

Materials-Enabled High-Efficiency Diesel Engines (CRADA with Caterpillar) Project ID: PM020

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Overview

Collaboration between ORNL and Caterpillar, Inc. to make use of advanced powertrain components to achieve and demonstrate significant improvements in engine efficiency to take advantage of advances in new materials

Timeline

- **Baseline experiments – 2009**
- **2nd Law Thermodynamic Analysis -2009**
- **Turbocharger analysis – April 2010**
- **Tier 4 biofuel study – August 2010**

Budget

- **FY2009: \$460K**
- **FY2010: \$240K**

Barriers

- **Inadequate design & performance data, test methods, tools, and durability data for widespread application of advanced materials**
- **Advances in thermal management and advanced combustion necessitate the development and utilization of advanced materials**
- **Material costs**

ORNL partnered with Caterpillar

Objective

Improve diesel engine performance, efficiency, and emissions through the application of materials enabling technologies

Relevant to DOE goal of reaching 55% efficiency in a heavy-duty diesel engine

For FY09:

- » **Perform baseline experimentation to confirm engine performance with Caterpillar specifications.**
- » **Perform 1st and 2nd Second Laws of Thermodynamic analyses of the engine (part of WFO activity).**

For FY10:

- » **Evaluate advanced component on ACERT C15 engine (part of WFO agreement)**

Milestones

FY 2009 Milestone - *Complete*

- **Commissioning of engine and dynamometer (April-09)**
- **Baseline experimentation (May-09)**
- **Identify thermal barrier coating for selected exhaust components.**

FY 2010 Milestones – *In Progress*

- **Evaluate performance of advanced turbocharger concept for improved efficiency and performance (April 2010)**
- **Evaluate the performance of biofuels on selected materials and components (scheduled for August 2010)**

Approach

This CRADA makes use of engine/combustion and materials expertise at Caterpillar and ORNL to provide new insight into the integration of novel materials technologies to better enable high temperature, high pressure engine operation.

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- Engine performance
- Diagnostics & analysis
- Materials characterization



CATERPILLAR

- Engine & tools
- Materials selection
- Technical support

Caterpillar WFOs

- Separate but highly complementary efforts to provide advanced modeling support and component technology on-engine

Materials & Engines approach provides a more complete understanding to better improve combustion, thermal management, emissions & cost reductions.

Summary of Technical Accomplishments

Cell infrastructure is completed and operational

Second-law analysis effort (leveraged with WFO activity) is complete

C15 engine has been broken in

- » **New test cell is fully operational**
- » **Instrumentation, data acquisition, and control systems have been fully commissioned**

Baseline testing of engine has been completed

Transient capability has been established

Advanced component comparison is underway

Technical Accomplishments:

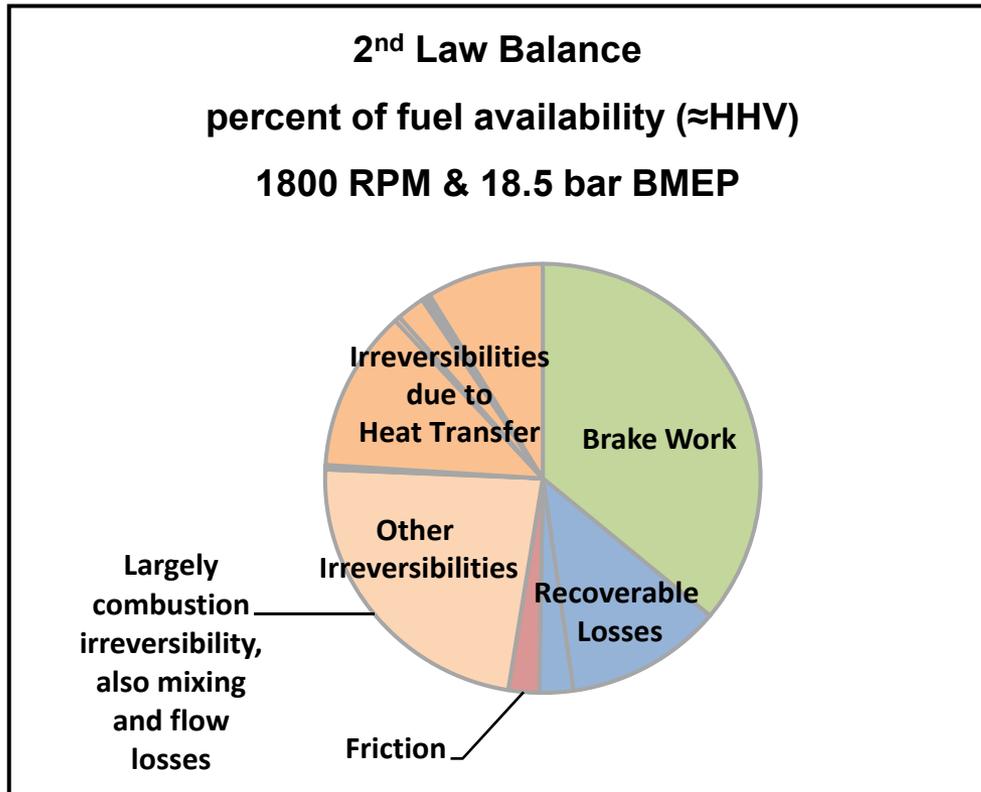
Cell infrastructure has been fully commissioned

