded.
- Get a bigger picture of how this technology can really be implemented, then pose work within that higher level framework. Perhaps this is happening, but not clearly evident during discussion. This work may also be interesting for combustion noise related to PCCI.
- Keep going, but get an industrial collaborator and an appropriate testbed engine. Work with other groups that have different HCCI engines to get a broader range of data sets.
- Involve industry partner who can help facilitate development and testing of the control concepts.
- Having the analysis of transition phenomena analyzed, control algorithms and sensors/actuators should be investigated.
- Appropriate next steps.
- They should monitor engine output variables beside cylinder pressure to develop a practical control scheme.
- May demonstrate how much HCCI region can be explained by better control in the transition.

In-Cylinder Combustion Studies and Modeling

X-Ray Characterization of Light-Duty Diesel Sprays, Chris Powell of Argonne National Laboratory

Brief Summary of Project



The goal of this project is to provide measurement techniques for diesel fuel injection sprays in the near-nozzle region in order to improve spray modeling. This project uses X-ray techniques to determine quantitative characteristics of the fuel spray.

Question 1: Relevance to overall DOE Objectives (Written responses from 12 of 18 reviewers)

In terms of DOE Program relevance, reviewers had mixed comments. One reviewer felt that not a lot of actual results were presented, that the presentation focused primarily on describing the instrumentation necessary for experimentation relating to engine applications, and that historically this project has provided little in the way of experimental results and/or interpretation. Another reviewer stated that while many parameters impact engine operation and their interactions are critical, this project only focuses on fuel spray.

Other reviewers intimated that the presenter provided a good summary for reasons for doing the research, that the project is critical to understanding spray structure and mixing, providing unique insight into mixing in core regions (especially dense core regions), and that the work is needed for spray development. Others went on to say that the research is very important to improving injector and combustion models, providing a key validation link between injector hydraulics and KIVA-esque combustion modeling, and that injector nozzle design and near-injector spray characteristics are key knowledge areas for predictive modeling and improved performance. The experimental technique is fairly well developed and is starting to generate quantitative information that can be used by modelers to study low pressure, near nozzle break-up phenomena. In general, spray physics are essential to the quantitative and qualitative characterization of diesel emissions. The experimental set-up does have limitations in that the high pressure chamber is limited to 20 atm, but the real return on investment should occur in the next few years when experiments start to approach more relevant engine-like operating conditions. Another reviewer stated that the work can be of great interest in relation to LTC and NOx aftertreatment research. The reviewer suggested that future work correlate observations with actual engine test results in specific applications, expanding to include L/D, sac geometry, etc. A reviewer said that the work supports diesel combustion modeling and optimization which is key to making light duty diesels viable.

Question 2: Approach to performing the research and development (Written responses from 11 of 18 reviewers)

In general, most reviewers stated that the research approach for this project is good and has shown steady improvement over time, i.e., 1 atm to 20 atm results in three years. The approach relies on good fundamentals, is understandable and seems reasonable. Issues of a high temperature and pressure environment are well addressed but difficult to achieve experimentally. The research has removed major barriers to imaging under “real-life” conditions short of an optical access engine. The research utilizes unique tools and “first class” facilities, but needs more interaction with modelers. There is too much lag time in disseminating modeling information. Additionally, some reviewers felt that results should be shown at pressures more consistent with actual diesel combustion processes (around 180 bar) and thus more relevant to diesel modelers. Higher chamber pressures at realistic in-cylinder bulk temperatures should be pursued through improvements in the experimental apparatus since near injection behavior is still not well understood by the engine research community and may hold the key to NOx and soot formation.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 12 of 18 reviewers)

In terms of technical accomplishments and progress, reviewers had mixed impressions. A reviewer was looking forward to specific results at high pressures. One reviewer felt that the research equipment continues to improve its capabilities, operating window, and applicability. Another stated that while the first steps (1 to 30 bar) towards higher pressure testing has been made through very careful redesign of the chamber, high temperatures seem to remain a problem. Higher pressures are being achieved, but some reviewers stated that it has taken a long time to get to this point. Efforts to improve high pressures and temperatures need to continue as rapidly as possible since the ultimate application of this tool is the CIDI engine. Several reviewers stated that more data output is needed for the level effort in the project. One reviewer thought it was difficult to judge project accomplishments because the presentation ran too long. Finally, one reviewer questioned what the implications would be for having a smaller pixel size on the x-ray monochrometer, and whether this provides research opportunities for other applications?

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 11 of 18 reviewers)

Most of the reviewers believed that the number and types of collaborations associated with this research were good, but the CRADA was just signed so it remains to be seen whether these collaborations will be fruitful. University and industry representation was seen as especially important over time as the modeling aspects of the project begin in the project. One reviewer commented that it was good to see interaction with fuel system manufacturers to keep the work relevant and is key to increasing knowledge and fostering improvements in industry. Another stated that collaboration with GM and the University of Wisconsin was appreciated. Finally, one evaluator questioned whether CRADAs are an effective way to work with industry since CRADAs seem to restrict the flow of information to the rest of the industry.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 18 reviewers)

Some reviewers hinted that progress to date has been good (i.e., reaching 30 bar test conditions), but many would like to see faster progress and higher pressures to further the development and usefulness of the tool. One reviewer indicated that the project appears to be set on generating results, and less on refining the experimental setup. For example, the research should focus less on taking more lower-pressure spray measurements on hydroground versus non-hydroground nozzles, and more on pushing up the spray chamber operating pressures. While reviewers generally acknowledged that the researcher ran short of time to provide future plans in his presentation, most would like to see more specifics in this regard, such as whether there is a plan for nozzle geometry, or how well the work will be incorporated into various models. Further, the researcher needs to explain how the work will contribute to improvements in fuel economy, emissions, and the state of the art in diesel combustion. Lastly, one reviewer stated that polymer windows research may not be able to achieve higher pressures and temperatures, and consequently, this may restrict the method to fundamental investigations only.

Specific Strengths and Weaknesses (Written responses from 14 of 18 reviewers)

- Specific Strengths
  - The APS is a major strength of this research and the work seems to be leveraging the unique capability of X-ray spectroscopy.
  - This is a unique method of evaluating an important (if not the most important) unknowns in high-pressure fuel sprays.
  - The research has a good number of collaborations with industry (helps to get different injector designs and engines) and with universities that can take results and develop models. The project continues to improve equipment and improve its usefulness.
  - Good industrial collaboration.
  - Focus in collaboration; drive to improve throughput; makes good use of unique facility.
  - Unique method for near-nozzle measurements.
  - Objective measures for model calibration are good.
  - The approach using X-rays for spray investigations is very helpful. The focus on improving simulation models in the dense spray core will improve the codes.
  - Unique experimental capability due to resources of the APS and very knowledgeable staff for setting up and

performing experiments.
  - Good development of this tool, important issues being addressed, and very good progress since last year.
  - Fundamental testing and analysis.
  - These measurements of fuel sprays are not obtainable by other means.
  - Good information on micrograms of fuel spray.
  - X ray experiment is not common.
- Specific Weaknesses
  - No weaknesses are significant.
  - Actual data presented is very minimal and clear specifics of how/what conditions the data was taken is pretty vague. I am frustrated.
  - The major factors affecting entrainment and mixing are mostly accounted for. However, the effects of evaporation/two-phase heat-mass transfer in the presence of charge motion may be significant as well, and this apparatus does not easily accommodate such effects.
  - All the modeling is done elsewhere; needs close work to get full value.
  - Might be interesting to see some correlation results at max pressure extrapolated to higher pressures.
  - Only mass distribution can be shown. Droplet sizes that are required for simulation can not be identified. The working principle does not allow investigations of shot-to-shot-differences.
  - Project is still not yielding engine relevant data; investigators should strictly focus on increasing the spray chamber operating pressure.
  - Progress has been slow.
  - It has taken a long time to get comprehensive results at representative conditions.
  - Interactions are missing and it is not clear from the presentation how the information relates to fuel economy and emissions. It seems that this project is still a long way from improving diesel combustion.
  - Ambient pressure at which the experiments are performed are too low to be directly useful to the diesel modeler.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 10 of 18 reviewers)

- The researcher should spend less time talking about the wonderful instrumentation and provide more RESULTS!!!!!!
- Continue to evaluate a focused set of parameters, based on interactions with industry. This may include mapping out the effects of hole size, ROI, DOI, SOI (simulating pressure/temp(?) conditions at pilot/main/post injections), and possibly even L/D effects of the holes.
- It would be good to see specific modeling effort tied to this program.
- Expand the scope of the work to include funding of phase-contrast radiography of the internal dynamics of fuel injectors.
- This work could help understand the operation of the next-generation of fuel injectors with increased/variable nozzle functionality. A second enhancement would be to expand the work to include 3-D tomographic spray analysis, since sprays are often not symmetrically uniform. These types of phenomena are important to understand to engineer improved fuel injectors and combustion systems in order to meet performance and emissions criteria.
- A window that is transparent to x-rays but can also withstand high temperatures and pressures is still the biggest hurdle.
- Parallel measurements at different locations in the spray may help to identify shot-to-shot differences and commercialization of the method.
- Alleviate any unnecessary low pressure spray measurements.
- Include study of SIDI spray-guided injector sprays.
- Added work on correlations between nozzle design parameters and spray results, as well as on linking desired spray patterns to optimum combustion would be a useful extension.
- Correlation with existing CFD codes would be useful. Academic collaborations were mentioned but no apparent highlights in the presentation material.

This category includes projects involving research into advanced post-combustion emission control technologies. Devices being investigated to control NOx emissions include NOx adsorbers and selective catalytic reduction. Research is also being conducted on diesel particulate filters to control PM emissions. These technologies are being investigated both for light-duty diesel vehicles and for heavy-duty diesel vehicles. Research is also being conducted on how these NOx and PM devices will interact with each other in an integrated emission control system.

Below is a summary of average scores for 2006 for the six projects reviewed in this category, along with the average, minimum, and maximum score for all projects in the combustion and emission control portions of this report. The highest score in this category for each question is highlighted.

Summary of Scores for Projects in this Section

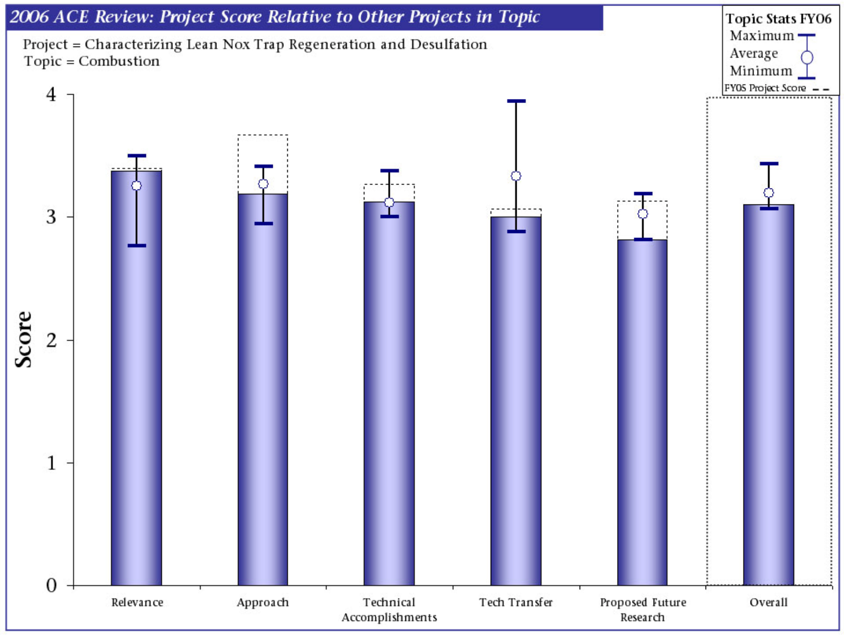
Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Project Average Score
52	*Characterizing Lean NOx Trap Regeneration and Desulfation* (Shean Huff, Oak Ridge National Laboratory)	3.38	3.19	3.13	3.00	2.81	3.10
55	*CLEERS DPF Characterization and Modeling* (Mark Stewart, Pacific Northwest National Laboratory)	3.29	**3.41**	3.06	3.65	3.13	3.31
58	*CLEERS-Overview and LNT R&D* (Stuart Daw, Oak Ridge National Laboratory)	3.35	**3.41**	**3.38**	**3.94**	3.07	**3.43**
60	*Fuel Efficient Diesel Particulate Filter Modeling and Development* (Heather Dillon, Pacific Northwest National Laboratory)	2.77	**3.41**	3.12	3.12	**3.19**	3.12
62	*Low Temperature HC/CO Oxidation Catalysis in Support of HCCI Emission Control* (Ken Rappe, Pacific Northwest National Laboratory)	**3.50**	2.94	3.06	2.88	2.94	3.06
65	*Mechanisms of Sulfur Poisoning of NOx Adsorber Materials* (Charles Peden, Pacific Northwest National Laboratory)	3.19	3.25	3.00	3.38	3.00	3.16
	Average Score for This Category	**3.25**	**3.27**	**3.12**	**3.33**	**3.02**	**3.20**

Overall Scores for Combustion and Emission Control

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Score
Average	3.29	3.27	3.04	3.30	3.11	3.20
Maximum	3.88	3.69	3.50	3.94	3.50	3.64
Minimum	2.77	2.64	2.17	2.50	2.75	2.61

Emission Control Devices for NOx and PM Control

Characterizing Lean NOx Trap Regeneration and Desulfation, Shean Huff of Oak Ridge National Laboratory)



Brief Summary of Project

In this study, researchers are characterizing the emissions of hydrogen, carbon monoxide, and hydrocarbons from a diesel engine and correlating these emissions of NOx adsorber reductant species to performance of several lean NOx traps.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 16 reviewers)

Reviewers offered a number of suggestions on the project. A reviewer felt that this project represented excellent work at ORNL, and that the interaction between engine management, different engine operation modes and catalytic activity is unique within the academic world. A reviewer said that more understanding of lean aftertreatment is critical. Another reviewer noted that finding ways to improve efficiency and reduce fuel consumption of the LNT process is a good goal. A reviewer observed that decreasing brake specific fuel consumption when operating the LNT is relevant to the DOE objectives, but the communication of the results is an issue with this project. A reviewer said that the project's Topic 4 on in-cylinder hydrogen production is relevant to improving aftertreatment regeneration, and that methods of producing in-cylinder hydrogen across operating conditions could be a valuable enabler to regenerations.

Several reviewers noted the rise of selective catalytic reduction (SCR) technology for NOx reduction. One said that LNTs may or may not be used as a NOx aftertreatment technology. This work; however, is well directed to identifying the engine control strategies necessary to utilize that technology. Another said that regeneration and desulfation of LNT in an efficient way is important, but SCR may win the race. A reviewer stated that SCR is getting greater attention, and a final reviewer noted the change in industry emphasis toward SCR.

Question 2: Approach to performing the research and development (Written responses from 6 of 16 reviewers)

Reviews were generally positive on this aspect of the research. A reviewer said that this approach uses a combination of engine control strategies, engine out measurements and inside the catalyst measurements to evaluate the activity of the LNT catalyst. This reviewer didn't see any way to improve the approach. Another felt that there was good use of prior year feedback to improve the project work. Solid approach with excellent experimental work, noted another reviewer.

Some reviewers offered specific suggestions on the research approach. One reviewer would like to see some emission test performance data to see the benefit on the LNT. Another said that the transient operation in LTC during regeneration is not well addressed, and that build-up of high EGR features a significant time delay. A final reviewer said that there was good use of SpaciMS. This reviewer would like to see interaction with a catalyst supplier who can use the information to modify formulations and reduce cost. More fundamental investigations are necessary. This reviewer suggested that industry should worry about the system and work out the details of regeneration and desulfation strategy, and that the laboratory should focus on the fundamentals of what is occurring in the catalyst beds during these activities to further the science.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 9 of 16 reviewers)

Reviewers offered positive comments on the technical accomplishments, but noted several areas for improvement.

A reviewer said that this is probably the most highly instrumented LNT aftertreatment system available. This work clearly indicates what sort of information can be obtained to develop an effective, fuel-efficient engine control strategy. Another reviewer said that the project had very interesting results on the LTC regeneration strategy. Finally, a reviewer thought that reducing the fuel penalty for LNT regeneration by using low temperature combustion looks promising, as this would allow rich operation without throttling.

Several suggestions were offered. One felt that more collaboration with catalyst manufacturers would be beneficial. Another said that it was speculation that sintering causes ammonia formation to increase, and the research team should confirm this. Another commented that a lot of work was done: this reviewer requested a focus on understanding and overcoming technical challenges. A reviewer appreciated the detailed analysis, but said that a focus on one single operating point is not sufficient to rank different systems. However, the whole work plan is large. Hydrogen production during lean phase was interesting (in one reviewer's opinion) and offers new possibilities with lean NOx catalysis as described in the hand-out. For the impatient observer, speed up of the project would be helpful. This reviewer said that more engine points should be investigated and a statement on the potential in test-cycles should be given next year. A final reviewer said that his score would have been 4 if our interest had not shifted toward SCR.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 10 of 16 reviewers)

Collaboration comments on this project were mixed. A reviewer felt that the project was well connected through the DEER Conference and CLEERS, a view echoed by other reviewers who said that CLEERS is the right focal point to discuss results and that the CLEERS group dynamics works well. A reviewer said that there appeared to be much in-house (ORNL) collaborations, but not much outside collaboration, other than with CLEERS.

Several reviewers noted the participation of Umicore in the project. One said that the collaboration was not clear other than some catalysts from Umicore. This was similarly noted by a reviewer who said that collaboration with specific partners was not mentioned in much detail (other than Umicore). Finally, a reviewer said that collaborations were not quite clear from the hand-out, but with Umicore a potential catalyst supplier is directly involved.

Other comments included that no OEM partners had been identified. A reviewer further elaborated, noting that more (or closer) participation with a catalyst supplier or engine OEM should be undertaken. A final reviewer said that the ORNL group is very open about their results and they are doing their testing on commercial catalysts. However, the engine studies are being done on an older technology engine and there is no direct coupling with industry on a more modern diesel using modern combustion technologies, this reviewer felt.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 16 reviewers)

The question of LNT use versus SCR use for practical emission control systems that was seen in the relevance section was also brought out in comments on the future research. A reviewer simply said to shift to SCR. Industry seems to be settling on SCR, noted another reviewer: interest in LNT is waning. A reviewer specifically noted that desulfation is still the biggest issue in LNT applications, and recommended that the team not focus on LNT so much due to application hurdles (production tolerances, operational differences, difficulties in combustion control). One reviewer offered the contrasting opinion that six months ago he wrote off LNT as an unusable technology, but this has changed, particularly for Bin 5 applications.

Other comments included that a baseline of catalyst durability after a number of current desulfations and then the durability of ORNL's new regeneration strategy is what needs to be developed. There is little interest in the poor durability of LNT after desulfation unless ORNL can determine why and propose how to improve it. This reviewer suggested a focus on fundamentals. Another reviewer believed that the future plans are very good, but wished that this project was tightly coupled with a newer engine technology. A reviewer was not clear as to what is meant by "multiple catalysts with same formulation"—does this mean repeatability runs with catalysts with essentially the same composition? In addition to the proposed plan a focus on by-product would be interesting to a reviewer, and how the unique engine possibilities can influence the product selectivity during the regeneration steps. A final reviewer was not clear what the future research approach will be.

