CRADA NFE-08-01671 – Materials for Advanced Turbocharger Design

Agreement - 17257

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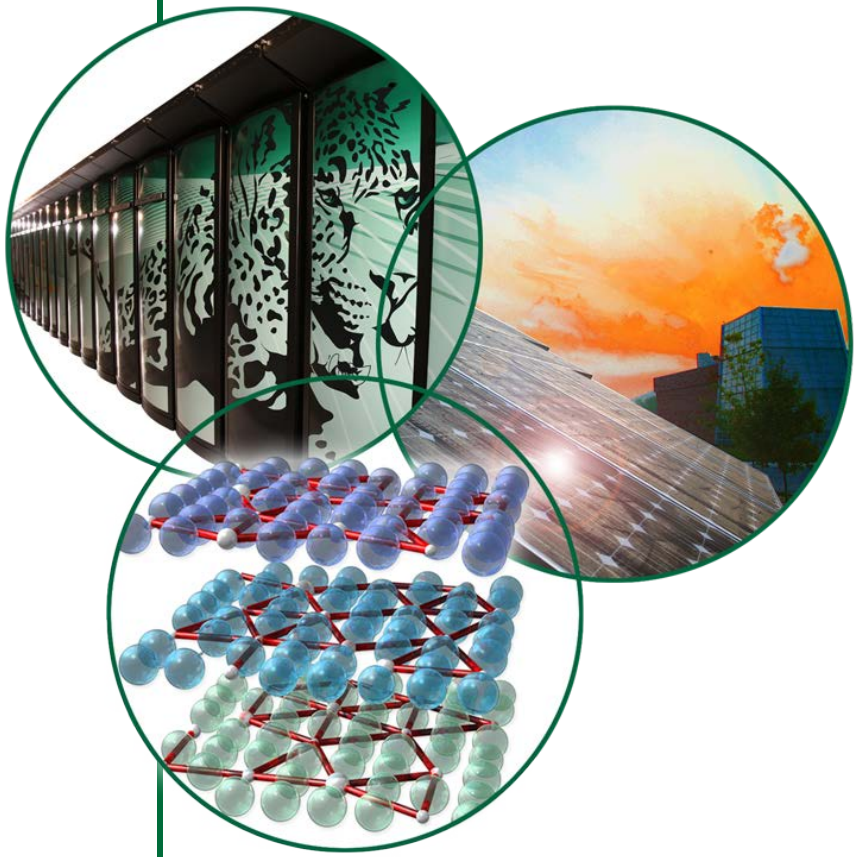
Oral – June 19, 2014

Project Area – Materials for Combustion Systems/High Efficiency Engines



Project ID – PM038

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U.S. DEPARTMENT OF ENERGY

Honeywell

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview

Timeline

- Project began – September, 2009
- Project ends – September, 2014
- Project is >75% complete

Budget

- Total Project Funding
  - DOE Share – 50%
  - Honeywell – 50%
- FY12 Funding - $300,000
- FY13 Funding - $0
- FY14 Funding – $150,000

Barriers

- **Barriers addressed include:**
  - Difficulty in simultaneously increasing efficiency and reducing emissions
  - HECC Technologies increase exhaust temperatures for turbochargers

Partners

• Honeywell suppliers for turbocharger components
• Engine customers for turbochargers (LD and HD engines)

