CF8C-Plus: A New Cast Stainless Steel for High-Temperature Diesel Exhaust Components

P.J. Maziasz, and J.P Shingledecker
Oak Ridge National Laboratory, and
M.J. Pollard
Caterpillar Technical Center

Research sponsored by the Heavy Vehicle Propulsion Materials Program, DOE Office of FreedomCAR and Vehicular Technology Program, under contract DE-AC05-00R22725 with UT-Battelle, LLC

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

CF8C-Plus cast stainless steel was developed to provide higher temperature capability and reliability for advanced diesel engine

turbo-housing

exhaust manifold

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

- **Cast stainless upgrade for SiMo cast-iron diesel engine exhaust components**

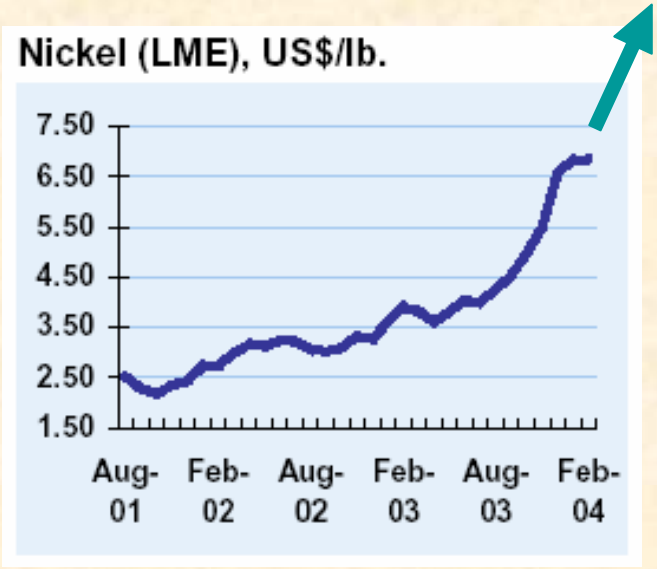
Materials Need: High Performance Low-Cost Alloy was Needed to Replace SiMo Cast Iron

Some Candidate Alloy Compositions (wt%)

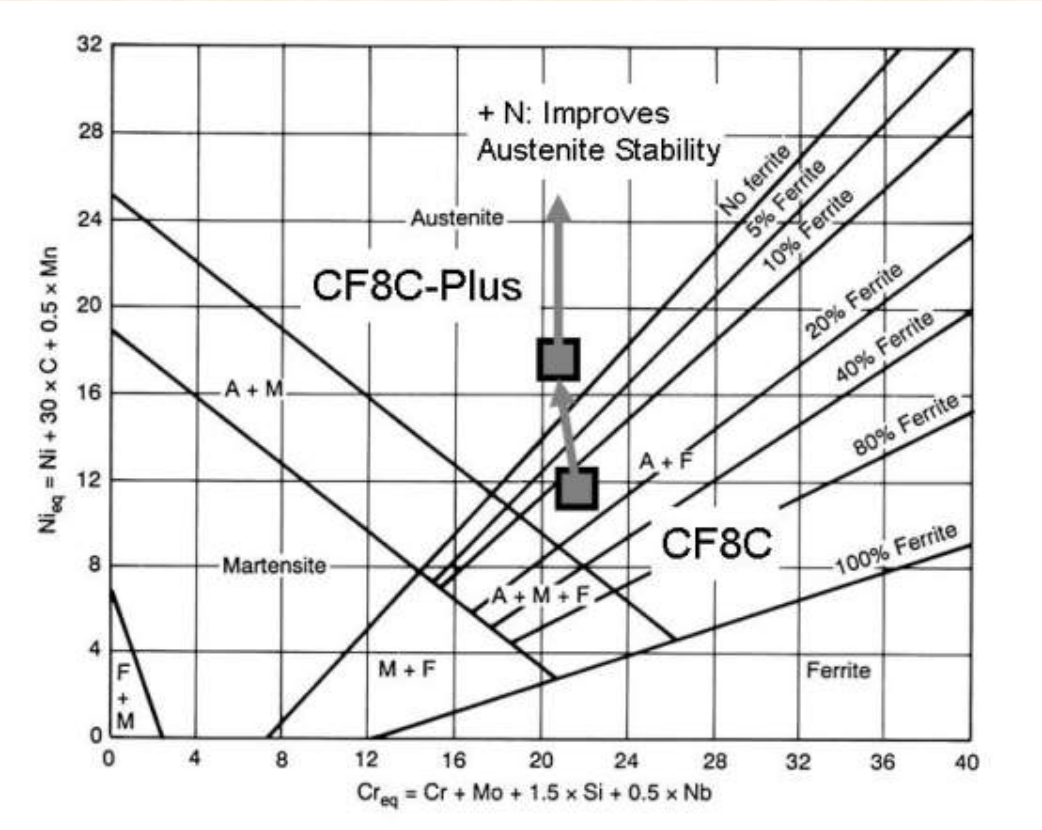
- SiMo Cast Iron: Fe-3.45C-4Si-0.6Mo-0.3Mn
- CF8C: Fe-19Cr-10Ni-0.07C-1.0Nb-0.7Mn-1Si
- CF8C-Plus: Fe-19Cr-12Ni-0.07C-0.07Nb-0.4Si-+Mn+N
- Ni-Resist: Fe-2Cr-35Ni-0.5Mn-5Si-1.9C