Specific Strengths and Weaknesses (Written responses from 11 of 16 reviewers)

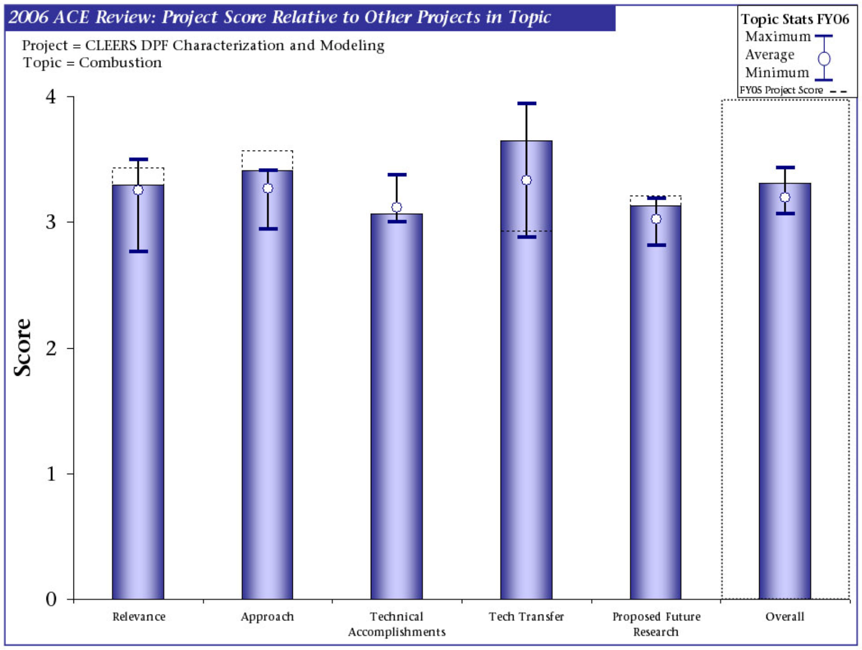
- Specific Strengths
  - Analytical evaluation of catalyst.
  - Analytical tools are a huge asset. Good use of them.
  - Good analytic tools and speciation.
  - Excellent analytics and test approach. Critical work for future emissions reduction while conserving fuel.
  - Good improvements in statistical rigor and multiple measurement tools, including SpaciMS.
  - The instrumentation at ORNL makes this an ideal place to do this work. In addition the professional staff expertise and range of experiments and simulation at ORNL help make this a very effective project.
  - Engine studies to develop understanding of lean NOx aftertreatment; investigation of hydrogen production in catalyst and in engine.
  - The combined sight of engine and aftertreatment is really very impressive for academia. There is no other place known to me except some of the OEM.
  - LNT issues are well addressed and engine hardware is up-to-date.
  - Good project, useful work to understand key LNT issues and decrease fuel penalty for regeneration.
- Specific Weaknesses
  - Difficult to improve this project .
  - Old Mercedes 1.7 L diesel combustion technology.
  - Difficult to determine the differences of LTC & DEM on tailpipe emissions.
  - There is probably a lot of great work done on this program; however there needs to be more effort put forth to communicate it appropriately. The regeneration strategy information is not new. I would estimate that all of the engine manufacturers have a good understanding of knobs to turn to achieve regeneration and/or desulfation.
  - Our interest in moving to SCR. Detailed strategies of OEMs are confidential, so some of this overlaps work there.
  - Good data collection and characterization, but the work could be improved by increased use of modeling and simulation. The ability to show experimental vs. modeled results would likely be valuable and could also promote increased understanding of the underlying phenomena at work. (This might be a good candidate for collaboration with another entity.)
  - Technology is still overly reliant on (unaffordable) PM.
  - How these results tie to real world? Steady state results correlate to transients?
  - Only one operating point in the part load regime limits the application to only fundamental work and light duty applications.
  - More direct collaboration with LNT catalyst and device developers in industry would be useful if possible.
  - Regenerations should be ended based on downstream sensors rather than based on time.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 10 of 16 reviewers)

- Identify a modern prototype diesel to use to evaluate these regeneration strategies.
- Use the newest, greatest formulation of LNT that catalyst suppliers can provide for future work.
- Move away from timed regenerations and use an oxygen sensor to determine when the LNT regeneration is complete.
- Shift to DOC/SCR/DPF systems including interaction with LTC.
- Can advanced controls / PM reduction (generally additional emphasis on affordability) be emphasized in the work being done?
- Transient engine operation from lean to rich is important for fuel consumption. This should be better addressed.
- Continue work but have a mechanism for high grading focus items and making sure fundamentals are understood
- Add work on SIDI stratified charge lean NOx aftertreatment.
- Need additional work at where these catalyst systems are not as effective. It appears that most work is directed at the sweet spot in the catalyst. Also need to evaluate other catalyst systems to determine if they exhibit different behaviors.

Emission Control Devices for NOx and PM Control

CLEERS DPF Characterization and Modeling, Mark Stewart of Pacific Northwest National Laboratory



Brief Summary of Project

This work is part of the CLEERS activity with DOE to develop computational simulation tools for realistic performance of lean-burn engines and emission control systems. Here, PNNL researchers are pursuing computational simulations of diesel particulate filter activity and comparing these simulations to actual single-channel diesel particulate filter materials loaded with diesel soot.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 17 reviewers)

Many positive comments were received on the relevance of this research. A reviewer felt this was excellent research into diesel particulate filters. Another said that this was good fundamental work, and the kind of work the National Laboratories should be doing. Improved understanding of performance of emissions systems is in line with DOE goals, noted a third reviewer. A reviewer offered that this was an excellent platform for exchange and helps to accelerate aftertreatment development through standardized description and testing of catalyst materials. A reviewer noted that the simulations seem to transition smoothly from deep bed filtration to soot cake filtration, and that the comments on the exit channel effects of oxidation are quite interesting. A final reviewer was not really sure there are any breakthroughs here, as simulations are already available and diesel particulate filters are going into production shortly.

Question 2: Approach to performing the research and development (Written responses from 4 of 17 reviewers)

A reviewer felt that this project offered a nice blend of fundamentals (pore space modeling, reaction kinetics) with performance in real materials. Another said that the single channel test bench was an exciting idea, and that the numerical approach was well accepted. A reviewer thought that the work needs to be focused more on real-world conditions. A final reviewer had several comments, including that the pore modeling approach seems to be working. This is such a tough problem. It is very encouraging. This reviewer suspected that this approach is used to model the soot accumulation in the cake. The reviewer also liked the thermograph experiments, and felt that they were interesting, but the reviewer did not understand the results. The experimental set up is very helpful to generating difficult-to-obtain DPF data.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 17 reviewers)

A reviewer said that it looks like very good progress is being made. Another said that great results were obtained considering the program size. A reviewer felt that the description of soot cake build-up and material characterization very good. The “continuous” plots of soot density from above the surface into the pores of the surface were very pleasing to a reviewer, who also said that the back pressure plot successfully shows the inflection point of the transition from deep bed filtration to cake filtration. Another reviewer said that the single channel apparatus offers a lot of possibilities, and the project had a good approach. Flow field distribution is helpful for understanding. This reviewer wondered if there is a way for validation. The reviewer also said that in addition to back-pressure, the weight of soot mass should be addressed. Finally, a reviewer said that the IR may not have the resolution necessary to give the detail the project team is seeking.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 17 reviewers)

Technology transfer was generally graded as being good, with several mentions of the CLEERS interaction. One reviewer said that there was good communication with the CLEERS group. Another said that the group of CLEERS collaborations is impressive. CLEERS group is a good way to focus the interactions, said a third reviewer. CLEERS DPF teleconferences and meetings result in excellent coordination, said a reviewer, who also highlighted the team's multiple presentations and meetings at various customers. A reviewer felt that in particular the international meetings (CLEERS workshop) with unlimited expert attendance were very well acknowledged. A reviewer said that there appears to be lots of involvement on a regular basis with variety of industrial and university and national lab participants. A final reviewer said that communication of the work is quite good, but that actual collaborative projects do not seem to be occurring.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 17 reviewers)

All the activities proposed are appropriate extensions of the work already accomplished, noted the first reviewer. A second reviewer said that the path forward was OK, but the team could perhaps do a little more work on specific C-NOx-reactions and C-O_2-reactions and their combined reactions. A more detailed work plan would be appreciated by a reviewer. A reviewer said that the team needs to concentrate on tracking information to device-scale filters, as well as the effect of multiple walls and thermal gradients that occur in the filter. A reviewer said that the team should make sure regeneration approaches match those of real world vehicle regenerations. Finally, a reviewer asked when we can expect to see similar work with other filtration materials such as sintered metals and metal foams.

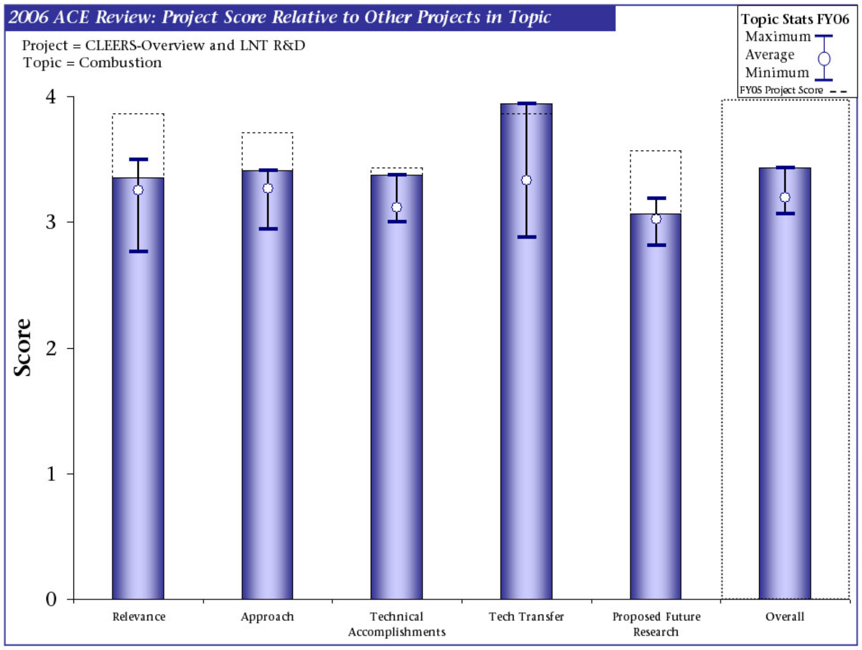
Specific Strengths and Weaknesses (Written responses from 11 of 17 reviewers)

- Specific Strengths
  - Good research team at PNNL. Good experimental facility. Good communication with industry.
  - The overall group with experts from industry and academics.
  - Excellent exchange of knowledge.
  - Modeling and experimental data to validate models.
  - Very good modeling development and developing fundamental explanations.
  - They seem to be developing a good model of diesel particulate filter.
  - Detailed understanding of soot loading and regeneration.
  - Excellent application of statistical techniques and information from other areas (soil permeability) to diesel particulate filters. Excellent use of models and simulations.
  - Blending of fundamentals (pore spacing modeling, reaction kinetics) with performance in real systems. Appears to be frequent collaboration with industry, universities, and government labs.
  - Great model and tool development. This is a methodology to be built upon and expanded to look at many fundamental aspects of particulate filtration, filter materials, and regeneration.
  - Detailed, micro scale modeling is rare; most models are more global scale.
- Specific Weaknesses
  - Nothing major.
  - None significant, though more integration of real device behavior might be useful.
  - Need to correlate with a real vehicle in a road generated regeneration.
  - No connection to real world regenerations. Too much emphasis on NO_2 oxidation rather than O_2 oxidation. Probably too focused on what's going on in the pores, when in real regenerations, not much regeneration may be likely to occur in pores.
  - Look to correlate to real world.
  - This work doesn't seem to lead to improvements in DPFs or their use.
  - While I realize the difficulty of measuring the soot oxidation within the filter substrate, I question whether the single filter channel is changing the soot oxidation process. It seems that the absence of radiation effects from the surrounding walls would be significant during a regeneration.
  - More fundamental chemistry using other lab resources.
  - It is hard to keep up with CDPF technology.
  - Can't see it.
  - The validation of the models still seems to be weak: not only backpressure behavior but accumulated soot

weight, filtration efficiency, (size distribution,) and distribution (uniform vs. non-uniform).

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 17 reviewers)

- Keep going—good work.
- Keep on going with exchange and standardization of material specs and testing. Improve validation by applying more detailed tests.
- PNNL has great chemistry capabilities that should be tapped to look at the chemistry taking place through your optical window. Raman, IR, others, to observe chemistry as soot is being regenerated both actively and passively. Expand the model to build catalyst coated filters. Expand regeneration study to look at active & passive regeneration of both catalyzed and uncatalyzed filters. The model should also be a building block to investigate strength of the materials and durability through thermal events.
- More overlap / collaboration with DPF manufacturers would be useful.
- Modeling study of Soot oxidation using software like CHEMKIN?
- This work is likely to payoff in the future when regular cordierite is expected to dominate as DPF support material. This work should focus on regular cordierite rather than RC.



Brief Summary of Project

This project offered an overview of the CLEERS activities, which have the overall objective of maximize energy efficiency and acceptability of lean-burn engines through improved simulation tools. ORNL is acting as the network hub for the CLEERS coordination, and is performing some characterization tests on commercial lean NOx trap materials.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 17 reviewers)

Comments were positive in general. One person felt that both the CLEERS efforts and LNT R&D are in-line with DOE's goals of advancing emissions technology. Another person commented that the coordination of CLEERS for LNT is excellent, adding that LNT for NOx abatement with respect to urea discussion very well addressed. One evaluator encouraged the researchers to keep focusing on the fundamental understanding of aftertreatment systems. Another reviewer noted the excellent exchange of knowledge among OEMs, catalyst and coating suppliers. They added that the well established material characterization, etc. helps to accelerate aftertreatment system development significantly. The final reviewer, however, felt that recent industry moves toward SCR have reduced his rating of the project; adding that last year it would have been 4.

Question 2: Approach to performing the research and development (Written responses from 5 of 17 reviewers)

Comments were positive in general. One reviewer noted that the researchers have shown good use of modeling and first principles chemistry to elucidate chemical reaction mechanisms and then compare them to experimental results. Another person added that the work was detailed and the systematic study was well-acknowledged. One person noted that the wide range of collaborations with many parties is very good. Another evaluator commented that the researchers' coordination of CLEERS workshop was outstanding, adding that one of their staff was an invited speaker and reported of the high quality of the workshop. The final reviewer noted their limited background in LNT, but they felt that the research could be more focused. They suggested that this may be the case, but perhaps the project is large in scope and the presentation was only able to provide an overview of sorts.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 17 reviewers)

Responses to this question were all positive. One reviewer commented on the excellent experimental work at ORNL, the excellent analytical equipment, as well as their very good understanding. This reviewer added that the reaction mechanism via NCO to NH_3 is interesting. Another reviewer agreed, stating that the determination that water-gas shift and isocyanate pathways are important is significant. Another reviewer noted the good correlation of compact chemistry model to the experimental results. Another person commented along these lines, stating that the researchers have shown good progress in understanding detailed reaction mechanisms. One reviewer felt that the technique of comparing actual information from a catalyst system to model data was interesting. One evaluator felt that there was very good progress in LNT understanding; test protocols and lab round robin have helped industry and academia. One of the reviewers noted that their company missed the May workshop; which sounded like it was a very significant event! The final reviewer agreed that the experiments were well performed, however, they felt that the simulation accuracy may be improved.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 17 reviewers)

Comments were all positive. Several people noted that the regular CLEERS workshops are very valuable with great interaction with the labs and communicating to industry. One person added that CLEERS appears to have significant involvement and collaboration with variety of OEMs, government labs, and universities. Another reviewer commented that it is encouraging to see the collaboration and coordination between the government labs, using the strength areas of each, as well as the involvement of industry partners. Another evaluator agreed, adding that the CLEERS workshops are well accepted in the engineering community. In particular the international, unlimited experts' attendance is exceptionally well established and helps a lot. The final reviewer stated that due to the coordination all information is bundled at ORNL, the process cannot be improved.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 17 reviewers)

One of the reviewers noted that the system approach seems to be established in the future; oxidation catalysts and other building blocks of an aftertreatment system. Another person simply noted the industry shift in emphasis to urea-SCR. A reviewer suggested that the team add work to investigate the NOx breakthrough during regeneration of LNT. The last reviewer felt that the outlook was not clear from handout; perhaps ORNL should think about how to improve the performance of LNT by the by-products or how to avoid issues by intelligent engine management.

Specific Strengths and Weaknesses (Written responses from 10 of 17 reviewers)

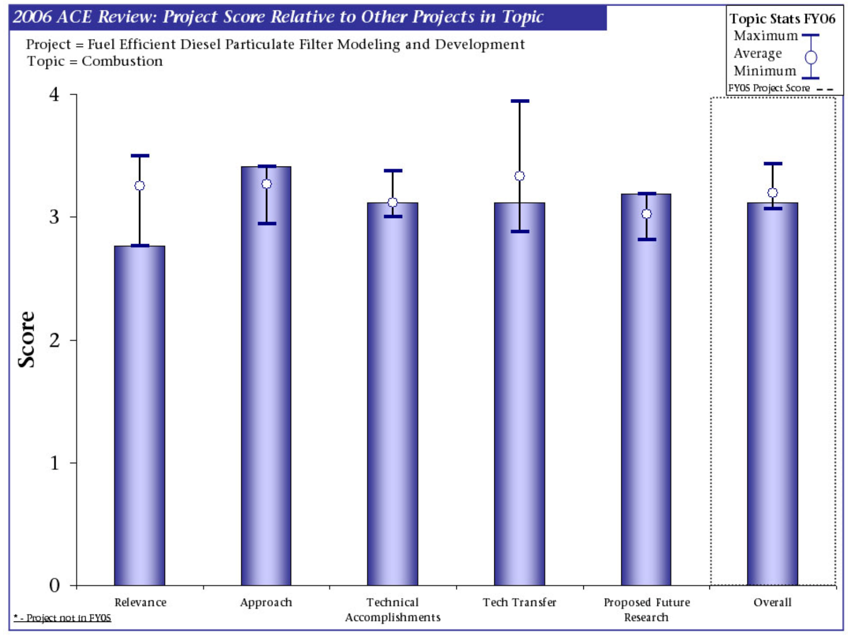
- Specific Strengths
  - Testing with commercial catalysts.
  - Very good efforts focused on understanding fundamentals (mechanisms and kinetics) of emission systems, model development, and coupling with and integration of the various emission components.
  - Great fundamental chemistry approach.
  - Excellent collaboration and great testing/modeling.
  - Excellent exchange of knowledge between experts.
  - Very good collaboration with many parties and focus on fully identifying LNT regeneration kinetics.
  - Collaboration with industry; investigation of mechanisms of LNT catalyst; focuses on what still is a critical area for diesel and lean gasoline: lean aftertreatment.
  - Excellent team work.
- Specific Weaknesses
  - Through no fault of ORNL, industry emphasis has moved from LNT (can't make NTE conditions) to urea SCR. We need similar level of effort and quality of work on SCR.
  - Improve linkage of reactor based work with tailpipe validation.
  - No apparent connection between this work and engine/LNT data.
  - Limited catalyst systems were evaluated also the impact of multiple catalyst elements on the engine emissions i.e., the interactions.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 12 of 17 reviewers)

- Combine LNT & SCR models.
- Apply the chemistry to other LNT materials as well as other aftertreatment devices.
- Attempt to validate modeling work based on engine/LNT experiments (both diesel and gasoline) rather than reactor experiments; add work to investigate NOx breakthrough during regeneration of LNT.
- Redirect most of the effort to SCR and to system interactions. There is a lot to learn about DOC/SCR/DPF systems (including perturbations of the order).
- Work on in-situ SCR should be a very high priority.
- For many of the OEMs who have not the capability of ORNL, the pathway to solutions would be important
- Shift project focus to SCR in future.
- Present scope and focus is appropriate.
- The planned work on sulfur effects may be critical to making a commercial LNT.
- Perhaps too much was covered in the presentation. The amount of information tended to mask the highlights of the work.

Emission Control Devices for NOx and PM Control

Fuel Efficient Diesel Particulate Filter Modeling and Development, Heather Dillon of Pacific Northwest National Laboratory



Brief Summary of Project

The goals of this project are to optimize Dow's ACM substrate as a fuel efficient DPF, investigate an optimized ACM substrate for a 4-way catalyst system, and assist in the rapid commercialization of a robust fuel efficient DPF substrate by integrating the PNNL substrate characterization into Dow's performance, structural integrity and durability models.

Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 17 reviewers)

One reviewer noted that this project was focused on the Dow DPF and went on to say that they felt that this is a good investment in DOE funds in order to evaluate an unusual filtration material. Others also had positive things to say. One evaluator simply stated that the project provides a useful look at a unique DPF material. Another added that the project has good potential to minimize back pressure of DPF during filtration and reduce fuel penalty of the aftertreatment system. One person added that the new DPF substrate good provide a significant improvement in exhaust aftertreatment. Other reviewers were more critical of the project. One reviewer commented that apparently the work only seeks to try to overcome any barriers/deficiencies of Dow's ACM DPF. They added that this project seems different from many of the others in that it is narrowly focused on advancing the technology of one specific company. Another also noted the string tie to one manufacturer, stating that there is a strong focus on Dow material, which is relevant for real application. However, no information was given about the material stability. From a health effect point of view these needles should be considered. They noted that the material is an alternative to SiC or cordierite, but asked what the advantages are. A reviewer did note that although the title included "fuel efficient DPF," there is no discussion on what makes this substrate fuel efficient. The final reviewer simply stated that it was not clear to them what the benefit of the Dow material is.

Question 2: Approach to performing the research and development (Written responses from 8 of 17 reviewers)

Responses to this question were generally positive. One person stated that the technical approach seems reasonable. Another person added that the approach is in principle good and the simulation work is good. One reviewer commented that the researchers have done an excellent description of the material: testing and simulation. One person noted there was good integration with a DPF manufacturer. Another person commented that the researchers have made good use of tools developed under CLEERS. Another reviewer had extensive comments. They stated that this work effectively leverages the DPF simulation technology that has been developed at PNNL. They add that a wide range of experimental techniques have been applied to this material, however, there was no discussion of durability of the material. If this material has a high propensity to fracture, that could limit the value of the material. This material gives the impression that it could easily fracture. One reviewer felt that they would like to see design of experiment approach and optimization of resulting models. Another reviewer was not sure what the targets/objectives of the program are. They added that it would be interesting to see comparisons to other, established materials in the discussion. The final reviewer wondered whether this is a "me too" project, or whether definitive objectives and performance targets have been established.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 17 reviewers)

Comments were all positive. One of the reviewer commented that the evaluation of this material is multi-pronged and very informative. Another noted the excellent analytical systems and test facilities. Another person highlighted that there has been excellent work progress for the short amount of available time. The last reviewer noted that the researchers have applied the tools to a new material.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 17 reviewers)

All of the reviewers save one noted the effective interaction with Dow. The regular meetings indicate good integration. One reviewer noted that PNNL was involved. One reviewer commented that this project is a good example of how a CRADA could/should be run. A reviewer did suggest that the team needs to increase its collaboration with OEMs.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 17 reviewers)

One reviewer agreed that the approach to use catalyzed filters and full size testing was the right approach. Another reviewer suggested that they would very much like to see an early project to demonstrate the durability of this material for automotive applications. Another person had a related comment suggesting that an engine OEM be engaged for the future study. One reviewer noted that they would like to see things such as thermal robustness, for conditions such as drop to idle, be evaluated. The last reviewer stated that the experimental validation work is appreciated. Soot mass should be considered. Is there an advantage to soot oxidation by the specific substrate morphology?

