VTP Fuel & Lubricant Technologies

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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VTP Annual Merit Review

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VTP Fuel & Lubricant Technologies

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Mission

Enable advanced combustion through improved understanding of fuel-property impacts, evaluate next-generation biofuels & develop efficiency-improving lubricants

Funding in millions	**FY 2011** . Approp.	**FY 2012** Approp.	**FY 2013** Request
Fuel and Lubricant Technologies	$10.7	$17.9	$11.6

Activities

- Chemical and physical fuel property exploitation
- Next-generation biofuel fit-for-service evaluation
- Lubricant additives and base oil development
- Open, bench-scale lubricant testing methodology
- Fully-formulated oil fit-for-service evaluation
- Supporting analytical work

Goals

- By *2020,* demonstrate expanded operational range of advanced combustion regimes to 75% of LD Federal Test Procedure
- By *2015,* demonstrate cost effective lubricant with 2% fuel economy improvement

Recent Competitive Awards

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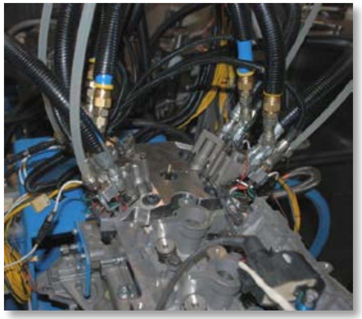
- 4 Fuels Awards
  - Ford: Fuel properties to enable lifted-flame combustion
  - MIT: supplementary alcohol injection for improved SI efficiency
  - NREL: evaluate various oxygenates for suitability as drop-in fuel components
  - Univ. Wisconsin: Optimize fuel-based combustion control of novel combustion strategies in light- and heavy-duty vehicles
- 4 Lubes Awards
  - Ford: RD&D on polyalkylene glycol (PAG)-based engine oil technology to reduce engine friction relative to current mineral and synthetic oils
  - MIT: segregated engine parts with tailored lubricants for each
  - ORNL: Ionic liquid multifunctional (anti-wear and friction modifier) lubricant additives to enable higher VI oils
  - ANL: Boron-based lubricant additives for improved efficiency and durability

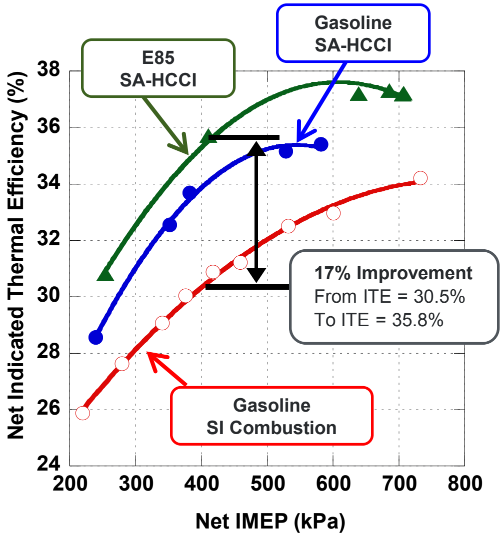
Efficiency and emissions opportunities for enabling low temperature combustion

Enables efficiency improvement and load expansion for Spark Assisted HCCI

- Efficiency improvement attributed to differences in thermochemical properties
- Load expansion attributed to higher octane for more optimized combustion phasing with acceptable pressure rise rates