Improving the properties of less expensive alloys without the costly addition of Ni offered the best opportunity

CF8C-Plus = Best Results



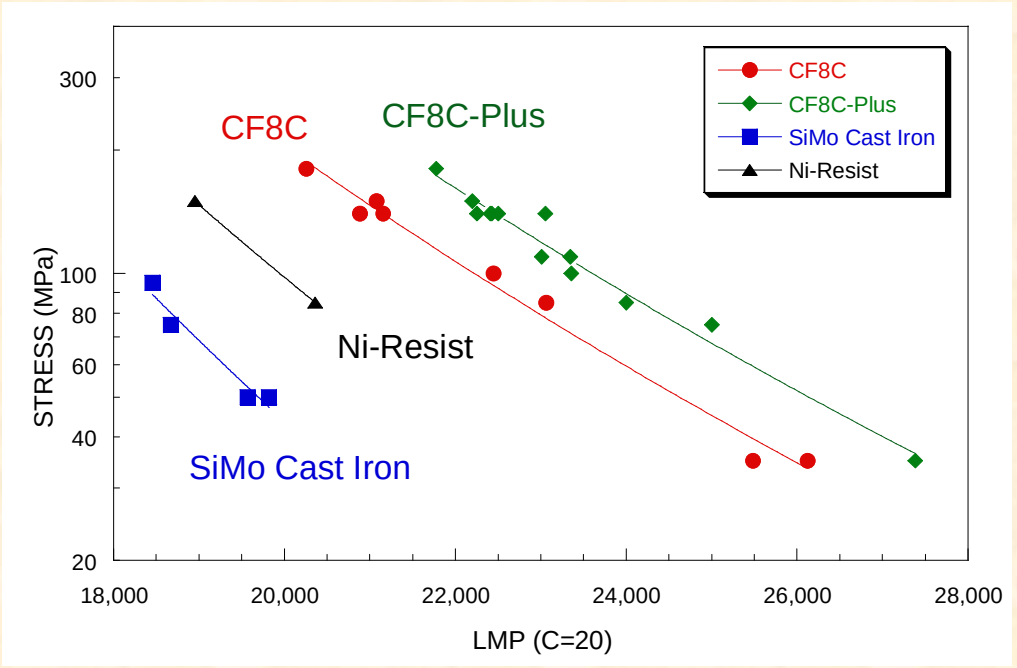
Alloy Development: Mn and N were the “Plus” added to improve austenite stability



- **Lower cost Mn and N were added instead of costly Ni for fully austenitic stainless steel**
- **CF8C = 15-25% Delta Ferrite, CF8C-Plus = 0% Delta Ferrite**

CF8C-Plus Cast Stainless Steel won a 2003 R&D100 Award for Outstanding Heat-Resistance at 850°C, and Successful Commercial Scale-Up in only 1.5 years