Specific Strengths and Weaknesses (Written responses from 9 of 17 reviewers)

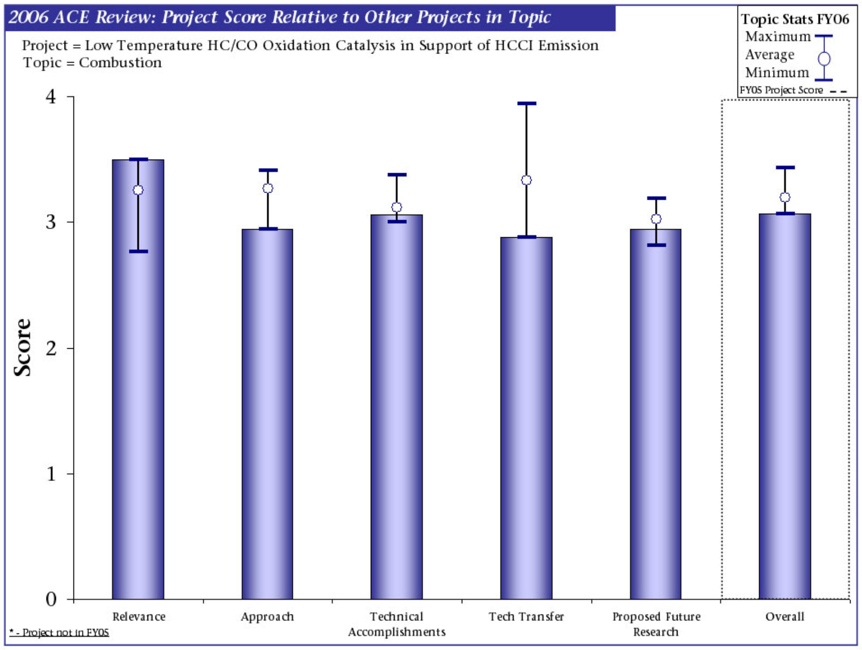
- Specific Strengths
  - This project leverages work and instrumentation that have been built up at PNNL for DPF studies. The project benefits greatly from that background. The collaboration with Dow appears also to be a strength.
  - Great model.
  - Interesting work on a new material.
  - Excellent experimental and analytical equipment.
  - Good analytical diagnostics.
  - Use of numerical methods for describing the material and single channel testing is an outstanding method.
  - Good modeling and integration with DPF manufacturer
  - The exposed single channel provides visual information that normally is hidden within a DPF.
  - Excellent modeling capabilities and measurement techniques
- Specific Weaknesses
  - Entire focus is on Dow ACM DPF. No mention of how/whether the learnings and discoveries can be leveraged for other systems.
  - Only applicable directly to Dow material.
  - Focus on only one material, but this was surely accepted at the beginning of the project.
  - What are the major improvements of this material over well established SiC or Cordierite materials?
  - All based on loading of clean support material; should include investigation of regenerations.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 17 reviewers)

- Durability studies need to be completed soon.
- Include comparison data of Cordierite and SiC materials during presentations for reference.
- Make comparisons between Dow and other materials—what are relative advantages and disadvantages and why?
- Need to start with results of actual DPF operating under typical regeneration conditions, so you make sure you are working on relevant problems. Not clear to me why this work is only with the Dow support, without any apparent work on the biggest limitation of the Dow support, which is cost.
- Perhaps the comparison to one of the standard materials or the link to other projects where alternative material are the focus.
- Demonstrate methods are applicable to other materials.
- Good 2007 work scope.
- Full scale engine tests should include measurements of filter efficiency and particle size distribution for comparison to Cordierite DPFs.

Emission Control Devices for NOx and PM Control

Low Temperature HC/CO Oxidation Catalysis in Support of HCCI Emission Control, Ken Rappe of Pacific Northwest National Laboratory



Brief Summary of Project

The objective of this project is to develop low temperature hydrocarbon and carbon monoxide catalysts to enable their use in HCCI engine applications. This work is being done at this point on a catalyst test bench.

Question 1: Relevance to overall DOE Objectives (Written responses from 11 of 18 reviewers)

Reviews were mostly positive on this research. A reviewer said that improving the performance of emissions reduction for advanced combustion systems is in-line with DOE goals. To overcome barriers for HCCI application like reducing HC- and CO-emissions is very important, said another reviewer. Likewise, a reviewer said that oxidation capability at low exhaust temperatures is important for HCCI engines. Another felt that this technology is certainly needed for HCCI and other low temperature combustion. A reviewer said that the project is directly addressing a known issue with HCCI combustion. Dealing with high HC/CO at low exhaust temperatures is a key issue for low-temperature combustion. If low temperature combustion is going to be successful, low temperature oxidation catalysts are necessary, in a reviewer's opinion. Similarly, a reviewer said it was very important to get low temperature catalyst activity, which will be very helpful for HC control of HCCI or PCCI, and also very helpful for after-treatment. Other comments were that this project meets a critical need and fits well to future requirements. The final reviewer disagreed with the others, and said that this project is very poorly designed to answer the questions posed for the problem. Also it is attempting to answer questions that the suppliers have a strong financial incentive to address. This reviewer saw no reason why DOE should be providing funding.

Question 2: Approach to performing the research and development (Written responses from 8 of 18 reviewers)

Review comments included that the approach seems reasonable, that the literature search is very thorough (good work), and that the catalyst sample heating to match the FTP test is unique and should lead to realistic testing. Another comment was that the very detailed study with a large matrix is well-acknowledged, but that powder formulations were only helpful for very fundamental studies. A reviewer said that the project's approach was very systematic, but a supplier for catalysts should be involved to whom results can be transferred for development and production in case promising materials will be identified. This reviewer thought that the transient test rig was good, and that coated substrates should be investigated soon. A reviewer suggested that the team propose or determine why the catalysts chosen are successful at low temperature catalyst activity.

A reviewer said that the team needs to look at some sort of degreening or aging—green catalysts are just not meaningful. Similarly, a reviewer noted that automotive/light duty catalysts are strongly influenced by the aging history (degreening at a minimum) of the catalyst. Aging affects the pgm sizes and morphology, the character of the washcoat and possibly the character of the hydrocarbon storage component. This reviewer noted that the project attempts to screen without at least an initial degreening. Degreening typically changes the light-off temperature by 25-75 degrees or more, and this effect varies depending on the composition. This reviewer believed that the data obtained so far is useless.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 10 of 18 reviewers)

Positive comments included that the project has made good progress: a reviewer liked the search results and small scale relative testing program. Very good progress and well organized project with dedicated and defined work share, in another's view. It looks like the team has made good progress in improving catalyst performance and approaching targets, said a reviewer. A reviewer said the results to date were impressive. A reviewer appreciated the inclusion of a timeline slide: all projects should do this. Low and high-temperature screening work shows good promise with the Pd/CeO_2 formulations, offered a reviewer. Lastly, a reviewer pointed out that some work is being done on new catalysts at PNNL and support materials, but that it is still early in the program, mostly concentrating on setting up equipment and literature mining.

A reviewer commented that many catalysts were evaluated, and suggested it is now time to narrow choices and focus. Another said that it is hard to know how good the results are with green catalysts. A final reviewer said that it is a waste of time for a national laboratory to learn how to coat monoliths. The suppliers do this regularly and do it for a business. Also testing the catalysts as powders is not very helpful since it is very difficult with a powder to end up with comparable space velocities. The light-off temperatures are dependent on space velocity. This reviewer said that the comparisons in this project need to be done at very similar space velocities. This reviewer doubted if this approach has consistently similar space velocities.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 10 of 18 reviewers)

One reviewer felt this was a great example of a joint program. Another wished he could see the results. Several reviewers noted the collaboration with Caterpillar, one noting that this looks like an outstanding project. One reviewer was surprised that Caterpillar has not addressed some of the issues described above in the design of this project. Several reviewers noted that a catalyst supplier should be involved, especially in case any promising materials are developed. A reviewer pointed out that no universities were involved. A reviewer noted that there were a limited number of collaborators due to CRADA setup (as noted as well by another reviewer who felt that CRADAs limit technology transfer). The reviewer presumed that collaboration between CRADA participants is good.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 7 of 18 reviewers)

One reviewer felt that the future plan was good. Suggestions included that the team should consider aging, and that there seems to be too much focus on C_3H_8 and CH_4 (with a proposal to add work on diesel fuel-like molecules to address this). Testing of coated monoliths is the right step, according to one reviewer, who said that transient investigations on a catalyst test bench may help understanding some fundamental questions. A reviewer thought that the time frame is somewhat long for the scope of the investigation. Another said that the catalyst formulations/substrates seem too limited to achieve the improvements required for the program. A final reviewer said that without a major overhaul of the approach, he saw no reason for this project to continue.

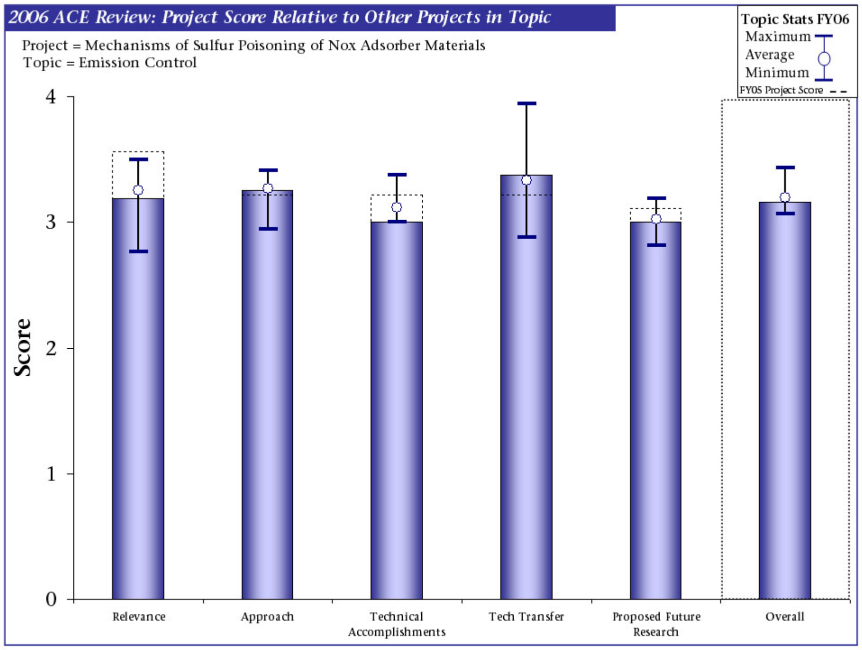
Specific Strengths and Weaknesses (Written responses from 13 of 18 reviewers)

- Specific Strengths
  - None.
  - Very relevant.
  - Very good progress to date, well presented.
  - Large volume of catalysts screened.
  - Very detailed matrix of formulations and dedicated work share between the involved parties reveals high efficiency.
  - Focused on key challenge for implementation of low temperature combustion for diesel.
  - Great goals, very specific.
  - Testing capability.
  - Good bench scale testing capabilities.
  - Good tools, right people, good industrial interface.
  - Transient test rig is interesting. Usually not so often used or described in literature.
  - Good to see active research and development in low-temperature HC/CO catalysts - this is needed to help

make low-temperature combustion possible for production applications.
  - Good work in literature mining. However, this may have been a liability as shown in weakness listed below.
- Specific Weaknesses
  - No.
  - None significant.
  - Timing.
  - Don't overlook aging.
  - Lack of aging data. Many good prospects have died from a bit of aging.
  - Very poor understanding of automotive catalysis.
  - Use of propane and propene when the speciation data does not indicate any HC above C_2.
  - More realistic exhaust component mixtures should be studied.
  - No interaction with catalyst supplier.
  - It seems that most of the core technology development was done at Caterpillar.
  - Powder formulations allow only fundamental investigations with limited applicability to final hardware.
  - It was not clear what the primary approach or thought process is for obtaining low temperature light off It seems like it is literature mining and trial and error Focusing on Pd- CeO_2 system which is relatively common in the catalyst industry so it is not clear how the low temperature light off will be achieved.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 12 of 18 reviewers)

- This project should be terminated.
- Modify the characterization gas stream to match the speciation results. It was not clear what was varied in slide 8.
- Add impact of other species such as O_2, H_2, and NO; all catalyst should be degreened prior to screening.
- I heard some discussions at DOE headquarters recently about possible quantum level computational work (molecular level) on catalysts. Not sure what is going on there or if that is in the future for some part of DOE at ORNL? However, as an engine guy, I like what you are doing now.



Brief Summary of Project

The objectives of this collaborative effort with Cummins and PNNL are to develop an understanding of the mechanisms of LNT deactivation due to high temperatures and the presence of sulfur species in the exhaust, apply the developing understanding to determine appropriate operating conditions, verify improved performance through materials characterization, lab and engine testing, and develop protocols and tools for failure analysis of used catalysts.

Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 16 reviewers)

Responses to this question were positive in general. One reviewer pointed out that understanding the effect of sulfur on lean NOx catalysts is critical to their utilization in production systems. They added that this work makes some very good steps in identifying those effects. Another reviewer indicated that durability and high noble metal loading of lean NOx traps (LNT) are key issues for diesel and lean gasoline engine applications. One person mentioned that understanding of LNT deactivation mechanisms and extension to improved formulations is consistent with DOE goals. A comment was made that this research is making good fundamental progress toward understanding LNT performance and desulfation. Another evaluator stated that deep understanding of the sulfur poisoning process is the key for a desulfation process which maintains the high NOx reduction efficiency of a LNT; therefore, the project is an excellent fit to the crucial point of development of LNT technology. Another thought that sulfur poisoning is still one of the root causes why LNTs are not yet used, adding that understanding these phenomena helps to improve engine efficiency and reduce emissions. One person stated that a year ago there was more relevance; industry interest is moving toward urea SCR. The last reviewer commented that the relevance of the results and the progress to overall DOE goals could use more discussion in the presentation.

Question 2: Approach to performing the research and development (Written responses from 7 of 16 reviewers)

Responses were positive in general. One person simply stated that the investigations applying different diagnostic methods were well acknowledged. Another person added that the researchers have done excellent research in a difficult area. One reviewer had very high praise for this work, stating that this appears to be the best work occurring in the industry for understanding the desulfation processes at this time. One person commented that the use of the advanced instrumentation at PNNL and good chemical intuition is a very productive approach to addressing the process of sulfur poisoning for LNTs. One reviewer stated that they had the impression from the way that the information was presented that a lot of effort was spent measuring platinum particle size. One evaluator stated that the researchers' objectives are good, but they had difficulty judging their approach from the presentation. The final reviewer had very detailed comments, noting that due to the competitiveness of LNT for OEMs there has been little new information in scientific literature during the last three years. However they strongly recommend studying the patent literature of the main OEMs and catalyst suppliers. They add that in the meantime some important patents have been published and with the information given there the project could make significant progress, mainly due to desulfation strategies. Based upon this, the project can identify new strategies which could help OEMs. In the study only hydrogen as reductant is used, but pure hydrogen is not realistic. When using a reformer at least CO is present; HC should also be investigated.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 16 reviewers)

One reviewer commented that there has been good progress, noting that it is interesting to note that desulfation may not be as bad as once thought. One evaluator noted that this work is giving us all sorts of clues about the sulfur poisoning effects, but it does not yet predict a clear mechanism for poisoning. Another person commented that progress has been slow but steady; challenges still remain and new questions arose. Another felt that the researcher have shown a lot of detailed results, but felt that it was hard to discern bottom-line successes in defining mechanisms and actionable results by industry collaborators from the information described in the slides and presentation. One person simply noted that at this point, the researchers still do not seem to know causes of LNT catalyst deactivation. Another person stated that the major roadblock to LNT for light-HD application is NTE: need conversion at 500°C and 200K miles. The final reviewer had detailed comments acknowledging that the basis for the excellent work is given at PNNL. They felt that the progress could speed up with the information from patents. They added that some of the information given in the presentation is not described in published literature and worthwhile for industry. They also noted that the focus this year was the sulfur removal process; noting that the crucial point of the removal process is also to avoid undesired reaction products. Their final comment was that the removal should consider a practical application.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 16 reviewers)

The reactions to this question were positive. Several people noted the participation of Johnson-Matthey and Cummins. One person stated that with Cummins and Johnson Matthey important industrial partners are part of the project. Another commented that the cooperation with Johnson Matthey and Cummins seems to work well. One person felt that the collaboration is consistent with CRADAs, and a limited number of collaborators. One evaluator noted that the interaction with Cummins and Johnson Matthey is definitely providing a very focused approach that is getting the most out of the expertise at PNNL. Another reviewer acknowledged the good collaboration with Cummins and Johnson Matthey and felt that it would be interesting to know if any of this information is new to Johnson Matthey (or other catalyst suppliers) or have they known this information for a while. They question that if the information is new, whether we should expect increased performance out of future LNTs. One reviewer added that the researchers have involved national laboratories along with industry and that the information has been presented at public presentations. The final reviewer suggested that the work be extended to engine-aged devices.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 16 reviewers)

Responses were mixed, with many people making suggestions for the researchers. One person simply stated that the future work appears appropriate. Another person suggested that it would be helpful if the authors presented a "strawman" mechanism for the poisoning so that all future results could be evaluated against that. They added that extending the studies to field aged LNTs is a very good direction. Another person commented that more details about how to understand LNT degradation are desired; noting that the researchers' usage of "real world" aged samples was well accepted. This is important work if we are ever going to introduce LNT technology into production. End-of-life efficiency does not appear to be adequate for high volume production at this time. The final reviewer was not certain that the proposed work is the best pathway to get answers to the questions.

Specific Strengths and Weaknesses (Written responses from 10 of 16 reviewers)

- Specific Strengths
  - Very good instrumentation and researchers at PNNL and good input from industry.
  - Results of desulfation with H_2O and CO_2.
  - Diagnostics to understand key issues with LNT: thermal durability and sulfation/desulfation.
  - Good fundamental understanding of LNT platinum size as a function of temperature. Good use of tools available at National Labs.
  - Great analysis methods, good learning.
  - Relevant topic.
  - Powerful analytical equipment.
  - Very detailed investigation of aging phenomena.
  - Significant progress understanding LNT aging.

  - Great tools. Usage of high energy XRD to determine what is going on in catalyst systems.
- Specific Weaknesses
  - Too much time spent on unrealistic gas streams (no H_2O and no CO_2).
  - Very difficult to follow as a non-expert in this field. The presentation was very detailed and a bit difficult to follow. I would suggest that you create a better outline or flow to the discussion. I felt like we were going from one technical tidbit to another without a cohesive story. I assume that there is a cohesive story, I am just not expert enough in this area to extract it from your presentation.
  - Industry interest is shifting to urea-SCR; we don't think LNT can make NTE high SV/high temperature requirements.
  - Extend beyond reactor aged hardware.
  - No real weakness; perhaps speed up due to the upcoming limits - industry needs solution very soon.
  - Complex phenomena hard to explain and a systematic study is time consuming.
  - Seems like this is in a fairly early phase; need more discussion in presentation about what the results mean, a little less on what was done.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 16 reviewers)

- It would be great if the team could be more specific on their view of the poisoning mechanism.
- Include catalysts with Rhodium to explain the role of rhodium and point way to reduce rhodium requirements of LNT; reduce work with no H_2O and no CO_2.
- The handouts were not in the distributed materials. Convey as much fundamental information as possible as quickly as possible.
- Shift the skills and resources toward urea-SCR.
- Make a patent survey.
- Shift efforts to support industry movement toward SCR.
- Improvement of cooperation with Johnson Matthey seems to be necessary (formulation of coating, manufacturing processes, etc).
- Next steps look reasonable.

The Health Impacts activity ensures that advanced fuel formulations are environmentally friendly and do not produce adverse effects on the ecosystem. To avoid unexpected, adverse environmental impacts from new vehicle technologies, this research proactively evaluates the impacts of changes in fuel, engine, and aftertreatment technologies on the ecosystem. Because new vehicle technologies are both exploratory and developmental, they are not yet in the commercial stages typically regulated by the U.S. Environmental Protection Agency (EPA).

The Health Impacts work includes research on ozone and particulate matter, both primary (directly emitted from mobile sources) and secondary (formed in the atmosphere from oxides of nitrogen, sulfur dioxide, and organic gases). Fuels examined include gasoline, diesel, biodiesel, natural gas, methanol, and ethanol.

Below is a summary of average scores for 2006 for the four projects reviewed in this category, along with the average, minimum, and maximum score for the health impacts projects. The highest score in this category for each question is highlighted.