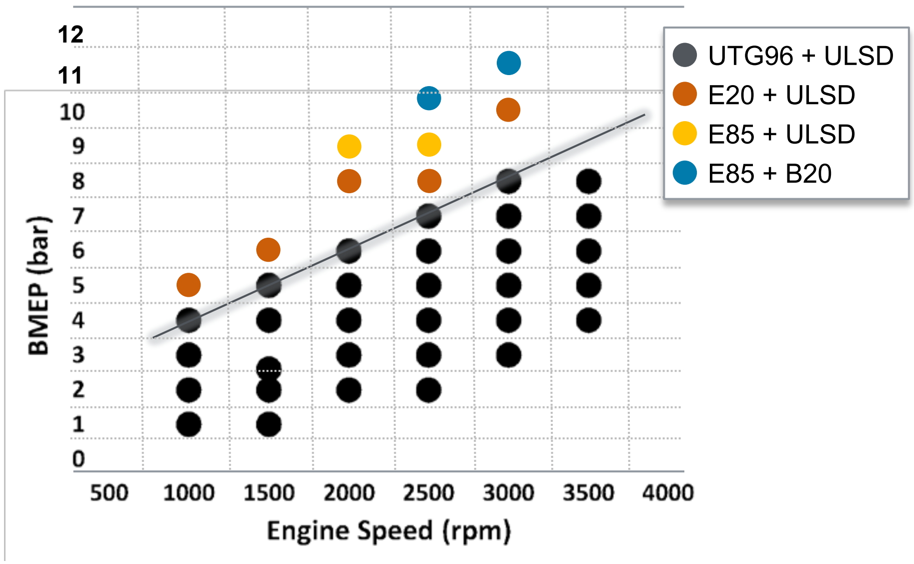


Research engine with fully flexible valve system, boosting, and EGR system.



Enables load expansion with RCCI combustion in a multi-cylinder engine

- Higher reactivity stratification for reactivity controlled compression ignition (RCCI) multi-fuel approaches
- Demonstrated efficiency, emissions, and load expansion improvements with ethanol and bio-diesel blends



Structure-Property Correlations for Unconventional Fuels

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Improved understanding of fuel chemistry is essential to best utilize unconventional fuel sources.

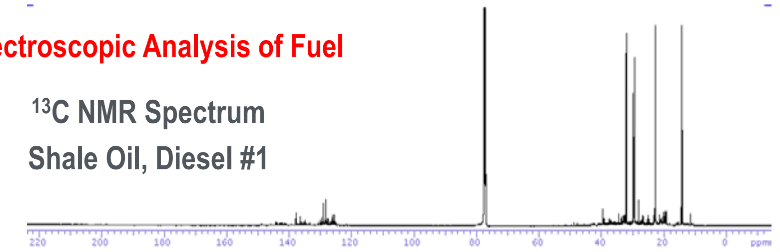
Fuels from unconventional sources

- Shale oil, oil sands, renewable diesel, etc.
- Vary in molecular structure
- Differ in their performance properties

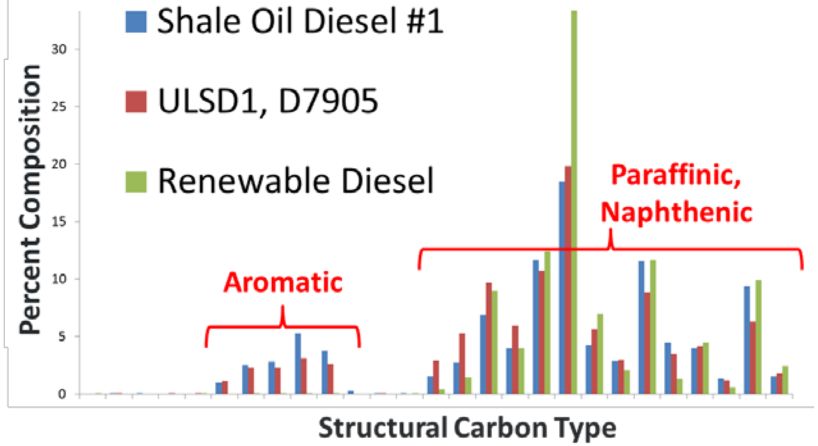
Correlating fuel molecular structure with performance

- Generate spectroscopic data to quantify fuel component types
- Reduce data sets to facilitate correlations with performance data
- Assemble lubricity, seal swell, and soot formation performance data
- Derive structure – property relationships