Creep-Rupture at 550-850°C

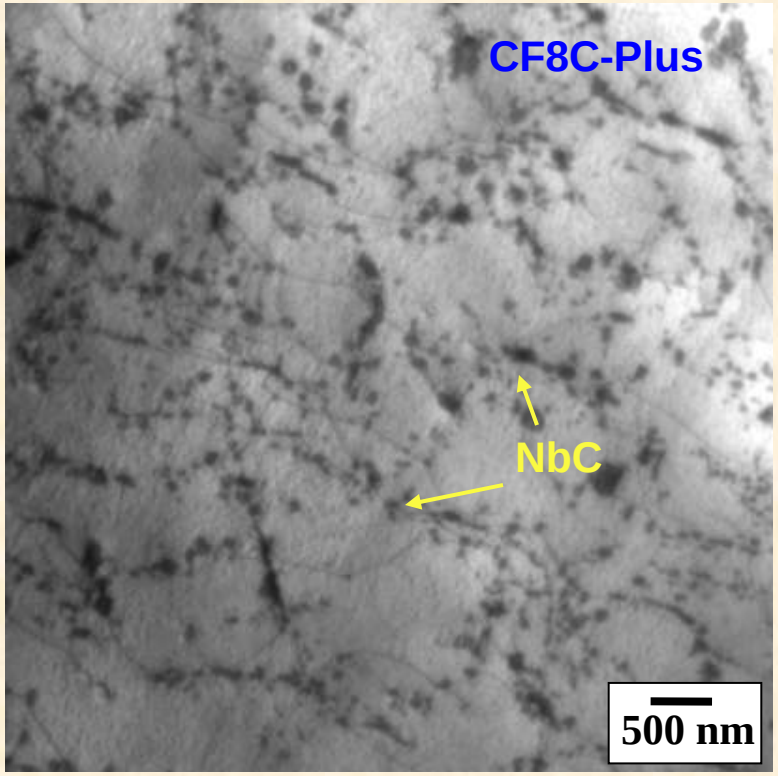


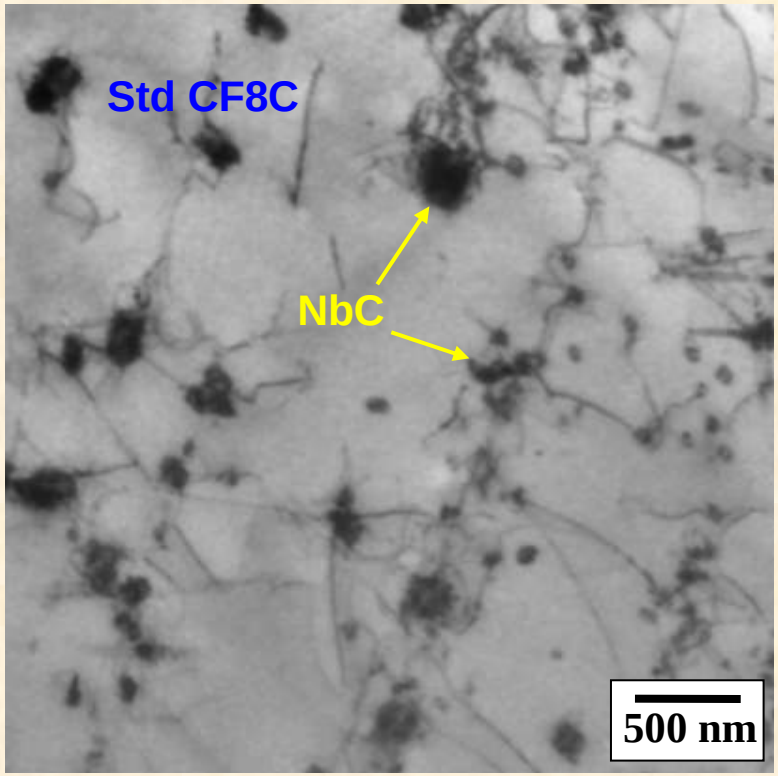
LMP (Larson-Miller Parameter) is calculated using creep-rupture time and temperature

Engineered Microstructure

- **CF8C-Plus Has "Super" Creep Resistance at 850°C Because Abundant, Stable Nano-NbC Precipitates Pin Dislocations**

