Title Slide

- New Austenitic Stainless Steels for Exhaust Components (Agreement 9112)
  - Philip J. Maziasz – ORNL (PI and Presenter) and Michael J. Pollard (PI) Caterpillar
  - Oak Ridge National Laboratory, Oak Ridge, TN
  - Tuesday, Feb. 26, 2008, morning session

"This presentation does not contain any proprietary or confidential information"

Purpose of Work

- This ORNL/Caterpillar CRADA project (3y + 4y extension) was defined to first develop, and then to commercialize CF8C-Plus cast stainless steel to provide higher temperature capability and reliability for advanced diesel engine exhaust components
- This CRADA will expire in July, 2008

Barriers – FY2008

- Technical Barriers – Verify the long-term benefits of CF8C-Plus cast stainless steels, and the upper temperature limits, for various diesel engine exhaust component applications
- Commercialization Barriers – Provide investment-grade patent portfolio, attract and interact with major industrial customers, and provide the data that shows CF8C-Plus steel works for their applications

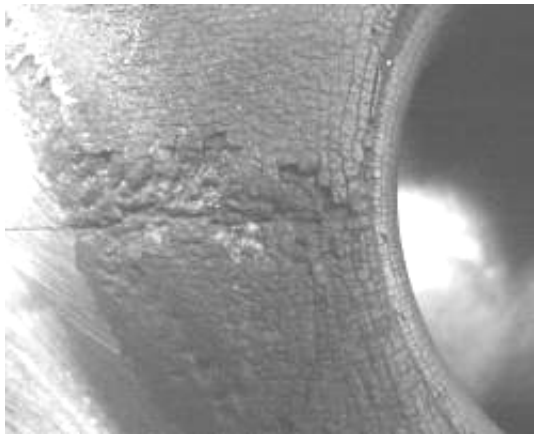
Approach – Alloy Development

- ORNL and Caterpillar developed cast CF8C-Plus steel using the “engineered microstructure” approach.
- CF8C-Plus steel was an “instant” success, with all first-heat, first-test results being fantastic. CF8C-Plus won a 2003 R&D 100 Award.
- CF8C-Plus was extensively tested to qualify it for diesel exhaust component applications
- CF8C-Plus Cu/W was developed to push strength even higher at 750-900^{o}C

Approach – Commercialization

- Caterpillar pursued initial diesel engine component applications
- ORNL generated short and long term creep and fatigue data, and metallurgical understanding to support CAT and non-CAT commercial applications
- CAT and ORNL work together to attract industrial end-users for commercial licensing, work with stainless steel foundries to support prototype trials, and generate needed mechanical properties data

CF8C-Plus cast stainless steel was developed as an upgrade for current exhaust alloys