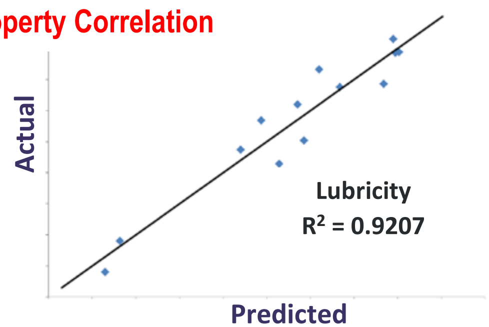
Spectroscopic Analysis of Fuel



Fuel - Structure Correlation



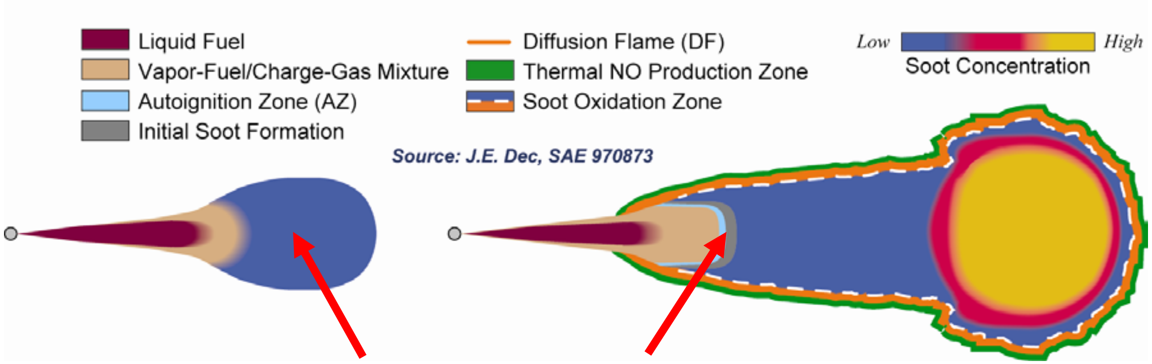
Structure - Property Correlation



The primary pathway for "the biodiesel NOx increase" shown

- Why does biodiesel tend to increase engine-out NOx emissions?
  - Understanding will help tailor combustion to mitigate NOx increase

- Accomplishments:
  - Showed that primary factor leading to the NOx increase appears to be ignition and combustion of mixtures that are closer to stoichiometric than for diesel fuel
    - Longer residence times, higher temperatures → more thermal NOx formation



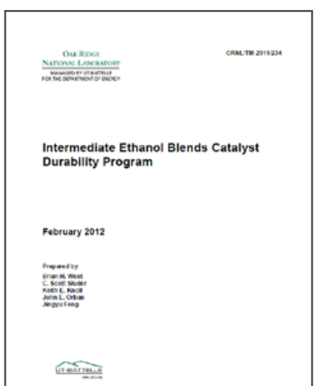
Mixtures closer to stoichiometric when fueling with biodiesel

SAE John Johnson and SAE Arch T Colwell Awards for outstanding research

Improved Biofuel Utilization

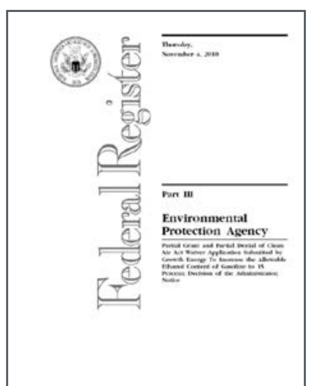
Increased utilization with legacy fleet

- Intermediate ethanol blends studied since 2007
  - $44M effort
  - SNREs, Vehicles, Infrastructure materials compatibility, etc
- Vehicle emissions testing and aging at three sites
  - 86 vehicles, >6.5 million miles
  - >300,000 gallons of fuel
  - Approximately 1000 emissions tests
- EPA cited DOE Studies in partial waiver