Relevance

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

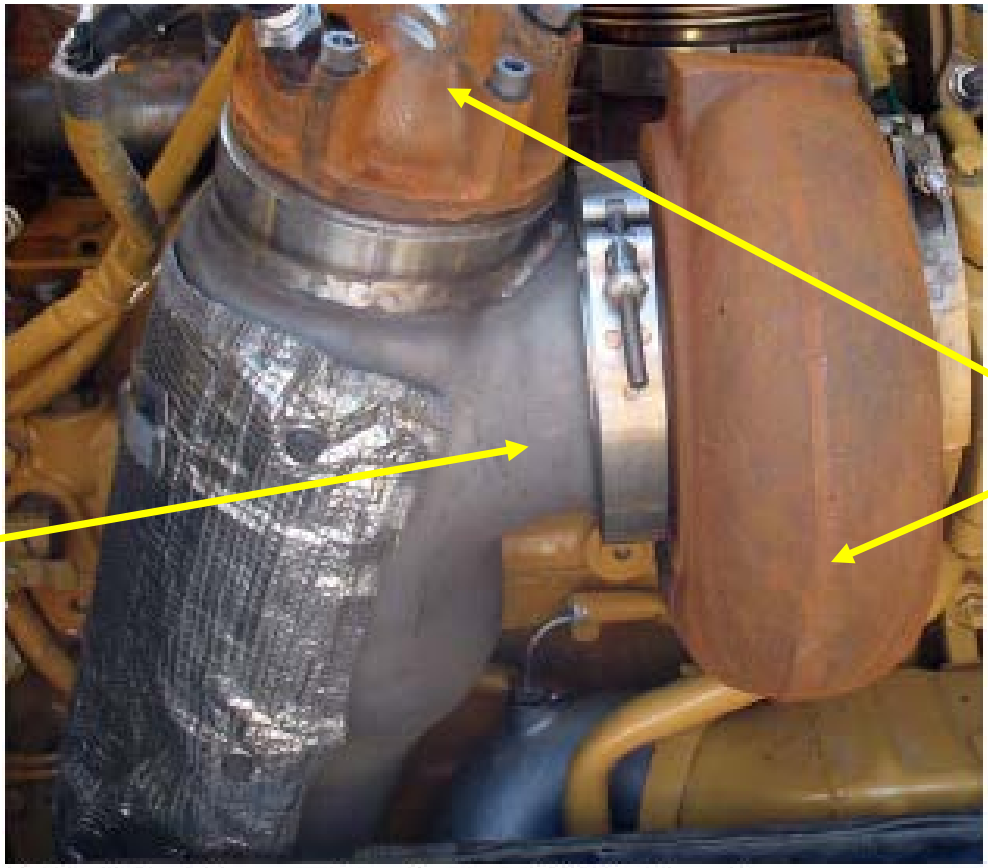
2015 Commercial Engine – Improve Efficiency by 20% over 2009 baseline efficiency

Turbocharging improves fuel efficiency particularly in gasoline engines

Technical Objective – Higher temperatures (>750°C, diesel, >950°C gasoline) exceed the strength and temperature capability of current materials, particularly cast-iron for turbocharger housings

Impact – Turbocharger housing and other components with more temperature capability and strength will enable higher, sustained operating temperatures. Stainless steel turbo-housings will also reduce weight and retain exhaust heat relative to cast-irons

Approach - Caterpillar Commercialized CF8C-Plus steel for the CRS component that are on all heavy-duty highway truck diesel engines since 2007 (Oct, 2006)



