# Materials-Enabled High-Efficiency Diesel Engines (CRADA with Caterpillar)

## Project ID – PM 06

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CATERPILLAR

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OAK RIDGE NATIONAL LABORATORY
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# Overview

## Timeline

- Begin transition of lab space to engine research cell - October 2008
- Commissioning of engine research cell with operational engine & dynamometer – March 2009
- Engine is operational
- Begin material/component evaluation – April 2009

## Budget

- Funding received in FY2008
  - DOE - $400K
  - ORNL (cell infrastructure) - $1000K
- Funding received in FY2009
  - DOE - $180K

## Technical Targets

- Develop supporting materials technology to enable Heavy-Duty diesel efficiency of 55%, while meeting prevailing EPA emission standards (by 2012)
- Engine life greater than 1 million miles (by 2012)

## 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

## Partners

- Caterpillar
  - Materials Performance & Advanced Powertrain Component Development Groups
  - In-kind contributions have consisted of two 600 hp DC dynamometers & a C15 ACERT engine with open control

# Study Objective

***Improve diesel engine performance, efficiency, and emissions through the application of materials enabling technologies. The goal is to reach 55% efficiency in a heavy-duty diesel engine.***

- **For FY08:**
  - **Completed transition of bare laboratory space to a heavy-duty engine research cell**
- **For FY09:**
  - **Commission C15 ACERT diesel engine by initiating baseline experimentation**
  - **Evaluation of thermal recovery benefit of a selected ceramic thermal barrier coating on exhaust components**

# Milestones

- **Milestones for FY2008:**
  - Complete installation of engine research cell (completed Sep-08)
    - Finalize cell design (including installation of control room)
    - Proper permits in place
    - Procure & install infrastructure
      - Additional power
      - Air handling system
      - Water tower installation
      - Noise suppression
      - ESH review
      - Instrumentation & Analyzers
      - Gas bank
      - Dyno controllers
      - Fuel handling equipment
      - Plumbing for fuel & water
      - Bedplate setup
      - Electrical wiring
      - Safety features
      - Room ventilation
      - Engine/Dyno coupling
- **Milestones for FY2009:**
  - Commissioning of engine and dynamometer (April-09)
  - Baseline experimentation (May-09)
  - Evaluation of thermal barrier coating for selected exhaust components (Aug-09)

# Approach

***This CRADA makes use of engine/combustion and materials expertise at Caterpillar and ORNL to provide new insight into the integration of these technologies through a materials-by-design approach to high temperature, high pressure engine operation.***