SiMo cast iron turbocharger-housing

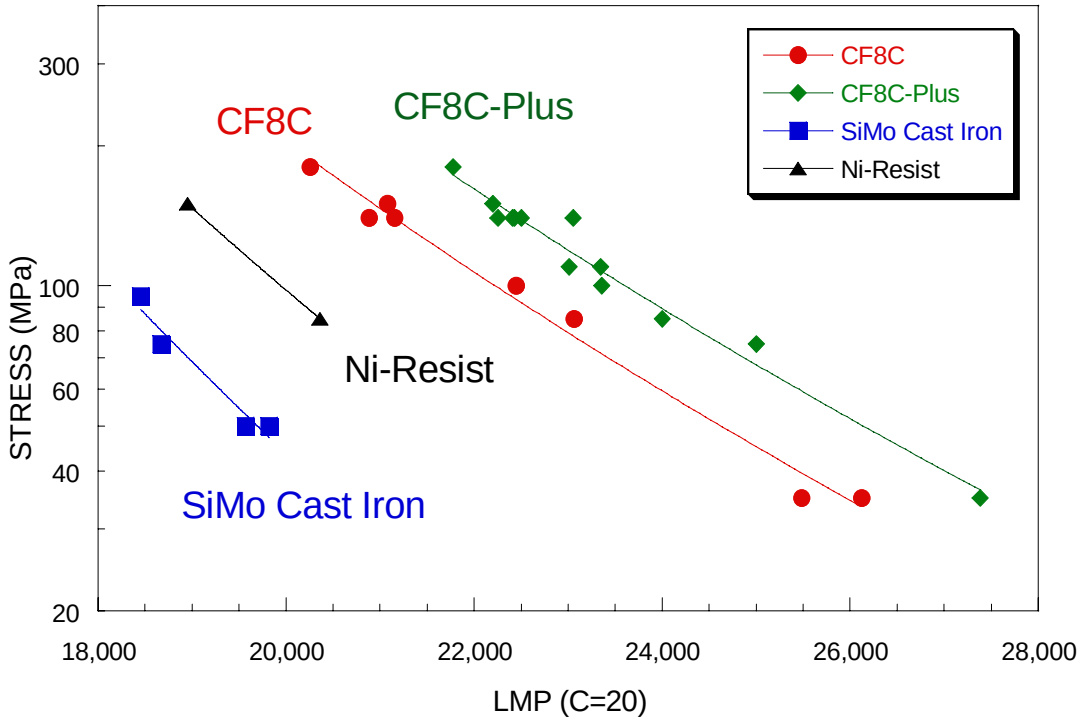
SiMo cast iron Exhaust manifold

C-15, 14.6L HD On-Highway Diesel Engine

CF8C-Plus Cast Stainless Steel won a 2003 R&D100 Award

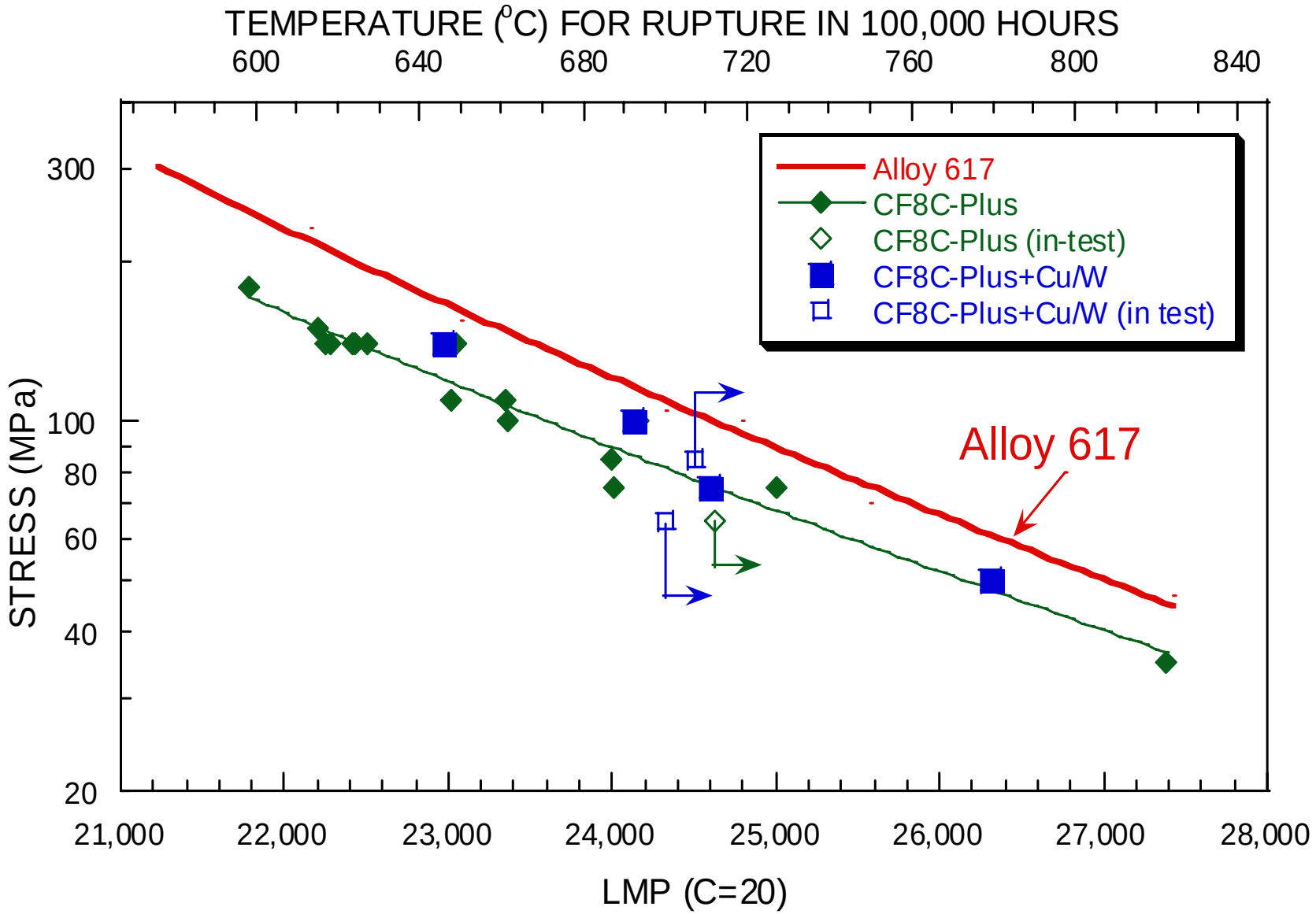
Outstanding Creep-Rupture Strength at 550-850°C