Caterpillar Regeneration System (CRS) Housing

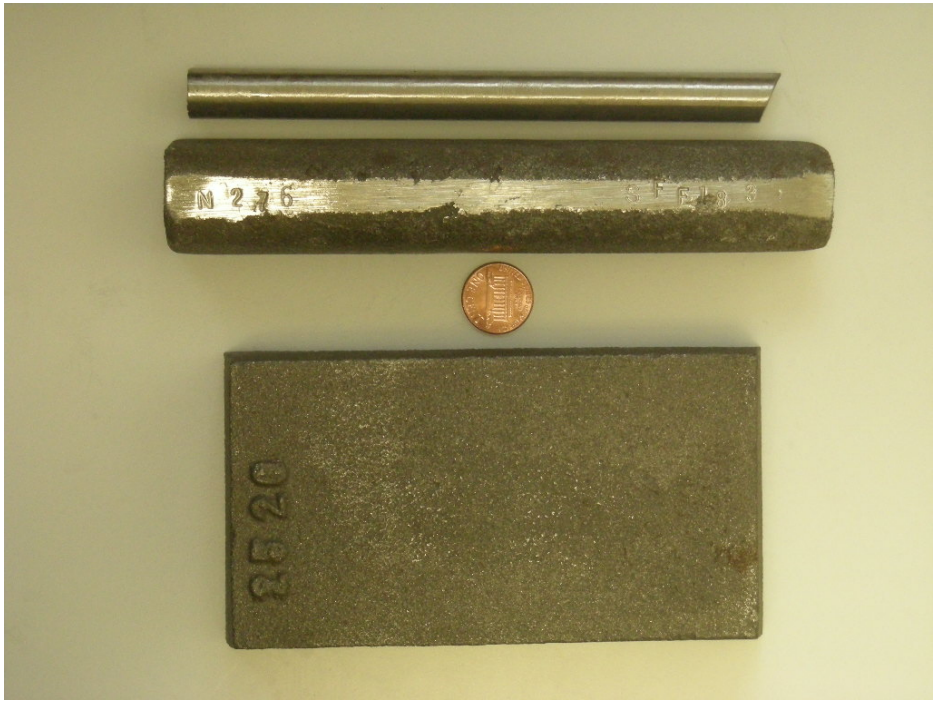
CF8C-Plus steel

SiMo Cast-iron

Over 500 tons of CF8C-Plus cast for CRS application (no failures, some >6 y)

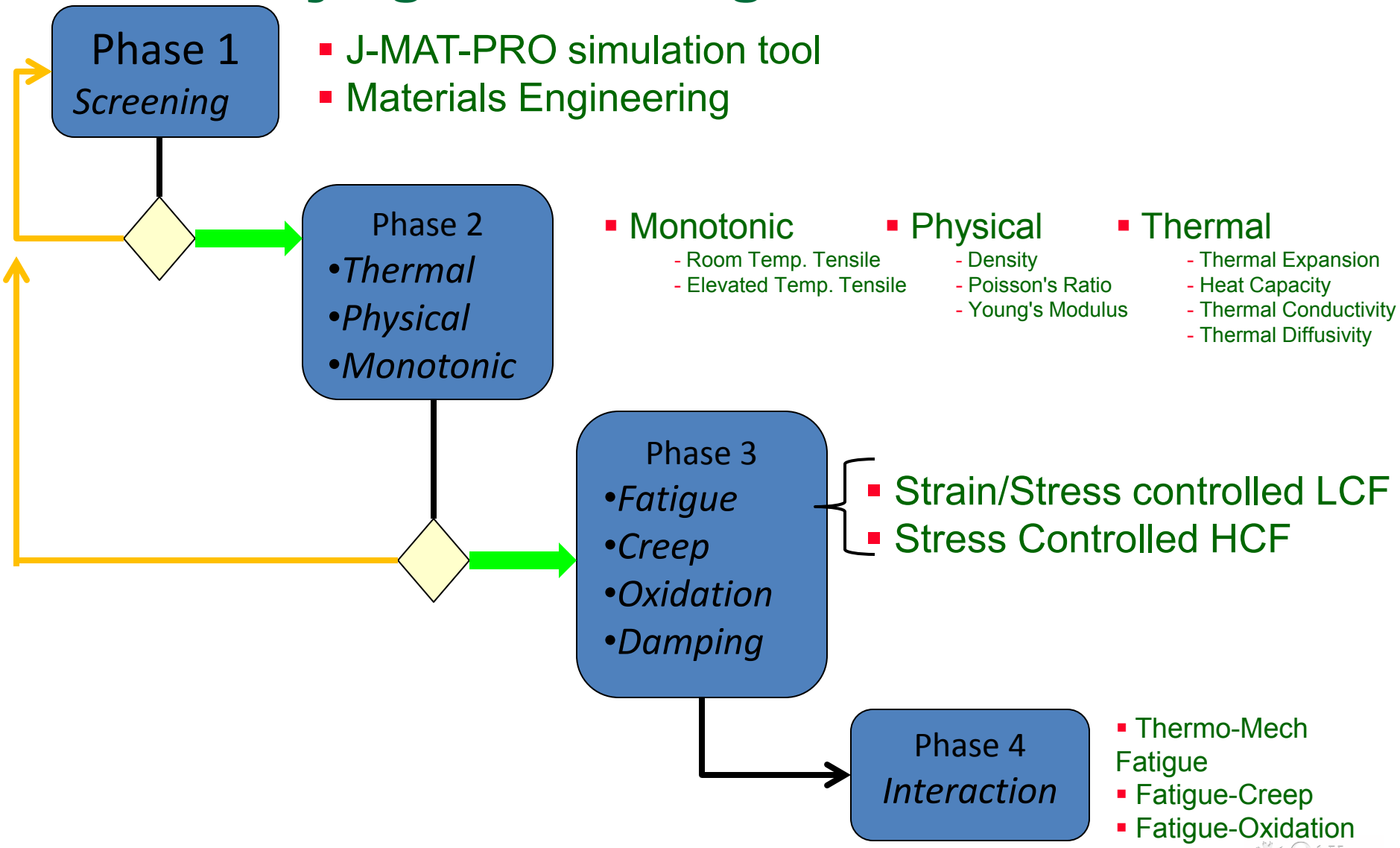
- Exhaust combustor (turbo exhaust + injected fuel) to clean out particulate filters: very high temperature and rapid cycling conditions

