# CRADA NFE-07-00995 – Materials for Advanced Engine Valve Train

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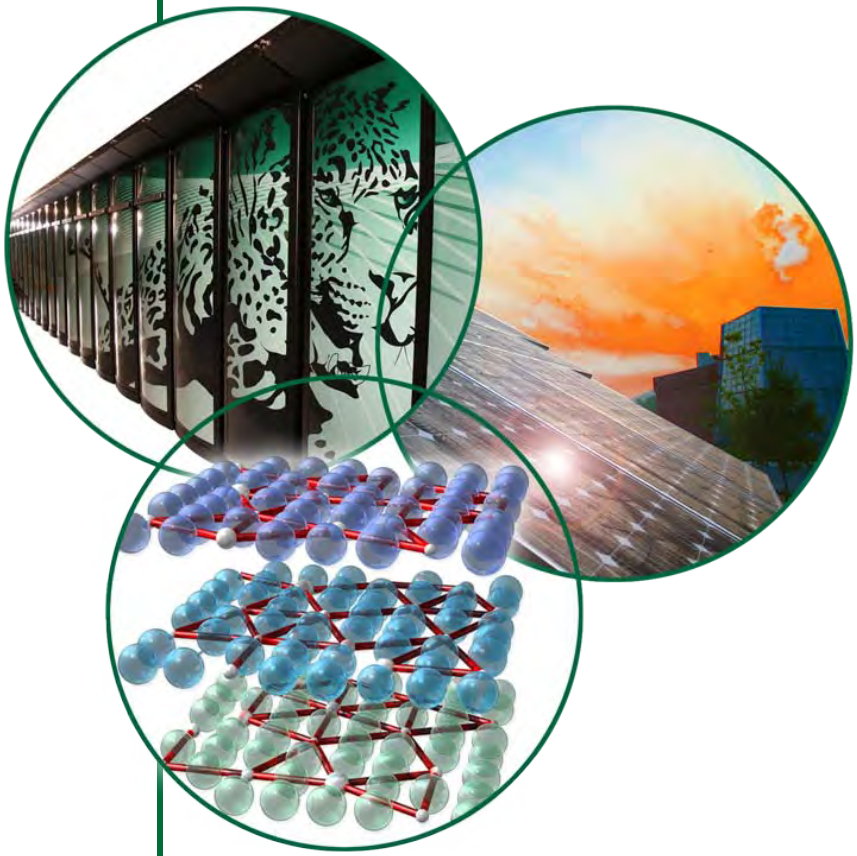

Project ID – PM022

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U.S. DEPARTMENT OF ENERGY

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# Overview

## Timeline

- Project began – October, 2007
- Project ends – December, 2012
- Project is 70% complete, with 24 month CRADA extension last year

## Budget

- Total Project Funding
  - DOE Share -50%
  - Caterpillar – 50%
- FY10 Funding - $275,000
- FY11 Funding - $225,000

## Barriers

- Changes in internal combustion regimes
  - Materials properties of exhaust valves will need to change to accommodate higher temperatures and pressures
- Lead time for materials commercialization
- Cost

## Partners

- Caterpillar's Tier I suppliers for exhaust valves and seat-inserts
- Materials producers for component suppliers

# Objective

This CRADA project is relevant to a key technical gap in Propulsion Materials that supports the following Advanced Combustion Engine goal:

**2015 Commercial Engine – Improve Thermal Efficiency by 20% over current baseline efficiency**

**Technical Objective** – Higher temperatures (>700-750C) cause unacceptable wear between exhaust valves and seat inserts, and reduce durability

**Impact** – Better exhaust valves and seat inserts with reduced wear at higher temperatures will have an immediate commercial impact on enabling more efficient diesel engines

# Approach

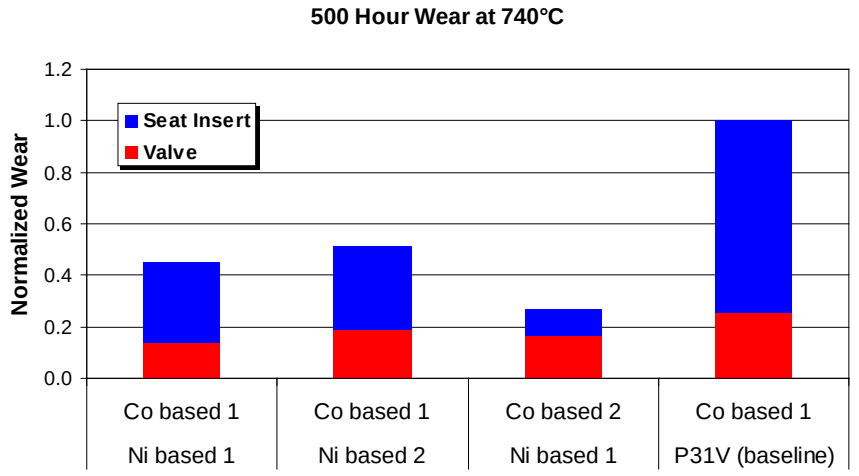
- Caterpillar and ORNL have characterized the root-causes of high temperature wear on engine and wear-rig tested standard valves and seats
- Caterpillar and ORNL have identified several Ni-based superalloys with more temperature capability than standard 31V alloy used for exhaust valves
- Caterpillar and ORNL have worked with valve supplier to obtain prototype valves and test specimens made from new superalloys with better high-temperature capability
- Caterpillar is performing accelerated wear- rig testing of prototype valves of new alloys;  ORNL is performing elevated temperature tensile and creep-testing to verify properties of new alloys