Intermediate Ethanol Blends Catalyst Durability Program

February 2012



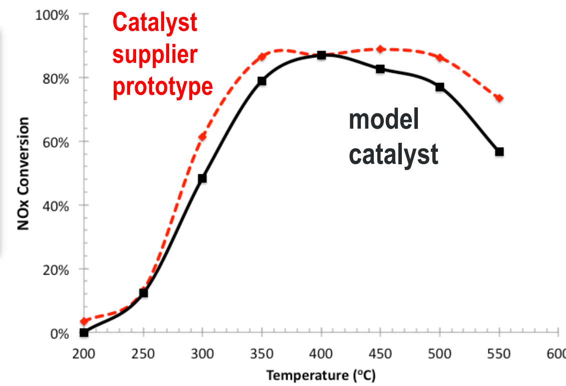
Federal Register

Part III

Environmental Protection Agency

Enabling lean NOx control with non-platinum metal

- Silver-alumina very effective with oxygenated reductant
- Lean-burn with biofuels for improved fuel economy and biofuel utilization



*Silver-alumina catalysts can yield **>90% NOx conversion** under lean conditions (ethanol reductant in this experiment)*

European lean-burn BMW 120i

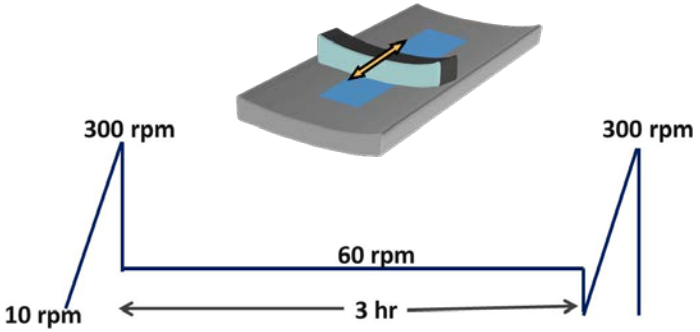
Lubrication Strategies/Tasks

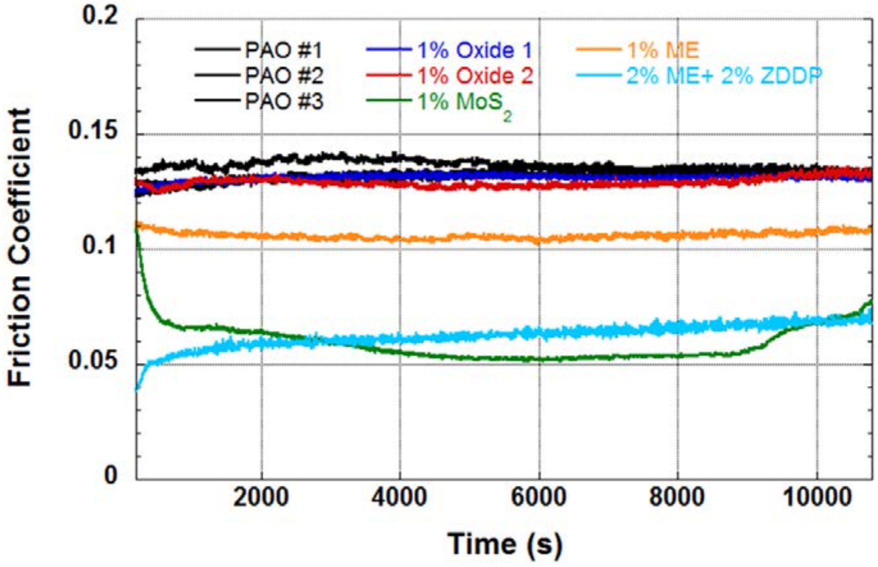
1. **Predictive modeling** - Integration of (continuum) component parasitic friction loss models into subsystems and vehicle level packages – 'what if' parametric studies
2. **Develop Science/Mechanistic Based Models** of Parasitic Losses and Durability/Reliability
3. **Lubricant Technology Development** – Develop advanced lubricants (basefluids and additives) that reduce frictional losses while maintaining or exceeding other performance metrics (durability, reliability, corrosion, deposits, etc.
4. **Engineered Surface Technology** Development – Develop advanced engineered surfaces (textures, designs, materials and coatings) that mitigate parasitic losses from a systems approach. Go beyond current ferrous based tribological systems.
5. **Validation of Modeling and Technologies** – Develop protocols to improve the fidelity of models and technologies. Improve correlation between labscale tests and engine/vehicle tests. Develop high fidelity databases for models and simulation of parasitic losses. Lab-Rig-Engine-Vehicle Validation Studies