Approach – Cast Keel Bars or Blocks for Properties Testing



alloy	Cr	Ni	Mn	Mo	Nb	C	N	Si	Fe
CF8C-Plus	19.1	12.5	3.5	0.35	0.94	0.09	0.24	0.6	bal
HK30-Nb	25.2	19.4	1.2	0.27	1.2	0.30		1.6	bal

Approach – Follow Honeywell Requirements for Qualifying Turbocharger Materials



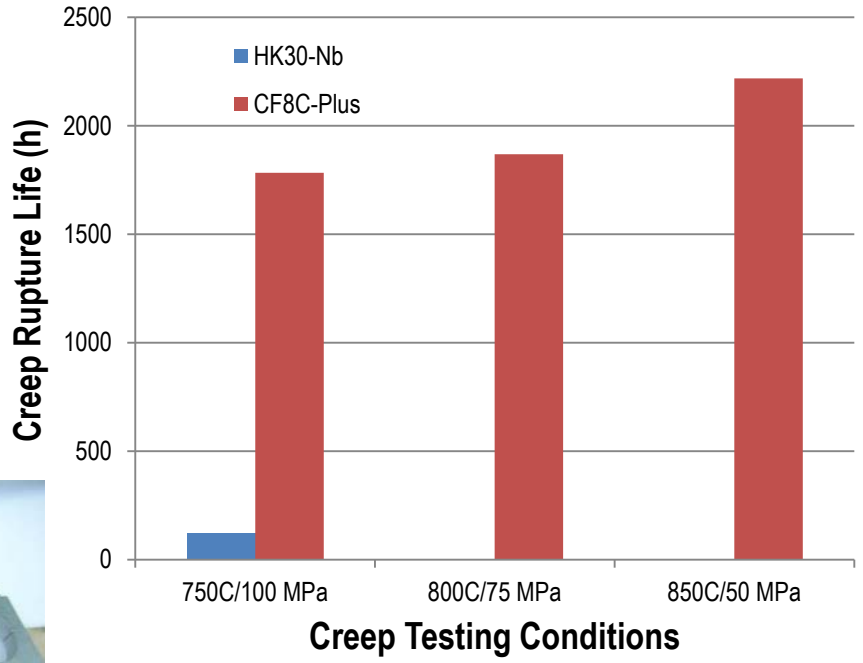
Milestones

- FY2013, Q1 – complete neutron-scattering residual-stress measurements on wheel/shaft assemblies with stress-relief heat-treatments (Dec, 2012, complete)
- FY2013, Q3 – begin creep-tests of cast CF8C-Plus stainless steels to facilitate gasoline turbocharger applications (July, 2013, complete)
- FY2014 , Q1– Complete diesel engine exhaust testing of CF8C-Plus steel at 800C (Dec. 2013, complete)
- FY2014 , Q2– Evaluate oxidation resistance of CF8C-Plus tested in diesel exhaust environment (Mar. 2014, complete)
- FY2014 , Q3 – Assist Honeywell in indentifying appropriate foundries for prototyping CF8C-Plus housings (June 2014, on track)

