NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Impact of Biodiesel Metals on Aftertreatment System Durability



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Vehicle Technologies Program Merit Review – Fuels and Lubricants Technologies

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Project ID: FT011

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Overview

Timeline

Start date: Oct 2011

End date: Sept 2012

Percent complete: 66%

Program funded one year at a time

Budget

Total project funding

FY11: $1.1 M

FY12: $1.3 M – estimated

NBB cooperative research and development agreement (CRADA) provides around $500K to cost-share biodiesel research

Barriers

VTP MYPP Fuels & Lubricants Technologies Goals

- By 2015 identify heavy-duty (HD) non-petroleum-based fuels that can achieve 15% petroleum displacement by 2030

Partners

- National Biodiesel Board (NBB) and member companies
- Manufacturers of Emission Controls Association (MECA) and member companies
- Engine Manufacturers Association (EMA) and member companies
- Coordinating Research Council (CRC) and member companies
- Ford Motor Company
- Caterpillar
- Oak Ridge National Laboratory (ORNL)

Relevance/Objective

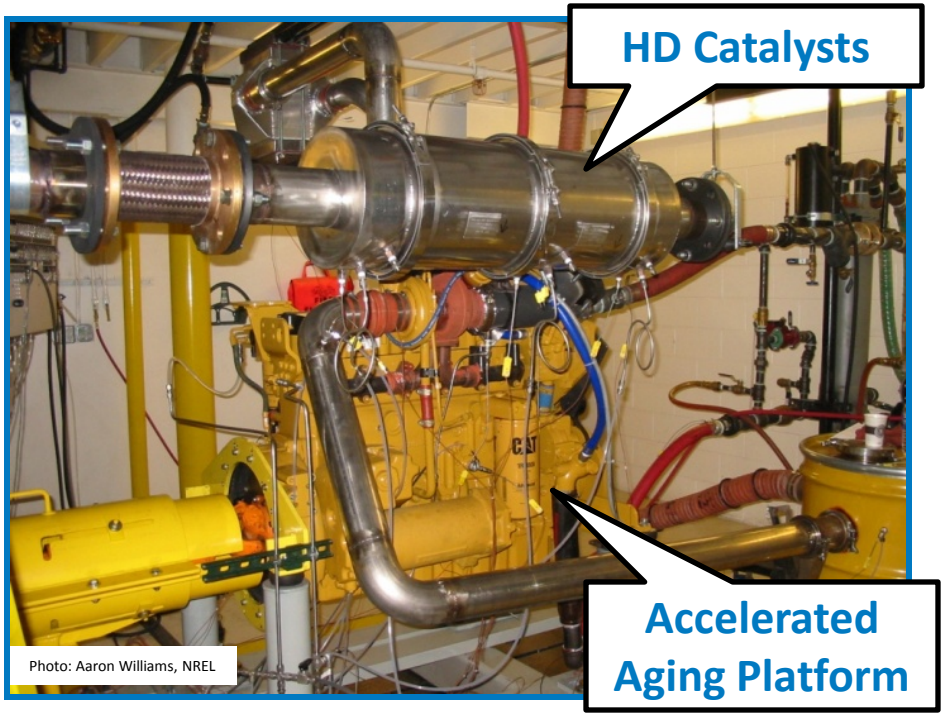
- Alkali and alkaline earth metals can be found in biodiesel at very low levels (ASTM D6751 allows < 5ppm Na + K and < 5ppm Ca + Mg in B100)
- These fuel metals form exhaust ash that can impact catalyst durability
- Project Objective – Determine the impact of biodiesel metals on the full useful life durability of modern diesel exhaust aftertreatment systems
- Relevance – Help remove technical barriers to the more widespread use of biofuels for petroleum displacement