Creep Tested 850°C/23,000 h





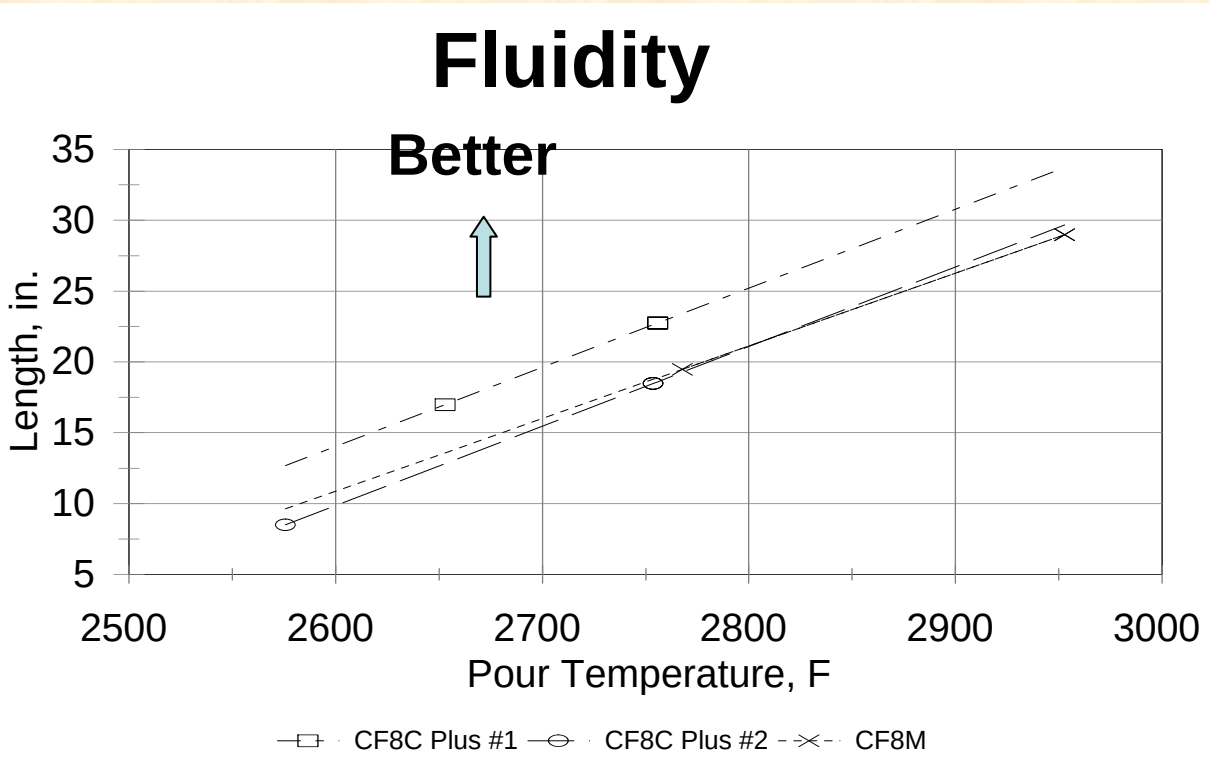
Creep Tested 850°C/500 h

(TEM, as cast)

CF8C-Plus Has Great Castability for Defect-Free Parts

CF8C-Plus Fluidity Spiral:

•Round-top trapezoid, 3/8" w (bottom), ¼" w (top), ¼" high
•Length = linear length of spiral

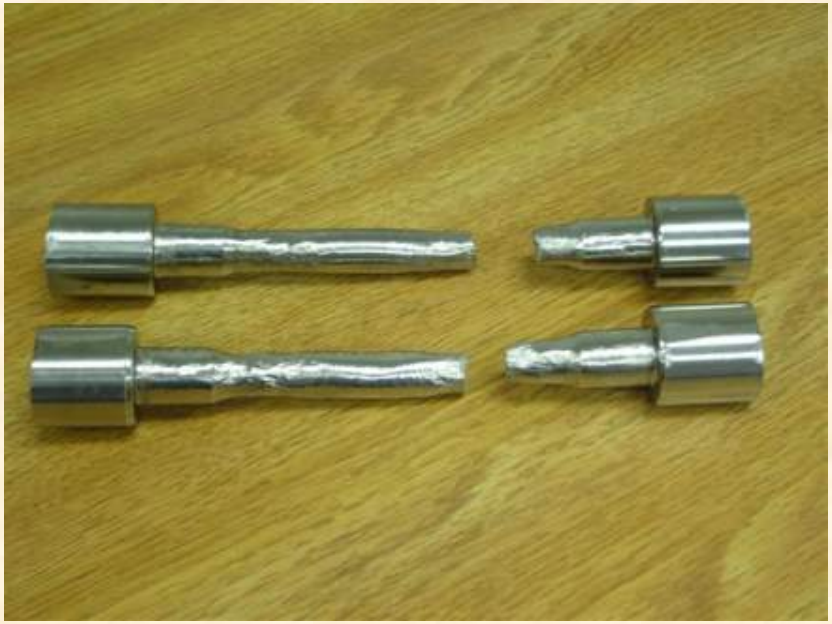


- CF8C-Plus (<0.5Si) shows as-good or better fluidity compared to CF8M (1.5Si) at equivalent pour temperatures

From Ron Bird, Stainless Foundry and Engineering

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 (SF&E)