Technical Accomplishments – Upgrade Turbo-Housing to Cast Stainless Steel

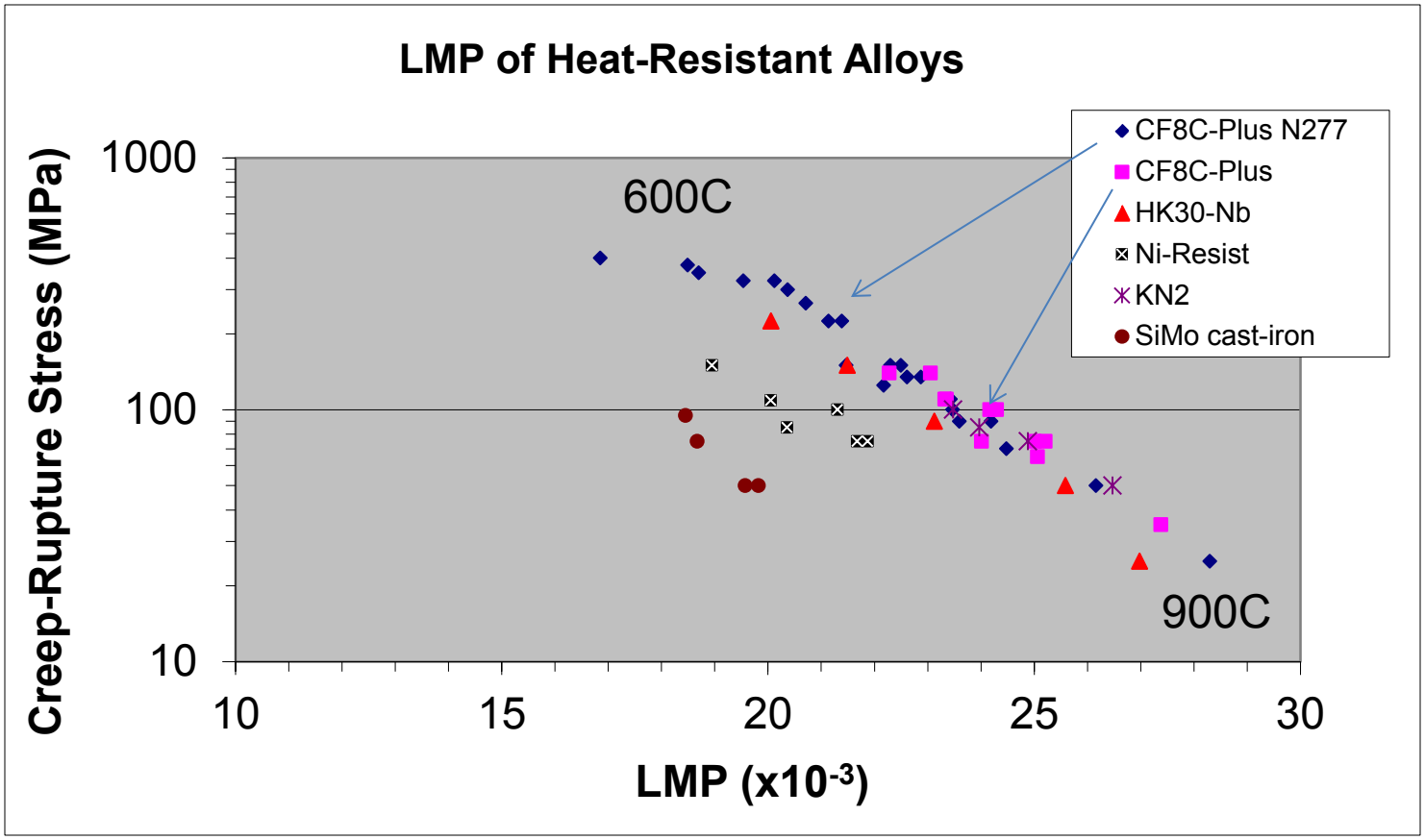
ORNL developed CF8C-Plus cast stainless steel with more strength than HK30Nb stainless alloy > 750°C.