- Gas Handling System (including internal plumbing)
- Water Tower (including internal plumbing)
- Fuel Storage & Delivery System (including internal plumbing)
- Room Ventilation & Exhaust (including ducting)
- Dynamometer & controller commissioned

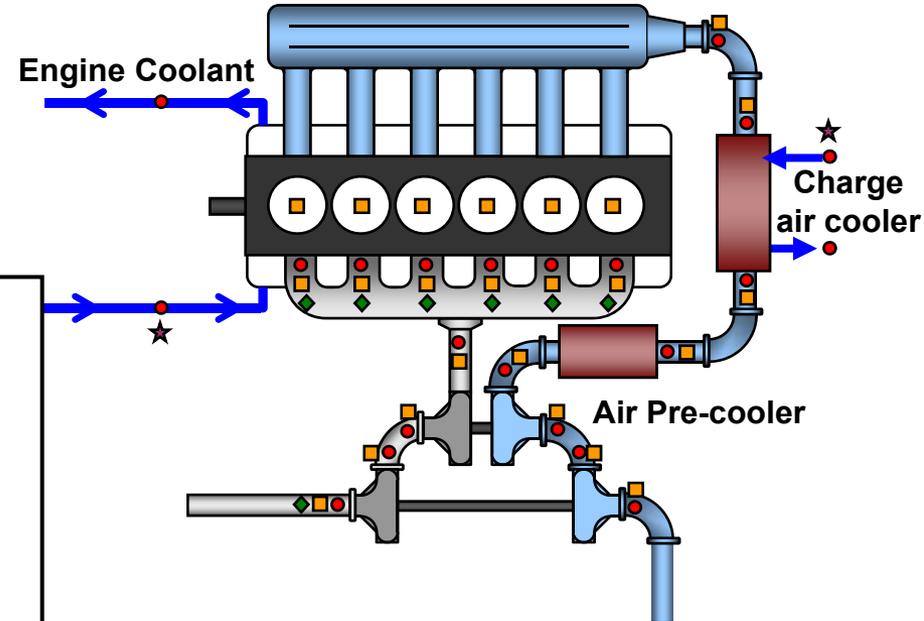


Technical Accomplishments: Instrumentation and 2nd Law analysis is complete

- Second-law analysis provides new insight into efficiency losses and opportunities



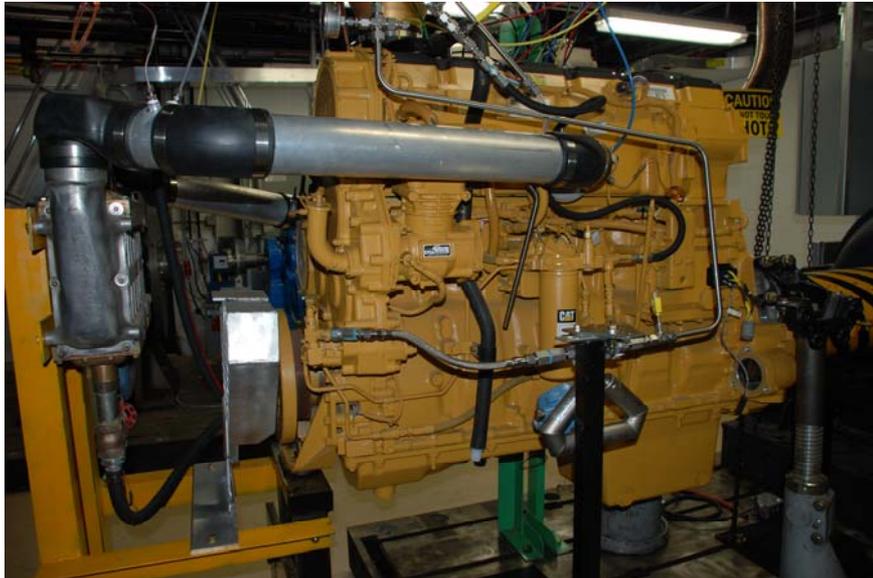
Instrumentation Schematic



- Coupling of experiment and modeling efforts is crucial to identification and implementation of advanced efficiency technologies