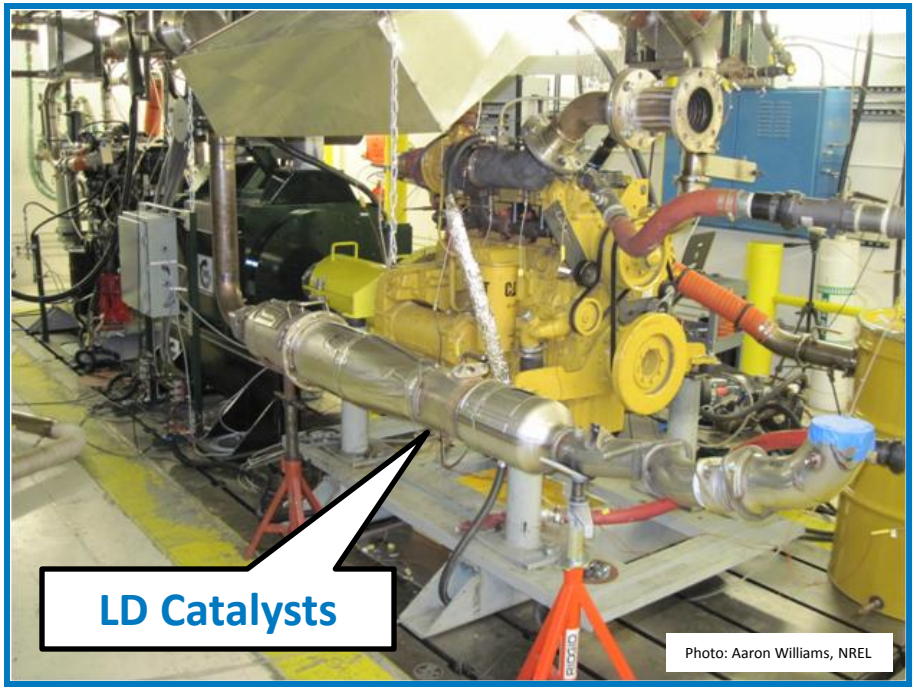
Milestones

Date	Milestone or Go/No-Go Decision	Status
Aug-11	**Impact of biodiesel ash-forming constituents on selective catalytic reduction (SCR) catalyst performance.** Effects of Na and K on both light-duty (LD) and HD configurations are being measured in accelerated tests.	Complete

Approach

- Conducted accelerated catalyst aging
- Accelerated metal exposure by doping fuel with high levels of metal impurities (Na, K and Ca)
- Tested multiple catalyst systems from both HD and LD applications
  - Catalyst aging included diesel oxidation catalyst (DOC), diesel particulate filter (DPF) and SCR catalysts
  - Catalyst aging and emissions testing conducted by NREL
  - Materials characterization and further emissions testing conducted by ORNL, Ford and MECA





Test Apparatus

- Aging full production exhaust systems from 2011 Ford F250 pickup
- Aging conducted on Cat C9 engine
- Engine is oversized for these catalysts so engine operating points were selected to achieve appropriate space velocities and temperatures

Test Cycle

- A three-mode, one-hour test cycle was developed for catalyst aging
- Space velocity and catalyst temps were selected from data from an F250 truck operating on the FTP and US06 cycles
- 100-hour accelerated test simulates 150k miles of B20 operation
- Emissions evaluation conducted every 10 hours on an F250 truck over the FTP on a chassis dynamometer


Photo: Aaron Williams, NREL

Engine Mode	Time (min)	SCR Space Velocity (1/hr)	SCR inlet T (°C)
1 (low-temp operation)	15	20k	200
2 (high-temp operation)	15	57k	340
3 (regen operation)	30	57k	700

Test fuels

Four separate catalyst systems were tested, one each with the following four fuels:

1. ULSD (baseline test)
2. B20 + 14 ppm Na doped using dioctyl sulfosuccinate sodium salt
3. B20 + 14 ppm K doped using potassium dodecylbenzene sulfonate
4. B20 + 14 ppm Ca doped using calcium naphthenate