Both have ten times more strength than SiMo cast-iron above 500-600°C



Current SiMo cast-iron turbocharger housing for diesel engine product

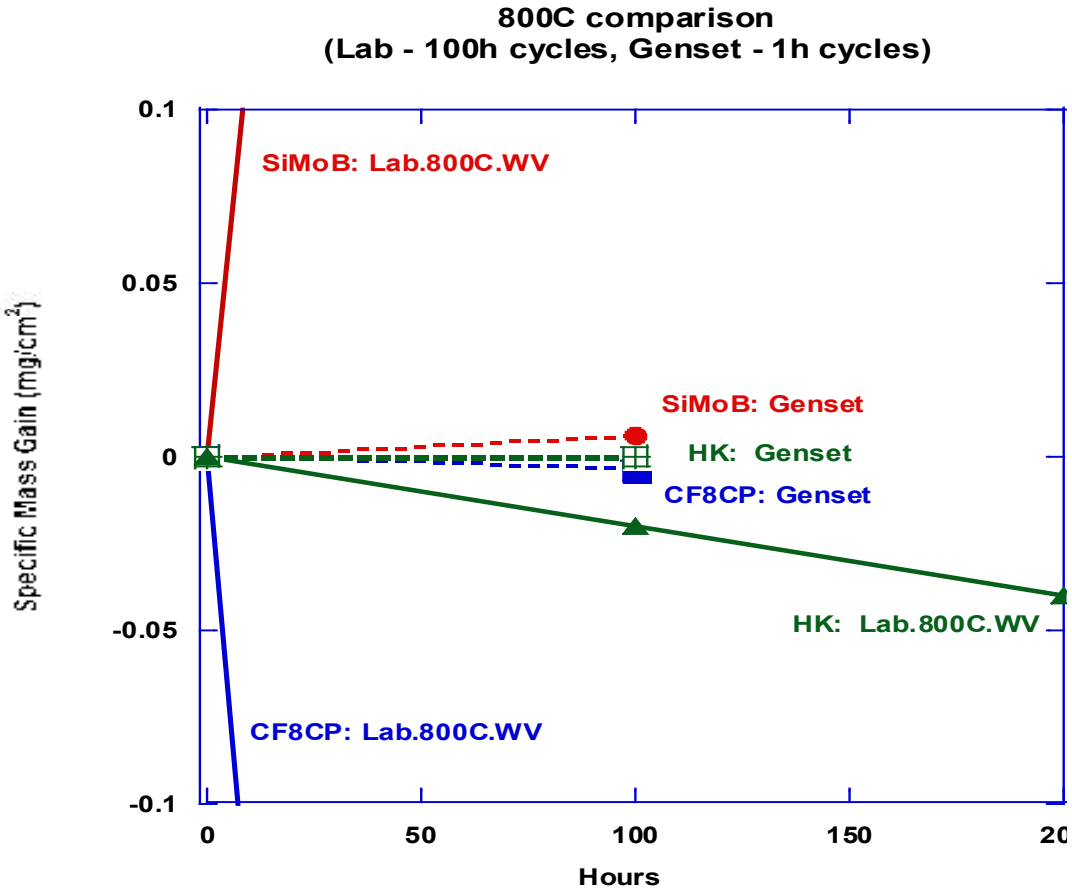
Technical Accomplishments – Upgrade Turbo-Housing to Cast Stainless Steel for More High-Temperature Creep Resistance



- CF8C-Plus cast stainless steel has significantly better creep-resistance than SiMo and Ni-resist cast irons at 700-900°C