Technical Accomplishments: Engine break-in has been completed

Break-in protocol consisted of repeating sequence of steady-state conditions shown in the table until 8 hours of run-time have been logged



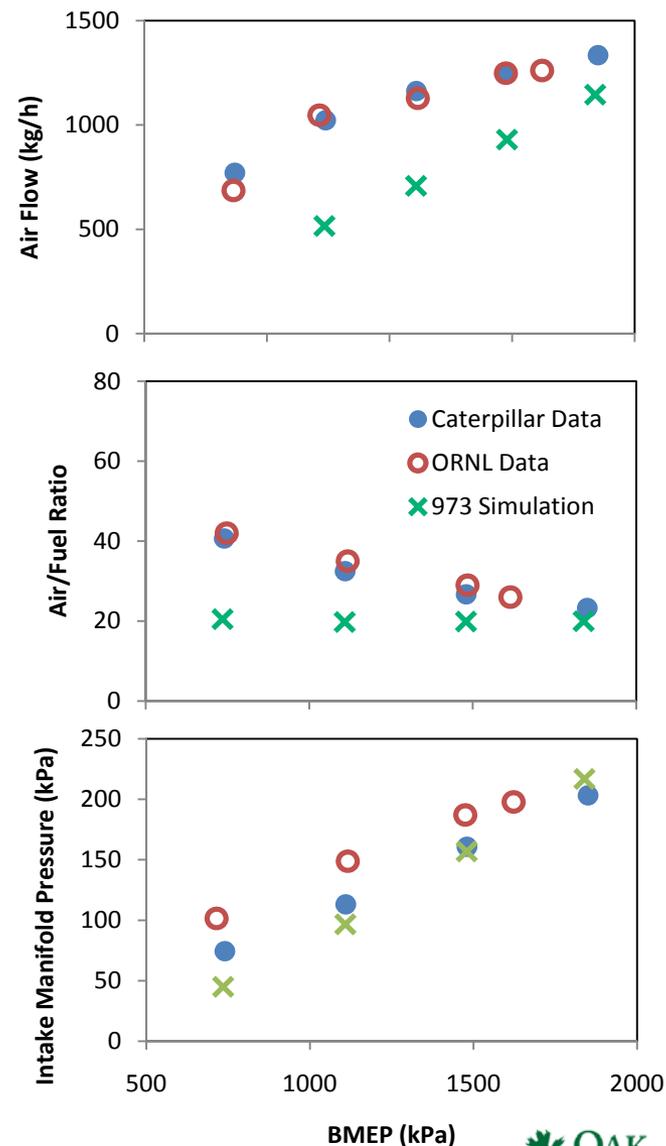
C15 Break-in Protocol			
Speed		Load	Time
Idle	(600 RPM)	0%	10 min
50%	(900 RPM)	0%	10 min
75%	(1350 RPM)	50% (830 ft-lb)	15 min
100%	(1800 RPM)	100% (1050 ft-lb)	55 min



Technical Accomplishments:

Baseline engine experiments have been completed

- Baseline testing of engine
 - » Results suggest different engine control calibrations
 - » Plots shown for 1200 RPM operation



Materials Evaluation Research Plan – Future Work

- 1. Receive and install Tier 4 engine. Engine will be equipped with EGR and emissions control**
 - Engine will be instrumented to assess 1st and 2nd Laws of Thermodynamic analyses
- 2. Evaluate engine performance with biofuels**
 - Efficiency
 - Emissions
 - Materials compatibility
- 3. Analyze components for durability**
 - Non-destructive evaluation
 - Micro-structural analyses
- 4. Temperature, flow rates, combustion data will be used to assess thermal management potential and identify locations for additional modifications**
- 5. Expand research plan to additional components & materials**

Summary

- **We have established a unique CRADA with Caterpillar with the goal of evaluating new materials systems for improved engine efficiency**
 - » **Combines ORNL materials and engine/combustion R&D expertise with industry partner**
 - » **Similarly, materials and engine research staff at Caterpillar are also working together**
- **Installation of C15 engine has been completed**
 - » **Engine break-in completed**
 - » **Baseline experiments completed**
 - **Comparison to Caterpillar-provided data**
 - **Different control calibration**
- **Evaluation of advanced components has begun**