1st commercial heats only 1.5y after initial lab-scale heat

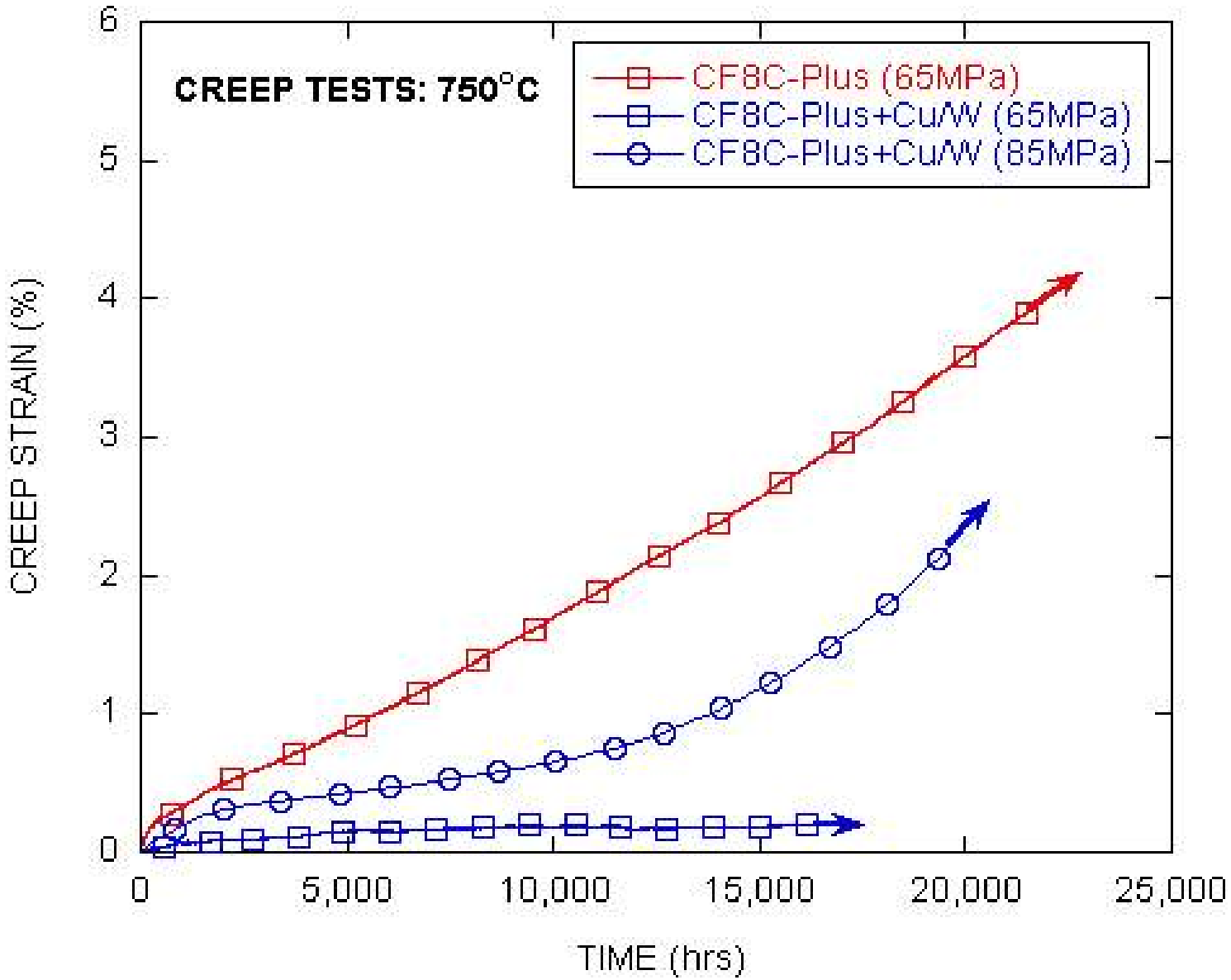


LMP (Larson-Miller Parameter) is calculated using creep-rupture time and temperature