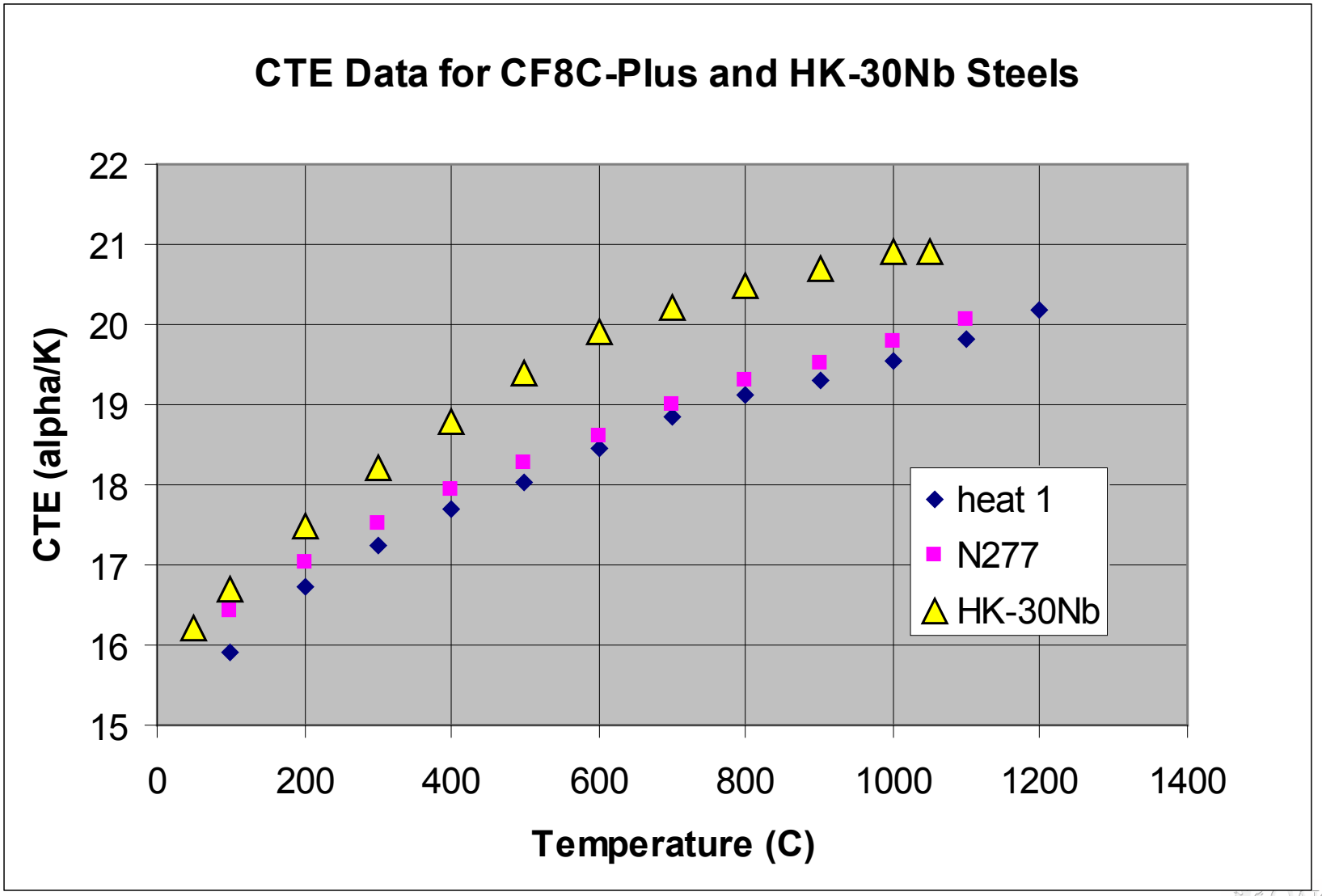
- CF8C-Plus stainless steel cost is about 33% less than HK30-Nb alloy

Technical Accomplishment – Oxidation Testing in a Diesel Exhaust Environment at 800C