Summary of Scores for Projects in this Section

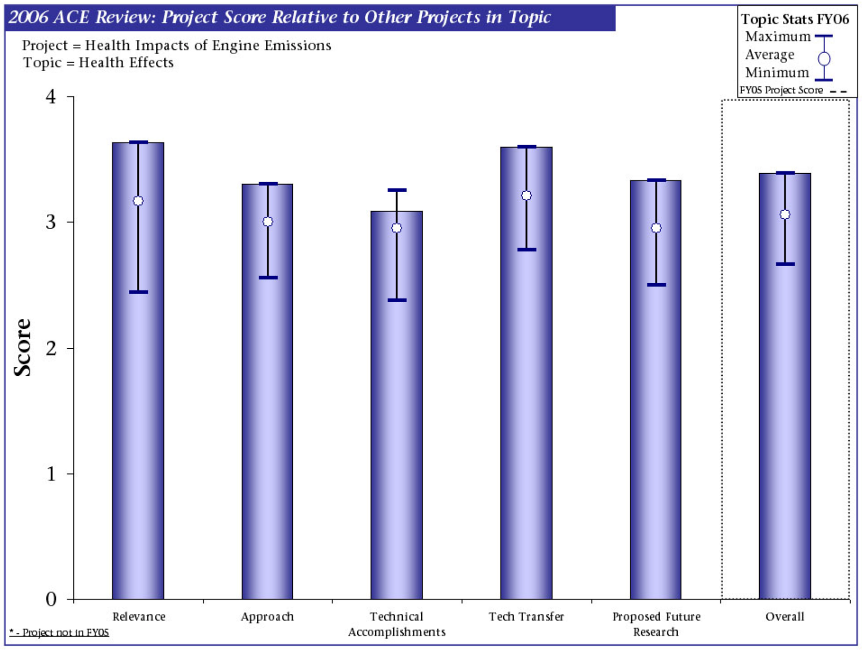
Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Project Average Score
70	*Health Impacts of Engine Emissions* (Joe Mauderly, Lovelace Respiratory Research Institute)	**3.64**	**3.30**	3.09	**3.60**	**3.33**	**3.39**
72	*Impact of Lubricants on Mobile Source Emissions* (Doug Lawson, National Renewable Energy Laboratory)	3.00	2.75	2.38	2.86	2.50	2.70
74	*Remote Sensing of Air Toxics at the Watt Road Environmental Laboratory* (Jim Parks, Oak Ridge National Laboratory)	2.44	2.56	2.89	2.78	2.67	2.67
76	*The FCVT Health Impacts Program-Health Effects Studies* (Doug Lawson, National Renewable Energy Laboratory)	3.42	3.25	**3.25**	3.42	3.00	3.18
	Average Score for This Category	**3.17**	**3.00**	**2.95**	**3.21**	**2.95**	**3.06**

Overall Scores for Health Impacts

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Score
Average	3.17	3.00	2.95	3.21	2.95	3.06
Maximum	3.64	3.30	3.25	3.60	3.33	3.39
Minimum	2.44	2.56	2.38	2.78	2.5	2.67

Health Impacts

Health Impacts of Engine Emissions, Joe Mauderly of Lovelace Respiratory Research Institute



Brief Summary of Project

This project looks at the health impacts of the DOE FreedomCAR programs to evaluate technology-specific health impacts. The project seeks to place the contribution of emissions to pollution hazards in the proper context, and determine key toxic emission components. The team ultimately is evaluating emerging technologies to mitigate unintended consequences.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 11 reviewers)

Responses to this question were all complimentary. One person simply noted that the project represents very good and highly relevant work. Another person commented that the study has value to DOE emissions goals; adding that it provides value to and justification to DOE goals as well. One evaluator commented that the connection of emissions and fuels technology to health effects is necessary and logical. They added that this is a very good application of public funding as long as research is shared with industry and reaches consensus with industry. The final reviewer commented that it seems to be very important to have scientific arguments at hand when or before environmental arguments come up that may not be statistically analyzed carefully and does not cover the whole picture.

Question 2: Approach to performing the research and development (Written responses from 3 of 11 reviewers)

Responses were positive. The first reviewer commented that laboratory investigations help to have profound arguments on hand and communicating the results is important. The second commented that the presenter provided a very logical progression of the study that was presented lucidly and was well supported. A third reviewer indicated he wasn't qualified to judge the approach.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 11 reviewers)

Responses to this question were mixed. One person simply stated that it appears like good progress. Another person commented that the result of the study will further help DOE goals and policy making. One evaluator noted that the major elements of the results and how they were achieved were not shown; however, the goal of rather objective than subjective interpretation of data is important. One person highlighted the fact that what was presented was old news, noting that Joe has used the same information the last few years. The last comment was that a study on bio-fuel is not enough, even though it has been widely used.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 11 reviewers)

Reactions were mixed to this question. One person simply noted that there are many industry collaborators. Another person felt that the project seems well connected to the various groups in industry. Another person acknowledged the good communication of data to major stakeholders. The last reviewer, however, commented that they did not note any collaborations being mentioned.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 11 reviewers)

Reactions to this question were all positive. One person commented that studying the health effects of new fuels and combustion regimes is important. Another person commented that the focus on emerging technologies seems appropriate. The final reviewer commented that the sampling of data before issues come up helps to prevent misunderstandings; however, judging technologies before they are thoroughly tested is sometimes misleading.

Specific Strengths and Weaknesses (Written responses from 6 of 11 reviewers)

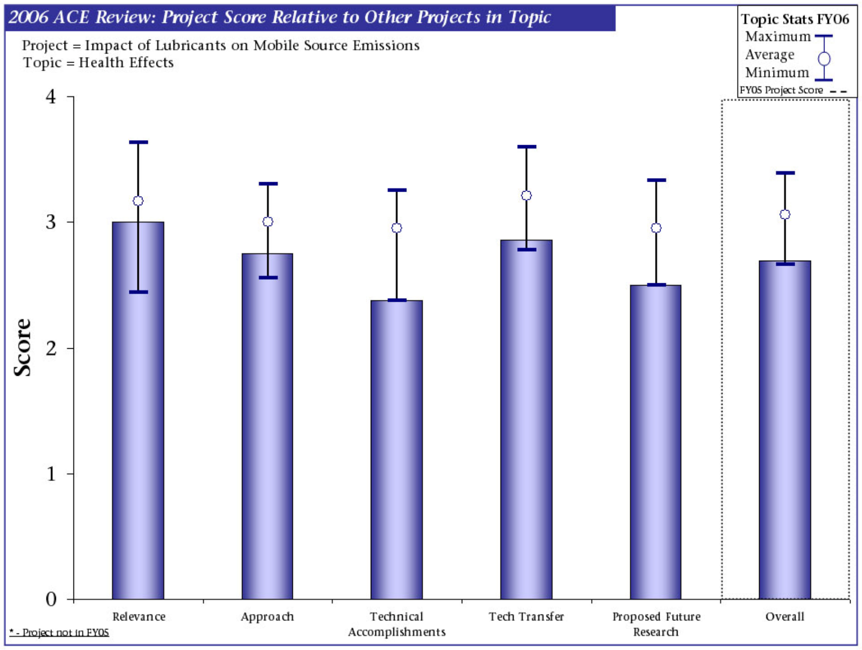
- Specific Strengths
  - Seems like correct work. Good focus in my view.
  - There is nothing like a little data to spoil grandstanders. This is providing great data to guide our work.
  - Detailed and systematic approach that tries to take all relevant cases into account.
  - Highly relevant work, well done, avoiding misdirected regulatory efforts is extremely valuable.
  - Testing capability of health effects.
  - There has been substantial contribution to health effects and particularly the importance of VOCs.
- Specific Weaknesses
  - None evident.
  - As always with biological studies, control is extremely difficult and the statistically relevant information is limited.
  - Always wish we had the answers now.
  - Neither the sponsors (DOE), nor the involved laboratories may be viewed as being independent and objective.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 11 reviewers)

- Compare health effects of E85 and gasoline in current flexible fuel vehicles.
- Discussion forum with OEMs may be helpful to be established.
- Some study about the emerging technologies should start early than plan. Should have more study on bio-fuel since it has been widely used.

Health Impacts

Impact of Lubricants on Mobile Source Emissions, Doug Lawson of the National Renewable Energy Laboratory



Brief Summary of Project

This project presentation highlighted work on diesel engine lubricant formulas as they change with emissions requirements, and how these affect vehicle emissions. Part of this work was the DOE Gasoline/Diesel PM Split Study, in which vehicles were tested and PM emissions were analyzed on a second-by-second basis.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 9 reviewers)

In general the reviewers thought that this is a very useful research area. According to one reviewer, oil research is a reasonably good fit for existing vehicles, but it is not very important for going forward with aftertreatment and closed crankcase ventilation systems. However, he added, that there may be enough unknowns that getting this data is worthwhile. Another person mentioned that influence of lubricant emission (oil consumption) becomes more important for future aftertreatment systems.

Question 2: Approach to performing the research and development (Written responses from 3 of 9 reviewers)

A comment was made that the presentation was not clear on what the approach is. One person mentioned that he is not in a good position to understand the approach. Another stated that the current focus is combustion and lube oil effect on engine out emissions, which is good; but should not be limited to it.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 9 reviewers)

One reviewer indicated that there were no accomplishments yet. To another, the presentation seemed more like a future plans discussion with a bit of data showing the effects. A comment was made that the results shown are poor and well known. A reviewer mentioned that he is looking forward to seeing the data.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 9 reviewers)

It was mentioned in the comments that changes and technology transfer will take some time. According to one reviewer, no cooperation was presented.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 9 reviewers)

A comment was made that more details are needed. One reviewer stated that he would need to see the scoping study to be able to evaluate the approach and relevance of this project. Another indicated that the work plan is weak and not detailed.

Specific Strengths and Weaknesses (Written responses from 5 of 9 reviewers)

- Specific Strengths
  - Looking at lubricants is an important area in the real world.
  - I really liked the acknowledgement that the real issue is political with older vehicles - high emitters (I have one myself).

– Very good plan.
– Lube oil has an important role in aftertreatment contamination and ageing. It may also contribute to hazardous uncontrolled emissions.
– Important study area; good approach.

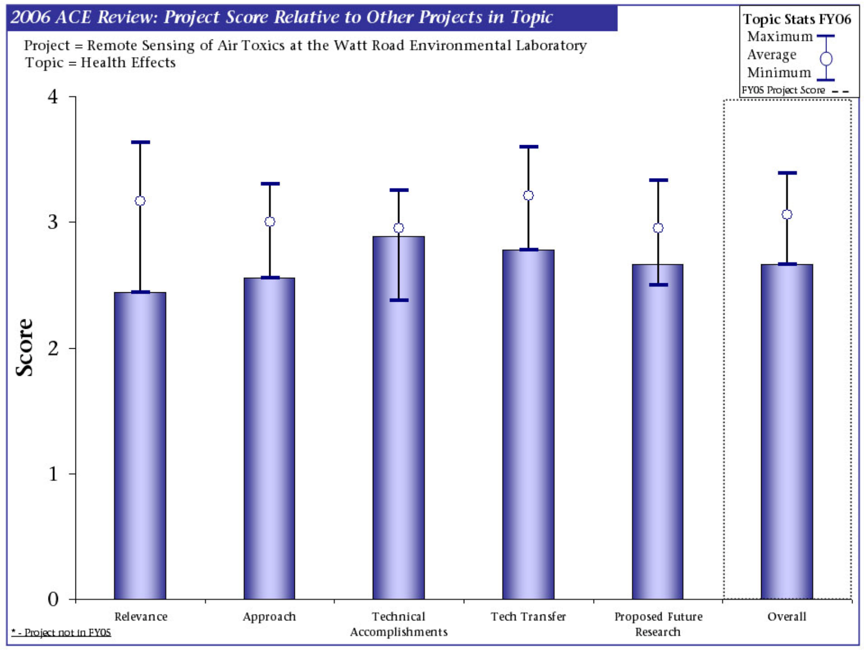
- Specific Weaknesses
  – Not well defined.
  – Link to health risks was not demonstrated.
  – It is unclear what this project specifically will be doing, although emissions from lube oil may be important.
  – Future plan is not well defined.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 9 reviewers)

- Keep going.
- Next steps in Phase 1 seem appropriate.
- I would suggest that the researcher consider the practical application of the work. If the real problem is the high emitter, and the solution is a new oil specification that was not originally specified with the "old beater," what would cause the owners of such vehicles to buy a new specification oil that may cost more money? That person will continue to buy API grades specified for his equipment at the lowest cost. If they cared about reducing oil-based emissions, they would have fixed the vehicle. So the net effect of the work is small regarding improving the environment.
- In terms of particulates, DOC and DPF may change the particulate matter composition completely; this needs to be taken into account - at least as a second step.

Health Impacts

Remote Sensing of Air Toxics at the Watt Road Environmental Laboratory, Jim Parks of Oak Ridge National Laboratory



Brief Summary of Project

This work is being performed at an Interstate interchange in the Knoxville, Tennessee area at which several truck stops are located. The objective is to measure real-world emissions from mobile sources, and to define and understand the mobile source impact on local and regional air quality. The team is deploying remote sensing technologies for mobile source emissions measurement, and linking emissions to air quality data and compare to large-eddy scale models with meteorological and geographical data.

Question 1: Relevance to overall DOE Objectives (Written responses from 3 of 9 reviewers)

Reactions to this question were mixed. One reviewer noted that if the objective is too understand real-life truck emissions, which is a worthwhile goal, especially with legacy vehicles. Another person agreed that the project is useful for informed regulatory actions. The final reviewer commented that the road and truck operation situation does not seem to reflect typical truck operation. They asked how this project will help to analyze health effect. They also felt that the scientific nature of the project missing, adding that if the results are used in the new EPA "emission factor" estimation program and finally end up in new emission limits, that they would expect a more scientific and accurate measurement.

Question 2: Approach to performing the research and development (Written responses from 3 of 9 reviewers)

Reactions were again mixed to this question. One reviewer felt that the researchers have used very interesting remote sampling techniques. Another reviewer agreed that the technology established may be interesting, but validation was not shown and accuracy estimates were missing. They added that other sources for particulates are neither identified nor quantitatively separated. The final reviewer had detailed comments, stating that the weigh station NOx measurements seem to be less than worthwhile to them. They felt that there are too many noise parameters in the experiment, as well as having the ability to capture only a narrow range of engine loads. They suggested using mobile emissions measurements along with a well-thought-out sampling of trucks that frequent the high density roads. They continued, adding that the general emissions data at the truck stop was more interesting, but wondered what the plan is to use this data; wondering if it could be used perhaps to limit idle operation of trucks at stops.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 9 reviewers)

One reviewer simply stated that the researchers have shown a good start for the first year. Another person commented that in reference to the stated goals of the project, it appears much has been done. The last reviewer commented that the measurement methods were fairly well established; however the validation is missing.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 9 reviewers)

Only two people responded. The first reviewer noted that no truck manufacturer, engine manufacturer, or other industry member was included. The second person commented that they were not really sure who is using this data to make decisions, but felt that it was interesting.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 9 reviewers)

Reactions to this question were negative. One person felt that other more accurate methods may lead to better understanding of emission factors. The last reviewer did not see a lot of value of the simulation of pollution with weather patterns, etc. They added that they think that the major point of truck stops versus highway has probably been done elsewhere.

Specific Strengths and Weaknesses (Written responses from 6 of 9 reviewers)

- Specific Strengths
  - Well planned study of heavy duty diesel impacts on real-world emissions.
  - Basic data collection at truck stop and interstate which would be typical.
  - Real world measurement.
  - Despite the "online" measurement of the emissions of trucks, the established emission map and corresponding conclusions are worthwhile noting.
  - Good information for regulatory input.
- Specific Weaknesses
  - The weight scale measurement of truck plumes does not seem worthwhile.
  - How does the data measure mass flows, and at what accuracy? Further validation is probably needed.
  - Inaccurate measurements that will not be able to achieve better accuracy.
  - Assume in future you can characterize truck parameters (year, cert emissions, weight, etc.) and correlate with remote measurements. If not, seems like this will be a good addition.
  - Experimental error control and analysis during and after the tests.
  - Put[ting] the NOx sensor at weigh station is not that representative.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 6 of 9 reviewers)

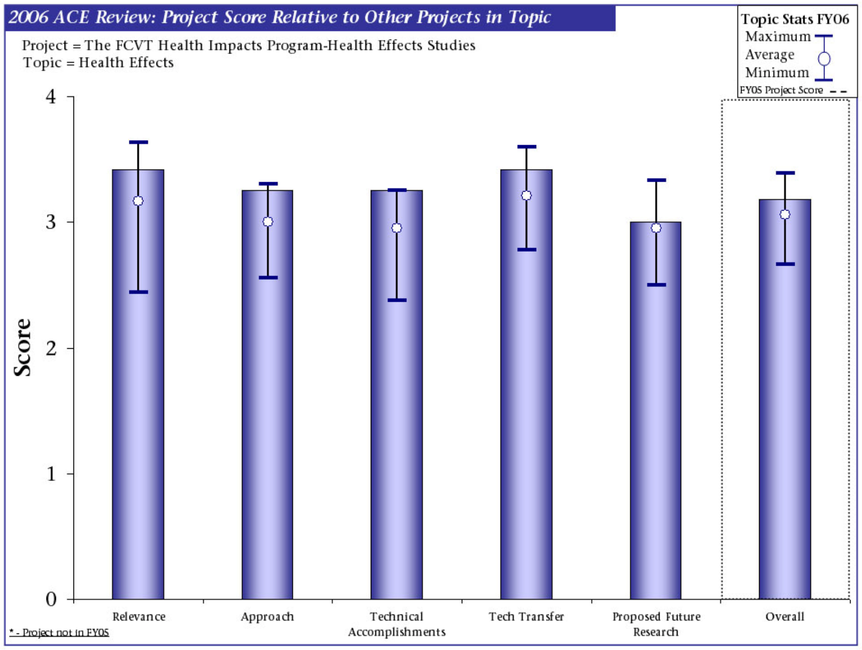
- Future work appears appropriate.
- It would help if the objective of the tests could be clarified.
- Clarify the meaning of the measurements.
- I would recommend canceling the modeling of atmosphere. You might consider also measuring the effect of idle management schemes employed by Cummins, Caterpillar, DDC, etc. Trucks will idle only as necessary… also have small gensets on trucks. How many trucks at the stop have these systems active (in addition to the electrical hitching posts)?
- Conduct measurements in test cells by simulating truck driving conditions and/or conduct onboard emission measurements with selected trucks.
- Should put sensors on the highway.

Health Impacts

The FCVT Health Impacts Program-Health Effects Studies, Doug Lawson of the National Renewable Energy Laboratory

Brief Summary of Project

This presentation discussed three separate projects: the weekend ozone study in which researchers examined the reasons behind an apparent rise in ozone levels on weekends when fewer vehicles are on the road; a school bus self-pollutions study in which school buses were extensively instrumented to evaluate the relative importance of tailpipe and crankcase particulate matter to on-board concentrations of PM; and the Advanced Collaborative Emissions Study (ACES) to evaluate new engine technologies before their use is widespread.



Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 12 reviewers)

The relevance of this project was generally judged to be very good. A reviewer said that the project objectives are excellent. Another said that this work provides important input for regulatory efforts. A reviewer commented that this is excellent work, and that checking commonly-held basic assumptions that can be in error is very important. A reviewer said that this was good work, and that we need to know why we are doing what we are doing. This project gives everyone a good context for emissions work, in this reviewer's opinion. A reviewer did note that health effect studies help improve engine efficiency only in an indirect manner (by avoiding probable future emission legislation focused on important emissions). A reviewer said that the weekend ozone has merit and value to DOE goals of emissions, but the school bus project is very irrelevant and does not contribute to any DOE stated goals. This project belongs to the EPA and should be funded by the EPA, according to this reviewer.

Question 2: Approach to performing the research and development (Written responses from 4 of 12 reviewers)

A reviewer said that the good scientific analysis of the school bus study helps to identify the real problems. Another reviewer said that the school bus portion of this project is an "undergraduate lesson in convective fluid mechanics." No mention was made of the characteristics of the engines in the buses (gas or diesel, '94, '98, or '04 compliant. 2 cycle or 4 cycle engine, etc.) This reviewer said that the weekend ozone study has good value and merit. This reviewer thought the approach of the ozone study is very logically executed and should be expanded. A final reviewer said that the weekend ozone study is interesting, but the material presented did not explain or necessarily attempt to explain the results. This reviewer had several questions about the study: were the ozone levels delayed, and is there a time constant involved? What are other confounding parameters for ozone? This reviewer said that this study could potentially be taken out of context. This reviewer thought that it would be nice to know that all ozone production mechanisms are considered and incorporated into the findings. This reviewer also thought that it would be good to include "noise" factors in this experiment. There is a tacit assumption that vehicle NOx emissions are directly affecting the ozone level; this reviewer wondered why we think this is true, and noted that "perhaps it is the backyard bbq".

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 12 reviewers)

Reviews on the technical accomplishments and progress were mixed. A reviewer felt there was good follow through on reviewer comments from last year, and that it is great to see large amounts of data pulled together to help us look at the issues rather than extrapolating from very few points. Another commented "Triple wow on NOx implications nationwide." Good results in the school bus study, said another reviewer, who continued by noting that a detailed analysis of the weekend-ozone study was missing. The final reviewer said that no technical progress can be ascertained from the school bus project.

<u>**Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 12 reviewers)**</u>

Technology transfer comments included that the researchers should keep up the public presentations to disseminate the information you are producing, and that in particular ACES includes every important stakeholder. A reviewer commented that it seems that more needs to be done to use the information obtained to influence regulators. The final reviewer said that no collaborations were mentioned.

<u>**Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 2 of 12 reviewers)**</u>

Only a few written comments on the future research were received. A reviewer said that the workplan looks promising for the future, and another reviewer said that no future research plans were mentioned.

<u>**Specific Strengths and Weaknesses (Written responses from 10 of 12 reviewers)**</u>

- <u>Specific Strengths</u>
  - Health is why we are doing emission controls.
  - Addressing extremely important questions using top rate data and analysis.
  - Interesting collection of raw data … great.
  - Ozone study.
  - Independent and reliable source applying scientific testing or analysis tools helps for an objective discussion.
  - This work is providing important information that needs to be used for policy decisions.
  - Carefully planned and analyzed work in an important area.
  - Good collaborations.
  - We need this big view study and learn about current on road conditions, rather than focusing too much on tail pipe
- <u>Specific Weaknesses</u>
  - None evident; hope the regulators are listening.
  - School Bus study.
  - Assumptions of connection with vehicle NOx emissions … how do you know this?
  - It takes a long time to get data, and for many of us the data are hard to understand (we aren't health people)
  - In case of US 2010 testing, only pre-production engines will be used.