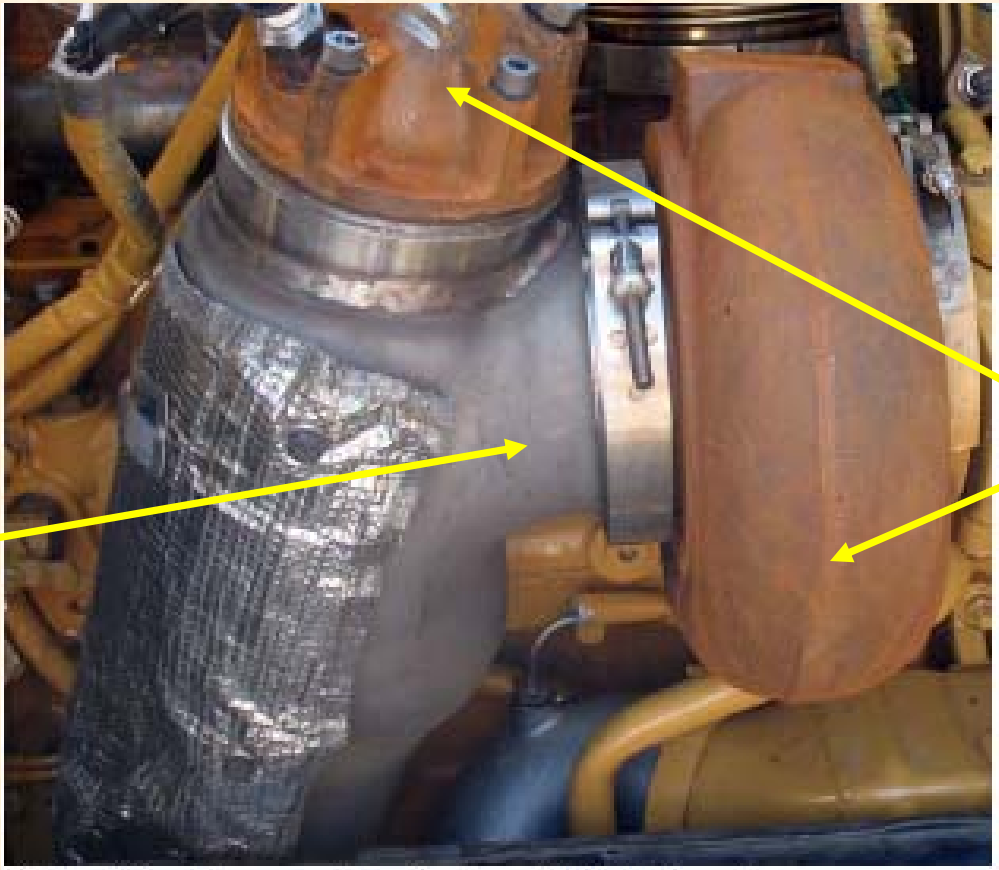


Welds of CF8C-Plus passed RT tensile tests for UTS and ductility, with 20% Better YS than base metal

Commercial Applications – Direct Replacement of NiResist for Natural Gas Reciprocating Engines at Reduced Cost *(Cost of CF8C-Plus = 80% of NiResist)*

45 lb static sand-cast CF8C-Plus exhaust component cast by Stainless Foundry and Engineering, Inc.

Caterpillar is now using **CF8C-Plus steel** for the CRS components which are on all heavy-duty highway truck diesel engines in 2007

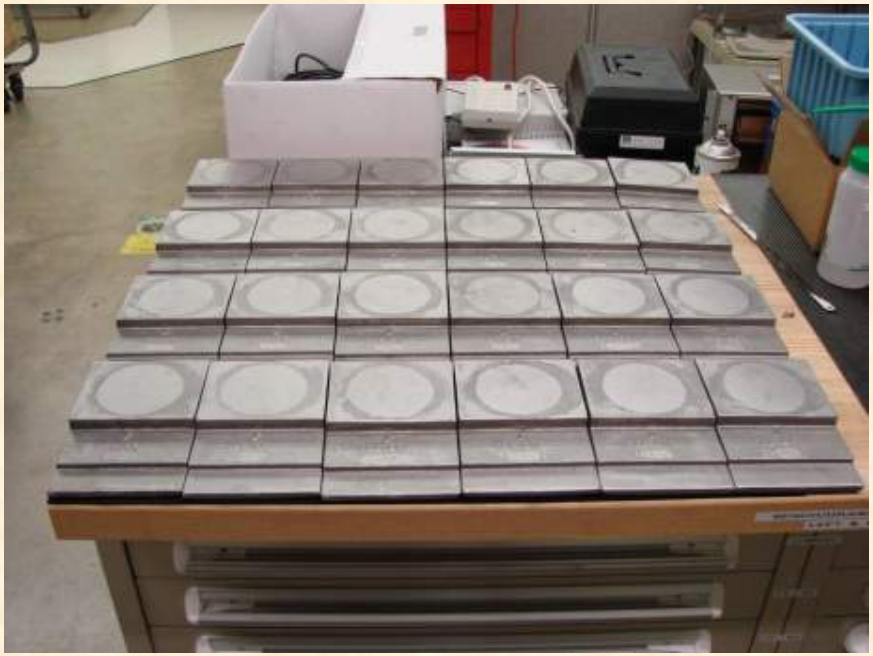


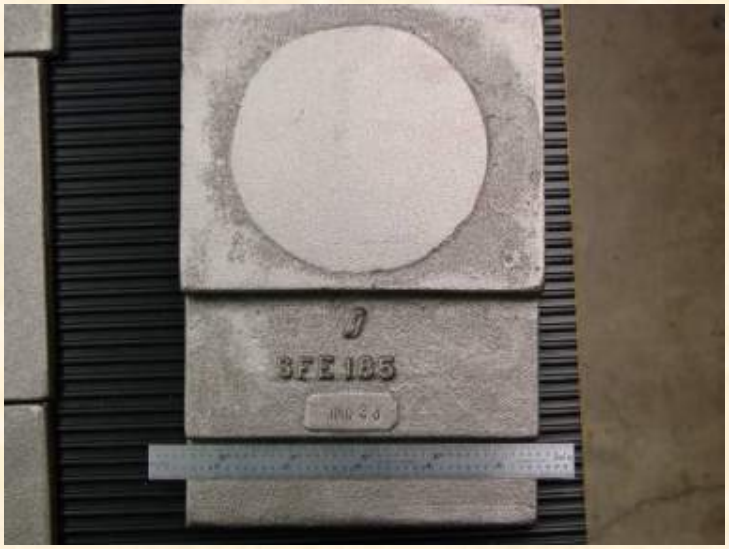
Caterpillar Regeneration System (CRS) Housing