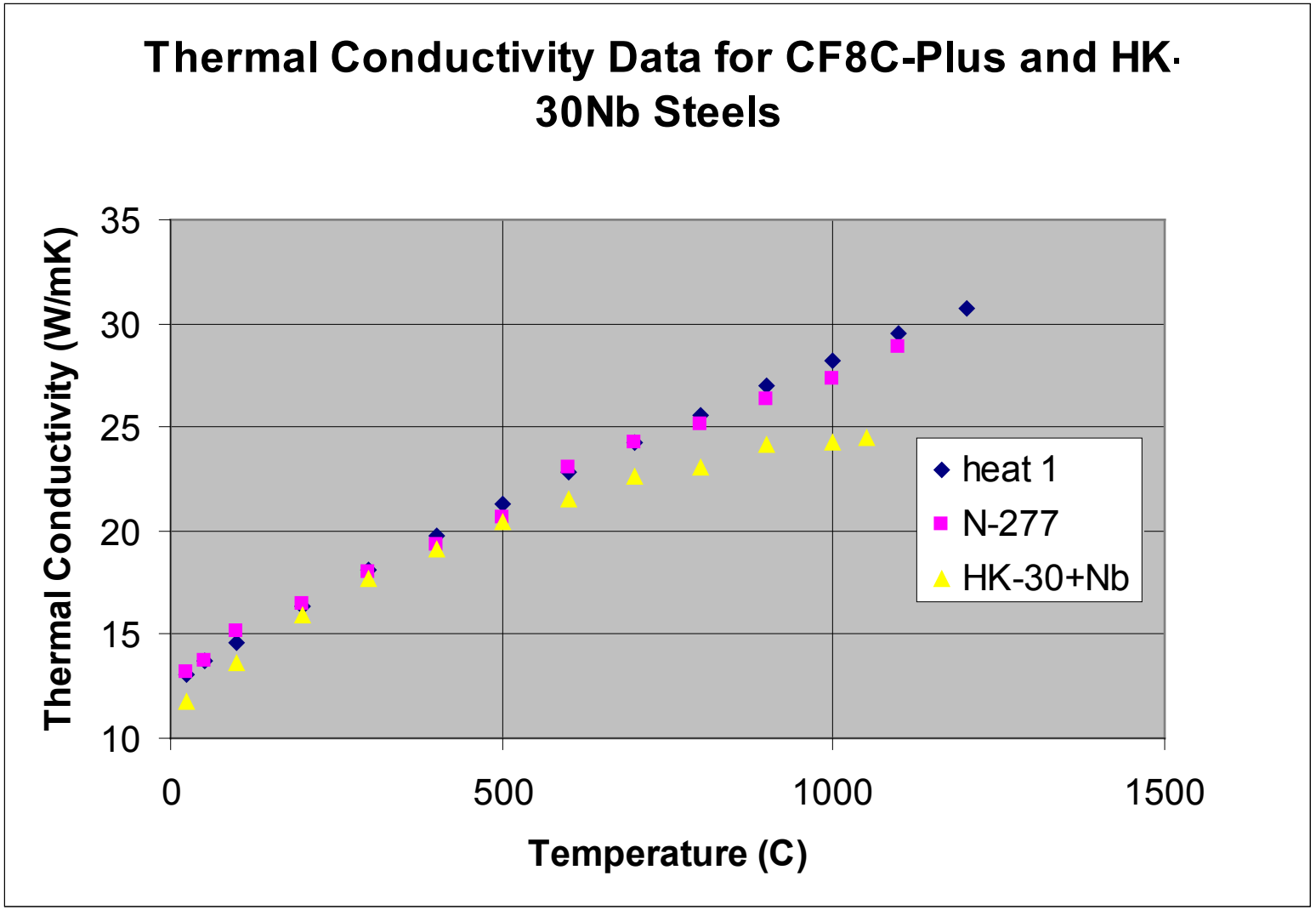


Preliminary tests indicated a substantially lower rate of oxidation after testing in actual diesel exhaust vs. laboratory air + 10%water vapor at 800C

Technical Accomplishment -Physical Properties – Thermal Expansion



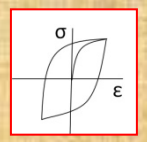
Technical Accomplishment - Physical Properties – Thermal Conductivity



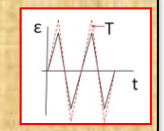
What's Next - High Temperature Material Testing

Material testing

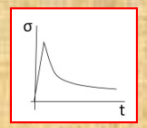
- LCF Iso-Thermal



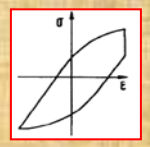
- Thermo Mechanical Fatigue



- Creep/ Stress Relaxation



- Fatigue with Dwell



- Creep-Fatigue-Oxidation

Issues and Barriers

- Decreased funding with increased Honeywell need for expensive testing (fatigue, creep, TMF)
- Upgrade of creep machines and fatigue machines after extended high temperature testing
- Installation of new diesel exhaust facility at ORNL
- Honeywell CRADA needs to be extended for 2 more years before September, 2014

Summary

- **Relevance** – Turbocharging improves fuel efficiency of gasoline engine vehicles
- **Approach/Strategy** – Work with Honeywell phased approach to qualifying CF8C-Plus steel for turbochargers
- **Accomplishments** – Completed Phase 1 testing creep, fatigue and thermal fatigue qualifying CF8C-Plus steel
- **Collaborations** – SF&E, Honeywell and potential engine customers (Caterpillar, Ford, etc.)
- **Proposed Future Work** – Phase 2 – 4 testing of CF8C-Plus, particularly fatigue and creep testing.