<u>**Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 12 reviewers)**</u>

- Keep going.
- Future work appears appropriate
- Is there any way to evaluate the use of ethanol blends on ozone?
- Provide a convincing story on weekend ozone connecting with lower vehicle NOx emissions …. there may be confounding parameters that were not presented …

The Fuels Technologies Program has two main goals. First, by 2007, identify fuel formulations optimized for use in 2007-2010 technology diesel engines that incorporate use of non-petroleum-based blending components with the potential to achieve at least a 5 percent replacement of petroleum fuels. Second, by 2010, identify fuel formulations optimized for use in advanced combustion engines (2010-2020) providing high efficiency and very low emissions, and validate that at least 5 percent replacement of petroleum fuels could be achieved in the following decade. Projects in this program are geared toward meeting these goals in both petroleum fuels and non-petroleum fuels arenas, and are working toward identifying fuel properties important to advanced combustion engines and toward identification of viable fuel formulation for advanced combustion engines.

Below is a summary of average scores for 2006 for the eleven projects reviewed in this category, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted.

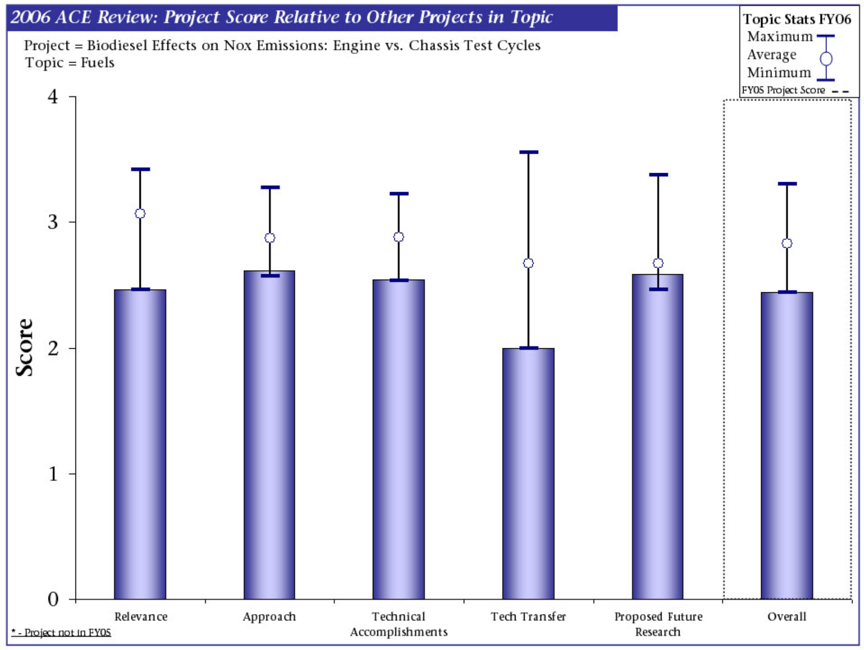
Summary of Scores for Projects in this Section

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomp-lishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Project Average Score
81	*Biodiesel Effects on NOx Emissions: Engine vs. Chassis Test Cycles* (Robert McCormick, National Renewable Energy Laboratory)	2.46	2.62	2.55	2.00	2.58	2.44
84	*Conventional and Alternative Fuels Low Temperature Combustion Research* (Charles Mueller, Sandia National Laboratories)	3.36	3.09	3.09	3.36	3.18	3.22
86	*Diesel Range Fuel Effects on Single Cylinder HCCI* (Jim Szybist, Oak Ridge National Laboratory)	2.93	2.60	3.00	2.14	2.85	2.70
89	*DPF Performance with Biodiesel Blends* (Aaron Williams, National Renewable Energy Laboratory)	3.14	2.79	2.79	2.92	2.71	2.87
92	*Effects of Biodiesel Blends on Performance of LD Diesel SCR Emission Control Systems* (Matt Thornton, National Renewable Energy Laboratory)	3.07	2.57	2.54	2.79	2.46	2.69
95	*Fuel and Lube Constituent Effects on Emissions Control Aging* (Todd Toops, Oak Ridge National Laboratory)	3.22	3.11	**3.22**	2.88	3.00	3.09
97	*Fuel Property Effects on Diesel High Efficiency Clean Combustion* (Scott Sluder, Oak Ridge National Laboratory)	3.25	2.83	2.83	2.67	2.91	2.90
99	*Fuels for Advanced Combustion Engines (FACE)* (Wendy Clark, National Renewable Energy Laboratory)	3.33	3.11	3.13	**3.56**	**3.38**	**3.30**
101	*Fundamental Studies of Fuels and Ignition and Their Relevance to Advanced Combustion* (Josh Taylor, National Renewable Energy Laboratory)	2.89	3.00	3.00	2.33	2.67	2.78
103	*Gasoline-Range Fuel Effects on HCCI* (Bruce Bunting, Oak Ridge National Laboratory)	3.10	3.20	3.20	2.80	3.20	3.10
105	*Oxidation Stability of Biodiesel and Biodiesel Blends* (Robert McCormick, National Renewable Energy Laboratory)	**3.42**	**3.27**	2.83	2.83	3.17	3.10
	Average Score for This Category	**3.07**	**2.87**	**2.88**	**2.67**	**2.67**	**2.83**

Overall Scores for Fuels Technologies

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score	Overall Score
Average	3.07	2.87	2.88	2.67	2.67	2.83
Maximum	3.42	3.27	3.22	3.56	3.38	3.30
Minimum	2.46	2.57	2.54	2.00	2.46	2.44

Biodiesel Effects on NOx Emissions: Engine vs. Chassis Test Cycles, Robert McCormick of the National Renewable Energy Laboratory



Brief Summary of Project

In this project, researchers are attempting to reveal why some tests show NOx emissions with B20 blends dropping and some show it increasing relative to conventional diesel. The team seeks to provide unbiased technical data to regulatory agencies on biodiesel emission factors. The approach is to test modern vehicles on the NREL heavy-duty chassis dynamometer, analyze chassis test results for different driving cycles with different NOx results, and compare engine and chassis test results for the same engine model and cycles for different vehicles.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 13 reviewers)

Reviewers had mixed feelings regarding the relevance of this project. One reviewer simply stated that this work is relevant to the overall DOE objectives. This is good up-to-date information on the impact of biodiesel on engine-out NOx emissions, commented another. This reviewer was also interested in the confidence of the numbers. A comment was made that it became obvious that the rumor of a dramatic increase in NOx-emissions by use of biodiesel seems to be discussed on more scientific-based data. One person thought that clarifying the NOx issue was useful, but he was not convinced whether it has a direct effect on DOE goals. Another felt that this was an interesting topic, but does not seem to help overcome any technical barrier toward the goal of high efficiency and low emissions. It would appear, according to a reviewer, that the drivers of this work are efforts by others to curtail the use of biodiesel due to a perceived increase in NOx emissions. According to him, the 2% range cited by early data and later EGR data is insignificant. He did not see how this work helps anyone. He also stated that this issue should be left for politics and no additional funds should be spent on this topic. Another reviewer also questioned whether it makes sense from a technical point of view to look for a 2% difference when the individual differences are almost larger. He did acknowledge that the target of the project might be more political to avoid a negative influence on biodiesel. One person felt that this study does not directly address DOE goals of efficiency, power, or emissions. He saw this work as a paper survey with results of MY05 tests not showing any conclusive evidence that NOx emissions are affected. He pointed out that this work compares engine dynamometer test data against chassis data; however, the investigation did not compare the deviations in data between the two types of testing. The final comment stated that it is not worth the money to study this 2% NOx increase or reduction.

Question 2: Approach to performing the research and development (Written responses from 6 of 13 reviewers)

One reviewer simply stated that the project is off to a good start. Another mentioned that NOx dependency of biodiesel on a test cycle is interesting work. One person indicated that he would prefer an organized attempt to get data for a designed sample of vehicles, not just accidental testing. Another stated that the results will live from statistics, requiring a large number of vehicles. According to him, that will be extremely costly. He also asked about the budget for this work. A comment was made that the difference between heavy- and light-duty emission responses on biodiesel use does not require chassis dynamometer testing but careful sampling of emission data from different engines. It was also noted that the paper report is very convoluted; if engine dynamometer data is stated to be different, it should be compared to chassis dynamometer data.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 13 reviewers)

One reviewer simply stated that the progress has been good. Another reviewer thought that the project has not started yet. A comment was made that the project is just starting. One person indicated that a fair amount of data were collected and analyzed in a short period of time. Another stated that he is looking forward to more data. A comment was made that no progress is discernable from the presentation that would aid emissions, efficiency, and power directly.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 13 reviewers)

Several reviewers noted that this project lacks collaboration. One reviewer asked how the work is planned to be communicated. It was unclear to him how the information will be disseminated. A comment was made that no OEM or truck manufacturer was involved. One person indicated that collaboration might provide more data and information. Two others mentioned that the presentation did not capture any collaboration effort. It was added that there was no noticeable outside participation, which could easily be accomplished. A suggestion was made to contact light- or heavy-duty OEMs to provide their own data for expansion of the database.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 13 reviewers)

One reviewer indicated that the approach using chassis dynamometer data is not the right approach for a scientific study. Another reviewer suggested testing multiple test cycles that are significantly different to try to bound the changes in engine-out NOx emissions. Another suggestion called for more engine dynamometer work, not just more chassis testing, which can be compared to the chassis testing that was presented. One reviewer simply stated that he thinks that this project should not continue.

Specific Strengths and Weaknesses (Written responses from 7 of 13 reviewers)

- Specific Strengths
  - Planned comparison of vehicles and engines for the same engine.
  - Real vehicle testing.
  - The response of different engines and different test cycles on emissions when biodiesel fuel is used is very important and interesting.
  - Useful in addressing a very specific issue.
  - This project addresses an important issue concerning the use of biodiesel.
- Specific Weaknesses
  - Inability to provide understanding of effect.
  - Need a correct sample on representative drive cycles.
  - Chassis dynamometer testing is limited to certain test cycles. Well controlled boundary conditions do not seem to apply.
  - Does not seem like results will have much impact, other than addressing a specific regulatory and possibly political issue.
  - Could use more analysis of the results from the design of experiments.
  - Incomplete work.

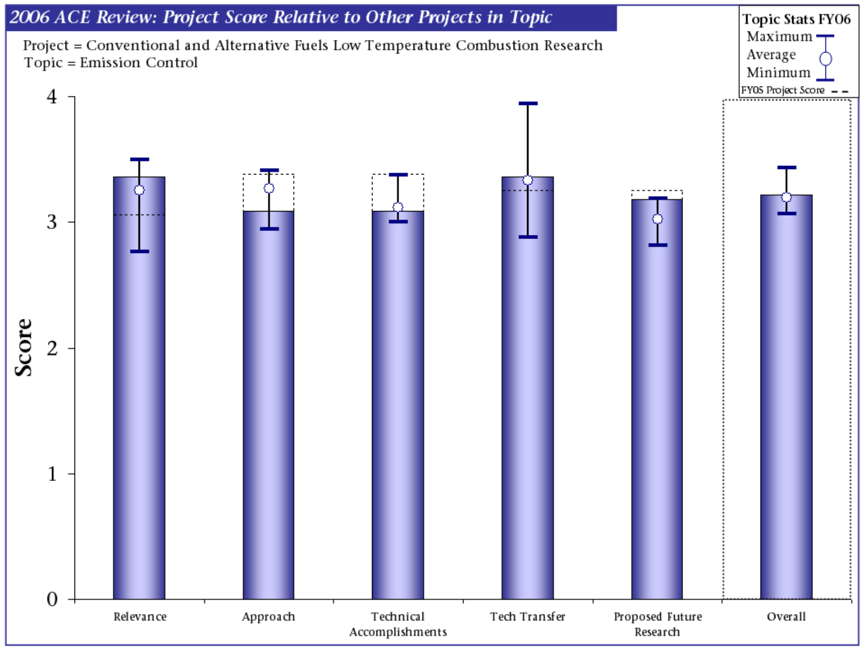
Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 10 of 13 reviewers)

- Keep going.
- Presented path forward seems straightforward and appropriate.
- Include heat release analysis so that the results can be understood in terms of the effects of biodiesel on combustion phasing.
- Take typical engines and test them in an engine test cell environment with well defined boundary conditions. Emission maps should be measured and compared with test cycles. This will explain most of the differences. Variations in the engine layout (e.g., fuel injection systems, air management systems, etc.) should be taken into account. Transient effects on NOx are of second order in this context.
- Conduct some steady-state tests to confirm the hypothesis that NOx increases at higher load and decreases at lighter load with B20.

- Plus or minus 2% change in NOx emissions with biodiesel use raises a question whether this is a technical problem worth investigating. Similar deviations could be accounted for by engine tolerances; however, technically credible data need to be made available to prevent erroneous conclusions.
- Would not spend additional time on this because NTE limits are 50% higher (in-use have even higher tolerance), therefore, continuing this investigation does not make much sense.
- The overall goal of the project is not clear. I would reconsider such a project.
- Given the number of variables and uncertainty, the researchers should not rush to develop conclusions, unless there is substantial evidence.

Fuels Technologies

Conventional and Alternative Fuels Low Temperature Combustion Research, Charles Mueller of Sandia National Laboratories)



Brief Summary of Project

This research is studying fuel effects on the barriers to HECC operation through the use of in-cylinder laser/imaging diagnostics. These observations are being synthesized into a fundamental physical understanding to feed work in fuel/engine strategies to achieve low temperature combustion. Current work focused on the extent to which mixing-controlled HECC is possible with more-conventional fuels (#2 diesel, paraffinic diesel, biodiesel), and showed that fuel can affect soot nanostructure and oxidation rate.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 11 reviewers)

Relevance was judged generally to be good, with one reviewer noting "outstanding as usual." A reviewer said the program has good alignment with DOE goals. Another said it seems that the work is very appropriate to the goals of the program. A third reviewer said that understanding fuel effects is important for HCCI or other premixed combustion techniques. A reviewer said the research was closely related to the real-world needs.

Question 2: Approach to performing the research and development (Written responses from 3 of 11 reviewers)

A reviewer said that the approach was sharply focused; simple and elegant. Another pointed out the detailed analysis with the interesting principle of the "overlimit function." This researcher thought that the number of operating points is very limited. A last reviewer commented that the approach seems good, but this reviewer would like to view all critical parameters for test (in additional to oxygen, what about fresh air and fuel?) This reviewer also suggested that the team might just use optimization instead of the F factor (which looked to the reviewer like a penalty function).

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 11 reviewers)

Review comments included that the team has made good progress in meeting project goals, and that the project shows good balance between testing and analysis. A reviewer said that the soot nanostructure work was nice. Another said that the overlimit function should be a useful tool. The final reviewer commented on the good progress with the yet-to-be-quantified effect of soot nanostructure impact on soot oxidation.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 11 reviewers)

Caterpillar's collaboration with the team was a focus of all the comments. A reviewer said that the Caterpillar internship is believed to be very helpful. Another pointed out the obvious good connection to Caterpillar. The final reviewer thought that the Caterpillar visit was a good idea.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 11 reviewers)

A reviewer said that the impact of fuel composition on soot characteristics should be interesting and valuable. Another liked the nanostructure comments, but was not sure whether or not this would lead to designer fuels. The final reviewer said that the wall impingement and tracer methodology for soot formation are good approaches.

Specific Strengths and Weaknesses (Written responses from 8 of 11 reviewers)

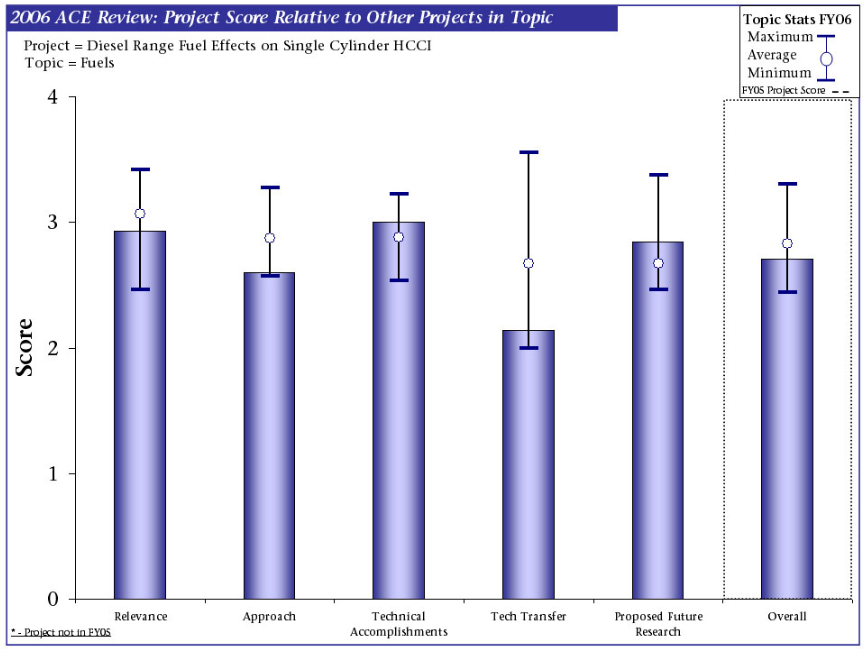
- Specific Strengths
  - Excellent fundamental work of fuel effects on high efficiency low emissions combustion.
  - Good basic data.
  - Fabulous experimental capability.
  - Aims to improve understanding of fuel composition on HECC performance.
  - Fuel/HECC interactions.
  - Useful HECC fundamentals extension.
  - Closing the gap between oxygenated fuels and conventional fuels via biodiesel and GTL helps understanding the fundamental phenomena.
  - The objective of low in-cylinder emissions is well-taken.
- Specific Weaknesses
  - None evident.
  - None significant.
  - Proprietary nature of research does not allow sharing much detail of engine side …
  - Experiments don’t seem to be organized and well planned. There seems to be a lot of overlap with other projects. There seems to be a lot of “let’s just do something and see what happens.”
  - Very limited operating point in the engine map. The power of the “overlimit function” may therefore be limited.
  - It is unclear that there is a direction other than highly oxygenated fuel to obtain HECC combustion.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 11 reviewers)

- Proposed 2007 objectives seem appropriate.
- Excellent fundamental work of fuel effects on high efficiency low emissions combustion.
- Sharpen experiment focus and be sure you are answering different questions than other projects.
- Connect fuel to nanostructure … what fuel chemistry affects the nanostructure … otherwise it is trial and error and why not just use the smoke or PM results …
- Try to get simulation more involved, in particular with the idea that soot nano-structure has a significant impact on soot oxidation (cooperation with LLNL planned but not detailed).
- It would be very useful to look at fuel volatility as well as composition effects. Volatility affects the in-cylinder fuel/air distribution which impacts soot, which impacts the LTC regime. It also gives insight into the relative importance of composition versus physical properties.
- Expand petroleum base fuel study, fuel composition effect etc.

Fuels Technologies

Diesel Range Fuel Effects on Single Cylinder HCCI, Jim Szybist of Oak Ridge National Laboratory



Brief Summary of Project

The focus of this project is to examine fuel composition effects on advanced combustion regimes for high efficiency engines meeting 2007-2010 standards. The team is attempting to provide straight-forward comparisons of combustion and performance of diesel fuels differing in properties and chemistry in an HCCI engine.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 15 reviewers)

Reactions to this question were mixed. One person simply stated that the project provides useful information. Another person acknowledged that the focus on fuel effects is important. One evaluator noted that an improved understanding of fuel effects on HCCI is consistent with DOE goals. Another mentioned that this is a good applied research project that highlights the sensitivity of HCCI combustion on fuel properties and the need for a fuel specific engine calibration. One person noted that the fuel variation and type are a major issue for HCCI, while another added that the fuel effects on HCCI combustion is an important factor for overcoming combustion control barriers. As the opposing view, one reviewer commented that it was too early to test fuels on an HCCI engine since no practical engines exist. Another person commented that the test platform is not very applicable to their applications of PCCI, but they acknowledge that these data may be useful for some HCCI work, just not within their company. The last reviewer was critical of the work, stating that it is a fundamental lesson in cetane number engine condition sweeps and is not very necessary. They conclude by stating that the cetane number trend investigation seems trivial.

Question 2: Approach to performing the research and development (Written responses from 11 of 15 reviewers)

Reponses were mixed, raising questions from many of the reviewers. One reviewer simply stated that the researchers have used good systematic studies. Another commented that the approach of testing fuels with different properties is good. One person felt that the addition of an atomizer and intake heater seems to be a good approach to minimize mixing effects and to maximize focus on fuel effects. Another evaluator commented that the approach seems to be reasonable, but the experiment was limited to a single fuel property variable with no mention of noise parameters. They added that the calibration parameter was limited to IMT to control combustion. Others were more critical, with one person commenting that it was not clear that system provides completely vaporized homogeneous charge. Another reviewer acknowledged that they were not a fuels expert, but HCCI fuels work they have seen in other venues raises made them question the results based on looking at cetane number as the only variable. They add that they felt that more precision is needed as to other fuel characteristics, e.g., volatility and reactivity. They continue that the linking of low-temp cool flame heat release just to cetane number is questionable, concluding that their understanding is that cool-flame heat release is driven mainly by normal heptane content in the fuel, not cetane number per se. Another reviewer commented that the large fuels matrix used in the project was well acknowledged, however, aromatic content was not varied systematically. Another person noted that the general approach is fair, but it would be fruitful if this fuels sensitivity study included higher load points versus light load points. They add that such an exercise could point toward fuel sensitivity on maximum attainable speed/load for a given fuel especially since other engine researchers are trying to push the HCCI combustion portion of an engine map. Another person simply stated that the project could benefit from more analytical study of the test results. One evaluator commented that using an engine at low BMEP without EGR does not address the major issue of high engine output, which is a major issue with HCCI engines.