Lubricant Additive Studies

Developing common set of test protocols to evaluate frictional behavior of advanced additives (friction modifiers)

- Common test protocols to evaluate frictional behavior of low-friction additives using ring-on-liner configuration



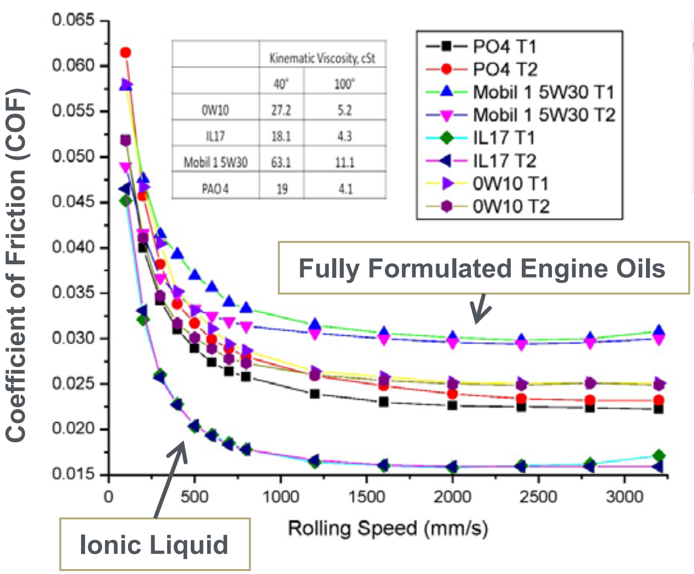


- Comparison of nanoparticulate additives and chemical additives show significant impact on friction response
- Characterization of surfaces in-progress to determine differences in surface finishes and formation of tribofilms

New Lubricant Technologies

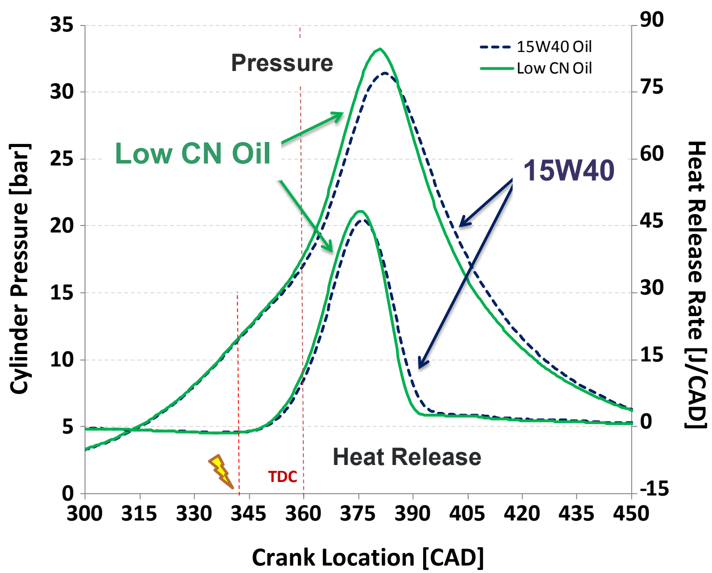
New classes of lubricants and additives based on ionic liquids (IL)

- More effective boundary lubrication – up to 40% friction reduction compared to fully formulated oils (lab scale)
- Enhanced engine durability due to superior functionality via forming a protective surface boundary film
- GM CRADA, FOA-239 with Shell



Low reactivity lubricants for more efficient operation

- Shown to mitigate spark-ignition gasoline engine knock
  - Allows for improved combustion phasing at higher loads
  - Use of higher compression ratio
- CRADA under development with Southwest Research Institute



Data courtesy of SwRI (Alger, 2012)