Photo: Aaron Williams, NREL

Dioctyl sulfosuccinate sodium salt


Photo: Aaron Williams, NREL

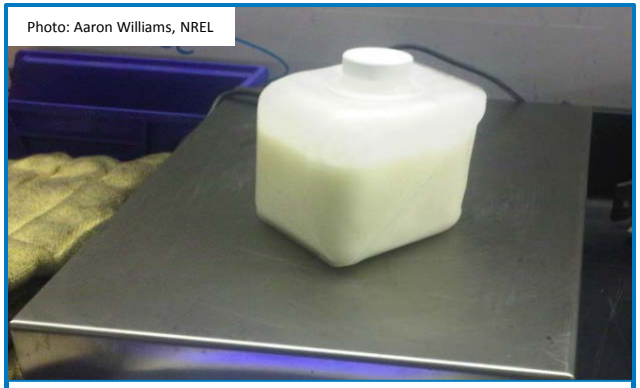


Photo: Aaron Williams, NREL

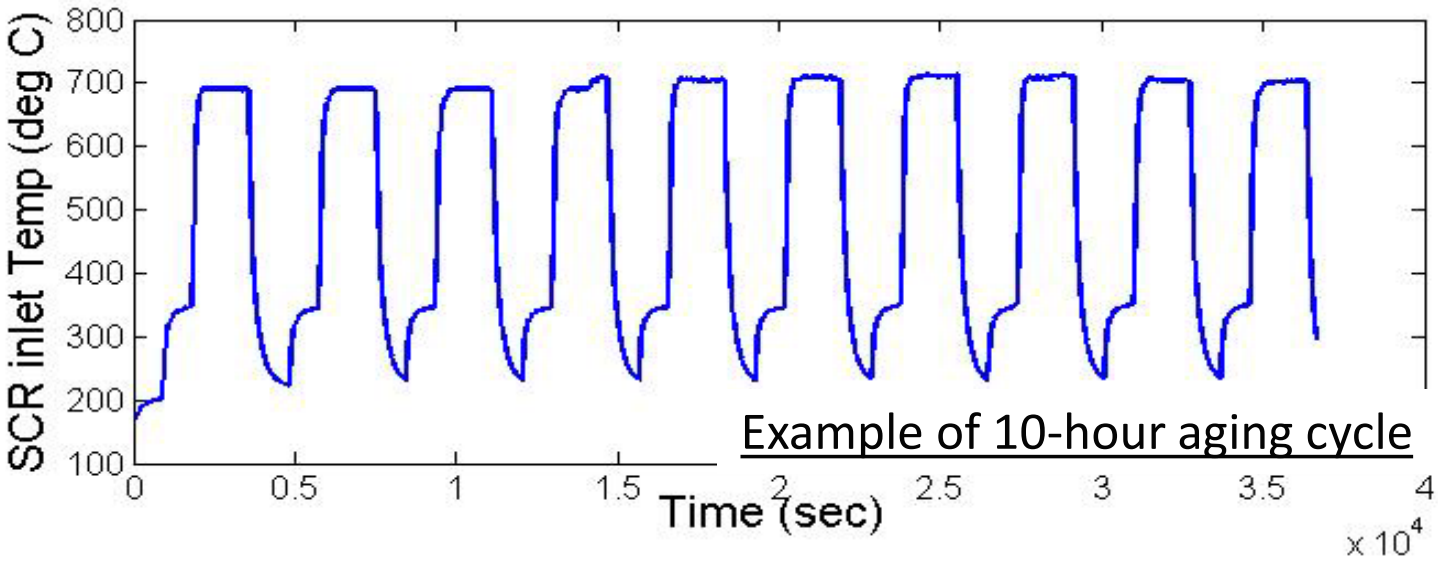
Potassium dodecylbenzene sulfonate


Photo: Aaron Williams, NREL

Calcium naphthenate

Temperature and Ash Exposure

	SCR > 600 C (hrs)	Avg SCR temp (deg C)	Ash Exposure (grams)
ULSD	45.8	486	28
B20 + Na	43.9	488	66
B20 + Ca	44.8	493	82
B20 + K	45.1	484	59



Example of 10-hour aging cycle

NO_x Emissions

HC Emissions

Summary

- Accelerated test method simulates aftertreatment aging to 150k miles of thermal and fuel ash exposure
- F250 pickup met NO_x and HC emissions standards after simulated 150k miles of exposure to B20 + Na, B20 + K and B20 + Ca
- ORNL and Ford are currently conducting post mortem analysis of aged parts

Collaboration and Coordination

- Research was conducted under a CRADA between NREL and the NBB
- This study was a collaboration with ORNL and Ford
- Significant technical input was provided by an industry steering committee that includes: Manufacturers of Emission Control Association, Engine Manufacturers Association, Caterpillar, Cummins, Case - New Holland, NGK, BASF and Umicore

Proposed Future Work

- Work in 2012 will focus on how biodiesel metals will impact the full useful life durability of HD catalyst systems. HD catalyst systems have a much longer 435,000-mile limit for full useful life durability.
- Research will determine if lower metal limits are necessary to protect catalyst durability during these longer periods of exposure.
- Research will also determine which of the metals (Na, K or Ca) has the most severe impact on catalyst durability.