The final reviewer reiterated earlier comments again that a cetane number investigation with a single cylinder is not needed. They commented further that the investigation did not address cetane number work for biodiesel, adding that the biodiesel investigation is also trivial. Engine data analysis and test matrix is very incomplete. The work needs collaboration with an organization that can give the investigators basic insight in diesel engine data analysis.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 15 reviewers)

This question generated both positive and negative responses. One person simply stated that the researchers have made good progress. Another person commented that the researchers look like they have shown good progress and interesting results. Another person commented that within the range of the experiment, the researchers have shown good progress. One reviewer noted there has been very good progress in built-up of test cell, specifically pointing out the vaporizer and apparatus. Another person had similar comments, noting that there has been very good progress for a first year effort. They commented that the first cut data points point out the need for advanced controls under the guise of possible multiple fuel usage. They add furthermore that the results point out the need to carefully consider the impact of any future commercial fuel property changes on the performance of future engines. One evaluator pointed out that while the results are interesting and suggestive, the operation at light loads without EGR provides data of limited usefulness. The last reviewer commented that no new ground has been broken with this work. They concluded by stating that the cetane number investigations and low IMEP work does not help with current difficulties of modern engines.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 9 of 15 reviewers)

All of the reviewers noted the limited (if any) collaborations the group has established. One reviewer noted that there was little mention about collaborations, other than with MIT in the last slide discussing future work. Another person felt that it was not obvious from their viewpoint how this work is connected with engine and fuels industry, concluding that the work appears to be more of a basic investigation (which is OK). One evaluator commented that it was not clear who is participating in the project: oil industry, OEMs, modeling workers. One reviewer commented that this is a new project and does not appear to include much industry or university interaction. They added that to date, such interaction might not have been necessary but in the future the researchers should include outside input when developing future test strategies. Another person commented that they did not note any collaborations from the presentation other than in the future work. One person stated that there was minimal evidence for collaboration; while some exists, they did not think it would take a significant time to initiate. One person felt that a wider collaboration seems worthwhile. Another said that it was important to work with engine and fuel manufacturers, but another reviewer disagreed, saying that he cannot see the advantage of commercial interaction, as it would be detrimental to the collaborator than beneficial.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 15 reviewers)

The reactions to this question were mixed. One reviewer commented that the proposed plans seem good. Another person felt that the future work on HECC will be able to compare same fuels with tests on engine at Cummins which would ground this single-cylinder test conclusion. One evaluator felt that the researchers have laid out reasonable future plans for a new project adding that it would be fruitful to include higher load points at some point in the future. Another person commented that adding oil sands fuels/blend stocks will be a good addition to fuel set. One reviewer noted that substantial levels of EGR need to be added so that the engine can be operated at much higher BMEP, preferably with boosting. One person however felt that the more detailed analysis is helpful and cooperation with modelers helps. Another simply stated that the plans are broad and could be deeper. The final reviewer noted that the work does not have a logical course of action. They felt that new work seems to be presented at random only addressing trendy diesel hot subjects rather than an investigation of fuels and their relationship to heat releases. They went on to ask where the real engine conditions, temps, boost, and engine speed are in the work plan.

Specific Strengths and Weaknesses (Written responses from 8 of 15 reviewers)

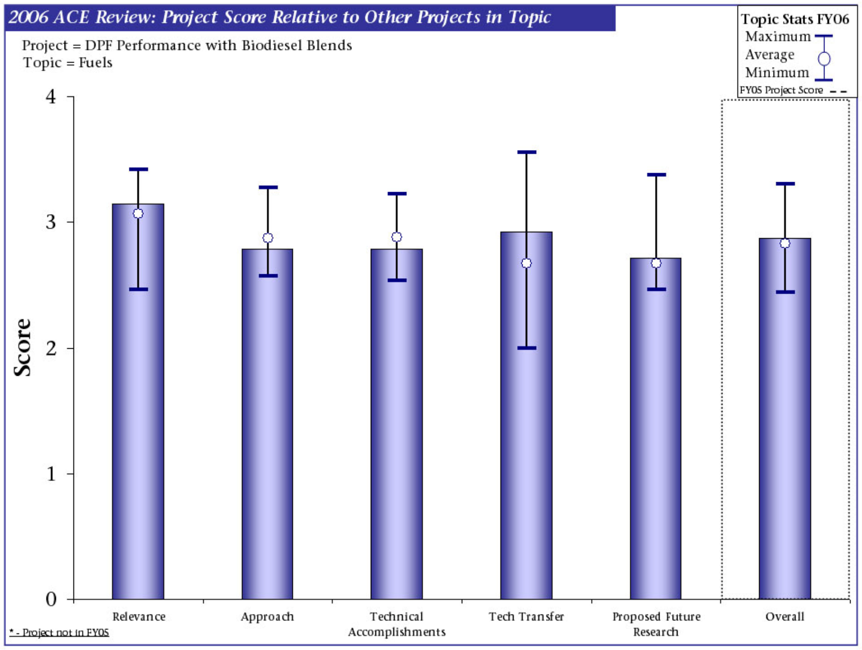
- Specific Strengths
  - Relation of speciation to high and low temperature release and combustion phasing.

- Testing a variety of diesel type fuels (reference fuels, petroleum derived diesel, synthetic diesel, and biodiesel).
  - Basic fuel property trends on what is believed to be a HCCI engine test.
  - Wide fuel variation from potential future sources
  - Very fundamental—though rather simple—investigations help to characterize different fuels.
  - Nice experimental tool for assessing fuel effects on controlling HCCI like combustion.
  - Good work, useful data, well presented.
  - Preliminary information on fuel effects on an HCCI engine is a significant contribution to the literature.
- Specific Weaknesses
  - Non-commercial fuel delivery and combustion system.
  - Applicability to high compression ratio, commercial engines.
  - Characterizing the fuels only by cetane number, instead of other additional characteristics.
  - Very fundamental work: vaporizer does not account for different vaporization parameters of fuels. Results can not [be] taken over directly to "real world" HCCI engines (direct injection, early or late fuel injection).
  - More industrial collaboration could be worthwhile.
  - The engine system is not representative of future diesel-fuel HCCI engines.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 11 of 15 reviewers)

- Future work direction as presented seems appropriate.
- Perform similar studies on production-like fuel and combustion system.
- Connect the work to real applications of HCCI or PCCI to commercial engines.
- Look for global explanations of observed effects. Build a framework for understanding.
- Adding a low cetane fuel or a crossover fuel that can be also be tested on a gasoline-like HCCI engine would be interesting. This would facilitate comparison of fuel effects on a wide range of advanced combustion engines.
- Consult HCCI fuels work by Tom Ryan et.al. of Southwest Research Institute, if possible (may not be in public domain).
- High end diesel may have droplets, but haven't seen mixing effects.
- Add systematic aromatics variation into the fuel matrix.
- Include more speed/load points in future work.
- Modify the engine to operate boosted with substantial EGR so that much higher BMEP is obtained.
- This research covers a lot of ground, but it would be nice to see some deeper insights come out. This is an area where collaboration with others could be advantageous.

DPF Performance with Biodiesel Blends, Aaron Williams of the National Renewable Energy Laboratory



Brief Summary of Project

In this project the National Renewable Energy Laboratory is looking at the effect of biodiesel blends on diesel particulate filters with a medium-duty diesel engine. This work is being done in cooperation with Cummins.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 14 reviewers)

In general the reviewers felt that this project was relevant to the overall DOE objectives. One reviewer indicated that understanding of biodiesel performance is in line with DOE goals. Another reviewer stated that this was an interesting topic. A comment was made that this project supports the use of biodiesel fuel and the ability of engine companies to permit use of biodiesel in their engines. One person felt that the presented data set was useful but limited. A point was brought up that biodiesel blends revealed significant problems in DPF applications in Europe; therefore, this issue needs to be addressed. A comment was made that the industry cannot change their DPF size or design based on one type of fuel. Industry has to plan for all possible fuels that may be available. The final comment indicated that this work helps to promote biodiesel use, but the major issues with biodiesel are stability, quality, and cost.

Question 2: Approach to performing the research and development (Written responses from 5 of 14 reviewers)

Reviewers had generally favorable comments regarding the research approach; however, several comments addressed the limitations of the work to date. A comment was made that this project, as presented, appears to be focused on the soot formation of biodiesel from one source (soy-based) in one specific DPF system. However, this project could be much more valuable if biodiesel fuel from various sources (soy- and non-soy-based) were tested in several DPF systems. A reviewer agreed with the previous comment, indicating that the results are specific to the CCRT system used in the experiment. According to him, there is a need for correlation of the results to the catalyst activity of the pre-catalyst. He added that the PM after the pre-catalyst should have been measured since the catalyst will impact the PM level. He suggested using the uncatalyzed DPF instead of pre-catalyst to determine the balance point and to understand differences in soot for comparison to active regeneration. Another reviewer praised the detailed analysis, pointing out that well established testing methods ensure good results. It was added that soot characterization is appreciated. A concern was raised about the balance point since power levels and NOx content can change from one fuel to another. A reviewer said that there was too much focus on passive regeneration, and that the team needs to increase emphasis on active regeneration.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 14 reviewers)

Several technical accomplishments of this research were noted. One reviewer felt that reasonable progress has been made in testing soot formation from one soy-based biodiesel in one DPF system. He was not convinced that use of high quality soy-based biodiesel with a DPF was considered a barrier. Another reviewer simply stated that this project has met its objectives. One person noted that interesting results have been presented, showing synergy between B20 and DPF in reducing PM. He asked if this has been validated with other biodiesel blends. A suggestion was made to rapidly transition to an active DPF to understand impacts on controls. It was acknowledged that this is planned in future work. A reviewer thought that it would be interesting to analyze the adsorbed species on the soot surface to see the differences. According to him, back pressure is only a poor indicator for soot mass; the weight soot mass is more important. The last comment complimented the systematic study of different blends.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 14 reviewers)

Collaboration with Cummins, as a CRADA partner, was acknowledged by several reviewers. One person stated that it is good that an OEM (Cummins) is a collaborator. Another agreed by stating that he is glad to see some industry collaboration. A comment was made that more collaboration with DPF suppliers is needed. It was added that closer direct coordination with DPF manufacturers would be worthwhile to help fully characterize the robustness. One reviewer felt that there were a limited number of collaborators. A comment was made that more involvement of simulation may be helpful. It was also noted that no university is involved in this research.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 7 of 14 reviewers)

One reviewer felt that good plans for further testing of this one soy-based biodiesel were presented. He noted that there were no apparent plans for testing biodiesel from other sources and with different quality. A suggestion was made to plan experiments more thoroughly to retrieve as much data from the experiments as possible and to extract maximum value. It was also suggested to focus on more fundamental understanding of the impact of fuels on aftertreatment system. Another also liked the proposed future research plan because it involves MY2007 engine which is the application with the largest number of engines in the field and not only a niche application. One person felt that the proposed future research will be useful but still limited due to a single type of a DPF and only soy-based biodiesel. A point was raised that transient/in-vehicle work is needed to confirm the results; it was noted that this is included in Phase 2. A reviewer commented that this work assumes that a DPF system could be designed based on whether biodiesel is used; this is practical only if biodiesel is mandated and used as part of an emissions certification fuel. The last comment complimented industry collaboration with Cummins and posed a question how soot specialists at universities are involved.

Specific Strengths and Weaknesses (Written responses from 8 of 14 reviewers)

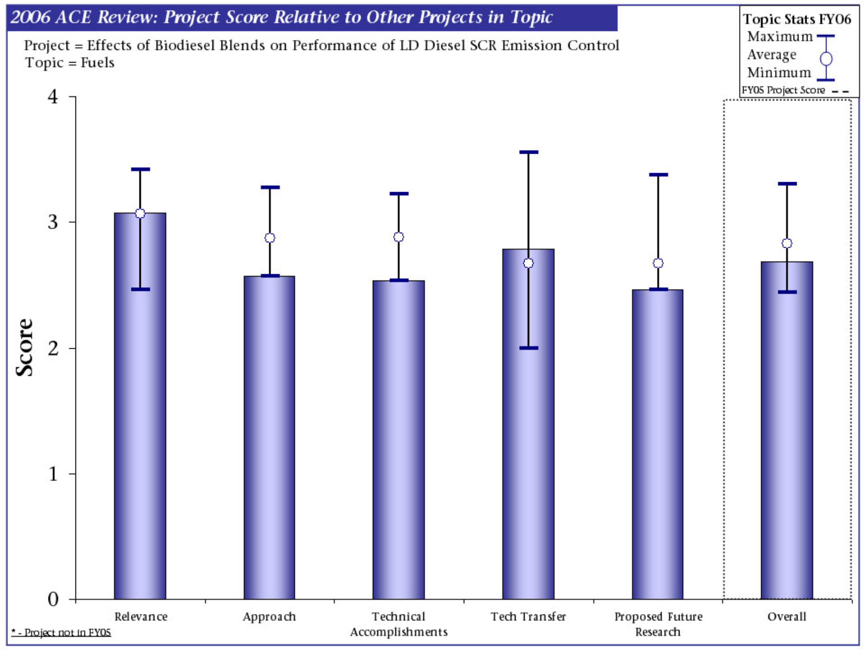
- Specific Strengths
  - New work exploring the effect of biodiesel on the reactivity of diesel particulate.
  - Engine testing of balance point.
  - Soot measurements being done in collaboration with Cummins.
  - Solid data on biodiesel effects.
  - The issue of the project is properly addressed. Effect on CRT is interesting.
  - Biodiesel blends become an issue in the future market.
  - Interesting initial results.
  - Demonstration of biodiesel use in particulate filter without any real issues.
- Specific Weaknesses
  - No emissions measured during DPF regeneration.
  - Has provided results from one high quality soy-based biodiesel but presents this as a general result for biodiesel. Need to test biodiesel from various sources with varying qualities.
  - Need carefully controlled bench scale testing to validate engine testing. To determine the balance point, use the uncatalyzed DPF and no pre-catalyst to understand active regeneration.
  - Limited to one engine/CCRT system and limited operating modes. PM size information would be useful. Other DPFs and regeneration strategies need testing.
  - Focused on passive DPF regeneration and balance point temperature; active regeneration will be much more important, particularly for light-duty diesel.
  - Should be baselining with DOC only. Is the DOC changing the DPF feedgas?
  - Soot mass is the key to safe regeneration and must be considered in the future.
  - Biodiesel may vary in quality, oxygen content, and therefore in different reactivity and morphology of soot. Different DPF materials are not addressed (yet).
  - Need quite a bit more characterization to understand wider applicability of this result, beyond this initial indication.
  - Perhaps not forward-looking enough. Mentions that they are working to obtain 2007 engine but perhaps the questions should be what will fuels look like beyond 2010 and what questions should we be addressing? A lot of work on HCCI seemingly ignores biodiesel but I may have missed it.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 10 of 14 reviewers)

- Add testing of biodiesel and ULSD from several sources.
- Validate particle morphology using Kyeong Lee's (ANL) techniques.
- Is there a difference in DPF internal temperatures during forced regeneration? Does easier combustion lead to higher temperature and/or larger thermal stresses? Are the engine NOx levels the same and could they be part of the difference in PM oxidation?
- The soot morphology and the influence on back-pressure in combination with soot mass should be investigated more.
- Include biodiesel blends from different sources. Active regeneration is not addressed adequately but may become a major hurdle, as in Europe. I also recommend including simulation or at least share the results.
- Wider characterization of results with a range of DPFs (including aged ones and ones from different manufacturers) would be helpful to understand the general applicability of the conclusions.
- How sensitive is the conclusion to the engine calibration?
- Conduct TGA measurements with NO_2 as well as O_2.
- Will more active soot from biodiesel lead to larger health issues?
- Look at soot accumulation and regeneration under engine certification cycles; include light duty engines and light duty certification cycles to scope of work.

Fuels Technologies

Effects of Biodiesel Blends on Performance of LD Diesel SCR Emission Control Systems, Matt Thornton of the National Renewable Energy Laboratory



Brief Summary of Project

Researchers are evaluating the impact of biodiesel fuel blends on emission control systems in this project. The project includes two emission control systems and two fuel blends on a LD platform (NOx adsorber catalyst with diesel particulate filter and selective catalytic reduction catalyst with a diesel particulate filter). Biodiesel blends of 5% and 20% biodiesel are being examined. An engine teardown program is planned for the end of the research.

Question 1: Relevance to overall DOE Objectives (Written responses from 10 of 14 reviewers)

Reviewers acknowledged the importance of effect biodiesel blends have on advanced aftertreatment systems. Several reviewers commented that this is interesting and important research area. One reviewer indicated that testing performance of emission systems with biodiesel seems consistent with DOE goals to advance alternative fuels. Another thought that the project goals, to determine deleterious effects of biodiesel blends on the performance of the aftertreatment devices, are clear and concise. According to him, this work is very appropriate. One person felt that the issues that this project addresses are very important. However, it will be difficult to work out all of the proposed topics in one single project. He added that the project is extremely broad, covering two different types of exhaust systems with a number of alternative materials and the effect of different fuels on the catalytic systems. One reviewer commented that compatibility with NOx aftertreatment is not likely to be a critical barrier for biodiesel. Another acknowledged the importance of the effect of biodiesel on aftertreatment systems, but stated that this is not the way to determine it. It was noted that the system is extremely complex and at the end the results live from small differences. One reviewer thought that this work is focused, well-planned and was presented well. Another was not sure DOE should support SCR development in this project. According to him, this project should use mature SCR technology and try to focus on the biodiesel effect and not on the SCR technology.

Question 2: Approach to performing the research and development (Written responses from 10 of 14 reviewers)

One reviewer indicated that this work is still in early stage but the right general elements are present. It is difficult to make general conclusions based on results from a particular aftertreatment system, added another. According to him, a more fundamental study might be more appropriate. One person felt that the presented approach seems reasonable. Another thought that this work seems a bit exploratory, but that is OK. He questioned the value of the simulation because it did not seem to fit the scope of the project. He also raised a question whether the project will use the default DaimlerChrysler calibration and regeneration methods. His next question was whether the controls confound the experiment (i.e., are not tuned for the fuel). A comment was made that a lot of time will be spent assembling the aftertreatment system and in the meantime Mercedes might be in the market with a production system. One person stated that a significant effort will be required to validate the model before moving to optimization. If the catalyst is a black box, he suggested taking the recommendations from the catalyst supplier on the urea injection and skipping the optimization step of the plan. If the urea SCR catalyst has vanadia, he suggested stopping the project. He felt that the work plan was poorly thought-out with respect to the objectives. He added that there is little fundamental focus and that the industry should handle system optimization. Another reviewer agreed that a new layout of urea based SCR or LNT requires significant efforts that are not adequately covered in this project or are significantly underestimated. He urged that an SCR-catalyst cannot be treated as a black box, at least not in a simulation code. He also added that validation of urea decomposition is missing. It was noted that this work involves determination of biodiesel fuel effects on durability and optimization. A suggestion was made to select a light-duty engine of a modern design, but not too modern to prevent advances of combustion technology from interfering with the results. Furthermore, the investigator must be aware of potential catalyst poisoning components that may be present in biodiesel. Characterization may be needed to address different blends available from the biodiesel market. One reviewer was confused because there seem to be two separate programs: one involving the design of an optimized aftertreatment system, and the other being an assessment of the impact of biodiesel on aftertreatment. The latter point could be studied with an existing SCR or NAC system. He stated that the two programs should not be carried out in conjunction.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 9 of 14 reviewers)

Several reviewers noted that this is a new project and since it is just starting, it is too early to comment on the technical accomplishments. One person indicated that achievements have been reasonable for a start-up project. Another stated that the project is new but it seems well-planned. According to one reviewer the testing setup took longer than expected. A suggestion was made to integrate a laboratory program for determining the critical poisoning points of the exhaust systems. Starting with engine or vehicle experiments might lead to results which cannot be interpreted in a clear way. It was mentioned that the program requires significant hardware changes and modifications.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 14 reviewers)

Reviewers acknowledged collaboration with FEV, EPA, MECA, and AVL. One of the comments was that there is very good cast of partners involved who do not normally work together. This shows the importance of the SCR technology for light-duty applications. One reviewer said that collaboration seems quite good. Importance of collaboration with MECA was acknowledged since they will have to warrant the performance of the emissions control systems. One person stated that based on the industrial collaboration the chance is given for a good project. However, from the discussion of the presentation, more thorough discussion with a “steering group” seems necessary. He pointed out that since the exhaust system is the focus of the project, it is not acceptable that it is treated as a black box. A comment was made that no OEM is involved which is not acceptable with all the significant changes encountered. It was suggested to include an engine/vehicle manufacturer.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 8 of 14 reviewers)

Reviewers had mixed comments regarding the proposed approach. Several reviewers were looking for more specific information regarding the proposed plan. One reviewer felt that future plan is not entirely clear and specific for achieving the final goal. It was mentioned that more information on the NAC and SCR catalysts is needed for the durability results to have applicability. One person suggested rethinking the project approach. The controls strategy was unclear to one reviewer. He could not understand why so much money is being spent on SCR modeling when the DaimlerChrysler system could be used instead. Another person agreed by suggesting to skip optimization and use what the catalyst suppliers recommend. This would save a significant amount of money, according to him. A comment was made that the plan exceeds the available funding. One reviewer noted that the project is young and therefore no data are available. He felt the project was presented in a well planned manner.

Specific Strengths and Weaknesses (Written responses from 10 of 14 reviewers)

- Specific Strengths
  - The project is well posed and it appears that the resources are available. Few results to date.
  - Information on durability effects with biodiesel is needed.
  - Industrial cooperation seems to be good.
  - This topic is important and covers a lot (probably too much!).
  - Trying to address some important and valid questions.
  - Good collaboration with the industry. Direct testing on a commercial system.