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

New Work on Step-Castings to get mechanical properties data on thin-sections, to support turbocharger and manifold applications

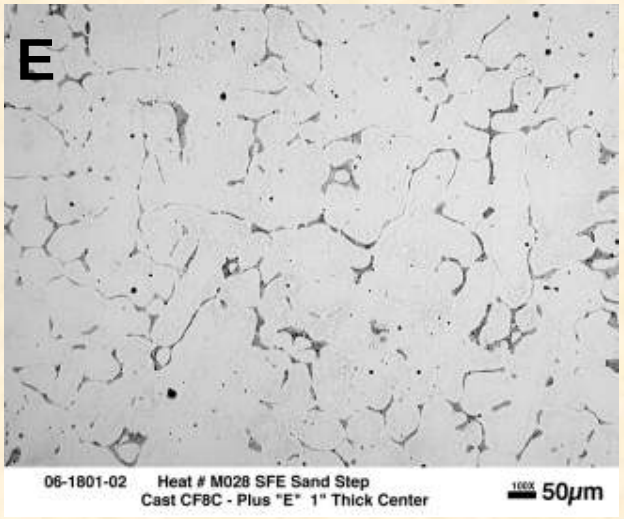
ORNL is using step-castings of CF8C-Plus and CF8C-Plus Cu/W to measure mechanical properties of the thin sections representative of heavy-diesel exhaust components