Technical Accomplishments - CF8C-Plus Steel Offers Creep Resistance Comparable to Superalloy 617 at the Cost of Stainless Steel

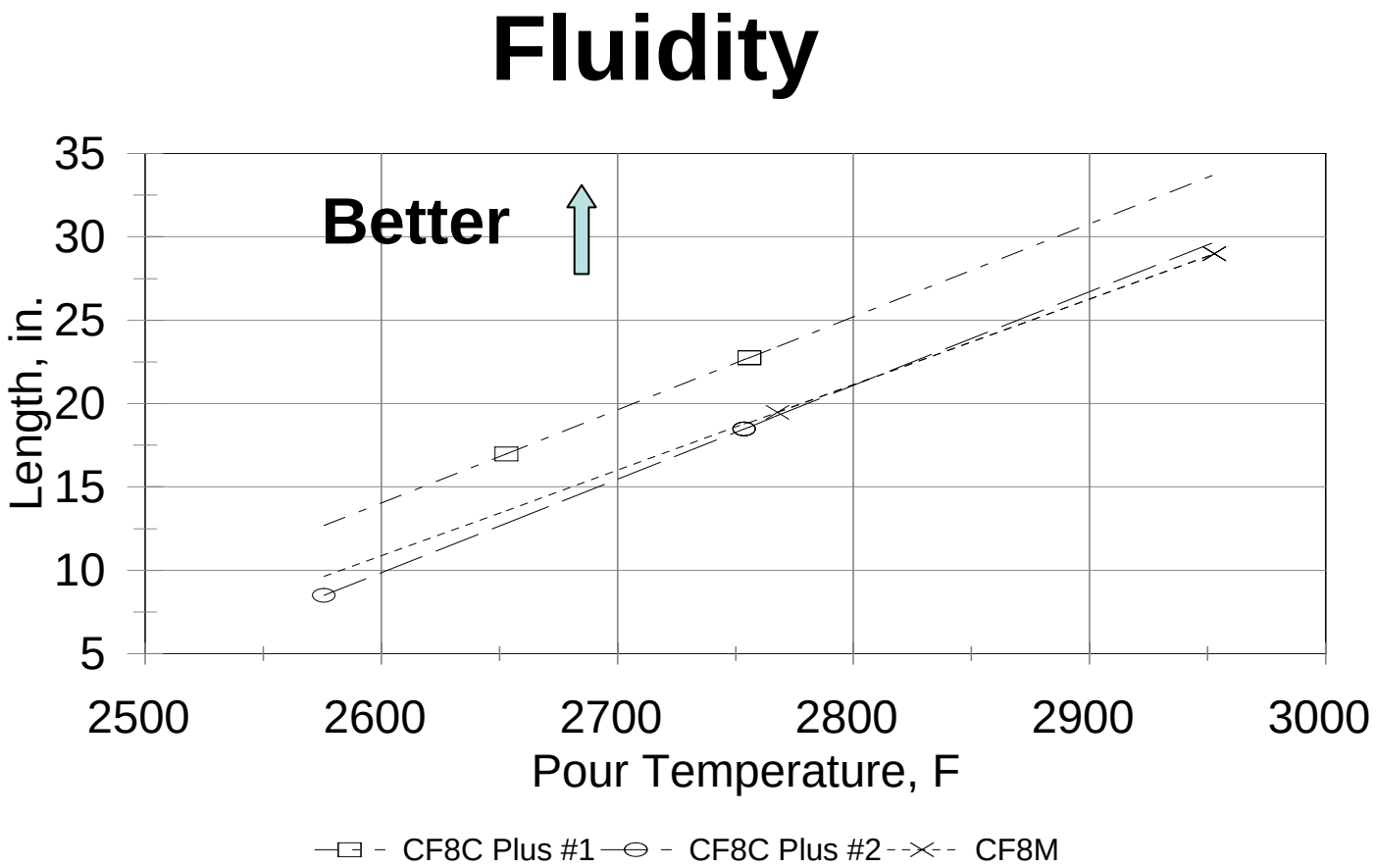


Technical Accomplishments - CF8C-Plus Cu/W has even more creep resistance at 750-850°C