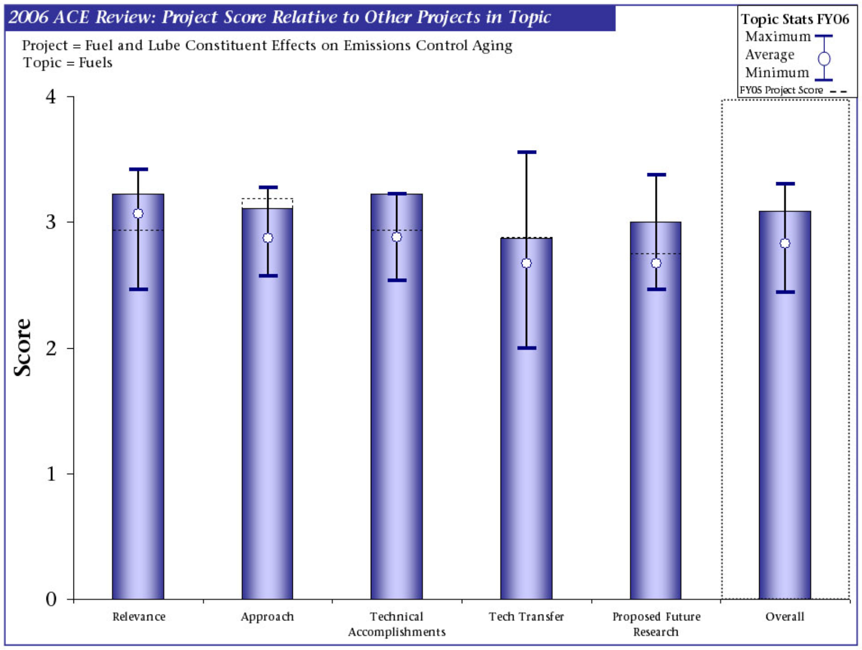
- Specific Weaknesses
  - Many issues of urea SCR system do not seem to be considered (i.e., interactions of the urea dosing strategy

with ammonia storage in the SCR).
   – Do not know why all of the SCR modeling is necessary. Use an existing system. Good question on vanadium in the SCR. DOE should at least know the basis for converter. The European SCR catalysts are most likely different from what would be used in the U.S.
   – No fundamental approach. Poorly planned work to resolve impacts of biodiesel on aftertreatment system.
   – Must know that SCR does not have vanadium (at least one U.S. manufacturer will not consider vanadium due to volatility issues). Temperatures needed for DPF regeneration will cause vanadium loss. Hydrocarbon poisoning of SCR is an issue that depends on the formulation.
   – Due to the broadness of the project the focus can be easily lost.
   – The proposed approach is limited because it does not seem to reflect production intent applications. A plan for ageing of engine and aftertreatment system with biodiesel was not demonstrated.
   – Too early stage and not enough detail to tell if data that will be gathered will really address the questions.
   – Not enough depth of knowledge and control over the system being tested.
   – NREL seems to be only managing subcontractors rather than controlling the program.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 10 of 14 reviewers)

- It would be helpful to start with an OEM system rather than building one from scratch. If the purpose is to look at fuel effects on NOx systems, it would seem to be helpful to look at the effects of fuel property changes other than biodiesel.
- It might be better to use an existing SCR system using a catalyst that has a better chance of being used in the US (i.e., zeolite). This project needs to be reviewed again by people more familiar with SCR systems that might be used in the U.S. (I know people at Cummins that could provide a much better review of this project and might provide better direction). This project needs a major review or rework prior to spending a lot of money!
- Re-scope the project and focus the work to understand the impact of biodiesel on aftertreatment systems and understand why there is an impact.
- Demand non-vanadium catalyst and concentrate on cold start warm-up. Study deposit build-up effects in EGR system. “Medium” budged level seems much too small to adequately analyze both systems.
- Built-up a strong steering group. A successful project could be extremely helpful for industry.
- Significant streamlining of the project is required. More focus on either ageing or influence of biodiesel fuel on emissions is requested. Funding will not allow doing everything in parallel!
- Need more focus/description on precisely how the modeling and test results will address the impact of biodiesel blends on emission control systems.
- Decide whether to use an SCR catalyst containing vanadium and possibly specify that it not contain this element.
- The SCR development and simulation should not be the focus of this project. Find the right available technology, otherwise wait for the right timing.

Fuel and Lube Constituent Effects on Emissions Control Aging, Todd Toops of Oak Ridge National Laboratory



Brief Summary of Project

The objective of this program is to develop rapid aging and poisoning protocols for diesel aftertreatment devices, to gain a more complete understanding of the processes and mechanisms for poisoning of aftertreatment devices through fuel and lubricating oil.

Question 1: Relevance to overall DOE Objectives (Written responses from 5 of 10 reviewers)

Important durability issues are being addressed, noted a reviewer. Very good fundamental research, in the opinion of another reviewer who felt this project was another good example of what the National Labs can contribute to the needed knowledge base. A reviewer said that this project is advancing the understanding of deactivation of emission control systems consistent with DOE goals. A reviewer said that the influence of lube oil becomes more critical with lower engine-out emissions and reduced sulfur contents in the fuel. The final reviewer wondered why the team was studying ash effects on DPF when these filters are almost in production and this data is widely known to engine manufacturers through previous research and their own field tests. This reviewer wondered what the new drivers were, and if this work was driven by new DPF materials driven by cost reduction. This reviewer was not really sure how this promotes fuel economy at this point. This reviewer did note that he was not as familiar with the LNT work.

Question 2: Approach to performing the research and development (Written responses from 6 of 10 reviewers)

The first reviewer said that the approach seemed reasonable, while the second reviewer pointed out the good approach of correlating lab investigation results with materials from the field. Very good systematic approach to understand aging/poisoning, said a reviewer. A reviewer noted that good analytical tools are available for the work. A reviewer suggested that LNT aging should be based on engine tests rather than reactor tests. Another suggested that if possible, the team should get in-use field returns of filters to correlate to bench testing rather than catastrophic failure returns.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 10 reviewers)

Progress was generally judged to be good or great. One reviewer said that the team should continue into more fundamental work and investigate specific sites of detrimental impact. Another said that good progress was made but results show differences between bench and field aging that should be addressed. Finally, a reviewer said that some progress was evident on LNT, but this reviewer was not sure what schedule was being used for the milestones.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 4 of 10 reviewers)

Reviewer comments were mixed. One said that there looks like a good connection with catalyst and filter suppliers. Another said that the project appears to be less connected to industry than other projects presented. The third would like to hear more timely updates of the research. The final reviewer said that cooperation efforts were not shown.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 10 reviewers)

A reviewer said that the team should keep moving forward, but focus even more on a fundamental understanding of the detrimental impacts of exhaust species. Another said that a better understanding about the background of field testing will be helpful. The final reviewer did not see great value above and beyond what the engine manufacturers are doing now (and have been doing).

Specific Strengths and Weaknesses (Written responses from 6 of 10 reviewers)

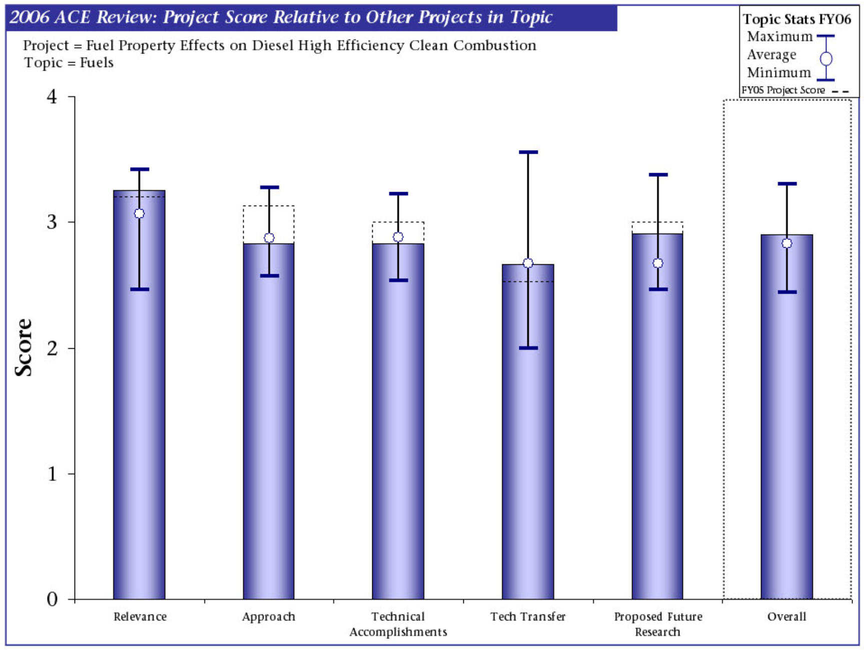
- Specific Strengths
  - Good overall progress.
  - Fundamental analyses of poisoning and thermal degradation mechanisms.
  - Attempts to correlate lab results with actual field-aged materials.
  - Analytical capabilities and experience of staff.
  - Publicly available aging data is needed; most work is proprietary.
  - Topic of the project is important and tools that are used are good.
- Specific Weaknesses
  - None specific.
  - Not sure about connecting to industry and how well the work is focused on solving specific problems with which industry needs help.
  - Difficult to get field samples that would be representative of real world aftertreatment devices.
  - Hard to get latest formulations for analysis.
  - Field testing as conducted currently does not allow a detailed view on the history of the application.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 10 reviewers)

- None specific.
- Do the engine manufacturers and after-treatment suppliers find value in this work? It was not clear this was the case based upon the presentation …
- I'm not sufficiently qualified to address the technical merit or accomplishments; it's not clear how much this complements or duplicates other literature work or work within catalyst manufacturers or OEMs.
- Evaluate LNT aging using engine tests; include studies of hydrocarbon catalyst contamination and coking.
- Include the impacts of variations of lube oil, variations of diesel fuel on ash chemical composition, and the impacts of DPF regeneration on ash interaction with the DPF.
- Extend to SCR aging.
- More careful check of differences between field aging and bench aging!

Fuels Technologies

Fuel Property Effects on Diesel High Efficiency Clean Combustion, Scott Sluder of Oak Ridge National Laboratory



Brief Summary of Project

Oak Ridge is performing engine-based evaluations of the performance of fuels in high efficiency clean combustion (HECC) modes in a light-duty diesel engine. In the current year, the team examined the HECC tolerance for oil-sands and 5% biodiesel fuel formulations, and participated in the design of a scientific fuel matrix for use in future work (FACE program), among other accomplishments.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 12 reviewers)

Responses were positive in general. One reviewer noted that the project's goal of the advancement of HECC consistent with DOE goals. Another person felt that supporting the fuel study for future engine is good money spending. One person simply stated that the presenter provided a useful HECC fuels effects overview. One evaluator commented that this is a very useful project and that they were not aware that there is in Europe a comparable project funded by the European Community. Several people noted the variety of fuel formulations that were tested. One person felt that the tested fuel formulations are very interesting for HECC since the physical parameters were in a very narrow band. Another person acknowledged that the program is relevant, though they felt that restricting blends to 5%, while practical, is likely too low to identify opportunities. The final reviewer did not see much variation in these fuels presented: this reviewer guessed that this is a finding in itself.

Question 2: Approach to performing the research and development (Written responses from 5 of 12 reviewers)

The responses were positive, but several reviewers had suggestions on how to improve the results. One reviewer simply noted that the approach seems good. One person commented that the baseline or the emission level of the used engine should be discussed. Another reviewer noted that the influence of the load and speed were covered, but felt that more operating points would be even better. Another person thought that there are probably differences in the details of the experimental data that would highlight fuel differences. The last reviewer recommended a design of experiment approach, showing all critical parameters. They suggested that perhaps there would be some dependency with engine injection characteristics; and felt that they should be included in a well-thought-out experiment.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 12 reviewers)

Responses were mixed to this question, with more people raising concerns and questions. One person simply stated that the researchers have shown very good progress. Another person noted that the detailed analysis of exhaust gas species was appreciated. One evaluator commented that progress has been good, but a deeper understanding would be valuable. Another person, however, felt that it was not clear from the presentation or hand-out what exactly HECC is in this project. Another person noted that the project could use more in-depth analysis of the test results. One person suggested that there should have better fuel matrix design and the team should test more fuels. The final reviewer had very detailed comments, stating that they thought that the interaction with the engine controls and variation could potentially change conclusions. They acknowledged that perhaps this was done, but it was not evident in the presentation. They added that there was some mention that engine parameters were adjusted without showing an increased range of PCCI, but the results indicated that within the fuels tested they did not see a great sensitivity.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 12 reviewers)

Responses were mixed, with many people suggesting that the researchers need to improve their interactions with industry. One person commented that the extent of collaboration seems similar to many of the other projects. Another reviewer noted that industry participation was not evident, though it would not take significant time and effort to initiate. Another person agreed, stating that optimization of cooperation with OEMs seem possible. Another reviewer commented that the collaborations were not seen from the hand-out, but regarding the presentation of Wendy Clark this reviewer assumed that there is a strong consortium (FACE) which is involved in the overall project. The last reviewer commented that more collaboration and deeper investigation of reasons for fuel difference may prove worthwhile.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 12 reviewers)

Results were again mixed to this question. Two reviewers commented that the plans look good. One evaluator noted that the researchers plan to focus on FACE fuels in the next fiscal year, which appears to be reasonable. They added that they would add the engine control interaction. One person commented that more detailed work also with blends is helpful. Another person pointed out that in general, the researchers found little effect due to fuel formulation. The final reviewer noted that the use of a well-characterized fuel matrix is essential for future progress.

Specific Strengths and Weaknesses (Written responses from 7 of 12 reviewers)

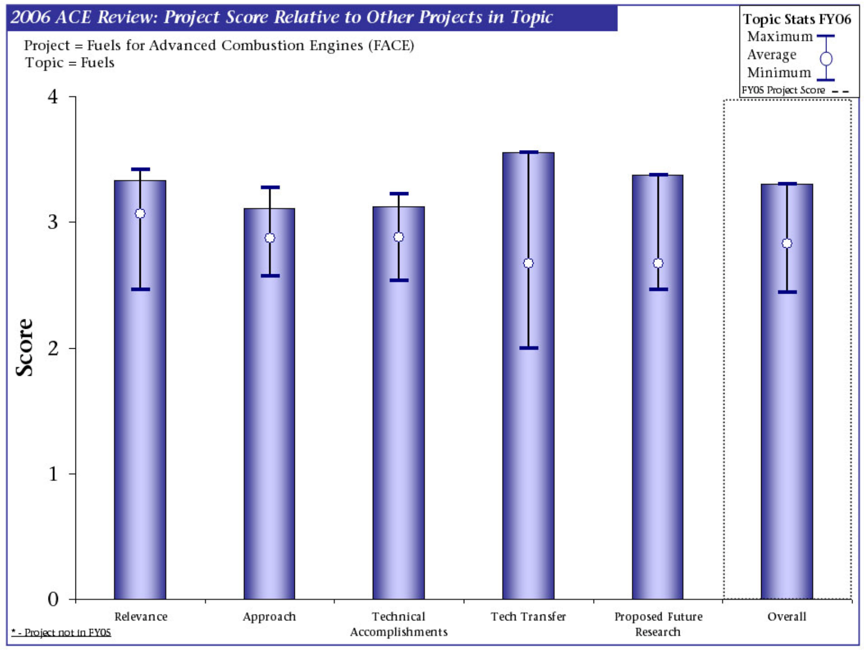
- Specific Strengths
  - Speciation results under HECC combustion modes.
  - Testing “real” fuels in a real engine.
  - Good tools and analyses.
  - Engine capabilities, operation strategies and analytical equipment are great.
  - Focus on fuel composition chemistry helps to separate physical property effects (viscosity, density, etc.) from chemical formulations (aromatics, oxygen).
  - Good overview work on HECC fuel effects.
  - Good experimental facilities, speciation capabilities.
- Specific Weaknesses
  - Old engine technology and not a well-planned fuel matrix.
  - Lack of engine critical parameters in experiments (as presented).
  - Need the wider fuel blend range. Can it tie to kinetics or models being done elsewhere?
  - The comparison to the baseline application of the engine is a point which should discussed by the project team. The application of the combustion is with respect to the emissions relatively old. Might be that with a more advanced application the differences between the used fuels will become different.
  - The HECC mode used seems to reflect more LTC than HCCI operation which limits the applicability of the results.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 12 reviewers)

- Upgrade engine and use well-designed fuel set, such as FACE fuels; until FACE fuels are available run evaluations with pure components and component blends to provide insight necessary to help design relevant fuels.
- Include engine critical parameters in the experiments.
- Keep going, get FACE fuels.
- Add more operating points; if possible: extend to other HECC combustion modes by varying other parameters than EGR only.
- Future work appears appropriate, look forward to further clarification of cause and effect relationships
- Well constructed fuel matrix.
- Need more tests for more fuels and better fuel matrix design.

Fuels Technologies

Fuels for Advanced Combustion Engines (FACE), Wendy Clark of the National Renewable Energy Laboratory



Brief Summary of Project

In the FACE program, the research team will be designing a set of research fuels suited for discerning effects on HECC that could be used across a range of programs. Participants include government agencies/national labs, automotive and diesel engine manufacturers, and energy companies.

Question 1: Relevance to overall DOE Objectives (Written responses from 2 of 9 reviewers)

One reviewer commented that the fuels work is important to future combustion techniques; the prime goal of creating a set of standard fuels that various entities can use for testing specific applications would be useful. Another person noted that a standardized fuel for advanced combustion techniques helps a lot in comparing results between different laboratories.

Question 2: Approach to performing the research and development (Written responses from 2 of 9 reviewers)

One reviewer commented that all most important stake holders are included, even though engine OEMs seem to be represented only as a minority. Another was surprised that the committee approach seemed to be a reasonable approach.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 9 reviewers)

Two reviewers had similar comments. One person commented that considering the difficulty in getting all different interests together, the progress seem to be OK. The second reviewer commented that the progress has been impressive, given the difficulty of working with so many companies. The final reviewer simply noted that the project has not produced results yet.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 9 reviewers)

Comments were positive. One person simply stated that the project seems well connected, while another commented that it would be hard to improve. The last reviewer felt that it would be too difficult to include other international stakeholders at this time of the project.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 1 of 9 reviewers)

One reviewer felt that the researchers presented a well outlined timeline; good approach in terms of quantity and quality of fuels.

Specific Strengths and Weaknesses (Written responses from 4 of 9 reviewers)

- Specific Strengths
  - Good basic idea, has the right involvement.
  - Since no regulatory goals are included, it seems to be easier to find common “standardized” fuels.
  - Useful program for cross comparison of results.

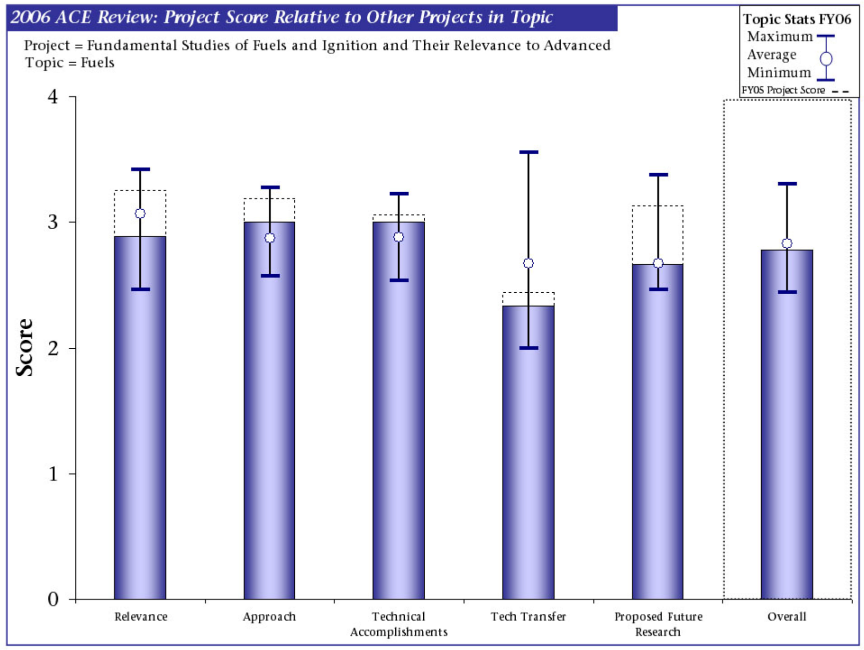
- Industry collaboration.
- Specific Weaknesses
  - None evident.
  - Seems to be very slow process, could have used this fuel data and specification about 6 months ago.
  - Must be like herding cats…
  - Maybe hard to get the interest of all stakeholders covered.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 4 of 9 reviewers)

- Keep going.
- Install a web-site with the results to ensure that also international groups can take advantage, e.g., researchers in Europe and Japan.
- Existing scope looks good.
- How much of the outcome can be shared with the public?

Fuels Technologies

Fundamental Studies of Fuels and Ignition and Their Relevance to Advanced Combustion, Josh Taylor of the National Renewable Energy Laboratory



Brief Summary of Project

The approach of this project at NREL is to develop a pathway to use easily measured ignition properties to derive ignition models for real fuels that can be used in an LTC engine model. The researchers are using an ignition quality tester (IQT) to measure ignition delay for various fuels to feed low-temperature combustion models.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 9 reviewers)

Responses to this question were positive. One person commented that ignition delay studies are important to DOE goals of efficiency, emissions, and power, adding that ignition delay quantification is critical work for future fuels such as biodiesel and other derivatives. Another reviewer agreed, stating that ignition delay is one of the key factors in understanding and influencing HCCI combustion. One reviewer described that the IQT is a method to estimate ignition delay in heterogeneous combustion and not homogeneous combustion, while another added that the basic fundamental ignition delay work with IQT seems to be worthwhile.