**CATERPILLAR**

- Engine & tools
- Materials selection
- Technical support

**Oak Ridge National Laboratory**

- Engine performance
- Diagnostics & analysis
- Materials characterization

**Caterpillar WFO**

- Separate but highly complementary effort to provide advanced modeling support

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

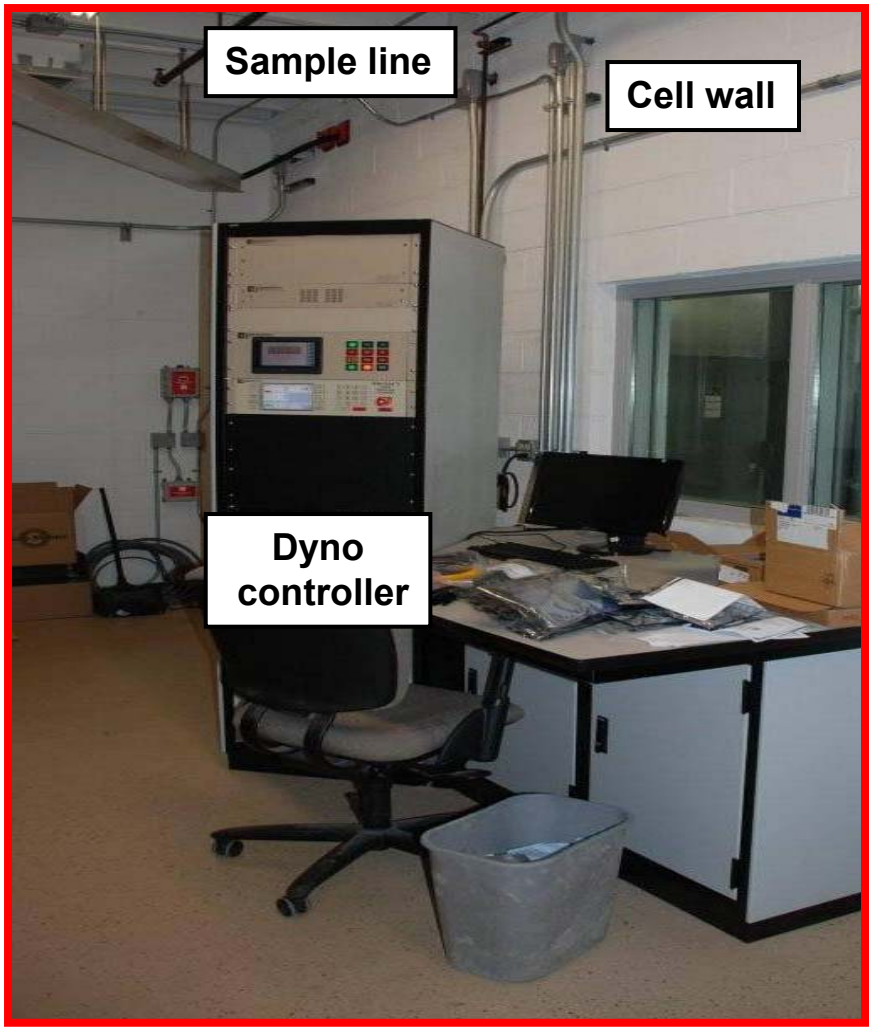
# Technical Accomplishments for FY-08

- **Complete installation & commissioning of experimental cell infrastructure:**
  - Gas Handling System (including internal plumbing)
  - Water Tower (including internal plumbing)
  - Fuel Storage & Delivery System (including internal plumbing)
  - Room Ventilation & Exhaust (including ducting)

# Technical Accomplishments for FY-08 (continued)

- **Completed construction of engine control room**
  - » Added wall, windows, & noise suppression
  - » Commissioned analytical bench
  - » Added power, furniture & emissions bench
  - » Dynamometer controllers added & commissioned
- **Completed dynamometer & engine installation**
  - » Installed bedplate & mounted engine
  - » Coupling adapter fabricated
  - » Added additional power for dyno operation