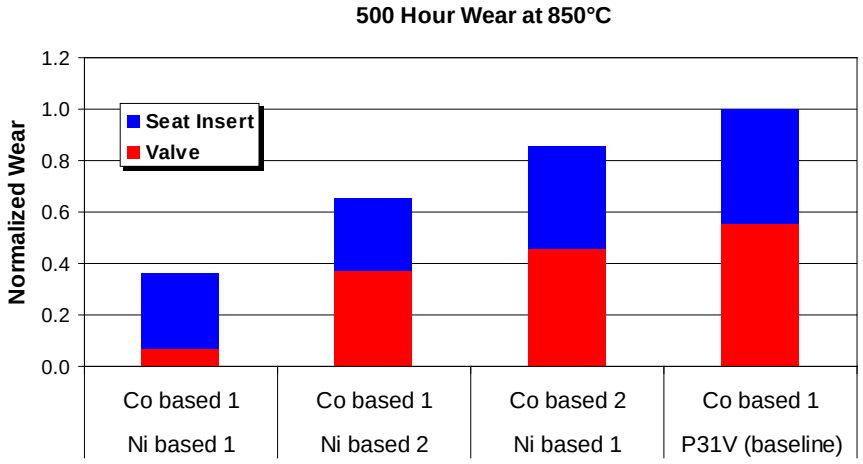
# Milestones

- FY2010 – Obtain mechanical testing specimens and prototype exhaust valves from new Ni-based superalloys (December, 2009, done)
- FY2011 – Complete initial rig-tests for wear-resistance of exhaust-valves of new Ni-based superalloys at Caterpillar (November, 2010, done)
- FY2011 – Complete initial creep-rupture testing of new Ni-based superalloys for exhaust valves at ORNL (February, 2011, done)

# Technical Accomplishments – Upgraded Exhaust Valves also Resist Wear

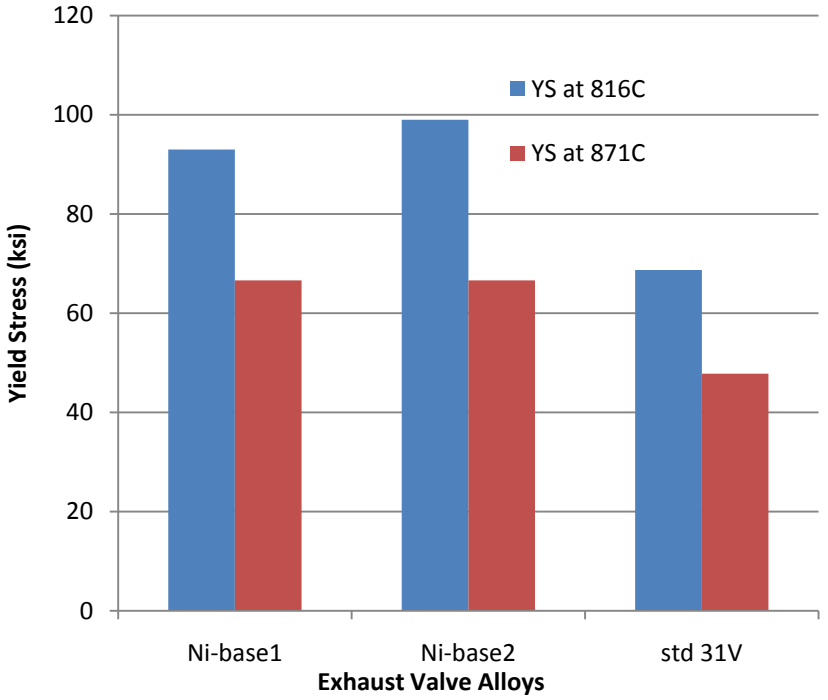
- Significant improvements in high temperature strength and wear resistance
- Ni-based 1 prototypes show
  - 2.7x improvement in wear life at 850ºC
  - 2.2x improvement in wear life at 740ºC
- Ni-based 2 prototypes show
  - 1.5x improvement in wear life at 850ºC
  - 2.0x improvement in wear life at 740ºC