Question 2: Approach to performing the research and development (Written responses from 3 of 9 reviewers)

Two reviewers noted that the approach is well focused, well-executed, balanced and appropriate. One of the reviewers added that the ignition delay setup may need to address higher chamber pressures in order to address those that are not in the HCCI regime. The last reviewer simply commented that IQT seems to be a nice apparatus to study ignition delay.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 3 of 9 reviewers)

Responses were positive in general. One person commented that the results are very interesting, although expected, with good explanation on a molecular basis. Another person simply noted that there was some good progress on testing. The last reviewer noted that the researchers presented good data, though they suggested that perhaps undefined fuels other than n-heptane should be examined to expand this database.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 3 of 9 reviewers)

One reviewer stated that no collaborations were mentioned. Another person suggested that more exchange with Sandia may be helpful and some more industry (either petroleum or automotive) engagement may be helpful. The last reviewer wondered (since this is standard test equipment) if there are others doing this work; if so, this could lead to more collaboration.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 9 reviewers)

One reviewer condoned the idea of performing confirming experiments with a single-cylinder engine with HCCI. One evaluator noted that only collaboration with NRC-Canada is likely to provide an HCCI test system. Another added that collaboration with NRC will certainly be helpful; however, NRC is not included in DOE funding. The last reviewer felt that the future work proposed is very well defined, but can still be expanded if resources are available.

Specific Strengths and Weaknesses (Written responses from 7 of 9 reviewers)

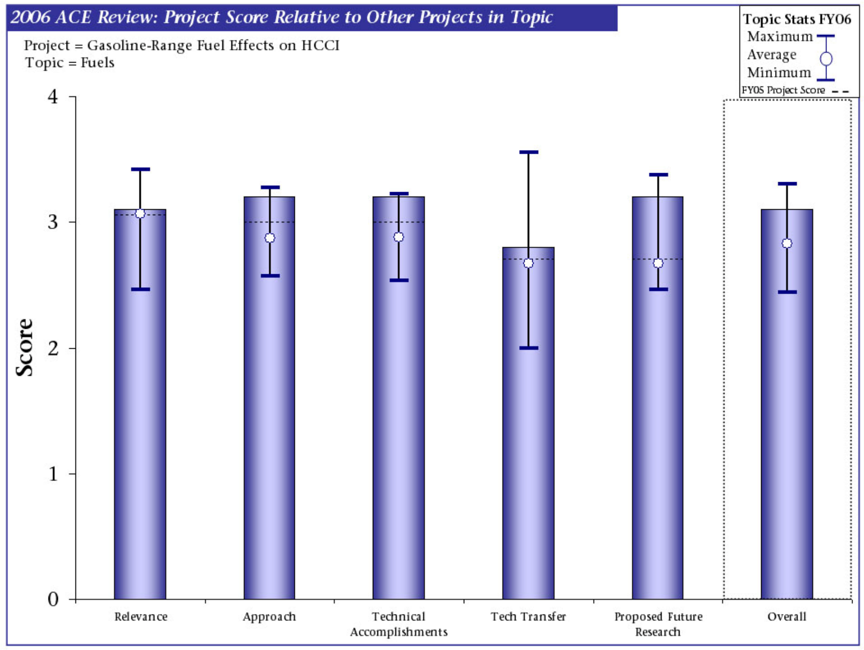
- Specific Strengths
  - Development of a tool to understand fuel effects on compression ignition under a variety of conditions.
  - Like to focus of the project and simple test facility.
  - Potentially useful data.
  - Very appropriate tool to investigate ignition delay which is important for HCCI or comparable combustion techniques.
  - Fundamental understanding of the chemicals.
  - Ignition delay is important to all combustion researchers.
  - IQT is cheap and fast tool to study fuel properties.
- Specific Weaknesses
  - No correlation with engine testing.
  - Must show correlation with some other experiments—can you show ignition delay similar to some engine under some condition to prove the simulation is meaningful?
  - No plan to have the results included into other DOE funded projects.
  - Results are probably not relevant to advanced combustion systems.
  - Fuel selection or variety.
  - Need to overcome the weakness of the IQT with better fuel injection.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 6 of 9 reviewers)

- Need to coordinate with engine studies of low temperature combustion to obtained representative conditions for the IQT testing and to validate the method as useful for describing fuel effects of IQT; investigate expansion of work to gasoline HCCI conditions and gasoline-like fuels.
- Include Sandia investigations (Lyle Pickett, Mark Musculus, et al) for soot formation. Also include simulation code programmers.
- They need to create a homogeneous compression ignition test fixture or engine.
- May put a better injector that can achieve homogenous charge into IQT, rather than study the current injector.

Gasoline-Range Fuel Effects on HCCI, Bruce Bunting of Oak Ridge National Laboratory

Brief Summary of Project



The vision of this research effort is to study the effects of fuel chemistry and properties on advanced combustion regimes with gasoline range fuels. The team will gain further understanding of fuel behavior under operating conditions of HCCI engines, study combustion behavior of fuels derived from new sources such as ethanol, vegetable derived fuels, heavy crude oil, and other non-traditional sources, provide experimental and modeling data which can be used to anticipate and optimize engines and controls for new fuels, and provide experimental and modeling data which can be used to help shape fuel decisions in the future.

Question 1: Relevance to overall DOE Objectives (Written responses from 4 of 10 reviewers)

The reviewers agreed that this project was relevant to the overall DOE objectives. One reviewer stated that understanding of the effects of fuel chemistry and properties of gasoline range fuels on advanced combustion systems is consistent with and supports the overall DOE objectives. Another indicated that the project fits the desired goals of understanding HCCI combustion with a set of fuel parameters. It was noted that Cummins currently does not have much interest in this field. A comment was made that the engine needs to be upgraded with direct injection and variable valve timing technology. The reviewers also liked the thoroughness of the fuel matrix.

Question 2: Approach to performing the research and development (Written responses from 3 of 10 reviewers)

Several reviewers complimented the research approach. One pointed out that testing of "real" gasoline type fuels and components in real engines is a valuable approach. Another liked the investigator's attempt to list critical fuel parameters and then show the responses to these parameters. It was pointed out that the statistics presented with the data and the plots showed a lot of data scatter.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 10 reviewers)

Reviewers mentioned good progress and commended the comprehensive data analysis. One person stated that it looks like good progress has been made in identifying the effects of fuel composition on engine performance. A comment was made that Oak Ridge National Laboratory completed the tasks that seem to be in their scope of work. Someone thought that it would be beneficial to define the confounding parameters mentioned by the principal investigator during the presentation. He added that it is not easy to keep these experiments "clean." It was also noted that identifying the octane number importance to HCCI gasoline operation was significant.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 2 of 10 reviewers)

The reviewers mentioned collaboration with AVL and good relationship with ExxonMobil.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 4 of 10 reviewers)

The comments were relatively positive with a few suggestions for improvement. One reviewer liked the presented plans. Another suggested partnering with an entity that can provide a well-running direct injection HCCI engine. A comment was made that future plans seem a bit ambiguous in regards to connection with industry and answering key questions that will drive improvements. It was also mentioned that all the elements outlined for future work are worthy, but it is not clear how they will fit together.

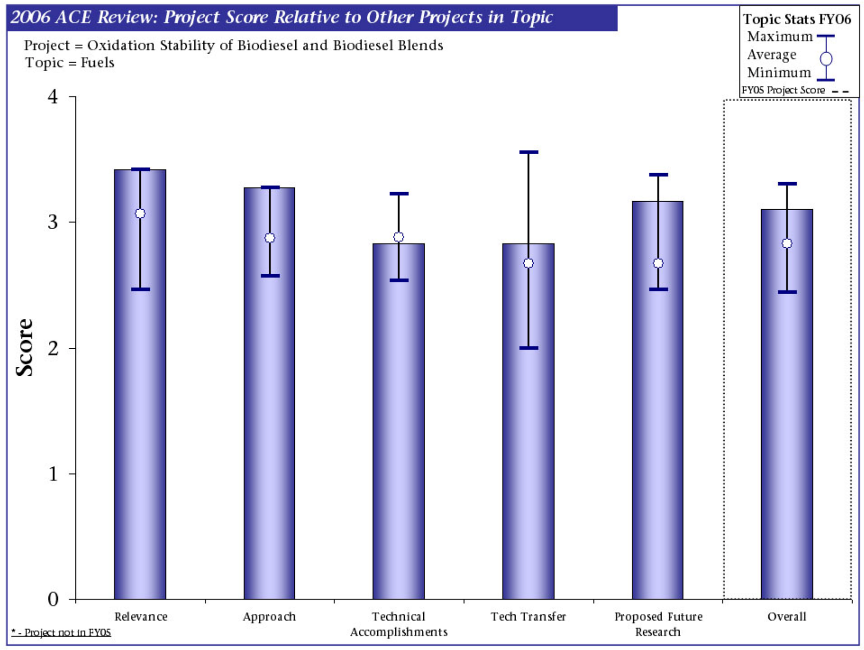
Specific Strengths and Weaknesses (Written responses from 5 of 10 reviewers)

- Specific Strengths
  - Investigation of the performance of a wide variety of fuels on gasoline HCCI combustion; this is an important field of study.
  - Statistics and display of raw data were helpful. It appeared that a design of experiment was used to create the test, but it was a bit unclear given the brief mention of the "confounding" factors which could include such basic items as air-fuel ratio. I liked the comment regarding other researchers testing HCCI and its controls evaluating their results in the light of fuel sensitivity!
  - Effect of gasoline like fuels and variations in fuel, with an effort to understand the relevant parameters.
  - Good fuels parametric work.
  - Fundamental understanding of the various fuel properties and ways to quantify their differences.
- Specific Weaknesses
  - Use of port fuel injection engine. Little optimization of combustion in the engine.
  - Would like to see a complete list of critical parameters followed by what was left out of the experiment or uncontrolled (basic assumptions). A number of the presentations skipped over this.
  - EVC is only one way to achieve HCCI combustion and probably not the most likely to see production.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 5 of 10 reviewers)

- Spend more time developing a good combustion system with direct injection (or obtain one from a partner) before conducting fuel effect studies.
- Good work.
- Keep going and identify new test-bed engine. Look for at least some data from a production-like engine, not just EVC and VCR research engines.
- Future work appears appropriate; looking forward to variable compression ratio and wider fuel component work.
- Should explore fuel effects on the HCCI region boundary.

Oxidation Stability of Biodiesel and Biodiesel Blends, Robert McCormick of the National Renewable Energy Laboratory



Brief Summary of Project

National Renewable Energy Laboratory researchers are working to determine if 100% biodiesel (B100) stability can be predicted by accelerated tests and to determine if B100 stability is predictive of the stability of B5 and/or B20 blends. In addition, the team will relate accelerated stability test results to more real world scenarios and will recommend stability test methods and limits for B100, B20, and if necessary B5 blends.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 12 reviewers)

Reactions were positive in general with a few concerns being raised. One person simply stated that the advancement of biodiesel consistent with DOE goals. Another person commented that this work is critical to the commercialization of biodiesel fuels, but this reviewer was concerned about the size of the impact of biodiesel on DOE's petroleum reduction because the yield per acre will be low. One evaluator commented that this project appears to be required work for biofuels. Others also had favorable responses. One person noted that stability of biodiesel is one of the major concerns with bio-fuels. Another person commented that the project is directly targeted on the major barrier for biodiesel, the fuel's oxidation stability. A reviewer commented that the project is important for future application, adding that the influence on combustion and exhaust system fits well to the industrial needs. The final reviewer commented that it is clear that product quality concerns are a barrier to biodiesel use, and since increased use meets a DOE goal, the project is relevant. They concluded by stating that normally they would not view this type of work as "National Lab worthy," but agree that in this case it is.

Question 2: Approach to performing the research and development (Written responses from 3 of 12 reviewers)

The few responses were positive, with one person noting that the range of different bio-fuels with their original sources (soy, rapeseed, etc.) is important. The last comment was that the approach seems logical and methodical. They added that they thought the work with Howard Fang sounded interesting, and would have liked to have heard more - the more detailed chemical knowledge that is available the more readily product quality improvement can be achieved.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 12 reviewers)

There were only a handful of responses to this question. One person simply stated that it seems like good progress to date. Another reviewer admitted that they do not have a good reference, but it appears that data is only now flowing, so they were not sure how this compares with the milestone schedule. They added that this work seems very necessary, noting that they were not sure how the standards are formed regarding tests (i.e. ASTM committee recommendations), but they are hopeful this work is connected. Another person commented that the progress demonstrated up to now is slow; adding that the improvement in timing was welcome.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 12 reviewers)

Reactions were mixed, but were generally positive. One person simply noted that the collaboration seems quite good. Another noted that the researchers are working with Cummins and others. One reviewer noted the cooperation with Cummins, ASTM and others seem to work OK. Another had similar comments, adding that it is good that there is some collaboration with ASTM and at least one OEM (Cummins) since these groups will play key roles in determining specifications for biodiesel use. One reviewer had an opposing point of view, stating that the collaboration was not quite clear, adding that the fact that it is half-funded from the National Biodiesel Board does not necessarily means that there is a close cooperation. The final reviewer suggested that the researchers might want to widen collaboration in the future.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 3 of 12 reviewers)

One person noted that the plans seem reasonable. Another person felt that the accelerated tests are very important for quality checks of bio-fuels. They added that quality (depending on the supplier) is often lacking behind the standards. The last reviewer liked Kevin's (and the reviewer's) question about hydrotreating biodiesel. They added that they thought that there is a wide range of ways to improve biodiesel stability and would like to see an honest comparison of their merits and demerits.

Specific Strengths and Weaknesses (Written responses from 7 of 12 reviewers)

- Specific Strengths
  - Systematic study of biodiesel oxidation and how to predict it with accelerated test methods.
  - Really good focus.
  - Much-needed hard data.
  - Topic is one of the major issues with bio-fuels.
  - Useful in better characterizing stability issues.
  - Stability of biodiesel is a very important issue.
  - Breadth and scope and industry involvement.
- Specific Weaknesses
  - Work plan does not include engine tests.
  - Relatively qualitative and early stage at present.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 12 reviewers)

- The aged B100 samples should be blended into the diesel fuels at B5 and B20 and oxidation properties measured.
- If the presenter feels the program is too large, recommend that you reduce scope to fit reasonable timing.
- Keep going as planned.
- Experts from oilers should be more involved.
- Show how to validate the accelerated aging tests, e.g., by "real-world" long term testing or engine testing.
- Future work plans seem appropriate, might want to eventually look in more depth at mechanisms behind biodiesel stability issues and work with additional collaborators.
- Need to expand the study to biofuels from different resources.

MERIT REVIEW AND PEER EVALUATION FORM

Evaluation Form **May 2006**

TOPIC: ______________________________

PRESENTER: ______________________________

REVIEWER NAME: ______________________________

Using the following criteria, please rate the **work** presented in the context of the program objectives. Please provide **specific** comments to support your evaluation.

1. Relevance to overall DOE objectives.

Numeric rating (circle one below)

4 = Outstanding, the project is sharply focused on one or more key technical barriers to development of clean, efficient engines.
3 = Good, most aspects of the project will contribute to significant progress in overcoming these barriers.
2 = Fair, some aspects of the project may lead to progress in overcoming some barriers.
1 = Poor, the project is very unlikely to make significant contributions to overcoming the barriers.

Specific comments

2. Approach to performing the research and development

Numeric rating (circle one below)

4 = Outstanding, it is difficult for the approach to be improved significantly.
3 = Good, the approach is generally well thought out and effective, but could be improved in a few areas.
2 = Fair, the approach has significant weaknesses.
1 = Poor, the approach is not responsive to the project objectives.

Specific comments

3. Technical Accomplishments and Progress toward project and DOE goals

Numeric rating (circle one below)

4 = Outstanding, the project has made excellent progress toward overcoming one or more key DOE program technical barriers; progress to date suggests that the barrier(s) will be overcome.
3 = Good, the project has shown significant progress toward overcoming barriers.
2 = Fair, the project has shown a modest amount of progress in overcoming barriers, and the overall rate of progress has been slow.
1 = Poor, the project has demonstrated little or no progress toward overcoming the barriers.

Specific comments

4. Technology Transfer/Collaborations with industry, universities, and other laboratories

Numeric rating (circle one below)
4 = Outstanding, close coordination with other institutions is in place; industrial partners are full participants.
3 = Good, some coordination exists; full coordination could be accomplished fairly quickly.
2 = Fair, some coordination exists; full coordination would take significant time and effort to initiate.
1 = Poor, most or all of the work is done at the Lab with little outside interaction.

Specific comments

5. Approach to and Relevance of Proposed Future Research

Numeric rating (circle one below)
4 = Outstanding, future work plan builds on past progress and is sharply focused on one or more key DOE program technical barriers.
3 = Good, future work plan builds on past progress and generally addresses removing or diminishing barriers in a reasonable timeframe.
2 = Fair, future work plan may lead to improvements, but should be better focused on removing or diminishing key barriers within a reasonable time period.
1 = Poor, future work plan has little relevance or benefit toward eliminating barriers.

Specific comments

6. Specific Strengths of This Research

7. Specific Weaknesses of This Research

8. Specific Recommendations or Additions/Deletions to Work Scope

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Acronym	*Definition*
A/F	Air/fuel ratio
ACE	Advanced Combustion Engine
ACES	Advanced Collaborative Emissions Study
ACM	Advanced Ceramic Material
AEC	Advanced Engine Combustion
ANL	Argonne National Laboratory
AOP	Annual Operating Plan
APS	Advanced Photon Source
APU	Auxiliary power unit
ASTM	American Society for Testing and Materials
B5	5% biodiesel blend (with 95% conventional diesel)
B20	20% biodiesel blend (with 80% conventional diesel)
B100	100% biodiesel blend
BMEP	Brake Mean Effective Pressure
CAI	Controlled auto ignition
CDPF	Catalyzed diesel particulate filter
CFD	Computational Fluid Dynamics
CHEMKIN	Chemical Kinetics software
CI	Compression Ignition
CIDI	Compression Ignition Direct Injection
CLEERS	Crosscut Lean Exhaust Emission Reduction Simulation
CO	Carbon monoxide
CRADA	Cooperative Research and Development Agreement
DDC	Detroit Diesel Corporation
DEER	Diesel Engine Emissions Reduction
DF-2	#2 Diesel Fuel
DI	Direct Injection
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DOI	Duration of Injection
DPF	Diesel particulate filter
E100	100% ethanol fuel
E85	85% ethanol fuel with 15% gasoline
EERE	DOE Office of Energy Efficiency and Renewable Energy
EGR	Exhaust Gas Recirculation
EPA	U.S. Environmental Protection Agency
EVC	Exhaust Valve Closing
FACE	Fuels for Advanced Combustion Engines
FCVT	FreedomCAR and Vehicle Technologies Program
FTP	Federal Test Procedure
FMEA	Failure modes and effects analysis
FY	Fiscal year
GTL	Gas-to-liquid fuels
HC	Hydrocarbons
HCCI	Homogeneous Charge Compression Ignition
HD	Heavy-duty

Acronym	*Definition*
HECC	High-Efficiency Clean Combustion
HSDI	High Speed Direct Injection
ICE	Internal Combustion Engine
IMEP	Indicated Mean Effective Pressure
IQT	Ignition Quality Tester
ISFC	Indicated Specific Fuel Consumption
KIVA	Modeling code developed at Los Alamos
LANL	Los Alamos National Laboratory
LD	Light-duty
LES	Large Eddy Simulation
LIF	Laser Induced Fluorescence
LLNL	Lawrence Livermore National Laboratory
LNT	Lean NOx Trap
LTC	Low-Temperature Combustion
MECA	Manufacturers of Emission Controls Association
MIT	Massachusetts Institute of Technology
MOU	Memorandum of Understanding
NAC	NOx Adsorber Catalyst
NOx	Oxides of nitrogen
NTE	Not-to-exceed
NRC	Natural Resources-Canada
NVO	Negative valve overlap
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PCCI	Premixed Charge Compression Ignition
PDF	Probability Density Function
PFI	Port Fuel Injection
PI	Principal Investigator
PIV	Particle Image Velocimetry
PLIF	Planar laser induced fluorescence
PM	Particulate matter
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
ROI	Rate of Injection
SAE	Society of Automotive Engineers
SCCI	Stratified Charge Compression Ignition
SCE	Single cylinder engine
SCR	Selective Catalytic Reduction
SI	Spark ignition
SiC	Silicon Carbide
SNL	Sandia National Laboratories
SOI	Start of Injection
SOW	Statement of Work
SpaciMS	Spacially Resolved Capillary Inlet MS
SV	Space Velocity
UIC	University of Illinois-Champaign

Acronym	*Definition*
USCAR	U.S. Council for Automotive Research
UW	University of Wisconsin
UW/ERC	University of Wisconsin Engine Research Center
VCR	Variable Compression Ratio
VGT	Variable Geometry Turbocharger
VOC	Volatile Organic Compounds
WSU	Wayne State University
XPS	X-Ray Photoelectron Spectroscopy
XRD	X-Ray Diffraction

A Strong Energy Portfolio for a Strong America
Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as vital new "energy carriers."

The Opportunities
Biomass Program
Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program
Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program
A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program
Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program
Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program
Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program
Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program
Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program
Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program
Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and businesses

Wind & Hydropower Technologies Program
Harnessing America's abundant natural resources for clean power generation

To learn more, visit www.eere.energy.gov

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