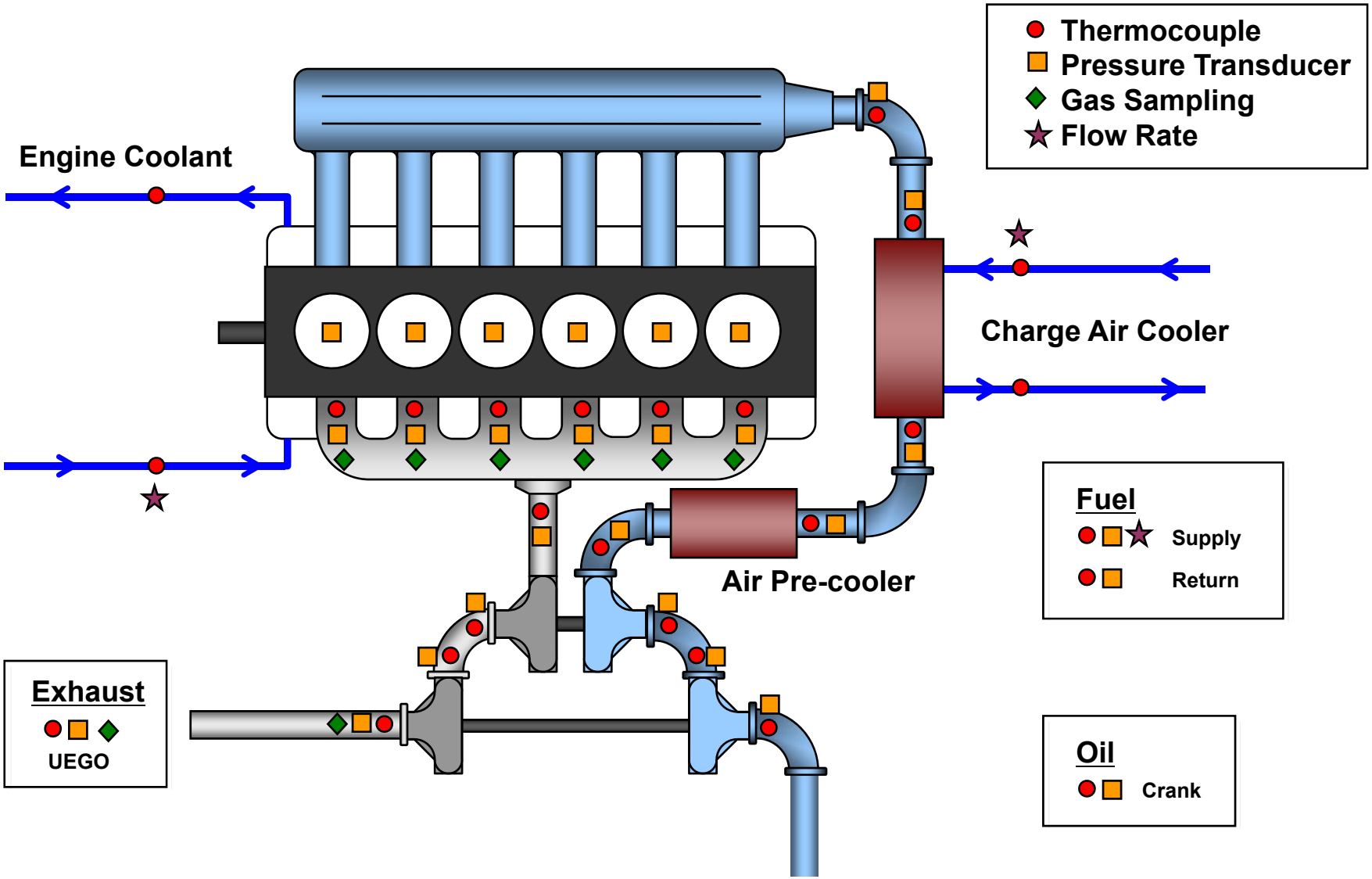
**Control Room**



# Technical Accomplishments for FY-09 (so far)

- **Data acquisition system installed**
- **Dynamometer & controller commissioned**
- **Water delivery system commissioned**
- **Engine has been instrumented**
  - » Temperature
  - » Pressures
  - » Flow rate
  - » Chemistry
- **Engine operational**
  - » Mar 13, 2009

# Instrumentation diagram for ACERT engine



# Activities for Next Fiscal Year

1. **Commission the engine “as-is”**
   - » Evaluate & compare engine performance to Caterpillar specifications
   - » Explore control parameters with engine performance
   - » Thermal analysis of engine components (especially exhaust)
   - » Commission bench analyzers, instrumentation & data acquisition system
2. **Install modified head**
   - » Instrumented for pressure & temperature measurements
   - » Explore control parameters with combustion behavior
3. **Begin materials performance evaluation**

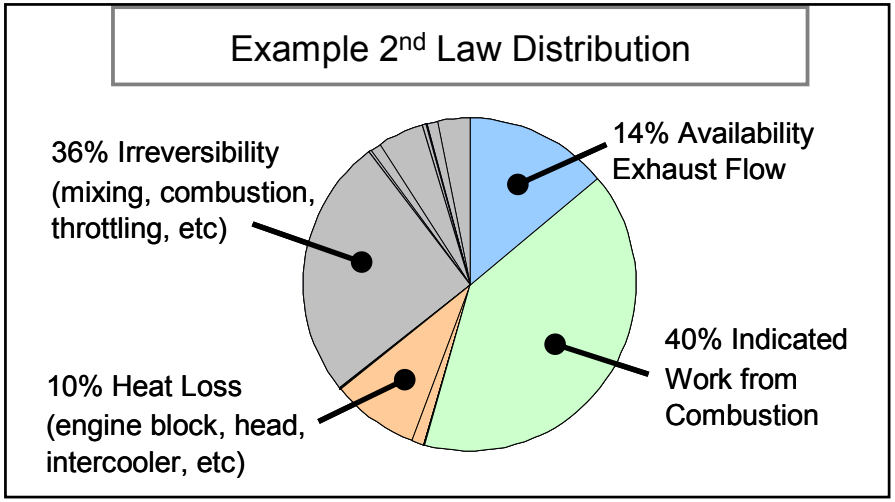
# Materials Evaluation Research Plan – Future Work

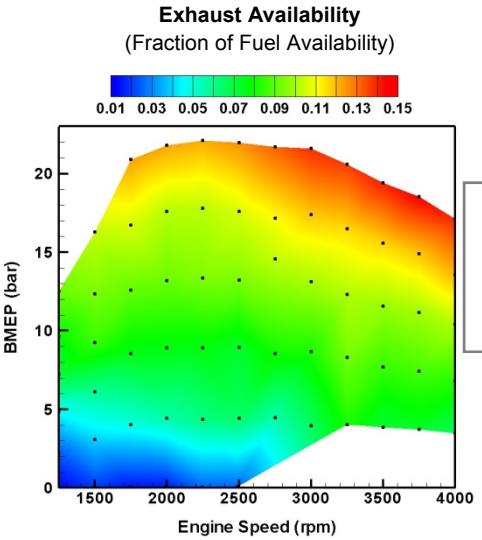
- **Selected material coating has the potential to:**
  - » Reduce thermal losses
  - » Reduce manufacturing cost
  - » Improve durability

1. **Evaluate the performance of a coated component in exhaust system (initial location is to be downstream of turbo)**
   - » Variables include:
     - Temperature
     - Exhaust flow rate
     - Transients
     - Exhaust chemistry
2. **Analyze component for structural integrity**
     - NDE
     - Microstructural analyses
3. **Temperature data entered into model to assess thermal management potential and identify locations for additional modifications**
4. **Expand research plan to additional components & materials**

# A modeling activity will be utilized to identify further efficiency opportunities & material improvements

- This activity is part of the WFO project but analysis will also support this CRADA
- Provides component-by-component evaluation of thermodynamic losses/opportunities as well as full-system overview.
- Evaluation of experimental data
  - » Characterize potential to recover/reduce thermal energy discarded to the environment.
- Thermal management of engine-system
  - » Balance several technologies competing for the same thermal resources.




**Example of exhaust availability for a Light-duty diesel**

# Summary

- We are establishing 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 Cell infrastructure has been completed.
  - » Caterpillar has provided ACERT C15 and associated hardware
  - » Received substantial internal ORNL funding
  - » Cell commissioning completed in December
- Baseline engine experiments begun early in 2009