# Technical Accomplishments – Upgraded Exhaust Valve Alloys Have Better High-Temperature Strength

Commercial Ni-based alloys 1 and 2 were chosen because they were stronger than std 31V alloy above 700-750°C



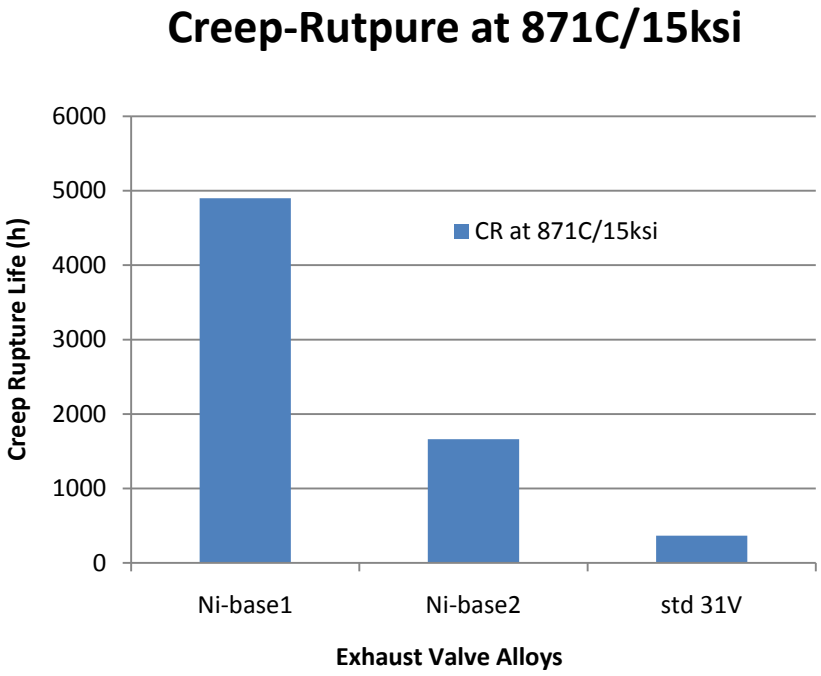

- New Ni-based alloys 1 and 2 both show higher yield strengths (YS) than standard 31V alloy
- Both new Ni-based alloys have similar YS at both 816 and 871°C

Tensile Tests to Measure Yield Strength at High Temperatures

# Technical Accomplishments – Upgraded Exhaust Valve Alloys Have Better High-Temperature Strength

Commercial Ni-based alloys 1 and 2 were chosen because they were stronger than std 31V alloy above 700-750°C

- New Ni-based alloy 1 has much more creep resistance than alloy 2 or standard 31V alloy at 871°C
- New Ni-based alloy 1 has similar creep-strength advantage at 816°C
- Differences in creep-resistance among the 3 alloys are much larger than tensile properties differences




Creep Tests to Measure Rupture Life at High Temperatures

# Collaboration and Coordination with Other Industrial Partners

- Caterpillar's seat maker is providing upgraded seat-inserts to test with upgraded valve alloys
- Caterpillar's valve maker obtained rod-stock of new upgraded Ni-based superalloys from alloy producers (2)
- Caterpillar's valve maker produced mechanical properties test specimens for ORNL, and manufactured new prototype exhaust valves for Caterpillar to test from new Ni-based superalloys

# Future Work – Aging, Wear-Rig Testing and Engine Testing

- Caterpillar will complete rig-test new prototype valves at various temperatures
- ORNL will complete aging (5000 h) and test mechanical properties of new Ni-based superalloys after aging
- Microstructural analysis of wear-tested valves and creep specimens will continue at ORNL
- Engine-tests of the durability of modified seat-inserts and upgraded exhaust valves are next

# Summary

- Caterpillar and ORNL previously clearly identified root-cause microscopic nature of wear attack for both seat-inserts and exhaust valves
- Caterpillar and ORNL used critical knowledge to select 2 new Ni-based superalloys with more performance at higher temperatures to further mitigate wear
- Caterpillar wear-rig testing of prototype valves at 850$^{o}$C shows superior performance of Ni-based superalloy 1 compared to standard 31V alloy exhaust valves
- ORNL creep-rupture testing at 816-871$^{o}$C shows superior creep-resistance of Ni-based alloy 1 compared to standard 31V exhaust valve alloy