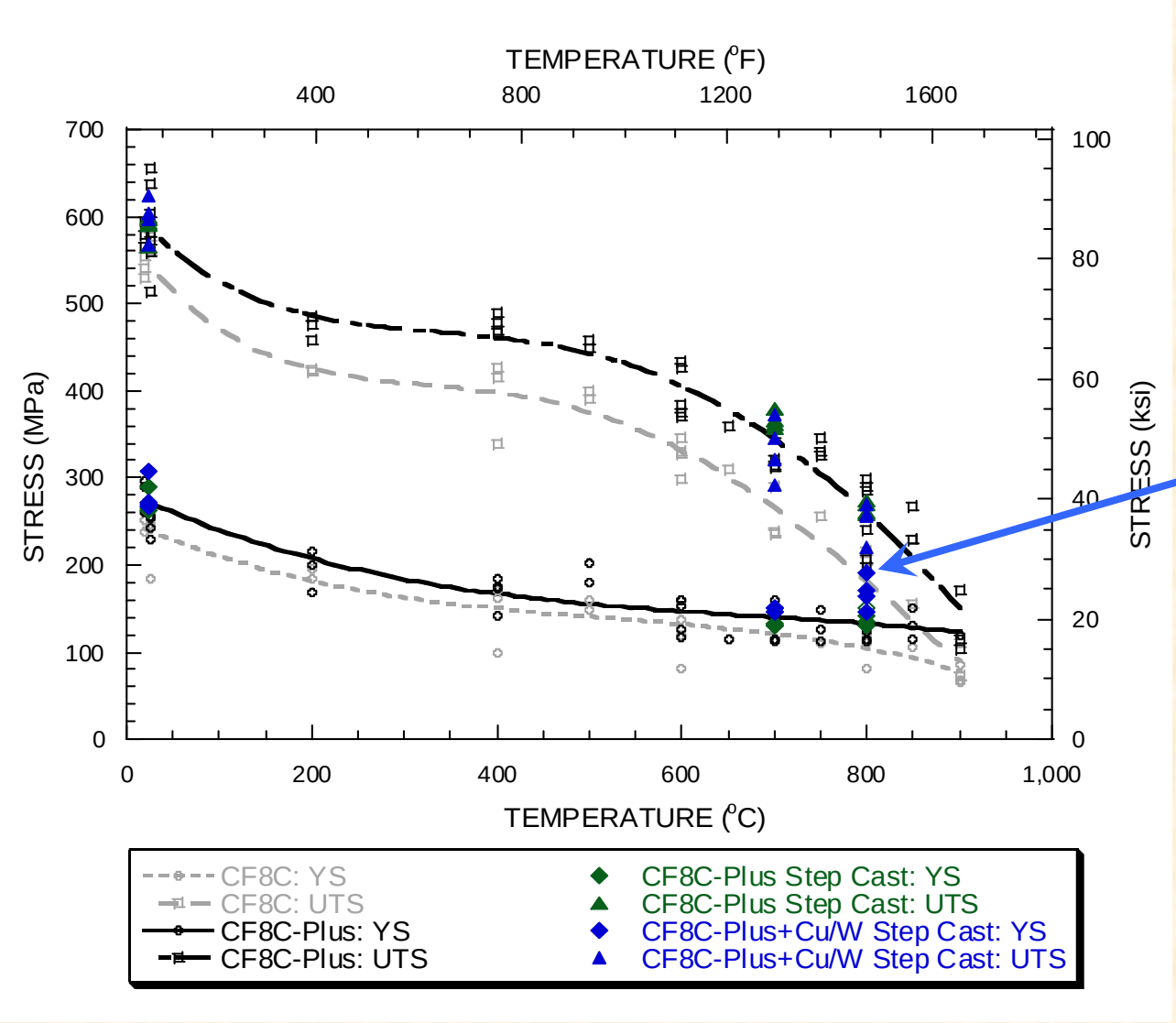


- Stainless Foundry & Engineering made step castings of CF8C-Plus and CF8C-Plus Cu/W in late 2006