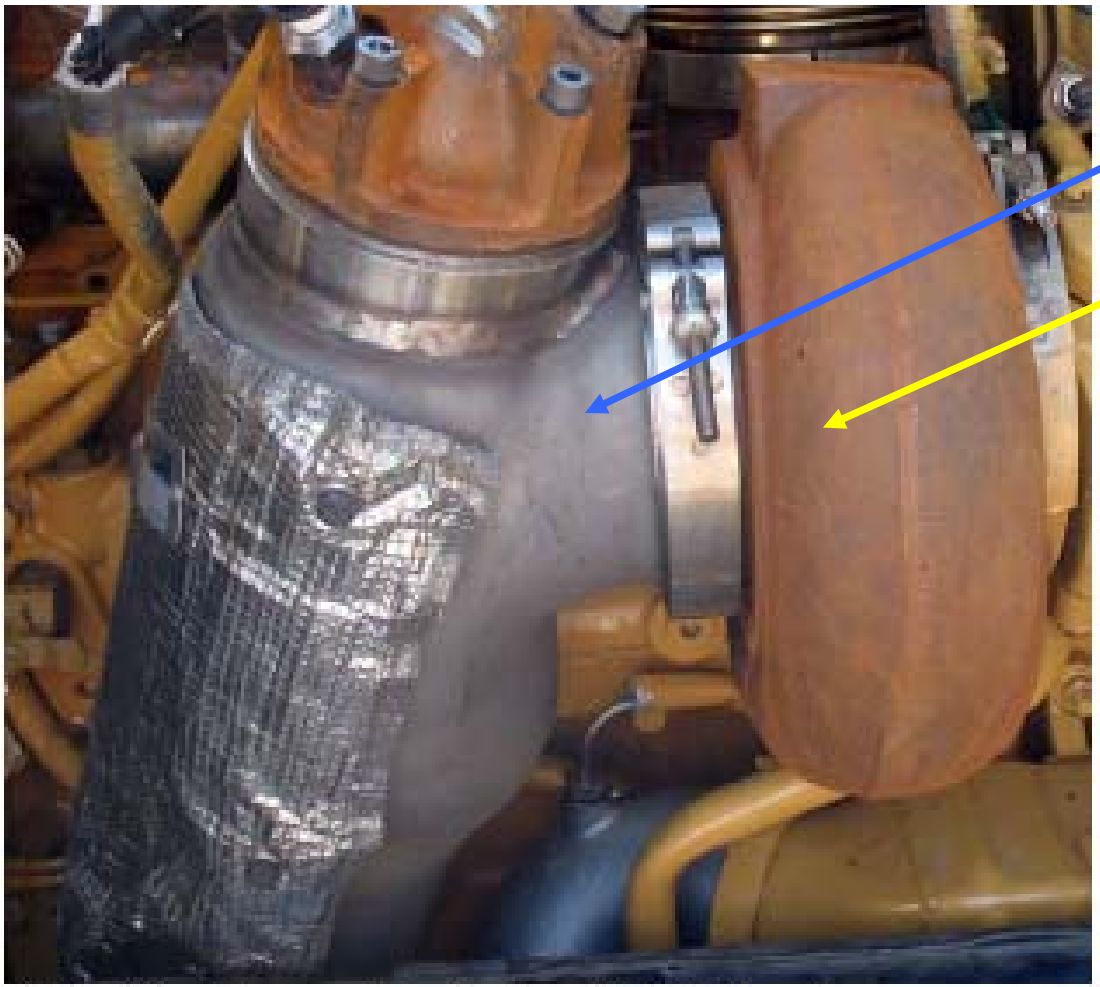
Technical Achievements - CF8C-Plus Steel Has Excellent Castability for Defect-Free Parts. CF8C-Plus Steel Requires No Additional Heat-Treatments

CF8C-Plus Fluidity Spiral



Stainless Foundry & Engineering – Milwaukee, WI

Technical Accomplishments - Caterpillar began using CF8C-Plus steel for the CRS components on all heavy-duty highway truck diesel engines in January, 2007