Thin Sections of CF8C-Plus have refined dendrite/grain structure

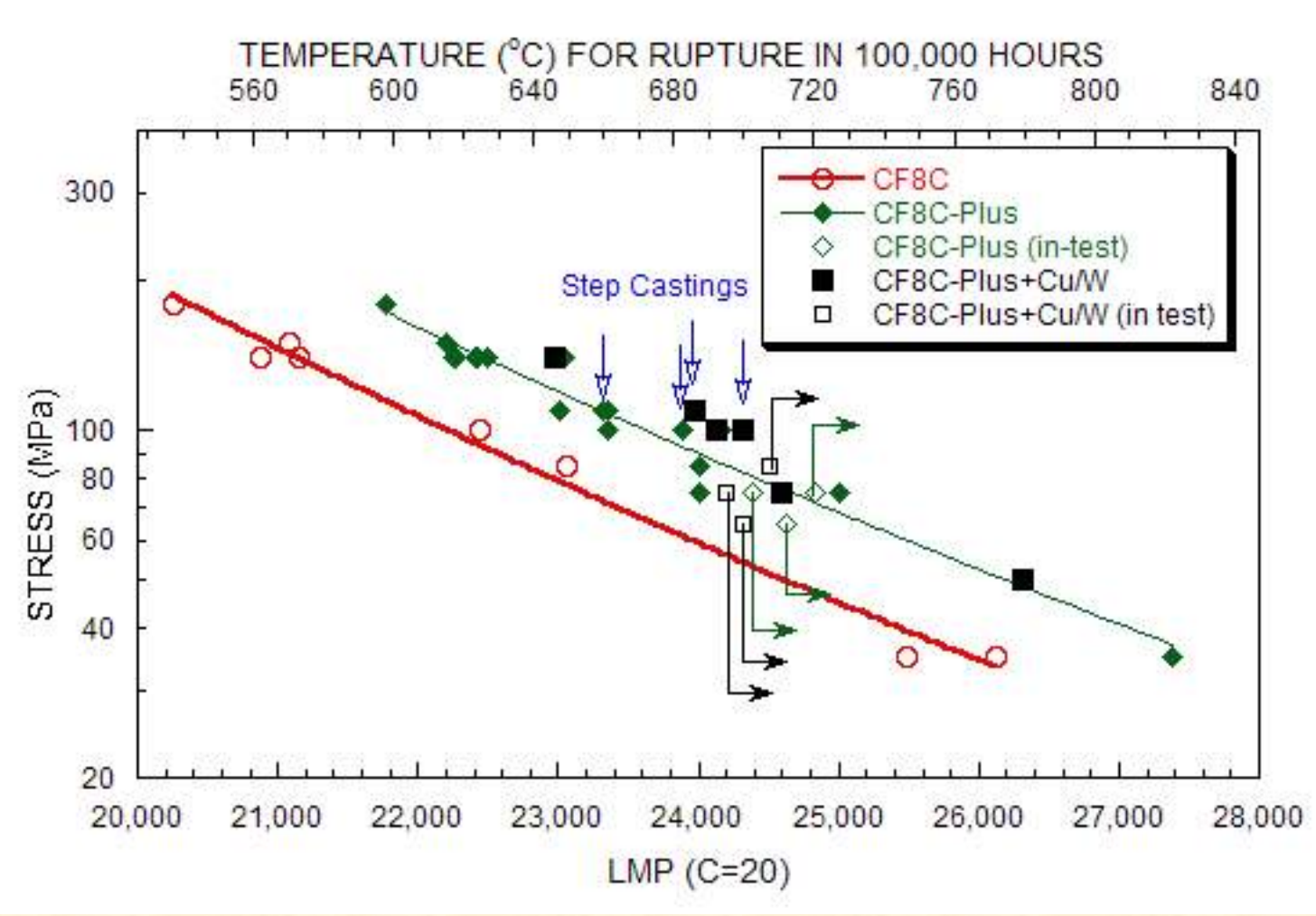


CF8C-Plus thin sections have YS as good or better than thicker sections

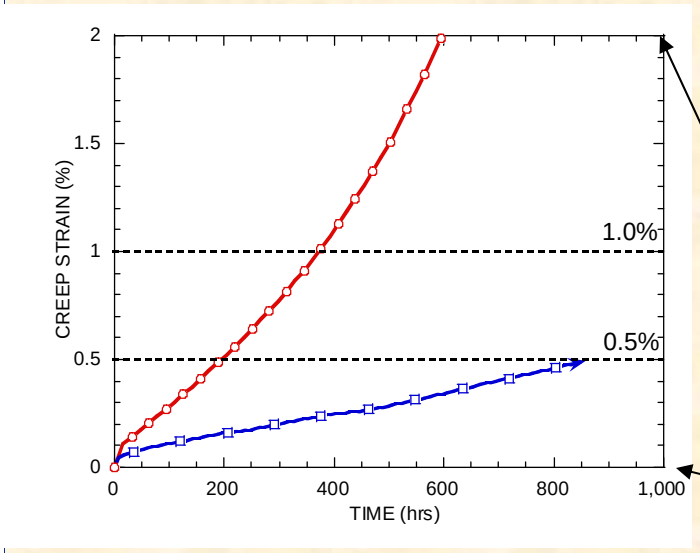


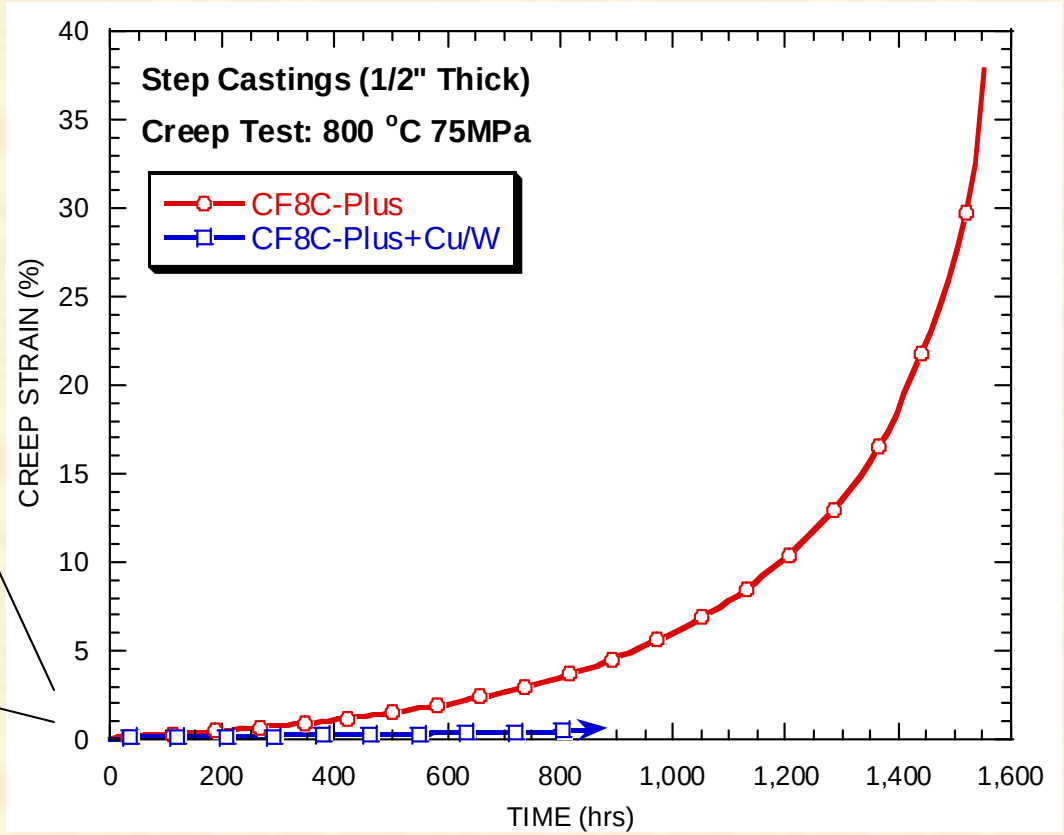
YS CF8C-Plus Cu/W

Preliminary data indicates CF8C-Plus thin-sections also have good creep and rupture resistance



CF8C-Plus Cu/W has improved creep resistance compared to CF8C-Plus





- Good creep resistance in thin-section casting is important for turbocharger and manifold applications

Conclusions for New CF8C-Plus cast austenitic stainless steel

- Castable, even as thin sheets
- Weldable
- Outstanding Creep Performance
- Cost-Effective
- Applications
  - **Caterpillar CRS components (on-highway in 2007)**
  - **Exhaust components for NG engines**
  - **Turbocharger housings**
  - **Numerous other potential spin-offs**