Caterpillar Regeneration System (CRS) Housing

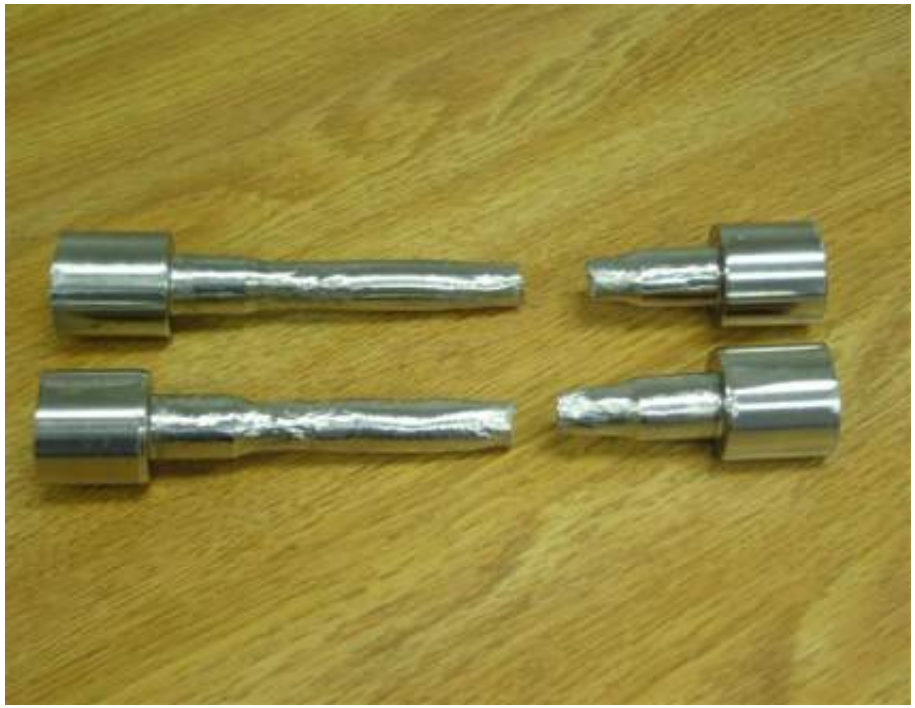
- Exhaust combustor (turbo exhaust + injected fuel) to clean out particulate filters: high temperature and rapid cycling conditions
- To date over 1 million lbs of CF8C-Plus steel have been cast for just this one application

Technology Transfer

- Caterpillar and ORNL have 1 U.S. Patent (7,153,373 B2, Dec. 26, 2006), 1 U.S. Patent-pending, and foreign-filings pending, to support commercial licensing interest
- ORNL and Caterpillar have applied for ASTM new alloy grade for CF8C-Plus steel, to support commercial licensing interest
- A major turbocharger OEM and a major gas-turbine OEM began licensing activities with Caterpillar in 2007 for CF8C-Plus steel

In May, 2007, CF8C-Plus was submitted to ASTM for approval of a new heat-resistant cast alloy grade – HG10MNN

Welds of CF8C-Plus passed U-bend Ductility test



Welds of CF8C-Plus passed RT tensile tests for UTS and ductility, with 20% Better YS than base metal

FY2008 Activities – Pursue Commercial Licensing for Turbocharger Application

- In FY2008, ORNL and Caterpillar have been interacting with a major turbocharger OEM to consider commercial licensing of CF8C-Plus as a performance/capability upgrade for SiMo cast-iron
- In FY2008, ORNL was awarded $500,000 by DOE/EERE Technology Commercialization and Development Program to support the turbocharger application

ORNL is using step-castings of CF8C-Plus to measure mechanical properties of thin sections representative of heavy-diesel exhaust components

Publications (2006-2007)

- "Developing New Cast Austenitic Stainless Steels with Improved High-Temperature Creep Resistance," by P.J. Maziasz, et al., paper CREEP2007-26840, Proc. 8th Internat. Conf. on Creep and Fatigue at Elevated Temperatures, at ASME-PVP2007 (22-26 July, 2007, San Antonio, TX)

Patents (2006-2007)

- US Patent 7,153,373 B2 (Dec. 26, 2006) on Heat and Corrosion Resistant Cast CF8C Type Stainless Steel with Improved High Temperature Strength and Ductility, by P.J. Maziasz, T. McGreevy, M.J. Pollard, C.W. Siebenaler, and R.W. Swindeman
- US Patent 7,255,755 (Aug. 14, 2007) on Heat and Corrosion Resistant Cast CN-12 Type Stainless Steel with Improved High Temperature Strength and Ductility, by P.J. Maziasz, T. McGreevy, M.J. Pollard, C.W. Siebenaler, and R.W. Swindeman